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70 Year for the First Faculty of Civil Engineering in Lithuania

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Abstract. This article is a brief overview of architectural and civil engineering studies in Lithuania and is dedicated to the first specialised technical faculty - Faculty of civil engineering, which commemorates 70 years anniversary. Studies of architecture and civil engineering are related to the origins of the first higher education institution in Lithuania established in 1579 lectures, which were related to technique, civil engineering and architecture. Russian tsarist authorities closed the University of Vilnius in 1832, but after approximately one hundred years, architectural and civil engineering studies were renewed at the University of Lithuania in Kaunas. Lithuanian presidential decree established Faculty of civil engineering in this University on 26th of July 1940. In the period of over 70 years the faculty has been reorganized several times, changed it's name, but remained in Kaunas university of technology till present days, keeping the traditions of civil engineering and architectural studies. Since the first three graduates in 1925 until year 2010 Kaunas' faculties released over 14 thousand graduates.
Keywords: architectural and civil engineering studies, higher education, Faculty of civil engineering, Kaunas university of technology, Vilnius Gediminas technical university.

BEGINNING OF ARCHITECTURE AND CONSTRUCTION STUDIES IN LITHUANIA

Architectural and civil engineering studies are related to the origins of the first higher education institution in Lithuania (Alma Academia et universitas Vilnensis Societat Jesus) established in 1579 lectures, which were related to technique, civil engineering and architecture. In 1775 architectural specialty was aproved and in 1793 an independent Department of architecture was established by the initiative of architecture professor Laurynas Stuoka-Gucevičius. Until University's closure in 1832 the Department of architecture had prepared more than 40 experts of architecture and construction.

University of Vilnius was closed in 1832 and Lithuanian youth, who had a wish to pursue higher education, went to study abroad. The most popular were higher education institutions in Russia. Many graduates of that time have become an outstanding researchers and experts of their fields. Most of them also became the creators of their own country's university and the first teachers of this higher school. S. Kerbedis A. Vilkutaitis, P. Vileišis and P. Čechavičius graduated St. Petersburg institute of road engineering. S. Grinkevičius, P. Markūnas, S. Kairys – St. Petersburg institute of technology, J. Šimoliūnas, K. Vasiliauskas – St. Petersburg institute of civil engineering. S. Dirmantas and S. Kolupaila – Moscow institute of measurement engineering. P. Jodelė graduated Kiev polytechnic institute. S. Stulginskis – Higher technical school in Prague. J. Dalinkevičius – St. Petersburg mining institute. M. Kaveckis – Kharkov university. M. Songaila – St. Petersburg art academy. V. Landsbergis-Žemkalnis finished Higher school of architecture in Rome. A. Janulis – Kazan art school. Not to mention many others.

On 27th of January 1920 Society of higher science established a voluntary based Higher courses in Kaunas. In these courses, along with others, was a Technical division, with three subdivisions: Civil engineering, Mechanical engineering and Technology. J. Šimoliūnas, who led University's Construction and road departments for a long time, was assigned as the head of Technical division. During 1936-43 he published "Construction" textbook containing 1432 pages and 3993 illustrations. All three subdivisions had the same study subjects for the first and second school years, while they started to differ in the third year of studies. Higher courses started preparing civil engineers. The first civil engineering teachers were as following: K. Vasiliauskas, P. Jodelė, S. Dirmantas, M. Songaila, J. Šimoliūnas and V. Verbickis. Later they formed the core of University's professoriate in the Technical faculty's Civil engineering division. Lithuanian government decided to establish the University on 13th of February 1922, on the basis of the State Council adopted University statute on 5th of December 1918. The University of Lithuania in Kaunas was inaugurated on 16th of February 1922. One of the five University's faculties was a Technical faculty. According to the first statute of the University of Lithuania in Kaunas, which Seimas has adopted on 12th of April 1922, Technical faculty established (among three others) a Civil engineering division with 7 departments of building profile: Technologies of construction and building

materials, Architectural, Surveying, Mechanics of construction, Hydroengineering, Roads and Bridges. In the Civil engineering division departments, there were respectively: 1923 - 8, 1927 - 17, 1932 and 1937 - 19 teachers working. The development of Kaunas faculties shown in Figure 1.

Civil engineering division prepared 190 engineers, in total, reaching 63 % of all graduates of the Technical faculty. In addition, construction-oriented courses were taught in the Technical faculty to other specialties: in the second year – building materials technology, construction, architectural drawing; in the third – building statics, architecture, iron structures, reinforced concrete; in the fourth – hydroengineering equipments, architectural design, plumbing, heating and ventilation. The first civil engineers graduated from the division in 1925 were – A. Račiukaitis, V. Snarskis and V. Vileišis. The first and only woman-graduate S. Mitkovskaitė completed her Civil engineering studies at the division in 1930.

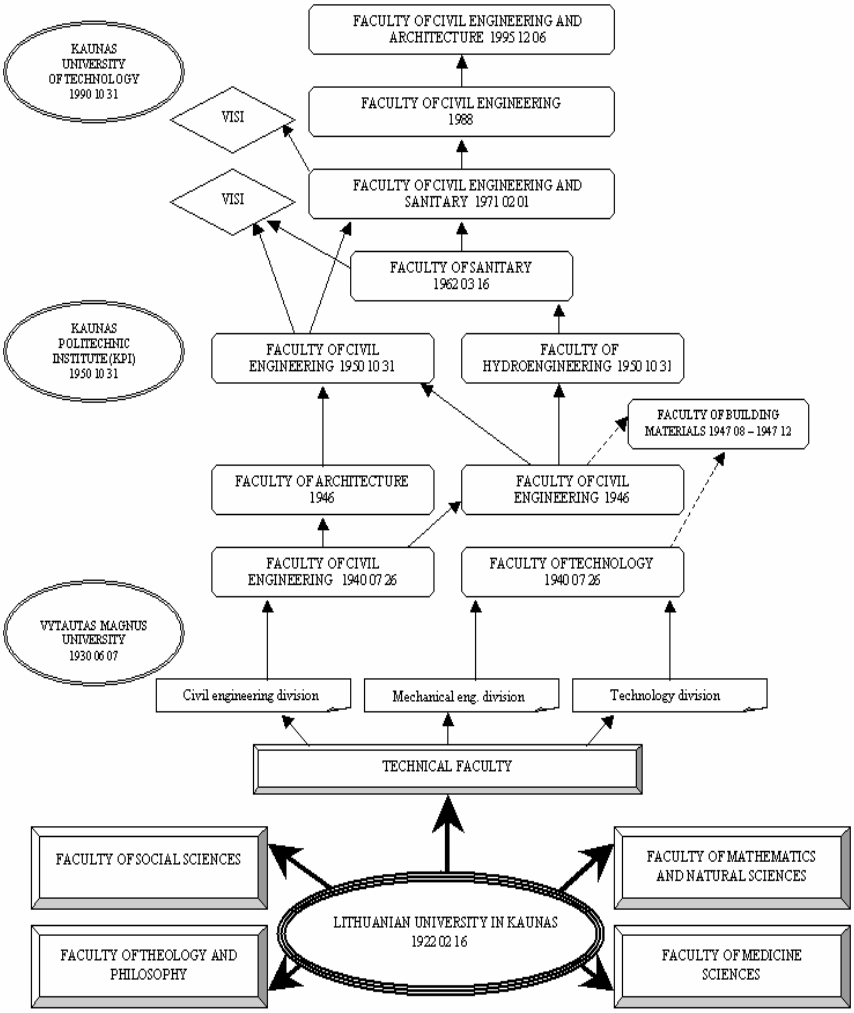

Figure 1. The development of Kaunas faculties (J. Deltuva *et al.*, 2000, H. Elzbutas *et al.*, 2010)

A number of students from the Civil engineering division later actively participated in the practical, scientific and educational activity. List of technical sciences's doctors and professors follows: J. Gabrys, J.Kuodis, V. Klimavičius; Ph.D. and associated professors: M. Stonis, S. Sčesnulevičius, S. Vasauskas, J. Peras, F. Bielinskis, K. Kaušinis, A. Bistrickas, P. Viliūnas, B. Žintelis, K. Kondratas, B. Ziberkas, V. Kriščiūnas, A.Citas and others. Later many of them prepared engineers in the University and in Kaunas polytechnic institute.

Scientific qualifications of department's lecturers were inadequate, therefore, management of the University promoted scientific activities, research result dispersion, scientific traineeships of young lecturers at foreign universities in every way possible. During 1924-1941 Technical faculty was publishing scientific journal "Technika". It's editors were P. Jodelė, K. Vasiliauskas and S. Kolupaila. In pre-war time four Civil engineering division lecturers defended their doctoral dissertations: M. Kaveckis defended his dissertation on the geology research in 1927-1930 period at Prague Grand Charles university in 1931; J. Kuodis dissertation "Reinforced concrete beam with high-quality steel" was defended at Vienna higher technical school after the scientific internship in 1934-1936; K. Vasiliauskas defended his dissertation "Influents and fictional loads" in the senate of

Vytautas Magnus university in 1938; and J. Gabrys dissertation "Concrete and reinforced concrete arches of the three joints" was defended at the University of Latvia in 1938.

DEVELOPMENT AND EVOLUTION OF CIVIL ENGINEERING FACULTY, ESTABLISHED IN VYTAUTAS MAGNUS UNIVERSITY

On the 1st of August 1940 "Valstybės žinios" ("Governmental news") announced about structural adjustment of Vytautas Magnus university. Technical faculty was reorganized into the faculties of Civil engineering and Technology. Faculty of civil engineering was the first specialized technical faculty in the history of Lithuania. At that time it consisted of Architecture, Surveying and Construction (with Construction, Hydroengineering and land reclamation branches) divisions. On the 15th of August 1940 twelve instead of former six building profile departments were approved: Topometric, Building statics, Roads, Bridges and iron structures, Hydrology and land reclamation, Hydroengineering, Geodesy and land management, Architecture and art history, Architecture encyclopedias, Architectural composition and drawing, Urban sanitary and Construction. At the beginning of the school year, from the 1st of October 1940 there were 15 departments: department of Hydrology and land reclamation has been split into Hydrology and Hydraulics and land reclamation, department of Geodesy and land management – into Astronomy and geodesy and Land management departments. In addition one new department of Engineering geology was found by it's initiator, member of the Lithuanian Science Academy prof. J. Dalinkevičius.

The first dean of the Civil engineering faculty was one of the most famous Lithuanian hydroengineering pioners prof. S. Kolupaila. He and all the other leaders of the University were released from their held positions by german government in the first days of war. Until November 1942 dean of the faculty was patriarch of Lithuanian sanitary engineering, signatory of Independence Act in 1918, a prominent social activist prof. S. Kairys. Later dean of the faculty was 1935-38 minister of Lithuanian national defence, brigadier general, a prominent surveyor prof. S. Dirmantas. In the end of the war majority of first facult's deans and department's heads were forced to emigrate to the west.

Beginning from 1943 Civil engineering faculty prepared architectural, engineering surveying, hydro-engineering and land reclamation specialists; dating from 1949 – road speciality graduates. In post-war period, concerning a huge increase in number of architecture students, USSR minister of higher education ordered Division of architecture to be reorganized into the Faculty of architecture at the beginning of 1945-46 school year. The first dean of the Faculty of architecture was assoc. prof. S. Stulginskis, later, since 1949 – assoc. prof S. Sčesnulevičius. In 1946 Faculty of architecture consisted of Architectural composition, Urban planning and architecture history, Painting and sculpture, Architectural and engineering construction departments.

The University was reorganized and split into Kaunas polytechnic institute and Kaunas medicine institute on the 31st of October 1950. In the Polytechnic institute faculties of Civil engineering and Architecture were reorganized into the faculties of Civil engineering and Hydroengineering (which was renamed as the Faculty of sanitary on the 16th of March 1962).

The right to defend doctoral and candidate dissertations was granted to the University and it's united sciences technical board in 1946. Technical sciences doctoral thesis were defended here by J. Kiškinas in 1947; A. Rozenbliumas, J. Mikuckas and J. Čeičys in 1948; R. Pesys in 1950. M. Kosčiauskas defended his surveying doctoral thesis in Vilnius university in 1948. In 1948 doctoral studies were validated to the Civil engineering faculty.

Structural and material research was particularly enlivened when budgetary funded problem oriented laboratory of building and thermal insulation materials was established in 1961. It's research facilities and staff members have been actively employed pusruing the increase of faculty's academic qualification. Three habilitated doctors and 37 doctoral (previously called – aspirant) dissertations have been developed in this laboratory until 1973.

Counting since 1956, civil engineering studies (alongside with other technical studies) spread all over Lithuania and Polytechnic institute branches were established in Vilnius, Klaipėda, Šiauliai and Panevežys, where later turned into independent universities.

Lithuanian higher and special education ministry's chamber adopted a resolution about part of the Kaunas polytechnic institute (KPI) Sanitary and Civil engineering faculties's specialities and lecturers transfer procedures to KPI Vilnius branch on 28th of March 1968. Specialities of architecture, civil engineering, surveying and road mounting were transferred in 1969-70, while heating, gas supply and ventilation, water supply and sewerage specialities and their shell departments moved to Vilnius in 1988. Kaunas's faculties lost half of their students and lecturers and consequintly restructured into Faculty of civil engineering and sanitary. KPI Vilnius branch was reorganized into Vilnius civil engineering institute on 18th of July 1969 (since 1990 renamed as Vilnius technical and since 1996 as Vilnius Gediminas technical university) and became Lithuania's major architectural and civil engineering scientific and educational institution (Figure 2).

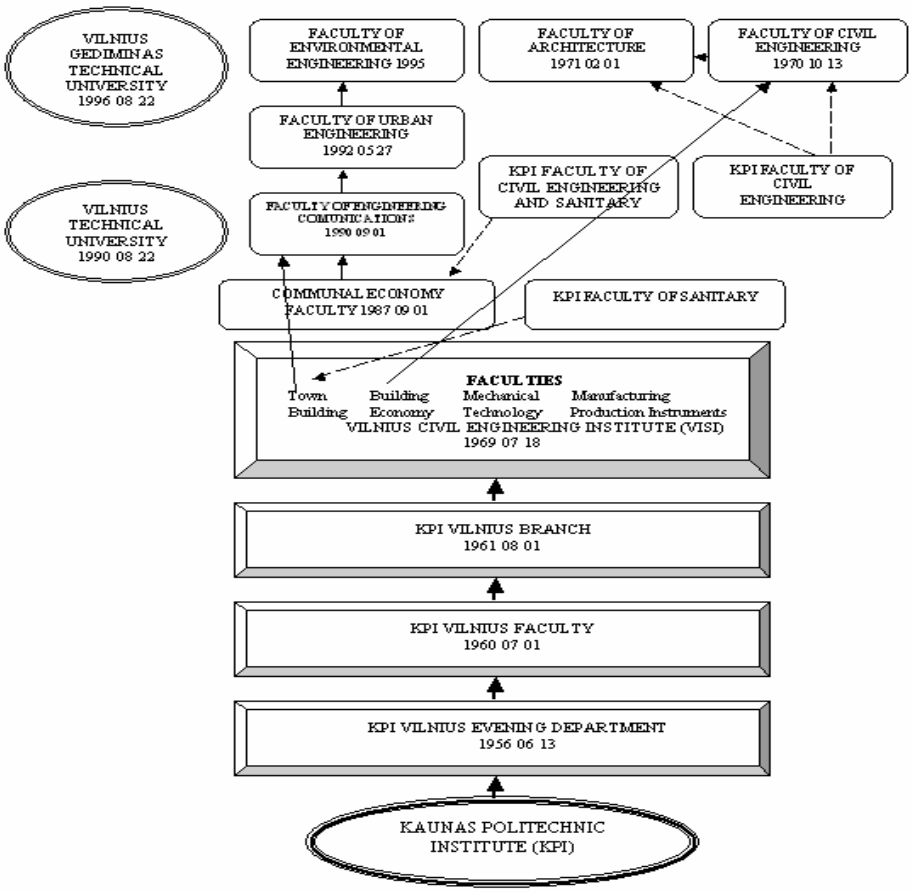

Figure 2. The development of Vilnius faculties (A. Nakas, 2006)

Full-time industrial and civil engineering studies in Kaunas were resumed in 1988. Faculty regained it's original – Civil engineering – title. During Lithuania's independence reinstatement, Kaunas polytechnic institute was restructured into Kaunas university of technology and all the specialities of studies were adjusted to bachelor and master study programmes. When Kaunas faculty renewed study porgramme of architecture in 1993, an increase number of students encouraged to restore architectural studies and research direction (Architecture and landscaping department) on 23rd of June 1995. Furthermore, under University's senate decision on 6th of December 1995 the Faculty was reorganized into the Faculty of civil engineering and architecture.

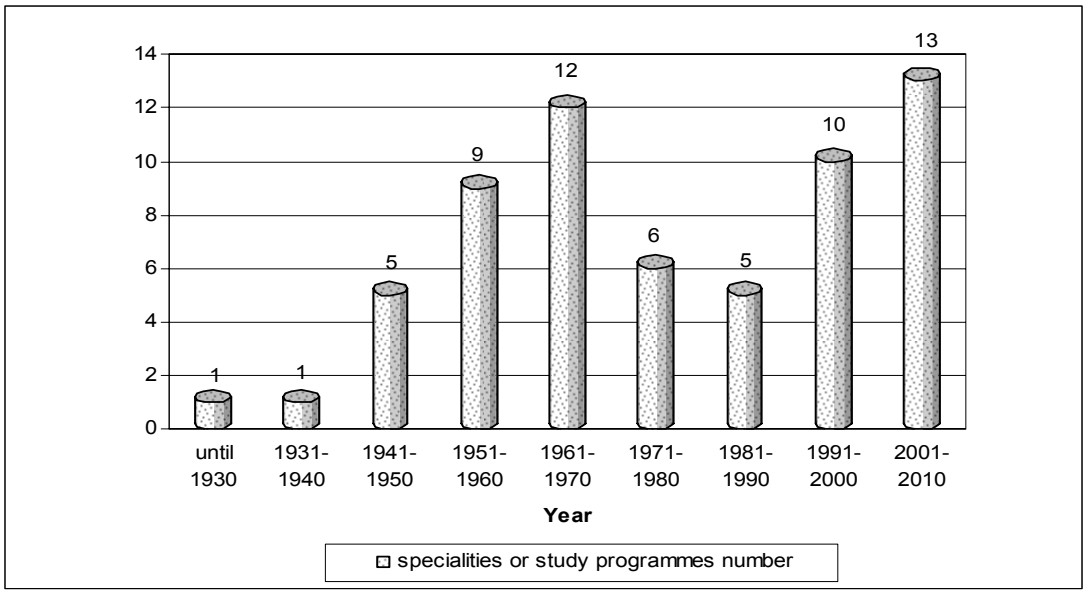

Figure 3. Number of specialities and study programmes in Kaunas faculties

Since the first three graduates in 1925 until 2010 Kaunas faculties produced over 14 thousand graduates (Figure 3, Figure 4). Especially significant numbers characterizes Kaunas polytechnic institute lifetime graduates abundance. Among them we find President A. M. Brazauskas, Independence Act signers, members of the Lithuanian academy of sciences, professors, past and present leaders of numerous public institutions, members of Lithuanian architects union, Construction association, Civil engineers union and other institutions heads, as well as state prize laureates for unique design and construction works. There are many leaders and specialists of building, construction industry and design companies among them too.

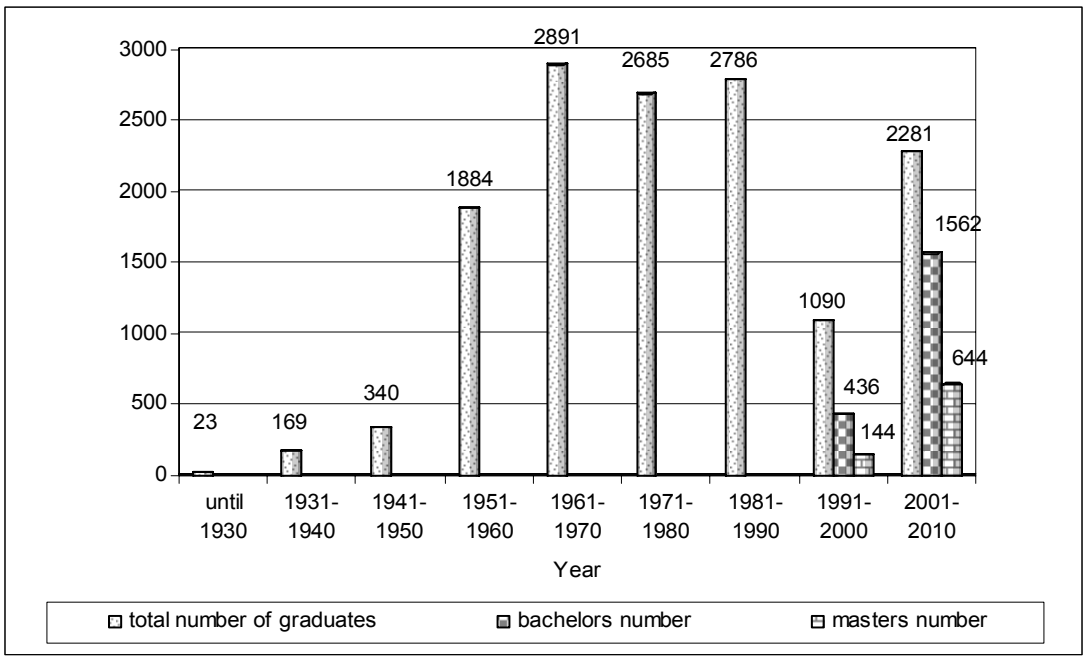

Figure 4. Graduates number in Kaunas faculties

Currently, civil engineering and related studies are organizes in five Lithuanian university schools: Kaunas university of technology (Faculty of civil engineering and architecture – architecture, landscape, civil engineering, building engineering systems, real estate management, materials science; KTU Panevežys institute – civil engineering); Klaipėda university (Construction department – civil engineering; Landscape architecture and environmental planning department – landscape architecture), Šiauliai university (Department of civil engineering – civil engineering), Vilnius Gediminas technical university (Faculty of civil engineering has civil engineering group study programmes, construction management, geotechnical, safety engineering and others; Faculty of environmental engineering – environmental engineering, civil engineering, building energy, building systems engineering, surveying, water supply and others; Faculty of architecture – architecture) and Vilnius academy of arts and it's Kaunas art institute (architecture).

CONCLUSIONS

The beginning of architectural and civil engineering studies in Lithuania can be mentioned from 1579 and these studies taught in the first Lithuanian high school (Alma academia et universitas Vilnensis societatis Jezus). The first department of Architecture was established in 1793 on architecture's prof. Laurynas Stuoka-Gucevičius initiative. More than 40 specialists of architecture and civil engineering were prepared in the Department of architecture until University's closure in 1832.

Regular architectural and civil engineering studies in Lithuania were revived after 88 years – on 27th of January 1920, when Higher courses were found, which, dating from 16th of February 1922 operated in Lithuania university in Kaunas (Vytautas Magnus university since 1930). University's Civil engineering division of Technical faculty prepared 190 engineers, representing 63 % of all graduates until 1940, when Civil engineering faculty was founded.

Counting from 1956, civil engineering studies (with other technical studies) outspread in whole Lithuania, when subdivisions of Kaunas Polytechnic Institute were established in Vilnius, Klaipėda, Šiauliai and Panevėžys. Later on, these subdivisions became independent high schools. Now these studies are organized by following institutions: Faculty of civil engineering and architecture of Kaunas university of technology; Panevėžys institute of Kaunas university of technology; faculties of Vilnius Gediminas technical university:

Civil engineering, Environmental engineering and Architecture; Departments of civil engineering of Klaipėda and Šiauliai Universities.

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Activities of Antanas Bistrickas in Kaunas Polytechnic Institute and its Predecessors

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Abstract. Commemorating its 70th years' anniversary the Faculty of Civil Engineering and Architecture of Kaunas University of Technology reminiscences about the workers, who served in the faculty and contributed to the establishment of this faculty. One of them was Associate Professor Antanas Bistrickas. This year we have commemorated his 110th birth anniversary. Antanas Bistrickas studied in University of Lithuania in Kaunas, in the Department of Bridges, and started the pedagogical and scientific activities in the same Department, that is one of the predecessors of the Department of the Building Structures. In interwar Lithuania Antanas Bistrickas worked on probation in Vienna High Technical School as also did some other young scientists, where he prepared the doctoral dissertation. His greatest input to the activities of this high school was contributed during post-war years. He contributed much in the founding and developing the Faculty of Civil Engineering, in the processes of its studies and scientific activities.

Keywords: University, Department of Building Structures, Bistrickas, scientific, pedagogic activities.

INTRODUCTION

The history of high school, as in general the history, is created by people. The trends and tendencies of studies, combinations of specialities, aspects of scientific researches and etc. depend on their one or another decisions, opinions, acts and works. Thus the High School commemorating the anniversary of its beginning reminds its workers who jointed in establishment of Vytautas Magnus University. One of the workers was Antanas Bistrickas. His 110th birth anniversary was marked this year. Remembering the study, occupational and professional pathway of Antanas Bistrickas there must be also reminded the beginning of Department of Building Constructions in the University. Namely here A. Bistrickas began his studies, here his pedagogical and scientific activities were continued and his practical work persisted till the sunset of his life.

DEVELOPMENT OF DEPARTMENT OF BUILDING STRUCTURES

Beginning of the Department of Building Structures is found in University of Lithuania in Kaunas, where in 1922 there were instituted Department of Building Mechanics, which was headed by K. Vasiliauskas, and Department of Bridges, which head was S. Grinkevičius (see figure 1). Basically, in the University the first lecturers of the subjects of building structures were alumnus of the high schools of Russia who were competently acquainted with the theory and practice of building construction of the Western Countries (Atkočiūnas, J., Bučas, J. and others, 2000).

In 1930 in the University the Department of Building Mechanics was modified to the Department of Building Statics, and since 1947 it was renamed to the Department of Structural Mechanics. The heads of these departments were Professor K. Vasiliauskas (1922 – 1956) and Professor V. Klimavičius (1956 – 1974). In 1940 the Department of Bridges was reorganised to the Department of Bridges and Iron Structures, and in 1941 – to the Department of Bridges and Structures (head of the department was J. Kuodis). In 1945 the Department was divided into two departments: Department of Reinforced Concrete Structures and Bridges (headed by A. Rozenbliumas) and Department of Metal and Timber Structures (headed by A. Bistrickas). In autumn of 1949 both these departments were united into the Department of Building Structures (headed by A. Rozenbliumas). After the reorganisation of Kaunas State University, the Department of Building Constructions in the newly established Polytechnic Institute was modified to the Department of Engineering Structures (headed by A. Rozenbliumas). In 1961 this department was subdivided into two departments: Department of Reinforced Concrete Structures (headed by A. Rozenbliumas, since 1969 headed by J. Valikonis) and Department of Metal Structures (head R. Pesys, from 1969 head was J. Paulauskas). The development of the department is presented in Figure 1. Antanas Bistrickas worked in the darker marked departments.

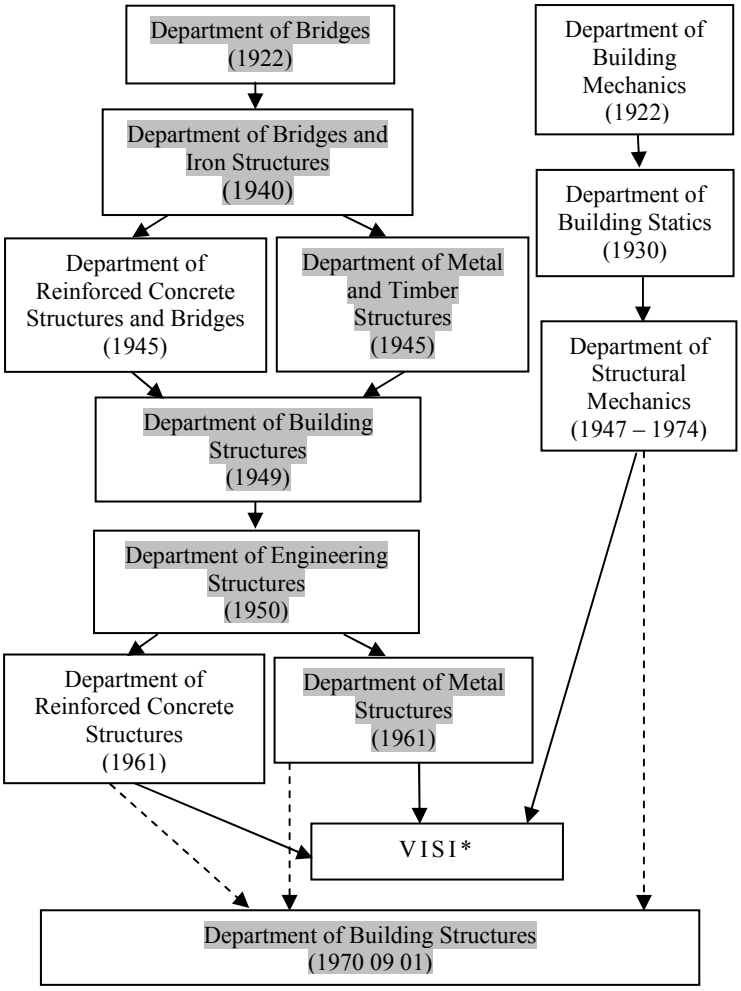

Figure 1. Development of Department of Building Structures.
*VISI – Vilnius Civil Engineering Institute

The first doctoral dissertations were defended during pre-war years. In 1936 lecturer of the Department of Bridges Jonas Kuodis defended his thesis "Reinforced concrete beam with steel of high quality" (Nakas, A. 1997) in Vienna High Technical School. Juozas Gabrys defended his dissertation "Concrete and reinforced concrete three-hinged arcs" in 1938 in University of Latvia. The dissertation of Kazimieras Vasiliauskas, head of the Department of Structural Statics, was defended in 1938 in Vytautas Magnus University in the trend of structural mechanics. During post-war period when in 1946 the University obtained the right to accept the defended dissertations, the dissertations of science candidate (doctor) were defended by: Anatolijus Rozenbliumas (head of Department of Reinforced Concrete Structures and Bridges) in 1948 and Ričardas Pesys (worker of the Department of the Engineering Structures) in 1950. Under the supervision of Professor K. Vasiliauskas, the lecturers of the Department of Structural Statics especially promptly prepared and defended their dissertations: in 1952 – Stasys Vasauskas, in 1953 – Vytautas Klimavičius, in 1954 – Aleksandras Čyras, in 1956 – Povilas Aukštakalnis, in 1957 – Antanas Stankus, in 1958 – Balys Garmus, in 1959 – Antanas Martišius and Antanas Kudzys.

THE ACTIVITY OF ANTANAS BISTRICKAS IN INTERWAR (1922-1940) PERIOD

In autumn of 1922 Antanas Bistrickas entered the Construction Division of Technical Faculty of the University of Lithuania in Kaunas. On 13th of February in 1932 he defended the diploma project "Iron Bridge across the Nemunas River near Jurbarkas" and acquired the title of certificated construction engineer.

Figure 2. Antanas Bistrickas after graduate studies
(from private family archive)

After finishing the University (Figure 2), in the beginning he served as a junior engineer in the Civil Construction Division of the Railway Board of the Ministry of Transport and Communications. Young and gifted engineer was noticed and invited to work in the Vytautas Magnus University by Professor S. Kolupaila. At the same time other bright engineers, such as Juozas Gabrys, Jonas Kuodis were invited to work in the University. On the 1st of March in 1933 Antanas Bistrickas began working in a position of junior assistant in the Department of Bridges, later he became senior assistant, then senior lecturer, associate professor and professor.

The direction office of Vytautas Magnus University was concerned about staff qualification and directed the young gifted lecturers to improve their knowledge to Vienna High Technical School.

Jonas Kuodis was the first worker sent to work on probation. On 11th of July in 1936 his doctoral degree of technical sciences was accredited in Vienna High Technical School, which was accepted as equivalent to doctoral degree of engineering sciences in 1936 by the Board of Technical Faculty of Vytautas Magnus University in Kaunas (Nakas, A. 1997). From September of 1936 to July of 1938 Antanas Bistrickas was also sent by the University to Vienna High Technical School, where he improved his knowledge and prepared the dissertation in the field of buckling. It is necessary to note that during war time the material of scientific work prepared in Vienna disappeared after returning to Lithuania. Beside the mentioned J. Kuodis and A. Bistrickas, A. Rozenbliumas also went to work on probation to Vienna High Technical School.

Figure 3. Construction of Ateitininku Palace
(presently the Third Building of Kaunas University of Technology)

After returning to Lithuania Antanas Bistrickas worked further in the Department of Bridges and gave the lectures on course of the Iron Structures to the students. Furthermore, he published the results of scientific researches in the scientific journals "Technika" ("Technique"), issued hereupon in the Faculty of Technology of the University, edited by Professors P. Jodelė, K. Vasiliauskas and S. Kolupaila.

In pre-war period Antanas Bistrickas productively acted in engineering design of number of buildings and technical supervision of their construction. Here we could mention the Ateitininku Palace (presently – III-rd building of Kaunas University of Technology, see Figure 3). In interwar period the aforesaid palace belonged to the Youth Catholic Organisation "Ateitininkai". Ateitininku Palace was their harbour and economic-cultural centre of the entire organisation. During war time the palace was passed from hand to hand. After war the Palace came to the restored Kaunas University and became a seed-plot of the culture of the University (Bučas, J. and others, 2000). Nowadays this Palace still keeps being a cultural centre of the University.

THE ACTIVITY OF ANTANAS BISTRICKAS IN POST-WAR (1941-1971) PERIOD

From 1941 to 1944 Antanas Bistrickas worked as a Vice-Dean (Associate Dean) of the Faculty of Construction of the University. At that date he lectured the students on Steel Bridges and Timber Structures.

While the front line was approaching the greater part of lecturers of the Faculty of Construction withdrew to the West. After the front reached the West, the activities of Faculty of Construction were recreated after war, only 3 heads of departments remained from the previous 15 – Professor J. Dalinkevičius, Professor K. Vasiliauskas and Associate Professor M. Ratautas. On the 1st of August, 1944 Associate Professor A. Bistrickas was appointed to be a Head of the Department of the Timber and Metal Structures. The positions of heads of other departments were occupied by R. Pesys, A. Rozenbliumas, S. Vabalevičius, S. Stulginskis, J. Mikuckas, S. Sčesnulevičius, V. Verbickas, J. Kiškinas and others. As earlier so now the departments were slender, in 1946 the departments had two-three lecturers (Elzbutas, H. and others, 2010). On 13th September, 1944 Antanas Bistrickas was nominated as a Dean of Faculty of Construction and worked in this position till November of 1945. In November of 1945 Rector and Professor A. Purėnas invited A. Bistrickas to work as a Vice-Rector of the University for the Domestic Affairs, and he served on this position till April of 1946.

The scientific and pedagogical competencies were topical and relevant both for Departments and Faculty. In the beginning of 1945 the High Certification Commission in Moscow legitimated the scientific degrees and academic titles acquired before the war: Professor title and scientific Doctor degree – to K. Vasiliauskas, Professor title – to K. Šleževičius, Associate Professor title - to J. Kiškinas, M. Ratautas and S. Stulginskis. A. Bistrickas was awarded the scientific title of Associate Professor in the Department of Metal and Timber Structures, which was headed by him at that date. On 7th June of 1945 following the rendering of Science Board of Vytautas Magnus University, the Education Commissar of the Lithuanian Soviet Socialist Republic J. Žiugžda nominated Antanas Bistrickas the Professor. His scientific works were: 1) rod junction operation on the influence of repeated static load; 2) impact of pure bending on deformations of hard and very hard timber fibre slabs.

Acting as a Dean of Faculty of Construction, Antanas Bistrickas (Figure 4) was a member of many commissions. As an example of the commission, we could mention the one which recommended to A. Rozenbliumas to take the staff place of Associate Professor (Nakas, A. 1997). The former students of Faculty of Construction of Vytautas Magnus University remember their first Dean in the composed book of memories: "… pleasant to recollect our first dean and professor Antanas Bistrickas – a reserved, kind-hearted, excellent specialist, rational pedagogue" (Vidurigis L., 2000).

Figure 4. Professor Antanas Bistrickas in his work office
(from private family archive)

In post-war Lithuania the consequences of the war were terrible. The knowledge and experience of the lecturers of the University in the construction field came in useful very much. Besides his main work in the University, Antanas Bistrickas projected many engineering designs, participated in various examinations, inspections and commissions surveying the bridges demolished and damaged during war time: Panemunės Bridge in Kaunas, Green Bridge in Vilnius, Aleksotas Bridge in Kaunas and Vilijampoles Bridge in Kaunas. He performed investigations of roof structures and provided consultations in different issues.

On the request of Technology Science Institute of Science Academy of Lithuanian Soviet Socialist Republic Antanas Bistrickas took part in the Commission of Postgraduate Studies (called *aspirantura*).

In 1949 Antanas Bistrickas published the book "Roofing by Materials in Rolls and Pieces, their Repair", translated from Russian language. In 1954 he wrote the book "Elements of Timber Structures", where he presented the methodology of calculation of timber structures according to the limit states. In 1958 he published his second book "Timber Structures", that was a manual of timber structures for the students of high schools for long years. In 1962 he also wrote Chapter VIII of the manual "Building Structures. Part I". He also prepared the different tables to estimate the structures.

In 1956 Antanas Bistrickas reviewed the manual "Masonry Structures" prepared by A. Rozenbliumas. In review of this manual (Nakas, A. 1997) he emphasised that it was a "… very good and useful book especially because it is issued in Lithuanian language". We must not forget that during post-war period there was a lack of literature of building constructions in Lithuanian. Unfortunately A. Rozenbliumas published the second manual "Masonry Structures" in Russian.

Antanas Bistrickas reviewed many other books: "Technology of Construction Works" and "Resistance of Materials" prepared by several authors, book of I. M. Vatriuk "Structure of Timber and Plastic", book of Jankauskas "Determination of Quality of Bearing Building Structures".

Except the pedagogical and scientific work, Antanas Bistrickas took an active part in social activities. He was a board member of Kaunas Polytechnic Institute Library, a chairman of Comrades' Court, a member of Department Commission of Faculty of Construction, a member of Trade Union Bureau and etc. On behalf of Lithuanian Association "Žinija" he gave the frequent lectures on plastics.

Antanas Bistrickas was awarded by the honour certificates by the State High and Special Secondary Science Committee of Ministers Board of Lithuanian Soviet Socialist Republic and Republic Committee of Trade Unions of Education, High Schools and Science Establishments of Lithuanian Soviet Socialist Republic on the occasion of the 25 years anniversary of the Lithuanian Soviet Socialist Republic.

CONCLUSION

1. Contributions of Antanas Bistrickas to reestablishment of activities of Faculty of Construction of Vytautas Magnus University during post-war period shall be estimable. During hard times in Lithuania he joined in upholding and cherishing the high science of Lithuania, working in Faculty of Construction in positions of Vice-Dean, Dean, Head of Department and Vice-Rector of the University.
2. The most productive years of Antanas Bistrickas as a pedagogue and scientist was period of 1941-1971. His method of lecturing displayed high inner culture of the lecturer, his pedagogical wisdom, experience and deep erudition. Present civil engineers and scientists learned from his written manuals and books.

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Wind Turbines Development in West Lithuania

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Abstract. The viable for production of electricity renewable energy types in Lithuania are the energy of water and wind. It is planned that in the future Lithuania would produce about 30% of energy from alternative sources. There are a exclusive favorable conditions in seaside. The priority is given to wind energy development in this region. **.** Examining the importance of alternative energy, the development potential of western Lithuania. It is reviewed the historical development of wind energy, it is considered installed separated wind power station parks
A separate chapter analyzes the development of wind turbines in the Baltic Sea (Lithuanian economic zone area). In submitted charts marked the existing and planned wind power station fields. There was provided to build 200 MW of total wind turbines in Lithuania which produce about 2.5 - 3 percent of total consumed electricity. This time (in begin of 2010) is operating about 84 MW of total wind power capacity.

Keywords: the wind turbines, the alternative energy, the renewable energy sources, the wind power station fields, the influence of wind turbines for environment.

INTRODUCTION

Exploratory relevance and Problems. In a world increasingly focus attention and effort solving problems, as human energy needs better to use renewable and alternative energy sources. In twentieth century the last decade highly accelerated alternative energy utilization rate. It has been done much and it is still working intensively in the field of technological development of solar, wind, hydro, biomass, biogas these changes are determined by high non-renewable resource scarcity (Kytra, 2002).

Since the restoration of independence in Lithuania is louder dealing about alternative energy. Debate on the energy sector in particular has intensified, preparing to close the Ignalina AE (which has already been made 31 December 2009). Also, abandonment of nuclear energy, which accounted for the majority of electricity production is the main burden lies with thermal power stations - it provides in the National Energy Strategy. However, scientists estimate that the air pollution may increase approximately twice (Katinas and Markevičius, 2000).

From alternative energy sources was made 4,6 percent of all electric power in Lithuania. By European Union It was committed to produce 7percent of energy with the so-called "green" manner for European Union by 2010. (Kytra, 2002).

The viable for production of electricity renewable energy types in Lithuania are the energy of water and wind .The European Parliament and Council Directive 2001/77/EC "Electric power generation using renewable energy resources, promotion of the internal electricity market" came into effect in 2001.This directive EU member countries set target, that to 2010, the part of renewable energy sources in country's fuel balance would be 12%, and produced from these resources electric energy - 22.1% of all electricity consumed in the country.

It is planned that in the future Lithuania would produce about 30% of energy from alternative sources. There is a exclusive favorable conditions in seaside. The priority is given to wind energy development in this region.

This energy technology in the last decade has become the most developing technologies around the world. 2 The power generated by wind turbines in the world already consisted about 57,837 MW. Most of them - 70.6% installed in Europe, 16.8% - North America and 12.6% - the rest of the world.

The wind turbines generates about 20 percent of consumed electricity in Denmark, while in such countries as Portugal, Spain and Germany - about 10 percent.

It is estimated that in 2020 in the world wind power would already produce 12 percent of all electricity. The advantages of wind energy - very clean source generated by electric power efficiency to 25-30 percent (Solar

panel efficiency up to 20 percent) autonomous, safe and growing cheapen energy source (Markevičius and Katinas, 2002).

It was provided to construct in Lithuania 200 MW of total capacity wind turbines in Lithuania which will produce about 2.5 - 3 percent of total consumed electricity .This time (in begin of 2010) is operating about 84 MW of total wind power capacity. The integration of constructed wind turbines to already formed urban structure also raises and environmental, quality of landscape problems.

Research tasks:

- ✓ To perform wind energy development analysis of historical evolution ;
- ✓ To clarify the wind turbines development options;
- ✓ To assess the potential impact of wind energy on the environment.

METHODS

- ✓ The analysis of scientific literature;
- ✓ The analysis of cartographic material;
- ✓ The analysis of object visual;
- ✓ The comparative analysis.

RESULTS

The evolutional analysis of wind turbines

Near the city Skuodas was built the used wind turbine of 160kw capacity which is brought from Denmark in 2002 .This is the horizontal wind turbine which has three wings, and length of one – 10,5 m (Katinas and Markevičius, 2000).

2004 April 15 in village Vidmantai (Kretinga region, near the Palanga) was opened - running the first demonstrative of 600 kW capacity industrial wind turbine in Lithuania (Built Kaišiadoriai and Magdeburg initiative of the diocese). It tower height - 78 metres, the diameter of impeller – 44 metres, the total height - 99.5 metres. The electrical energy is generating by 630 kW power variable speed asynchronous generator. Maximum power - 630 kW can be reached when wind speed is 11.5 m/s. When wind speed reaches 25 m/s powerhouse is suspended automatically.

The minimum required wind speed - 3 m/s This wind turbine did not reap the objections from population. Conversely – the coming people from other regions of Lithuania fascinated by this new and an interesting subject. Coming to Palanga by national Highway A11, the vertical of power meets in the middle panoramic road. This place was chosen for the rational reasons - in pipeline protection zone.

It was planned and built the first six wind-power park near the road of Klaipeda - Palanga (within the village of Lankučiai in 2004). However the Danes owned the company "UAB BNE" 5,4 MW power wind park has not been connected to electricity network The wind power park was built violating the planning process and when the local population resisted wasn't granted permission for their operation. They were dismantled, transported to Poland and then built.

There was began to construct the largest in the Baltic countries (30 MW) 15 wind park in Lithuanian coastal mainland.(see Figure 2).The wind power park was equipped in Kiauleikiai, Kviečiai and Rūdaičiai villages (in the area between Palanga and Kretinga, near Vidmantai village). One electrical tower height - 85 metres. It consists of four separated sections mounted in height - from 14 to 25,5 meters. On the tower is mounted "gondola" of 7 meters diameter which equipped with three wings the length of each - 34 meters. The diameter of impeller - 71 meters. The height of installed power with raised wing is 120,5 meters. This wind park produces about 64 million kWh of electricity over this year.

These power plants fall into protection zone of resort area. It was planned to build additional five wind power plants in this area. All 15 power plants are not concentrated in one field, but scattered in large extensively urbanized area among small groups of private land (see Figure 2).

At the same time (in 2006) was constructed and a second wind park in Kretinga area. But there was chosen a better place for park - a district in the north, Benaiciai village. There was equipped six 2,75 MW power wind power plant, the total power - 16 megawatts .Park equipped in no such urbanized and non promising areas, because there were received less of objection from population. In landscaping value respect this place to build wind power plants are also suitable.

It was opened the third 14 megawatt wind power park (7 Wind Power) Sūdėnai village, municipality of Darbėnai (in the north of Kretinga district) in 2009.It is expected, that seven wind power per year will produce about 33 Giga Wh of electricity. That amount of electricity annually consumes about 30 to 40 thousand people.

There was built and fourth wind power park in 2009. The location was choose in southwest part of Kretinga region, in village of Liepynės (see Figure 2). The park consists of six wind power plants (4 of 2 MW, one - 800 kW and other- 330 kW). The total capacity - 9.13 MW. This site (Liepynė village) is located near the arterial pipeline. Also further from the settlements of Palanga, than the first wind power park.

It was constructed 6 wind power plants park (12 MW) in district of Šilute, Mockiai village in 2009. The wind power type – Enercon E-82.

There was constructed 17 wind-power park (32 MW) in the northern part of Kretinga districts, Benaičiai village (6 wind power plants park, see figure 2) in beginning of 2010.

The construction of wind power in the western part of Kretinga region initiated and this, that at this area is hold 110 kW electric power line, and the wind power parks can to connect to the such power network only. (Grecevičius *et al*., 2008).

This time is planned to build 18 wind turbines (of 35 MW powers) in municipality of Priekulė, in region of Klaipeda (in Dreverna - 11, Priekulė - 5, Lėbartai - 2), which will occupy the area of 165 hectares. Near the Dreverna, beside the Wilhelm channel is planned to set out a power line to reduce the negative effects of bird's migration. It is planned to construct power stations by distance of 500 – 1700 meters from residential homes.

It is started to develop the project of wind turbines in Šilutė area. Under this project in area of 762 hectares will be built from 100 to 150 wind turbines. Its will be in cadastral areas of Juknaičiu, Pašyšiai, Usėnai and Degučiai, in region of Silute near Regional Park of Nemunas Delta (Juškevicius *et al.*, 2008).

It is analyzed opportunity to construct the wind turbines near the old dump of Klaipeda (Kalotė), which has already closed.

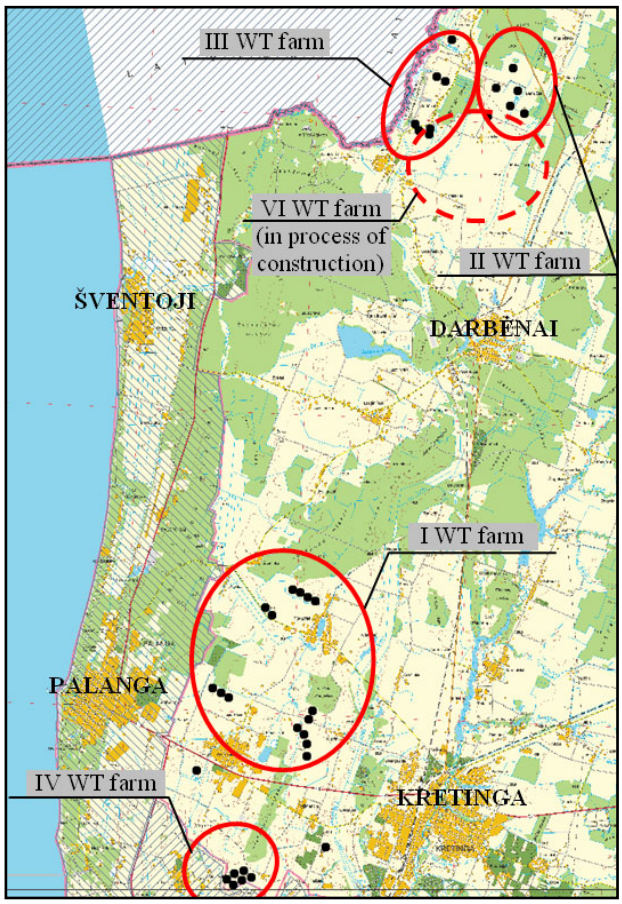

Figure 1. The location of existing wind turbines (VE) in the region of Kretinga (the author of map Abromas J., 2010)

The development of wind turbines at sea

The main reason why wind power started to build in the sea, it has become increasingly supplicated search of suitable places to install them on overland.

The wind turbines sceptics maintain that, this huge wind traps pose a significant noise, deter or fatally damaging the birds, changing the natural landscape and deteriorating the living conditions of surrounding population.

Globally, investors are facing the same problem - an appropriate location to install wind park search and with difficulties to obtain permits for their construction.

Meanwhile power-station at the sea, several kilometers from the shore is invisible to the naked eye, and it seems doesn't much of harm to the environment.

There are also unsuitable sites, places where the fault lies in the chemical weapons, geologically inappropriate location. The main requirement for the construction of these plants - they are strictly forbidden to install them in bird migration routes and fishing areas

News is that in the sea is more wind, hence is greater production of electrical energy. By comparison: in land average wind speed of 7 m/s, in the sea near the shore it reaches 10 m/s and away from the coast 11 m / s. When are favorable conditions, in the park of marine power plants can to produce up to 50 percent more electric power than on overland. This should expiate higher input constructing in the sea: the concentration of salt in water requires special corrosion-resistant materials, used in the electrical structures only, their installation and maintenance works will also cost significantly more than land power plants (Surokaitė, 2009).

The wind energy at sea was 1080 megawatts, or only 1,9 percent of the total energy of wind in Europe It is received provision to develop faster wind energy at sea. The wind turbines in the sea will produce already 3,500 megawatts of electricity, or 4 percent of the total powers of the wind in 2010.The development of wind turbines accelerate and that the parks will be merged into a single "Supergrid network. It is already built on Ireland. It is prepared project of 550 million euro and how to connect the 350 km length Lithuania, Kaliningrad region and Polish wind power plants into a single network in the Baltic Sea "Bosegrid". The fast development of wind energy is in the North Sea, where leaders are Germany and the Netherlands. The leaders in development of wind parks at Baltic Sea are Denmark.

The scientists from Lithuania, Kaliningrad and Polish prepared a schemes in which locations of sea can be wind turbines in 2006.Lithuania provides five areas, in Kaliningrad water region - two, in Poland - four (see Figure 3)

Wind turbines at sea in the Lithuanian waters provided total 237 sq. km. area. In five separate sites could result about 500 power plants. Their combined output concluded by 2220 megawatts. Currently, there are free local areas over 370 megawatts for wind power parks. It was proposed for Lithuania to use planned wind farms sites in Kaliningrad region .Near the Lithuanian border and Nida, 8 km from the coast, it is provided the site of 24-sq. km, the site of 28 square meters km. near the shore at Zelenograd.

For example, at the Klaipeda potential wind-power park is provided by distance of 16-25 km from the coast. It is alleged that about 15 km from the shore is difficult to discern power. It doubts for the possibility of house plants at Neringa, because then the distance from the coast would be the lowest - about 4-16 km. As well as the Curonian Spit is a very important area, the visual pollution is not acceptable here.

It was planned, that the first wind turbine in the sea, at the Lithuanian coast will be built in 2011, but because for the huge need manufacturers can't to produce the proper quantity, therefore is believed that the first power plant at the Lithuanian sea coast will be built about 2013.

Before beginning to the construct at sea wind parks need to adjust the legal bas of the coastal zone. It must be made also maritime administration. It would help to solve the problems of constructing wind power in the sea. The prices of constructing power at sea depends on their attachment to the bottom .If would used floating wind power, the price would be almost equivalent to be built on land.

The wind turbines at the sea may be useful not only for power generation. The western shipyard has demonstrated that can to build high-technology service platforms "Wind Lift" for external wind parks. It emerged a new industry of wind power energy in Lithuania

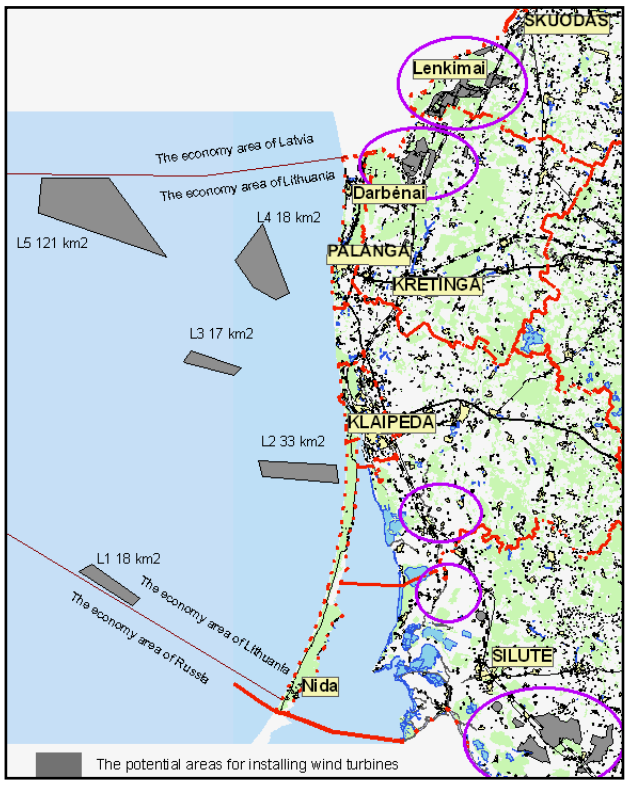

Figure 2. The potential areas for installing wind turbines

The impact of wind turbines on the environment

The influence on landscape and visual impact. In flatlands and average mountain peaks, where wind power due for favorable wind conditions in particular are often built in Europe, they are often visible from far. Depending on weather conditions, wind turbine can be seen from the distance of 15-25 km, if they are no obstructions. In some cases, the early negative internal disposition, vision of wind turbines in environment may to cause some discomfort. This can be explained, and by researchers conducted surveys.

For example, by accomplished study in Germany, 73 percent of respondents indicated, that wind power plants, unlike thermal power plants and high voltage power lines, not interfere. In addition, the study of scientists showed that a large amount of wind power in a small area can even change the local climate. When is high concentration of powerhouse, the air temperature at night can to rise 2 degrees and the wind speed to increase 3-5 m/s (Buķelis, 2009).

The wind turbines – a category of special buildings, the builders emphasize, that towers of wind turbines change, but not disfigure local landscape. The gondolas of wind turbines is situated overhead (about 70-120 m) and the impellers is painted a light grey colour, and towers are from grey converting to light green colour which merges with the sky and the green background and is in the underlying, nature and mix of tower structures, and existing landscape acquires a new quality. High mast with turbines and the wings becomes a dominant of landscape. This can to diversify the landscape of plains, to enrich and higher sites of relief, the hills – to underline, to reveal. The detail analysis of installed wind-power sites near Palanga showed, that the first (demonstrative) of wind turbines blend harmoniously into the existing landscape. Looking at the first wind power park (15 wind power stations) is visible that their sites for construction could have been a better choice. There is a discussion for the number of plants and the layout of the settlements

The wind energy is also characterized, that it is scattered and its accumulation requires a certain amount of wind plants, situated in large area. Approximately is calculated that for the electrical installation of 1 MW must

be 0.08 to 0,13 km2 of land area. However, about 90 % of this area can be used for agricultural purposes or left natural vegetation. In addition, wind turbines does not cause the degradation of land and the dissolution of their would not arise problems for the using of the land area.

The influence of noise for the population. The shoulders of wind turbines may to reflect and to dispel electromagnetic waves, thus causing interference to telecommunications systems, making the negative impact for television, radio, various air traffic management systems. However, since the shoulder is now used in the manufacture of non-metallic materials, so the impact is negligible and does not cause major problems.

Acting power causes some noise. This noise has the mechanical and aerodynamic nature. The wind turbines, which the diameter of impeller is 20 m dominate mechanical noise, and larger - aerodynamic. The noise is one of the most limiting factors for the construction of wind turbines, where they are installed near the settlements, residential buildings. (Tsoutsos *et al.*, 2009).

The noise is increasing, when increasing the speed of wind but only to the limit, until the wind turbine reaches its maximum allowable under construction wing speed. Depending on the type of turbine, the maximum speed of rotation is adjustable, guiding electrical angle of the wings against the wind, and when a very strong wind is the speed wind turbine is stopped automatically in order to avoid structural damages.

By applicable hygiene norm HN 335007 in Lithuania residential and public purpose spaces in the environment during the night allowed a maximum 55 dB (A) sound level. Previously, it was allowed only 45dB (A). It is maintaining that, the sound level of modern 2MW turbine by distance of 65 meters corresponds this 55 dB (A) rate. And now the sanitary protection zone of wind turbines is 80 meters, instead previously force 300 m (see Figure 3).

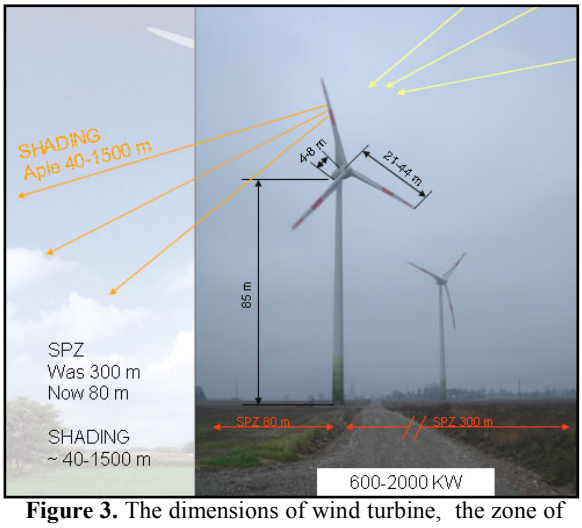

Figure 3. The dimensions of wind turbine, the zone of sanitary protection and the shading characteristics (The author of map Abromas J., 2010)

The wrong choice for installation of wind turbines or the insufficient distances to the living environment can to influence the bad feeling of people, the insomnia, and to cause the psycho-social impact. On purpose to avoid negative impact or reduce it, in the detailed planning stage the impact on public health screening or the full impact on public health assessment procedures.

Disturbing problem become formation of moving shadow for the rotation of blade. However, it can be properly planned to avoid residential electrical layout, direction of solar respect.

The effect on birds. Previously, the collisions of birds with wind turbines risk was considered very high, however new research think about that contrary. Observations in Germany, Holland, Denmark, Great Britain has shown that in small and medium-sized wind turbines birds are killed rarely. But this problem is topical, when the wind parks find in the massive ways of birds migration or in the zone European interest birds stay area.

The most of the birds generally follow the rotor area, because they fly above it (eg., travel), or after it (eg., the transition period). May be at risk for bird of prey, whereas the greater parts of their time (during the search for food) are in the rotor height. (Jallouli and Moreau, 2009).

The impact of wind turbines to the different species of birds is different, but is not great. Has long been view that, wind turbines have an impact on breeding birds lifestyle, because these caused by the shadows of the wings can to support as shadows of birds prey. However it emerged, that wind turbines does not affect the breeding species lifestyle, because they understand that the shadows of wing not risk. Birds also influenced by rotational speed of the wings in the wind turbines. It is maintaining that rotating blades of wind turbines by speed 17 -35 rpm do not endanger flying birds, and rotating by higher speed impellers can to lead to danger. (Buķelis, 2009).

The particular attention is paid to wind turbines potential impact on wildlife and vegetation in protected areas - national parks, reserves, protected areas and sites of Natura 2000. Installing of wind turbines in such sensitive environment often is carried out a full environmental assessment.

CONCLUSIONS

1. Compared with other regions of Lithuania, the coastal habitat excreted for the ecological energy resources: the strong winds of sea and waves, geothermal waters, most of sunny days.

2. The development of wind turbines in west Lithuania is inevitable. However, the wind power sites are necessary to group into different positions, them out away from settlements, important protected areas. The most

suitable places are in northern part of Kretinga, Skuodas, Mažeikiai areas. In Šilutė area. The development in Šilutė area is complicated for existing protected areas.

3. In order to avoid the negative impact of wind turbines and other alternative energy objects it is necessary to develop special mitigation plan of west Lithuania alternative renewable energy layout and existing wind turbines, to do the research.

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The City in Change, What Is Its Name?

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Abstract. The evolution of architecture in the independent Lithuania is discussed in this article. In the background of the global "architectural integration" the issue of possibility to preserve the identity and uniqueness of Lithuanian architecture is raised. In the text emphasised is the importance of sign-marked architecture which is related to cultural layers of the nation.
At the same time the search for the link between an individual sign and the memorable identifiable cityscape is presented. Reconcilability of the Lithuanian cityscape, identity search and preservation is named as the principal creative task of an architect.

Keywords: identity, sign, architecture, uniqueness.

INTRODUCTION

The article aims to determine possibilities of Lithuanian architecture sustaining its regional and national features.

Today an international globalization process takes place. Traditional cultures are integrated and graded. Is it possible to create modern and easily identifiable Lithuanian architecture or it is just an illusion? Can we predict specific features of Lithuanian architecture which would show existence of Lithuanian Architecture School?

During the 20 years of Independent Lithuania its architecture has been integrating into a multi-colored context of world architecture. Accelerating spread of IT technologies, visual contexts and financial abilities of builders allow to absorb experience of international architecture. It is an all-embracing architectural process which affects changes of towns and their images. Serious risks come out and affect professional architects during the world wide integration process. The results of their works quickly change the townscapes of Lithuania. International influences became sorely vivid. Not just a separate building but the whole city picture obtains features of international architecture. That is why the title of the article "The City in Change, What is its Name?" points out even more than a question of architecture identity. The process involves all parts of cultural entirety and should be analyzed and perceived.

The aim of the article was to grope and discuss the following topics:

Identity of Lithuanian architecture – possible or imaginable?

Influences of world architecture and the problem of the uniqueness of an architectural object;

The scale of the architectural values of the terrain – signs and context.

METHODS

The comparative method has been chosen for the analysis. The up-to-date Lithuanian architecture works have been compared with the objects built by foreign architects. Roots of architectural-cultural identity were quested, the correlation of this process with the phenomenon of "Critical Regionalism" were also analysed.

RESULTS

Experience of the development of Lithuanian architecture during recent two decades deserves researching. The architectural process has undergone the boom of growth, its discoveries and losses; it was miscellaneous and interesting. The aim of this report is to discuss how this process has influenced the architectural structures, gave deformations to them or raised new strong sprouts.

Identification of the features of Lithuanian architecture in contemporary process of the intense international informational – technological – cultural – political communication, – is it possible? Or do we vainly imagine that we may affirm that it is possible to preserve and develop LITHUANIAN ARCITECTURE, identifiable and supposed.

In the reality of today's Lithuania we may ask a question, may be a painful one, - CAN A POVERTY-STRICKEN POSSESS ITS IDENTITY?

Figure 1. Skyscraper, the bank Vilnius, A.Ambrasas, 2009

Bank buildings (Figure 1) in the centre of Vilnius demonstrate bright individual architecture. Rich and versatile forms of the edifice, bright and memorable silhouette turn it to be a prominent sign of Vilnius [http://www.ambrasas.lt].

Figure 2. Expo Edifice, Vilnius, R. Palekas, 2007

The Exhibition Pavilion (Figure 2) is an example of the "clean" architecture. The architecture of this building is strong and conceptual; its forms and materials, the short-spoken expression are characteristic to Scandinavian (Baltic) architecture [http://www.palekas.lt].

The roots of the country in nature, cultural, political and economical structures have many faces and definitions. The processes of changes in architectural identity depend on the alternations of the influencing factors mentioned above.

As in every nation, architecture in Lithuania has been developing by cognizing laws of existence both of nature as well as society. For us the notion of "NATIONAL ARCHITECTURE" is tightly associated to the architectural objects of villages and little towns. At the same time, throughout the whole existence of the state of Lithuania, its architecture experienced major or minor influences of European architectural styles.

In Lithuania, the transformed international influences together with rustic architecture compose unanimous structure of Lithuanian architecture. Thus Vilnius is inconceivable without Italian Baroque; Klaipeda can not be imagined without the German fachwerk or Kaunas without the complex of strongholds.

In such background of architectural "integration" we are always accompanied by the problem of uniqueness of an architectural object. By admitting that uniqueness of a building is defined by objective and subjective factors, let us analyse them. The subjective factor depends on mental qualities of an architect - creator, his power and singularity. In the whole world names of architects are greatly valued. They form the special architectural Olympus, their projects (successful and occasionally not such) guarantee to the Developer a long-term publicity and commercial success. The viewers in the world also acquire the right to enjoy and admire the unique 'brand' pieces of architecture. Today the architect's name is the most marketable item in the world.

Figure 3. Library Cottbus, Herzog & De Meuron. 2005 (Daab gmbh, 2007)

Figure 4. Bussines center building, Kaunas (Adomaitis, 2008, http://www.rastudija.com)

Figure 5. „The Gherkin" Tower, Lord Norman Foster 2004, (www.fosterandpartners.com)

Figure 6. Jean Nouvel „Aghbar Tower" Barselona, 2004m.(*http://www.jeannouvel.com*)

By comparing the presented buildings we may accuse R.Adomaitis (Figure 4) for emulating the project of Hercog&De Meuron (Figure 3). So then what about Lord Norman Foster and Jean Nouvel? At the same time towers "Cucumbers" in different cities became their architectural symbols (Figure 5 and Figure 6).

"Architecture is an interesting mirror of the society, and although being slightly curved it allows as least guessing what is taking place in this society. Reflecting the surrounding world the mirror also tells something about itself. The projects of 2007-2008 represent the variety of the modern architecture typical of Europe, which becomes for us as our own. Will we aim at individuality of architecture by arrogant and drastic cuts of our own signs, making them as original as possible, to the environment created through centuries, or will we search for inspiration in an equal dialogue with the past? This choice will determine what things will be conveyed by our architecture to a contemporary and future observer about our ideas, experiences, a relation with the world and past. Maybe the slowdown conditioned by a very trying time over this important period of search for individuality will give an opportunity to concentrate, think over, perceive" (Kulikauskas, 2009).

The contest for Guggenheim-Hermitage museum in Vilnius was organized in 2008, three 'brand' names – architects Zaha Hadid, Massimiliano Fuksas and Daniel Libeskind were invited by Vilnius Municipality (Figures 7, 8, 9). The site for an object was chosen on the waterside of the river Neris, in the central part of the city which is undoubtedly very important in the city-texture. The architectural projects presented by the three authors significantly change the city-face. These propositions caused discussions among Lithuanian architects about the origin of such architecture, its psychological, emotional, cultural and financial acceptability.

Contest of Gugenheim museum in Vilnius, 2008 (http://www.delfi.lt):

Figure 7. Project of arch. Daniel Libeskind

Figure 8. Project of arch. Zaha Hadid

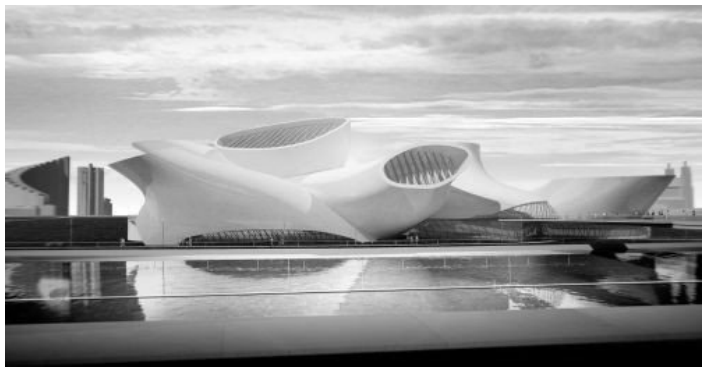

Figure 9. Project of arch. Massimiliano Fuksas

“Some enthusiastic voices greeted: “Guggenheim will change the face of the city! Absolutely! However this fact testifies not the worthiness of the conception, on the contrary it is the proof about the erroneousness of the idea. Vilnius has a distinctive, unique and beautiful face which is accepted as universal value. We are obliged and committed to protect it. And what is more, the cityscape has already been disfigured by the architectural jumble on the right bank of the Neris, all those glass-boxes with rickety walls and off-going roofs, lumbering the panorama of the downtown and the Neris valley. In this most picturesque place only Guggenheim is missing!” [A face of Gugenheim for Vilnius!.2008. In: Literatūra ir menas. Lietuvos rašytojų sąjungos savaitraštis.Vilnius, 2008.Vol. 3192]

Nowadays the uniqueness in architecture is especially connected with the usage of modern technologies. Prosperous states make great investments into modern technologies related to energy usage, modern structures and materials, engineering. The emerging symbols of the economic growth in exploding cities demonstrate these objective and subjective potentials.

We may see that in the process of such a rapid city-development the architectural form and style wander from one city to another, live next to other styles and forms.

We will see that in the forthcoming ten years of such architectural development we will not be able to identify different countries of the world, distinguish and name the city’s silhouette.

We memorise and recognise cityscapes through architectural signs. The city signs, especially those expressive ones, create history of city architecture. Lithuanian signs are known to the world.

Figure 10. The Gediminas Castle, Vilnius [www.musupaveldas.lt]

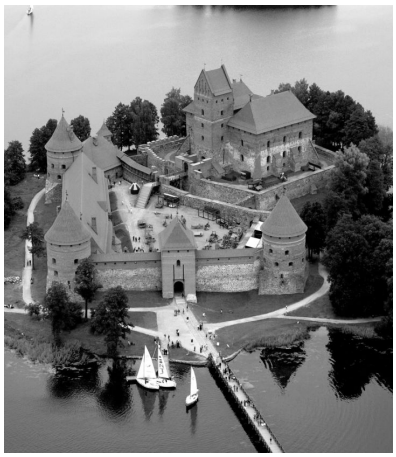

Figure 11. The Trakai Castle

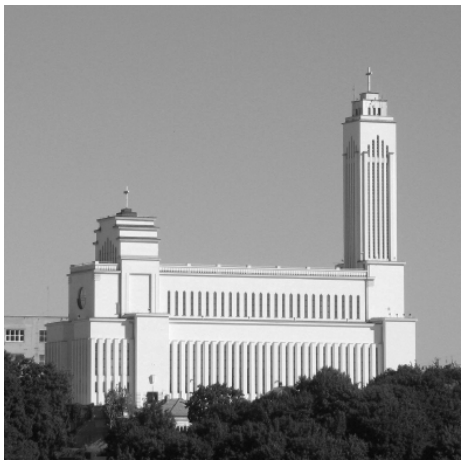

Figure 12. The Resurrection Church Kaunas K.Reisonas 1933, Spindys 2004 (Architecture of Kaunas)

Figure 13. The Tower of commercial complex “Europa”,Vilnius A.Ambrasas 2004 (*http://www.ambrasas.lt)*

The ancient signs reached us as symbols of the identity of our state (the Gediminas Castle (Figure 10, the Trakai Castle (Figure 11) though, throughout the centuries, their authenticity has survived various deformations (wars, fires, restorations and renovations). These objects are not just nationally important, they are significant

signs of Lithuanian identity in the world. They are protected by international laws and organizations. However the shorter is the time distance separating us from the origination of a particular architectural object, the more difficult it is to preserve the building from rapid deformations.

The presented architectural objects are those exceptional signs that throughout history have developed into the mirage entirety of city values. However with every new project – a new sign - again arises a discussion, claiming to determine the terrain's value scale, in which the non-traditional system leads from a single sign to the entirety or vice versa. The question is – can we accept the signs that may destroy the society? Does the society get enriched by accepting various emphatic signs? In many cases, at the moment when a new pronounced sign emerges it causes great tensions between a context possessing defined values and a new bright architectural sign which is not directly related to these values.

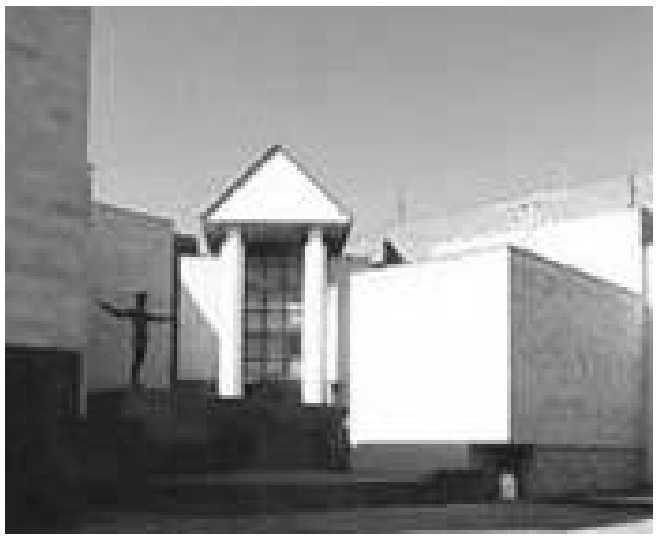

Figure 14. Art Galery, Kaunas, E.Miliunas 1989 (http://www.muziejai.lt/)

A similar sort of discussion blew up about the uprising of M.Zilinskas Art Gallery (Figure 14). The new structure disrupted the solid building-up line of Independence Square by introducing the "minor piazza" in front of the main entrance. Up to nowadays such a device is treated as a violation of urban and heritage-preservation specifications. Meanwhile the museum became a distinctive sign testifying the 20th century Kaunas architecture.

Figure 15. Department Store "Merkurijus",Kaunas, A.Sprindys 1983 [http://www.miestai.net/]

After the commercial centre "Merkurijus" (Figure 15) was constructed in the Liberty Avenue, it was much disputed about as to destroying the historical building-up line by forming a new plaza. This new square came to existence as a full-bloodied public space of a city to arrange festive events, concerts, recreational activities. Today "Merkurijus" no longer exists. The piazza will disappear as well. (Institute of Civil engineering and architecture research. Architecture of Kaunas, 1991)

Figure 16. Commercial-residential building "Tower" Kaunas, G.Natkevicius, 2008 (http://www.natkevicius.lt)

The multifunctional centre "Tower" (Figure 16) in the central part of the city was adversely assessed for being too high. In the meantime the Kaunas centre is not built-up intensely enough.

The story of Eifel Tower gave us a good lesson. The discussion about this sign of architecture history indicates that there do exist architecture pioneers who take a risk to be condemned by professionals as well as by the city and global society.

How much time does it take to assimilate the meaning of a new sign in regard to the entirety?

Figure 17. Millhouse of etnographical musem Rumsiskes

Figure 18. Wind power plants around Kretinga

Does the new sign prepare the way for a new entirety? Will the sum-total of new signs create the new city identity? Will it be strong enough for the expression in form to last for centuries ahead?

It is a paradox that the most revolutionary contemporary suggestions "discover" the primary human architectural forms. Motivation of human accommodation, sequence of causality of constructional methods and integration is under investigation.

It is paradoxical that the conception about authenticity of architectural expression turns around in the circle of time.

CONCLUSIONS

The lessons perceived and the circle of discoveries, turn around in time coming back to the explanation of reason and outcomes.

We move from the delivered aspirations to real solutions. Participation in the global creative process in architecture helps to revise motivations and to justify ambitions. There remains the eternal desire TO RECOGNISE THE SILHOUETTE OF THE NATIVE CITY.

At this economically tight period for the Republic of Lithuania, by creating the new architecture will we remain identifiable and not lose dignity?

It is essential to analyse the process of urban evolution by supporting and developing the identity of Lithuanian cityscape.

It is important to assess the individuality of the new architectural signs and their relation to the entirety of the cityscape. Expressive and identifiable architectural signs provide cityscape values that are transfered through ages.

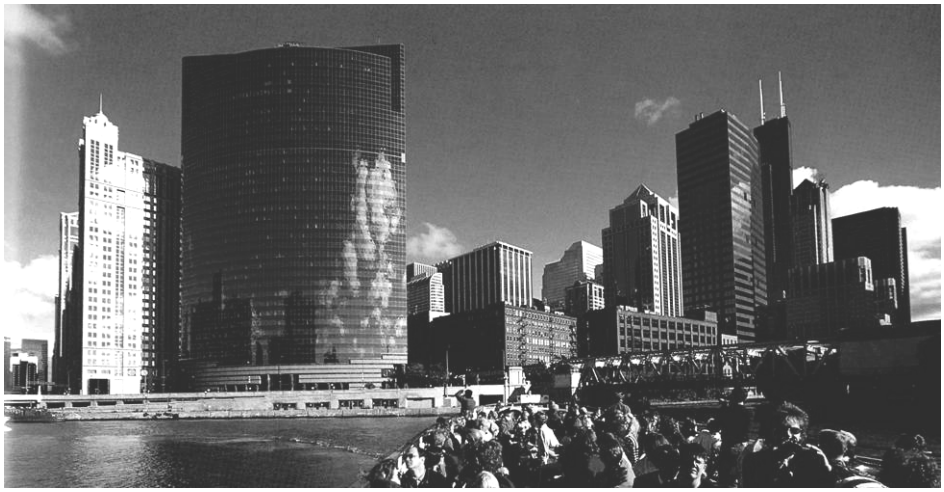

Figure 19. The siluete of Chicago city (Most beautiful cities of the World, 2008)

Figure 20. The siluete of new Vilnius city (http://www.krantai.lt)

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On Building Information Modeling in Early Design Phases: A Case Study of BIM-Based Architectural Competition

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Abstract. This paper summarises research results of BIM (Building Information Modeling) application in early architectural design, attempts to determine the problems, capture the trends of object-oriented modeling and find the relations of BIM with CAAD (Computer Aided Architectural Design) education. The aspects of implementation of object-oriented and BIM-related modeling methods and relations with existing designing praxis are discussed. The evolution and the phases of dominating CAAD technology and its emerging with information systems leading to intelligence and concept of BIM supporting the whole life cycle of the building are analysed. Different object-oriented modeling software alternatives are discussed and compared. The IFC (Industry Foundation Classes) format enabling the interchange of the BIM information between different CAAD software in AEC industry is presented. The results of the study - the methods and a set of digital tools developed for solving of the problem are presented. An innovative international BIM-based architectural competition as a case study that took control over important design parameters and interrelations with the CAAD education are discussed. Main phases of the process, deliverables, client procedures and tools supporting competition entrants and issues of the competition are presented. The factors of the case study concerning CAAD theory and praxis are analysed. The problems and conflicts during the process of competition have been revealed.

Keywords: Computer Aided Architectural Design (CAAD); Architecture Engineering Construction (AEC); Building Information Modeling (BIM); Industry Foundation Classes (IFC).

INTRODUCTION

The research concerns the possibilities and limitations of object-oriented modeling when it evolves implementing the building information modeling (BIM) concept in the field of computer aided architectural design (CAAD). The impulse for the research was an open international planning and design competition encouraging making a summary of recent investigations, determining the problems and capturing the trends of CAAD.

Architects seek to create a design concept representing it graphically in digital space. Then they try gradually to convert it into more detailed intelligent design assigning the properties necessary to produce final project documentation that is in accordance with contemporary demands. It seems theoretically there are all the prepositions (methodology, technology, software) created today. But this process is still not seamless and smooth in practice.

Main assumption of our study is that the contemporary designing process could be improved. The objectives of the research is to find the methods, theoretical and practical solutions for creating intelligent models, compensate the shortcomings of the existing technologies and subsequently improve CAAD education. These objectives determined largely the choice of the methods used.

EVOLUTION TO OBJECT ORIENTED MODELING

Visual reasoning and evaluation is a fundamental attribute of architectural design. But as stated (Koutamanis, 2001) one of the most significant consequences of computerization in design practice is a spectacular increase in the amount and complexity of information produced for the specification, analysis and communication of design decisions and products.

Designing and consulting companies are no longer capable to work in an old fashioned style because of the short terms and high demands of the participants of investment cycle. So nowadays architects and AEC community have to deal with big amounts of heterogeneous information while developing the projects of built environment.

In designing practice in last two, three decades we observe a gradual improvement process of dominating CAAD technology as the phases of its evolution:

- 2D layered drawings that included simple block definitions and its references.

- 2.5D and 3D models consisting of pure geometric objects (entities like faces, surfaces, solids) that mostly included only block references possibly integrated with numeric or character attribute data.
- 2.5D and 3D models that included a layer key styles technics for logical managing of graphical project information in applications for AEC industry. The entities possibly were enriched with extended non-graphical data (Extended Data known as XDATA). The features of dynamic blocks improved the functionality of programs.
- Object-oriented 3D models built of intelligent and flexible AEC objects as the parts of buildings (e.g. AEC_Wall, AEC_Roof, etc.). AEC objects are defined by the set of native parameters and they can be additionally associated with the data structures named "Property Set Definitions" (PSD). Essential feature of the definition of that type is the ability to edit the objects by changing dynamically the property value in the property dialog tables (palettes) or through the direct geometric modification of the object.

Gradually CAAD systems adopted more features of the information systems so increasing the intelligence of CAAD objects. As a resulting logical issue of the fourth phase the BIM (Building Information Model) concept supporting the whole life cycle of the building was declared. The idea of the digital BIM model technologically was supported with the development of the AEC-related format named IFC (Industry Foundation Classes). This format enabled the interchange of the information between different CAAD software and also became a bridge between CAAD and the third-party programs.

The ability to keep building information up to date in an integrated digital environment gives architects, engineers, contractors, owners a clear overall vision of the projects, as well as the ability to make better decisions faster. Although building information modeling is an approach and not a technology, it does require suitable technology to be implemented effectively.

The competition was a stimulus for the AEC society to try to understand the theory and use in practice BIM approach and technologies.

AEC BIM RELATED SOFTWARE ALTERNATIVES

There are at least five commercially available and implemented differently in (IT) information technology viewpoint CAAD systems that can generate object oriented BIM related models: ArchiCAD, Revit, AutoCAD Architecture, Bentley Architecture, Allplan. The problems start with the most frequent question that arises both among practitioners and in academy society. Which software to prefer in education and in design studio:

- working with the huge centralized database stored in one project file (e.g. Revit).
- working with the group of separate smaller project files represented as external references and managed by the project navigator (e.g. AutoCAD Architecture).

There is no clear answer to that question. According to our experience all the systems are viable and competitive and each of them have advantages that are difficult to deny. Some of them are designed as more conceptual systems, try to capture more general design features and have bi-directional associativity between different parts of the project. The others demonstrate more flexibility because of advanced native graphical editor that can be used in a creative way. The recent systems can be more suitable for interdisciplinary design when there is a need for closer collaboration and exchange of data with the building engineering systems.

METHODS OF THE RESEARCH

The study has both theoretical and experimental character. The methods used in the research were: geometric 3D modeling, algorithm and program development, architectural design with computational design tools, AEC object-oriented modeling, analysis and synthesis of integrated data structures.

Basic iterative procedures implementing the plan of the work were: a) generation of experimental fragments of the model representing the architectural concept, b) development / modifying of the digital tools, c) non-graphical data integration with the objects of geometric model, d) exporting the design information interchange IFC format file and its analysis in the model server application.

The IFC (Industry Foundation Classes) file format provides an interoperability solution between different software applications and is based on international standards for common objects in the building industry.

AutoCAD Architecture – a flexible, extensible, prevailing CAAD system was used as a main environment. Programming languages and programming technologies used : VLIDE (Visual LISP interactive development environment), VBA (Visual Basic for Applications - an object-oriented programming environment).

RESULTS

Main results of the study are the methods and a set of digital tools developed for solving of the problem. The experience aquired allowed also to formulate the tasks to be solved in the future.

In technological point of view the problem of architectural designing using AEC objects always consists of two parts: 1. the concept usually represented by the spatial model of the object 2. the architectural working

drawings extracted from the model or generated independently. In early design stages essential part nowadays becomes the model of the concept that consists of two parts : a) geometry b) additional associated data.

The methods proposed concern the above mentioned parts.

The methods for the first part are based on automatic *conversions* between different types of objects in combination with the editing possibilities of different types of geometric objects. According to this approach the digital design is comprised of *mixed* 3D model consisting from various object types. Different object types mainly are used as intermediate auxiliary ones. Important issues are the productivity of modeling / remodeling and the possibility to achieve the final objects – AEC objects that would allow to create portable BIM in IFC format. Main demands the proposed methods and the final model should fulfill are: high integrity of the model, acceptance of coincident different object types, feasible transition from the concept to more detailed construction representation.

On this purpose three groups of digital tools were proposed and used: 1. Originally developed functions 2. The functions developed earlier and adapted for the actual research 3. The tools on the stage of designing and development and only partially used for the research. The tools of first group generally are implemented as short but rather specialized programs for the appropriate tasks and they can be relatively readily modified. The second group tools are selected and modified from our existing software and algorithm library developed earlier. They are of the larger extent, include more universal features, and have documented formal parameters what enables to integrate them into other managing functions. The tools of the third group are mainly addressed for control and managing of additionally associated non-graphical data. The feedback of actual study particularly of the architectural competition is a base for their further development.

It is important that the researcher investigates carefully the functionality of the existing tools of standard software used as a working environment in advance to make the right program development plan.

I. From the point of view of the purpose all the digital tools in question can be classified:
II. For utilization of the procedures of the object types conversion,
III. For helping to solve various geometric tasks of modeling,
IV. For making manipulation of logical structure of the design easier and quicker.

Common feature and principle of the first group functions is that the geometry during the conversion is inherited from original object fully or partly with the possibility to add remaining geometric parameters interactively. Some of these tools compute also the resulting evaluation parameter values (areas, perimeters, volumes) and provide the user with the alternate controlling method in comparison with the AEC property sets. As a result of the conversion the AEC objects or the intermediate objects are used for computation or final conversion to AEC objects. The list of the types of AEC objects possible to convert covers more items than it were introduced in the competition. As the initial objects usually can be used 3D lines, 2D polylines, arcs, block references with the option to extract and use automatically the names of blocks as the predefined styles of AEC objects. These methods enable also to control the angles of the 3D orientation of architectural and structural elements (slopes, rotation angles about the longitudinal axes). The properties of the objects of 2.5D geometry are useful when controlling spatial angles. The reverse conversion with object duplication helps to solve annoying snapping problem of specific points that is usual in CAAD programs.

Thereby the architect or the structural engineer initially can deal only with more abstract, schematic information avoiding the web of lines meaning layered wall, roof structures or the edges of structural members. Definite steps of the procedures depend on the types of initial objects, the intention, and the type of the final objects. Figure 1 shows one of the most popular technological conversion schemes to achieve the objects AEC_SLAB.

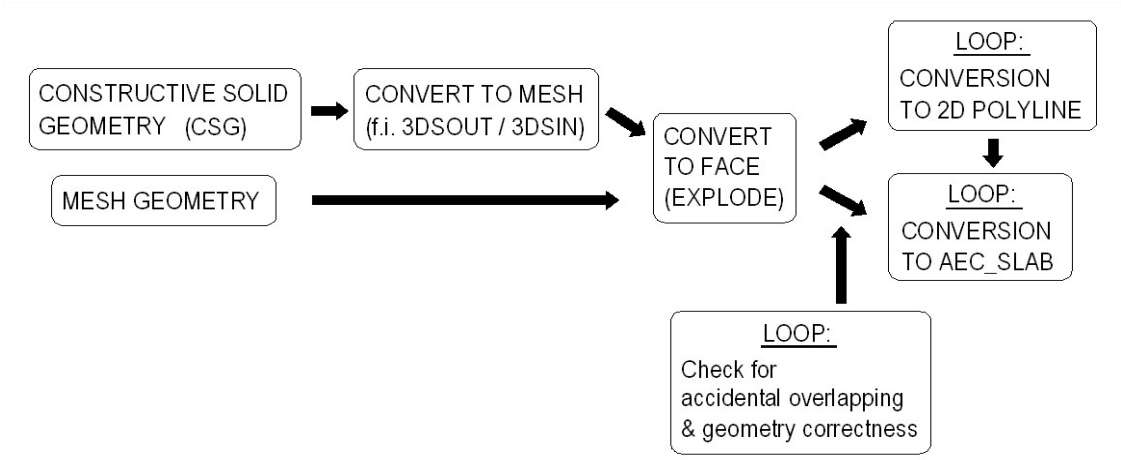

Figure 1. Typical scheme of model geometry conversion to AEC objects

Some simple conversion procedures are possible using standard AEC commands but the productivity is low or in some cases the process is possible only theoretically. The productivity becomes an issue especially when the geometry is more complex, the model is built of a big number of objects or if there is a need for more design alternatives (Figure 2).

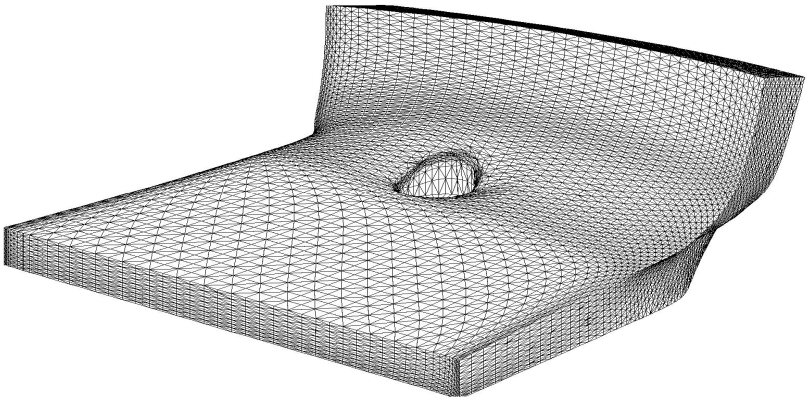

Figure 2. Preliminar design concept automatically converted into valid AEC objects
(the design team: A. Skiezgelas, V. Biekša, R. Kilčiauskas, M. Kanevičius)

The tools of the second group are aimed for quicker solving of the typical intermediate modeling tasks: spatial intersections, footprints of objects, aligning of the heights and orientation of objects, correction of the linear dimensions of objects and the distances between parallel objects, control of linear equality, correction of the values of angles, etc. Main common characteristics and the source of the productivity of these utilities is that generally they use basic CAD wireframe objects, transformations of construction plane in the model space, and have very short dialog based on defaults. For instance, the functions of that group helped easily to generate the lines of intersection and footprint lines of the building volume proposed for the competition in the given terrain model (Figure 3).

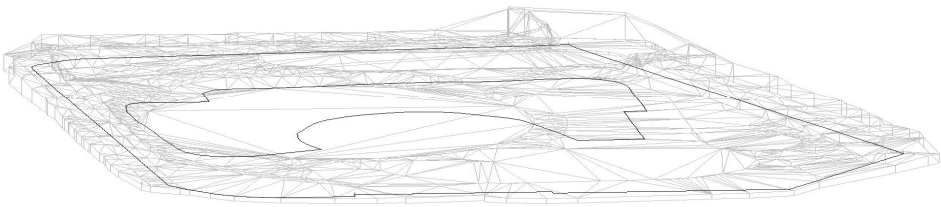

Figure 3. Lines of intersection and footprint of the building in the terrain model

The third group is a wide extension of the standard CAD and AEC set of tools that use both external references and layers as the managing units. To the same group belong programmed tools accelerating logical filtering of objects using different criterions. Conversion technique and complex mixed models with overlapping edges lead to large and puzzling resulting geometric structures. Large or more detailed designs require from the architect to create permanently the various combinations of logical parts of design and examine the mismatches. Particularly competition proposals required a special visual and non-formal assigning procedure for the logical

property “internal or external object“. The problem is to perform the actions quickly, fluently, avoiding mistakes. Created functions allow user to manipulate (switch on / off, freeze / thaw, lock / unlock, unload / reload, detach) layers and external references by selecting the geometry using digitizer instead of browsing in the lists trying to identify the names of named objects. The options of accelerated use of the predefined wildcard strings applied to layer names, layer states applied to the groups of layers, and accelerated “layer-walk” technique without dialog boxes that hide the drawing are designed and programmed.

The second part of the competition problem as mentioned was the assigning the property sets and their values to the AEC objects using correct formats. That was the most challenging technological part of the competition.

ARCHITECTURAL COMPETITION CASE STUDY RESULTS

3D BIM models with associated necessary data can take more control over design already on early design phases including the architectural competition phase. The case was an open planning and design competition for the National Museum of Art, Architecture and Design (Oslo, Norway) we (A. Kančas Design Studio) participated (Figure 4). The client and the organizer was Norwegian Statsbygg in collaboration with Jotne EPM Technology and Norske Arkitekters Landsforbund (NAL).

Figure 4. National Museum at Vestbanen. Bird eye view of the design proposal
(the design: team A. Kančas, G. Kančaitė, T. Petreikis, K. Kajokas, G. Cinelis)

The essential element of the museum solution – rounded inner yard inside the building with all exhibition spaces arranged around it. Building volumes are situated in circle position around the courtyard – open-air sculpture park, with all the storeys, possessing museum halls, accessible from the spiral ramp.

Main deliverable in this innovative competition was a digital 3D BIM model created with an object oriented design tool and represented in open BIM standards / formats (IFC release 2x3) that meets the specifications provided in client’s documentation. Ordinary documentation set submitted by the client (building brief, space program and functional requirements, GIS related data) included also the necessary measures related to energy saving through the choice of concept during the competition. For the purposes of conceptual visualization of the proposal participants of the competition had to place the models according to geo-referenced 3D points. Later the client included the model by using CAD / GIS application in a larger surrounding area.

The model submitted to the client had to include information about space / zone floor areas and explicit information about internal / external envelop objects, number of storeys, main entrance storey etc. This information was used by the client to ensure function / area requirements programmed versus proposed / modeled and subsequent energy analysis. Client also specified valid types of AEC objects to be used in the model (AEC_SPACE, AEC_WALL, AEC_SLAB, AEC_WINDOW, AEC_DOOR).

There were four main not clearly distinguished and intertwined phases we performed during the competition:

1. Clarifying of the client’s assignment (the brief), initial tests and preparation. It was important part of the work.
2. Setting up the concept, sketching and conceptual modeling.
3. More detailed modeling, definition of the property set data and its integration with the model objects.
4. Checking and correction of BIM model both visually and using various digital tools.

The architects had to find the way how to assign to some objects property set definitions interactively. The originally programmed functions helped to shorten repetitive procedures when the model evolved.

The client took great effort supporting competition entrants via internet. Experts from Norway provided “Question & Answer”service, temporary licence of IFC model server - a special software allowing offline tests

of BIM model correctness and supply missing information interactively. Additional free software from academic institutions for IFC files visualization and analysis was helpful too.

DISCUSSION

On the one hand the final desirable result of modeling developed on early design stage is very integral 3D AEC / BIM model accumulating necessary architectural information that is able to evolve smoothly to more detailed structural representation. It is beyond argue that object oriented BIM model is the most flexible and dynamic kind of model for that purpose. On the other hand no one type of model object including AEC possesses all the necessary features for editing operations. When solving that controversial issue our recommendation is to use mixed models built of various types of coincident objects. As a rule the automatic conversion of intermediate objects using where necessary originally programmed loops can significantly increase the productivity of generating of the AEC models.

In our opinion widely used practice of modeling trying to use only solid CSG type objects in the final model is perverse. It could cause heavy geometry with its slow processing, not adequate intelligence, and editing faults. The same time CSG objects could be useful as intermediate objects in editing and conversion procedures.

Straight-forward modeling using only AEC objects not always leads to successful geometric solutions (the solution could be wrong or no solution at all). Meanwhile these problems (intersections, footprints) can be fixed using basic wireframe and surface CAD objects and appropriate proposed functions from the second group described above with subsequent generation of the AEC objects.

Often it is argued that the designer is not able to handle multi-layered models with overlapping geometry of the edges and various combinations of external references. This is well-known problematic aspect of the right object selection and identification that could be solved using proposed tools of the third group for logical managing, direct selection, and filtering.

Theory and praxis

The participation and analysis of the process of competition revealed those problems and conflicts that otherwise could be only anticipated. Basic theoretical knowledge being the background and the most important component not always is sufficient in practice.

To a great extent the client was making too optimistic hypothesis about the possibilities of entrants to fulfill the conditions of the competition. The reality was that many participants from various countries gave up when “ordinary” model of pure geometry was not admitted or when they met the first difficulties working with property sets. Some of the AEC professionals were confused by that fact. Some teams had the problems even with AEC object identification in their models creating messy big files.

Many young architects knew the object oriented methods from CAAD courses while at university. But the knowledge and experience was not enough to fix all the problems practically.

The other issues of the case that concern the problem of CAAD theory and praxis were:

- BIM-related requirements changed in some extent during the competition. For instance, a new AEC object (AEC_Curtain_Wall) was introduced as a legal one forcing the architects to demonstrate the flexibility remaking some parts of the model.
- Sometimes the provided information especially relating GIS data was somewhat inconsistent, incomplete. One could try to find appropriate processing methods of the data like 3D lines.
- Because of mismatches of the names / formats of some AEC objects during IFC tests using model server it was a problem with the transfer of some area data. Theoretically there was an option to supply or correct object property values in model server itself. Practically it was not so fluent and natural process because of the problems of objects’ visual identification and nonconformity with original model.

CONCLUSIONS

BIM-related modeling method is the most promising method for the building industry in general because it is meant to support the project and the architectural object in all phases of the investment cycle – from early design to its demolition, on all levels of its representation – from the abstract to the detailed, for all representatives of the society – from the researcher and the designer to the facility manager and the worker of municipality.

There are no ideal CAD objects in the point of view of editing. For efficient generating and editing of an object oriented BIM model the conversion approach of the different types of objects and the tools for creating of the mixed models are proposed. Intermediate objects are considered to help an architect or an engineer to achieve final AEC objects. Special digital tools for solving 3D geometric modeling tasks and manipulating with the logical parts of complex model are proposed.

Contemporary CAAD system as a BIM-related application has to be provided with the rich set of features of the information systems that allow the architect and the engineer in a focused and flexible way to assign and

transfer, check and query, save and extract additional automatic and manual architectural and engineering information. Currently there is a good theoretical and technological basis created. For implementing the BIM concept in reality intelligent tools for managing of data structures are considered to be simple in practical use especially when processing bigger complex models. The group of tools of quick filtering and manipulating of layers and external references partly help to solve these tasks in current stage of research. The functionality of these features will be significantly improved using VBA programming environment in the future.

The open international architectural competition activities and experience exposed definite problems of different origin and level. As an outcome some propositions can be introduced:

1. There is always a problem to create a digital building model of the strictly predefined objects because of the nature of architectural design : geometrical forms and their structure determine the choice of the types of digital objects but not vice versa. The client should possess the methods and tools allowing the processing the most liberal list of objects and predefine only a technology.
2. Technological sequence of generating and checking of the BIM model using IFC format files in the client's model server was not adequate in practice for some intended purposes. It was convincing for visual general control of the designed inserted volume. But the correcting and additional assigning of the property set definitions and their values caused the mismatches with respect to the original digital model. The identification of individual AEC objects in model server representation in comparison with original model was rather inconvenient.
3. The client relied mainly on the IT competency of the architects and prepared appropriate end-user oriented specifications and requirements. This approach forced the users in case of property set failures of model server try to find patiently the "trial & error" solution. However the information from the client's IT experts (e.g. the examples of the critical extracts from the final IFC files) would be useful for the system analysts of design studios.

The competition was a good experimental design event where the declared BIM statements were tested worldwide in the practical implementation. Likely the majority of the planning and design activities in the future will be based on BIM modeling. Thus joint efforts are needed to overcome the challenges: for the contractor to prepare the requirements, appropriate tools and services to run the process smoothly, for the design studios to acquire appropriate know how and practice, for architecture and civil engineering schools to provide a well-structured knowledge and good exposure of the students in BIM topics.

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Sustainable Tools for Preserving Identity of Open Public Spaces. Case Study: Belgrade

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Abstract. The identity of the city is a complex phenomenon that combines the multiple identities that together form a complete experience and perception of the city. Physical, social and cultural identity influence the formation of a recognizable place in the material and spiritual sense. These elements contribute to the creation of specific characters, shaped and defined in the form of image or reputation of the place, which is in the contemporary period, sometimes, crucial to the development process and better positioning of places in the world and regional networks of cities.
In the function of merge the space and the formation of a new town center, which would avoid monocentricity and which can help the evenly development of the city, was created an analytical tool that can explore a variety of physical and functional characteristics of urban space. The analytical procedure was applied in the study of specific polygons on the territory of Vračar City Municipality (City of Belgrade). The result of the investigations enabled the mapping of potentials and problems of the subject polygon that prevent or encourage the development of local centers observed, strokes which also represent their connections, and diversity of use of public space.

Key words: renewal, identity preservation, public space, Belgrade.

INTRODUCTION

The process of urban revival is complex and ambiguous, and its success is conditioned by numerous factors and the readines of the society and the local community to successfully combat numerous problems, opting for best quality solutions that will be valuated in future eras. In the planning of the main composition framework of a city and its entities, more significant city public open spaces represent an integral element which often dominates the entire planned composition. These urban micro elements can not be regarded only as a simple architectural sum, but rather as an entity, with continuity and values closely linked to the consistency of the city and the memory imprint created over the ages.

More and more, planners are realizing the necessity of polycentric development of cities and the significance of the the networking of focal points of a city, as potential secondaty and tertiary city centers. The basic goal of this paper is to definie potential tools that would be used in processes of regeneration of important urban open spaces, with the goal to upgrade their quality, by realizing organic and vibrant spaces for all users. Analysis was implemented in concrete urban spaces, in the City Municipality of Vracar, with the goal to regenerate them and maintain their identity, as well as to link them into a new municipal network of centers.

To a greater or lesser extent, every milleu posesses specificities differing from others, and making it unique. These specificities are a consequence of the cultural, traditional, historical, specific and individual experiences of an area, in conjunction forming its identity. The physical aspect directly results from spatial characteristics i.e. its level of construction, while the functional aspect is a consequence of the activities taking place within a space. The cultural factor determines the significance attributed to specific sites by individuals or groups, and varies in accordance with differences in ethnicity, social background, age and gender. Sets of images of urban milleus and memory simbolize the belonging to a specific place and indicate "cultural control over specific spaces" (Lynch, 1971). However, we do not have to regard the identity of a city or some urban entity only as a sum of specificities and differences that separate it from others, but also as a sum of similarities that place it within a specific type.

During the last decades of the previous century, theoreticians (Boyer, 1994), (Halbwachs, 1950), (Hayden, 1995) dealt with the significance of social memory which is transferred by repeating rituals, ceremonies and specific behavioral codes, and unbreakably linked to public open spaces. As opposed to the theory that memory and identity are imprinted exclusively into physical forms, they postulated a new theory based on research, emphasizing that memory is unbreakably linked to spaces in which specific social events take place. On the other hand, when researching identity, certain authors place the focus on the social basis, deeming that identity is

not a fixed category, but rather that it is constantly changing and upgrading, and is primarily dependent on social relations, simultaneously indicating the affirmation of differences. (Azripe *et al*., 2000).

Kevin Lynch, who belonged to this group of theoreticians who explained social identity via the individualistic, worked on the study of mental images possesed by inhabitants, linking identitety to the visual characteristics of a city. He believes that identity is the simplest form of feeling and comprehending space, i.e. an individual characteristic (a live, clear, unique, or at least a characteristic image) according to which we recognize a city or its part, and that "a good representation of the milleu gives the one who possesses it a strong feeling of emotional security, which is the very opposite of fear originating from the loss of orientation". Basic qualities valuated in these memory images are by all means the clarity and the possibility to read the urban landscape, i.e. the possibility to easily and quickly recognize individual urban segments and organize then into a coherent image. This quality significantly influences the feeling of security of the user of space, as well as a change of the "depth and intensity of the experience" of a certain space, with the goal to create not only well organized urban segments, but spaces possessing a certain "symbolism and poetry". The sense i.e. the comprehension of space directly depends on the form and the quality of this space, but also depends on culture, temperament, status, experience and the reason why the space user is observing. Therefore, one can conclude that the sense of space is variable, that it depends on the observer and his capability to notice and differentiate spaces and forms, and that urban spaces have multiple meanings because they are observed by multiple individuals. This capability is additionally strenghthened by activities, events, manifestations in the space, that over time, in the eye of the beholder become a permanent and live part of that space (Lacroix, 2009).

Many authors (Halbwachs, Boer, Lozano) refer to the "soul of the city", which they define as a structural connection between the city and its inhabitants, emphasizing the importance of a collective memory or social memory. In this case, the soul of the city is a historical category, a characteristic linked to events or physical structures that used to exist (the Bastille in Paris) or constructions that have continued their existance in a different form or with a different designation (theater in Zrenjanin – earlier a horse stable). In his work "La Memoire Collective", Halbwachs states that a group of users of a certain space after a certain period of time changes and adapts that space according to own ideas, but at the same time is itself changed adapting to the material resources of that space. (Florida, 2002) Another characteristic of group behaviour is that it encloses itself within the limits that it itself had formed (similar comments are found in Lynch, who confirms this thesis when defining boundaries and districts), and a third characteristic is that a group creates its opinion of itself based on the image of the external environment and the character of the relations that it had established with it (identification of a place with ones personal identity). A similar thesis was expressed also by Hillier and Hanson, who believe that "mental maps" are an integral part of the user's perception of a constructed space, and that they are in fact a part of the "coded morphological dictionary" composed of stable spatial and social principles of construction inherited from the past. (Hannigan, 1998).

When it comes to the revival of cities in order to make them competitive at the regional and global level, in the last few decades three most frequent development strategies are apparent: city of illusion/fantasy (inspired by the success of Disneyland and Las Vegas), approach of developing "cultural incubators" (Montreal, Minsk, Graz), and revival of cities based on design (Leeds, Barcelona, Torino, etc.). A fantasy city relies on Private Public Partnership (PPP) and tax subsidies in order to realize buildings with authorship that would contribute to a new brand/image of the city, and entertainment palaces, and to support art (concert halls, museums, galleries, casinos, sports stadiums, megaplex cinemas, shopping malls, etc.) (Elin, 2002), (Gladstone, 1998). Expected results from the development of the entertainment industry on prompting and accelerating revitalization of the neighborhood are in most cases only patial, i.e. most frequently have a local character (tourists and users most often remain only within the confines of the entertainment space, rarely going into local shops, services, restaurants...). One of the projects based on this strategy is the European project – Capital of Cultural (every year one European city becomes the cultural capital, and is able to use certain funds (EDRF) in order to create such an image). The project was suggested with the goal of becoming an important stimulus for the development of tourism and urban revival. This developmental strategy has also highlighted differences between expectations (project benefit/success) and reality. No significant ties were noted between projects of cultural development and creative industries, while gentrification processes were not halted (artists moved out of restored quarters because spaces became too expensive). The approach of cultural incubators is a continuation of the European Capital of Cultural project. It emphasizes the importance of using art and culture to form creative spaces and production, in order to attract users (primarily tourists), and to achieve a new image of the city (Lozano, 1990), (Connerton, 1989). In this case, during the reconstruction of parts of the city, it is difficult to avoid gentrification, thus one can pose the question of authenticity and the tendency of this to over time become a city of illusions ("Disneyfication"). Revival of cities based on design mainly pertains to cities with an industrial past. The economic tranformation of such cities, according to Lacroix (Hillier *et.al,*. 2001] is performed based on creative industries, with the precedence of design and creative individuals. In this manner, cities achieve their cognizability and the status of Cities of Design established by UNESCO (Buenos Aires, Montreal, Berlin),

which introduces them to the Creative City Network. Thus, new models of Private Public Partnerships are affirmed at the city level, and aid the opening of creative and social potentials of cultural industries.

METHODS

The first research -research of physical qualities of open urban spaces in the territory of the City Munnicipality of Vracar, i.e. "mental mapping", was done using the direct population survey method. 868 citizens were questioned during two weeksin November in 2009 (5% of the population of Vracar Municipality). The sociodemographic characteristics of the respondents were quite similar with sociodemographic structure of the inhabitants of Vracar Municipality (more than 60% citizens were older than 45 years with average of 44,5 year; 60% have got high school education).

Based on the theory defined by Kevin Lynch, the questionnaire contained five sections dealing with thematic entities determined by one of the elements that form the image of a city or some other territorial framework (in this case the territory of the Municipality of Vracar): directions (roads or channels), areas (districts), boundaries (edges), nodes, and reference points (landmarks). Processing of results of individual questionnaire sections identified concrete spaces and objects corresponding to individual elements of the image of Vracar. By pooling results for individual parts and their distribution on the map of the Municipality of Vracar spatial entities were noted that encompass most of the elements of the Vracar image, and that therefore have potential for forming local centers recognized by inhabitants.

The second research carried out at the School of Architecture, University in Belgrade, is the evaluation of open public urban spaces belonging to the territory of the City Munnicipality of Vracar, based on six criteria (opening, silhuette, colors, continuity, dominants, and proportions), which represent elements of the urbanistic composition. This research was done using the method of survey to poll students of the first year of basic academic studies of architecture after they completed the course Design of Open Public Spaces – Urbanistic Composition. The number of students who was involved in this research was 600.

The third research has been done with space syntax method. Space Syntax is the world's first computer-based modelling technique to treat cities and buildings 'space first'. Research using Space Syntax modelling shows:how movement patterns and flows in cities are powerfully shaped by the street network and how this relation shapes the evolution of the local centres and sub-centres that makes cities liveable (Hillier, 2001, 2005). Four softwers are used durung the resarch: Mapinfo,ArcGIS Shapefile,Excel Workbook and Tab Delimited Text File. This method was used in municipality Vracar to measure the frequency of use of observed public urban space, as well as their interrelationships, i.e. main accesses. The counting of thepedestrians has been done during the pick time (between8.00-9.30 and 16.30-18.00), as well as the middle pick time (between 10 -12.00 and 14 – 16.00). It has been done every day during one week in November 2009. The goal of this research was to show how and when (during the week, during the weekend, during the day) people use particular spaces in the territory of City Municipality of Vracar as potential local centers (Kalenic green market, Cvetni trg, plateau in front of Belgrade Drama Theater).

RESULTS

Research 1 - Directions: roads or channels

"Roads are the channels that the viewer takes", for many representing dominant elements of their image of the city. (Jordan, 2003) Here, the starting point is the fact that while moving through it people observe space and the city.

Processed results of the questionnaire section dealing with the topic of directions as an element of the image of Vracar, indicated that the most important directions are Kralja Milana street, Makenzijeva street, Maksima Gorkog street, Juzni bulevar, Njegoseva street, and Milesevska street. Results have shown that most of the singled out streets either connect or are at a tangent with three spatial entities in Vracar: Cvetni trg (Kralja Milana street and Njegoseva street), Kalenic green market (Njegoseva street and Maksima Gorkog street), and the space surrounding Belgrade Drama Theater (Milesevska street and the extension of Makenzijeva street i.e. Cara Nikolaja II street).

Boundaries (edges)

According to Lynch, Boundries or edges represent those linear elements of city spaces that "form a boundry between various phases and represent continuity gaps". (Jorda,n 2003) Based on this definition, a section of the questionnaire was created with the goal to identify those spatial elements of the image of observed space that correspond to this category in the territory of the City Municipality of Vracar.

This section of research led to the conclusion that certain street streches characterized as directions, also appeared in the category of boundries, but with new stretches also appearing, such as Beogradska street and Resavska street, that subjects identify as obsticles within the continuity.

Areas (districts)

Areas or districts are sections of the city that can be viewed in two dimensions, and which according to Lynch, "the observer enters as sometning new, because he knows that an urban region has its special character". (Jordan, 2003) These spaces are recognized from within, but can also serve as external landmarks, id they posses characteristics that can be viewed from a distance1.

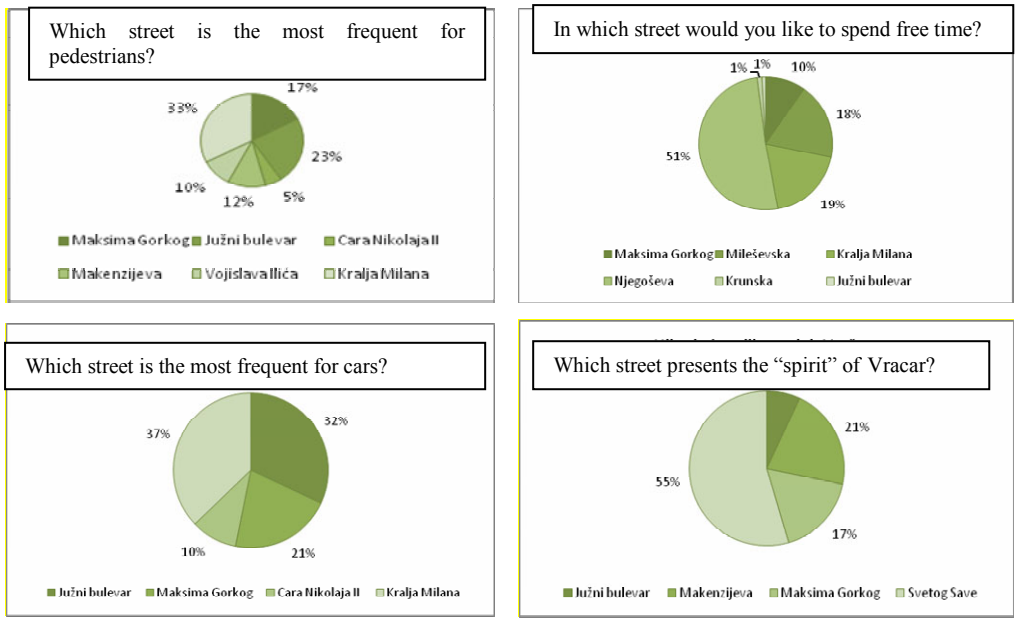

Figure 1. The results of questionnaire about directions

Processing of the section of the questionnaire dealing with the topic of areas (districts) leads to the conclusion that answers to posed questions to the greatest extent single out the space of Svetosavki plateau as the most characteristic space in Vracar and a space that the citizens are most attached to. The second place, according to the number of answers from subjects, is the space of Kalenic green market, followed by the space of Cvetni trg and Crveni krst (namely, the area in the vicinity of Belgrade Drama Theater).

Nodes

According to the Kevin Lynch's theory "nodes are strategic points of a city (territory), that an observer can enter, as well as those intensive focal points that are his starting points or end points". (Jordan, 2003) Based on a thus set definition, the fourth segment of the second questionnaire section was formed, with the goal to establish which parts of Vracar can be characterized as nodes.

According to survey results, the most important node concerning recreational acivity is Svetosavski plateau, concerning the purcasing of food, Kalenic green market, and concerning entertaining contents, the space in the immediate vicinity of Cvetni trg.

Reference points (landmarks)

Reference points or landmarks represent specific orientation points, and their significance is that they "stand out as individual markers among a multitude of other objects". (Jordan, 2003) They are also important because they become "key elements of the structure and identity of a region, and people rely on them to a great extent if they take certain routes more frequently". (Jordan, 2003)

Based on responses to posed questions, the temple of St. Sava is the most important reference point (landmark) in Vracar. Other buildings, although dominant by their height, form or materialization, are not as recognized a characteristic of Vracar.

Overall results of the implemented survey are presented on the orthophoto image encompassing the territorial framework of the City Municipality of Vracar (Figure 1) by using symbols labeling elements of the image of observed space according to Kevin Lynch.

[1] Adapted from Lynch, Kevin. *The image of the City.* Translated by: Milutin M. Maksimovic. Beograd: Gradjevinska knjiga, 1974.

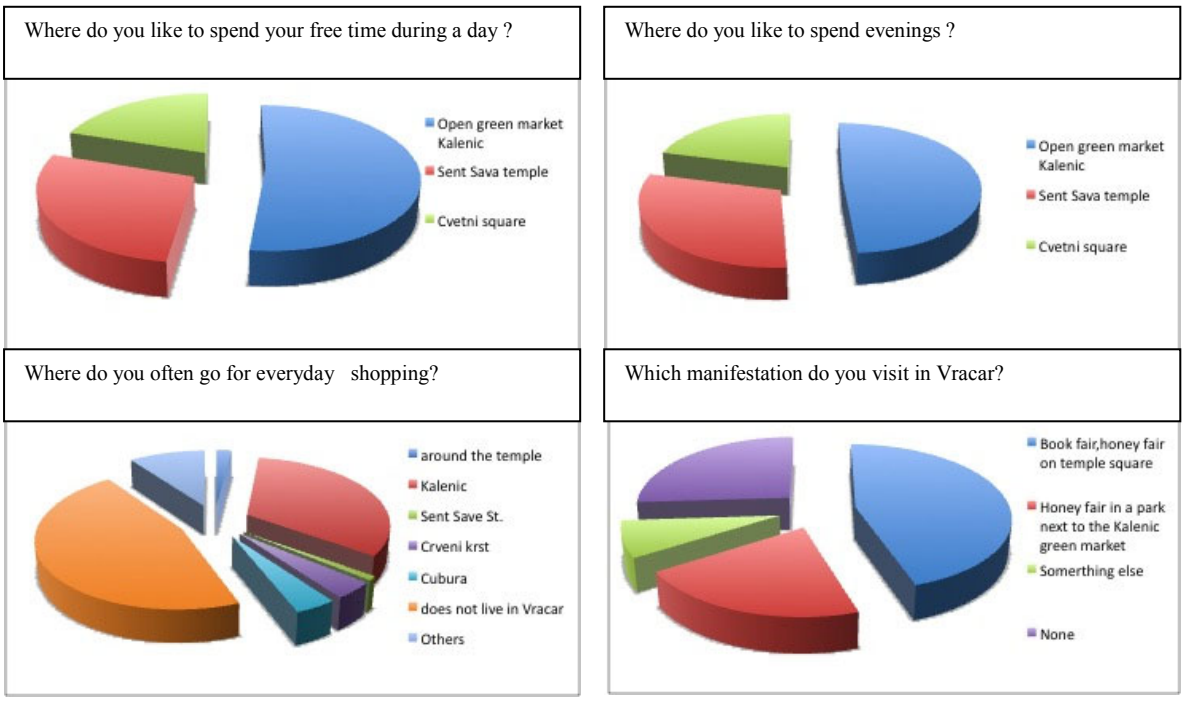

Figure 2. The results of questionnaire about the nodes

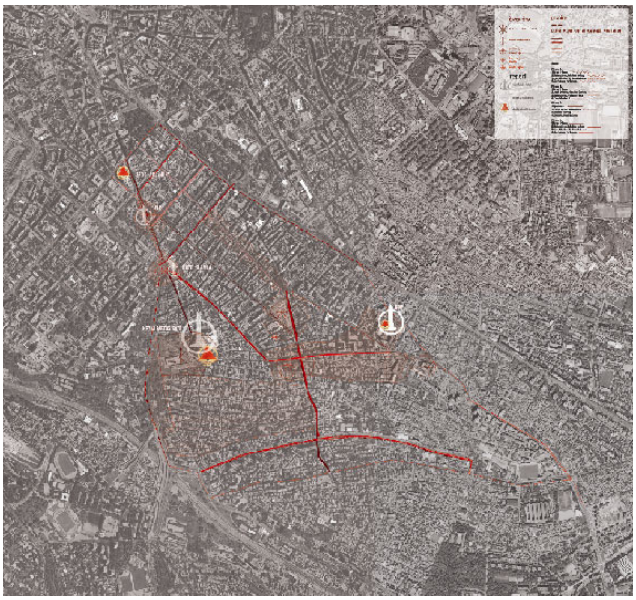

Figure 3: Distibution of elements of the image of Vracar

The Figure 3 shows that the area of Svetosavski plateau, dominated by the temple of St. Sava, as the most significant landmark of this territory, contains the largest number of elements of the Vracar image. Other elements are grouped around three spatial entities that are the subject of this research: the surroundings of Cvetni trg, Kalenic green market, and the surroundings of Belgrade Drama Theater. In addition, directions singled out as important are exactly those stretches that connect these three mentioned locations: Makenzijeva street, Cara Nikolaja II street, Maksima Gorkog street, Njegoseva street, and Milesevska street. An important stretch, characterized both as a direction and as a boundry, is Kralja Milana street which touches upon the space of Cvetni trg.

During further research, by applying the metod of spatial suntax and valuation of individual elements of the urbanistic composition, physical and functional characteristics of mentioned spaces will be analyzed with the aim to note regularities that single out mentioned spaces within the overall image of Vracar.

Research 2 - Evaluation of open public urban spaces in Vracar

This section is presenting a part of the results of valuation of open public urban spaces of Vracar according to established criteria pertaining to the space of Kalenic green market, Cvetni trg, the space in the immediate surroundings of Belgrade Drama Theater, and street stretches connecting them (Njegoseva street, Maksima Gorkog street, Milesevska street, and Cara Nikolaja II street).

Table 1: Presentation of results of evaluation of observed public urban spaces

Streets and squares	openings	siluets	coloures	continuity	proportions	landmarks
Maksima Gorkog	2	2	3	3	2	2
Cara Nikolaja II	4	3	3	3	4	4
Njegoseva	4	3	1	4	5	5
Milesevska	4	3	4	3	2	4
Kalenic pijaca	4	2	1	4	2	2
Cvetni trg	4	5	5	4	5	4
Plato BDP-a	5	3	4	3	1	4

Results presented in Table 1 show that individual spaces singled out on the "mental map" of Vracar by the citizens of Vracar and Belgrade, according to the opinion of the sample that can be characterized as the expert community do not fulfill certain criteria used to analyze urbanistic composition. However, this tool is in fact used to establish problems, that will be overcome using adequate physical interventions in space. The type of physical intervention will be established based on the type of problem indicated by individual criteria. The main goal of potential intervention in space is to upgrade the quality of space and of the locations that people eagerly visit, and to which they are linked by specific memories and feelings.

Research 3 - using the space syntax model in the area of potential municipal centers and their interrelationships

Measurements with space syntax method show that the manner of use of observed spaces is in agreement with their contents. According to these results, Kalenic green market is mostly used in the morning on working days, with the highest frequency of use on weekends, when the green market works at full capacity. The space of the plateau in front of Belgrade Drama Theater has a uniform frequency of use during a working day which is conditioned by the position of the public transport station. A somewhat higher frequency of visits to this space is noted in the evening period, when there are performances in Belgrade Drama Theater. The frequency of use for Cvetni trg (Figure 2) is conditioned by the contents within that space, dominated by catering facilities, and this primarily along the stretch of Njegoseva street. This space is equally used on working days and during weekends, but a higher frequency of use is visible in evening hours.

This research makes it possible to register the manners of use for certain spaces, i.e. the problems conditioning the fact that certain spaces are not used. Thus, the manner of intervention to correct noted problems would be directed at introducing activities that would have the goal to prompt the use of those spaces that are less used.

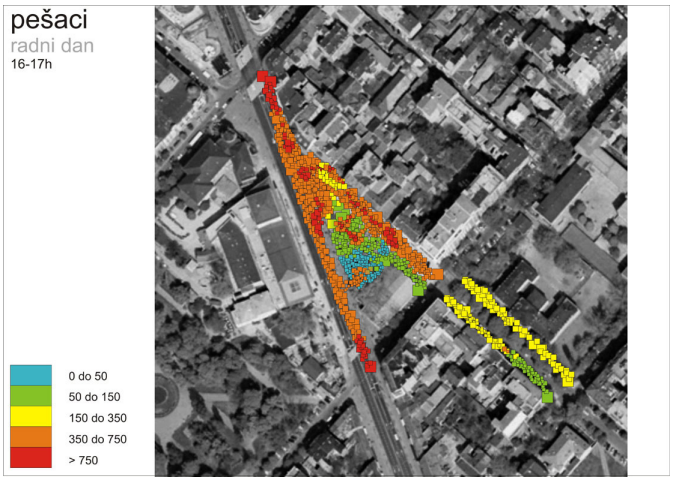

Figure 4: Frequency of use of Cvetni trg on working days in the 4 pm – 5 pm period (according the space syntax methodology)

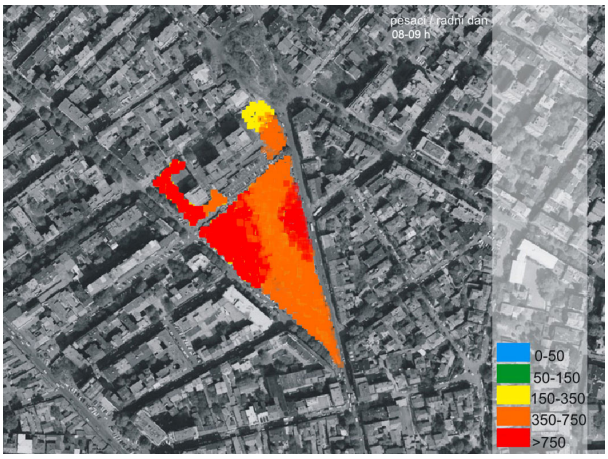

Figure 5: Frequency of use of Cvetni trg on working days in the 8 am – 9 am period

DISCUSSION

Any city desiring to become a metropolis or to maintain its significance in the global city network, should accept the revival and regeneration of the historical city nucleus and of significant open urban spaces, as one of its strategic development goals. Old historical nuclei, especially in cities with an attractive construction heritage, should recover their former signficance in the sociological, cultural, and economic sense (urban reneisance), which will have a reflexive effect on the prosperity of all citizens (development of tourism, better functioning, more jobs, economic prosperity). For a local community to attract capital and investors, it is often indispensable for it to show that it differs from other milleus, which it will most easily do by emphasizing the identity of the place, the specificities and the diversity of its offer. For such entities, the upgrading of urbanity is directly linked to previous factors.

Spatial-social interdependence represented by urbanity as a characteristic, indicates the complexity of city revival. In cities presently in transition, it does not suffice to apply only physical revival, but also a transformation of attitudes both of citizens, and of those who govern. Priorities in urban revival are: revival of damaged urbanity, ongoing education of the population relevant to topics of urban revival and regeneration, designing of urban spaces in a manner contributing to profitability and to becoming generators of future development, as well as forming of recognizable spaces with ethnic specificities and elements of identitety, forming of compact multifunctional urban nuclei, and activation of historical and cultural heritage.

Public spaces should reinstate their significance as gathering points and points for cellebrations, representing a reflection of urban culture, while architecture would be the most important means to create an urban identity that could offer the indispensable cultural symbolization enriched by modified elements of urban myths and rituals.

Tools presented in this paper, as a suggestion for some future development and transformation of public spaces in central urban nuclei, were formed based on spatial syntaxes, the theories of Kevin Lynch, and research implemented with students attending the subject "Shaping Public Urban Spaces – Urbanistic Composition". The future of these spaces, however, is not to copy models or good examples. The right approach to the problem of development, construction and transformation of open public urban spaces should be sought in accepting modern principles adapted to local conditions and trends that inavoidably lead to the formation of a specific model of sustainable public spaces.

CONCLUSION

The main goal of the research was to find out what tools can be used in urban design to enable open public spaces to become more vibrant and more pleasant for users.

The research of open public spaces in Municipality Vracar, according the Lynch theory shows that the problem with clear directions and boundaries as well as insufficiant number of landmarks cause unattractive open public places which are not readable and fluent. The nodes has positioned well but the connections between them are poor according the users. Recognizing the main problems.

The research of valuation of open public urban spaces of Vracar according the morphological criteria of physical structure and open public space shows what is missing and what parameters urban designer should consider during the design process as well as how to create the hierarchy between them. This research was focused on individual open public space.

The research according space syntax was focused on the whole area of Municipality Vracar. It shows the problems in a network of the open public spaces. Despite the narrow streets with heavier traffic flows, people tend to walk more on streets which connect main places/nodes. Pedestrian flows at the afternoon are typically

higher than pedestrian flows in the morning or evening. More women than men are walking and more non-tourists than tourists. Different users occur at different times of the day; for example, the peak period for older people is morning while that for younger is late afternoon end evening. Research also shows that active frontage of the buildings along the streets enhance the moving especially if the main open public place is near by. A further aim of this research is to provide information for creating key walking route network in Municipality Vracar, connecting the main open public spaces and providing vibrant and high qualty places.

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Miscellaneous Environmental Visual Impacts of Sustainable Buildings

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Abstract. The architecture and its' links with the surrounding environment are important from the social, cultural, economic, and environmental points of view. This justifies the need to apply the principles of the sustainable development to the building design, construction, and exploitation. The main principle of sustainable visual links between the building and the surrounding environment is the contextuality. The types and levels of contextuality of sustainable buildings may differ: these buildings can become the background for valuable historic buildings or natural elements, can add value to the visual environment and become the integral elements of certain type of landscape, or can visually dominate in the surrounding environment. The means for determining the proper type of contextuality for the sustainable building are the visual impact assessment and determination of the identity index. Considering that, the article aims to present the guidelines for environmental visual impact assessment of sustainable buildings and the hypothetical matrix of possible identity indexes of sustainable buildings as the aid to the sustainable design.

Keywords: sustainable architecture, environmental visual impact, identity index, contextuality.

INTRODUCTION

The sustainable development, usually defined as the development satisfying the needs of the present generations without compromising the future generations to meet their own needs presently is analyzed in four overlapping dimensions, i.e. social, cultural, economic, and environmental (Benson and Roe, 2000; JDSD, 2002). The basic principles of sustainable development relevant in all four dimensions are: the social cohesion and equity, quality of life, preservation of cultural diversity, economic wellbeing, sustainable consumption and production, preservation of biodiversity, and rational use of resources and energy (Throsby, 2002; REUSDS, 2006). According to J. Wines (2000), the construction of residential buildings consumes one-sixth of the world's fresh water supply, one quarter of its wood harvest, and two fifths of its fossil fuels and manufactured materials. However, the architecture and its' links with the context strongly influence not only natural diversity, consumption and production, use of resources and energy. It is also closely related with the non-material wellbeing of society and communities and the preservation of cultural diversity and heritage. This demonstrates the importance of the concept of sustainable development in construction and use of buildings and their interactions with the surrounding environment, including their environmental visual impact.

The aim of this article is to present the hypothetical guidelines for environmental visual impact assessment of sustainable buildings and to develop the matrix of possible identity indexes for sustainable architecture in different contextual environment. In order to reach this aim, the following *tasks* were implemented: the notion of sustainable architecture and its main features were presented, the problems and predominant trends of visual expression of sustainable buildings were distinguished, the principles of environmental visual impact assessment of sustainable buildings were discussed, and the possible identity indexes of sustainable buildings were defined.

METHODS

The methods of the research include the analysis of literature and examples of sustainable buildings and systematization, comparison, and generalization of the collected data. The concept of the identity index and the principles of environmental visual impact assessment were also applied in the research.

RESULTS AND DISCUSSION

Visual expression of sustainable architecture and its trends

Definition and features of sustainable architecture. The critics of modernist planning and design, such as J. Jacobs (1961) and F. Hundertwasser (Rand, 2007) had early identified the failures of the modernist architecture to coexist harmoniously with nature and historical environment and its possible negative impacts on

communities and society. However, their ideas were seriously considered only in the second half of the 20th century with the rise of the concept of sustainable development. Sustainable architecture is still often perceived as exceptionally "green" or "ecological", disregarding its links with cultural context and social environment. However, the expanding concept sustainable development requires the broader definition of this phenomenon. The universally acknowledged social and cultural dimensions of sustainable development and the principle of intra-generational equity (Throsby, 2002) determine that *visual and psychological acceptability, contextuality and legibility*, and *social responsibility* should be equally important in sustainable building design, as *durability and flexibility* and *ecological responsibility* (Figure 1).

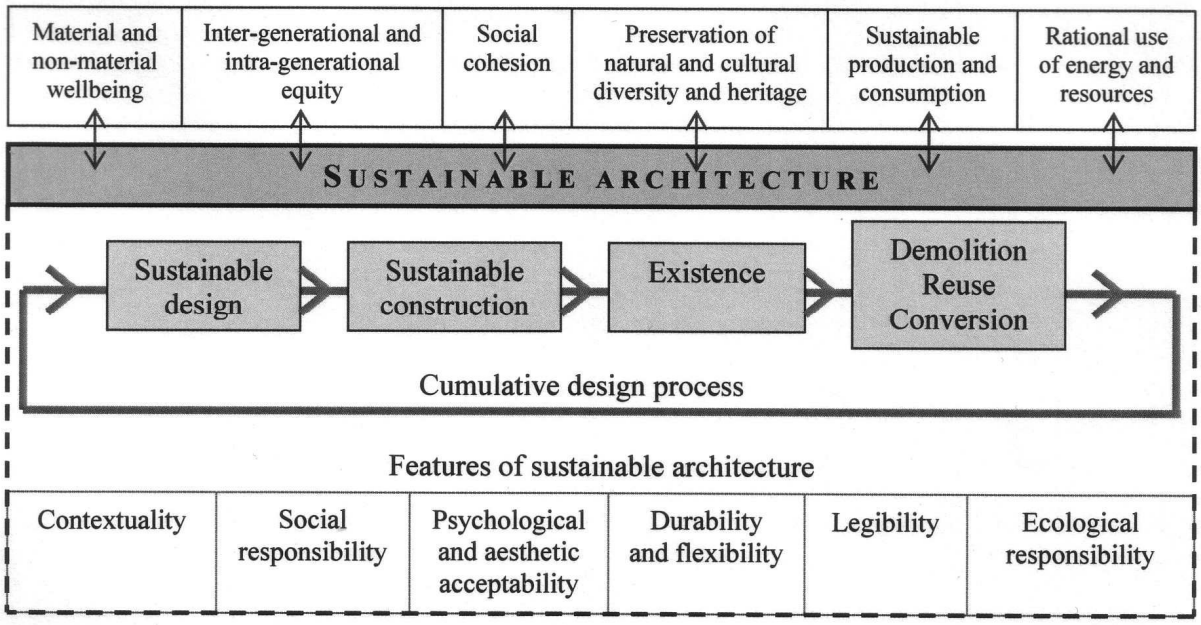


Figure 1. The notion and features of sustainable architecture

The sustainable architecture should be regarded as the architecture entirely based on the principles of sustainable development. The sustainability of the building should be programmed in the stage of design and be present throughout the entire cycle of the existence of the building: form the design and preparation of the construction site to the demolition or reuse of the building or conversion of the site. The sustainable architecture not only should embody the principles of sustainability itself; it also should enhance the sustainable development of the environment: to promote the rational use of energy and resources, social cohesion, preservation of historic and natural environment, and contribute to the improvement of general quality of life.

Trends of visual expression of sustainable buildings. The environmentally friendly building design becomes increasingly popular among architects and attains the considerable attention of architectural critics. J. Wines (2000), R. Munster (2008) and others present numerous projects and realizations, which at a certain extent embody the principles of sustainable development. These examples demonstrate a vast array of visual expression possibilities of sustainable buildings. Architectural expression of the sustainable building depends on numerous internal and external factors, including the architect's idea, the source of inspiration, and the material and non-material environment of the site (Figure 2). These factors determine the priorities of the architect towards some principles of sustainable design and the overall architectural result. The analysis of the projects and realizations referred to as sustainable by the critics allowed tracing some links between the visual expression and scale of the building and its surrounding environment, and, based on the analysis of J. Wines (2000), distinguishing the main trends of visual expression of sustainable buildings:

1. The trend of *aesthetization of green technology and ecological innovations* can be seen in many realizations around the world (for example, works of T. Herzog and Jourda and Perraudin) and probably is the most popular trend of environmentally friendly design. Such *eco-tech* buildings, often resembling the glass architecture of modernism, vary in scale from small houses to large public and commercial complexes and usually appear in peri-urban and urban environment and sometimes as the contrasting interventions in natural landscape.

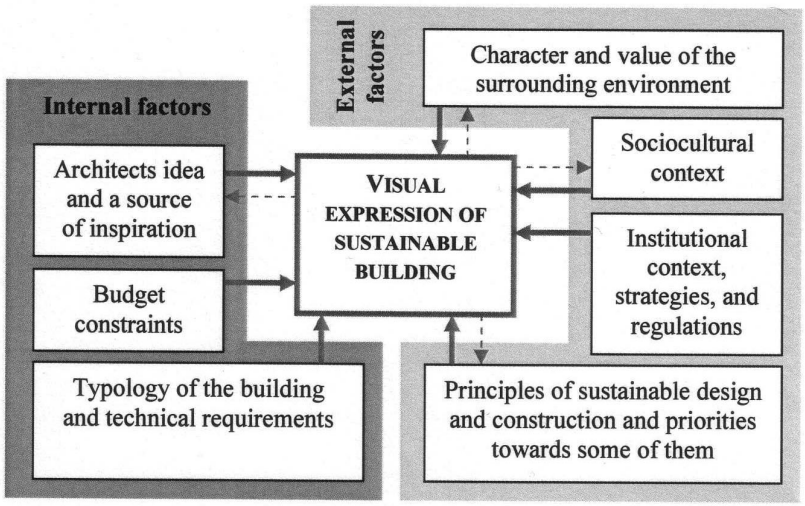


Figure 2. Factors determining visual expression of sustainable building

2. *The building-garden concept* best seen in the realizations of Ushida-Findlay Partnership is based on the idea of integrating the house and the garden and usually appears on a small scale in peri-urban and urban environment.

3. *The building-landscape concept* based on the integration of architecture and landscape is evident in pioneering works of E. Ambasz and G. Peichl. Such concept is usually realized in the large scale in natural environment.

4. *The trend of interpretation of natural forms* or *organic building design* takes its inspiration from the elements and forms of nature as well as from the cosmology. This trend, evolving from 1970', can be exemplified by the works of Jersey Devil company, A. Quarmby, and P. Vetsch. Such "organic" buildings, mainly of small scale, are usually constructed in natural, rural, or peri-urban environment.

5. *The use and interpretation of vernacular technologies and forms* is becoming increasingly popular in the developed and developing countries, as it uses local materials, revives and employs traditional skills. In Western countries such buildings are mainly constructed in rural and natural environment (for example, studio in the West Country by D. Lea). In Asian or African countries, were the vernacular construction traditions, such as mud-brick dwellings, are still used in cities, this trend may also appear in the urban environment.

6. *The interpretation of historic urban forms* or *the trend of harmony with the historic urban environment* is still rarely observed in the literature on environmentally friendly architecture, as the sustainable design is mainly associated with vernacular or organic forms. However, the need to preserve historic urban environment, to sustain its continuity, evolution, and socioeconomic viability, at the same time improving ecological conditions, is undoubtedly relevant. These principles can be seen in the Municipal Museum Abteiberg in Monchengladbach by H. Hollein. The volumes of the museum building are integrated into small-scale urban fabric; they recall historic architectural forms and layout, but still clearly reflect the period of their creation. The structure, built into hillside, provides the green roofs and facades that can be used as open public space.

Possibilities of optimization of visual links between sustainable buildings and their contextual environment

Quantitative and qualitative contextuality of sustainable buildings. The main feature of the sustainable architecture determining its visual links with the surrounding environment is the *contextuality*. The analysis of the examples of environmentally friendly buildings has revealed not only the variety of architectural expressions, but also their miscellaneous visual links with their context: some buildings are almost *completely integrated* into the environment and seem to be a part of landscape; part of the analyzed buildings add value to the peri-urban, urban, and historic urban environment *without radically changing its character*; some of the analyzed examples clearly *dominate* in rural, natural, or urban landscapes.

The *SID Identity Index context theory* (Turner, 1998) states that the type and levels of contextuality can be quantitatively determined by the *identity index*. This index can be used to define the extent to which sustainable building will be *similar to*, *different from* or *identical with* its context. The theories of context treat "the environment" in different ways: aesthetic, visual, ecological, and social. In this research we mainly consider the visual environment of the sustainable building. An Identity Index, using a percentage scale, is a good way of describing the degree of similarity, identity or difference between the features (physical and visual-spiritual characteristics) of a building and its visual environment. A project can be visually identical in one respect and different in others, as when a skyscraper is faced in a local stone. The identity index of materials, size and style of this tower block can be 90%, 20%, and 10%. This shows the identity values for a stone-clad tower block in an historic stone-built town. They range from 90% identity for building materials to 10% identity for architectural style. The overall identity index is 40%. The index could be lower if the coefficients of weight are applied. For example, the scale and style could be considered as the main factors determining the visual contextuality of sustainable building. In this case it is possible to conclude that the contextuality of the object is average or low from *quantitative point of view*. But it is also necessary to evaluate the contextuality from *qualitative point of*

view and in this case the evaluation becomes much more subjective and relative. Different identity indexes of sustainable architecture can be seen as positive as well as negative depending on the character and value of the surrounding environment and the predefined *conception of landscape formation*, i.e. do we need to change or to sustain the visual character of landscape.

The analysis of literature and examples allowed distinguishing several qualitative problems related with the contextuality of environmentally friendly architecture. For example, it is widely acknowledged that the language of the symbols of architectural objects has to be understandable for local population. This means that architects have to find ways of architectural expression which allow using the symbols characteristic not only to the contemporary collective culture but to the local context as well. The basis of the contextuality for sustainable building design commonly becomes the advanced construction technologies and ecological innovations or organic cosmological aesthetics that already have the savor of internationality and do not necessarily speak "the understandable architectural language" to local communities and have weak links with the character of local landscape. In other cases the use and interpretation of vernacular technologies and forms as well as of forms of local landscape, fully suitable in the rural and natural environment, causes the problems of visual coherence in the urban and especially in the historic urban context.

Determining optimal visual links between sustainable buildings and their contextual environment. Considering the revealed quantitative and qualitative aspects of contextuality of sustainable buildings, it is important to answer many questions: which trend of visual expression of sustainable buildings can be used in the urban, peri-urban, rural and natural environment; what possible identity indexes of various aspects of sustainable architecture could be in the different types of contextual environment; what are the common quality criteria of visual expression of sustainable buildings and so on. The proposed matrix of possible identity indexes of the main features of sustainable buildings in different contextual visual environment (Table 1) can be helpful in the process of sustainable building design.

Table 1. The hypothetical matrix of possible identity indexes of the main features of sustainable buildings in different contextual environment

Trends of visual expression of sustainable buildings	**Types of contextual visual environment**																			
	Historic Urban				**Urban**				**Peri-urban**				**Rural**				**Natural**			
	Physical and visual aspects of sustainable buildings and their possible values																			
	Size	Materials	Style	Colors	Size	Materials	Style	Colors	Size	Materials	Style	Colors	Size	Materials	Style	Colors	Size	Materials	Style	Colors
1. Eco-tech buildings	61– 90%	10 – 30%	10 – 30%	10 – 60%	10 – 90%	10 – 60%	10 – 60%	10 – 90 %	10 – 60%	10 – 30%	10 – 30%	10 – 60%	10 – 60%	10 – 30%	10 – 30%	10 – 60%	10 – 60%	10 – 30%	10 – 30%	10 – 60%
2. Building-garden concept	-	-	-	-	31 – 90%	10 – 30%	10 – 30%	10 – 60%	31 – 90%	10 – 60%	10 – 30%	31 – 90%	-	-	-	-	-	-	-	-
3. Building-landscape concept	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10 – 60%	31 – 90%	31 – 90%	31 – 90%
4. Interpretation of natural forms	-	-	-	-	-	-	-	-	31 – 60%	10 – 60%	10 – 30%	10 – 90 %	31 – 60%	10 – 30%	10 – 30%	10 – 90%	10 – 30%	10 – 30%	31 – 60%	61 – 90%
5. Interpretation of vernacular technologies and forms	-	-	-	-	-	-	-	-	-	-	-	-	61 – 90%	61 – 90%	61 – 90%	61 – 90%	61 – 90%	31 – 60%	31 – 60%	61 – 90%
6. Interpretation of historic urban forms	61– 90%	61– 90%	61– 90%	61– 90%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The data from the matrix can be integrated with the *conception of landscape formation* which has to be established in the territory plans or in the stage of pre-design analysis. The process of visual impact assessment can be applied in order to integrate quantitative and qualitative aspects of contextuality of sustainable building and to determine the optimal visual links between the building and its contextual environment (Figure 3)

The whole process of visual impact assessment of sustainable building has to be performed as follows:

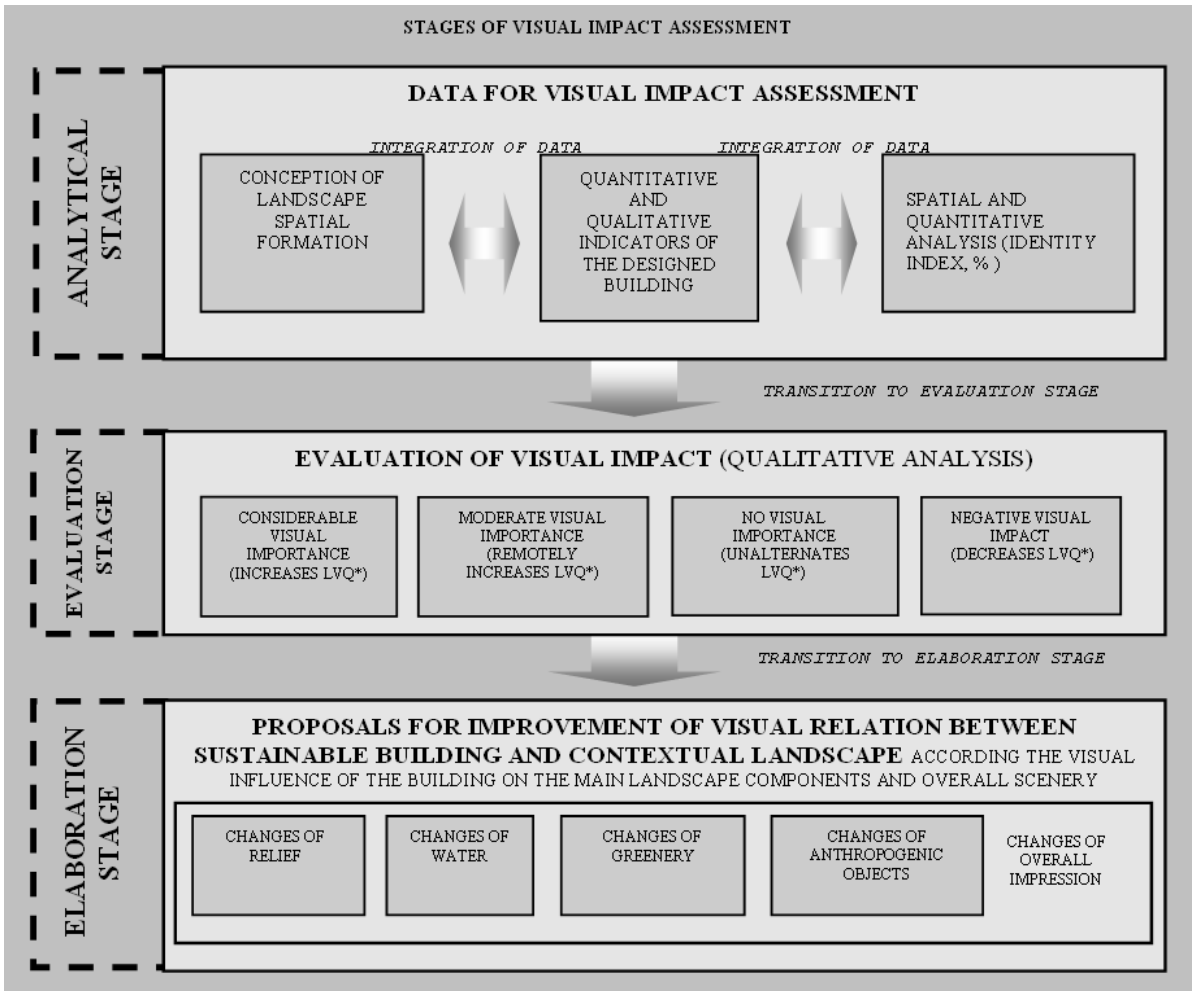
1. Establishment of the quality indicators of *the standard visual type of landscape*: determining characteristics of visual spaces, proportions of opened and developed territories, principles of the layout of buildings and greenery, possible visual contextuality of buildings considering physical (size, materials, constructions) and visual-spiritual (forms, lines, colors, textures, style, purpose and etc.) characteristics.

2. Establishment of *the present visual character of landscape* and comparison with the standard indicators of landscape visual quality.

3. Formation of *the target spatial model of landscape* (preparation of the *conception of landscape formation*) the visual indicators of which have to meet the criterions of vitality, complexity, harmony, expressivity, uniqueness, functionality and meaningfulness.

4. After characterizing physical and visual features of the designed building, the *possible changes of landscape visual character* have to be established and evaluated from the *spatial* (typical viewing places and visual spaces, zones of visual influence), *quantitative* (levels of identity indexes of physical and visual characteristics of the building) and *qualitative* (character of contextuality of the building) point of view.

5. In the stage of elaboration the *proposals of improvement of visual relation between the designed building and the contextual landscape* have to be prepared according the visual influence of the building on the main landscape components and the overall scenery.



* - *landscape visual quality*

Figure 3. The model of the process of visual impact assessment of sustainable building

CONCLUSIONS

1. The sustainable building based on the principles of contextuality and legibility, social and ecological responsibility, psychological and aesthetic acceptability, durability and flexibility can acquire different forms of architectural expression, ranging from modernist eco-tech design to almost complete integration with natural or historic environment. The trends of architectural expression of sustainable buildings depend on numerous internal factors, such as the idea and a source of inspiration of the designer and the budget constraints and on the external factors, the main of which is the character and value of the surrounding environment.

2. The visual contextuality of the building is one of the main aspects determining its sociocultural sustainability. Visual contextuality can be measured form the quantitative point of view using the Identity Index. This index, using a percentage scale, can be helpful in determining to what extent the design proposal is different from, similar to or identical with the visual environment of the site. However, the design solution cannot be based solely on the quantitative analysis. The qualitative and quantitative aspects of contextuality can be integrated through the process of visual impact assessment of sustainable building. This process encompasses the analysis of landscape, determining its present and desirable characteristics, quantitative and qualitative analysis of the design proposal, and their optimal integration.

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KSM – Katowice Housing Cooperative. The city image changing

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Abstract. KSM – (KHC) Katowice Housing Cooperative was founded in 1957 and currently it is the biggest such an institution in Katowice, Upper Silesia, Poland. Its assets include 17 housing estates, located in 11 town districts.
These housing estates are different in terms of built up area size, technology, urban layout, the date of creation.
Due to the location and individual nature of buildings they can be divided as follows:
- single tower blocks
- scattered housing estates
- central housing estates
- peripheral housing estates.

The Cooperative's activity has been lasting for 53 years, therefore it shares responsibility for shaping the urban and architectural structure of the city.
The article discusses the development of various districts of Katowice based on KSM's housing estates.
This includes the presentation of the city center as well, where the Cooperative owns "City Centre", "Centre-I" and "The Star" housing estates and "The Super-Unit" block of flats - located at the main city axis, at the time when the city is looking for its new identity.
An important element of this article is the Cooperative *today* and also its latest building achievements.

Keywords: city image, building technology, cooperative.

INTRODUCTION

The history of cooperative movement dates back to the 19th century. In 1908 Chorzów Housing Cooperative was founded, the first one in Upper Silesia, regarded as the oldest institution of such type in Poland, and still operating to date. It is from this institution that in 1957 Katowice Housing Cooperative was separated, the housing resources of which constitute the research material of this study.

Nowadays in Poland housing cooperatives own about 26 % of all housing resources, making them one of the most common forms of occupancy. Quality analyses of the built environment, including housing cooperatives, are performed on wide scale and in various aspects.

Among many professional publications devoted to this field of study the following should be mentioned: concerning housing estates and social concepts: Syrkus H., Ku idei osiedla społecznego 1925-1975 [Towards the concept of social housing estate 1925-1975], PWN, Warsaw, 1976; Syrkus H., Społeczne cele urbanizacji. Człowiek i środowisko [Social aims of urbanization. Man and the environment] PWN, Warsaw 1984; concerning the construction processes of housing estates: Lugez J., Budownictwo mieszkaniowe z elementów wielkopłytowych (Construction of housing estate from concrete slasb), Arkady, Warsaw, 1978; Biliński T., Gaczek W., Klorek E., Systemy prefabrykowanego budownictwa ogólnego [Prefabricated systems of construction], course book issued at Poznan University of Technology, Poznań 1975; concering the modernization of housing estates: Wojtkun G., Osiedle mieszkaniowe w strukturze miasta XX wieku [Housing estate in the structure of the 20th century citie], Publishing House of Szczecin University of Technology, Szczecin 2004; Chmielewski J.M., Mirecka M., Modernizacja osiedli mieszkaniowych [Modernization of housing estates], Publishing House of Warsaw Technical University, Warsaw 2007, concerning social housing worldwide: Życiński J., Budownictwo mieszkaniowe w Europie Zachodniej. Historia mieszkaniowej solidarności [Housing in Western Europe. The history of housing solidarity], S. P. K. B. The Homeless Foundation, Warsaw 2006.

Housing in post-communist countries was the topic of an international conference organized by the Faculty of Architecture, Silesian University of Technology in cooperation with IAPS (International Association for People-Environment Studies): Housing and environmental conditions in post-communist countries, the outcome of which is a monograph under the same title prepared under the supervision of Komar B., Kucharczyk – Brus B. published by the Publishing House of the Silesian University of Technology in 2007.

The scope of this paper is to present the urban and architectural image of Katowice, shaped, among other factors, by the housing estates erected and managed by KSM, the monitoring of changes in technologies used in the construction of housing estates in the successive decades, and KSM's strategy and response to the challenges posed by modern times.

METHODS

The research material comprises 17 housing estates managed by KSM and grouped in 11 districts of the city of Katowice. The research methods included literature analyses, legal acts analyses, site inspections. Also, interesting photographical material was gathered: documenting the housing estates as of *today* (elaborated by the author), and archival materials made available by Arch. Jurand Jarecki, one of the main designers of the city of Katowice in the 1960s and the 1970s. However, the richest analytical part are KSM' s documentation resources and interviews representatives.

RESULTS

Katowice was granted the town charter in 1865. In the 19th century the most important determinant of its development was the railway line constructed in 1846, connecting Berlin and Myslowice. Public utility buildings, tenement houses and roads were built in the vicinity of the railway. The urban tissue congested around the railway. The town grew along its east-west axis. The south-north axis of Katowice was initially designated by the estates of its owners- the Thiele-Winckler family. The autonomy of the estates area and of Brynów district were abolished as late as in 1924, and on July 1st 1924 the lands were incorporated into the town limits. On June 15th the Silesian Parliament passed the resolution concerning broadening the town boundaries and creating Great Katowice (ed. Szaflarski J., 1978).

In World War Two Katowice did not suffer a lot of damage, but the post-War years brought about a big influx of repatriates from Poland's former eastern territories (50417 people) who put their future hopes to the town's industrial potential. Yet, there were not enough flats to accommodate the masses of the new comers. At that time, because of the government's policy, housing cooperative movement was in a state of crisis. After 1948 the role of housing cooperatives was reduced only to administrative functions and, to top it all, in 1951 the cooperatives were taken over by the state administration and deprived of their right to dispose of flats which had so far been common property of the cooperative members. In 1952 the housing cooperatives were incorporated into the national economic plan, yet not given any credit facilities. Finally, in 1956–1958,the state adopted a new direction and the housing cooperatives became a part of the national housing resources policy, indeed they started to function not only as economic entities but also to assume social and even political roles.

In 1957 when Katowice Housing Cooperative started its independent operations, the first priority was to build new housing facilities, so much in demand. KSM's first building located at Graniczna Street, far from the town centre, was taken over from the employer's establishment.

Table 1. KSM activities in the years 1960-1965

Year	Number of built houses, the name of the settlement	Total number of buildings
1960	3*- Oś. Ligota, 1- Oś. Zawodzie, 1-Oś. Szopienice, 2 (1*) – Oś. Śródmieście,	7
1961	2- Oś. Zawodzie, 2- Oś. Murcki, 5- Oś. Wierzbowa, 2 – Oś. Śródmieście, 1- Oś. Ścigały	12
1962	1 – Oś. Zawodzie, 2- Oś. Szopienice, 2- Oś. Murcki, 1 – Oś. Śródmieście	6
1963	4- Oś. Centrum-I, 1 – Oś. Śródmieście, 1- Oś. Ścigały, 1 – Oś. Ściegiennego	7
1964	2 – Oś. Centrum – I, 1- Oś. Śródmieście, 1 – Oś. Szopienice, 1 – Oś. Zawodzie, 1- Oś. Murcki	6
1965	1-Oś. Centrum, 1- Oś. Śródmieście, 1- Oś. Murcki, 1 –Oś. Wierzbowa, 1* – Oś. Graniczna, 3- Oś. Szopienice	8
* - building inherited from the employer's establishment		

The next years resulted in KSM's independently erected buildings. The analysis of KSM's documentation revealed that it adopted an interesting strategy and did not build successive housing estates as a whole, but tried to secure an equal growth of different city quarters (Table 1). For example, during five years (1960-1965) the Cooperative erected buildings in the following districts: Centrum-I, Śródmieście, Wierzbowa, Zawodzie, Ligota, Ścigały, Murcki and Szopienice. The last three estates were built to address the needs of the employer - coal mines: "Katowice", Murcki and Szopienice, in consistence with the trend prevailing in the Post War period.

In the 1960s there was still a noticeable discord between the east-west axis settlements and the north-south axis developments. The north-south axis had dispersed settlements, many waste lands and poor quality buildings. It also contained huge brownfields previously occupied by "Marta" steel works. In the northern part of the city the following housing estates were built: Centrum – I, Wierzbowa, Ściegiennego. Since the 1950s the cooperative also started to put up in-fill buildings in the most extensive housing estate: "Śródmieście".

Figure 1. Katowice, view of the Super-Unit and the roundabout in memorial of Gen. J. Ziętek in 1970, (source: Gliszczyński J. 1974)

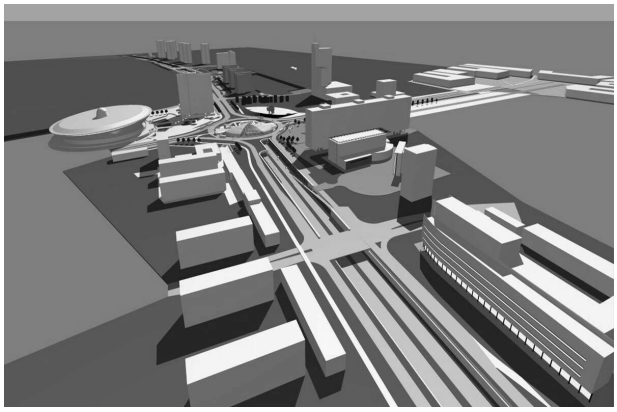

Figure 2. Model of the current view of the DTŚ (Diameter Route) and roundabout, called today Roundabout Art. (source: www.um.katowice.pl)

Concurrently, planning works on the city centre were undertaken. The token of the changes initiated in 1965 was the roundabout (traffic circle) in memorial of General Jerzy Ziętek (Figure 1) – a big transport and transit junction which facilitated the traffic along the north south axis (Korfantego Alley, former Armii Czerwonej Street) and free transit traffic along the east-west axis (Roździeńskiego Alley). In 1967 "Haperowiec" building designed by Jurand Jarecki and Marian Skałkowski was erected at Sokolskiej 33. In 1969 at Korfantego Alley "Super-Unit" block of flats emerged, designed by Arch. Mieczysław Król. Both buildings were KMS's initiative and constituted a part of a great development complex designed by the above mentioned architects, creating a new image of this part of Katowice.

So far "Super-Unit" has been subjected to many analyses (for example, growing environmental stress in the course of the 30 years of its performance conducted by the author of this paper, the results of which were published in monographs: (Komar B., Kucharczyk-Brus B., (Eds.) 2007) and (Niezabitowska E., Masły D., (Eds.) 2007) and in the materials of the II Health and Architecture Symposium held in Gliwice in 2004 (Komar B., 2004).

The emergence of the two above mentioned facilities resulted in another exodus of people from rural areas and from the neighboring zones to the city of Katowice. About 1660 people settled in "Super–Unit", and 300 people in "Haperowiec". In those times both buildings epitomized the fulfillment of the dream about workers' own luxurious home.

Continuing the growth of the eastern part of the city in the vicinity of Gen. Zietek traffic circle the Cooperative constructed "Gwiazda" (Star) estate (1966–1983), with two classical blocks of flats and four characteristic 25-floor buildings in the shape of a star, giving this part of the city an individual look image to be admired from the main access road connecting Warsaw and Katowice.

In 1979 KSM reached the peak of its activity, as it erected 29 buildings. Moreover, at the other side of Roździeńskiego Alley, opposite Gwiazdy estate (the Star estate) in 1977 – 1988 Kukuczki estate emerged - one of the best planned and well functioning housing projects. Its positive features include, first and foremost: maintaining the proportions between developed and green zones and playground squares, which occupy 46 % of the total surface area of the estate. It is very well equipped with service outlets located in separate units or on the ground floors of housing units, it has well-planned communication routes and two modern playgrounds.

Concurrently, in 1969–1987 Giszowiec housing estate was built, which contributed to the development of the central and eastern part of the city. The estate grew on the grounds of the residential district which had been designed and constructed in 1907–1910 by George and Emil Zillmann and reflected the concept of the Garden City, created by English urban planner Sir Ebenezer Howard. The district was erected for miners employed at

"Giesche" mine. The design was a small settlement, with the market square surrounded by the most important functional buildings: forestry headquarters, administration building, inn, bowling house, theatre room, band shell. The housing facilities reflected the form of detached Upper Silesian homesteads. In 1964 new "Staszic" coal mine was opened up in the vicinity of Giszowiec housing estate, and the demand for flats grew together with the increasing number of miners. Accordingly, over 60 years old houses were demolished to give way to high blocks of flats which were allotted to the management of housing cooperatives, including KSM. Fortunately, in 1978, 1982 and 1987 some particular parts of Giszowiec estate were listed as national heritage, which stopped the cycle of demolition works. Still, only one third of this historical settlement was saved from obliteration.

Figure 3. Katowice, Giszowiec estate
(source: author's photo archive)

Figure 4. Katowice, Zgrzebnioka estate
(source: author's photo archive)

During the times of the Polish Peoples' Republic the authorities were persistent in fighting the name of "Giszowiec" by pronouncing it German and promoting a new name: "Housing Estate in Memorial of Stanisław Staszic". It was only in 1990 that the City Council passed a resolution to restore the name Giszowiec. Nowadays the historical part of the estate is a tourist attraction of Katowice and Katowice Voivodeship.

In Giszowiec estate (Figure 3) 45 buildings are owned by KSM. The discord between the historical settlements and big blocks of flats is clearly felt. One of the problems evident in the estate is the insufficiency of services, the outcome of which was the emergence of a trade street, with ad-hoc trade stands and goods sold directly from trucks. In this particular case KSM's efforts to shape the city image clearly failed.

The year 1989 marked the change of the political system in Poland, opening of the borders, migrations for work, introduction of the free market economy, emergence of a strong developers' market, shrinking of cooperative housing initiatives. This period brought about new problems and new challenges both for the city of Katowice and for the whole Silesian Voivodeship. Heavy industry, exerting negative environmental impacts, collapsed, resulting in the closing down of steel mills and coal mines. A lot of people lost their job, which, in turn, contributed to the impoverishment of the society and cooperative housing members. The number of the inhabitants started to decrease. However, one of the positive aspects of the changes was the development of a pro-environmental attitude of the city and of the whole region.

In such difficult times, not giving up to recession, KSM started the construction of its 17th housing estate. "Zgrzebnioka" estate was built in the recreational and green zone, the enclave of peace and quiet. The last house was completed in 2007. The estate is located in the western part of the city of Katowice.

The free market economy, the growth of the developers' market, Poland's opening up to global trends, have all contributed to the emergence of new, higher requirements that newly built flats and housing estates have to comply with.

To face these, KSM equipped the newest part of its "Zgrzebnioka" housing estate (Fig. 4.) with many services located on the ground floors of the buildings, and endowed the facades with modern architectural forms. The brick technology of construction traditional and typical for the region facilitated the formation of architectural details. The bodies of the newly constructed buildings contain a strong sense of modernism so typical of the 1920s and the 1930s.

The analysis of the documentation at KSM's disposal showed that the Cooperative had used brick before as an element supporting the concrete slab technology and the monolithic one (Table 2).

Among the estates managed by KSM there are some where brick was not used at all: Centrum – I, Super-Unit, Haperowiec, Gwiazdy, Giszowiec, Murcki, Kukuczki, Janów.

Table 2. Technology for KSM's building settlements

The name of the settlement	Year of construction	Building technology
OŚ. CENTRUM – I	1960-1970	Concrete slabs; Skeleton- ferro-concrete structure; Framework structure
OŚ. SUPER-UNIT	1968-1969	Ferro-concrete- monolith
OŚ. HAPEROWIEC	1967	Skeleton-steel
OS. ŚRÓDMIEŚCIE	1958-1979	Brick, PGS; brick + aerated/ gas concrete , concrete slabs, brick + siporex; PGS 24
OŚ. GWIAZDY	1966-1983	Sideslip; PGS
OŚ. GISZOWIEC	1969-1987	Concrete slabs, skeleton structure, sideslip, concrete slab from W-70 to W-83
OŚ. MURCKI	1962-1975	Big block
OŚ. WIERZBOWA	1960-1982	Brick; ELBIS; East German concrete slabs
OŚ. KUKUCZKI	1977-1988	Concrete slabs
OŚ. ŚCIGAŁY	1961-2001	Brick; WK-70; Ferro-concrete +hollow bricks
OŚ. GRANICZNA	1957-1990	Concrete slabs; skeleton +brick+ PGS 24; brick
OŚ. SZOPIENICE	1959-1983	Brick; W-70; big slabs; ELBIS;
OŚ. JANÓW	1969-1975	ELBIS
OŚ. ŚCIEGIENNEGO	1963-1997	ELBIS; brick; concrete slabs; big block "DOMINO 68";
OŚ. ZAWODZIE	1960-2007	Brick; brick + PGS; PGS; W-70 SG; Concrete slabs with T system, East German concrete slabs, insulation slabs
OŚ. ZGRZEBNIOKA	1979-2007	Monolith; insulation slabs, concrete slabs, brick
OŚ. LIGOTA	1960-1978	Concrete slabs, East German concrete slabs, brick

To face modern and global energy-efficiency trends KSM commenced the activities of providing thermal protection to facades. To achieve this, 13 years ago a central renovation fund was created (separately from the renovation funds managed by particular housing estates) and a dynamic financial and renovation strategy formulated for the next 10 years, specifying particular repair and modernization works. Thus, it is possible to equal the technical condition of all buildings at all estates. Currently, almost all the buildings are thermally-insulated and their facades are painted in bright, sandy colors. The window frames have also been replaced.

But, considering the quantity of the buildings managed by KSM, some of them will have to undergo thermal protection measures once again, not only because of their dirtiness, but because of changes in the binding standards (ZUAT recommendations, PN-EN 13499 European standards, (Lipnicka M., 2008)).

Thermo-modernization measures have started in 1993 (Giszowiec, Resources of Katowice Housing Cooperative) and will be continued in the nearest future.

To recapitulate, KSM's estates are grouped in the following districts of Katowice:

Downtown: Centrum – I, Śródmieście, Superjednostka (Super-Unit), Haperowiec, Gwiazdy, Wierzbowa, J. Kukuczki,F. Ścigały, Graniczna;

- **Norhtern**: P. Ściegiennego;
- **Southern**: Murcki;
- **Eastern**: Giszowiec, Szopienice, Janów, Zawodzie;
- **Western**: A. Zgrzebnioka

KSM's housing resources include 314 buildings:

- 228 buildings up to 5– floors,
- 92 buildings from 6 to 11–floors,
- 21 buildings taller than 11– floors.

The tallest buildings (above 11 floors) are located in the following housing estates: Gwiazdy (6), Ściegiennego (4), Zawodzie (5). Other tall buildings are "Super-Unit" and "Haperowiec".

In newer estates, especially A. Zgrzebnioka, buildings up to 5 floors predominate, offering more pleasant, human scale and friendly living environment. The majority of cooperative buildings reflect the aesthetic trends of pre-cast technology so popular in the Eastern Block countries. Fortunately, housing complexes designed at the end of the 20th century and early 21st century explicitly reject this low quality stylistics in favour of richer and more rational forms. A good example is the housing complex at Floriana Street and Krasińskiego Street in Graniczna estate constructed in 1990, or the already mentioned settlements in the new part of Zgrzebnioka estate. Currently the cooperative is about to start several new housing projects: Rekreacyjna Dolina – Mały Staw (Recreation Valley – the Small Pond, Figure 5.), Rekreacyjna Dolina – Duży Staw (Recreation Valley – the Big Pond, Figure 6.), and is completing Świerkowe estate and 8 multi-family houses in Zawodzie estate.

Figure 5. Katowice, Recreation Valley – the Small Pond (source: www.urbanity.pl)

Figure 6. Katowice, Recreation Valley – the Big Pond (source: www.urbanity.pl)

DISCUSSION

The concepts of social building, and, first and foremost, cooperative building, described from different angles in professional literature are evidently perceptible in KSM's operation. In their aesthetics and technologies the Cooperative's housing resources the priorities changing over the successive decades.

The biggest number of buildings was constructed in Downtown district in the period 1958 – 2001. This is where two significant buildings: "Super–Unit" and "Haperowiec" are located, as well as Centrum – I housing project. It is the author's opinion that these facilities evoke many reservations. This view is substantiated by the fact that so far, despite several architectural competitions, a good project of the modernization of the city centre has not been found. Centrum – I estate suffers from excessive vehicle congestion because in its nearest vicinity, and party on its premises, there are many public utility offices requiring parking spaces. Unfortunately, the design architects did not predict such rapid growth of transport. Besides, just as "Super–Unit" and "Haperowiec", the estate is located by a main transportation route currently called DTŚ (Diameter Route, Fig 2.) so, to put things mildly, it is not an oasis of peace and quiet.

The entire downtown complex, of which "Super–Unit" is a significant part, is still waiting for a concept that would make it more human and offer some attractions typical of urban space. In the meantime, the huge scale of the settlements and low quality of materials contribute to the degradation of this part of Katowice. The aesthetics of the buildings is closer to infamous estates constructed in the communist times rather than to the centre of a modern urban agglomeration. The demolition of the two buildings is uneconomical, as they are built of ferro-concrete- monolith ("Super –Unit") and steel skeleton structure ("Haperowiec"); not to mention the fact that the modernization of the interiors (for example joining small flats into bigger units that would comply with the binding standards) is practically impossible. Last year the Cooperative started works on the thermal insulation of "Super –Unit" and completed the renovation of "Haperowiec". The image of the two facilities improved and the facades were taken care of. It should be mentioned that the previously mentioned studies of the "Super–Unit" revealed that the inhabitants rather than being concerned about the improvement of the quality of their building and the renovation of its facade, are interested in the basic functions – provision of habitation space. And although the image of the city centre does not depend on the Cooperative, it is invited to many design works and discussions on this issue.

The construction permits issued for such buildings in the 1960s and 1970s were a response to the demand for flats and, accordingly, fulfilled the demand. Unfortunately, the designers did not look ahead to the future to enable the adjustments of the buildings to the needs of the 21st century.

CONCLUSIONS

The discussed issues involved in cooperative building and housing may be helpful to designers, researchers and especially to housing cooperatives, which, despite the flourishing growth of individual and developers' building activity, still exist on the market. And although the operation of many cooperatives is limited only to the maintenance of its housing resources, KSM continues to build new housing estates, participating in the changes of the image of Katowice.

Cooperative building and housing has declined in its importance for the last several years, at least as far as the market share in new flats is concerned. However, in view of the resources at their disposal, the cooperatives are still tycoons, although they build less. According to the data published by the Polish Statistical Office for the year 2005, the national housing resources compiled 12.77 ml flats, over 26 % of which (every fourth flat) was owned by housing cooperatives, whereas 2/3 of all flats were located in urbanized areas.

The data explicitly indicate the importance of monitoring the resources of cooperative housing, as they still contribute to shaping the images of our cities.

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Possibilities of Integrated Valuation of Built Heritage Changes: Towards the Sustainable Development of Protected Areas

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Abstract. The socioeconomic and sociocultural peculiarities of Lithuanian post-communist society, including the ignorance of the heritage preservation principles and the constant changes of the legal basis, strongly influence the transformations of the built heritage of the country and especially the heritage objects and ensembles existing in the protected areas. The theoretical and practical fundamentals of the institution and formation of the network of the protected territories in Lithuania are based on the ideas of the natural protection and the historic preservation remains a secondary matter in this case. This justifies the need of the methodological identification and the integrated cultural and economic valuation of the built heritage changes in the protected areas. The notion of the built heritage changes, the tendencies of the built heritage changes in Lithuanian protected areas and the possibilities of their identification and valuation are discussed in the article and the framework for the identification and integrated valuation of the built heritage changes in the protected areas is presented.

Keywords: built heritage changes, protected areas, integrated valuation, sustainable development.

INTRODUCTION

Numerous processes taking place in Lithuania in the recent decades had radically changed the political, social, economic, and cultural climate of the country. This socioeconomic, sociocultural, and ideological transition inevitably influences the physical state and the cultural value of the country's built heritage. It is universally acknowledged that continuous maintenance, appropriate use, and the professional management are crucial for the preservation of the built heritage and they had already become an inseparable parts of the contemporary heritage preservation policies. However, the evaluation and regulation of the changes of the built heritage should not be forgotten. It is especially important in the countries or regions, which are undergoing or had undergone the radical political, cultural, or economic transformations or changes in the heritage preservation systems. Lithuania undergoing the post-communist transition and its' built heritage preservation regulated by the repeatedly changing legal system are the particular cases. The analysis of the present state of the built heritage and its preservation in Lithuanian protected areas (Mlinkauskienė, 2010) demonstrates that the existing heritage preservation means cannot assess and arrest the processes of the built heritage decay. This justifies the need of the inventory of the built heritage changes in Lithuanian protected areas and their comprehensive assessment encompassing the cultural and economic valuation.

The aim of this article is to determine the theoretical possibilities and to propose the methodological framework for the identification and integrated cultural and economic valuation of the built heritage changes in the protected areas. In order to reach this aim, the notion of the built heritage changes, the tendencies of the built heritage changes in Lithuanian protected areas and the possibilities of their identification and integrated valuation were discussed, and the hypothetical framework for the identification and integrated valuation of the built heritage changes in the protected areas was developed.

METHODS

The methodology of the research encompasses the desk-top study and the research on site in Lithuanian protected areas and includes the analysis of literature from the fields of cultural and environmental economics and heritage preservation, the analysis of archival documents, and analysis on site of the physical state and valuable features of the built heritage objects existing in the protected areas.

RESULTS

Definition and tendencies of the built heritage changes

The built heritage changes. The built heritage objects, especially in the post-communist countries, are often treated as the static valuable entity and their evolution is rarely analyzed or even acknowledged. In such situation the notion of the built heritage changes can be viewed negatively, as it is mainly used to describe the declining valuable features, authenticity or the deteriorating physical state. However, the changes of the built heritage caused by the *direct* physical and *indirect* sociocultural, socioeconomic, and political factors are much more complex phenomena and often cannot be defined as unambiguously positive or negative.

The analysis of literature allowed defining the built heritage changes (Figure 1) as the identified physical alterations of the built heritage object, such as the decay or improvement of its physical state, the changes of its structure or integrity, the transformations of its valuable features and the links with the surrounding environment. It is possible to distinguish three main types of the built heritage changes: 1) *negative* built heritage changes caused by the natural forces and destructive interventions; 2) *positive* built heritage changes caused by the interventions necessary for the preservation of the built heritage object and its valuable features; 3) *miscellaneous* or complex changes of the built heritage objects which cannot be unambiguously defined as positive or negative. For example, the renovation and reuse of the built heritage object cause the improvement of its physical state and may add new values; however, such interventions can be considered as threatening the authenticity of the object. The reasonable balance between the renovation, reuse and preservation of the authentic features can be viewed as the *miscellaneous* change.

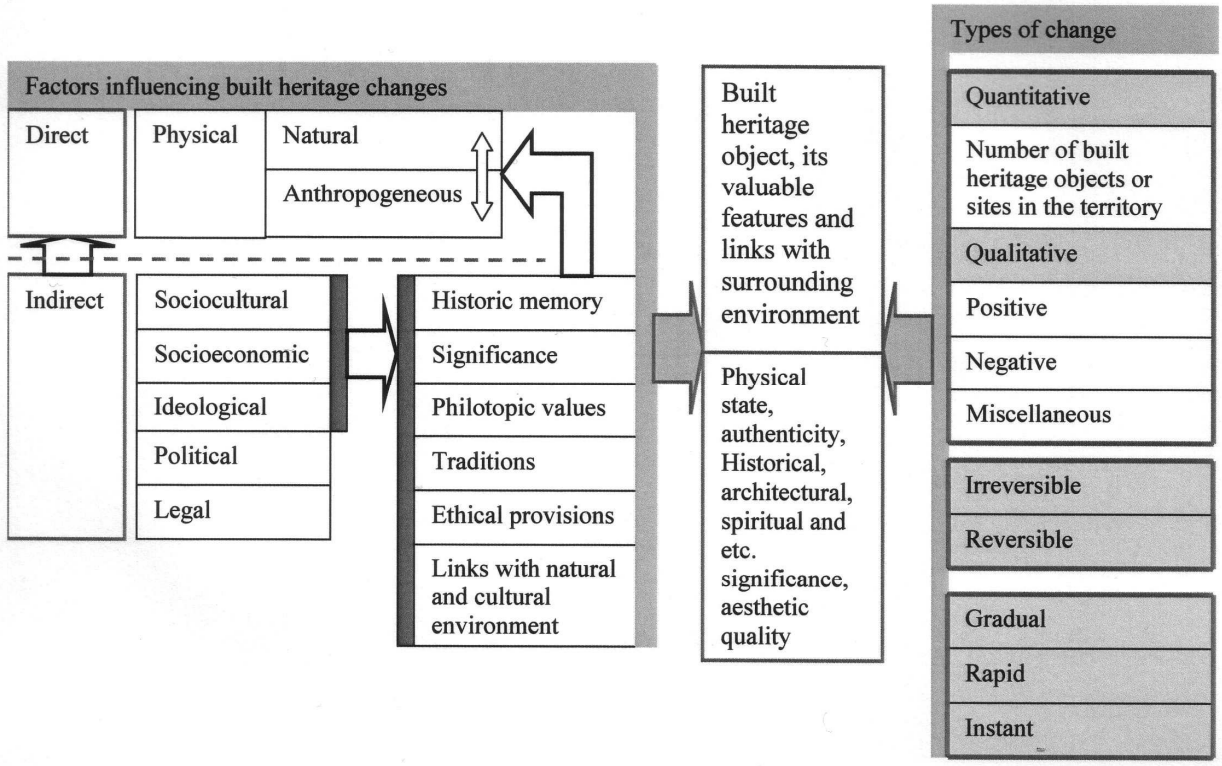

Figure 1. The built heritage changes and their reasons

The tendencies of the built heritage changes in the protected areas. The recommendations of the International Union for Conservation of Nature suggest that the national parks should be instituted for the preservation of large natural areas; meanwhile, the regional parks should be instituted for the protection of the exceptional areas of cultural landscape. The priorities of regional parks should be the use and maintenance of the valuable landscape features and cognitive recreation (IUCN, 2009). Consequently, the inventory and assessment of the built heritage changes in regional parks are of crucial importance in order to determine the tendencies of its development under the increasing recreational use after the restoration of the independence. Therefore, the built heritage of the regional parks, which cover 54 percent of the total area of all the protected territories in Lithuania, was selected for the quantitative and qualitative analysis of changes. Quantitative analysis of the built heritage changes was carried out in Neris, Varniai, Panemuniai, Meteliai, Veisiejai, Salantai, and Pagramantis regional parks. The qualitative analysis of the built heritage changes was carried out only in the regional parks having the considerable quantity of the built heritage objects i.e. Dieveniškiai historical, Varniai, Salantai, and Panemuniai regional parks. The analysis was aimed at determining the built heritage changes, which had

occurred in the protected areas during the years of the post-communist transition, i.e. after the restoration of the independence of the country.

The analysis of quantitative changes of the built heritage in the regional parks was based on the analysis of archival data and the analysis on site. The analysis of archival data allowed determining the extent of the built heritage objects and their territorial dispersion. It was determined that the number of the built heritage objects existing in the regional parks included into the National Register has decreased by 57 percent after the restoration of the independence. The main reasons of this change are: the deferred inventory, the financial problems, the deferred maintenance, and the exclusion from the register.

The analysis of the qualitative changes was based on the analysis on site. The analysis included the determination of changes of the valuable properties of heritage objects, the evaluation of the type of ownership, function, the present use, tourist infrastructure, and the determination of the zone of the functional priority of the park in which the object under valuation is located. It was determined that the changes of the valuable features of the built heritage object are interconnected with its use: the most significant negative changes were identified in abandoned objects. In cases when the built heritage objects are adapted to new functions their changes are miscellaneous and the balance between the preservation of authentic features and the innovations can be sustained. It was also determined that the reuse of the built heritage objects causes the changes of their environment: the more developed infrastructure usually was recorded near the objects, which are used for cognitive recreation or tourism. The primary uses guaranty the best preservation of the valuable features. It was determined that the qualitative changes of the built heritage objects depend on the functional zone of the park in which the objects are situated: the zones with the recreational priority provide the best possibilities for the reuse and preservation of the built heritage objects; meanwhile, in the zones with conservational priority only representational objects and objects that have retained their primary function are well preserved. In other zones the reuse and renovation of the heritage objects usually threaten their authenticity.

The analysis allowed concluding that after the restoration of the independence the changes of the built heritage in the protected areas were mainly influenced by the processes related with the restitution of the private property, the intensification of the recreational activities and related businesses, the intensification of the use of forests, the invasion of constructions, weakening of the administrational control and responsibility, and the insufficient information of the society and its involvement into the heritage preservation processes. The tendencies of the rapid and multidimensional change revealed by this analysis allow concluding that the regulation of the built heritage changes in the protected areas is an important measure for sustaining the viability of the built heritage objects and maintaining their physical state and valuable features. The efficient regulation of these changes, i.e. the elimination or mitigation of the negative influences, the encouragement of positive changes or the balance between the use and the preservation, should be based on the methodological means.

The experience of the identification and valuation of the built heritage changes

Monitoring of the built heritage changes. The principal method for the identification of the built heritage changes is monitoring. The monitoring of the built heritage changes is aimed at observing systematically, at analyzing and forecasting the state of the built environment, at determining the changes conditioned by the natural and anthropogeneous factors (VAMP, 1998).

In Lithuania the monitoring researches of the built heritage are performed from 1998. The recent activities of the built heritage monitoring in Lithuania are associated with the international program Development of a Monitoring System for Cultural Heritage through European Co-operation. The analysis of the archeological and historical objects carried out in the frame of this program encompasses the following monitoring researches (DEMOTEC-A, 2003):

1) *the retrospective monitoring*, which determines the primary physical state, the threat of the environmental impacts and the preliminary preservation recommendations after the analysis of the archival documents;

2) *the diagnostic monitoring*, which is defined as the assessment of the objects by analyzing the deviations from the standard physical state and the threats of the environmental impacts and providing the preliminary preservation recommendations;

3) *the systematic monitoring*, which encompasses preparing the reports with the preservation recommendations for five years.

However, no unified program, system or methodology for the built heritage monitoring currently exist in Lithuania. The main attention is still devoted to the heritage territories of the international significance and the inventories of the built heritage changes are carried out unsystematically, only identifying the damaged objects.

The tendencies of the built heritage valuation. The built heritage objects existing in the urbanized or in relatively natural protected areas are traded in markets (provide the exchange value) and / or provide the economic benefits of other kinds (the use and non-use values) and at the same time generate the cultural value. Considering that, they can be treated as the economic cultural goods (Navrud and Ready, 2002; Throsby, 2002)

and can be evaluated form the cultural and from the economic points of view. The changes of the physical state and valuable features of the built heritage objects can cause the changes of their cultural and economic value. Consequently, not only the identification of built heritage changes, but also their comprehensive integrated cultural and economic valuations is necessary in order to understand better and regulate the built heritage changes.

Cultural valuation of the built heritage changes is mainly aggravated by the absence of a universal model for the cultural value assessment. The postmodern notion of the cultural value defines it as a social construct determined by the cultural context, time, and place (Avrami *et al.*, 2002; Stephenson, 2008). This approach, according to R. Mason (2002) and D. Throsby (2002), has generated the so called "crisis of value" in the contemporary cultural theory: the notion of cultural value has been extended, though any appropriate theory for its determination and assessment was not proposed. However, the cultural value of the built heritage object is one of the main factors that inform the decision-making. Therefore, method for assessing the cultural value based on distinguishing its' composite elements or main features is frequently applied in the recent decades. Researchers and institutions propose different classifications of these elements or features: aesthetic value, spiritual value, social value, historical value, symbolic value, authenticity value (Throsby, 2002); aesthetic, historic, scientific, social or spiritual value for past, present or future generations (BC, 1988) etc.

Economic valuation of the built heritage changes is encouraged by the findings of the cultural economists (Mason, 2002; Throsby, 2002), which suggest that cultural goods, including the built heritage existing in the protected areas, can provide additional exchange, use and non-use economic values determined by their spiritual, historical, architectural significance, associative values etc. Consequently, it is possible to assume that the changes of these characteristics caused by the changes of the built heritage object, its valuable features or links with the surrounding environment can cause the changes in their economic value. Economic valuation of the built heritage objects as a real estate, based on their market prices is a common procedure. Services provided by the built heritage objects can also be partially measured by using the market data. However, the ignorance of the changes of use and non-use economic values of the built heritage as a public or merit good would lead to an incomplete picture of the benefits that it provides to the society and its preservation possibilities. The analysis of literature has demonstrated that the so-called non-market valuation methods (the travel cost method, the hedonic price method, the contingent valuation method), enabling to determine the non-market values and to integrate the society into the valuation process, are being increasingly applied to value the built heritage objects and sites in the recent decades.

The hypothetical framework for the identification and integrated valuation of the built heritage changes in the protected areas

The first step striving towards the comprehensive regulation of the built heritage changes is the identification and comprehensive assessment of these changes. We propose the hypothetical framework for the assessment of the built heritage changes in the protected areas, consisting of monitoring and integrated cultural and economic valuation (Figure 2).

Identification of the built heritage changes. The process of monitoring of the built heritage can be subdivided into the following steps:

1) selection of the territory for the analysis;
2) selection of the built heritage objects and the time interval for the analysis;
3) analysis of the quantitative and qualitative built heritage changes;
4) generalization of the results and formulation of the conclusions.

After the selection of the territory for the research, the analysis of the archival and other documentation should be carried out. This analysis of documents or preliminary analysis is the preparatory stage of the analysis. It aims at determining the location of the built heritage objects, analyzing the significant historical data and documents related with these objects, and gathering the existing data of the previous analyses concerning the physical state and valuable features of the built heritage objects. This preliminary analysis is the equivalent of the retrospective monitoring.

The analysis on site is the main stage of the identification of the built heritage changes. First of all it aims at determining the exact geographical location of the built heritage objects. This stage of the analysis can be subdivided into the identification of quantitative and qualitative changes of the built heritage. This stage can involve not only the observation and recording of heritage objects in photographs but also the sociological surveys aimed at analyzing the social significance of the built heritage objects. The analysis on site can be referred to as the diagnostic monitoring.

The processing of the gathered data encompasses the analysis, comparison, and systematization of the archival data and data from the analysis on site. It aims at determining the tendencies of the built heritage changes, identifying the objects or the groups of objects under the threat of decay and the main direct and indirect factors influencing built heritage changes.

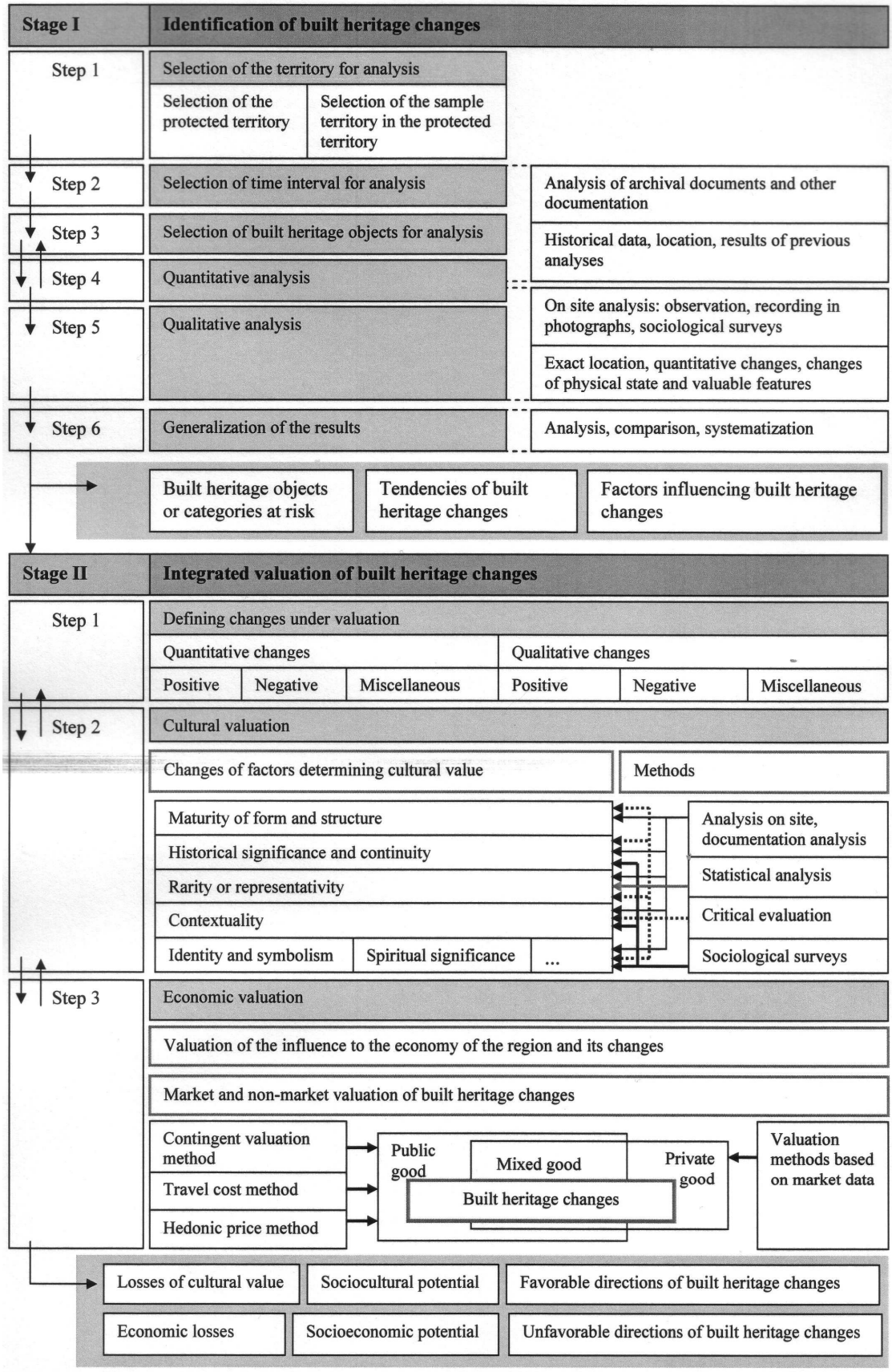

Figure 2. Hypothetical framework for the identification and integrated valuation of the built heritage changes in the protected areas

Integrated valuation of the built heritage changes. The identification of the economic losses and the losses of cultural value caused by the built heritage changes as well as the identification of the socioeconomic and sociocultural potential and the favorable directions of changes are necessary for the efficient regulation of the built heritage changes in the protected territories. This can be achieved by the integrated economic and cultural valuation of the built heritage changes. This process can be subdivided into the following steps:

1) defining the type of the built heritage change under valuation (quantitative or qualitative; positive, negative, miscellaneous);
2) cultural valuation of built heritage change;
3) economic valuation of built heritage change;
4) generalization of the results and formulation of the conclusions.

Cultural valuation of the built heritage change includes the assessment of changes of factors determining the cultural value of heritage object, such as the form and structure, historical significance and continuity, rarity or representativity, contextuality, identity and symbolism, spiritual significance. Variety of methods, including the documentation analysis, analysis on site, statistical analysis, critical or expert evaluation, and various forms of sociological research (interviews, surveys, focus groups), can be applied for the cultural valuation. Economic valuation of the built heritage changes can encompass not only market and non-market valuation of the built heritage changes but also the assessment of the influence of these changes on the local economy or economy of the region.

Variety of methods can be applied for market and non-market valuation of the built heritage changes. Market valuation is usually based on the existing market data, such as the real estate prices, sales of products or services etc. The hedonic price method, the travel cost method, and the contingent valuation method can be applied for the non-market valuation of the built heritage changes in the protected areas. However, the use of the travel cost method and the hedonic price method enables to measure only the non-market use values; meanwhile, the estimates obtained using the contingent valuation method encompass the use as well as non-use values.

DISCUSSION

The built heritage is influenced by the direct and indirect, natural and anthropogeneous factors and is constantly changing. The changes of the built heritage can be defined as the identified physical alterations and/or alterations of values and significance of the heritage object. The analysis of literature has demonstrated that the notions of built heritage changes and of regulation of built heritage changes do exist neither in national nor in international legal basis regulating heritage preservation. Evaluation of built heritage changes, determining their causes and consequences, and the elimination of the negative impacts are not regulated by any legal documents. Consequently, the definition, identification and assessment of the built heritage changes and the research on the regulation of preservation and use processes are not only the task of theory and experiments, but also the question of social, cultural, and economic relevance.

In Lithuania during the period of post-communist transition the material heritage of the past is still losing social interests and possibilities of traditional use not only in the territories of intensive agricultural activities or urban expansion, but also in the protected natural or slightly urbanized areas. The reuse of the built heritage in these new social and economic circumstances fosters its renovation and conversion. These processes of innovation, however, in many cases are hardly compatible with the preservation of the authenticity. Meanwhile, the mechanisms of systematic and constant monitoring and regulation of quantitative and qualitative changes of the built heritage are not prepared and the monitoring and systematic regulations of changes of the built heritage are not carried out. However, the main aim of the preservation of the built heritage in the protected areas is to preserve all the identified valuable properties and to retain regional cultural peculiarities and the main strategic aim of the development of protected areas is to assure the protection of natural and cultural properties, to reach gradually the European standards of protection and to adjust the management of the built heritage to the new economic and social conditions (VAMP, 1998). Consequently, the identification and integrated cultural and economic valuation of the built heritage changes in the protected areas is of crucial importance and is necessary in order to determine the tendencies of change and the sociocultural and economic potential of the built heritage.

The integration of cultural and economic valuation of the built heritage is not widely analyzed area. According to R. Mason (2002), a consideration of economic value has traditionally lain outside the traditional competence of the conservation professionals and the integration of cultural and economic values presents a particular challenge. Meanwhile, according to Shubik (1999), economists arguing in favor of the economic valuation of cultural goods are often accused of trying to price the priceless. However, the information about the economic value of the built heritage and the changes of this value caused by any direct or indirect influences may be helpful in the decision-making process and can be integrated into the cost-benefit or cost effectiveness analyses. Besides that, the non-market valuation of the built heritage is rather new and rapidly developing area of research and still very little is done in this field in the post-communist countries. This encourages the further

development and practical testing of the hypothetical framework for the identification and integrated valuation of the built heritage changes in Lithuanian protected areas.

CONCLUSIONS

1. The analysis of the built heritage changes in the protected territories allowed determining that these territories do not secure the reduction of negative built heritage changes. These territories hold the potential for the use, reuse, and preservation of the built heritage objects; however, no methodology for monitoring and integrated assessment of the built heritage changes exists, no systematic assessments of the changes of built heritage, its maintenance, use, and preservation are carried out.

2. The methodological means for the regulation of the built heritage changes in the protected areas should be based on the program of the comprehensive assessment of the built heritage changes and its' possible integration into the heritage preservation activities in these areas. The main parts of the proposed hypothetical framework for identification and integrated valuation of the built heritage changes in the protected areas are the following: 1) the identification of quantitative and qualitative built heritage changes; 2) the integrated cultural and economic valuation of these changes.

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Tendencies in Developing Urban Concepts of Multi-Family Housing Complexes in Poland in the Beginning of XXI Century

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Abstract
During last twenty years in Poland there were constructed many interesting housing estates. Standard of housing environment, standard of flats are growing, also urban solutions are developing. Some of these realizations show new directions and give a new quality of Polish housing in the XXI century. The author analyses urban aspects of these projects, asking also about influence for the city space.
The analysis was carried out in the frame of scientific work financed by the Polish Ministery of Science & High Education in the years 2010-2011 as research project No. N N527 075838.

Keywords: housing estate, urban concept, city, semi-public space, heterotype.

INTRODUCTION

The period of an economic transformation in Poland resulted in many interesting realizations of housing architecture. At the beginning of the XXI century a few housing estates came into existence, which – because of applied urban planning and architectural solutions - we can regard as a kind of architectural icons of Polish housing. We can regard as such important following complexes: Marina Mokotow, Eco Park (Warsaw), Wilanow Town, some estates from Lublin, Poznan, Bialystok, Krakow, etc. The purpose of study is characteristics of the housing environment based on these important examples, choosen by the author.

METHODS

The scope includes analysis – for first urban composition of complexes, solutions of the wheeled and walking transport, systems of parking, secondly spatial concepts of surroundings – standards of semi-public space, recreational space. The author is also asking questions about the place of these estates-icons in the city structure, about the context and the relation to the public spaces and the access to the social services (schools, kindergardens, etc.). The applied base on base method will allow on approval assessments of urban planning concepts, concepts - which determine clear directions of creating contemporary housing structures in Poland.

RESULTS - ANALYSIS OF CASE STUDIES

Modernism ideas

Despite the crisis of modernist ideas in planning housing complexes, which started from the 80's and the period of prefabrication, such solutions based on urban modernistic philosophy appear in the work of many Polish architectural offices also today. The flagship example of this is Marina Mokotow Estate, located in Warsaw close to downtown. The author of this project is an office APA Kurylowicz & Associates. The project was developed in 2002-2005, and the construction in 2003-2005. Residential area is designated, inter alia, by the streets: Raclawicka and Zwirki&Wigury, has an area of 21.5 hectares. They designed here 1476 flats and 64 houses. The main intention of the authors was "an attempt to enter a new urban fabric of the existing city structure of the upper Mokotow" (Majewski, 2005).

The main principle of urban concept was to locate the recreational area on the north-south axis, area in the form of a landscaped park, with a lake (Figure 2). From the North assumption closes the apartment building, designed on the plan of the curve, which - in the intention of the authors - is the frontage of the square, "court d'honneur ' - entrance to the estate. From the eastern side the area of the park with a lake is surrounded by buildings in the form of 4-storey city villas , forming an irregular line of frontage; on the west side – they designed buildings of 7 floors high, designating a rigid line of frontage. The eastern part of the estate is designed on clearly defined grid of streets, which determine the various quarters of development, referring to the scale of development in adjacent quarters of Mokotow. It should be stressed that the urban layout of the entire estate is

very clear, consistent, and buildings located in a hierarchical way - from large multi-family units designed around the lake, through the rectangular grid of streets lined with city villas with several apartments and single-family houses (Figure1). There is no sophisticated space exploration, but the whole settlement was composed according to precisely planning principles. In that way we obtained spatial order.

In the first stage three types of residential buildings were designed, which gave the benchmark for other teams to further work on specific projects. The architecture of buildings is strongly connected to neo modernist style. The proportions are very good, materials used - high quality, great finish, refined details have become the standard housing. Multi-family buildings have withdrawn last floors, where recreational spaces have been arranged on the roofs and spacious loggia; apartments located in the ground floor have direct access to gardens. The composition of the facade of buildings is based on clearly tripartite division. Colours of the buildings give them a characteristic of individualism. Architecture of urban villas and cottages corresponds the Warsaw architecture of the thirties. However, the level of architectural solutions is diverse.

Unfortunately - housing estate is a closed, gated space isolated from the city by two fences systems. The first system is the external perimeter (rampart, and the belt of bushes, kilometres of fence), the second - it's inside, it surrounds individual buildings. Semi public estate space means – except the park and artificial lake – the space of small streets along the fences.

Figure 1. Plan of Marina Mokotow Estate, Warsaw - rectangular grid of street lines. (left)
Figure 2. Public space (the lake) in the gated Marina Mokotow Estate, Warsaw. (right)

Creating city structures of XXI c.

A very interesting example of the exploration of urban structures of the XXI century in postindustrial city is Eco Park - a new housing estate in Warsaw. It was designed by the office of APA Kurylowicz & Associates and completed at the beginning of the first decade of the XXI century. The project included master plan and design of several quarters of development. The estate was built on the area of 19 hectares, located in the district Mokotow Fields, area of previous park that is a green area on the basis of the decision of the General Plan of 1931, that separates residential areas of Mokotow and Ochota. Total investment includes the construction of about two thousand flats, giving a rate of 105 dwellings per 1 ha. Land settlement was divided into three parts of varying height and development density (Figure 3). These three parts, "neighborhoods", were placed on both sides of the main communication - the boulevard, which had to be preserved because of the existing avenue of beech and which is a key element of future public space (agora). Character of agora- square is created by greenery and covered passage - a gallery, which is a compulsory part of the eastern elevation of each quarter of the western districts, and which protects the entrance to the services located on the ground floors. The boulevard bended in the mid-course in the central district area – where a few public buildings surround the agora- square (Figure 4).

Each of the "neighborhoods" has been divided into four to eight quarters - gathered around a green courtyard and supported by one entrance to the underground car parks. The size of each quarter is 80 to 150 apartments, of the community - neighborhood unit (Figure 5 & 6). Community shall have its own board, a duty of care assigned to them and the distinct nature of green architecture - the neighborhood's identity (Kurylowicz,

2007). Individual residential quarters were designed by different teams of authors, the emergence in the competitions. The main intention of the authors was to create the urban space with different character and clearly defined public spaces, while maintaining relationships with existing urban green areas and enrich it with new green spaces. That concept is fordem by: green public area, which is the avenue of the boulevard, which forms the backbone of communication north - south, generally the park - green belt along the western border and green interior of residential quarters, combined with open and public spaces and green parks.

The pilot quarter - Camerata – was designed on the base of the principle, that each flat should has its own individual character and the possibility of any arrangement, moreover - its own private open space - a patio, garden or terrace before, also common to all the internal garden. The entrances to the apartments are designed with half-opened galleries and staircases or private front-gardens, giving each apartment can be "home" inserted into the structure of four-storey building. Eco Park Estate is open, is available for residents of the capital. Asking about the name of estate - the authors contest that was to be a garden-city in postindustrial city.

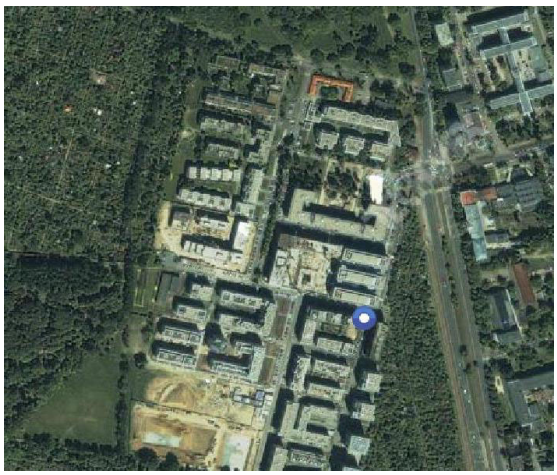

Figure 3. Plan of Eko-Park Estate, Warsaw – clear scheme of quarters. (left)
Figure 4. Main square-agora in Eko Park Estate, Warsaw. (right)

Figure 5 and 6. Neighborhood units – semi public space in the quarters in Eko Park Estate, Warsaw

Traditional urban city concept

Wilanow Town is the realization of urban design in the new part of Wilanow. Wilanow is one of the most famous, prestigious residential areas of Warsaw. Known primarily due to the tourist attractions - the seventeenth-century palace of King Jan III Sobieski and recreational areas - the Royal Gardens, parks, proximity to graduation tower in Konstancin. Wilanow Town refers in its assumptions to the idea of a European city. Author of urban design - American architect Guy Castelain Perry and Studio IN-VI was designed from scratch the largest contemporary development in Poland. The architectural concept assumes Wilanow Town friendly towns, while the open space harmoniously arranged including such city facilities as the town hall, market squares, squares and charming streets. For the everyday comfort of people designers provided shopping malls, banks, kindergartens, schools, temples, offices, hotels, cinemas, theaters, cafes and restaurants. Completely planned

residential vision is realized by Polish and foreign developers. It is expected that the total population in over four years will reach 35 to 50 thousand people.

Wilanow Town designed as a large, unified estate. Master plan covers an area of approximately 169 hectares (Figure 7). The area was divided into clear quarters, the buildings were set up along the streets of communication in such a way that each quarter is usually designated by perimeter buildings with four or three sides, forming a clear urban frontages. The plan is limited to a maximum building height of 20 meters. The external elevations of buildings (color, finish) should correspond to the adjacent city of palace and park complex Wilanow. By now there were constructed about four thousand attractive apartments, duplex and penthouses (from 31.2 m^2 to 163.7 m^2) and functional schemes to ensure convenience and quality of life. The highest floors form the emphasizing dominants in the corners and over the entrances. An additional attraction of the apartments on the top floors are available with terraces. Other apartments have private balconies, loggias, winter gardens or front-gardens.

Along the Klimczak street, the main axis of the expansion of Wilanow Town, completed the construction of canal water and planted with the plant, thus creating a recreational space for residents. From the beginning the investment has been criticized by many experts, and the same housing estate residents, because no regard to the consequences of the project. The estate began to become complex blocks, without main elements of land use and infrastructure. There is no school (even private), no kindergarten, there are very few shops, cultural and recreational buildings canceled. Only in 2009 they started the construction of a new bus station at the intersection of the future al. Rzeczypospolitej and Branicki street[2]. The estate is currently about 60% completed, while the infrastructure is completed in approximately 30%. Plans for public schools and kindergartens are now ready and the site of their building purchased by the City of St. Warsaw, but nobody knows when it will be built. The first playground Orlik and one private kindergarden are to be completed in the autumn. Inhabitants of estate expect construction of commercial and improvement of road infrastructure. The Project of Wilanow Town received in 2008 the urban prize "Excellence of the Year" from the organization ISOCARP. Moreover, receiving a prestigious "Award for Excellence" in 2010 was recognized by Urban Land Institute - ULI in the edition of the Awards for Excellence EMEA, because the project is carried out exclusively with private funds, without the financial assistance of the public sector. Housing varied destination is open. Project of Wilanow Town characterized by the absence of fences on the total area of 169 hectares. You cannot get inside the quarters, to semi-public spaces, which are only available to residents. As the investment assets the following features were regarded: its huge size; lack of fencing; coherent nature, i.e. the arrangement and density of buildings; rich architecture; referring to people of different social status. Issue of housing is characterized by height and density of buildings. Wilanow Town is opposed to widely pervasive phenomenon in the world, i.e. urban sprawl - uncontrolled growing towns[3].

New Wilanow (first part of investment) is built to the highest standards, including in ecological dimension, following the paradigm of sustainable development (Baranowski, 1997). This is reflected both in the used construction materials and technological solutions as well as care for the residents friendly environment. Biologically active area of invested parcels is 43.6% (normally this type of buildings 20-30%) (Figure 9). Current projects include the highest degree of natural light and sunshine duration of dwellings, providing in the southern elevation windows of glass absorbing harmful solar radiation. The construction of buildings was made using special solutions and it does not disturb the groundwater system. Both the implementation of construction, insulation and finishes used natural materials such as sand, gravel, lime, plaster, ceramic components, mineral wool, natural stones (marble, granite, travertine), glass and wood. Saving energy is an important determinant of the choice of technology implementation of the New Wilanow. And so the penetration rate is below 0.3 for the walls, and 1.1 for glass in the windows, which corresponds to the standard adopted in the European Union. In all buildings there have been provided solutions for waste segregation. New Wilanow is fully able to operate by persons with disabilities, in particular, moving on wheelchairs (Figure 8). All stairways are equipped with elevators for access to dwellings on each floor and underground garages, also designers dedicated parking spaces tailored to their needs. Special attention was paid for attractive landscaped and plants. In these houses and neighborhood residents will surely feel nice and comfortable, in complete harmony with nature.

[2] www.warszawa.wikia.com
[3] www.miasteczko-wilanów.pl

Figure 7. Master Plan of the Wilanow Town, 1999.

Figure 8. Lifts for people on wheelchairs in Wilanow Town. (left)
Figure 9. Green semi-public space inside the quarter, Wilanow Town. (right)

Heterotypes – model of living in the multifunctional complex

It is a model of dwelling we can find last years in European metropolises as well as in major cities. Flats are located in complex, where different functions are appearing, e.g. services, offices, recreation (flat, work, rest in one place). Such buildings should be designed in the way enough flexible so it is easy to convert functions of the space without the necessity of reconstruction of the building – if in the future the idea of use needs will change. Building dwelling spaces for the anonymous user, for individual arranging is becoming increasingly common. However proposals worked out are going farther - so that flats are characterized by not only a rate of the usable area, but also by the volume what will still make them more attractive in possibilities of shaping the space (Thill, 2004).

An interesting realization of contemporary residential architecture - example of heterotype (Tokajuk, 2009) - is the estate in Lublin near Popieluszko street, designed by architect Boleslaw Stelmach. Closed urban composition of ten 4-storey buildings, dramatically cuts the street from the buildings (Figure 10). Services are available only from the streets because the sight of a white wall cuts deep into the ground. Horizontal divisions are predominant in the white facade, in which the accent falls on the last floor of the wooden lining in a dark color. Entrances to buildings shall be located inside courtyards. A similar circular route sets communications

leading to garages on the ground floor of buildings. Simple spatial concept creates a closed quarter of residential buildings in a district settlement from the years of '40 and '50 near the city center. By the close of buildings located on the plot and the involving of wheeled transport to the interior of the quarter – it is lack of recreational semi-public places (like green areas with playgrounds for children) (Figure 11). Very meticulous use of each square meter for the construction of dwellings did not give the possibility of creating a common recreation area for residents of the quarter.

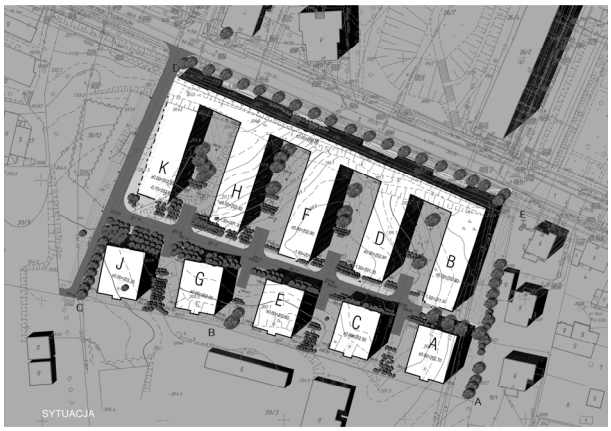

Figure 10. Plan of estate in Lublin, Popieluszko street. (left)
Figure 11. Courtyard in the estate in Lublin, Popieluszko street. (right)

DISCUSSION

All four housing estates which are subject of above analysis combines a high level architecture of the buildings and a very good quality of construction. In addition - the buildings are equipped with elevators (or ramps), adapted them for use by people with disabilities, just solved the problem of parking through the use of underground garages. Standard of semi-public spaces is also high. These aspects should be evaluated as a step forward in the design of modern residential complexes in Poland at the beginning of the XXI century and the creation of a new quality. The analysis showed, however, significant differences in the way of urban development and the relationship to public spaces in housing estates and its parts.

Marina Mokotow - is a city in the city, in most is reversed from the surrounding buildings, is a product of alienated, creating an artificial world with artificial lake, the "forbidden city" - without the possibility of entry. Interesting spatial solution is an artificial lake - with stone edges, streams and bridges, the center of the assumptions in the plan of authors - the area of public land available to residents of the capital, after the construction – gated community. A question mark is the design of so large recreation areas separated from the town; it is rather successful marketing. For the urban structure it would be better probably to transfer them to the public spaces and reduce it inside the settlements. In terms of urban planning and architectural forms of buildings - Marina is the quintessence of main stream of Neo Modernism style turn of the twentieth and twenty-first century.

Eco Park Estate has a legible urban plan, which is the consequence of imposed and adopted regulations. The original solutions as a result of work of many project teams create a high aesthetic coherence each of the 21 quarters and high quality architecture. The quarters are partially open to the public spaces, and a general plan of the settlement assumed from the beginning of a very conscious shaping of public spaces with good integration with the city. There was provided the location of trade, services, on the ground floors of buildings and public facilities. Through the multi-functionality Eco-Park has become an example of heterotype in the urban structure.

Wilanow Town, arranged by a consistent system of closed quarters of the building, represents a step backwards in the composition of urban housing structure. The idea of creation clear city streets with buildings along appears to be generally correct, but the manner of its implementation - the 'dead' ground floors with no services, trade, and the lack of schools, kindergartens and other infrastructure - seems inappropriate. We can see no thinking about making public spaces and promotion a model of life: housing, job - a shopping center. There is also the fundamental question of whether high buildings (6 floors) in open landscape - is the best model for living in the XXI century?

Finally, the presented housing from Lublin is an interesting, successful example of urban "implant" in the existing city. Thanks to its multi-purpose functional structure is also an example of urban heterotype. Good proportions and architecture of the estate are his strengths, but solution of car communication inside the quarter causes loss of ability for design places of recreation.

CONCLUSIONS

The settlements analysed in this study - because of the architectural and urban solutions and scale assumption - can be regarded without hesitation as icons of Polish housing architecture the beginning of the XXI century. Some of them are rather a summary of modernist ideas in designing contemporary living environment, part of them is trying to pave a new direction. As the applications must be noted that contemporary residential complexes implemented should take into account not only spatial, but also economical aspects. Large estates should meet other criteria, resulting also from the city's needs. In some cases, clearly lacked good planning at the communal level, which led to the creation of a closed estate, divided from urban space. There was the sales policy of public space, without a clear formulation of the conditions how to develop it. The correct relationship of housing environment and public spaces, good incorporation into the existing urban, mixed-use and ecological solutions are the features which should characterize the housing environment of XXI century.

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Social and Architectural Aspects of Revitalization of Historic Urban Centers in Lithuania: Experience and Tendencies

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Abstract. The comprehensive works of rehabilitation of Lithuanian historic urban centers were carried out during the period of the Soviet occupation. The insularity of the Soviet empire, ideological reasons and the absence of the private property have determined certain architectural expressions and solutions for the social problems. After the restoration of the country's independence, the problems and tendencies typical to Western city centers, such as commercialization of public spaces, gentrification, and mass tourism started to appear in Lithuanian historic urban environment. This justifies the aim of the article, which is to analyze and compare the Lithuanian experience of rehabilitation of historic urban centers during the period of the Soviet occupation and the contemporary tendencies of architectural and social changes taking place in the historic city centers after the restoration of the independence of the country and to distinguish the desirable directions of the interventions in and the social revitalization of Lithuanian historic urban centers.

Keywords: historic city center, revitalization, heritage preservation, post-communist country, Lithuania.

INTRODUCTION

The historic cores of numerous Lithuanian cities and towns have the historical origins and some of them started to evolve in the Middle Ages together with the Lithuanian state. The form, structure, and the image of the urban settlements are changing over time. According to J. Bučas (2007), the industrialization and the post-war expansion of the urban settlements of the country had completely changed their image from the compact closed city to a hardly definable sprawl of residential areas. What was defined as the European city by the M. Weber (Vanagas, 1996) currently became only a small area surrounded by the vast urbanized territories. The industrialization, commercialization and territorial expansion of the urban settlements, which was quite late in Lithuania compared to its' Western European counterparts and took place mainly in the second half of the 20th century, can be described by the concepts of the "critical zone" and "urban explosion-implosion" elaborated by the French thinker H. Lefebvre (2003). According to him, "the industrial city (often a shapeless town, a barely urban agglomeration, a conglomerate, or conurbation <…>) serves as a prelude to the "critical zone". At this moment, the effects of "implosion-explosion" are mostly felt. The increase in industrial production is superimposed on the growth of commercial exchange and multiplies the number of such exchanges. This growth extends from simple barter to the global market. <…> Buying and selling, merchandise and market, money and capital appear to sweep away all obstacles. Urban reality <…> becomes a productive force, like science." H. Lefebvre (2003) describes the ambiguous changes of the social and physical reality related to these processes: urban concentration, rural exodus, extension of the urban fabric, and complete subordination of the agrarian to the urban. These concepts clearly demonstrate the role of the urban center in the expanding cities and in the increasing social urbanization of the 20th and 21st centuries. Even if the cities and the urbanity itself expand, the urban concentration takes place at the same time. J. Bučas (2007) has noted that in this phase of urban explosion the historic urban core and its sociocultural content remain the generators of the image of the city. According to him, "The historic center of Kaunas (Old town, New town, and historic suburb of Vilijampolė) will remain the "business card" of the city we wish it or not. The main visual landmarks, such as the confluence of the Nemunas and Neris rivers, green riversides, the Old town and the spire of the Resurrection church are not only the valuable architectural and urban properties, but also the asset providing the identity, the distinctiveness, the visual and mental images of the city". The inseparable interrelations of the centrality and the urban expansion are also demonstrated by the insights of M. Cirtautas (2010) and A. Giddens (2005). M. Cirtautas (2010) states that the main reason of the formation of the peri-urban and semi-urban areas is the existence of the central city.

According to A. Giddens (2005), the revitalization of the city should include not only the regeneration of its' inner deprived or abandoned areas, but also the management of its expansion and the coordination of both processes. The notion of the historic city center used in this article is presented in the Figure 1.

The social dimension of cities is also changing over time. M. Weber has described the self-sufficient and self-governing closed communities of the Medieval European cities. The contemporary resident of the city primarily is the citizen of the state, its' potential protector obedient to its' laws and norms (Vanagas, 1996; Giddens, 2005). The German sociologist W. Siebel states that the society, which has produced the form and shape of the traditional European city does not exist anymore (Sucker, 2010). The residents of the contemporary large urban settlements can hardly be defined as a closed community; they rather form an urban society or a sum of various territorial and non-territorial communities. The territorial communities of the historic urban core and historic suburbs constitute only a minor part of the residents of the city. Meanwhile, the city center as the generator of its identity and image, the area where numerous administrational, cultural, religious, and commercial institutions are concentrated, is the interest and responsibility not only of its communities, but also of much wider society, governmental and nongovernmental institutions, and other interest groups. Discussing the transformations of the urban societies in Lithuania, the half of century of the communist rule and the characteristics of the post-communist society, identified by numerous thinkers and researchers cannot be ignored. The problematic of the revitalization of historic urban centers in the post-communist countries can be related with the following characteristics of societies and institutions: the lack of personal initiative and responsibility (Berend, 2007; Samalavičius, 2008a), mistrust in governmental institutions, corruption and consequent legal nihilism (Friedmann, 2005; Berend, 2007).

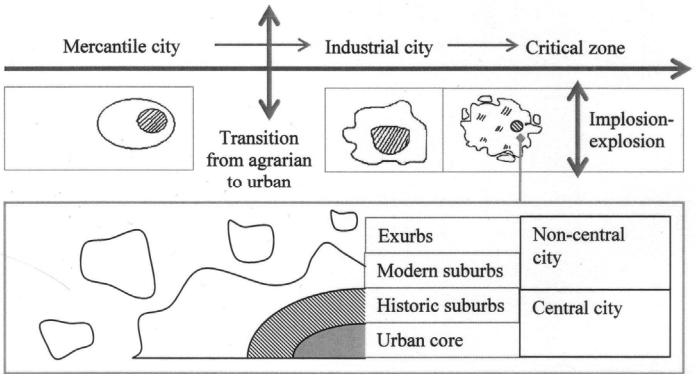

Figure 1. The notion and development of the historic city center with reference to H. Lefebvre (2003), J. Bučas (2007), and M. Cirtautas (2010)

The significance of the European city centers to their societies was revealed by the post-war reconstruction efforts. The World War II has left numerous European city centers with ruins and wastelands. According to R. Čepaitienė (2005), the reconstruction efforts took different forms in different cities: some of them were more oriented towards the functional and utilitarian aspects, the requirements of modern wellbeing and living conditions (Berlin, Moscow); in other cities the patriotism and the concern about the image of the city were the priorities and had engendered the imitations and interpretations of the historic architecture. The reconstruction of the historic center of Warsaw razed to the ground during the World War II is the best example of patriotism, resistance, and almost exact imitations of the historic architecture and urban layout (Tung, 2001; Čepaitienė, 2005). The reconstructions, modernizations, and revitalizations of historic urban centers were progressing, the economies and societies were changing, professionals were learning from the previous mistakes. Gradually new integrated forms of city center revitalization encompassing market forces and social initiatives had evolved. In the course of this process some common ideas were formulated and expressed in the international documents, such as the Venice Charter, the Washington Charter (Bardauskas and Karčiauskas, 1997), the Memorandum of Vienna (2005) and others.

The post-war reconstruction and modernization of historic urban centers in Lithuania were started under a Soviet regime. Both principal directions, i.e. radical modernization and imitation of historical forms, identified by R. Čepaitienė (2005), were taking place in Lithuanian cities. However, the ideological climate, the specific economic and social conditions, different forms of obedience and resistance to the communist rule, the absence of the private ownership, the insularity of the regime and consequent lack of information and international cooperation had inevitably influenced the solutions to the social problems of historic city centers and the architectural expressions of the interventions. After the restoration of the independence, Lithuanian cities had directly jumped into the free market economy and were affected by the globalizing forces. The situation of the post-communist Lithuanian cities can be well described by the lines of K. Sucker (2010), which in fact are attributed to very different city of Istanbul: "without the cultural backbone of civic management <…> city is now in the late stage of capitalism and has integrated the global tendencies of neo-liberalism directly into the production of the urban space. It demonstrates, therefore, clearly the realities of the society through the characteristics of the built environment." Numerous social and architectural processes and tendencies are currently emerging in Lithuanian city centers; however the comprehensive efforts of city center revitalization are

weak or inexistent. The architectural interventions and the management of the social and economic environment also seem disconnected. Such situation justifies *the aim of the article*, which is to analyze the experience of management and interventions in historic urban centers in Lithuania during the Soviet occupation and after the restoration of the independence from the architectural and social points of view and to formulate the hypothetical guidelines for the practice of city center revitalization in the contemporary sociocultural and socioeconomic context of Lithuanian cities. In order to clarify this aim, the hypothesis of the research was formulated:

- The post-war reconstruction and modernization of historic urban cores were characteristic to numerous European cities damaged by the World War II. However, the ideological and economic conditions of the Soviet regime had influenced the processes of reconstruction and modernization of Lithuanian historic city centers and conditioned specific attitudes to and solutions of the social problems and the character of the architectural expression of the interventions;
- After the restoration of the independence the processes and transformations (commercialization, gentrification, mass tourism, public-private partnerships) typical to the urban cores of Western countries, characterized as liberal democracies and free market economies, are starting to appear in Lithuanian historic city centers;
- The experience of the Soviet occupation may have a specific influence on the communities of city centers, the society, the institutional environment, and the character of the architectural interventions;
- The comprehensive revitalization and sociocultural and aesthetic continuity of historic urban centers of Lithuanian cities lie in the integrated management of the whole urban environment and its' dynamics, social inclusion, and the postmodern forms of contextual architecture.

METHODS

The methodology of the research encompasses the *desktop study* and the *observations on site*. The desktop study was aimed to analyze the literature and documents concerning the interventions and management of historic centers in Lithuania and other Central and Eastern European countries. A short review of the experience of city center revitalization in the Western countries was also carried out in order to make a comparison with the practices and trends observed in Lithuania during the communist rule and after the restoration of the independence. The observations on site were carried out in the central part of Kaunas (Old town, New town and historic suburb of Vilijampolė) in order to ascertain the trends and results of the interventions identified after the analysis of literature. The characteristic examples of new architecture in the historic urban environment were recorded in photographs. The results of the desktop study and of the observation on site were compared and generalized and the hypothetical guidelines for the social revitalization of and architectural interventions in Lithuanian historic urban centers were formulated. The methodology of the research is presented in the Figure 2.

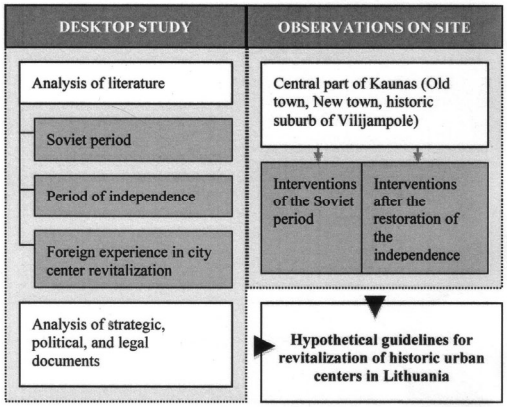

Figure 2. The scheme of the research methodology

RESULTS

Social and architectural aspects of city center revitalization in literature and documents

The analysis of literature has demonstrated that Lithuanian researchers and practitioners had devoted a considerable attention to the interventions in the historic urban centers beginning with the first efforts of the post-war reconstruction. The analyses of the Soviet period were inevitably influenced by the ideological climate, relevant problems and the economic situation of the time. The literature of the Soviet period was mainly devoted to the *presenting the results of various analyses* and the *recommendations for the interventions*. The analysis of literature demonstrates the strong interest of the researches of that period in the problems of harmony between the historic architecture and new insertions. For example, V. Jurkštas, V. Dvariškis, J. Glemža had proposed the different strategies how to attain the coherence of historic urban fabric and new construction (Čepaitienė, 2005). V. Jurkštas (1994) has distinguished several strategies of architectural design in historic urban environment: similar architecture based on imitation and stylization of historical forms and details, contrasting architecture, neutral architecture, inspired architecture, and the architecture of the autonomous manner. J. Glemža recommended the reconstruction of the volumes and exteriors of valuable buildings and ensembles based on the comprehensive documentation in valuable historic context; in less valuable historic context he recommended the modern contrasting interventions. This allows concluding that historic reconstruction, imitation of historic forms and pseudo-historical aesthetics were acceptable for the preservationists of the Soviet period. According to J.

Vanagas (1991, 1996), the science of sociology was ignored during the Soviet period; however, the social dimension of the reconstruction and modernization of the historic urban centers is visible in the researches of the period. For example, P. Vičkus (1986) had published the study of social and economic factors of the reconstruction of historic urban centers. J. Vanagas (1991, 1996) with V. Jurkštas had initiated comprehensive sociological analyses of historic urban centers of Vilnius, Kaunas, and Klaipėda in 1960'. The analyses were targeted at the social-demographic characteristics, lifestyles, needs, and the identification with the living environment of the residents of historic centers. J. Vanagas (1996) has applied the sociological method of analogies or prototypes to the forecasting of social development of historic urban centers. The households with certain social-demographic characteristics, living conditions, and lifestyles were selected and analyzed as the prototypes of the future residents of historic urban centers and as the basis for the design proposals. The improvement of living conditions in the densely built historic cores was one of the major concerns of the Soviet period (Čepaitienė, 2005). For Example, J. Vanagas (1996) has proposed the program for the improvement and harmonization on Vilnius historic center, as the residential complex, encompassing the reduction of pollution, noise, congestion of residents and daily visitors, solving traffic, lighting, and aeration problems, the expansion of green areas.

After the restoration of the independence, the array of the analyzed subjects and the opinions and ideas presented has substantially widened. The analysis of literature allowed distinguishing the main categories of contemporary researches devoted to historic urban centers: retrospective analyses, publications of the research results, criticism and identification of the problems, guidelines and recommendations, and innovative ideas.

Retrospective analyses. The restoration of the independence and the radical shift in values, political, social life, and economy allowed reevaluating the experience of the reconstruction and modernization of historic urban centers. However, this is still rarely analyzed subject. One of the most comprehensive retrospective analyses of the interventions of the Soviet period was presented by R. Čepaitienė (2005). In this study she discusses the ideologies and practical results of the so-called "old town regeneration" and concludes that, even if oriented towards the complex action, it resulted only in separate demonstrative interventions and ignored the integrity of the historic urban cores because of the scarcity of funds and unsuccessful administration. R. Buivydas (2006) analyses the architectural insertions in the historic center of Vilnius of the last decade of the independence and indicates the positive shifts towards the harmonious coherence with the historic environment.

Results of the researches. The market economy and private property makes the complex regeneration of historic urban fabric impossible. In the past these complex efforts had fostered numerous researches in country's scientific institutions. After the restoration of the independence, the quantity of the researches concerning revitalization of historic urban centers has decreased. Several interesting researches, however, can be mentioned. For example, E. Navickienė (2006) presents a comprehensive analysis of the experience and principles of creation of new architecture in historic environment. The research encompasses the analysis of legal documents, recommendations, and the attitudes of professionals as well as the practical examples. D. Krupickaitė and H. Standl (2004) have analyzed the phenomenon of gentrification – the social changes fostered by the growing prestige of the historic urban areas, when higher social classes tend to push out the residents of lower social classes – and its' manifestations in the Lithuanian context.

Critical analyses. The analysis of literature demonstrates that the quantity and the array of the critical analyses and views have considerably increased with the processes of democratization. In the advent of the independence A. Gražys identified four main problems concerning the state of Vilnius historic center: the conflict between the historic urban fabric and the changing forms of ownership, the conflict between the new values of the market economy and the misunderstanding of values of historic environment, the conflict between the abstract preservation requirements and the practical needs of renovation and repair, and conflicts between the interest groups (Čepaitienė, 2005). After nearly two decades of the independence the researchers and thinkers raise similar problems. For example, R. Buivydas (2006) identifies the legal nihilism and the efforts to avoid strict heritage preservation regulations in Vilnius historic center. G. Filipavičienė ir S. Puodžiukaitė (2009) raise the questions if the historic urban cores should function as a museum, reserve, or as an integral part of the contemporary city. According to them, the formal constrictions of the organic growth in the living city raise numerous conflicts and only a living tradition of maintenance and public perception of values of the historic environment are the keys for preserving historic cities. A. Samalavičius (2008, 2009) identifies the vanishing sense of place in Vilnius and the commercialization of the public spaces. It is interesting to note that the foreign researchers (Friedmann, 2005; Rypkema, 2007) looking at the historic preservation and urban development of the post-communist countries also identify the legal nihilism and the overwhelming power of capital as the main negative trends.

Guidelines, recommendations, and innovative ideas. Only a part of the identified problems attains appropriate solutions. Guidelines and recommendations abundant in the Soviet period currently are not so popular among the researchers. The analysis of the development of the image of Kaunas by J. Bučas (2007) is an exception in this case. J. Bučas (2007) has discussed the problems of revitalization of Kaunas historic center and

highlighted the main directions of their solutions related to the integral development of the whole city and its image: the preservation of culturally valuable properties, renovation of infrastructure, revitalization of and support to the local economy, creation and development of viable public spaces, development of social and cultural infrastructure, encouraging the initiatives and cohesion in local communities, and the economic compensations and incentives for the owners of heritage objects. Such recommendations are similar to the ideas of integrated revitalization of historic urban areas widely accepted in the Western countries (Gražulevičiūtė-Vileniškė and Urbonas, 2010). J. Bučas (2007, 2008) also presents some innovative ideas in Lithuanian context concerning revitalization of historic urban centers. According to him, the high-rise constructions in the visual neighborhood of historic urban centers should not be viewed solely as a threat, their contrasting architecture can highlight the value of the historic environment at the same time embodying the progress and retaining businesses in city center. Compact urban development also contributes to the ecological sustainability.

The analysis of legal, political, and strategic documents concerning historic preservation and revitalization of historic urban environment revealed interesting aspects related to the shifts in concepts of historic preservation in Lithuania. The revitalization and architectural interventions in the historic urban centers in Lithuania are managed and regulated mainly by various city-level strategies, programs, panning documents, and heritage preservation regulations targeted to the specific objects or areas as well as by the general national documents, such as the Law of Protection of Immovable Cultural Heritage (Lietuvos…, 2004). The example of the city-level strategic documents and programs are the Vilnius Old Town Revitalization Strategy (Vilniaus…, 1998), declaring the principles of multifunctionality, public and private partnership, and the integration of heritage preservation and new development, and thematic annual programs of old tow revitalization prepared by the Vilnius Old Town Renewal Agency (Vilniaus… 2010). Any strategic, political or legal documents of national level concerning revitalization of historic urban centers currently do not exist. However, general strategic, political, and legal documents concerning heritage preservation and architecture can provide interesting insights on the priorities and possibilities of management and interventions in the historic urban centers. For example, the international regional document, so-called Riga Charter (Rygos…, 2000), adopted in 2000 by the scientific committee of experts from the Central and Eastern European countries, ICCROM, and the United Kingdom tries to mitigate the principles of the Venice charter (1964) and advocates the rebuilding (reconstruction) of lost historic buildings. The Charter (Rygos…, 2000) states that "the reconstruction of cultural heritage lost because of the natural disasters or human actions can be acceptable in the circumstances, when the heritage object under consideration is of exceptional artistic, symbolic meaning or has the exceptional significance in urban or rural environment". The main conditions for the reconstruction are the comprehensive analyses, historic documentation, and contextuality. The Charter also highlights the importance of public participation in the decision-making: "in all the cases the relevance of the reconstruction must be determined through the comprehensive open consultations between the governmental institutions, local government, and interested public" (Rygos…, 2000). The acceptability of the rebuilding of lost valuable historic buildings is also integrated in the legal document of national level i.e. the Law of Protection of Immovable Cultural Heritage (Lietuvos…, 2004). The law clarifies that historic reconstruction must not only be based on the comprehensive documentation and analyzes, but also must not cause the damage to the valuable relics of the building. The law also emphasizes the importance of public participation in the decision-making and highlights the social dimension of heritage preservation: revitalization and cognition of heritage objects are regarded as the integral parts of heritage preservation process. Meanwhile, the national political document "The Description of the Trends of Architectural Policy of the Republic of Lithuania" adopted in 2005 (Lietuvos…, 2005) demonstrates the clear shift towards the Western tradition of integrated historic preservation and architectural innovations in the historic urban environment. The document emphasizes the constant evolution and the social dimension of the built environment: "The creation of architecture is <…> the creation of cultural, social, and economic values and relationships and also reflects their historical development. <…> The extent and values of urban and architectural heritage are not clearly defined or limited". It states that the contemporary interventions should be based on the local identities and can add value to the historic environment. The document does not provide any clear directions for the architectural expression of the interventions in the historic environment but highlights the importance of sustainability and the ethical dimension. The provisions of the latter document correspond to the ideas of the integrated management of the urban environment and historic cityscapes expressed in the latest international documents (Vienos…, 2005; Communication…, 2006).

The experience of city center revitalization in Lithuania

The analysis of literature allowed distinguishing several main trends of architectural interventions and social processes in the historic environment of Lithuanian cities, encompassing the periods of the Soviet occupation and after the restoration of the independence: modernization and radical urban and architectural innovations, pseudo-historic architecture and historic reconstruction, commercialization of public spaces,

commercialization, decay, and self-regeneration of historic suburbs, gentrification, and the steps towards the public participation and the harmonious development of the built historic environment.

Figure 3. Radical modernist intervention of the Soviet period in the historic center of Kaunas

Modernization and radical urban and architectural innovations. Radical post-war innovations in historic urban centers, motivated by the needs to rationalize their structure and improve the living conditions, and their outcomes were the reality of numerous European cities damaged and not by the bombs of the World War II. The countries of the Soviet bloc were not an exception too. However, the peculiarities of the Soviet system had a certain effect on the ideology and the results of the modernization. According to R. Čepaitienė (2005), the Soviet ideology of the value of the past in the quest of the creation of the future determined the attitudes towards the historic preservation. In the Soviet case the "old" was adapted to the "new" not vice versa. Consequently, the historic urban centers were treated by the bureaucrats as every ordinary neighborhood and reconstructed based on the determined norms of planning and sanitary. The other peculiarity of the Soviet regime was the absence of the private property; this allowed the reconstruction and modernization of the entire quarters. These circumstances allowed the drastic interventions in historic urban fabric reducing the density and opening vast spaces. Historic houses, which could have been easily repaired, were demolished (Čepaitienė, 2005). The ideas of how the new architectural interventions in the historical fabric should look like went into two different directions. Some architects clearly underlined the need to harmonize the new architecture with the contextual environment. Meanwhile, the proponents of the modernism argued for the contrasting interventions. According to R. Buivydas (2006), "one of the indicators of the professional courage and advancement of the architect was the priority towards the new construction instead of the old building of "low value" and the ability to create the architecture clearly contrasting with the historic environment". This resulted in numerous modernist interventions of different quality in historic urban centers during the Soviet period (Figure 3). The proponents of the contrasting modernism continue to work in the historic environment. Currently the emergence of the modernist insertions is mainly related with the commercial development. R. Buivydas (2006) defines this trend of the contemporary architecture in the historic urban environment as the "dialog with itself": "the expression of such objects is oriented towards themselves and declares their autonomy. Only their size and location are their features communicating with the historic center."

Figure 4. The Lower castle: the contemporary historic reconstruction in the historic center of Vilnius

Pseudo-historic architecture and historic reconstruction. The efforts to achieve the visual coherence with the historic environment reflect the other interesting aspect of the reconstruction of historic urban fabric during the Soviet period. The analysis allowed distinguishing three principal directions of these efforts: reconstruction of historic volumes and details, neutral architecture, and architecture with pseudo-historic aesthetics. In this case the visual coherence was achieved; however, this architecture lacks several qualities currently considered as essential for the revitalization and sustainable development of the historic environment: it treats the historic urban center as the stable physical environment, the evolution of which is already finished, and does not evoke the senses of evolution and continuity. However, the changing sociocultural and socioeconomic content inevitably causes some changes in the physical fabric. Besides that, the neutral and pseudo-historic architecture lacks informativeness: the spectators can hardly comprehend the period of its creation. The trends of historic reconstruction and pseudo-historic aesthetics continue to exist after the restoration of the independence. The shifts in the political system gave the additional symbolism to the historic reconstruction: after the collapse of the Soviet bloc numerous historic buildings, destroyed by the regime or even earlier, were rebuilt as a sign of the independence and historical justice. The Blackheads house in Riga and the Lower castle in Vilnius (Figure 4) are the characteristic examples of this trend. However, the recent debates and the decision on the restoration of

Kaunas castle demonstrate the shift towards the Western European concepts of restoration. The design proposal is based on the principle of informativeness: the historical remains and the new additions can be clearly distinguished by the spectator (Figure 5, a).

Commercialization. The opening of the borders after the restoration of the independence, the radical shift from the central planned economy to the competitive free market economy and the recent economic boom had inevitably brought changes to the historic city centers. The researchers indentify the manifestations of the commercialization in the public urban spaces and architecture (Samalavičius, 2008, 2008a). In some historic cities of Western Europe, such as Venice, Florence in Italy or York in England, the commercialization of public spaces is mainly caused by the mass tourism. The development of tourism and recreation and its' infrastructure was also characteristic to the Soviet regime. R. Čepaitienė (2005) presents the example of Trakai historic town, where the residential and recreational buildings of large volumes fractured the harmonious natural-architectural landscape. After the restoration of the independence Vilnius became a favorite destination of international tourists. This certainly has some influence on the socioeconomic and sociocultural climate of the city center. However, the negative effects of tourism are not clearly felt or identified by the researchers. This can be explained by the fact, that Vilnius mainly attracts cultural not mass tourists. The commercialization and physical changes of the historic centers and neighboring areas of Vilnius and Kaunas are mainly caused not by tourism, but by the real estate and retail development. The Description of the Trends of Architectural Policy of the Republic of Lithuania shortly summarizes on this situation: "During the period of transition the construction industry attains large investments and the quantity of new constructions rapidly increases, however, this results in negative effects on the quality of architectural and urban design: on the sustainability of buildings, physical and aesthetic quality, links with the surrounding natural or built environment, and long-term interconnections with the architectural heritage and sociocultural environment. The investments in the construction industry are essential to the economic development of the country, however, the desire of the investors for the fast and large profits negatively affect architecture and urban planning" (Lietuvos…, 2005). The new commercial developments in the historic city centers (Figure 5, e, f, g, h) and their surroundings evoke different opinions and reactions.

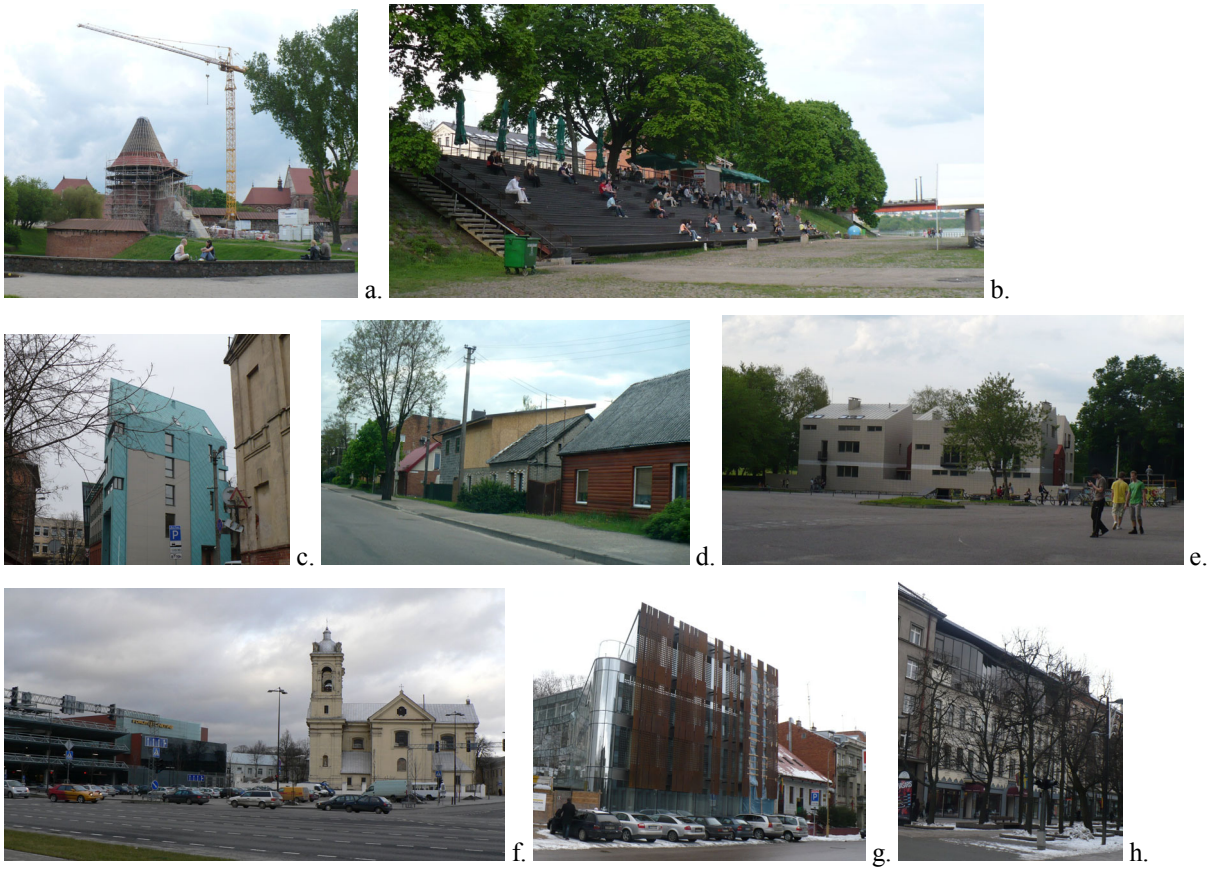

Figure 5. The contemporary development in the historic urban environment in Kaunas:
a – restoration of Kaunas castle based on the Western European heritage preservation traditions; b – new viable public space in Kaunas historic core; c – informative architecture based on the architectural context and contemporary trends and materials; d – "self-regeneration" of historic suburb of "Vilijampolė"; e – development of residential function in Kaunas historic core; f, g, h – different faces of commercialization in the New town of Kaunas

The new contrasting developments of small and large scale in the vicinity of historic architectural and urban structures can be seen as the instruments for highlighting their distinctiveness and cultural value (Bučas, 2007, 2008). However, this development also attains the severe criticisms. A. Samalavičius (2008) parallels the new development in Vilnius in the right bank of the Neris River to the "urban surgery" proposed by Le Corbusier in the first half of the 20th century and describes the architecture of the high-rise buildings as the old-fashioned modernism of 1970' and 1980'.

Processes in historic suburbs. The criticism of new commercial development in Vilnius by A. Samalavičius (2008) and the remarks on the image of Kaunas by J. Bučas (2007) reveal the ambiguous phenomenon of changes in historic suburbs, which gradually became a part of the central city. The processes in Lithuanian historic suburbs range from the physical and social decay to the deliberate destruction in order to clear out the space for the new construction and clearly reflect the two different but threatening situations of heritage preservation identified by D. Rypkema (2007): problems, when there are not enough and too much financial resources. A. Samalavičius (2008) presents the example of the historic suburb of Šnipiškės with the characteristic urban structure and wooden architecture in Vilnius on the right bank of the Neris River, which was almost completely erased by the new administrational and commercial development. The redevelopment of the area started during the Soviet period with the construction of the high-rise hotel and gradually resulted in the famous Vilnius "downtown" or "architectural hill". Very different situation can be seen in the historic suburb of Vilijampolė in Kaunas. The suburb with well-preserved urban structure, dating back to the 17th century, is on a verge of physical and social decay. According to J. Bučas (2007), "Vilijampolė was the closest and most significant suburb of Kaunas for centuries. During the Soviet period it was transformed into the industrial hub. Currently the decaying territory negatively affects the image of the city". J. Jacobs (1961) had described the ability of the historic urban neighborhoods to regenerate themselves. She noted that the district in Boston called the North End with traditional layout of blocks and mixed uses has self-regenerated without any governmental subsidies during two decades: "Dozens and dozens of buildings had been rehabilitated. Instead of mattresses against the windows there were Venetian blinds and glimpses of fresh paint. Many of the small, converted houses now had only one or two families in them instead of the old crowded three or four. <...> The rehabilitation work has been almost entirely financed by business and housing earnings within the district, plowed back in, and by skilled work bartered among residents and relatives of residents". During the current economic downturn, when the prices of construction and repair works are getting lower, some signs of self-regeneration or self-repair can be seen in Vilijampolė. However, the quality of works and the materials used and the architectural expression of the interventions are far from being in harmony with the historical character of the neighborhood (Figure 5, d). This allows making a presumption that for the sufficient self-regeneration certain financial and social capital is needed.

Gentrification. The term "gentrification" only recently was accepted into the discussions concerning the social and physical changes in the historic environment in Lithuania and is mainly linked with the experience of the Western countries. However, it is necessary to note that the idea of "improving" the social environment in the historic urban centers existed in the period of the Soviet occupation as well. For example, J. Vanagas (1996) has noted that "The regeneration of the historic urban centers sometimes requires a certain means of "social prophylactic", i.e. to diminish the concentration of asocial individuals and to attract the creative, intelligent residents, which understand the values and attractiveness of the historic environment". The analyses by J. Vanagas (1996) of the social-demographic characteristics of the households living in the historic centers demonstrated the specific diverse social composition: large numbers of elderly residents and large families as well as of small households. The social status of the residents was also very diverse: from the jobless asocial individuals to highly qualified professionals. The experience of the Western countries (Bromley *et al.*, 2005) demonstrates that the social composition of historic urban centers tends to change from the diverse to homogeneous: the prestige of the historic environment tends to attract young active wealthy individuals and small households, meanwhile, the households of lower social status are being pushed out. The favorable outcome of these social changes is the improvement of the physical state of the built environment; however it increases the social inequality and threatens the identity of the area. The researches and observations demonstrate that this process, often referred to as gentrification, is taking place in the historic neighborhoods of Lithuanian cities (Krupickaitė and Standl, 2004; Lietuvoje…, 2010). However, D. Krupickaitė and H. Standl (2004) identify some peculiarities of the Lithuanian, and probably the Central and Eastern European, gentrification. According to them, in the Lithuanian case the social composition of the neighborhood and its' image and prestige change much more rapidly than the quality of the physical environment.

Public participation. The active participation of the society and communities and open discussions with the stakeholders are seen as one of the essential components of the effective integrated city center revitalization in the Western countries (Tung, 2001). The foreign experience demonstrates that public participation should not be limited with the legally defined formal procedures, but should extend into the complementary informal meetings and comprehensive sociological analyses (Wood and Landry, 2008). The efforts of the information center of

Vilnius Old Town Renewal Agency, which aims at the dissemination of information about the valuable features of Vilnius historic center and consulting the private owners about the issues of heritage preservation and restoration, can be an example in this regard. The information center organizes seminars and teachings for the society, owners of historic buildings, and investors, youth education programs, participates in international projects and encourages the international exchange of information, publishes informational books and booklets (Vilniaus…, 2010). The agency also carries out the surveys of the residents of Vilnius historic center and built heritage owners. The governmental institutions responsible for heritage preservation also make efforts to involve the society and stakeholders into heritage preservation processes. For example, the Department of Cultural Heritage under the Ministry of Culture organizes the events for the professionals and society and provides the comprehensive information on its' activities and achievements online (Kultūros..., 2010). However, the researches demonstrate that the society of the country do not tend to participate actively in the decision making processes. For example, J. Jakaitis (2005) notes that 82 percent of the surveyed individuals view negatively or with indifference the possibility to participate in the processes of territorial planning. According to the researchers, the reasons of this unwillingness to participate and the lack of initiative and responsibility may lie in the experience of the Soviet occupation (Berend, 2007), weak traditions of democracy, and weakly expressed sense of architectural aesthetics (Samalavičius, 2008, 2008a). A. Samalavičius (2008) strictly comments on this state of the society: "The silence of the society favorable for the further "urban surgery" demonstrates the certain shifts in our historical consciousness during the decades of the independence and the atrophying sense of the architectural aesthetics. Only the awakening of these understandings and connecting them to the aesthetic and economic interests would allow to preserve a part of the historical cityscape for the future generations, which, let's hope, will overcome the apathy, indifference, and cynicism. The apathy of the society lights a green light for the moral corruption of wide range."

Integrity and evolution of the historic environment. The restoration of the country's independence allowed rethinking the trends of architectural expression of the interventions in historic urban centers. The restitution of the private property does not allow further relying upon the complex regeneration of historic centers and fosters to search for new ways to preserve the integrity of the historic environment. Possibilities of information and experience exchange brought the architecture of postmodernism to Lithuania. This trend became very popular in 1990' and some of its' manifestations in architecture, especially in suburban houses, balance on the edge of kitsch. However, the practical experience has demonstrated that the postmodern architecture, encouraging using the historic buildings and environment as a source of inspiration and based on a symbolism and communication, can be very successful in the historic urban centers. Such architecture allowed finding the middle path between the imitations or anonymous neutral architecture and the radical modernism; it reflects the period of its' creation and preserves the identity and visual coherence of the historic environment at the same time. The dimension of the communication and symbols allows the direct interactions between the architecture and the society without the help of the architectural critics and creates a sense of the historic environment as an evolving integrity. E. Navickienė (2006) presents several successful examples of the postmodern architecture in the historic centers of Kaunas, Vilnius, and Klaipėda. R. Buivydas (2006) describes this trend of the interventions in the historic urban environment as "the reincarnation of the historic spirit". According to him, in this case a new complex architectural language seeks the organic links with the historical context; it is not aimed at recreating the signs of the past, but adapts the historical spirit of the context and the specific features of the structure of a certain place. The efforts to integrate the society into heritage preservation processes and the possibility of the architectural language local and universal at the same time allows expecting for the harmonious evolution of the physical historic environment and its' sociocultural content. The architectural interventions based on the principles of informativeness and continuity (Figure 5, c) and the viable public space (Figure 5, b) recently created in Kaunas historic center can be seen as the steps towards that.

DISCUSSION

The results of the research had confirmed all the hypothetical statements concerning the peculiarities of the interventions in historic urban centers during the Soviet period and after the restoration of the independence. The post-war reconstruction and modernization of historic centers took the same directions as in the Western European countries, however the political, ideological and economic reality determined several specific features: the complexity and large scale of the interventions (intentions to reconstruct the entire quarters), the absence of public participation or protests, the acceptance of the pseudo-historic aesthetics by the professional community. After the restoration of the independence, the situation in historic urban centers has radically changed: complex reconstruction became impossible because of the restitution of the private property; free market economy together with the Western lifestyles brought the trends of commercialization and gentrification to the historic neighborhoods of Lithuanian cities. However, the outcomes of these new processes, especially of commercialization, are aggravated by the passiveness of the post-communist society and the non-transparent activities of the developers and institutions. Meanwhile, the social dimension of city center revitalization and the

integrated efforts encompassing physical, social environment, and the economic viability are still very weak or even absent in the Lithuanian practice. The analysis allowed distinguishing the desirable directions of the interventions in and the social revitalization of Lithuanian historic urban centers:

1. The concept of complex regeneration which, became impossible after the restoration of the independence, should be re-oriented towards the concept of *integrated revitalization*, widespread in the Western European countries, which strives not only towards the large scale interventions, but also towards integrating physical, social, cultural, and economic dimensions of the urban center and linking the city center rehabilitation efforts with the sustainable development of the whole city.

2. *Multifunctionality and social diversity* were the historically inherent qualities of historic urban cores and suburbs. The negative outcomes of radical commercialization as well as of abandonment and social decay demonstrate that small and medium businesses and diverse social composition are favorable for the harmonious development of the historic urban environment.

3. The indecisiveness to participate in the decision-making processes concerning rehabilitation of historic urban centers, the lack of personal responsibility and initiative characteristic to the post-communist societies determine that *the public participation* should not be limited to the obligatory procedures, but must be extended to various informal discussions, focus groups, surveys and must be based on the principle that the decision-makers go to communities not vice versa. Only the benevolence of the private sector and institutions can create effective public-private partnerships.

4. The architectural expression of the interventions in the historic urban centers should be based on the principles of *informativeness, continuity,* and *evolution*: it should not mislead the spectator by imitating the historical aesthetics, but the historical context could serve as a source of inspiration. There cannot be a recipe for the good architecture, but high quality, the principles of sustainable construction and design, understanding the present needs and values of the society and respecting the past could be the guidelines; the trends of post-modern design hold the promise in this case.

CONCLUSIONS

1. In the context of contemporary processes of urban concentration, rural exodus, and the extension of the urban fabric, the historic urban centers of Lithuanian cities, some of them dating to the Middle Ages, still remain the important sociocultural and socioeconomic focal points and the generators of the image of the city. The radical ideological, political, cultural, and economic shifts of the 20th century determine the peculiarities of the rehabilitation and management of Lithuanian historic urban centers and justify the need of their comprehensive analysis from the architectural and social points of view.

2. The analysis of literature has demonstrated that the architectural and social dimensions of the city center reconstruction and rehabilitation were under consideration by Lithuanian theorists and practitioners during the Soviet period and after the restoration of the independence. The ideological climate and the economic conditions under the communist rule had determined that the main interests of the researchers were focused on the architectural dimension and on the discussions and recommendations on how the modern architectural interventions in the historic urban fabric should look like. After the restoration of the independence, the spectrum of the analyzed subjects and attitudes expressed has considerably widened and, instead of reserved recommendations, numerous critical analyses and radical innovative ideas had emerged. The range of the guidelines and recommendations, however, has narrowed and only several interesting visions of historic city center rehabilitation were presented.

3. The analysis of literature and observations on site allowed distinguishing the main social and architectural trends of city center reconstructions in Lithuania during the Soviet period and after the restoration of the independence. The spectrum of the character of architectural and urban interventions ranges from the radical large-scale interventions and contrasting modernist architecture to the historic reconstructions and pseudo-historic aesthetics. The postmodern architecture based on the principles of contextuality, communication, and symbolism can be mentioned as the positive trend in this context. The sociocultural and socioeconomic dimensions of city center reconstruction and rehabilitation can be described by the diverse and conflicting terms: the commercialization, gentrification, passiveness of communities and general public, and the first steps towards the public participation.

4. The results of the research allow making the presumption that the comprehensive rehabilitation of historic centers of Lithuanian cities can be achieved by the integrated management of their social, cultural, economic, and physical dimensions. The main objectives of such management should be the multifunctionality, social diversity, comprehensive involvement of the society and local communities in the revitalization processes, and the architectural and urban interventions based on the principles of informativeness, continuity, evolution, and visual integrity.

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Social-Spatial Code of Kaunas Downtown Area Within Complexity of Interactions

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Abstract. City is a complex open system. Understanding complexity of urban form and urban interactions plays a vital role in integration of urban environment and society. The impact of different land management regimes on social codes of existing urban structures is often not considered by the planners.
Lithuania in 20th century experienced the variety of political regimes with different land management policies and tools: Lithuanian Republic with private lend property until WW2, the Soviet regime with state land property and period of regained independence since 1990 and restitution of land property.
Kaunas downtown area represents a case of evolutionary urban development with formally respected spatial characteristics. Despite the mentioned architectural respect different land management regimes significantly changed social-spatial code of the area, e.g. changes of the symmetry of the urban system, its depth, fragmentization, integrity zones, etc. The article represents the first stage of investigation of changes of the social-spatial code of Kaunas downtown area comparing situation of 1937 and 1988. The theory of space syntax and the model of serial vision are used as theoretical and methodological background for investigation. Results of investigation demonstrate and help to understand complex interaction of land management and urban developments. They could be used for modeling of changing urban situation or making prognosis.

Keywords: urban social-spatial code, space syntax, urban complexity, Kaunas, Lithuania.

INTRODUCTION

Theory of cultural-historical psychology was developed by Michael Cole some years ago. Concept of cultural artifact (Cole, 1996) is one of the key ideas of the above mentioned theory. Cultural artifacts by being ideal and material at the same time form autonomous semantic system (Chandler, 2001) and as such represent some kind of containers of outer cultural-historical consciousness. Developing the above mentioned idea in the context of urban studies it could be stated that urban structure represents significant amount of cultural-historical artifact and as such should be treated as a complex autonomous system. Prove for this kind of treatment could be presented by the triple model of cityscape as an integral unity. According to the research conducted in DELFT (Tress, Tress, Harms, Smeets, 2004) the cityscape consist of the following autonomous but inseparable parts: matterscape, mentalscape and powerscape. Having in mid the social-cultural complexity of urban structure architects and urban planners should be aware of so called *butterfly affects* that could demonstrate themselves in the cityscapes. It means that even some "non architectural" actions can cause significant and consciously unplanned changes in cityscape structure, e.g. some land management tools that often are considered by the "pure" architects as factors of the second or third importance, can cause essential mutations in the cityscape. Such an essential mutation of urban structure could be presented by the changes in pattern language as it is understood in the works of Christopher Alexander (Alexander, Ishikawa, Silverstein, 1977) and Nikos A.Salingaros (Salingaros, 2006). If prove for such mutation could be found it would mean two interrelated things:

- Urban structure is created not only by the single acts of planners and architects. It is formed permanently by various actions and processes.
- Land management tools should be considered as important permanent formants of urban structure and architects should be aware of it.

The aim of presented here investigation was to prove the both of above mentioned statements.

URBAN SOCIAL-SPATIAL CODE AND METHODS FOR ITS INVESTIGATION

Nikos A.Salingaros has described two types of architectural language: language of forms and language of patterns (Salingaros, 2006). The first one is more evident and obvious for the observer but the second one is

essential for the all kinds of interactions between human beings and environments. When having in mind the complexity of both the cityscape and society-environment interactions the pattern language could be described as social-cultural code of the environment. This code, as a set of spatial-social rules, determines how we perceive the environment, how we act in the environment and where we act in it.

There are a lot of structural models of the cityscape but for the presented investigation the most complex two of them were used in the integrated manner: spatial syntax model by Bill Hillier (Hillier, Hanson, 2003) and model of the cityscape by Gordon Cullen (Cullen, 2009). The first one represents the most deeply modeled social-cultural features of the space such as depth and shallowness, integration and control, symmetry and asymmetry, unity and fragmentation, axiality and convexity. The second one is focused on the essential features of urban design and perception of urban spaces: serial vision, *hereness* and *thereness*, space and place, line of life, etc. Integrated together these two models will allow constructing full picture of urban social-spatial code and its rules.

INVESTIGATED AREA AND SOME PRINCIPLES

The next task is to find a proper urban area for investigation. The area should meet the following requirements:

- It should represent as long continuity of urban evolution in time as possible;
- It should be autonomous as urban unit;
- The investigated are should present through its history preserved stable architectural characteristics;
- The radical shift of land management regimes of the area without significant change of the architectural features should be present in the history of the investigated urban territory.

Kaunas downtown fulfills all of the mentioned above requirements. It consists of the Old Town that was established at the beginning of the 15th century and the New Town planned in the manner of the Classicism in the first half of the 19th century. Through all the ages of its existence this urban area demonstrates the evolutional development instead of revolutional one. Today the area is protected together with all of its essential architectural features as an object of cultural heritage. During the Soviet occupation the political system in Lithuania was radically changed. The same happened with land management. One of the fundamental changes that affected urban planning was cancellation of private land property and introduction of state land property as the only one that was allowed. In new urban development areas it allowed for relatively free operations with the land. Together with the ideas of modern city planning that came into force after Stalin's death in Soviet Union it created conditions for the revolution in urban planning, but in the territories of cultural heritage protection the former architectural features were more or less respected. Some minor changes at the level of single architectural objects took place in Kaunas downtown, e.g. location of building not along the historical red line, change of the height, etc. Nevertheless the main change was not the architectural but land managemental: all formal and informal boarders between land possessions inside old quarters were destroyed. Since 1990 the opposite process takes place: former property is restituted to the legal owners where it is possible to do that. Because of the geographical and urban situation Kaunas downtown could be treated as autonomous part of the city. Size of investigated area is around 500ha. It continues 5 km in Northwest-Southeast and 2 km in Northeast-Southwest directions.

There urban structure in two historical periods will be compared in the investigation of changes of the social-spatial code in Kaunas Downtown: pre-WW2 period and the end of the Soviet occupation. Theories of Bill Hillier and Gordo Cullen are used as the theoretical background for investigation. Basic information is collected form the historical maps form 1935 and Russian military maps form 1988. *Depthmap* software is used to perform some analysis of the investigated urban object. When comparing and modeling two periods the focus was made on changes influenced by the destruction of land property borders.

Some basic principles for interpretation of the topographical data were established at the beginning of the research because not all needed information was present on the used maps.

For 1935 maps: principle of the shortest way from entrance to convex space; property boarders were treated as real physical boarders; one property means one house and one entrance; houses aligned by the streets; etc.

For 1988 maps: principle of the shortest way from house entrance to convex space; principle of the nearest convex space for exit from a house; identification of a building as a house by address; physical boarders were considered only where they were shown on the maps; etc.

RESULTS OF INVESTIGATION

Changes in the system of convex spaces. Using Depthmap software depth of the system of convex spaces was analyzed from all the main entrance points to the investigated area: Savanoriu Street, Parodos Street, Train station, Vytauto Bridge, Vilijampoles Bridge and the line of life of the area – Laisves Avenue. In 1935 from the entrance at Vilijampoles bridge (Figure 1) the depth of the biggest part of convex spaces is around 4-6 steps; the highest depth from Vilijampoles bridge was calculated for the entrance area at the Train station – 11 steps.

Similar situation was observed from other entrance points. Results of the depth calculation from Laisves Avenue: depth of the biggest part of the New Town convex spaces is 2 steps; in the Old Towns the value goes up to 4-5 steps; only few spaces at the borders of the investigated area obtain the value of 6-7 steps and in few curved streets at the fairest corner of the area convex spaces have the depth of 11 steps. Situation in 1988 from Vilijampoles Bridge (Figure 1): bigger part in the convex spaces in the streets have the same value as in the year 1935 but the newly appeared potential public convex spaces inside the quarters have the depth value from 8 to 13 steps. Situation if looking from Laisves Avenue which preserved its function of the line of life in the period of Soviet Occupation (Figure 2): depth of the biggest part of the New Town streets/convex spaces is 2 steps; in the Old Town the value goes up to 4-5 steps; the newly created potential public convex spaces inside the quarters have the value of 6-10 steps just few meters from Laisves Avenue.

When calculating the *connectivity* (control) of the system of convex spaces the following results were obtained (Figure 3):

- In 1935 all spaces with the highest control value were concentrated on the axe of Laisves Avenue. The single dominant line of life was formed.
- In 1988 there is no single dominant line of life in Kaunas Downtown. Laisves Avenue as a complex of convex spaces preserved its importance, but the digital value of its spaces has decreased and in addition two new potential lines of life appeared: one to the north in the area of transformed Vienybes Square and at the riverfront of Nemunas. The last area pretends to the role of the new main line of life according to the digital connectivity (control) values.

Generally it could be stated that without radical changes of architectural-urban form and mainly just because of the changed land management forms the depth of the system of the convex spaces in the area was significantly increased and few competing lines of life appeared in the investigated territory.

Depths of single convex spaces. This value is calculated by the number of steps from exits of houses to the single nearest convex space. Earlier it was assumed that one land plot had one living house lined along the boarder of a street with direct exit to it in 1935. If this was true then it could be concluded that the major part of the convex spaces in 1935 were reachable from the nearest houses in one step. During the Soviet Occupation there a lot of living houses were built inside the quarters. Furthermore the living function moved from the streets to the inner of the quarters and not all quarters were made potentially available for the public transit. In both cases depth of a big part of the single convex spaces in Kaunas Downtown was increased up to 2-4 steps.

Changes in the system of axial lines. All possible axial lines were generated in Kaunas Downtown area and the significant change was noted: a lot of new potential axial lines appeared inside the transformed inner spaces of various quarters.

When *integration* of axial lines was calculated the following picture appeared (Figure 4): the main integrating axis during both compared periods remain the same and are concentrated around Laisves Avenue.

During the investigation the step depth from Laisves Avenue as the main line of life of the area during both periods was calculated. In 1935 the system is quite shallow: depth of the axis varies from 1 to 6 steps. In 1988 the depth of the system was increased up to 8 steps. It happened mainly because of the inner quarter spaces that were opened for potential transit. It is very important to note that the deepest axis appeared very close to the shallowest axe.

Speaking about the results of axial control analysis the following difference should be pointed out: in 1935 there was the only dominant axe with high enough control values in the investigated area and it was Laisves avenue; in 1988 there area already four axes with similarly high control values in Kaunas Downtown. The most important thing about these differences is that quit radical change from mono-axial to multi-axial system was achieved without introduction of new street.

Symmetry and asymmetry. Looking at the changes in the Elementary Formulae of the analyzed urban structure the following essential change could be observed with a naked eye: system became more asymmetric because more central place and block (estate) formulae could be observed in 1988 in addition to in 1935 already ring street. The new formulae represent asymmetric spatial relations.

Here and there. According to Gordon Cullen Serial Vision is a fundamental feature of any perceived cityscape. It means that spaces of the cityscape are perceived as constantly changed here and there locations. Two principle patterns of here and there relation are described: know here and unknown there; known here and known there. As in any city with a rectangular plan known hereness and known thereness dominates the cityscape. The same is true for both the Old town and the New Town of Kaunas in 1935. What have changed in 1988? Because of the transformation of formerly closed and segregated inners spaces of quarters into continued potentially public labyrinth like spatial structures the conditions of serial vision in the investigated area were altered. There appeared urban transit areas with spatial code that is completely different from the existing one: in addition to known hereness and known thereness the known hereness and unknown thereness was formed. As result of this transformation two essentially different urban layers of the downtown area appeared in the place where the only layer existed before.

Place and space. The concept of space and place is explored and used by a big number of researches: Gordon Cullen, Yi-Fu Tuan (Yi-Fu Tuan, 1977) and many others. If simplified the concept means that there are two types of location designed for two different fundamental activities in the cityscape: space for movement and place for stay. The first one is open for transit; the second one is closed and forms some kind of cozy secure nest for various social or individual, public or private activities. In its essence space can be only public, place could be either private or public. The various measures of urban design could be employed for creation of space and place and it can mean changes in urban spatial codes but the most important questions for the present research are following: do some places were transformed into spaces in 1988? Do some spaces were transformed into places? Earlier mentioned transformation of the interior of the quarters played a radical role here: when transit inside quarters appeared the private places were transformed into either public places or public spaces. Such transformation should be counted as quite radical change in the social-spatial code of the area.

The presented results of investigation do not reveal the all changes of social-spatial code or pattern of Kaunas Downtown and the investigation should be continued but even at this initially stage of research the preliminary conclusions could be made.

CONCLUSIONS

Research results demonstrate quite radical urban mutations and complexity of urban structure.

Changes in land management system and tools without any significant urban or architectural alterations have caused changes in social-spatial code of Kaunas Downtown area in 1935-1988. The following changes have been induced:

- Significantly increased depth of the system of convex spaces;
- Increased depth of single convex spaces;
- Increased depth of the system of axial spaces;
- Increased number of axial spaces;
- Generally all urban structure became more asymmetric;
- In addition to dominating in the area known here and known there code the known here and unknown there code was added;
- Big number of private spaces was transformed into public spaces and public spaces.

Results of the research that even “non architectural” aspects of urban design and planning could be very important and should be considered by the professionals.

Identified time and initial source of the changes draw attention to the fact that urban structure is or could be changed permanently because of its complexity. Single acts of planning are not the only starting points for significant urban changes (e.g. changes of the social-spatial code).

Figure 1. The step depth from Vilijampoles bridge: A – the system in 1935, B – the system in 1988

Figure 2. The step depth from Laisves Avenue: A – the system in 1935, B – the system in 1988

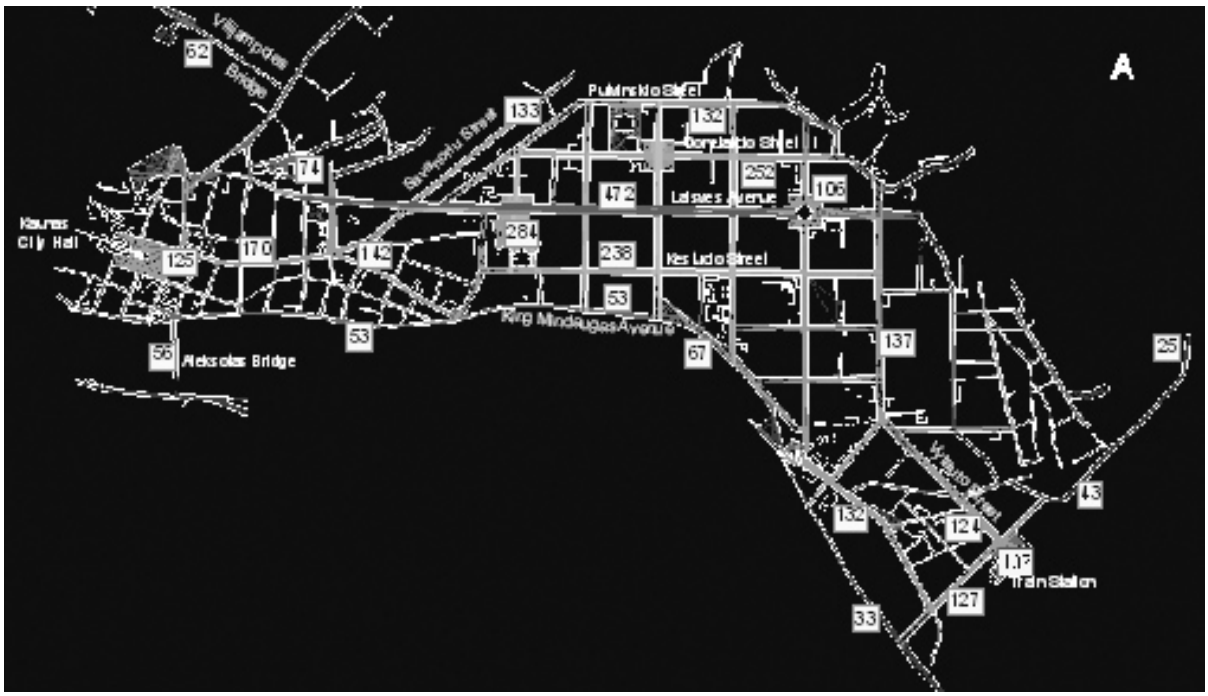

Figure 3. The connectivity (control) of the system: A – the system in 1935, B – the system in 1988

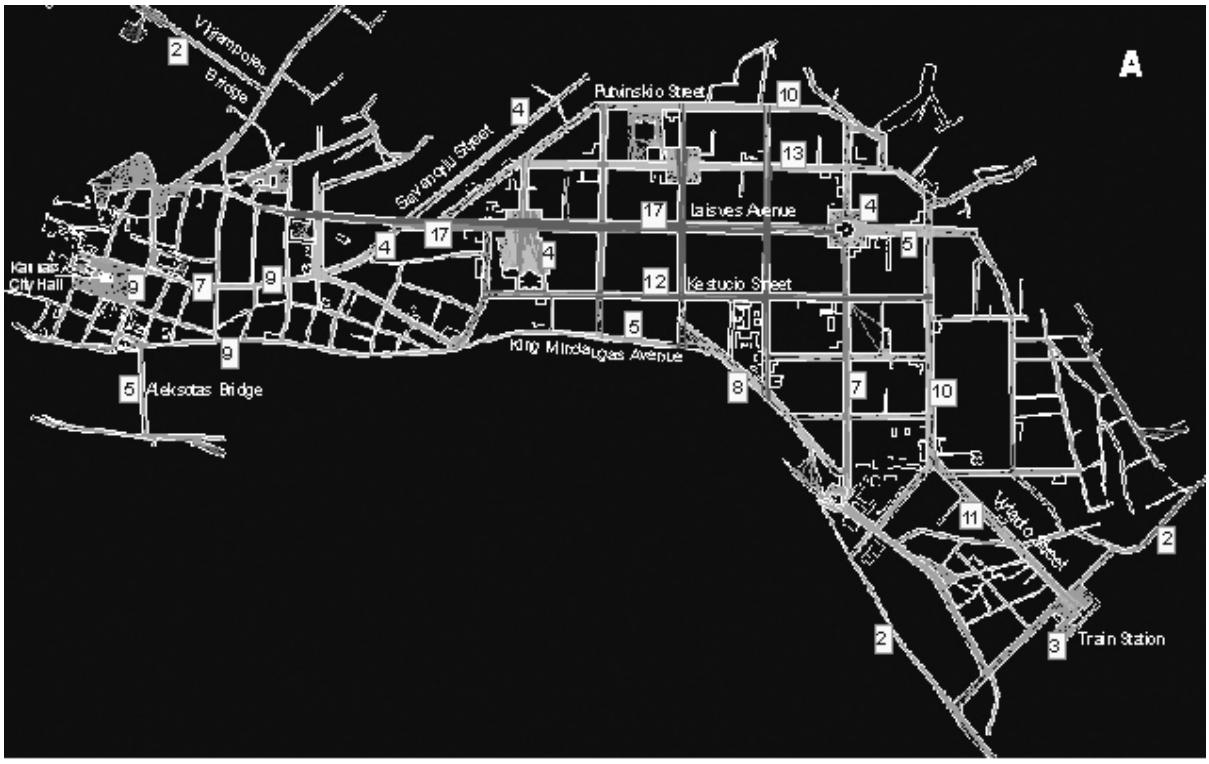

Figure 4. The integration of the system: A – the system in 1935, B – the system in 1988

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The Lost of Strength Resources on Exploitation of Steel Building Structures in Corrosive Environment

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Abstract. The nowadays application of game methods in theory and practice of building design, technology and exploitation there needs for data and characteristics to be related with long time strength resources, reliability and durability. They are actual for steel beams, columns, peeps as well as for their joints safety using or their strengthening means on further exploitation.
With this intense there were examined a data of corrosive destruction of steel elements into natural atmosphere of Lithuanian actual environment and in modeled conditions.

Keywords: building structures, steel, corrosion, liveliness.

INTRODUCTION

There are actual now for sustainable building (An agenda…, 2001) an application of new effective methods and means as a game theory, dynamic programming (Kvederytė *et al*. 2000, Kudzys and Juocevičius, 2005). It seems it can be helpful for modernization of the theory and practice to be used for design, technology and exploitation nowadays modern building structures.

Beside of other facts and problems there may by into account nowadays most corrodible surroundings to be related with exploitation of building structures (Šukytė *et al*. 2002, Liipa and Špakauskas, 2002, Kavolėlis and Bakutis, 2004, Karlson and Svenson, 1994).

Correspondingly for realization of these conceptions there are desirable a data about longevity of structural resources, reliability, durability and possible dispersion causality of characteristics, be related with corrosion of building structures and its components: bars, beams, columns, pipes, tubes etc as well as their joints subjected to corrosion (Keras *et al*. 2005; Keras and Mockiene, 2007; 2009).

METHODS

Inducement of following study and succession of the methodical intentions, points and measures leans upon a comparative analysis of before hand information. This information contains a data about formation, location and subversive chemical (electrochemical) activity of destructive dash, theirs interaction with steel components in building structures. It is characteristic to long time exploitation of structures in open air, livestock etc.

On methodical point of view this interaction is considered only as a generative of destructions into steel elements putting building structures. An attention to chemical or microphysical mechanisms of damages there is minimal. It is not a determinant directly decide a macro characteristics, liveliness, reliability or durability of building structures.

As a goal – objects for a following study and basis of methodical outline there are prevised an items:

- photofixation of damaged surfaces for statistical lot of data and revealing of characteristic damages on structural elements forming a steel pylons-supports for electricity transmission lines, musts etc at previous coated by painting after a long time exploitation (Figure 1).
- Discussions on after-effects generated by those damages as a submicro-and microconcentrators of stresses and strains.
- Study of alterations in following behaviour of damaged structure in whole by using an imitation modeling and estimations on computer.

Carry out of any physical (mechanical) experiments with structures based on general destination or special assignment there are not prevised. Foreseen there a photofixation of factual results after long time exploitation

on elements of structures can be appreciated as a passive experiment. All the same results of this passive experiment is mostly close to factual (tipical) situation and – practicable.

Material of observed elements with considered damages is characteristic steel CT 3.

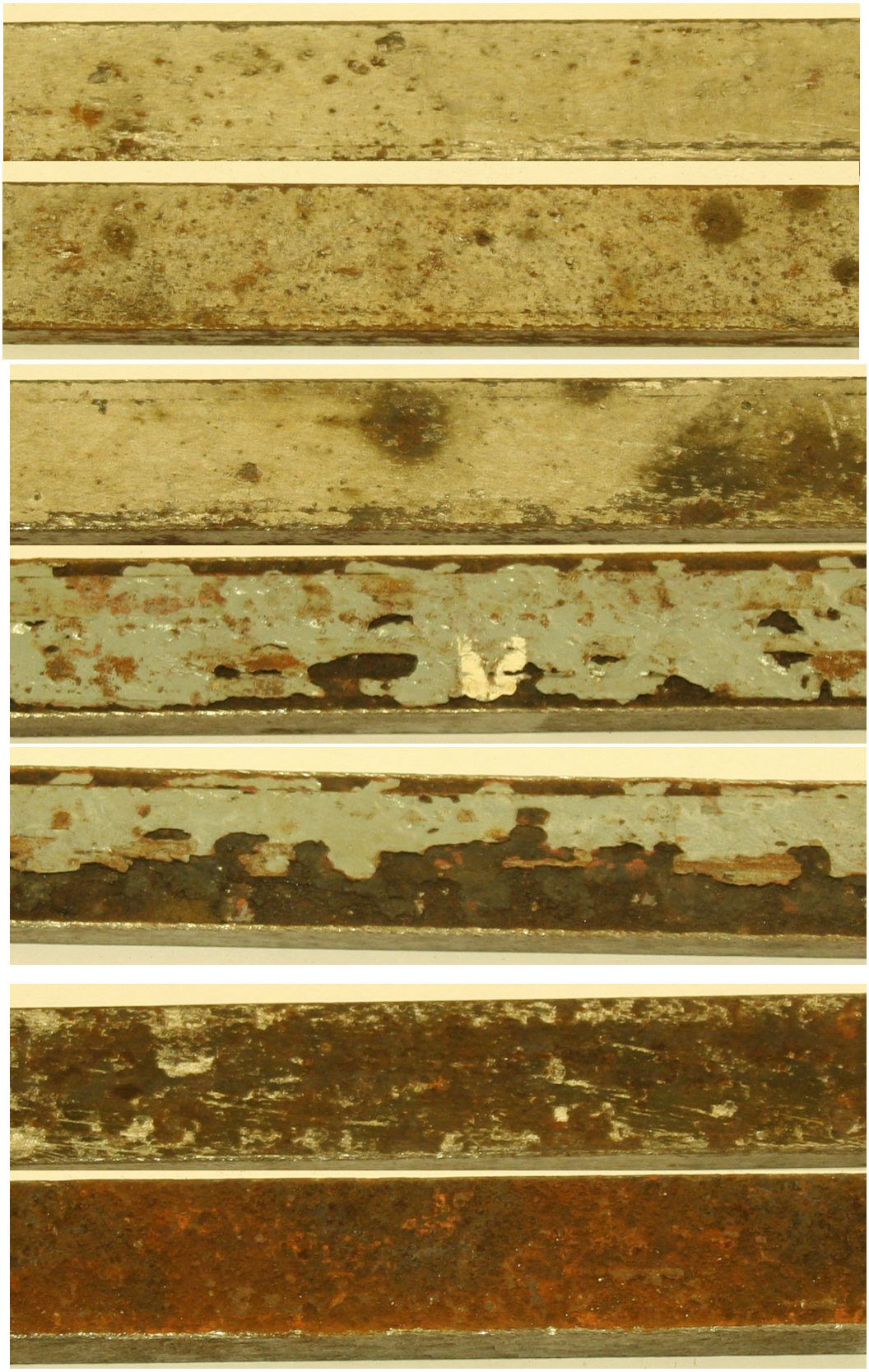

Figure 1. Photofixation of damaged surfaces

A sequel of chemical dissociation and microphysical disintegration – forms of rudimental damages – there also are considered as an initial basic determinant for a more peril secondary destruction. So, it is meaningful to fix, group and estimate as it possible an elementary forms of damages from position of building structure mechanics and when it is desirable – macro fracture mechanics in relation with distribution of macro stress and strains. Correspondingly an after effect of corrodive damages – submicro and macro concentrations of stress and strains is purposeful to accept into consideration at first.

Ordinary various forms of corrosive damages in steel inevitable turn up at spells between adjacent technical service instants prevised for theirs removing.

Usually it is a pointing type corrosion damages at first. It forming an inevitable from mycron to millimeter level of damages. Mostly perilous they evoluted to wedge shaped rust ravice and to secondary undersurface form of corrosion – most dangerous form for a liveliness of steel structural elements.

After that, with account of corrodive damages and theirs after – effects are elaborated an imitative models for musts (cantilever trusses) subjected to long time corrodive destruction. Sense of imitational modeling is provoked, by questionable part of stock coefficients γ. From a methodical point there is possible to study an actual variations of structure behaviour when any damages or after effects are happen. Basic foreseeing and line up of imitative modeling is to allocate possible damages or theirs combinations characteristic to any elements of building structure exploit some time and to evaluate his behaviour. So, methodical point there can be generalized into thesis "what can be happen when happen".

Forms of corrosion may be appreciated with respect to sustainable building theory and practice

Among the big number of corrosion forms to be happen in practice there can be selected ones characteristic to building structures, sets or knots. They are presented in Figure 2.

The variety of corrosion forms may be studied in connection with strength of building structures and peculiarities of their exploitation. In general outline there are significant for strength of structural elements a twelve forms of ordinary natural corrosion and some phenomenons of electrochemical corrosion. These forms are presented on Figure 1.

Amongst natural premises of corrosion extand in whole as a characteristic to liveliness or deterioriation of contemporary building steel structures can be pointed out chemical, electromagnetic and microbiological factors stimulating a corrodive destruction of steel. Natural corrosion is related with interactions amongst elements of atmosphere or water without any aggressive pollution premises or other factors stimulating a corrodive destruction of steel and elements of metal. However an intensive technical progress generate an aggressive agents of pollution in atmosphere of buildings: biological, chemical, electromagnetical genuine. Especially it is urgent to nowadays radio- and telemasts, supports for elektronetwors of high voltage, large livestock farms, bridges, industrial objects with chemical technology of production.

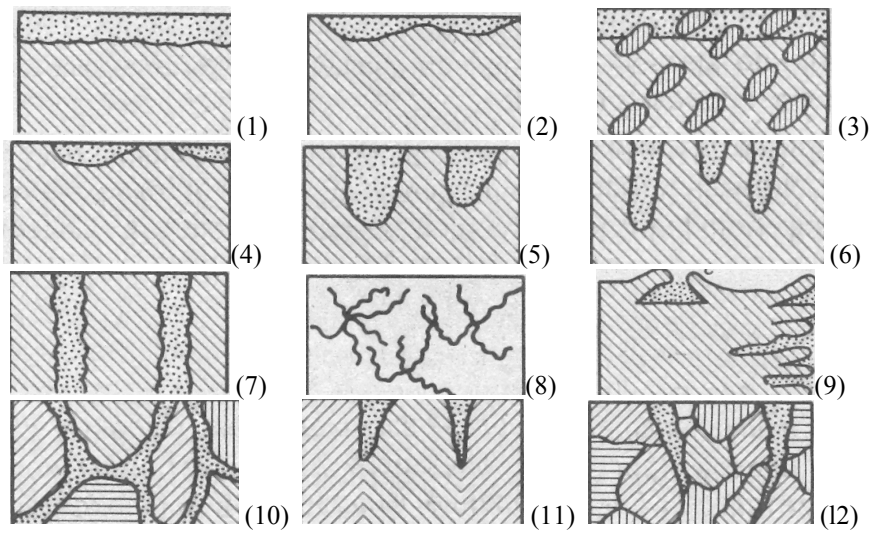

Figure 2. Corrosion forms

1 - relatively even distribution of damages; 2 - irregular form of corrodive destruction; 3 - point type corrodes; 4 - blot type corrodes; 5 - crater type; 6 - pitting corrodes; 7 - through type; 8 - thread cracking type; 9 - corrodes under surface; 10 - crystals corrodes along edges of crystals; 11 - perilous a wedge form of corrosion; 12 - transcrystalitic corrodes

These factors generate a specifical chemical, physic-chemical, electrochemical, biochemical forms of steel corrosion.

At the same time there also exists some visible corrosion forms characteristic to materials or protective coatings on metal shape of building structures. Forms of corrodive damages interesting for design of building structures and for sustainable building in whole can be described according to specific nature of damages are observed onto body.

There can be fixed at first an ordinary form of corrosion with relatively even distribution of damages (Figure 2, (1)). It can to be generated by relatively homogeneous corrosive environment onto steel surfaces without of anticorrosive protection. In the majority of cases analogous there can be a final surface of structural element after natural evolution of long time process enveloping a sequence point-pitting-irregular corrosion. It is possible there can be observed some intermediate elements of metal destruction by corrosion.

Irregular form of corrodive destructions (Figure 2, (2)) is practically most spread one. It can be detected on building elements with anticorrodive protection of surface as well as without of any protection. It can be expound by some initial varieties and irregularities characteristic to materials, used for structural elements, protective coatings, and surrounding in practice.

Practically anyone protection is not ideally complete and entire. Also a corrodive surroundings or environment is not quite homogeneous and did not ensured an uniformity of corrosive coercion. The latest contains a various microconcentrations of coercion agents and these local cloudlets. Owing to local irregularities of corroded material (protection layer) and local cloudlets of corrodive agents irregularity of corrosion is consecutive order of corrosion process in metal structures of building. Generally an initially coercion can be realized by forming of coercive drops or any other forms of condensation.

So, there may be underlined: the dispersion of initial damages of corrosion in building structures is a process with probabilistic characteristics.

Accordingly to mentioned specific traits and aspects various selective forms of initial corrosion running is observed onto structural elements of buildings. Amongst these selective forms there can be fixed point type (Figure 2, (3)), pitting (Figure 2, (6)), blot type (Figure 2, (4)), crater type (Figure 2, (5)), through type (Figure 2, (7)) of corrosion. Also point type corrosion can to evaluate there to thread cracking type (Figure 2, (8)), transcrystalitic (Figure 2, (12)) or to damages along edges of crystals (Figure 2, (10)). Quite perilous is an ordinary invisible form corrodes under surface (Figure 2, (9)). This phenomena starts from pointing damage and evolute under protective coating or sometimes extends into depth layers of steel. Products of steel corrosion obtain a largest volume then an adequate initial volume of material. Consequently a significant zone of steel around undersurface corrosion focus is spontaneously torn up. It is quite complicated mater to foreseen and to prevent this after effect timely.

Also there is perilous a wedge form of corrosion (Figure 2, (11)). The top of such corrosion wedge ordinary is sharp and is able to generate cracks.

The formation and development of the presented nature variations of corrosion processes lying from structure of material, chemical composition of material to be corroded, as well as a chemical content of surroundings. The all presented forms can be found out when corrosion of the steel building structures is examined. There are probable the forms 3-6 in most cases can be developed initially into small-grained metals. The forms 10-12 are most characteristic for coarse-grained and for crystallized structures. Consequently 9-th form is most frequent case for metal elements with various coatings of surface as a stain, plate with nickel etc. The damages of certain area of the structural element raise a concentration of stress and strains into surroundings of corrosive defects. Area of such concentration is a largest then area of corrosive defect directly. The fact of the stress and strains concentration negatively adverse onto strength and deformation of element in whole. Expecially it affects on strength of quasibritle materials as a contemporary high strength and thin sheet metal structures.

After effects of corrosion on loses of strength resources and liveliness of steel structures

Studies carried out into Kaunas University of technology reveals the some aspects urgent to design of structures related with steel corrosion in structural elements. One of the topic aspects is hardness and brittleness of structural steel. It can be generated by loses of plasticity and strength of steel structures under deformation in corroded layers of material. These effects can be generated by various displays of corrosion. At first it can be generated when atoms from petroleum products or any other sulphuretted hydrogen sources or any dampness polluted by these products etc are in tight interaction with metal surface.

The serious factor for after effect of brittleness is a concentration of stress and strain around various damages of corrosion. There can be observed a Fridmans studied effect of hardness in superficial layer of structural element. Also there can be observed premises for a formation of Griffith defects. It is most probably when wedge or thread type corrosion are generate.

Concentration of stresses and strains stimulate corrosion again. There is generated an interrelation by means of direct and indirect dependence corrosion –strains into corroded element of structure.

A significant concentration and micro concentrations of stresses and strains leads to following mechanical brittle cracking. Cracking can stimulate a following corrosion. In any cases there can be fixed an effects alike to Rebinder phenomenon in some respects.

Studies disclose a secondary after effects, related with interaction of chemical, physical and mechanical (phenomenological) processes. The secondary effects of corrosion are generated at first by spreading of initial corrodive damages. In the beginning there can be observed a micro cracking generated by joining of initial damages and formation of microcracks amongst them. Time to time they can turn into macrocracks (Figure 3). These processes a directly related with an intensification of stress concentrations and microconcetrations. Finally it leading to the significant loses of initial resources of fenomenomenological strength of material (Keras and Mockiene, 2007).

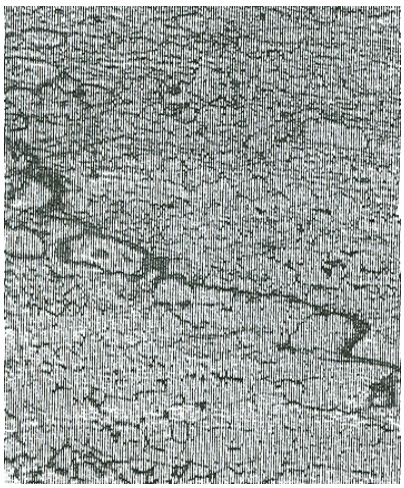

Figure 3. Damage aggregation process. The view of slow, monotonous disintegration of a welded seam (as a result of the common corrosion and wind pulsatile impact)

Imitation of structural compositions destructive process

Under the conditions of enlarging modern communication means, systems and their application space, the need for high-rise engineering structures (masts, towers etc) continuously increases. Traditionally the construction of such structures is designed with regard to many independent factors: purpose, dislocation place, climate, technology, resources etc. Often these factors are contradicting each other. The quite significant problems for a masts designer there are also corrosion resistance, long time viability resources, stress–strain distributions into guys, lattice of structure or foundations of the masts.

The investigations into the situations of service, accidents etc of such a kind of structures allow to reason that in the theory and practice of developing high-rise structures there exist important, but still unsolved theoretical and practical problems. For instance, the fact should be kept in mind that when designing high-rise structures not enough attention is paid to their service conditions and possible changes in apriori choosen calculation schemes as well as to the resulting processes connected with atmospheric pollution, humidity, electric discharges etc. In case of high-rise engineering structures, the impact of chemical, electromagnetic and other kinds of pollution may even be more dangerous in comparison with the dwelling and public houses.

It is most likely that in Lithuanian geographical situation the pollution flows (aggressive clouds) effecting high-rise structures may come form different localities (Šukyte *et al.*2002). For instance:

- By prevailing south-west winds in a fraction of a year these clouds reach Lithuania from European industrial regions and Konigsberg (Kaliningrad) district.
- The prevailing in winter winds of northern-eastern direction carry pollutants from Belorussian and Russian industrial regions and some military objects.
- Different winds and local atmospheric whirlwinds bring local pollutants and in Latvia produced ones. Especially harmful are chemically aggressive pollutants from the largest operating pollution sources (Kėdainiai, Jonava, Elektrėnai, Mažeikiai, Naujoji Akmenė and similar objects).

The possibility of different premature damage of the mast structural elements is evaluated by probabilistic parameters. The probability of dangerous coincidences (and consequences) is difficult to forecast in a general case. Therefore a large family (virtual multidimensional space) of potential destruction variants may develop. Sometimes it is called cursed Bellmann multi-dimensionality. However, by applying a systematic view and

operational planning methods, by combining in complex with energetic conditions and criteria, the technology of immitational modelling of damage sequence becomes considerably simple. It becomes possible and useful to reconstruct and forecast different possible situations, based on the principle "what would happen, if something" and using immitational modelling. Some of these procedures are not complicated in a computer variant. Their results are conveniently shown by strain-disintegration graphs (Keras *et al*. 2005).

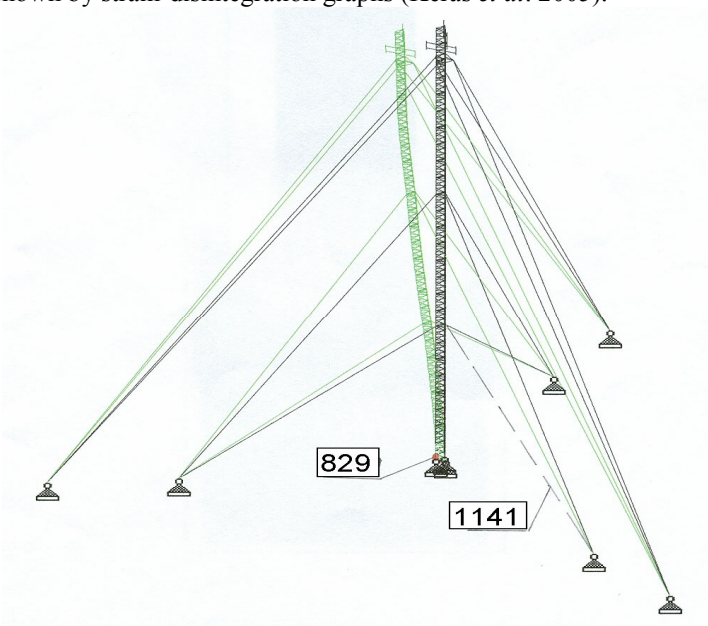

Figure 4. Mast displacements when the guy 1141 does not operate

As example of immitational modelling results, is examined some episodes of 78 m height mast (with three-level guys and cross-sectional lattice) deformation and disintegration operations. In this case, the distribution of the mast element stresses by relieving its guys is studied. Having stopped the first level guy 1141 working normally, the largest stress at beginning in the element 876 is found in the element 829 (Figure 4). Its magnitude is by 209,4 kN larger than 173,6 kN (element bearing capacity). Thus, the first limit state in the bar is considerably exceeded. However, the mast displacements satisfy the second limit state criteria: 50,7 cm less than l/100 = 7800/100 = 78 cm.

When the first level guy 1141 is released by 35 %, its initial tension diminishes from 6 kN to 3,9 kN, its stresses from 67,07 to 43,59 MPa. At this time the mast element 876 subjected to the largest stress practically fully applies the bearing capacity resources. Therefore, a larger than 35 % of the above-mentioned guy release is dangerous in respect of the mast viability.

Figure 5. Initial corrodive damages of mast elements

CONCLUSIONS

The protective coatings of structures are not quite reliable guaranty of theirs safety into nowaday corodive surroundings. Initialy pointing, then undersurface, pitting, blot, further undersurface, wedge type or other after forms of corrosion there are generated a serious weakeness of structures.

Corrosion is not a force majore for losses of strength resourses as a overloadings by snow, wind etc. But an accumulations of corrodive defects at time can be most perrilous than short time overloadings.

Immitative modeling disclose: a concentrations of stresses and strains around corodive damages of steel stimulte a secondary effects as a Griffith cracking, microprocesses like a Rebinder effect and consequently brittleness of deformation character, weakening of metal structures, losses of strength resources and bearing capacity of structures.

On the basis of quasi-brittle material theory with help of modern computer programs stagies of deformations precritical failure and following losses of structure can be modeled.

For perfection of the limit state theory related with design of buildings it is purposefull to do some corrections into basic methodical provisions. There are a number of structural materials and stress-strain situations when for description (or simulation) of deformation – failure process may be used a provisions of quasi-brittle solid instead to elasto-plastic solid theory. Corrosion of steel structures, elements and joints is a factor of these brittleness development.

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On Some Causes of Wooden Structures' Damage with Cracks and Evaluation of Their Technical State

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Abstract: The article describes major causes of cracks formation in wooden structures and evaluation methods of wooden structures bearing capacity with damages in the form of cracks, based on principles of fracture mechanics. Criteria dependence of wood fracture in the presence of cracks under combined loading is revealed. Dependence of wood fracture toughness on its density and thickness of element is also shown. All described dependences are received experimentally by the author.

Keywords: Wooden structures, wood fracture toughness, coefficients of stress intensity, bearing capacity.

INTRODUCTION

Durability of wooden structures depends on quality of design, manufacturing conditions, transportation, erection and maintenance. Violation of normative documents' requirements at any of stages, as well as imperfection thereof, lead to formation and development of structures' damages in the course of maintenance. All these stages are of particular importance for glued wooden structures for which sizeable cross-sectional dimensions are typical.

It's common knowledge that depending on category of defects wooden structures under maintenance can be divided into three groups:

– group of emergency and pre-emergency structures having damages and defects of the first category that reduce strength of wooden elements, units, joints and structure bearing capacity in general, which can result in fracture and be the cause of accident;

– group of structures under observation, that requires continual monitoring and has defects of group two, i.e., partial loosening of wooden elements, units and joints, which within given maintenance interval didn't reduce strength and stability of structure as a whole, but with time may lead to reduction of their bearing capacity and be the cause of fracture;

– group of defect-free structures having no defects and being in satisfactory condition.

In the course of maintenance wooden structures endure both physical and moral (functional) wear. The physical wear of wooden structures is the major reason for rehabilitation and is the aftermath of physical, chemical and biological influences. Damages of wooden structures occurring in the course of maintenance by the form of manifestations can be divided into visible and cover-up ones. Visible damages include sags, twisting, longitudinal bend, broken or damaged elements, dote, insects affects, corrosion of steel elements, loosening of bolted joints, mechanical damages, cracks. Cover-up damages include wood damage due to chemical influence, age of wood, internal cracks, cover-up dote, cover-up insects affect, corrosion of joint elements in zones inaccessible for examination, structure fatigue due to vibration loads.

Works of Y.M. Ivanov, E.N. Kvasnikov, E.N. Serov, R.B. Orlovich, S.B. Turkovsky, A.S. Freydin and many other scientists deal with study of the state of wooden structures in the course of maintenance.

RESULTS

Most typical damages of wooden structures are surface and through-depth cracks, testified by results of studying a wide range of projects made by the author himself/herself and other experts (Figures 1-3).

The causes for cracks occurrence are far from comprehensive account of wood properties as anisotropic material in design of pin joints, availability of natural flaws and concentration of strains in joint couplings, disturbances related to temperature and humidity conditions of maintenance and erection, imperfection of calculated prerequisites in evaluation of bearing capacity of wooden structures' elements under conditions of complicated non-uniform strained state.

Owing to the fact that wood is non-uniform anisotropic material with poor resistance to shear along and extension across fibres, difficulties in design are mostly related to transfer of forces in joint couplings. Here the major concentration of stresses takes place, resulting with time in formation of cracks along fibres and fracture of an element or structure as a whole.

Figure 1. Cracks in arcs with 49 m long spans

Figure 2. Through-thickness crack in support girder element

Figure 3. Surface cracks in girder elements

Most crucial technological factors affecting durability of glued wooden structures, are pressing modes, opening and closing of conditioning, as well as physical and structural parameters of wood supplied for gluing: humidity, internal stresses, warpage, length of growth rings. Violation of the technological mode most often leads to lamination of boards and fracture of toothed glued joints.

The principal technological techniques aiming at reduction of cracking in Glued Wood Structures (GWS) are replacement of traditional continuous-across-section-width layers for composite elements, or arrangement of metal or fibreglass plastic reinforcing bars across wood fibres. Regardless of obvious advantages composite layers didn't find widespread application in manufacture of wooden structures due to high labour and material consumption.

Practice of wooden structures maintenance shows that in number of cases their fracture starts with cracking of end face sections, where wood is most prone to humidification. In works it was shown that as a result of force and temperature-humidity influence in wood of support and ridge arc elements extended-across-fibres and chipping stresses occur, leading to cracks formation (Orlovich *et al*, 1980; Orlovich and Naichuck, 1981). It should also be mentioned that when extended across fibres wood is less durable than when stresses act along fibres. Besides, extended across fibres stresses in glued wood are also dangerous due to greater surface porosity of wood giving rise to ruptures along glued joints. According to Y.Ivanov and Y.Slavic it has no obvious adhesion nature, but is sequence of the relative reduction of long cohesion strength of glued interlayer (Ivanov and Slavic, 1987). Thus, during examination of three-joint arcs in several projects in support and ridge elements both surface and through-thickness cracks having length from several centimetres to several meters were detected. Long-term monitoring of such defects' behaviour showed the tendency towards development both along length of arcs and depth of cross section, and dependence on the type of stress state. Similar results were obtained when examining buildings and structures with metal-wood arcs of MWA types, bent and glued frames of BGF frames, frames having joints between post and crossbar of CD type and beams (Natakhin, 1981; Osvensky, 1979; Orlovich, 1980).

Cracking along wood fibers, in accordance with kinetic theory of strength, is the sequence of damages accumulation inside wood due to stresses resulting from non-stationary force and temperature-humidity influence. As this, cracking is often observed during initial years of wooden structures maintenance, which testifies to high degree of damaging during storage, transportation and erection. On the other hand it is also known that for certain geometrical cracks' parameters the structures do not reduce their bearing capacity and continue trouble-free work for the entire duration of established maintenance period. Due to this topical for practice is the task of determining critical dimensions of cracks when the structure doesn't meet requirements of extreme states, or visa versa – forecast of residual resource by known geometrical parameters of cracks. Solution of these tacks is only possible using apparatus of fracture mechanics accounting for wood anisotropy.

As cracks are widespread type of wooden structures elements' damage as a result of external and internal forces influence during maintenance, it is obvious that estimation of strength must also include ability of material to resist their propagation, in other words, characteristics of fracture toughness must be used.

As a result of experimental study of wooden beams with longitudinal shrinkage cracks on side surfaces made by E.N. Kvasnikov, it was found that their bearing capacity during spalling along the neutral layer reduced twice (Kvasnikov, 1972). To the same extend results of studies show, as well as occurrence of accidents of wooden structures due to cracks they contained (Naichuk, 2004). The issue of cracks influence on bearing capacity (for glued wooden structures in particular) is of principal importance, as during real-sized investigations of GWS one often faces dilemma of reinforcing or not reinforcing the structure. Monitoring cracks behaviour in three-joint arcs at a number of projects the author made during the last eight years showed, that cracks had tendency to develop both along length of arcs and across cross-section width, as well as intensification of deformations. After that these structures were reinforced.

The forecast of efficiency of wooden structures having cracks includes two inherently interrelated tasks: identification of causes giving rise to cracks occurrence, and development of procedures in order to reduce negative influence of cracks on bearing capacity and durability of wooden structures. Solution of the first task is complicated by the fact, that during examination we often don't really know the history of structure behaviour, including all stages during which damages in the form of cracks are formed. As is well known, these stages are manufacture (occurrence of technological stresses), transportation, storage, erection (influence of tough temperature-humidity environmental conditions), and maintenance proper (influence of load and temperature-humidity load operation mode inside building). Due to this most often the following task is set – evaluation of bearing capacity of wooden structures with cracks.

Bearing capacity of cracked wooden structures with can be estimated by mathematical simulation based on principles and approaches of fracture mechanics. Fully understanding approximation and known drawbacks of this method, the author considers it promising, in particular in evaluation of strength and durability of structures. Such simulation includes two independent tasks: determination of deflected mode (DM) of cracked structure; b) evaluation of cracked structure strength.

Determination of cracked structure DM presents no major problems when numerical method is used, method of finite elements in particular. Presently a great number of computer programs have been developed, that allow not only to determine cracked structures DM, but also such fracture parameters as stress intensity coefficients (SIC)) K_I and K_{II} towards crack summit. In accordance with studies (Naichuk, 2006; Naichuk and Zakharkevich, 2005) criterion dependence is used for estimation of bearing capacity of structures having damages in the form of cracks

$$K_I / K_{IC}^P + (K_{II} / K_{IIC}^P)^2 = 1, \tag{1}$$

where K_I and K_{II} – SIC reflecting geometrical shape of cracked structure and conditions for its loading; K_{IC}^P and K_{IIC}^P – calculated values of wood fracture toughness with normal transverse rupture and chipping along fibres, correspondingly.

Values of wood fracture toughness K_{IC}^P and K_{IIC}^P are determined by formulae

$$K_{IC}^P = 0{,}086\, m_{\rho I}\, m_{bI} \tag{2}$$

$$K_{IIC}^P = 0{,}604\, m_{\rho II} \tag{3}$$

where, for the case of normal rupture (tension across fibres)

$$m_{\rho I} = -0{,}4889 + 2{,}64558 \cdot 10^{-3} \rho + 6{,}64263 \cdot 10^{-7} \rho^2 \tag{3}$$

$$m_{bI} = 1{,}177869 - 0{,}006108 b + 0{,}0000415 b^2 \quad \text{at } 10 \le b \le 140 \tag{4}$$

for the case of transverse shear (chipping along fibres)

$$m_{\rho II} = -0{,}8907 + 0{,}0039 \rho \tag{5}$$

CONCLUSIONS

If we know crack depth and width, its place in structure, wood density, and also use appropriate program complex allowing determining SIC values in structure cracks summits and expressions (1-5), structure bearing capacity can be determined.

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Experimental Investigation of Bearing Capacity of Reinforced Concrete Non-pressure 2000 and 2400 mm Diameter Pipes for Deep Burial

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Abstract: This article describes results of experimental study of bearing capacity of reinforced concrete gravity flow pipes with 2000 and 2400 mm diameter and depth of burial 4-10 m. The pipes were trilinear load tested and their deflected mode after soil backfill studied. The study showed that results of pipes' load testing and data on deformation of pipe wall ring cross-section after backfill allow to determine actual values of loads acting on pipes and reveal their reserves in bearing capacity.

Keywords: reinforced concrete pipes, depth of burial, bearing capacity, experimental investigations, cross-section warping.

INTRODUCTION

The object of investigations is reinforced concrete gravity-flow pipes with 2000 and 2400 mm diameter designed for arrangement of deep-buried sewers.

The objective of investigations is development of new effective structures of non-pressure pipes 2000 and 2400 mm in diameter, providing required performance with depth of burial down to 10 m (above pipe top) without using cast-in-situ reinforced concrete collars.

Hypothesis. The bearing capacity of reinforced concrete gravity-flow pipes of specific diameter and bearing capacity group can be represented as graph P-Δ, characteristic points of which are established by results of load pipes bench testing,

where P – equivalent external vertical linear load on pipe;

Δ - warping (variation of vertical or horizontal dimension) of the pipe ring cross-section.

Objectives of investigations:

1. Determination of ratios (P-Δ) and characteristic points by results of pipes load bench tests.
2. Study of deflected modes after pipes layout and soil backfill and plotting of pipe ring cross-section warping versus depth of burial (H-Δ).
3. Analysis of experimental study results and plotting calculated ratios (P-Δ) for specific type of pipes, with indication of characteristic points (moment of cracks formation, values of normative and calculated load).

The study was made on full-size specimens of reinforced concrete non-pressure pipes 2000 and 2400 mm in diameter of group three, three-five in bearing capacity.

METHODS

Design solution of pipes

Lately in the Republic of Belarus and CIS reinforced concrete gravity flow pipes with diameter over 1600 mm have been manufactured using vibrocompaction method. Technical characteristics of pipes were set in State Standard ГОСТ 6482, the drawback of which was strict regulation of geometrical dimensions and parameters of reinforcing cage. Thus effective length of pipe 2000 mm in diameter with 130 mm thick walls amounted to 4.5 m. In order to limit the number of butt joints and due to high labour-intensiveness of butts' sealing process (joint packing), State Standard ГОСТ 6482 didn't provide for manufacture of pipes less than 3.5 m long. And production of special sealing collars in the USSR was not available.

Maximum burial depth (over pipe top) of pipes 2000 mm in diameter amounted to 4 m (group two in bearing capacity). For greater depth of burial the pipes were enclosed in cast-in-situ reinforced concrete shells of series 3.008.1-1 with pipe wrap from 180° to 360° , or cover-up methods of sewers construction were used (МОСИНЖПРОЕКТ, 1983).

In European countries reinforced concrete gravity flow pipes over 1500 mm in diameter are manufactured, as a rule, by vibrocompaction method; it is based on the use of rigid concrete mixes, allowing for “immediate” formwork’ removal, avoiding thermal humid treatment of articles. The length of these pipes (dictated by formwork removal) is 2-2.5 m. Special rubber collars are used for sealing pipes butt joints (Беккер and Гюнтер, 2005).

BelNIIS Institute has developed new designs of reinforced concrete gravity flow pipes 2000 and 2400 mm in diameter having five groups of bearing capacity and intended for burial depth down to 10 m. Design solutions of pipes were developed with regard to vibrocompaction manufacturing technology. Effective (with no account of socket) length of pipes is taken equal 2.5 m. Thickness of pipe walls varies according to diameter and group of bearing capacity. For pipes 2000 mm in diameter wall thickness is: 150 mm for round pipes of group 1-3 in bearing capacity, and 200 mm for pipes with bottom of group 3-5 in bearing capacity. Pipes with 2400 mm diameter are made with flat bottom of 3-5 group in bearing capacity and wall thickness of 250 mm. But joint of pipes is of spigot-and-faucet type sealed with circular rubber collar of “dovetail” type. Pipes are designed with flat bottom to be placed on soil bedding. The bottom also reinforces (at the expense of thickening) the pipe chute.

Pipe walls are reinforced with double cylindrical cages symmetrically positioned near external and external edge. Strength and crack resistance of pipes were calculated in accordance with Construction Norms of Belarus СНБ 5.03.01 similar to reinforced concrete bent elements in which limited (up to 0.3 mm) crack opening is allowed with the current normative values of external load (СНБ 5.03.01-02, 2003). Design grade of concrete – C 25/30. Schematic view of the pipe with bottom is shown in Figure 1.

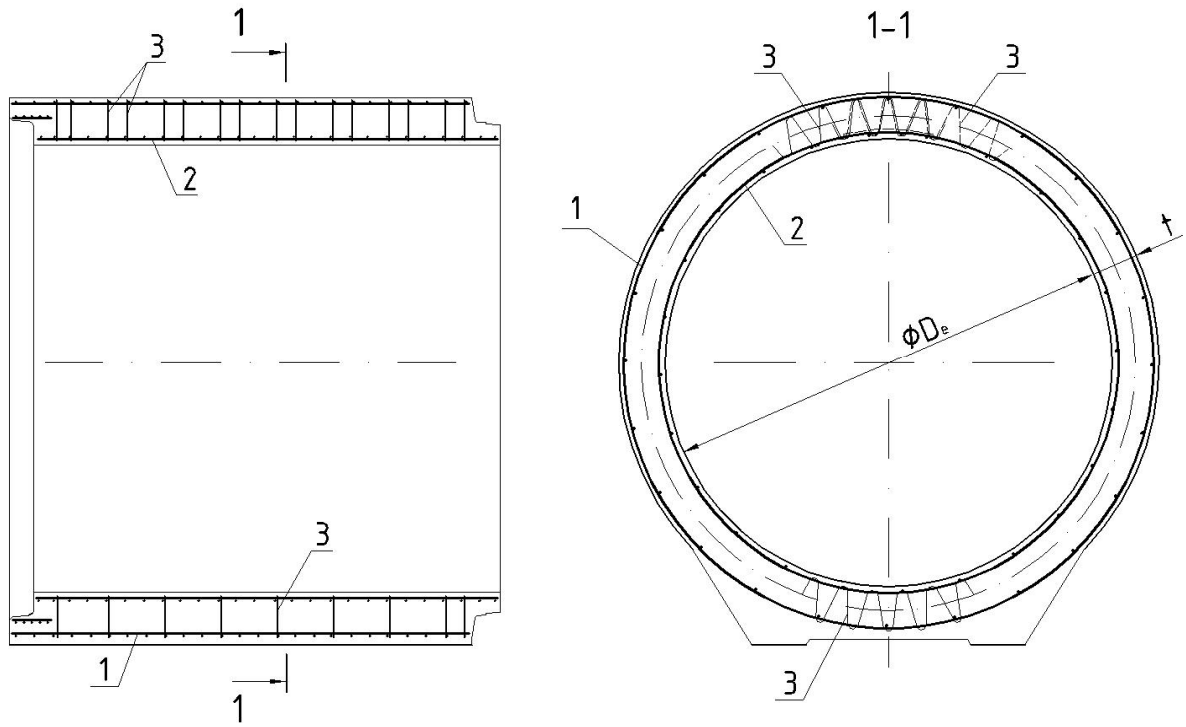

Figure 1. Design solution for deep-buried pipe: 1 – external cylindrical hull; 2 – internal cylindrical hull; 3 – “comb” reinforcing element

External load values are determined as per Instruction СН 000-75 for averaged placement conditions and higher degree of pockets’ soil compaction. Values of reference test loads are assigned with regard to directions of State Standard ГОСТ 8829 and safety factor C=1.4 (СНБ 5.03.01-02, 2003). General technical characteristics of pipes are given in Table 1.

Table 1. General technical characteristics of pipes

Grade of pipe	Thickness of pipe wall, mm	Parameters of reinforcement cages			Reference loads P, kN/m	
		∅ spirals, mm	spiral pitch, mm	mass of cages, kg	cracking	strength
ТБ200.25-1	150	8	90	164.7	54.5	96.9
ТБ200.25-2			60	240.2	72.8	142.6
ТБ200.25-3			40	389.5	94.6	185.4
ТБП200.25-3	200	10	85	296.2	114.5	208.2
ТБП200.25-4			65	381.9	147.5	268.2
ТБП200.25-5			50	484.7	181.8	330.6
ТБП240.25-3	250	10	85	398.3	158.0	287.2
ТБП240.25-4			65	498.8	204.5	371.9
ТБП240.25-5			50	590.3	252.8	459.6

Pipes 2000 mm in diameter of group three in bearing capacity (with 6 m deep burial) are designed in two versions: circular with wall thickness of 150 mm, and with bottom having wall thickness of 200 mm. The chute and arch of circular pipes are provided with additional reinforcing elements ("combs"). Circular pipes are 30% lighter of thick-walled ones, still due to high consumption of reinforcement bars and labour intensiveness (installation of combs) they are more expensive, and besides require accurate alignment of crown centres with the chute during laying, which is not always observed.

Manufacture of pipes has been mastered by Spetszhelezobeton RUE where moulding complex VARIANT from Pfeiffer company is used. Reinforcing cages are manufactured on cage-welding machine made by MBK company, Germany (Шепелевич and Басевич, 2007).

Load-testing of pipes.

Full-size specimens of pipes were tested for strength and crack-resistance under trilinear load according to method of Standard of Belarus СТБ 1163. At each stage of loading variations of vertical and horizontal diameters of pipes, as well as longitudinal and inclined width of cracks opening in the crown (most heavily loaded section) were measured. Overall view of testing site and nature of cracks formation in pipe crown are shown in Figures 2 and 3. Totally more than 10 full-size specimens were tested, including fragments (without socket), from group two to five in bearing capacity.

Figure 2. Load testing pipe of grade ТБП 200.25-5

Figure 3. Nature of cracks formation in the pipe crown

Pipes of grade ТБ200.25-2 and ТБ200.25.3 were first used in the construction of storm water sewers in the residential area Druzhba in the city of Minsk in the years 2007-2008. In so doing designers (including authors of the article) were monitoring the technical state of pipes after backfill. Degree of actual pipe loading was determined by measuring its horizontal diameter (using special hole gage with indicator attached to one of its ends), as well as availability and width of cracks opening in the crown.

RESULTS

Experimental investigations of horizontal diameter variation (variations of vertical diameter are close to those for horizontal ones) Δ, and maximum width of cracks opening *wk* in the crown of trial specimens of pipes of the second, third (thin and thick walls) and fifth group of bearing capacity (see Table 1) under influence of

evenly distributed vertical load P applied to the generatrix, are shown on Figures 4 and 5.

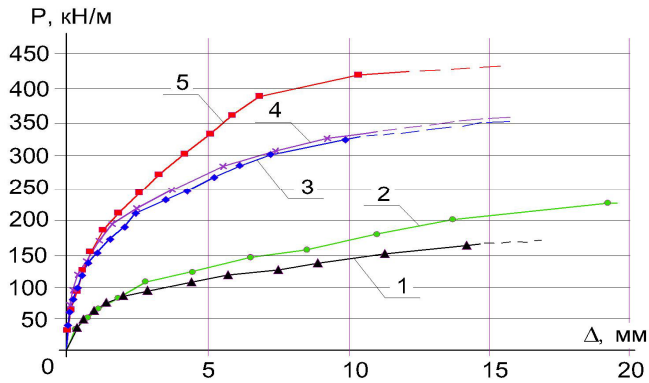

Figure 4. Graphic relationship (P-Δ) for pipes of grades:
1 - ТБ200.25-2, 2 - ТБ200.25-3, 3 - ТБП200.25-3, 4 - ТБП240.25-3, 5- ТБП200.25-5

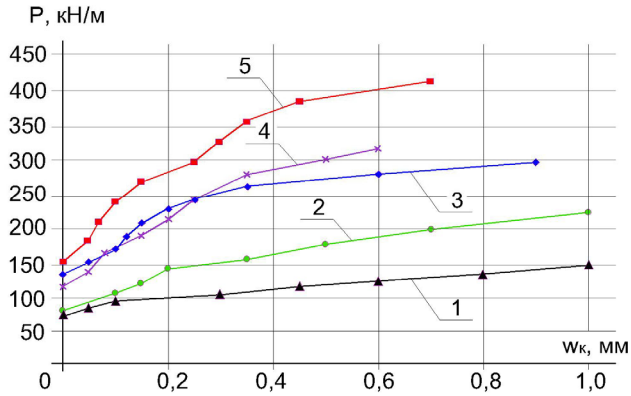

Figure 5. Graphic relationship (P-w_k) for pipes of grades:
1 - ТБ200.25-2, 2 - ТБ200.25-3, 3 - ТБП200.25-3, 4 - ТБП240.25-3, 5- ТБП200.25-5

Analysis of investigation results shows that during initial loading stages (before cracks are formed) variation (increase) of the horizontal diameter in circular (thin-walled) pipes from the second and third groups of bearing capacity, as well as in pipes with bottom (thick-walled) didn't essentially differ. Differences started to appear after cracks were formed. As the loads further increased, accelerated change of horizontal and vertical diameters, formation of new and widening of existing crown and chute cracks, as well as opening of cracks on the outside lateral surface of pipes were observed. The first cracks formation (in all pipes) was registered under loads exceeding design load for crack resistance, which is stipulated by high tensile strength of vibration compacted concrete (Шепелевич, 2009).

Exhaustion of bearing capacity of thin-walled circular pipes was characterized by their gradual "subsidence" after extreme load values were reached. This nature of deformation is stipulated by static indetermination of such structures (formation of plastic "gimbals" in the pipe crown and chute, and redistribution of bending moment to lateral facets).

The nature of thick-walled (with bottom) pipes essentially differs from that of thin-walled ones. The bending rigidity of crown wall in such pipes is ≈2 times higher than in thin-walled pipes. At the same time rigidity of chute wall (for account of the bottom) is noticeably higher than of the crown. Destruction of these pipes during tests occurs along the inclined crack passing across one of the support bar angles ≈ 45° to vertical line. At that this nature of destruction doesn't correspond to actual behaviour of structure in soil, and for pipes of fourth and fifth groups of bearing capacity to resist design loads additional reinforcing cages ("combs") must be provided for in this section.

Analysis of relationships given in figures 4 and 5 shows that deformation nature of pipes ТБП200.25-3 and ТБП240.25-3 (on plots - branches 3 and 4) practically doesn't differ. The reason is that relationship of wall thickness and mean radius in these pipes doesn't substantially differ.

At large the tests showed that structural behaviour of pipes sustains design loads, and pipes provided with bottom have additional reserves both in crack resistance and strength (see plots in Figures 4-5 and reference loads in Table 1).

As stated above, design calculations of pipes for strength and crack resistance are made accounting for averaged laying conditions. At that of great importance are not only grade of backfill soil, but also degree of its compaction in the pipe laying area ("pockets"). Practical experience shows that failure to meet requirements for degree of pockets' soil compaction (up to Ку≥0.95) can result in noticeable ring cross-section deformation and formation of cracks in the crown (and chute of thin-walled pipes) having width of opening over 1 mm. In other words, in crown and chute plastic gimbals are formed, and they indicate approach of external load to the limiting value.

Figure 6 shows graphic relationships (obtained through processing results of measurements of pipes after backfill) of horizontal diameter variation Δ and maximum width of cracks opening *wk* for various backfill height (H) for pipes of grade ТБ200.25-2 (applied for backfill height up to 4 m) and ТБ200.25.3 (applied for backfill height from 4 m and up to 7 m). The ordinate axis also shows calculated vertical (equivalent) linear load P. Similar graphic relationships for pipes of grades ТБП240.25-3 and ТБП240.25-4 are given in Figure 7. Analysis shows that obtained relationships are extrapolated to results of load testing trial pipes specimens (See plots in figures 4 and 5).

It should also be mentioned that during manufacture of pipes by vibration compaction method all pipes were produced using single vibration mandrel and in one and the same outside solid mould, i.e., they are "twins" (by geometrical dimensions). In other words, value of horizontal diameter variation and maximum width of cracks opening in the crown can serve as reference for external pipe load and reserve of its bearing capacity, if there are relevant relationships obtained by results of its load testing.

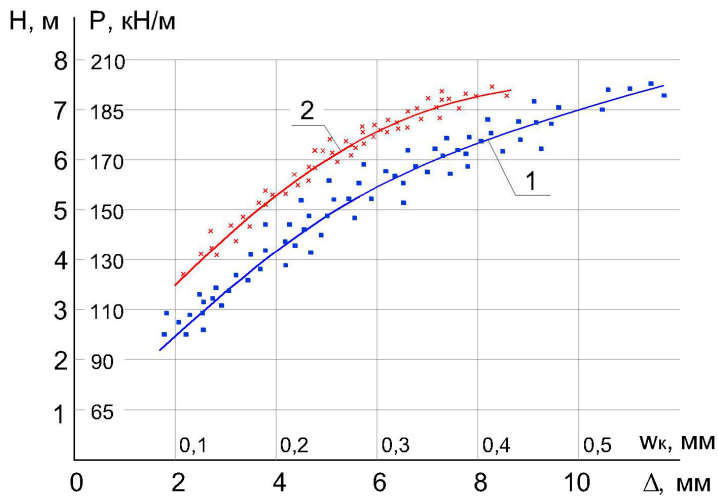

Figure 6. Graphic relationships of pipe horizontal diameter variation Δ - 1 and width of crack opening wk – 2 for pipes of grade ТБП200.25

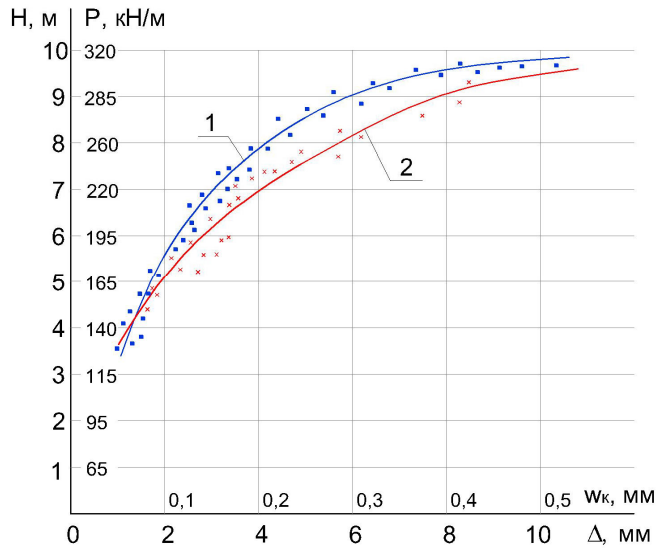

Figure 7. Graphic relationships of pipe horizontal diameter variation Δ - 1 and width of crack opening wk – 2 for pipes of grade ТБП240.25

CONCLUSIONS:

Results of experimental investigations allow drawing the following conclusions:

1. Results of pipes load bench tests and values of deformation of pipe wall ring cross-section under project construction conditions allow determining actual values of pipes external loads and obtain calculated relationships (P-Δ) with characteristic points in order to forecast pipe bearing capacity under operation conditions.

2. Technical characteristics of reinforced concrete gravity flow pipes 2000 and 2400 mm in diameter allow burying them to depth down to 10 m without additional reinforcement.

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Special Silicate Disperse Paints: Formulation, Production and Properties

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Abstract. The research examined changes of physical mechanical and maintenance properties of silicate disperse paints by way of changing the main components of the quantities and adding of hydrophobic additives.
It was found that addition 2% of the hydrophobic additives, such as emulsions of aminosiloxan, aminosilan or silicon resin, considerably improved the hydrophobic properties of silicate dispersion paint coatings. Furthermore, treating dry coating surface with liquid repellent increases the hydrophobic properties of coatings. Abrasive resistance of silicate dispersion coatings and the traction grows with increase of the amount of liquid glass, while wet scrub resistance of coatings can be improved by increasing the amount of polymer dispersions. However, adding more than 7% polymer dispersion significantly decreases the water vapour permeability of coating. The amount of liquid glass has no significant effect on coating characteristics of water vapour permeability.
On the basis of the results, special silicate dispersion paints were developed with an exceptionally high feature of high water resistance, high mechanical resistance, good cleanability, especially good water vapour permeability or cost-effectiveness. Also, the paper presents the testing results of physical and mechanical properties of industrially produced special silicate dispersion paints coatings.

Keywords: special paints, silicate paints, hydrophobic additives, water permeability, water vapour permeability, abrasive resistance

INTRODUCTION

Building facade thermal insulation systems have recently been widely used in construction in Lithuania. Special requirements are established for the finishing coatings of such systems: they have to be waterproof, resistant to atmospheric effects, chemically aggressive agents, bond well with the base and be highly permeable to water vapour and gas (Ramanauskas and Stankevičius, 2000). Such requirements are largely met by mineral silicate paint coats, but they are too permeable to water, are not elastic and strong enough (Miniotaitė and Stankevičius, 2001). In addition, once prepared for use, paints are unstable and have to be used up fast (Weinmann, 1986).

Liquid potassium glass modified with polymer dispersions and with additives added produces much more stable silicate/dispersive paint that can be stored for an extended period of time (Daunoravičius *et al.* 2008). However, universal paints of usually simplified formulation that are designed for common use fall short of meeting today's needs. Although general-purpose paints have quite good technical and decorative properties, such as colour, covering, normal drying time, their coatings usually do not have any exclusive properties, particularly higher waterproofness levels and increased permeability to water vapour. Other important physical mechanical and performance characteristics include resistance to wet scrubbing, friction, contamination, scratching, etc.

On the other hand, the technology of paint makes it very difficult or even impossible to produce a universal paint with very good technical and performance properties. While some properties are improved, others inevitably worsen. For instance, if decorative properties get better, the mechanical ones worsen, and improvement of waterproofness may lead to lower permeability to vapour, etc. (Margraf and Könner, 1998). Therefore, the main goal was to create paints with a certain well-defined special property, without making other indicators much worse. The main requirement of being environmentally friendly has to be in any case.

The previous thesis (Daunoravičius *et al.* 2009) set thresholds for the quantitative proportions of the main components of paint ensuring appropriate technological parameters of paint, stability of stored paint and the quality of the coat. In addition, it was presumed that if the quantities of individual components were modified within the established limits, the main technological properties of paint and the performance characteristics of its coat, such as permeability to water and vapour, mechanical strength of a dry and wet coat, the strength of its

adhesion to the base, could be changed significantly. Waterproofness can be boosted by the addition of various hydrophobic additives or their treatment with water-repelling liquids (Wagner, 1995).

This thesis is focused on correction of paint formulations within the set limits, selection and testing of hydrophobic additives to identify the effects of the quantity of the main components and the variety and quantity of additives on the properties of paint coats.

The purpose of the thesis is to create paints with different special properties by changing the quantities of the main components of universal silicate dispersion paints and using hydrophobic additives, and to carry out laboratory and production tests on the paints.

The tests performed correspond to global paint industry development tendencies, i.e. a decrease in the quantity of organic components, an increase in the quantity of non-organic substances and growth of the demand for special paints.

MATERIALS AND METHODS OF TESTING

To make the paint, we used industrial liquid potassium glass *Trasol KE-K* with a density of 1.24 g/cm^3 and a silicate module of 3.86. Such liquid glass was modified with styrene/acryl polymer dispersion *Finndisp A 11* with a particle size of 0.19 µm and a pH of 7.5–8.5, with the minimum film forming temperature being +14 ^{o}C and a non-volatile particle content of 48%.

The characteristics of non-organic pigments that are resistant to alkali and light are presented in Table 1, and those of the micro-fillings used are provided in Table 2.

Table 1. Pigments used in paint and their characteristics

Name	Chemical formulation	Colour	Average particle size, µm
Red iron oxide (hematite)	Fe_2O_3 (under 95 %)	Dark red	0.17
Yellow iron oxide	Fe_2O_3 (<84 %)	Yellow	0.7
Chromium oxide	Cr_2O_3	Green	0.30
Iron black (magnetite)	Fe_3O_4	Black	0.20
Titan white	TiO_2 (rutile)	White	0.10

Table 2. Micro-fillings and their characteristics

Micro-filling	Chemical formula	Particle shape	Average particle size, µm
Talcum	$3MgO{\cdot}4SiO_2{\cdot}H_2O$	Lamellar	10
Calcite	$CaCO_3$	Ball	6
Calcite	$CaCO_3$	Ball	10
Ground ceramics	Al, Si oxides	Ball	40
Chalk	$CaCO_3$	Ball	30

To prepare the paint, the following additives were used to ensure the right technological properties of the paint and technical characteristics of painting: liquid glass stabilisers, viscosity modifiers, thickening agents, dispergators, counter-foamers and emulsifiers. These additives were not tested and their quantities were chosen based on the manufacturers' recommendations.

The water vapour permeability of paint coatings was identified on the basis of LST EN ISO 7783-2:2002 using mortar board samples. 200 µm thick coatings formed on the boards were hardened for 14 days at a temperature of +21°C, ±2°C and relative air humidity of 60%, ±10%. Later, the samples were tightly attached to glasses with water. The glasses were placed into the test chamber with controlled temperature and humidity. At certain intervals, the sample glasses would be weighed to calculate the density of vapour passing through the paint coating according to LST EN ISO 7783-2.

The resistance of paint coatings to abrasion was identified on the basis of LST EN ISO 7784-2:2006 using a Taber device (Figure 1) and 10 mm concrete panel samples with paint coatings applied and hardened in the same manner.

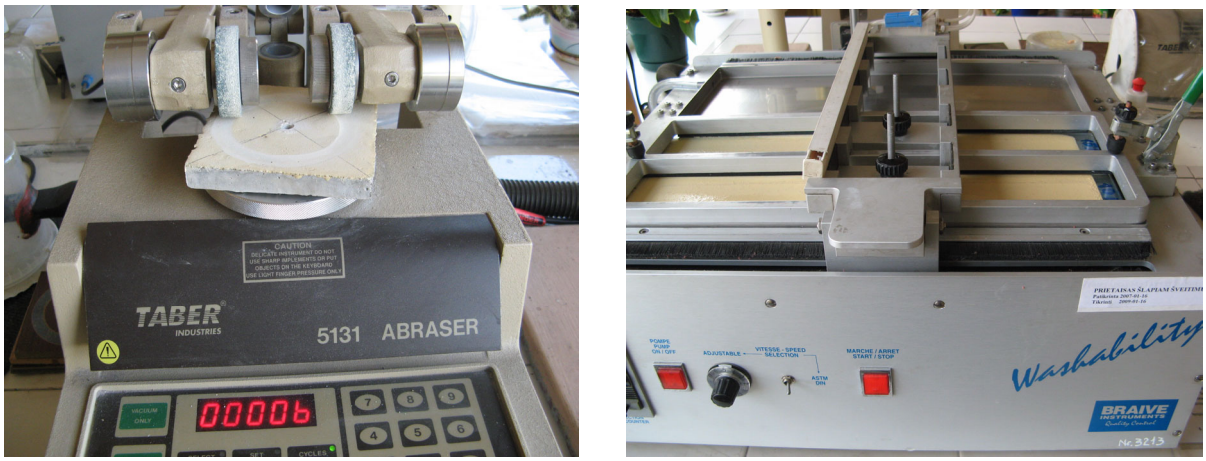

Figure1. Identifying paint coating resistance to abrasion using a Taber device on the left and establishing resistance of paint coating to wet scrubbing using a Braive Instruments device on the right

Coating resistance to wet scrubbing: 200 µm thick paint coatings were formed on window pane lamellas and then hardened for 14 days at a temperature of +21°C, ±2°C and relative air humidity of 60%, ±10%. After that, the coatings were tested using a Braive Instruments device (Figure 1) on the basis of the standard methodology as defined by LST EN ISO 11998:2006.

Water permeability was established on the basis of LST EN 1062-3:2008 using 3 cm thick 225 cm^2 standard concrete panels with 200 µm paint coatings formed on them, which were hardened for 14 days at a temperature of +21°C, ±2°C and relative air humidity of 60%, ±10%.

Strength of adhesion when tearing paint coatings off concrete panels was identified under LST EN 1504:2004 using a CONTROLS device 58-C0215/T. The test paint was applied on dry standard concrete panels in a 240 µm layer and then hardened for 14 days at a temperature of +21°C, ±2°C and relative air humidity of 60%, ±10%.

Resistance to atmospheric effects: coatings were artificially aged in a *QUV/ spray* machine with *UVA 340* bulbs. The test cycle consisted of 5 hours of irradiation and 12 minutes of watering. 200 µm thick paint coatings were formed on glass lamellas. The samples were inspected once every 20 cycles. Before an inspection, the coatings were washed using a soft sponge and warm water (water temperature would be below +30°C) and then left to dry. Inspections can usually identify the following defects in the coatings: peeling, cracking, gaps, bubbles, chalking, contamination and discolouration. Chalking is the emission of easily removable particles on the coating surface after one or several of its components, normally the binding agent, breaks down. Chalking products can be removed from the coating using a duct tape. Chalking products that stuck to the tape were checked against a contrast base. The level of chalking and other abrasions in the coating was assessed on the basis of the benchmark pictures and benchmark scales provided in LST EN ISO 4628.

RESULTS AND THEIR DISCUSSION

The quantities of the main paint components were selected based on the above (Weinmann, *1986*) assumptions of optimising silicate dispersion paints, i.e. by making the following quantitative proportions: a proportion of pigment and filling mass of 1:3.3, a total proportion of liquid glass and polymeric dispersion hard substance mass and the total filling and pigment mass of 1:3.5, a percentage ratio of the mass of fine (5 µm) to coarse (10 µm) fillings of 57:43.

The formulation of paint that matches the above ratios as well as the properties of the hardened coating is presented in Table 3.

This is a universal, quite cost-effective paint with good technological, technical and performance properties. However, it also has shortcoming, with high water permeability being the most important one.

Silicon organic compounds were used to make the paint hydrophobic. There are many types of silicon hydrophobic materials, depending on the length of alkyl groups adjoining the Si component. As shown by the data presented in Figure 2, the most effective paint additives are aminosilane and aminosiloxane emulsions as well as silicon resin emulsion. Hardened coatings can also be made hydrophobic by applying hydrophobic liquids on the outside. However, this method produces slightly inferior results.

Table 3. Test silicate dispersion paint formulation and the properties of the paint

Pant component	Quantity, % of mass	Coating properties
Water	20.5	Vapour permeability: 214 g/m^2 per day; Capillary water absorption: 1.59 kg/m^2 (per day); Resistance to wet scrubbing: 4,800 cycles; Resistance to abrasion: 29.8 mg/100 revs Strength of bond with concrete: 2.4 MPa Chalking grade: 2
Liquid glass	28	
Polymeric dispersion *Finndisp A 11*	6	
Carbonate filling, 5 µm	16	
Carbonate filling, 10 µm	12	
Talcum	5	
TiO_2	10	
Dispergator	0.3	
Stabiliser 1	0.2	
Stabiliser 2	0.1	
Thickening agent	0.1	
Anti-foamer	0.3	
Emulsifier	1.0	
Viscosity modifier	0.5	

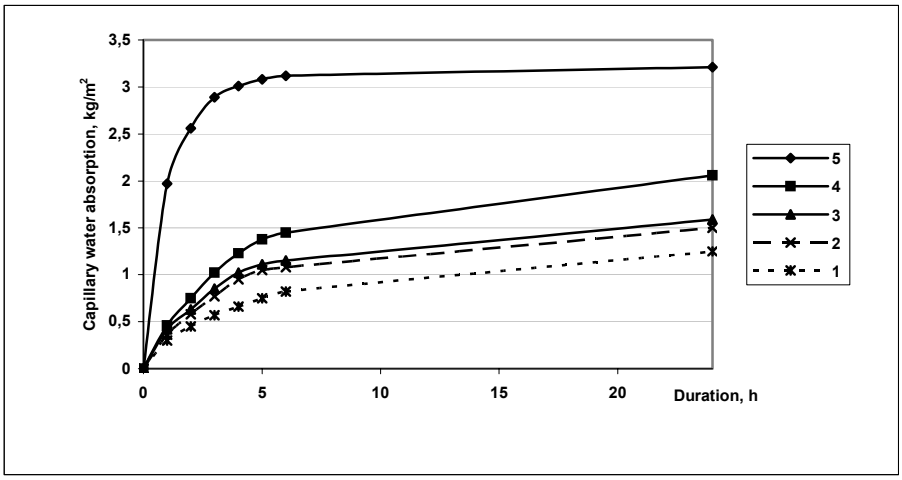

Figure 2. Dependence of the capillary water absorption indicator in paint coatings on the type of the hydrophobic agent and the method of hydrophobic treatment: *1* – 1.5 per cent aminosiloxane emulsion added to the paint; *2* – 1.5 per cent silicone resin emulsion added to the paint; *3* – 1.5 per cent aminosilane emulsion added; *4* – hardened coating treated with hydrophobic liquid; *5* – coating without hydrophobic treatment

As the quantity of the hydrophobic additive increases (Figure 3) its hydrophobic effect becomes relatively smaller and therefore the most effective content of such additive is 2 per cent of the total mass of the paint.

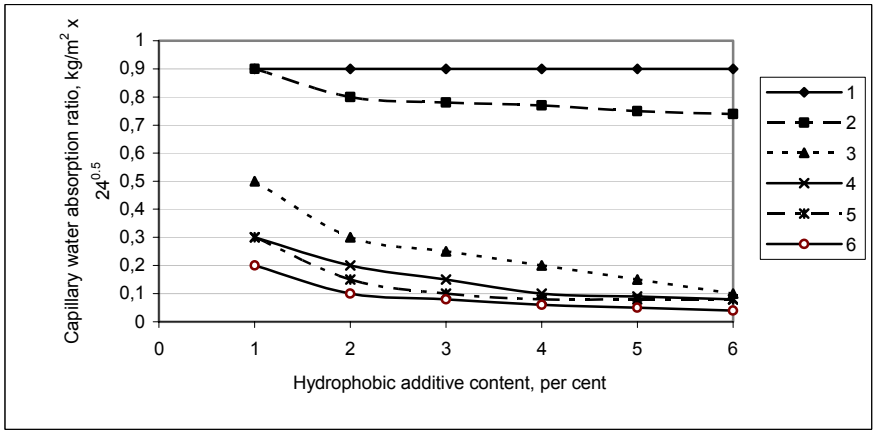

Figure 3. Dependence of the capillary water absorption indicator in test paint coatings on the type of the hydrophobic agent and the method of hydrophobic treatment: *1* – aluminium stearate; *2* – silicone oil emulsion; *3* – silicone resin emulsion 1; *4* – silicone resin emulsion 2; *5* – aminosilane emulsion; *6* – aminosiloxane emulsion

The strength of dry boats was assessed through their resistance to abrasion. The results indicate that resistance to abrasion depends to some extent on the quantitative ratio between the liquid glass and the fillings and pigments (Figure 4). By increasing the liquid glass content from 14 per cent to 21.5 per cent, the loss of the coating mass to abrasion can be brought down by 40 per cent. Whereas modifying dispersion could even reduce resistance of dry coatings to abrasion a little.

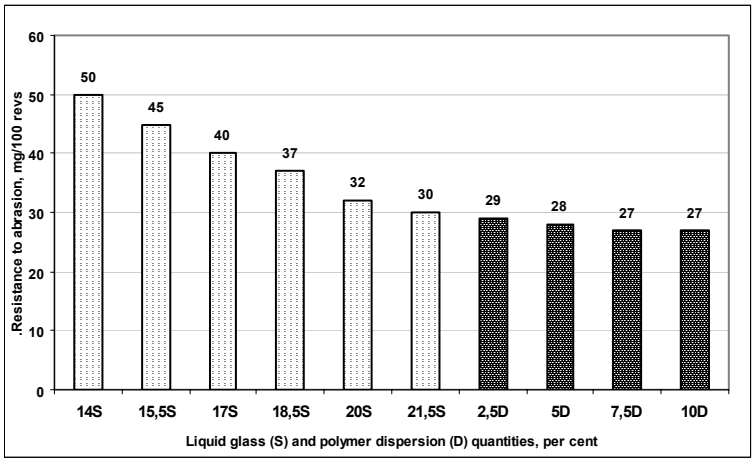

Figure 4. Dependence of paint coating resistance to abrasion on the content of liquid glass and modifying dispersion added to paints with 21.5 per cent liquid glass content

Changes in the resistance of coatings to wet scrubbing are of a similar nature. Given a larger amount of liquid glass, resistance to wet scrubbing increases to 70%. Given a larger amount of dispersion, it increases to 25% (Figure 5).

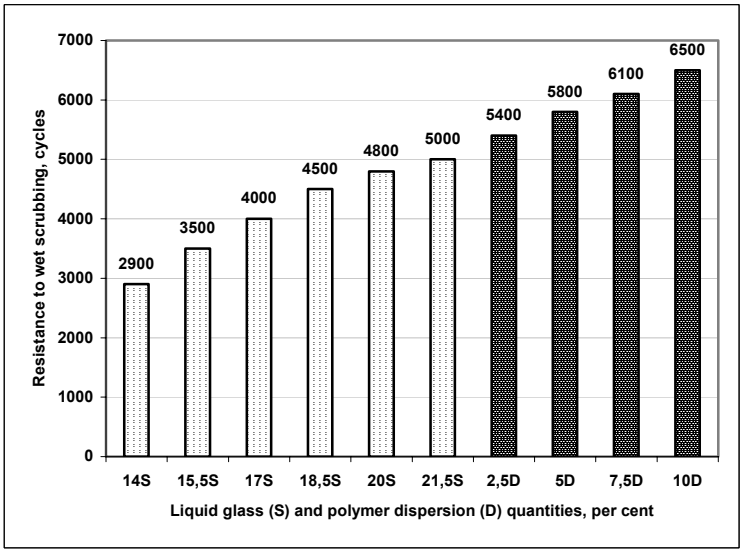

Figure 5. Dependence of paint coating resistance to wet scrubbing on the content of liquid glass and modifying emulsion added to paint with 21.5 per cent liquid glass content

The results of the strength of coating adhesion to concrete by tearing are shown in Figure 6. Apparently, this indicator depends on the content of the binding agent used in the paint, i.e. liquid glass the most. If the content of liquid glass in paint is raised from 14 per cent to 21.5 per cent, the strength of paint-to-concrete cohesion goes up to 65 per cent. Whereas addition of modifying polymer emulsion (dark columns) will only slightly increase the strength of cohesion with the base.

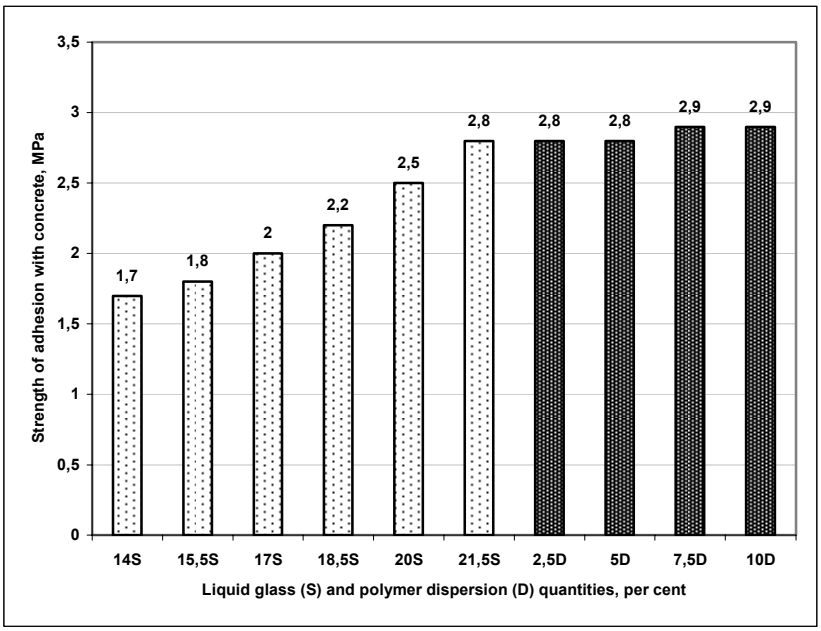

Figure 6. Dependence of the strength of paint coating adhesion to concrete by tearing on the content of liquid glass and polymer dispersion added to paint with 21.5 per cent liquid glass content

The results of the tests of dependence of vapour permeability on the content of the binding agent, i.e. liquid glass and the modifying agent, i.e. polymer dispersion is shown in Figure 7.

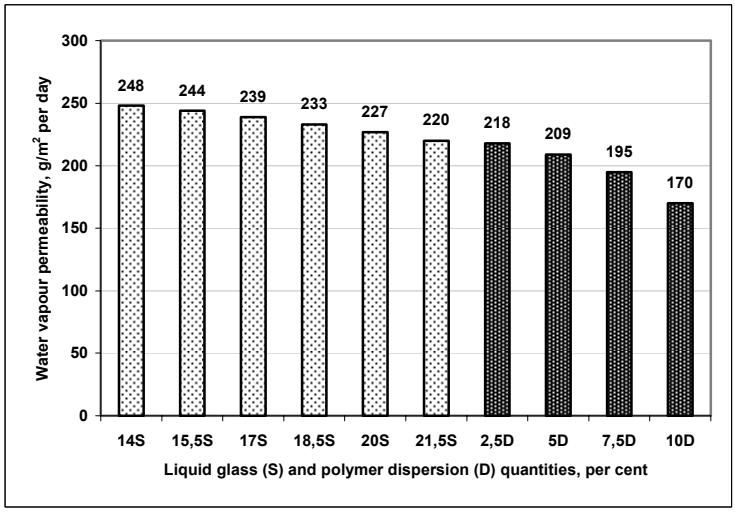

Figure 7. Dependence of paint coating vapour permeability on the content of liquid glass and polymer dispersion added to paint with 21.5 per cent liquid glass content

Paint coating vapour permeability does not depend on the content of the binding agent a lot. As the content of liquid glass in the paint increases, vapour permeability deteriorates slightly. However vapour permeability of coatings can be reduced further (by roughly 20 per cent) through the addition of polymer emulsion, especially when its content in paint is increased to 10 per cent.

Paint coating resistance to atmospheric impacts was identified through accelerated ageing using a QUV-spray machine. The chalking of the coatings and other visual changes were assessed after a certain amount of test cycles. The extent of coating chalking after 100 test cycles is shown in Figure 8.

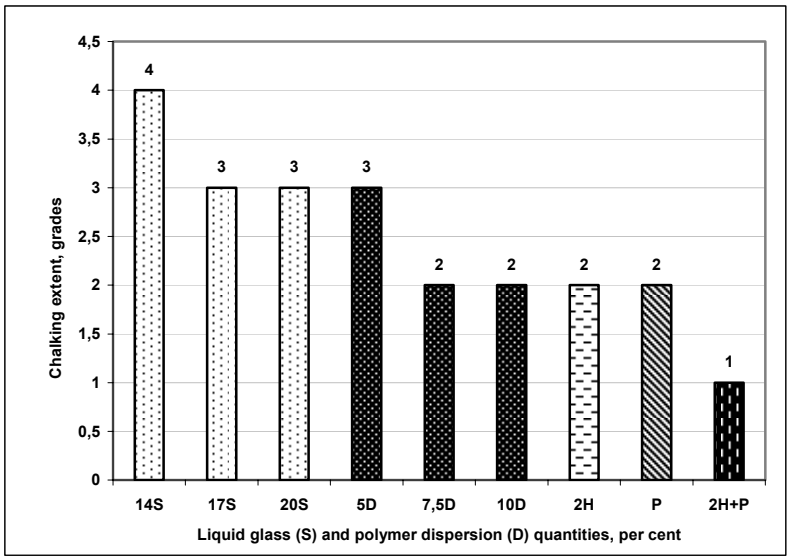

Figure 8. Dependence of the extent of paint coating chalking on the content of liquid glass, polymer dispersion added to paint with 20 per cent liquid glass content and the method of hydrophobic treatment (H – by adding the hydrophobic agent to paint with 20 per cent liquid glass and 7.5 per cent dispersion content; P – by treating hardened coating surface with silicon liquid; H+P – by adding the additive and treating the hardened surface)

It can be seen that after accelerated ageing trials, coatings with higher liquid glass content chalk less. A similar tendency is observed when the polymer dispersion content goes up to 7.5 per cent. The extent of chalking can be brought down by another grade by treating paint coatings hydrophobically in an integrated way. No other visual defects were observed in paint coatings in the process of accelerated ageing.

Given the above dependencies of formulations and properties, the formulations of silicate dispersion paint could be adjusted accordingly to change the coating properties and come up with paint with certain special properties.

The aforementioned trials determined dependencies between the content of core components or additives in paint and the properties of the paint. On that basis, the base formulation of silicate dispersion paint was adjusted in a focused way, producing paint with certain special properties. The development of the formulation of such paint was based on an assumption that in order to produce paint with the necessary special property one has to increase (reduce) the content of the component that affects it to the maximum extent possible. Such adjustment can only be done within well-defined limits, maintaining rational quantitative ratios of all the core components of paint.

By changing the content of the core components of paint and by using extra additives, several types of special silicate dispersion paint were produced, each with a certain particularly distinctive property like hydrophobia, resistance to mechanical impacts or atmospheric effects, extremely high water vapour permeability.

On top of that, lab tests of paint established that an increase in the content of fillings and thickeners in paint produces a thicker layer that does not run off vertical surfaces and levels out small surface irregularities. An increase in the content of the binding agent and hydrophobic treatment of paint will produce a paint that is more resistant to dirt and washing. A cost-efficient paint that still possesses decent properties can be produced by reducing the content of the binding agent and adding cheaper fillings.

The resultant special paint (Table 4) was manufactured. The paint was made using an industrial-grade paint mixer by adding the components in the following way: first the water, the dispergator, the stabiliser, some of the anti-foamer and the thickening agent were added together and mixed for 30 minutes. Then followed the titanium dioxide, the fillings and the concoction was mixed for 60 minutes. Eventually, the dispersion, the remaining portion of the anti-foaming agent, the viscosity modifier and the emulsifier were added and the stirring continued for another 30 minutes. The liquid glass was added at the end of the technological process, followed by another 15 minutes of mixing. When making the paint in a ball mill, the components should be added in a more or less the same manner as above. However, in that case the components can be added in two stages, stage two involving the addition of the liquid glass, the dispersion, part of the anti-foamer, the viscosity modifier and the emulsifier. For the first stage, the mixing should continue for 2.5 hours, and for another 30 minutes once all of the components have been added.

Table 4. Formulation of special silicate dispersion paints

Component	Paint formulation marker						
	SDB	SDH	SDD	SDP	SDG	SDS	SDE
Water	20.5	20	19.5	17	22	21.5	26.5
Liquid glass	28	27	**31.0**	30.5	27	26	25
Polymer dispersion	6	7	6	**8**	**4**	6	5
Pigment (titanium dioxide)	10	8.5	8	8	5	5	5
Pigment (iron oxide)	-	-	-	-	-	**6**	-
Talcum	5	5	5	5	5	5	8
Carbonate filling (large particles)	12	12	12	12	12	12	5
Carbonate filling (fine particles)	16	16	16	16	16	16	8
Cheaper filling (ceramics, chalk)	-	-	-	-	**6**	-	**15**
Stabiliser 1	0.2	0.2	0.2	0.2	0.3	0.2	0.3
Stabiliser 2	0.1	0.1	0.1	0.1	-	0.1	-
Dispergator	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Thickener	0.1	0.1	0.1	0.1	0.6	0.1	0.1
Viscosity modifier	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Anti-foamer	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Emulsifier	1	1	1	1	1	1	1
Hydrophobic agent	-	**2**	-	**1**	-	-	-

Paint formulation marker legent: SDB – base (universal) formulation; SDH – waterproof paint; SDD – abrasion-resistant paint; SDP – washing-resistant paint; SDG – paint with high level of water permeability; SDS – coloured paint; SDE – cost-efficient paint.

Component content that determines a certain special property of the paint is given in bold.

The testing results of physical and mechanical properties of industrially produced special silicate dispersion paints coatings presented in Table 5.

Table 5. Properties of special silicate dispersion paint

Indicator	Paint formulation marker						
	SDB	SDH	SDD	SDP	SDG	SDS	SDE
Vapour permeability, g/m^2 per day	214	203	220	218	**296**	225	248
Capillary water absorption, kg/m^2	1.59	**0.95**	1.32	1.18	2.20	2.10	2.35
Resistance to wet scrubbing, cycle	4800	6000	6400	**6800**	4400	4800	4200
Resistance to abrasion, mg/100 revs	29.8	29.4	**15.0**	18.4	28.5	29.4	31.6
Strength of cohesion with concrete, MPa	2.4	2.2	2.8	2.7	1.9	2.0	1.7
Chalking, grade	2	2	2	2	4	3	4
Colour	White	White	White	White	White	**Misc.**	White
Production price, LTL (manufacturer's data)	211	241	219	225	178	215	**156**

Indicator of the special property of the paint is given in bold.

CONCLUSIONS

1. Water permeability of coatings can be reduced two or more times by adding 2 per cent of hydrophobic additives (silicones) to the paint and by treating hardened coatings with hydrophobic liquids. The extent of chalking of coatings with hydrophobic treatment drops by two grades. Coatings with hydrophobic treatment are resistant to wet scrubbing by 20 to 25 per cent.
2. The strength of silicate dispersion paint coatings is determined by liquid glass. With its content increasing from 14 per cent to 21.5 per cent, coating resistance to abrasion goes up by 40 per cent, the strength of cohesion with the base improves up to 65 per cent, and the paint becomes 70 per cent more resistant to wet scrubbing. Modifying polymer dispersion affects the strength of coatings to a much smaller extent. However, it makes coatings considerably (up to 20 per cent) more resistant to wet scrubbing. Besides, the addition of 7 per cent dispersion drops the level of coating chalking by one grade.
3. Vapour permeability of silicate dispersion paint coatings decreases the most (by up to 23 per cent) when the content of polymer dispersion is increased above 7 per cent. Hydrophobic treatment of coatings does not affect vapour permeability in any significant way. When the liquid glass content is raised from 14 per cent to 21.5 per cent, vapour permeability drops a little (by up to 12 per cent).
4. Paint with one single exceptionally well-distinguished property of the coat, like hydrophobia, resistance to mechanical impacts, resistance to washing, water vapour permeability can be produced by increasing

(reducing) the content of the component that determines that property, or through the addition of additives. An addition of 2 per cent of hydrophobic agent produced highly waterproof (0.95 kg/m^2) paint, when the liquid glass content was raised to 31.0 per cent, the paint became resistant to abrasion (15.0 mg/100 revs), and when the polymer dispersion content was increased up 8 per cent, the washing-resistant properties of the paint improved up to 6800 cycles. Paint with better water vapour permeability qualities (296 g/m^2·per day) was produced by dropping the liquid glass content to 27 per cent and that of polymer dispersion to 4 per cent. On top of that, 6 per cent of mineral pigment added resulted in coloured paint, and by adding 15 per cent of cheaper filling the paint became more cost-efficient.

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Investigation of Lightweight Concrete with Porous Aggregates

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Abstract. The growing amount of waste glass encouraged producers to use this material in the manufacture of building products such as expanded glass pellets. This paper analyses the experimental research performed to assess the impact of expanded glass granules on the basic physical - mechanical properties of lightweight concrete specimens and to compare them with the physical and mechanical properties of expanded clay specimens. Mixtures for the specimens were made of Portland cement, water, expanded glass and expanded clay granules of 0/5 and 5/10 fractions. 3 different lightweight concrete mixtures with glass foam granules and 3 mixtures with expanded clay granules were made by changing the percentage of lightweight aggregate in lightweight concrete mixture in relation to the total aggregate content. Studies have shown that the maximum compressive strength was obtained in mixtures S2 and K2, where the percentage of 0/5 fraction fine aggregate was 27.4% and the percentage of 5/10 fraction coarse aggregate was 72.6%. Further increase of 0/5 fraction fine aggregate content is unreasonable because the strength properties of the specimens decline. When 5/10 fraction coarse aggregate content is reduced, the strength of concrete with expanded glass aggregate increases more intensively than the density, until the optimal composition of lightweight concrete is achieved. The average coefficient of thermal conductivity in expanded glass concrete products is about 1.2 times lower compared to expanded clay concrete products. Thus, when the minimum required strength is achieved, the thermal resistance of lightweight concrete with expanded glass aggregate will be higher than the thermal resistance of concrete with expanded clay.

Keywords: porous aggregates, foam glass, expanded clay, density, thermal conductivity, lightweight concrete.

INTRODUCTION

As the energy prices have a tendency to grow, energy saving is becoming an important issue. Growing consumption increases the amounts of waste glass that needs to be recycled. Gas-producing components in glass mass release gas at 700-900 ºC temperature (Mladenovic *at al* 2008). The expanding gas creates pores in liquid glass mass and at the end of recycling process expanded glass of spongy structure is obtained. Thus, recycled waste glass turns into a perfect thermal insulation material, which allows reducing energy costs.

Expanded glass (porous glass) is a finely porous (85–90 % porosity), clean, light, flame retardant, easily handled, efficient and environmentally friendly building material with excellent properties of thermal insulation. Nowadays glass foam manufacturers use about 98 % of various glass waste and only 2 % of pure glass. Expanded glass manufacturers use cheap glass that has uniform chemical composition and does not crystallize until the end of the foaming process; it must also have a low melting point and its viscosity must reduce at higher melting point (Manevich *et al.* 2008). These properties are often met in the glass of the following composition: about 73 % of SiO_2, 1 – 2 % of Al_2O_3, 6 – 9 % of CaO, 4 % of MgO, 14 – 15 % of Na_2O, 0.5 % of SO_3, up to 0.4 % of Fe_2O_3 (Shutov *et al.* 2008). Three types of products are manufactured from expanded glass: Glass blocks and other moulded products, expanded glass chips, and expanded glass granules (Hurley 2003).

Expanded glass is widely used in construction because of its good qualities (heat and sound insulation, mechanical strength, good bonding with other materials, etc.). Expanded glass has excellent design and technical properties and therefore is used as a heat insulating material to lag partitions in industrial and civil buildings. Expanded glass can be used as the heat-insulating material from a relatively low temperature to 450 °C temperature. Expanded glass floats on water; the floatability of mechanically damaged or fragmented expanded glass does not change; therefore it can be used to produce life-saving appliances, to build pontoon bridges, to increase the buoyancy of steel structures, to insulate sea and river vessel bulkheads and boiler rooms. Expanded glass chips are used as an aggregate material in precast concrete products and thermal insulation of roofs.

Expanded clay is lightweight and porous material. Expanded clay pellets are round shape with parched coating. It is an artificial material made of clay burned in heater at 1150 ºC temperature (Žurauskienė *et al.* 2009). The final properties of expanded clay depends on the type of clay, additives and heating temperature (Arioz *et al.* 2008).

The main purpose of the experimental research was to investigate the physical and mechanical properties of lightweight concrete with porous expanded glass aggregate and to select the optimal composition of the mortar

mixture for the manufacturing of lightweight concrete blocks. Thermal conductivity, compressive strength and density of expanded glass products were determined during the research. Expanded clay concrete products were made to compare the said characteristics.

0/5 and 5/10 fraction expanded glass and expanded clay granules were used in the experimental research. One of the most important stages of the research was to calculate the adequate proportion of fine and coarse porous aggregate matters and the cement and water ratio. Many factors have influence on the results of the research. Firstly, the characteristics and the content of mortar mixture components have to be balanced. Secondly, the appropriate concrete mixing process and the conditions of compaction and setting of the blocks in the casting moulds must be chosen.

METHODS

In this study Portland cement CEM I 42.5 R was used with compressive strength properties of 28 MPa after 2 days, and 54 MPa after 28 days of curing.

To produce lightweight concrete, fractions 0/5 and 5/10 of porous aggregates were used - expanded glass (Table 1) and expanded clay aggregates (Table 2).

Table 1. Physical properties of foam glass aggregates

No.	Property, unit	0/5 fr.	5/10 fr.
1	Bulk density, kg/m^3	179.1	108.8
2	Particle density, kg/m^3	-	176.0
3	Water absorption after 1h, %	-	45.8
4	Cylindrical strenght, N/mm^2	-	1.0

Table 2. Physical properties of expanded clay aggregates

No.	Property, unit	0/5 fr.	5/10 fr.
1	Bulk density, kg/m^3	652.0	380.0
2	Particle density, kg/m^3	-	571.7
3	Water absorption after 1h, %	-	18.2
4	Cylindrical strenght, N/mm^2	-	3.0

The study includes 6 different lightweight concrete compositions - 3 with expanded glass aggregates (Table 3), and 3 with expanded clay aggregates (Table 4).

Table 3. Composition of lightweight concrete with foam glass aggregates

No.	Material and quantities per 1m^3 of concrete				W/C
	Portland cement CEM I 42.5R, kg	Foam glass pellets fr. 0/5, kg	Foam glass pellets fr. 5/10, kg	Water, l	
S1	200	60	114	100	0.5
S2	200	69	105	100	
S3	200	77	97	100	

Table 4. Composition of lightweight concrete with expanded clay aggregates

No.	Material and quantities per 1m^3 of concrete				W/C
	Portland cement CEM I 42.5R, kg	Expanded clay granules fr. 0/5, kg	Expanded clay granules fr. 5/10, kg	Water, l	
K1	200	189	359	100	0.5
K2	200	224	340	100	
K3	200	250	314	100	

Mortar mixtures were mixed in the forced mixer using dry aggregate matter. Cement and aggregate matter were dosed by weight and water was dosed by volume. The mixing process lasted about 2 minutes and was performed in two stages: Stage I: cement and aggregate matter were poured into a wet mixture and stirred for about 1 minute; Stage II: the required amount of water was added and stirred for one minute more.

To determine the thermal conductivity, 250×250×30 mm specimens were moulded and compacted on the laboratory vibration table and subjected to 30 kg extra load. To determine the density, water absorbability and compressive strength, 70.7×70.7×70.7 mm specimens were moulded and subjected to 12 kg extra load.

Specimens were compacted in metal casting moulds in 2 stages: Stage I: the compacting lasted for 6 seconds; Stage II: the casting mould was topped with mortar mix and compacted about 4 seconds. The moulded specimens were covered with polyethylene film and left to harden for 24 hours in ambient temperature at 20±2

ºC. After 24 hours the specimens were remoulded and stored in the curing chamber at 20±2 ºC temperature and ≥90 % relative humidity for 27 days.

The density of lightweight concrete specimens was determined in accordance with the standard LST EN 12390-7, the compressive strength was determined in accordance with the standard LST EN 12390-3. The specimens were loaded to failure in compression by a hydraulic press, which complies with standard LST EN 12390-4 requirements. The specimens must have the shape of a cube in accordance with standard LST EN 12390-1 requirements. Water absorbability of the specimens was determined in accordance with standard LST EN 1428.18:1997 by soaking the specimens in water for 1 h; the thermal conductivity value was determined in accordance with standard LST EN 1745:2002 by exposing the tested specimen to a stable flow of heat.

Samples of expanded glass and expanded clay pallets (fractions 0/5 and 5/10), used in this study, are shown in Figure 1a and 1b respectively. Samples of lightweight concrete specimens are shown in Figure 1c and 1d (expanded glass and clay respectively).

Figure 1. Lightweight aggregates and lightweight concrete specimens. Expanded glass pallets (a), expanded clay pallets (b), specimen of concrete with expanded glass aggregate (c), specimen of concrete with expanded clay aggregate (d)

RESULTS

Figure 2 illustrates the dependence of the density of 70.7×70.7×70.7 mm specimens made of lightweight concrete with expanded glass and expanded clay aggregates on the mortar mixture composition. The density of concrete with expanded glass aggregate ranges from 450 kg/m^3 to 470 kg/m^3. The density range in concrete with expanded clay aggregate was wider, i.e. from 690 kg/m^3 to 750 kg/m^3. In both cases the highest density was obtained in specimens where the proportion of fine and coarse aggregate material in per cent was 28/72 (Figure 2). The comparison of density in S2 and K2 mortar mixtures revealed that the density of specimens with expanded clay aggregate was 1.6 times higher than the density of specimens with expanded glass aggregate. The density and porosity of expanded glass granules depends on the granule expansion degree. A very important rule to follow is to ensure uniform compaction conditions of lightweight concrete specimens of different composition: the compacting time and extra load applied to specimens placed on the vibration table must be the same subject to the dimensions of moulded specimens. These conditions are influenced by the slump flow, setting time and other factors.

Figure 3 illustrates the dependence of the compressive strength of lightweight concrete with expanded glass and expanded clay aggregates on the mortar mixture composition. The diagram shows that compressive strength of the specimens depends on the composition of the mortar mixture. The experimental research results have revealed that the compressive strength of specimens with expanded glass aggregates is about 4 times lower than the compressive strength of specimens with expanded clay aggregates. The reduction in compressive strength may be influenced by several factors: different density, cylinder strength (crushing strength) (Tables 1 and 2) of expanded glass and expanded clay and different density of moulded concrete specimens (Figure 2).

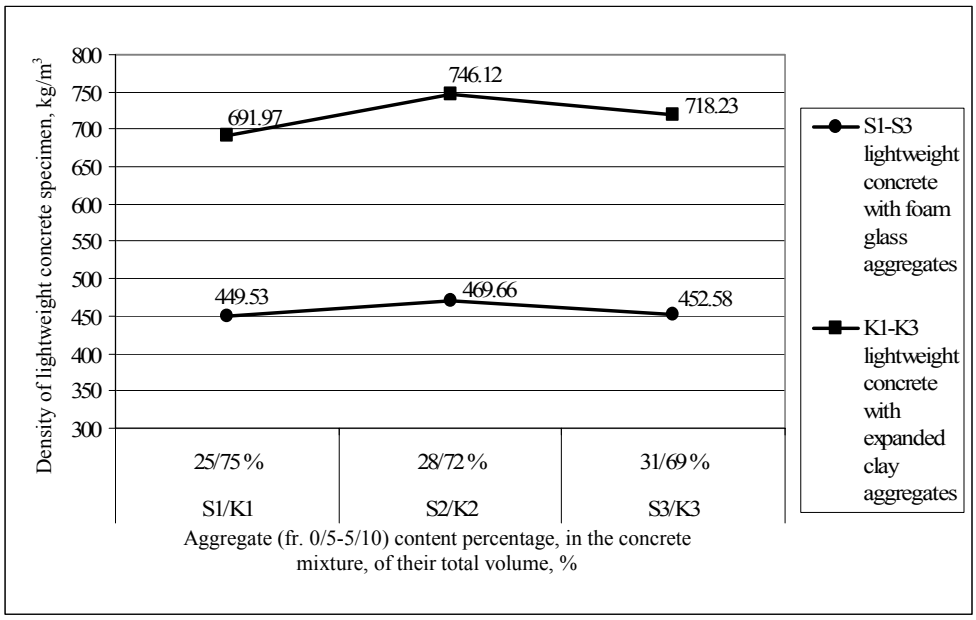

Figure 2. Dependence of the density on the mortar mixture composition, for lightweight concrete specimen with expanded glass or expanded clay aggregate

The comparison of density (Figure 2) and compressive strength (Figure 3) in lightweight concrete specimens has shown that compressive strength increases with density. The highest compressive strength was obtained in specimens made of S2 mortar mixture with expanded glass and in specimens made of K2 mortar mixture with expanded clay. Better thermal and strength characteristics of lightweight concrete are obtained with the change in the proportion of fine and coarse aggregate materials. The highest strength in lightweight concrete specimens with expanded glass and expanded clay was obtained when fine aggregate (0/5 fraction) content in the mixture was 28 % and coarse aggregate (5/10 fraction) content was 72 %. When fine (0/5 fraction) porous aggregate content in the mortar mixture is increased, the resulting porous structure of lightweight concrete causes the compressive strength of the specimens to reduce.

Compressive strength tests revealed that expanded glass does not decompose immediately when the critical compression threshold is achieved. When the specimen is subjected to gradually increased load, the walls of the pores in direct contact with the press plates crumble into fine powder and the specimen fails when the powder of crumbled walls of the pores fills cavities of the pores.

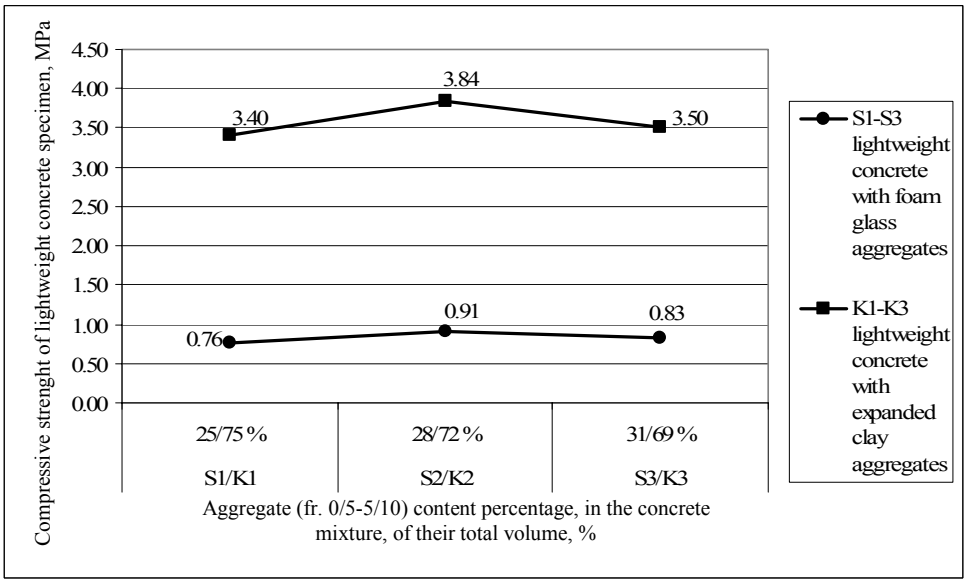

Figure 3. Dependence of the compressive strength on the mortar mixture composition, for lightweight concrete specimen with expanded glass or expanded clay aggregate

Figure 4 illustrates the dependence of thermal conductivity coefficient of lightweight concrete with expanded glass and expanded clay aggregates on the mortar mixture composition. The diagrams show that S1 and K1 lightweight concrete mixtures have the lowest thermal conductivity value. Apparently, higher closed porosity or gaseous phase is achieved in specimens of this concrete mixture and therefore their density and corresponding compressive strength is lower. The coefficient of thermal conductivity λ in lightweight concrete with expanded glass aggregate is 1.2 times lower compared to λ values in lightweight concrete with expanded clay. Consequently, the thermal resistance of lightweight concrete with expanded glass aggregate is higher than the thermal resistance of concrete with porous expanded clay aggregate.

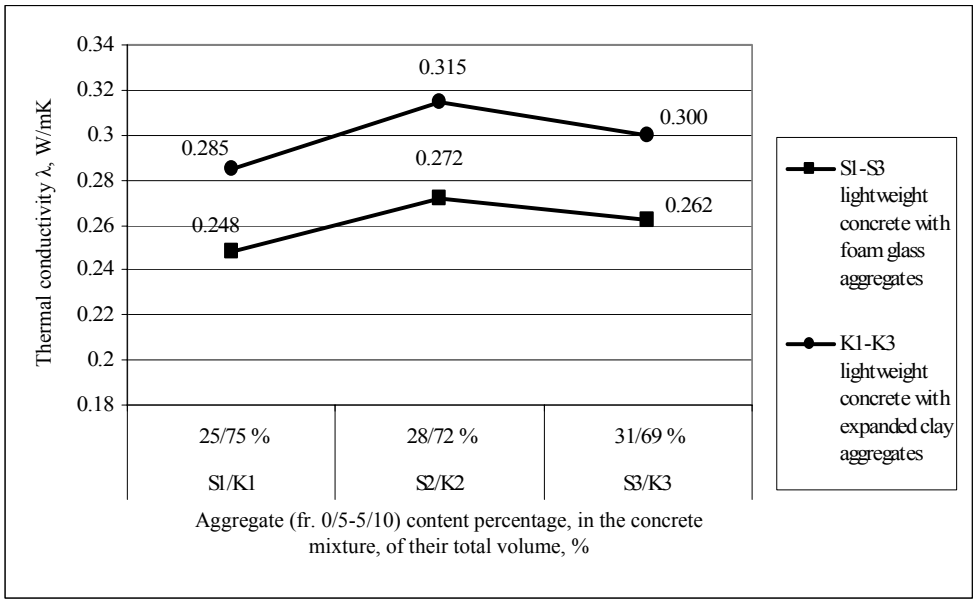

Figure 4. Dependence of thermal conductivity coefficient on the mortar mixture composition, for lightweight concrete specimen with expanded glass or expanded clay aggregate

The overview of the test results of the density and thermal conductivity in lightweight concrete has shown that with higher density of the specimens their compressive strength increases more than the coefficient of thermal conductivity (λ). Consequently, mechanical strength of the specimens can be increased by slightly reducing their thermal insulation capacity and vice versa. The obtained results have shown that λ in lightweight concrete specimen's increases in approximate proportion to the increase in the density of the specimens (Figure 2 and 4). Such a tendency of change is observed in the charts of λ change in lightweight concrete with expanded glass and in lightweight concrete with expanded clay aggregates.

Figure 4 illustrates the dependence of thermal conductivity coefficient of lightweight concrete with expanded glass and expanded clay aggregates on the mortar mixture composition. The diagrams show that S1 and K1 lightweight concrete mixtures have the lowest thermal conductivity value. Apparently, higher closed porosity or gaseous phase is achieved in specimens of this concrete mixture and therefore their density and corresponding compressive strength is lower. The coefficient of thermal conductivity λ in lightweight concrete with expanded glass aggregate is 1.2 times lower compared to λ values in lightweight concrete with expanded clay. Consequently, the thermal resistance of lightweight concrete with expanded glass aggregate is higher than the thermal resistance of concrete with porous expanded clay aggregate.

The overview of the test results of the density and thermal conductivity in lightweight concrete has shown that with higher density of the specimens their compressive strength increases more than the coefficient of thermal conductivity (λ). Consequently, mechanical strength of the specimens can be increased by slightly reducing their thermal insulation capacity and vice versa. The obtained results have shown that λ in lightweight concrete specimen's increases in approximate proportion to the increase in the density of the specimens (Figure 2 and 4). Such a tendency of change is observed in the charts of λ change in lightweight concrete with expanded glass and in lightweight concrete with expanded clay aggregates.

Figure 5 illustrates the dependence of water absorbability on the composition of mortar mixture. The figure shows that concrete with expanded glass aggregate has 2 times bigger water absorbability than concrete with expanded clay aggregate. This can be explained by lower density of expanded glass. Consequently, expanded glass has more open pores which absorb more water. It depends on the number of open pores: the more open

pores the material has, the higher water absorbability is achieved. The density and porosity of expanded glass granules depends on the granule expansion degree.

The testing of density (Figure 2) and water absorbability (Figure 5) in lightweight concrete specimens has shown that water absorbability reduces with the increase of density. Specimens of lower density have numerous open pores and capillaries, which absorb water. Specimens made of S1 and K1 concrete mixtures have more open pores compared to specimens of S3, K3 or S2 and K2 concrete mixtures. In each case under the research we have seen that water absorbability reduces in approximate proportion to the increase in specimen density.

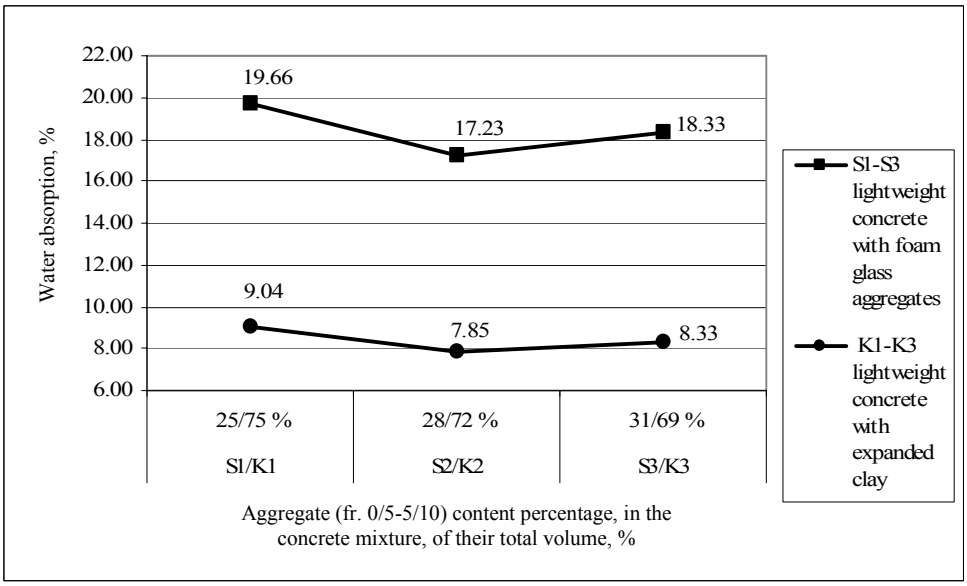

Figure 5. Dependence of water absorb-ability on the composition of mortar mixture, for lightweight concrete specimen with expanded glass or expanded clay aggregate

CONCLUSIONS

The highest density was obtained in lightweight concrete specimens made of the second mortar mixture (S2; K2). The density of concrete with expanded clay (K2) is 1.6 times higher than the density of concrete with expanded glass (S2).

The compressive strength of specimens made of concrete with expanded glass aggregate was 4 times lower compared to the strength of concrete with expanded clay aggregate; the said values actually correspond to the cylinder strength (crushing strength) and particle density of granules used as aggregate material.

Studies have shown that the maximum compressive strength was obtained in mixtures S2 and K2, where the percentage of 0/5 fraction fine aggregate was 27.4 % and the percentage of 5/10 fraction coarse aggregate was 72.6 %. Further increase of 0/5 fraction fine aggregate content is unreasonable because the strength properties of the specimens decline.

When 5/10 fraction coarse aggregate content is reduced, the strength of concrete with expanded glass aggregate increases more intensively than the density, until the optimal composition of lightweight concrete is achieved.

To increase the mechanical strength of specimen's thermal insulation capacity should be slightly reduced because with the increase in density the compressive strength increases faster than the coefficient of thermal conductivity.

The average coefficient of thermal conductivity in expanded glass concrete products is about 1.2 times lower compared to expanded clay concrete products. Thus, when the minimum required strength is achieved, the thermal resistance of lightweight concrete with expanded glass aggregate will be higher than the thermal resistance of concrete with expanded clay.

Water absorbability in concrete with foam glass aggregate is about 2 times higher than in concrete with expanded clay aggregate. Such difference is obtained due to lower density in expanded glass granules and correspondingly in lightweight concrete specimens. When the number of open pores is bigger, water is absorbed easier, but it is also removed easier compared to specimens with expanded clay aggregates.

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Utilisation of Bore-Silicate Glass Waste as a Micro-Filler for Concrete

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Abstract. Lamp glass is waste product which can not be utilized by traditional way. The possibilities for use lamp bore-silicate glass powder as cement replacing admixture in conventional concrete have been investigated in this work. Experimental work provides preparation of standard concrete samples and sample testing after the 7 and 28 day ageing period in standard condition. The following glass materials were used for cement replacement: rough ground glass powder, glass dust from filters (both materials were obtained from glass treatment plant) and additionally ground glass powder. The effect of glass powder on cement setting time was investigated. The experimental results indicate that cement replacing by rough glass powder decrease compressive strength. Fine glass particles make possible to replace up to 20 of cement without loss in strength characteristics. Fine glass powder performs long-term hardening effect. The best compressive strength results were achieved by using 60 minutes ground glass, glass dust obtained from filters gives smaller effect. Summarizing results of investigation it may be concluded that ground bore-silicate lamp glass successfully may be applied as micro filler for concrete as cement replacing material.

Keywords: waste, bore-silicate glass, concrete, strength

INTRODUCTION

Glass is silicate material, containing different oxides, the main component is silicate oxide SiO_2 in amorphous state. Several types of glass, such as soda-lime silicate, alkali-silicate, bore-silicate glass are producing in the world. The object in this research is bore-silicate glass remaining after fluorescence lamp utilization. In accordance with European Committee decision, all simple incandescent lamp should be replaced by fluorescent lamp till 2012, therefore the problem of it recycling and utilization will be more actual after some years. Although large part of glass waste nowadays is soda-silicate glass (bottle glass, windows glass), its collecting and recycling procedures are worked out satisfactory, lamp glass is specific waste product and can not be utilized by traditional way.

One of the ways of glass waste utilization is application of it as concrete filler. Glass waste application in concrete was investigated sufficiently in previous years (Siddique, 2008, Jin *et al.* 2000, Shao *et al.* 2000). A coarse crushed glass used as concrete aggregate can cause the alkali-silicate reactions in hard concrete, resulting in harmful expansion in interface between cement and glass surface (Shayan and Xu, 2006, Shayan, 2002). Some investigations indicate that ordinary glass can be used not only as passive filler in concrete, but also as an active component that initiate reaction with cement minerals. It is proved that ground glass particles (<75 μm) may be beneficial component in concrete. It is proved, that glass micro-filler initiate puzzolanic reaction and harmful expansion deformations don't occur (Schwarz and Neithalath, 2008). Investigations of microstructure have shown that glass powder form a dense concrete matrix and improve concrete properties.

Modern concrete technology provides use of complex multi-component mix systems. Special requirements for aggregate grading are to be taken into account and especially fine particles (so called "micro filler") content should be controlled. Micro filler improves mix workability and provides particle dense packing in hydrated cement paste. Micro filler is important component which guarantee mix pumpability. Dolomite, limestone powder, fly-ash and silica fume are usually used as micro-filler in modern concrete mixes. Micro filler is one of most expensive mix component, it cost may make up a half part from cement cost. Micro filler replacement by waste products gives possible to achieve economy effect and to solve environmental protection task simultaneously. Thus lamp glass waste utilization in concrete is very actual task in concrete technology.

The aim of this work is to investigate possibilities to use fine powders of bore-silicate lamp glass waste as micro filler for conventional plastic concrete mixes.

METHODS

The object of this study is recycling material glass powder (GP) obtained from fluorescente lamp glass utilization. Investigation procedure of recycled lamp glass provides determination of chemical composition and

analysis of grading. Particle size distribution of material (grading composition) was made by method of laser diffraction analysis. Testing materials was dispersed in water using ultrasonic bath. Three samples of each type glass waste have been tested.

In order to increase glass reactivity material was additionally 60 minutes ground in planetary ball mill Retsch PM400. Obtained activated powder was used for concrete mix preparation.

Glass admixture effect on cement setting time was investigated by Vicat method according with EN 196-3:1995 using Vicas apparatus. This procedure is used to determine the quantity of water required to produce a cement paste of standard consistence and to calculate the initial and final setting time of neat cement past of standard consistence. Standard consistency cement slurry was prepared preliminary. The main criteria of setting time is depth of penetration of special needle in Vicas device.

Laboratory mixes were designed without plasticizing agent, close to concrete mix commonly used in industry. Normal moderate hardening portland cement CEM I 42.5 N was applied as binding agent. Natural local dolomite based aggregate (gravel) was used for mix preparation. Natural sand was applied as fine aggregate of a concrete. Proportions between aggregates were calculated in order to obtain the best grading curve of aggregate, taking into account optimum range curves in accordance with DIN 1045. Modern concrete technology provides controlling not only aggregate grading curve, but also fine particle content, which is necessary to provide satisfactory mix workability. In order to obtain pumpable concrete, recommended fine particle content (< 0.125 mm) is 375…450 kg/m^3. Modern advanced concretes such as self-compacting, high strength and high performance concrete are very susceptible for content of micro-filler admixture.

The experimental work provides cement replacing by glass powder in amount of 0, 10, 20, 30, 40 and 50 %.

Concrete mixes was prepared in laboratory drum mixer (capacity 50 l). The dry ingredients were weighed and mixed for a one minute, 80 % from designed water content was added during next 1 minute. Remaining water has been added to the mix during mixing.

Mixes were tested for workability using slump test for conventional concrete. Water dosage is selected to provide cone slump in range 150 ... 170 mm (cone slump class S4).

Standard testing samples cubes 100 x 100 x 100 mm were produced for investigation the mechanical characteristics of the material. Concrete mixtures were cast into the oiled steel moulds and compacted at the vibrating table. After two days samples was dismantled. The standard hardening conditions (temperature +20°C, RH > 95 %) were provided for the samples. Sample measurements and testing were performed after ageing period in the standard conditions.

The samples were tested on compression strength in conformity with LVS EN 12390-3:2002. The compressive strength was tested by testing machine with accuracy $\pm$1%, the rate of loading was 0.7 MPa/sec.

Produced samples were tested after 7 and 28 days. Compressive strength and density of hardened concrete was determined.

RESULTS

Composition of recycled glass powder

The investigated material is powder obtained from fluorescente lamp glass utilization plant. Lamp recycling process includes lamp classification, glass separation, cleaning from harmful components and grinding. The waste product is white glass powder (GP) having grain size smaller than 0.2 mm. Preliminary investigation of chemical composition and grading composition of received waste product was carried out. Chemical analysis results of glass waste are summarized in Table 1 (Shakhmenko *et al.* 2010). The product contains 74.3 % of silicium oxide SiO_2, and 16.6 % of bore oxide B_2O_3, thus material is classified as bore-silicate glass.

Table 1. Chemical composition glass waste

Components	Content (% by mass)	Tolerance, ± %
SiO_2	74.25	0.5
PbO	0	0.5
B_2O_3	16.63	0.5
Al_2O_3	1.65	0.3
Fe_2O_3	0.16	0.05
CaO	2.09	0.2
MgO	0	0.2
Na_2O	3.82	0.1
K_2O	0.93	0.1
Total	99.48	-

Grading curves for rough ground material, ground materials during 60 minutes and fine glass dust, obtained by laser difraction method, are shown in Figure 1. Grading analyze shows that rough ground material contains wide particle size in range from 2 µm up to 70 µm, average grain size 26,3 µm. Glass dust from filters has average particle size 5,0 µm. Grading composition analysis indicates on considerable increase in fine particle content after powder additional grinding (Figure 1), average grain size of additionally ground glass is 4,0 µm.

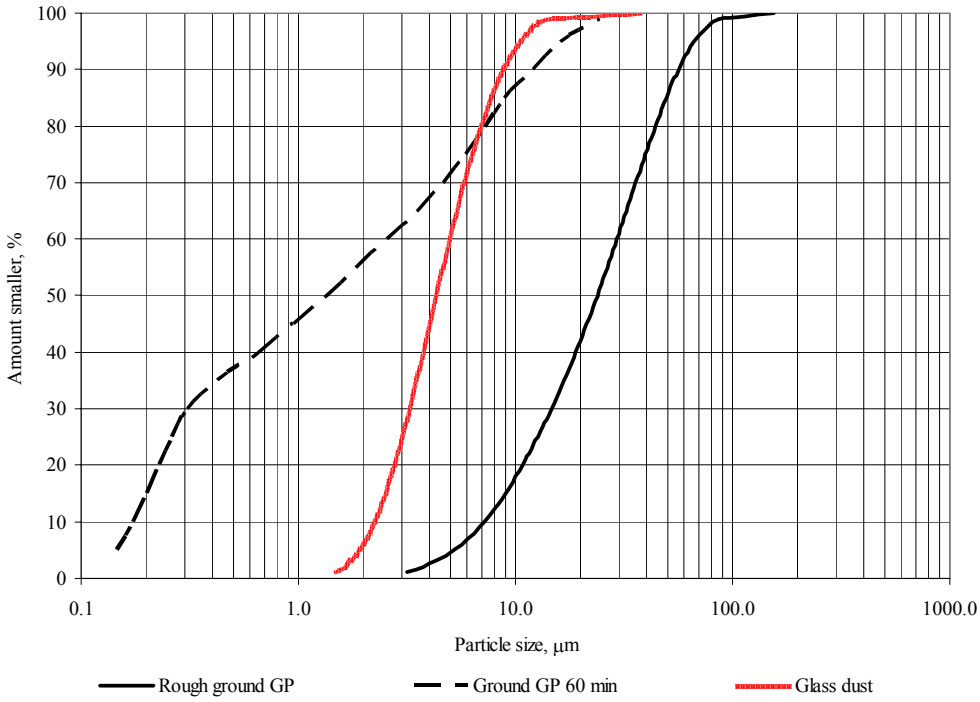

Figure 1. Glass powder grading curves (by laser difraction method)

Glass waste effect on cement setting time

Setting time is one of the most important characteristics of binding agent. It make possible for normal transportation and placing of concrete mixture. On order to estimate glass powder effect on cement setting time, pure cement slurry and mixes containing 20% of glass powder and 80% of cement was tested in conformity with LVS EN 197-3. Composition, containing rough glass powder, glass dust and additionally ground glass were examined. Mix containing 20% of silica fume also was tested for obtaining of additional result. A trial has done each 15 minutes until the depth of needle penetration is 5 mm. The elapsed time from mixing the water with dry cement till this moment is called initial setting time.

The diagrams reproducing yield of penetration depending on time are shown in Figure 2. Setting time results are summarized in Table 2.

Table 2. Setting time for cement containing micro fillers

	100% CEM I 42,5N	80% CEM I 42.5 N, 20% raw glass powder	80% CEM I 42.5 N, 20% 60min. ground glass	80% CEM I 42.5 N, 20% silica fume	80% CEM I 42.5 N, 20% glass dust
Begin of setting	170	230	100	130	110
End of setting	270	340	260	250	240
W/C ratio	0.33	0.44	0.42	0.44	0.44

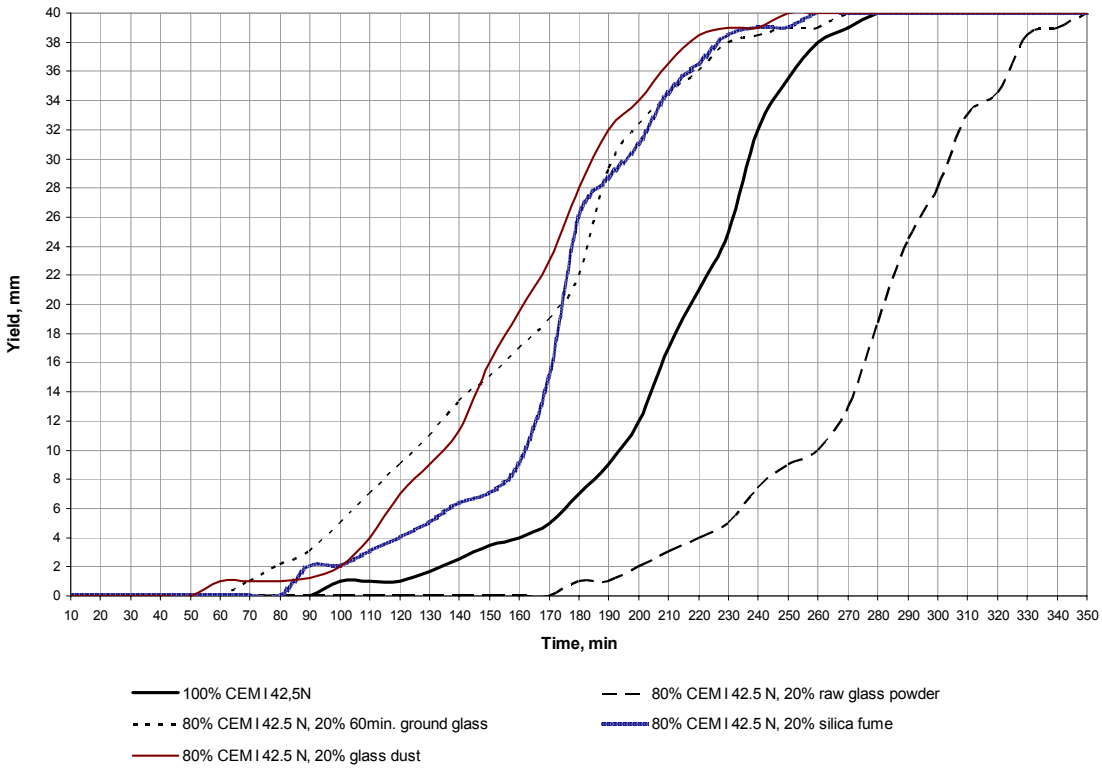

Figure 2. Cement mix setting diagrams

Concrete samples with cement replaced by recycled glass powder

The influence of recycled glass powder on concrete properties was investigated using 3 type of glass recycled material. In the first series of samples cement was partly replaced by rough glass powder (GP), obtained from lamp recycling plant. In the second part additionally ground (60 minutes) ground glass powder was used, in the third series lamp glass filter dust obtained from lamp recycling plant was applied as cement replacing material. Mix compositions and value of concrete density are summarized in Table 3.

The results of determination of compressive strength are shown in Figure 3 (7 days) and Figure 4 (28 days).

Table 3. Mix compositions and density of hardened concrete

Cement replacement by glass, %	**0**	**10**	**20**	**30**	**40**	**50**
Portlandecemt I CEM 42.5 N	350	315	280	245	210	175
Gravel 4/20mm Gravel 2/11mm Sand 0/4mm	520 490 730					
Rough glass powder	0	35	70	105	140	175
Water	200	200	200	200	200	200
Water-Cement ratio	0.57	0.63	0.71	0.82	0.95	1.14
Concrete density, kg/m^3	2334	2349	2331	2336	2324	2317
Additionally ground glass powder	0	35	70	105	140	175
Water	200	200	200	200	200	200
Water-Cement ratio	0.57	0.63	0.71	0.82	0.95	1.14
Concrete density, kg/m^3	2355	2333	2337	2342	2313	2299
Glass dust from filters	0	35	70	105	140	175
Water	210	206	200	191	203	240
Water-Cement ratio	0.60	0.65	0.71	0.78	0.97	1.37
Concrete density, kg/m^3	2360	2313	2260	2239	2211	2210

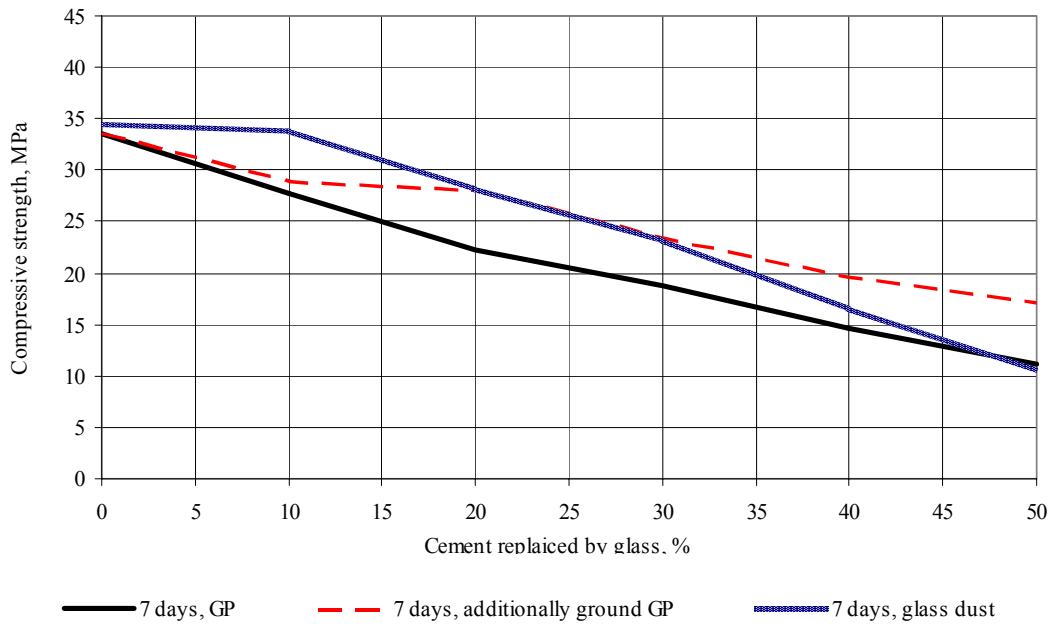

Figure 3. Cement replacement by glass powder: 7 days compressive strength results

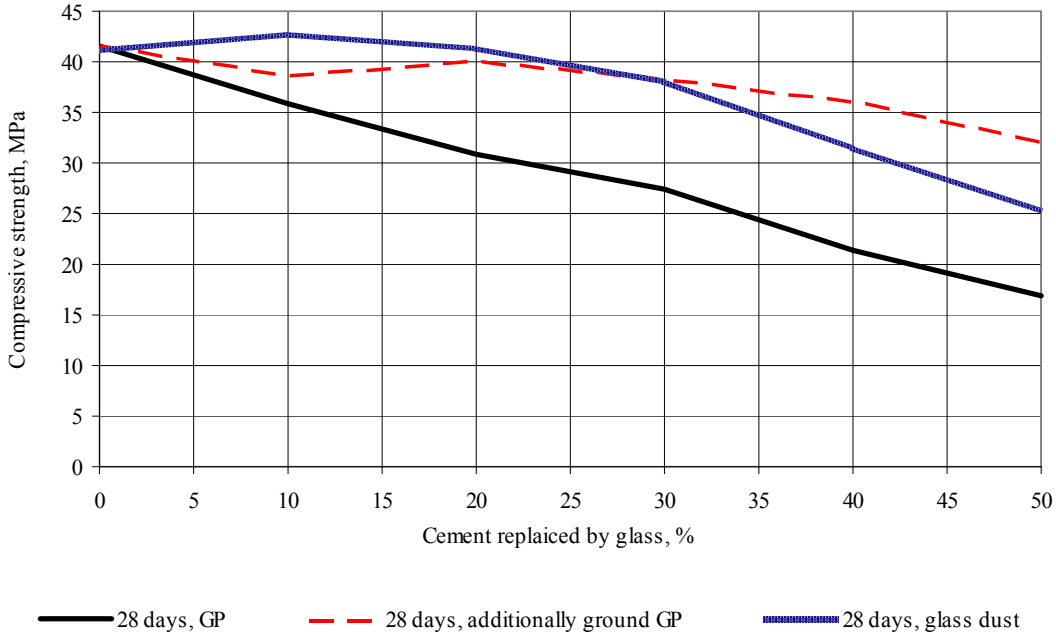

Figure 4. Influence of additionally grinded lamp glass: 28 days compressive strength results

DISCUSSION

Bore-silicate glass waste is investigated with aim to use this material for producing concrete. It was observed the concrete mixes containing ground glass has more tacky consistency in comparison with conventional concrete mix. Glass powder improves mix workability, makes mix more homogene and prevent segregation. Glass powder effect on cement setting time must be taken into account. Roughly ground glass increase cement setting time, but fine grained powder has accelerating effect on cement setting time. It must be emphasised, that concrete mixes containing all types of glass powder very quicly (during first hour) lose workability. This effect must be investigated more orderly in future.

Required water content differs fractionally for all mixes, excepting mix with 50 % replacement by glass dust (water consumption increase by 20%).

Glass grinding effect on mix density is negligible, (mostly within 1%). Bigger decrease in density (up to 5% or 120 kg/m^3) take place if cement replaced by additionally ground glass >40% and glass dust >10%. This effect may be expounded by entraining of additional air in concrete mix.

Experimental results indicate decreasing the compressive strength of concrete in 7 and 28 days when part of cement was replaced by rough grinded glass filler, thus roughly ground glass powder effect as inert micro filler.

In case of use additionally activated glass powder (60 minutes ground) or glass dust, increasing in compressive strength was observed after 28 days hardening. Compressive strength in 7 days decreases in all cases. This effect may be explained by activating of puzzolanic reactions caused by glass additional grinding and increasing of specific surface. Experimental results indicate that it is possible to achieve very economical ("green") concrete compositions with law cement content. For example, replacing 30 % of cement by fine grained glass powder, 28 day compressive strength decreases only by 10 %.

At the same time some possible negative effects of cement replacement by recycled glass not yet investigated in our work. For example: chemical resistance, frost resistance, water permeability, shrinkage, creep and other factors, which determine long-term performance of material. Hygienic and ecological estimation of lamp glass recycling products application as concrete micro filler also must be carried out carefully.

CONCLUSIONS

- Bore-silicate glass powder improves concrete mix workability, makes mix more tacky and homogene.
- The properties of fresh concrete mix and properties of hardened concrete considerably depend on finess of glass powder.
- Roughly ground glass increase cement setting time. At the same time, additionally ground glass powder and glass dust considerable accelerate cement setting processes. Lose of mix workability (during first hour) take place in cases of all type of glass powders.
- Cement replacement by roughly ground bore-silicate glass powder reduce compressive strength in 7 and 28 days. Roughly ground glass powder effect as inert micro filler.
- Additionally (60 min.) ground glass powder as well as glass dust demonstrates properties of active micro filler which performs long-term hardening effect. Cement replacement by fine grinded powder reduce compressive strength in 7 days and demonstrates considarable strength gain in 28 days.
- Up to 20 % of cement may be replaced by activated glass powder (or filter dust) without reducing in 28 day compressive strength.
- Durability and physical properties of concrete containing glass powder must be investigated in the future in a more detailed way.

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Properties of Mortars Containing Ash from Sewage Sludge Incineration

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Abstract. The incineration of sludge is one of currant methods of its disposal. Considering the chemical and physical properties of sewage sludge ash an attempt was made to introduce it into cement composite as a replacement of Portland cement – active addition. The analogy between the ash from sludge combustion and traditional mineral additions used in cement composites technology was observed. It was found that the ground ash points out the pozzolanic activity. The addition causes the delay of the beginning of the cement-binder hydration process, but it does not prolong the entire setting time. The presence of the ground ash causes the slowdown in the dynamics of the compressive as well as flexural strength development of cement composites but it does not reduce the final strength. The results presented indicate the possibility to reuse the ash from sludge combustion in cement based materials.

Keywords: mortar, sewage sludge ash, pozzolanic activity, setting time, strength development.

INTRODUCTION

The development of technology in different industrial sectors causes the formation of new kinds of by-products or very large changes in composition and properties of known waste. The knowledge about them is usually insufficient among potential consumers. The products of the sludge incineration belong to this kind of waste.

The attempts of the multidirectional economical use of ashes originating from the combustion of different fuels have been undertaken for many years (Tay *et al.* 1997), (Ferreira *et al*. 2003), (Morino *et al*. 2005). Different ashes are rich in some elements and compounds (such as metals and salts) and therefore they have some potential to be used as raw materials. One of their main users is the industry of building materials. The character of the building materials manufacturing makes it possible to dispose pecks of waste from other industrial sectors. Many incineration residues have been successfully used in construction materials (Aubert *et al.* 2007), (Monzo *et al.* 1999). Sewage sludge, especially after thermal processing, can be utilized in this way. The amount of waste suitable to disposal, the requirements for them, and also tolerant changes in chemical composition and other properties depend on the kind of building material produced.

At present, the most widely applied treatment for the inertization of ash from municipal waste is the solidification/stabilization process, generally using cement as a binder (Ferreira *et al*. 2003), (Monzo *et al.* 1999). The standard for concretes EN 206-1: 2003 allows introducing different mineral additions which can influence the properties of fresh to concrete and other materials on the basis of the cement, as well as the properties of hardened material. Two types of inorganic additions are mentioned:

- additions almost neutral (type I) – substances inert in the environment of hydrating cement,
- additions with pozzolanic properties or latent hydraulic properties (type II) – substances active in the environment of cement paste.

The product of the incineration of sludge shows the certain analogy to traditional accepted mineral additions (coal fly ash, silica fume, and furnace slag) applied in the technology of cement composites. This analogy of the composition and the pozzolanic activity gives good prerequisites for their utilization as the partial replacement of Portland cement in concrete. The significant arguments for the application of waste in processes of the building materials manufacturing, besides economic profits and aspiration to the improvement of the environment state, are very often technical advantages resulting from by-products introduction into some building materials. The evaluation of the waste material suitability for each application should take into account the following factors: suitability for processing, the influence on technical characteristics of material and the environmental impact.

As yet, there is not sufficient background knowledge for the utilization of ashes from the combustion of sludge as a component in the manufacturing of building materials, neither from an environmental point of view nor from a technical standpoint.

The aim of the analyses presented, was the determination of chemical and physical properties of material obtained as a result of the sludge incineration and the preliminary evaluation of possibility of its utilization in cement based materials. Considering the character of material tested, its chemical composition, granulation and density, an attempt was made to introduce it to concrete in an as-received form as a replacement of Portland cement – active addition (type II).

The requirements for application of ashes from the combustion of sludge, as components of concrete, are not standardized, thus the investigations were carried out on the basis of current standards for and fly ash for concrete.

MATERIALS AND METHODS

Ash characterisation

The ash tested was obtained as a result of the incineration of sludge from the municipal waste-water treatment plant (Liu *et al.* 1997), (Wiliams, 2005). The process goes ahead in two stages. At first, the sludge of 80% RH is dried using recirculated air of the temperature ca. 50°C. In the thermal treatment installation the dried sludge of 20% RH is combusted in the furnace chamber, in bottom section at the temperature above 600°C, and later in upper section, the sludge is afterburned in the temperature above 850°C. The residence time of the combustion gas molecule in the afterburning chamber is longer than 2 seconds. The composition of cleaned gas, emitted to the atmosphere, is monitored continuously.

The characterisation of sludge ash was performed aiming to investigate the potential of exploiting these residues in cement based materials. The burnt sludge has the form of mix of bottom ash and slag with bulk density of 500 kg/m^3 and specific gravity 2520 kg/m^3, comparable with properties of various waste materials applied as mineral additions to cement based materials.

The analysis of the ash morphology was carried out by means of the scanning electronic microscope (E-SEM) which allows leading the observation of samples without their coating with electric current conductible material and without the necessity of high-vacuum keeping in specimen chamber. The preliminary analysis of chemical composition of ash was made using the energy dispersive X-ray analyser EDS. Selected results of the observation and the qualitative analysis are shown in Figure 1. The ash exhibited the loose and rough structure (Figure 1a). The irregular grains with strongly extended surface, testifying to the large porosity, dominate in the material. Spherical and similar to rectangular forms of grains are very rare. In chemical composition the presence of such elements as silicon, carbon, magnesium, aluminium, iron, calcium and the meaning content of phosphorus were identified.

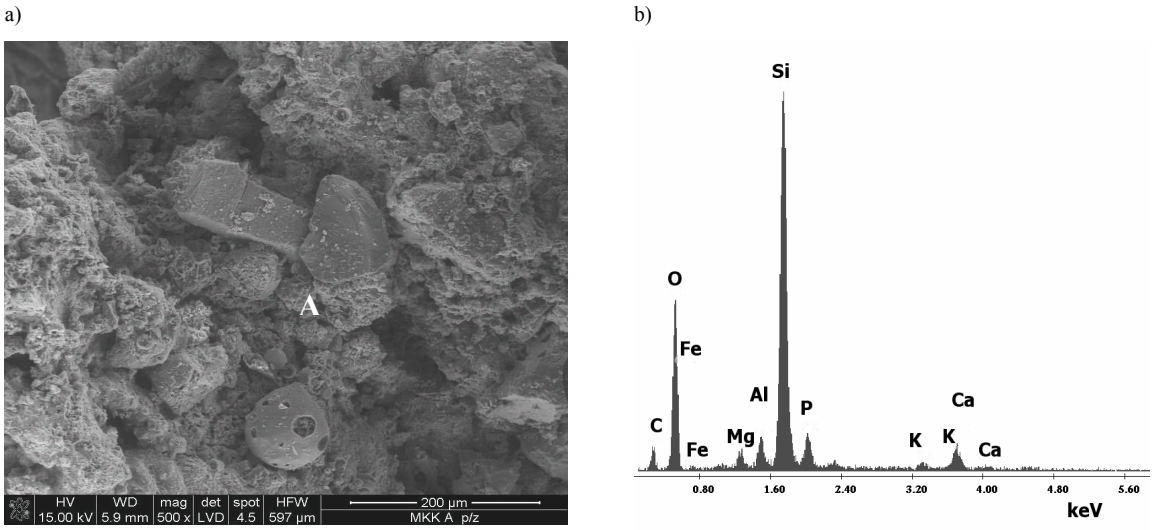

Figure 1. E-SEM micrograph of sewage sludge ash, 500× (a) and EDS analysis in point A (b)

The results of chemical analysis of ash are presented in Table 1.

Table 1. Chemical analysis of ash tested

Component	Content, %	Component	Content, %
Loss on ignition	8,65	TiO_2	0,41
SiO_2	34,68	SO_3	0,60
Fe_2O_3	10,32	S^{2-}	0,20
Al_2O_3	6,32	Na_2O	0,70
CaO	15,42	K_2O	1,30
MgO	2,65	P_2O_5	18,17

Silica, iron and calcium oxides are the major compounds of ash. The ash was characterized by relatively low content of aluminium oxide and low SO_3 level. The large content of CaO and P_2O_5 can cause disturbances in the cement hydration process (Neville, 2002). Because of the content of unburnt carbon, expressed by loss on ignition, the ash can be numbered to the category C according to EN 450-1: 2007 (loss on ignition among 4% and 9%). The unburnt carbon can cause the decrease in pozzolanic activity of material (Neville, 2002). The content of alkalies, MgO, Cl^- and soluble phosphates does not exceed the values acceptable according to EN 450-1: 2007. The average pH value of water extract from ash was 8,61. The quantitative content of trace elements in the ash is presented in Table 2. No extreme values were observed.

Table 2. Trace elements concentration (ppm) in comparison to dry mass of by-product

Trace element	Content (ppm)
Cr	85
Cd	<0,375
Zn	1119
Cu	357
Ni	65
Pb	26
Hg	0,20

The average water absorbability of ash in natural state was 65% after 24 h and 71% after 48 h of test.

Experimental procedures for testing sludge ash as replacement for cement

The ground material was used as the active mineral addition for mortars. The ash was ground in the laboratory ball mill. The ground material was characterized by the granulation below 0,063 mm.

The utilization of ground ash as supplementary cementing material demands estimation of its influence on physical processes occurring during the cement setting. The test of water requirement for normal consistency and setting time were measured by the Vicat apparatus using the samples of pastes consisted binder and water according to EN 206-1:2003.

The development of mortar strength was investigated. Whereat, the speed of the setting and the speed of the hardening i.e. the speed of the increase in strength, are independent (Neville, 2002). The influence of waste material on mechanical properties was determined using the samples of mortar containing different amount of ash. The ordinary Portland cement (OPC) CEM I 42,5 N-HSR/NA and river sand, fraction 0÷2 mm were used. Mortar is characterized by higher binder content related to filler in comparison to concrete, thus the observations of supplementary cementitious material influence are easier.

The compositions of mortars tested were given in Table 3. The ordinary mortar without any addition was made for reference and the mortars with 10% and 25% cement replacement by ground ash from sludge combustion have been prepared for testing.

Table 3. Composition of the mortar mixes in kg/m^3

Component	Composition of mix with ash [kg/m^3]		
	0%	10%	25%
Cement	450	405	337,5
Water	225	225	225
Sand	1350	1350	1350
Ground ash	-	45	112,5

According to Neville (2002), a property determined the suitability of the active addition to the manufacturing of cement based composites is its pozzolanic activity. There are different methods to assess the material activity in the reaction with cement, but the most authoritative and the most certain is the method of the test of compressive strength of cement with ash and comparing its results with compressive strength of cement without the addition (Neville, 2002).

Pozzolanic activity of ash was evaluated according to standard EN 450-1:2007. The pozzolanic activity index was determined on the basis of the comparison of compressive strength of mortars containing 75% of cement and 25% of ground ash, and mortar without addition.

The tests of mortar strength were conducted using prism shaped samples (40×40×160 mm). After casting the samples were kept in moulds during 48 h since the delay of hydration process of binder. The aim to apply the prism shaped specimens was to evaluate the compressive as well as the flexural strength. The flexural strength was determined in bending test and every series consisted of three replicates. The compressive strength was determined on half-prism samples. Every series consisted of six replicates. After demoulding, the samples were stored in the tap water at the temperature 18±2°C to the time of the test. The strength properties of mortars were determined after 28, 90 and 180 days of storage.

RESULTS AND DISCUSSION

The introduction of ash into mortar had an effect on its bulk density. The bulk density of hardened mortar containing 0, 10 and 25% of sludge ash, was 2219 kg/m^3, 2187 kg/m^3 and 2075 kg/m^3, respectively.

Calculated indexes of the pozzolanic activity of the ground ash together with values required for coal fly ash, were presented in Table 4. Despite the large content of unburnt carbon, the indexes exceed the required values, what proves the correct course of pozzolanic reaction during cement hydration. The pozzolanic effect of sewage sludge ash can be explained by the reaction between the calcium aluminosilicate phase contained in ash and the calcium hydroxide from cement.

Table 4. Pozzolanic activity indexes (acc. to EN 450-1) of ground sludge ash

Mortar age	Requirements	Activity index
28 days	75%	92%
90 days	85%	99%

The test results of water requirement for normal consistence of paste with 0, 10 and 25% of ash, were 128, 142 and 148 ml, respectively. The sludge ash influence on setting time of binders with ash and cement was presented in Figure 2.

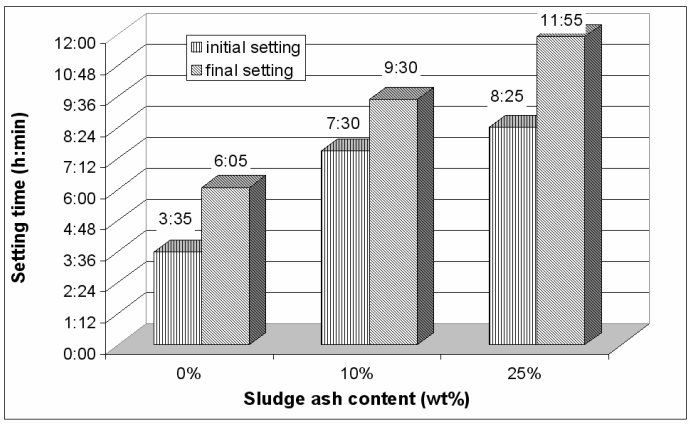

Figure 2. Initial and final setting time of pastes with ground ash addition

During the test of setting time it was found that the ground ash, both in the quantity of 10% and 25% of cement mass, considerably delayed the initial time of setting, however the entire time, from the beginning to the finish of setting, does not change essentially in comparison to control paste with Portland cement. The reason of the slowdown of cement hydration process can be the presence of the significant amount of the phosphorus in the ash in comparison to the typical hydraulic binder. The phosphorus contained in the ash passes to the liquid phase of paste in the form of PO_4^{3+} ions which reacting with Ca^{2+} ions, forming the difficulty soluble calcium phosphate $Ca_3(PO_4)_2$ on cement grains and makes the access of water difficult, which has an effect on cement hydration (Neville, 2002).

The test results of compressive as well as flexural strength of mortars are presented in Table 5.

Table 5. Strength development of mortars with ground ash addition

Content of ash related to cement mass	Compressive strength after days (MPa)			Flexural strength after days (MPa)		
	28	90	180	28	90	180
0%	35,8	43,4	45,6	7,9	8,0	8,2
10%	39,4	39,9	47,9	7,2	7,6	8,0
25%	32,3	43,2	50,8	6,4	7,7	8,1

After 28 days of curing the mortar with 10% of ash gained higher compressive strength than the mortar without the mineral addition. The test results after 180 of storage show that both mixes containing ash were able to develop higher strength than the control mortar. It is found, in considered range of ground ash content in mix, that the rate of strength development is lower for mixtures containing ash, at early ages. The rate of strength gain in mortars with ash is significant between 28- and 180-days. The analysis of variations in flexural strength of mortars containing ground material, could notice that the replacement of part of cement causes the slight worsening of strength tested after 28 days of curing in comparison to unmodified mortar. Positive effects of the addition can be observed after 90 days of curing, when the strength of mortar with 10% and 25% of ash is comparable with the strength of referenced mortar.

The greatest increase in strength among 28 and 180 day of curing was evident for mortar containing 25% of ash related to cement mass. The slowed down process of the binder hydration, and consequently the slow development of or mortar strength, is a characteristic phenomenon for binders of pozzolanic properties. Even at longer curing, the mortar with ground ash from sludge combustion gains strength fairly higher than that of the concrete made with only Portland cement. Similar results have been found by other workers for coal fly ash.

CONCLUSIONS

The chemical composition and the morphology of the sewage sludge combustion product differs from well-known by-products used as a components of cement based materials. The ash showed acceptable chemical and physical quality for the production of cement mortars, final mechanical properties of which are acceptable for various applications. It should be mentioned, that practical utilization of ash needs different manufacturing instructions, particularly during casting and curing of cement based composites.

The ash can be used as partial replacement for cement, but the material needs a pre-treatment (grinding) for this application. The ground ash points out the pozzolanic activity. The addition has an effect on the slowdown of the process of cement composites hardening but it does not reduce their final strength. Although the rate of strength increase of sludge ash mortar is slower and sustains for longer periods, after 90 days of curing, mortars with up to 25% cement replacement by ash addition attained higher strength than referenced mortar. The utilization of ground ash as the partial replacement of the cement demands the prolonged time of curing, which is needed for specific applications or the higher setting time could be overcome by the introductions of set-accelerating admixtures. In this case, the tests of the compatibility of admixtures and the ash are indispensable.

Generally, the widespread utilization of different ashes in practice is limited by the variability in their compositions. Considering the chemical constitution and properties of material, the particular applications of ash as a component of mortar for elements or structures exploited under certain service conditions should be confirmed by research of required properties for these conditions in long-term tests. Further research should include the waste material influence on concrete durability to evaluate the suitability of concrete with sludge ash in various environmental conditions.

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Functional Properties of Glass-Ceramics for Building Application

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Abstract. Dense glass-ceramic composite materials (bulk density 2.5 – 2.7 g/cm^3; water uptake 0.9 – 5.5 %) were produced from waste glass, steel cooling refuse, aluminium scrap metal processing waste and carbonate less clay. The functional properties of these novel materials as well as their environmental impact were detected. Some mechanical characteristics such as ultimate stress (σ^*) of these materials were determined by four point bending, results are comparable to building ceramics. The correlation between structure, composition and properties of sintered glass-ceramic materials as a function of sintering temperature rate was studied. Ecotoxicity of glass-ceramic containing industrial waste was determined by *Daphnia magna* ecotoxicity test (LVS EN ISO 6341:1996). LC_{50} concentrations were measured.

Keywords: Glass-ceramics, industrial waste recycling, ecotoxicity, Daphnia magna.

INTRODUCTION

Scientists in the European Union and around the world work actively at different waste recycling issues, creating materials which are inert and storable in geological formation or which are new materials usable in national economics (Barbieri *et al.* 2000; Appendino *et al.* 2004; Cheng and Chen *et al.* 2003). Characteristic properties of industrial wastes are: their chemical composition, mechanical and physical/chemical properties, which were specified according to existing standards. After summarizing the data achieved it is possible to evaluate the suitability of waste for production of new composite materials. One possibility to recycle industrial waste is the production of glass-ceramic materials using powder technology and sintering by thermal treatment. Glass-ceramics are fine-grained polycrystalline materials formed, when glasses of suitable composition are heat treated, thus undergoing controlled crystallization to the lower energy crystalline state. However, only specific glass compositions are suitable precursors for glass-ceramics. Some glasses are too stable and difficult to crystallize, such as ordinary window glass, whereas others crystallize too readily in an uncontrollable manner resulting in undesirable microstructures. Secondly, heat treatment is a critical factor in attaining acceptable and reproducible products (Rawlings *et al.* 2006).

Novel glass-ceramic matrix composites A, E1 and E2 were developed using clay as the matrix and combination of Latvian industrial wastes – steel cooling refuses, etching refuses, peat ash, alumina scrap waste and waste glass. In order to make the manufacturing technology of novel glass-ceramic materials suitable to ordinary equipment, e.g. similar like one available in a ceramic plant for productions of building materials, it is necessary to investigate the relationships between the structure of materials, composition, crystalline phases created in glass-ceramic microstructure and mechanical properties at different sintering temperatures. The influence of each crystalline phase on the glass-ceramic mechanical properties could be established during comparison of mechanical properties of materials developed in various rate of thermal treatment.

In this work we present data on the microscale morphology of glass-ceramics materials, their mineralogical and chemical composition, as well as the relationship of the characteristic properties of the materials versus the rate of the thermal treatment.

However not all the industrial waste can be successfully recycled or used for production of new functional composite materials. In this case it is necessary to process them in order to prevent any harm to environment. It

is considered that one and the same industrial waste can have diametrically different environmental impact or environmental compatibility that is determined by waste chemical composition, which in its turn depends on production technology and raw materials used for production. Chemical substances (in this case – industrial wastes) are ecologically compatible only if they do not emit to the environment at any stage of their life cycle dangerous for environment or toxic substances (Walker *et al.* 2001). Material environmental impact is also characterized by lifetime and stability in natural or extreme conditions. However the most comprehensive concept of environmental impact of materials, such as their suitability for use in the places of close contact with living organisms, including human, may be achieved with toxicity tests. Due to the necessity to maintain the test objects in specific environmental conditions, it is required to provide bioassays in accordance with standards, applied for drinking water, sewage water and natural water tests. Still there is a lack of united technique for industrial wastes and waste containing composite materials toxicity determination.

Biotesting methods are based on detection of organism response to environmental changes. Comparing to chemical methods they give a range of advantages, offering the opportunity to evaluate the negative impact of different substances upon organisms, independent of their chemical composition. Use of ecotoxicological tests (bioassays) has a range of advantages: bioassays are adequate and accurate environment test methods at relatively low expenses; tests can be used for various ecosystems (sediments, waste water, etc.); unlike chemical methods, they allow to evaluate the substance impact, even without knowing its chemical structure.

There are no developed standard methods for characterization of ecological compatibility of building materials, specially containing harmful and toxic industrial waste.

To achieve the social acceptance of new composite products containing industrial waste it is necessary to establish methods to measure the possible negative impact of these materials on the environment.

METHODS

The following raw materials were applied: etching refuse, steel cooling refuse from Latvian steel production factory "Liepajas Metalurgs", waste glass from JSC "Valmiera Glass Fibre", peat ash from Riga "Thermal power station" and lime less clay from deposit "Liepa". The clay was used as plasticizer for press powders as well as in order to improve mechanical properties and the bonding between the particles of green body. The main elements of glass are: Si, Na, Ca, Al, Mg, K, Ti, Fe, while the etching refuse according to previous studies (Rozenstrauha *et al. 2005*) contains Ca, Fe, Al, Mg, silica, sulphur and carbon compounds; steel cooling refuse - Fe, Ca and as trace element Cr, but aluminium scrap metal processing waste – Al, Si, Ca, Zn, Fe and Cu. Taking into account the chemical and mineralogical composition of the selected waste materials, various mixtures for glass-ceramics productions during sintering were prepared, as described before (Rozenstrauha *et al.* 2009). According to their sintering behaviour, three more suitable compositions, labelled as E1, E2 and A were selected, as shown in Table 1.

Table 1. Waste containing mixtures (components in wt %) used for the fabrication of glass-ceramics and properties of sintered materials E1, E2 and A

Components of mixtures and properties of materials	E1	E2	A
Steel cooling refuse	30	30	-
Aluminium scrap metal processing waste	30	30	-
Waste glass	20	10	10
Clay	20	30	25
Etching refuse	-	-	15
Peat ash	-	-	50
Bulk density, g/cm^3	2.7	2.5	2.5
Water uptake, %	0.9	5.5	0.4

The mechanical properties of the glass-ceramic composite materials were determined by 4 point bending. The specimens were shaped to a parallelepiped 35.0±0.1 mm long, 6.0±0.03 mm wide and 6.0±0.03 mm thick. The tests were carried out on an Instron-4301 testing machine (Great Britain). For each group eight specimens were tested up to the point of specimen failure. The results of mechanical tests of these composite materials are presented in Table 2 and Figure 3. The sintered glass-ceramic materials were investigated with SEM-EDAX and XRF analysis. SEM-EDAX analysis was made using a JEOL 6380LV scanning electron microscope on polished sections which were coated with Au or C layer as a conducting layer to avoid sample charging. A set of secondary images was also taken with the same instrument to examine the surface morphology of the studied specimens.

Ecotoxicity of glass ceramic composite materials was determined by the using of acute toxicity test EN ISO 6341:1996 – Determination of the inhibition of mobility of *Daphnia magna* Straus (Cladocera, Crustacea). To

determine ecotoxicological properties of glass-ceramic materials *Daphnia magna* culture DM – VD13.07.05 (culture collection of Latvian Institute of Aquatic Ecology) was used as test object (Figure 1).

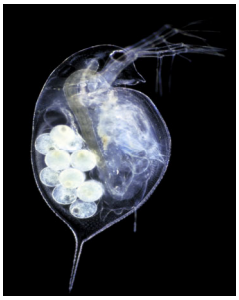

Figure 1. *Daphnia magna* with eggs

After 48 hours of exposition percentage of immobilized animals related to the general amount of used *D. magna* was detected and LC_{50} was calculated by Probit analysis. Toxicity of composite materials was detected in two forms of materials consistence – monolithic and powdered. Ecotoxicologial tests with monolithic materials were made without any treatment, as well as after thermal treatment - in order to clarify the impact of temperature on toxicants extraction from materials (temperature was increased until water starts to condensate on the walls of test vessel; after that suspension was cooled till test condition temperature 20±2 ^{o}C).

For powdered materials three types of tests were used: (1) with powdered suspension in water – to determine the influence of particles; (2) with filtrate of powdered suspension - to determine the influence of filtrate; (3) after thermal treatment of powdered suspension.

RESULTS

Studies on the relations between the microstructure of glass-ceramic and its mechanical properties

Morphological structure analysis for glass-ceramics E1 and E2 shows that samples are relatively similar (Figure 2). For example, glass-ceramics E1 and E2 in the sintering temperature 1140°C, have comparable microstructure (Figure 2, - a and d).

Table 2. Elementary chemical composition of surface and ultimate stress of glass-ceramic materials E-1 and E-2, sintered at different temperatures

Sintering temperature, ^{o}C	Ultimate stress (σ*), MPa, mean ± SD	Elements, wt %							
		O	Na	Mg	Al	Si	K	Ca	Fe
E1 1140	39.24 ± 5.0	41.66	3.82	0.77	13.22	34.43	3.07	-	3.02
E1 1160	64.55 ± 8.59	46.77	5.07	0.76	13.77	26.10	0.96	3.96	2.64
E1 1180	42.78 ± 11.64	50.83	4.79	0.44	11.82	23.44	0.44	3.93	4.31
E2 1140	38.50 ± 4.0	36.03	3.71	0.32	14.75	30.40	2.34	6.40	6.05
E2 1160	42.77 ± 8.98	41.24	1.93	1.11	9.10	21.67	1.73	0.47	22.75
E2 1180	38.02 ± 9.3	49.86	2.81	1.89	12.93	21.04	3.27	5.66	2.53

While some differences can be observed with increasing of sintering temperature – at the temperature 1180°C material E2 shows an increased porosity (Figure 2, f). The microstructures of materials E1, sintered at temperatures of 1140°C and 1160°C (Fig. 2, - a and b) show a surface with tiny pores and chemical composition of the matrix with a relatively high content of silica (34.43 – 26.10 wt %) and alumina (13.22 – 13.77 wt %), see in Table 2. This could be explained by the formation of a crystalline network of alumosilicates in the microstructure of glass-ceramic.

The microstructure of this glass-ceramics has uniformly distributed small pores (0.5μm< pore size < 10.0μm), interconnected with possible alumosilicate and other crystals. The image showing the microstructure of material E1 (Figure 2, c), sintered by thermal treatment temperature 1180°C, demonstrates that the surface of glass-ceramics has a higher roughness and bigger pores. This could be explained with the formation of a network of bubbles caused by the melting of the glassy phase together with the evolution of gases that are generated by the decomposition of some inorganic phases which are present in the material.

The data in Figure 3 show that the ultimate stress of glass-ceramic sintered at temperature 1160°C is considerably higher than glass-ceramic sintered at temperature 1140°C for both types of composites. The mechanical properties of material are improved by iron containing crystalline phases, which could be formed due to the high iron content in material from 2.64 until 4.61 wt % (Table 2).

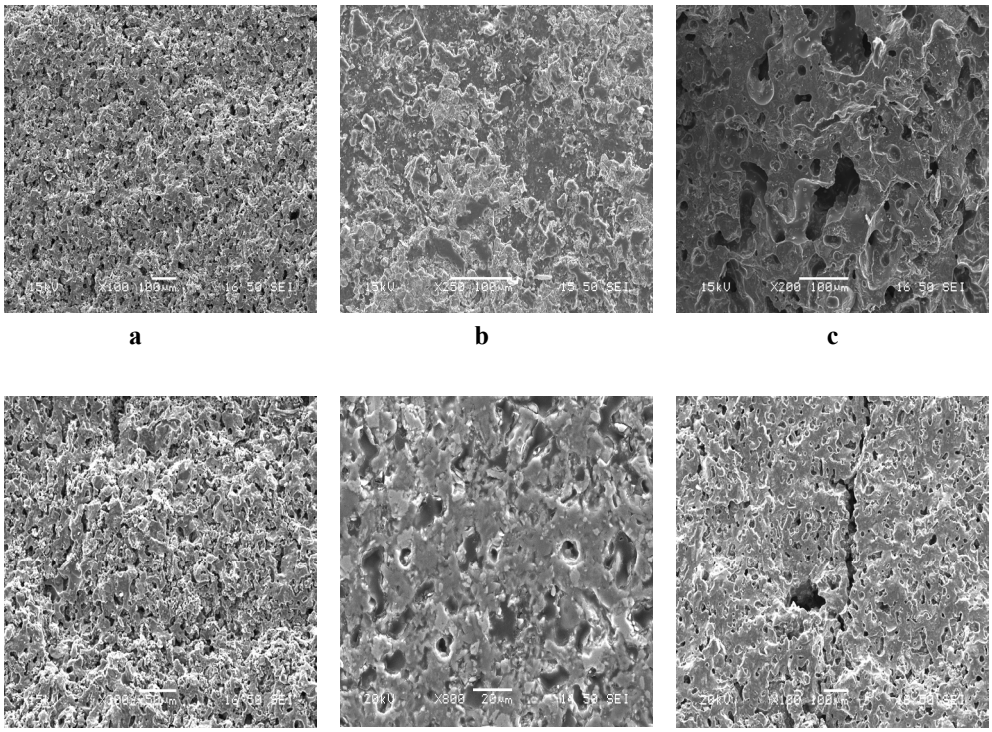

Figure 2. Scanning electron photomicrographs of the surface of the E1 and E2 glass-ceramics materials sintered at different temperatures (for E1 sintering temperatures are 1140 - a, 1160 - b and 1180°C – c, and for E2 sintering temperatures are 1140 - d, 1160 - e and 1180°C – f)

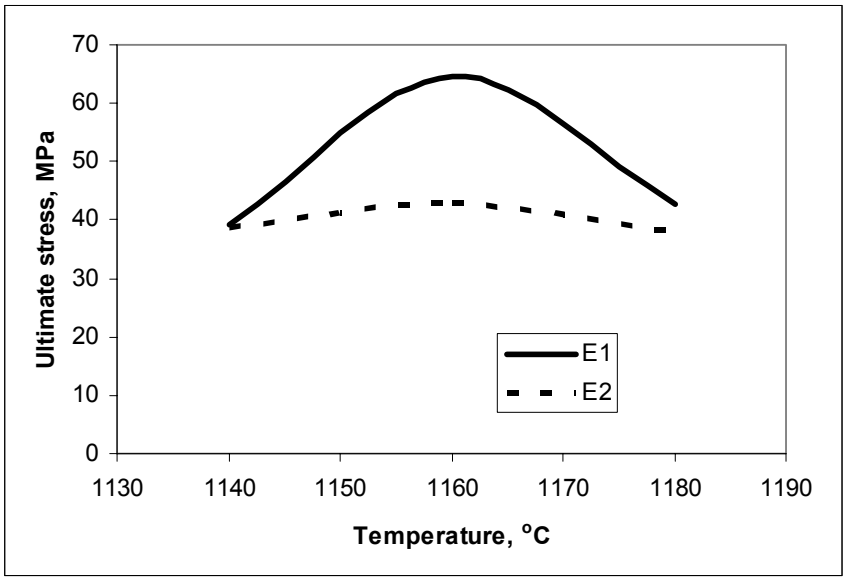

Figure 3. Ultimate stress of glass-ceramic materials as a function of sintering temperature

Material E1 sintered at the temperature 1180°C shows the decreasing of mechanical properties (until 42.78±11.64 MPa) due to the higher porosity of microstructure (Figure 2, c; Table 2).

In comparison with material E1, the microstructure of glass-ceramic E2 (Figure 2, - d, e and f) matrix is characterized by a larger number of isolated pores, approximately 0.5–10 µm in diameter. It conforms with the bulk density of materials – for material E1 the bulk density is 2.7 g/cm^3, for material E2 – 2.5 g/cm^3 (Table 1). Furthermore, in corresponding of microstructure of materials, the mechanical properties of material E2 show the

same consequence: materials with similar microstructure have no significant changes of mechanical properties during sintering interval (1140 – 1180°C) – it varied between 38.50±4.0 and 42.77±9.98 MPa (Figure 2 - d, e and f; Figure 3 – curve E2).

Ecotoxicity of glass ceramic composite materials

Ecotoxicological tests with **monolithic materials**, both for **A** and **E1**, **did not show any toxic effects** – mortality of *Daphnia magna* was not detected, showing that sintered monolithic glass-ceramics materials are non-toxic to environment. Even after thermal treatment of materials in order to facilitate the leaching of toxicants into the test solution the death of *Daphnia magna* was not detected.

In comparison to monolithic materials, powdered materials A and E1 showed a negative impact on development of test organisms.

Suspension of powdered material E1 caused 85 % mortality of *D. magna* at presence of highest experimental concentration (80.0 g/l). Toxicity of this material correlated with concentration of test solutions – with the increase of concentration of powdered material increased also mortality of test organisms *D. magna*. LC_{50} for this material after 48 hours exposure corresponded to 10.28 g/L. Toxicity of filtrate of powdered material E1 was significantly lower and was expressed by 19 % mortality (Figure 4).

Toxicity of suspension, as well as filtrate of powdered material A was significantly lower in comparison to material E1, causing 20 % and 13 % mortality at the presence of highest experimental concentration (80.0 g/l), respectively (Figure 4). Mortality of *D. magna* at the presence of powdered material did not reach 50 %; therefore LC_{50} concentration was not detected. Comparing test results of suspension and filtrate it can be concluded, that mechanical influence of particles on *D. magna* body is dominant and there is low concentration of toxic substances in filtrates.

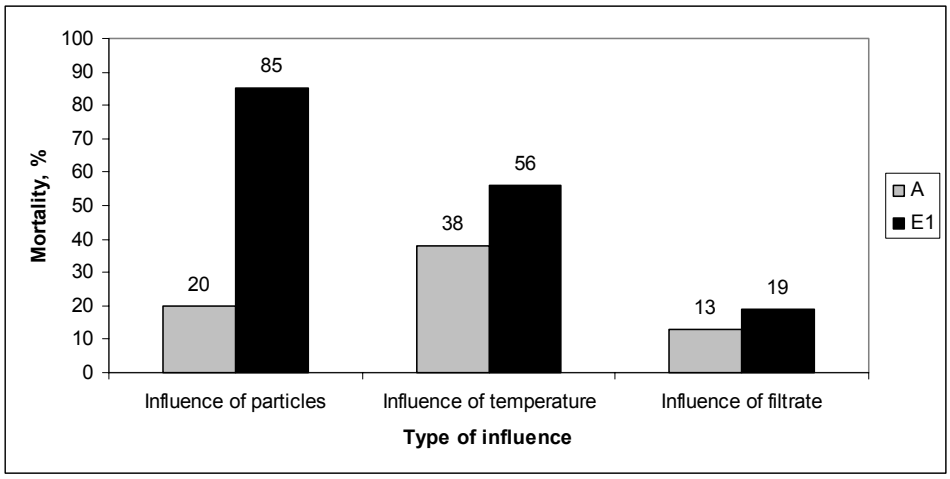

Figure 4. The influence of powdered materials on mortality (%) of *D. magna*

The influence of heating on toxicity of powdered materials E1 and A is not equipollent. Heating of suspension of material A significantly elevated toxicity, resulting in increase of *D. magna* mortality compared to the influence of particles (from 20 % to 38 %). It could be explained by an increase of concentrations of leached toxic substances in test solution.

The impact of heating on toxicity expression of E1 suspension was opposite and decreased negative impact was observed (from 85 % mortality to 56 %; Figure 3).

DISCUSSION

Mechanical and microstructure properties

From the studies of materials microstructure, chemical composition of materials surface and mechanical properties the relevancies in each developed direction could be summarized. The chemical composition is important for the creation of the needed functional properties of waste containing glass-ceramic – the microstructure, which ensures the incorporation of harmful substances of industrial waste into the crystalline network of glass-ceramic. Furthermore, the crystalline network of microstructure and the building of crystalline phases during the sintering temperature are responsible for good mechanical properties of glass-ceramic. From previous results it could be concluded, that produced glass-ceramic containing industrial waste according to their mechanical properties could be used as building material – the ultimate stress of sintered material (42.70±9.98 –

64.55±8.59 MPa) corresponds to the other glass-ceramics materials containing industrial waste described in literature (Rawlings *et al.* 2006).

Ecological impact of glass-ceramic materials

The acquired results showed, that consistence of composite materials is relevant - powdered form of glass-ceramic composite materials shows high or moderate toxicity (mortality 85 % and 20 % for E1 and A respectively) while the monolithic form of the composite material did not show any toxicity. Negative impact of powdered material could be explained with larger surface area of particles that ensures higher leaching quantity of harmful substances.

Remarkable difference in test organism's survival after exposition in particles suspension and filtrate could be explained with possible overlapping of the influence of leached toxicants in water and mechanic influence of particles on *D. magna*, having inconvenienced ability of moving, food filtration, breathing etc.

Differences in ecotoxicity expression of powdered materials A and E1 could be explained with properties and toxicity of raw materials, in proportion to composition of waste containing mixtures used for fabrication of glass-ceramics (Table 1). Taking into account the high content of aluminium in the composition of aluminium scrap metal processing waste (one of raw materials for E1), negative impact of E1 material could be connected with toxicity of aluminium compounds not incorporated in crystalline structure of material.

High proportional content of raw material that is used as dilution material (peat ash, glass and clay) of hazardous wastes assures low toxicity of material A. Beside that peat ash and waste glass, used in composition of this material to dilute potentially toxic substances and to incorporate potentially toxic substances into the crystalline network of material, is characterized by low content of heavy metals.

In comparison to powdered materials, toxicity of monolithic materials is independent from material composition, indicating on inertization of industrial waste toxic substances, forming structure of glass-ceramic composite materials. Therefore it could be concluded, that owing the high bulk density (2.5 – 3.2 g/cm^3, Table 1) and low water uptake (0.4 – 5.5 %, Table 1) monolithic glass ceramic materials did not express toxic effects and could be accepted as environmental friendly for freshwater ecosystems.

CONCLUSIONS

- In correlation of structural properties of glass-ceramic the following relevance could be seen: in sintering temperature interval (1140 – 1180°C) the improving of mechanical properties of materials corresponds to the changes of materials microstructure - crystalline phase with uniformly distributed small pores in microstructure (Figure 2, - b and e) corresponds to the highest ultimate stress (64.55±8.59 MPa for material E1 and 42.77±9.98 MPa for material E2), whereas the higher porosity of microstructure (Figure 2, - c and f) resulted with decreasing of ultimate stress of glass-ceramics (42.78±11.64 MPa for material E1 and 38.02±9.3 MPa for material E2);
- Produced glass-ceramic containing industrial waste at sintering temperature interval 1140 – 1180°C according to their mechanical properties could be used as a building materials – the ultimate stress of sintered material exceeds the requirements of Latvian standard for building ceramics LVS EN 14411;
- *Daphnia magna* test can be successfully used for determination of ecotoxicity of glass-ceramics composite materials;
- Powdered material A containing big amount of non-harmful industrial waste – peat ash, glass and clay show relatively low negative impact on environment, whereas toxicity of powdered material E1 could be explained by notable aluminium and iron content in raw materials – 30 % of aluminium scrap metal processing waste and 30 % of steel cooling refuse;
- Consistence of glass-ceramic composite materials play significant role in toxicity expression - the monolithic materials did not show any acute toxicity effects and could be accepted as environmental friendly for freshwater ecosystems;
- The production of glass-ceramic is one of the options for inertization of the harmful industrial waste in building materials or deposition of them into the geological formation.

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Influence of Waterproofing Admixtures on Properties of Hardened Concrete

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Abstract. It is important to have the concrete and reinforced concrete in buildings structures with less permeable liquid or less sorption of moisture. The study rated the liquid crystalline waterproofing concrete plasticizer and powdered waterproofing admixtures influence on structure of the hardened concrete and its physical properties associated with water penetration through element of structure. Explored concrete samples were compared with similar composition of the concrete, in which preparation was used super plasticizer. Concrete samples were formed from concrete mix which was industrially produced or prepared in laboratory conditions. The impact of a production method and the mixing quality on hardened concrete was determined. Additionally, the influence of the waterproofing admixtures on physical and mechanical properties of concrete was estimated. Considering the effect of both waterproofing admixtures on internal concrete permeability, the analysis of structure survey was presented. Based on these results, the process of the sorption of moisture or moisture in liquid form was compared at the drying freshly moulded concrete.

Keywords: waterproofing admixtures, super plasticizers, sorption of moisture, physical and mechanical properties of concrete.

INTRODUCTION

Humidity in a form of sorption or liquid form results in various processes of concrete structures and generally moistens the floor and the lower part of the wall. In order to avoid these processes, waterproofing materials are used in structures of the floors and lower walls; water drainage system is properly installed. In industrial and public buildings, there are cases where after a short period of maintenance the bubbles and cracking zones form on the surface of the floor with a coating. One of the reasons for such destruction is often a great accumulation of moisture content in concrete floor construction.

Some authors (Mu *et al.* 2009) note that based on moisture diffusion theory, the interior relative humidity of concrete can be predicted from moisture loss. By then incorporating these predicted relative humidity values into an existing relative humidity – shrinkage relationship, the shrinkage of concrete can be accurately modelled.

Sample preconditioning by oven-drying induces micro cracks with widths of 0.5–10 μm that are interconnected and randomly orientated. Micro cracking has a far greater influence on permeability than diffusivity or sorptivity, when comparing the same sample dried at 50°C and 105°C (Wong *et al.* 2009). It is argued that the higher permeability of concrete is attributable to more microcracking, and because the microcracks and paste are less tortuous than the equivalent mortar.

According to whether or not stresses can be created in structures when the deformation is restrained, the deformation of concrete in early ages may be divided into two categories: non-deleterious deformation and deleterious deformation. The deformation occurring after setting belongs to the category of deleterious deformation, whereas the deformation occurring before the setting point is non-deleterious deformation (Zhang *et al.* 2010).

Within the tested range, the influence of the volume to surface ratio (V/S) of the concrete specimens on the water absorption by immersion is not significant (with respect to the level of significance of 1%) when considering the natural scatter on the test results. The water absorption by immersion until saturation gives an estimation of the total (reachable) pore volume of the concrete, but gives no accurate indication on the concrete permeability, which is more important with regard to these durability issues (De Schutter *et al.* 2004).

At the depth of 20 mm, the mass variation reached a maximum, about 5% after 200 days. At greater depth, drying is not stabilised and continues. At the depth of 80 mm, internal relative humidity is still higher than 83% after more than one year (Multon *et al.* 2004).

The results indicated a strong dependence of the moisture diffusivity on the moisture content when above 80% saturation, whereas below this value it remains almost constant. The moisture diffusivity is significantly reduced with increased moist curing period (Cano-Barrita *et al.* 2004).

Water bounded by capillary forces stays in the capillary pores with a diameter of less than 20-40 μm. In such pores the running water is acted by capillary forces. The narrower capillary is, the greater capillary forces are. Capillaries with a smaller diameter than 0.2 μm can fill in with water from vapour sorption of water and condensation. Larger capillaries can be filled in with water only by directly contacting with water. It is possible to remove the water bounded by capillary forces in + (100...105)°C temperature. Free water stays in large capillary pores (with a diameter greater than 20-40 μm) and large cavities. Free water is easily removed by drying.

Dried material moistens, after finding its way into the air with a relative humidity. While moistened material dries to a certain limit, when brought into the drier air. It is the so-called moisture desorption. Usually moisture as vapour or liquid is moving in the same direction. Movement is caused by the partial vapour pressure and temperature gradients in the material. The movement of liquid water in material is conditioned by capillary gravitation, osmotic and gravity. It is estimated that within the boundaries of moisture sorption the major part of humidity is moving by diffusion of water vapour. Capillary condensation begins in capillaries, if relative humidity of ambient air is greater than 80-85%.

Drying is a process where the heat-treatment evaporates moisture and removes its' vapour. When material is drying, diffuse process happens, that is to say moisture evaporates (diffuses) from the surface of material into the environment and diffuses from the inner layers to the surface. Evaporation, and thus drying, intensifies with increasing vapour pressure, which is greater, if material is wetter and the drying temperature is higher. When material is drying, the humidity balance between material and environment is achieved after a certain period of time (Kaupienė *et al.* 2008), which is called the equilibrium moisture. Thereinafter material does not dry anymore. Equilibrium moisture amount depends on the parameters of the ambient air and humidity in connection with the material and the material properties. This moisture moves inside the material in the existence of pressure, which is greater than a capillary, and easily evaporates from the surface of material layers in natural drying conditions. Although the manufacturers of coatings indicate the necessary limits of moisture on the surface of concrete when laying the coating, but the process of moisture drying in the form of sorption or liquid in the freshly moulded concrete is not ascertained in detail.

THE EXPERIMENTAL METHODS AND MATERIALS

Compressive strength of samples was determined after 28 days of hardening in 2-4 hours from the samples removal of water (Figure 1). The density of concrete to the part of samples in this series was determined according to LST EN 12390-7:2009, and the compressive strength - in accordance with LST EN 12390-3:2009. During the samples' compression the speed of strength lifting was 0.6 MPa/s. Other samples, 2 hours after removing them from water, were marked (Table 1), weighed and placed in drying oven SNOL 67/350 LN (t_{max} = 350°C, 67l capacity), which provided a constant drying temperature (t = +100±5°C). Each day, samples were weighed on balances, capturing the loss of concrete moisture due to drying.

Figure 1. Samples were cured in a water bath

Two special waterproofing admixtures were used in this investigation, which were compared with the effective super plasticizer. Polycarboxylate ether super plasticizer was used for the production of the first composition („A", „A1") of concrete mixture, which can be used for self-compacting concrete (SCC), as well as

to produce very strong concretes, impermeable to water. Main material is ether of polycarboxylate, state – light yellow liquid, density – 1100 kg/m^3. Recommended doses are 0.2...1.6% of cement weight.

Another concrete mixture was produced with the admixture of liquid crystalline waterproofing plasticizer (composition „B“, „B1“), which during the lifetime in a moist environment can form additional crystals, which reduces the width of the opening up capillary cracks. This way, the water permeability of concrete is reduced, resulting from sealed cracks up to 0.4 mm. State – liquid, density – 1160 kg/m^3. Recommended doses are 2.0...3.0% of cement weight. Using this admixture a maximum W/C ratio can not exceed 0.55.

The third concrete mixture was produced with waterproofing admixture in powdered form (composition „C“, „C1“). It is designed for mortars of external use, concrete constructions of the moulded floors, foundations, basement walls, and bath. The surfaces of structures with this admixture become impermeable to water. This protects spaces from immediate effect of ground dampness and rain water. The admixture contains Portland cement, very fine quartz sand and active chemicals (ground limestone), which react with products of cement hydration, when there is an excess of moisture in fresh concrete. Like so new structures are compound, which fills capillaries of concrete pores'. State - solid powder, the recommended maximum amount of concrete powder mixture is 2% of the total content of cement. Bulk density of powder waterproofing admixture is 1450 kg/m^3.

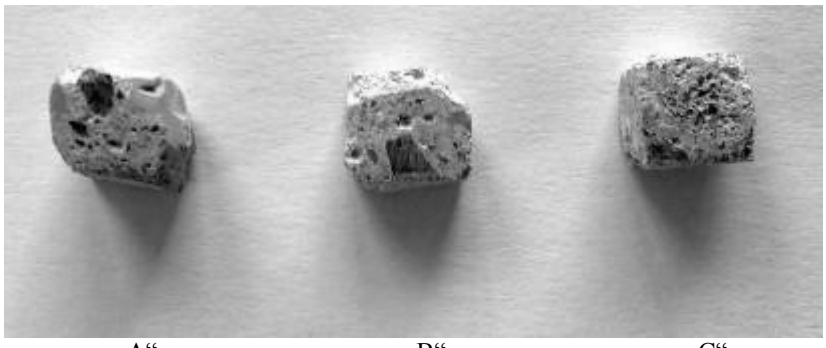
The sand fraction 0/4 mm was used for the production of cubes from investigative concrete, the particles' density - 2570 kg/m^3, bulk density - 1655 kg/m^3, coarse module - 2.2. As coarse aggregates it was used crushed gravel fraction 4/16 mm, the particles' density - 2584 kg/m^3, bulk density - 1420 kg/m^3, pollution with clays' particles - ≤ 1.5%.

In the production of concrete cubes it was used CEM II/A-LL 42.5 R cement, which technical characteristics are presented in Table 1.

Table 1. Characteristics of investigated cement CEM II/A-LL 42.5 R.

No.	Properties	Test Results	Requirements of LST EN 197-1:2001 /A1:2006/A3:2007		Test methods
			min.	max.	
1.	Compressive strength, MPa				LST EN 196-1:2005
1.1.	Early strength after 2 days	30.5	20.0		
1.2.	Standard strength at 28 days	53.1	42.5	62.5	
2.	Initial setting time (min)	330	60		LST EN 196-3:2005+A1:2009
3.	Soundness (volume stability) (mm)	0.0		10	LST EN 196-3:2005+A1:2009
4.	Water content for normal consistence cement paste, (%)	25.6			LST EN 196-3:2005+A1:2009
5.	Loss on ignition,% (by weight)	5.39			LST EN 196-2:2005 7 p.
6.	Insoluble residue,% (by weight)	0.60			LST EN 196-2:2005 9 p.
7.	Sulphate (SO_3),% (by weight)	2.68		4.0	LST EN 196-2:2005 8 p.
8.	Chloride,% (by weight)	0.004		0.10	LST EN 196-2:2005 14 p.
9.	Alkalis expressed by equivalent Na_2O,% (by weight)	0.80		0.8	LST EN 196-2:2005 17 p.

For the evaluation of the structure of hardened concrete, the examples of samples (Figure 2) were investigated by employing a scanning electronic microscope (SEM).



„A“ „B“ „C“

Figure 2. Specimen samples which were given for testing with scanning electronic microscope

COMPARISONS OF RESEARCH RESULTS

For the investigation of influence of waterproofing admixtures, some concrete mixes (marking and compositions were presented in Tables 2 and 3) were mixed by forced mixing in laboratory mixer, the others - by forced mixing in industrial mixer of 1.5 m^3 volume. Concrete mixture properties were determined 5 min past mixing. The slump of concrete mixture was determined in accordance with LST EN 12350-2:2009. The samples were formed in metal forms on the laboratory vibrating equipment. The samples of 6 units 100x100x100 mm were made with different admixtures and blending conditions, out of which three cubes were used for physical and mechanical properties of concrete to identify, the other three cubes were used for the kinetics of moisture movement to determine (of which one sample - for the analysis of concrete structures).

Table 2. The marking of concrete tested.

Marking	The marking complies with admixture
A	Concrete mixture was mixed in industrial mixer, using polycarboxylate ether super plasticizer
B	Concrete mixture was mixed in industrial mixer, using an admixture of liquid crystalline waterproofing plasticizer
C	Concrete mixture was mixed in industrial mixer, using a waterproofing admixture in a form of powder
A1	Concrete mixture was mixed in laboratory mixer, using polycarboxylate ether super plasticizer
B1	Concrete mixture was mixed in laboratory mixer, using an admixture of liquid crystalline waterproofing plasticizer
C1	Concrete mixture was mixed in laboratory mixer, using a waterproofing admixture in a form of powder

Table 3. Compositions of tested concrete mixtures.

Marking	Quantities of materials for 1 m^3 of concrete mixture, kg				Admixtures in 1 m^3 of concrete mixture, kg / (%)	W/C
	Cement CEM II AL-L 42,5 R	Crushed gravel fr. 4/16	Sand fr. 0/4	Water		
A	420	950	830	160	2.5 (0.6)	0.38
B	420	950	830	160	8.4 (2.0)	0.38
C	420	950	830	175	8.4 (2.0)	0.42
A1	420	950	830	160	2.5 (0.6)	0.38
B1	420	950	830	160	8.4 (2.0)	0.38
C1	420	950	830	175	8.4 (2.0)	0.42

Studied properties of concrete mixtures are below in Table 4.

Table 4. Properties of concrete mixtures tested.

Characteristic	Measurement units	Marking of concrete composition	Test result	Slump Class according to LST EN 12350-2:2009
Slump	mm	A	130*	S3 (100-150 mm)
		B	130*	
		C	120*	
		A1	130*	
		B1	130*	
		C1	120*	

Note: * The case of slumping - normal.

Comparing Tables 3 and 4 it can be noticed that to achieve slump class S3 for the „C“ and „C1“ compositions of concrete mixtures it was necessary to add about 15 liters/m^3 more water when compared with

other mixtures. Therefore, willing not to increase the powdered waterproofing admixtures in concrete and achieve a uniform slump in concrete mix, W/C ratio was increased from 0.38 to 0.42 (Table 3).

Testing the impact of waterproofing admixtures on hardened concrete properties, its effect on moisture desorption and physical - mechanical properties of concrete was assessed. All the properties of concrete were determined after hardening concrete in water for 28 days (Figure 1).

After performing the investigation of density evaluation (Figure 3) it can be noticed that by using either super plasticizer of polycarboxylate ether (compositions „A" and „A1") or admixture of liquid crystalline waterproofing plasticizer (compositions „B" and „B1") is obtained a similar density of concrete (2360...2400 kg/m^3). Meanwhile, the density of concrete's with powdered waterproofing admixture (compositions „C" and „C1") fell to 3.93...7.27% and amounted to 2200...2290 kg/m^3.

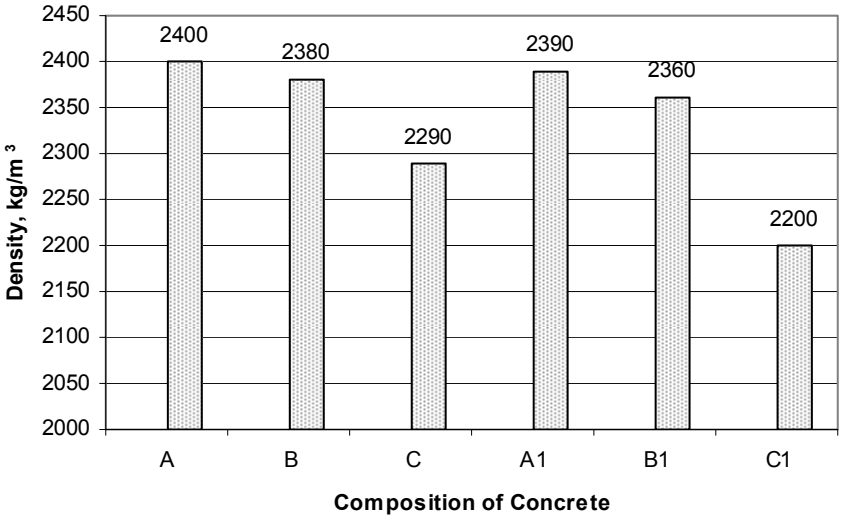


Figure 3. Density of hardened concrete specimens

Evaluating the results of mechanical testing (Figure 4) it can be noticed that the compressive strength of concrete samples in the „C" and „C1" compositions was smaller than in the remaining sample compositions. The compressive strength of concrete samples in these compositions was influenced by higher W/C ratio (0.42 instead of the other formations of the former 0.38, Table 3).

In addition, it can be noticed that the mixing method also influenced the compressive strength of the samples. The compressive strength of hardened concretes, which was mixed in an industrial mixer, was about 8% higher than the one blended in a laboratory mixer (Figure 4). This can be explained by the fact that materials and used admixtures were mixed better when mixing in an industrial mixer at a greater intensity of mixing. When the porosity of concrete is increasing and capillary pores are communicating among themselves, the moisture permeability of concrete is also increasing.

After 28 days of concrete curing in water, cubes were weighed and placed in drying oven SNOL 67/350 LN, which was kept at a constant temperature of +100±5°C. Every day, 30 minutes after disconnecting the drying oven, the samples were weighed. After the calculations of sample weight loss due to drying of concrete, it appears that samples, produced of the mixtures which were mixed in an industrial mixer, moisture loss was lower than the samples' which were blended in a laboratory mixer. It can be noticed, that the weight reduction (moisture shrinkage) of samples „C" composition after 35 days and after 43 days have no difference (Figure 5). This showed faster moisture desorption in these concrete samples. Accelerated moisture desorption in the samples of „C" composition might have been caused by the cracks of an increased width when compared with the „A" concrete composition (Figure 6). During this study, the weight change of „B" and „B1" composition samples, during the drying process of concrete, was noticed to be less as compared with other samples. This can be explained by the fact that the „B" and „B1" samples were produced with the admixture of liquid crystalline waterproofing plasticizer, which while concrete hardened, made the tubes with crystals in its capillaries, which reduces the concrete pore diameter (Figure 7).

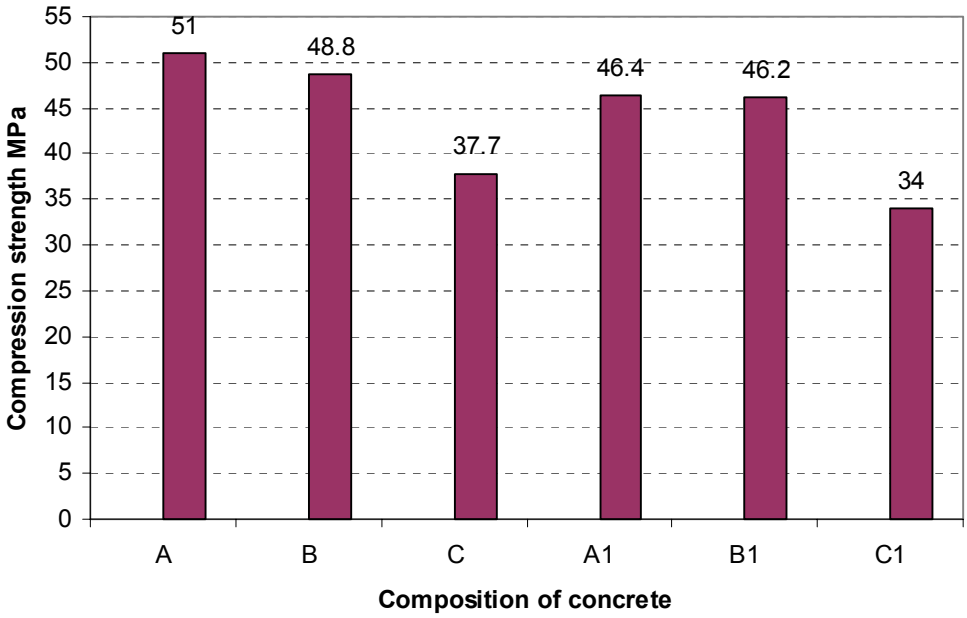


Figure 4. Compressive strength of concrete samples

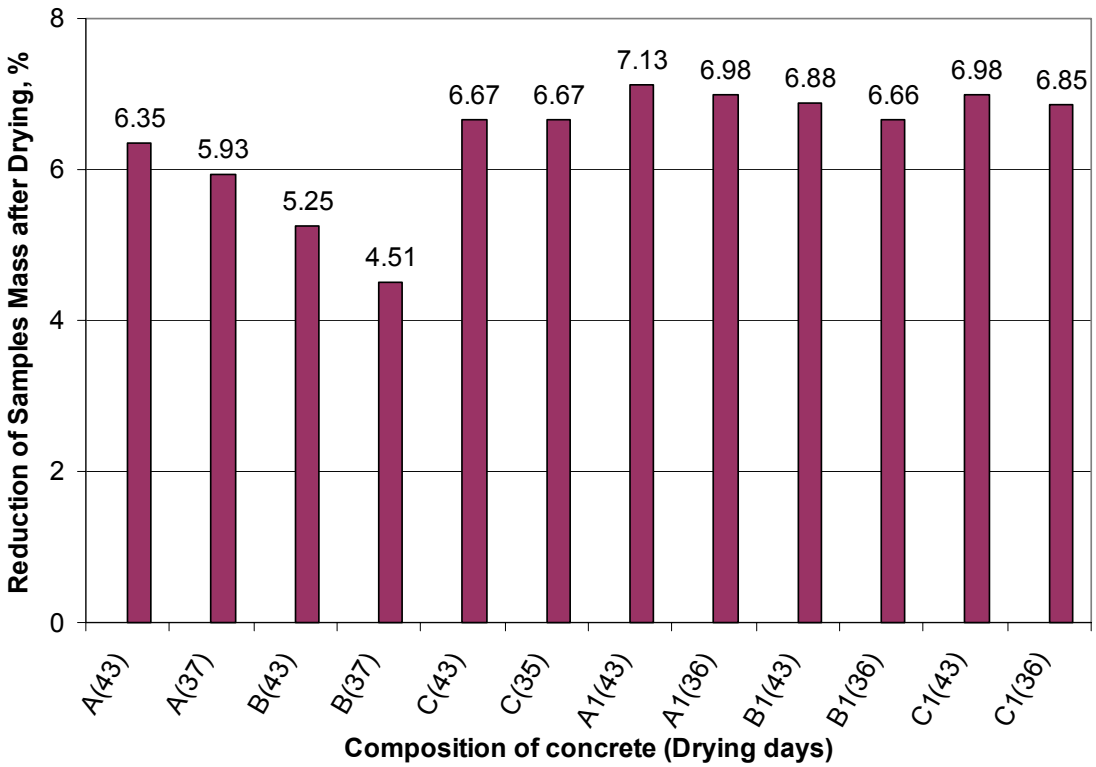
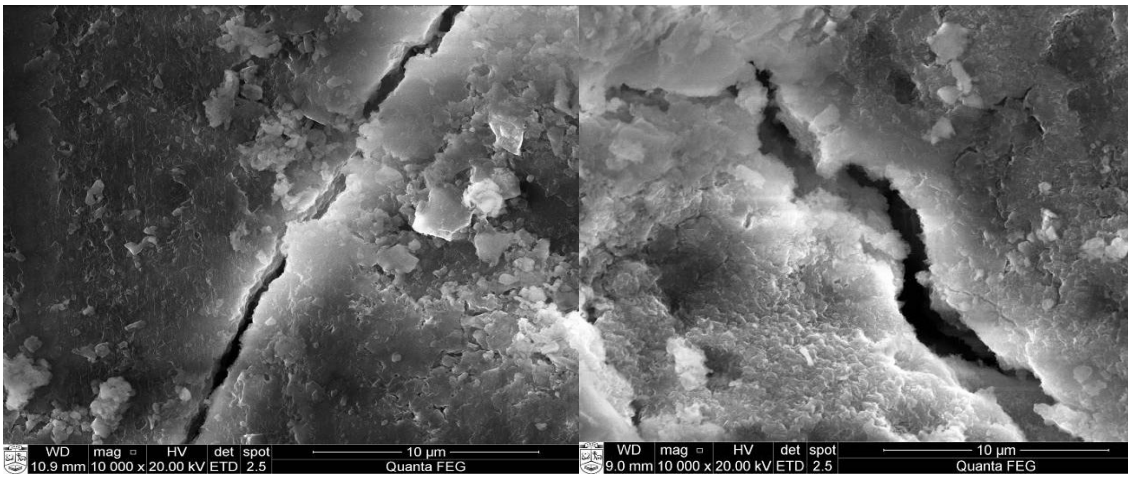
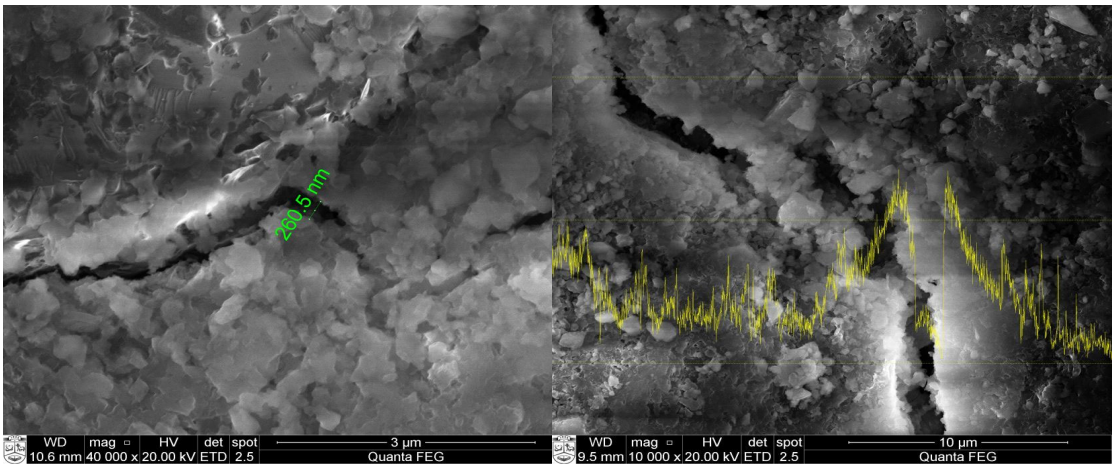


Figure 5. Weight loss of specimens after concrete drying at a temperature of +100±5°C



„A“ „C“

Figure 6. A comparison of cracks formed in the sample cement stone between „A” and „C” concrete compositions



„B“ „B1“

Figure 7. Crystals formed in the cracks of „B” and „B1” composition of concrete samples in cement stone reduced the crack length and width

CONCLUSIONS

1. The mixing of the same composition of concrete mixture influences hardened concrete moisture desorption.
2. Drying the concrete with the waterproofing admixture in the form of powder at +100±5°C and in desorption, equilibrium moisture content stabilizes within 35 to 36 days. In concretes with polycarboxylate ether super plasticizer or with the admixture of liquid crystalline waterproofing plasticizer the equilibrium of moisture content is reached within 41 to 43 days.
3. Cracks with greater width are more characteristic for cement stone structure of concrete with waterproofing admixtures when compared with concrete, made by using polycarboxylate ether super plasticizer.
4. Cracks of cement stone in concrete with admixture of liquid crystalline waterproofing plasticizer are “closed” by crystals formed by this admixture, and that leads to lower moisture migration in concrete.

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Pozzolanic Additives Influence on Ultra High Performance Concrete Properties

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Abstract. This article describes, what high performance conrete is, what kind of structure this concrete has, what components are included in concrete mixture, how should be done mixing procedure, described properties of used materials and on what purpose this concrete mixture could be used. During the research was investigated how different amount of amorphous SiO_2 affecting fresh and hardened concrete properties, all results are shown in charts.

Key words: UHPC, pozzolanic additives, amorphous SiO_2, water absorption, mixture viscosity.

INTRODUCTION

Over the past few decades, concrete technology made impressive progress. One of the most important events, it is designed ultra high performance concrete (in short UHPC), which is so strong what in some cases can match even the steel. Although UHPC concept changed over the time, but today it is known as a concrete which has compressive strength greater than 100 MPa. Lithuania are not so advanced in concrete technology, so all types of concrete which has greater than 100 MPa are known as UHPC, foreign countries have additional classification: HPC, which has compressive strength 100-150 MPa and greater than 150 MPa compressive strength known as UHPC.

The main weakness of concrete is coarse aggregates, eliminating this weakness opens new opportunities for developing concrete compressive strength (Aïtcin *et al*. 2000). Using this unusual idea and additional use of pozzolanic additives lets achieve such concrete mixture, which could without any effort reach greater than 150 MPa. In order to produce such strength concrete it is necessary to use high qualities aggregates and properly choose proportion of used components. Pozzolanic additives are essential, because it makes more intensive hydration process, which makes more intensive crystallization process. During this chemical reaction grows larger crystals, which are essential for reaching greater concrete compressive strength, also during the same chemical reaction decreases porosity of concrete, which are also relevant to compressive strength (Zanni *et al*. 2001). Also pozzolanic additives allow optimize the structure and density, which affects the concrete micro and macro structure. Different types of additives have different effect for hydration process some additives could accelerate hydration process, while others could decelerate (Korpa *et al*. 2004).

The tiniest additive – microsilica is the most commonly used pozzolanic in UHPC. Its grain size smaller than 0,1 µm, also it is an amorphous and highly reactive additive. Microsilica increases compressive and flexure strength, increases abrasion resistance, reduces permeability, fills gaps between components also increases the technological properties of the mixture (Luther *et al*. 1990).

Concrete strength and density increases due to eliminating coarse aggregate. Due to increased density reduces porosity, which has positive effect for concretes mechanical and durability properties. In Lithuania UHPC has a great potential and could be used in various fields, such us: constructing new or repairing old bridge constructive, producing deep foundation, used in aggressive environment, build power plants, also it could be used as protective layer contacting with aggressive environment and in many other areas, where is needed high compressive resistance. One of the major UHPC disadvantages is relatively high costs (it is expensive and more accessible for industrial use) and requires high amount of cement (approximately of 700 kg/m^3). With the same amount of cement can be produced several time the same construction, however evaluated additional labor, maintenance costs and longer life span, UHPC has significant potential to be widely used in the future.

STRUCTURE AND MATERIALS OF UHPC

According to purposed polistructural theory (Sobolev *et al*. 2004) materials properties depend on macro level (the overall behavior of the cement and aggregates) and the micro level (other modified cement paste particles and impurities). Tipical UHPC composition consists of sand, cement, microsilica, crushed quartz, fibers, superpalsticizer and water. Each component of the mixture in its own way helps to optimize the properties of concrete, thus obtained extremely strong material with increased durability. In order to achieve strong, density and durable material essential to choose properly proportion of components. All components should conclude the most compact cohesion and maximum density. During optimal proportion selection must be taken another important factor, fine aggregates in the matrix are better set in movable inclusion rather than in a rigid skeleton. This compact structure can be achieved in two ways (Figure 1): by creating Compact packing or Spacing packing (Vernet *et al*. 2004). The main difference between two packings is that Compact packing can also lead to optimal cohesion, but still will remain a rigid skeleton, which can lead hardened concrete to fragile collapse, to avoid this, effort should be made a by making Spacing packing. Advantage of Spacing packing, that all particles are distributed in larger space, thus each particle are surrounded by at least two layers of cement, so in such way we achieving increased modulus of elasticity and material will become less fragile. Maintaining a minimum ratio between the mean diameters of two consecutive granular class sizes of 13 gives the desired spacing packing (Richard *et al*. 1995).

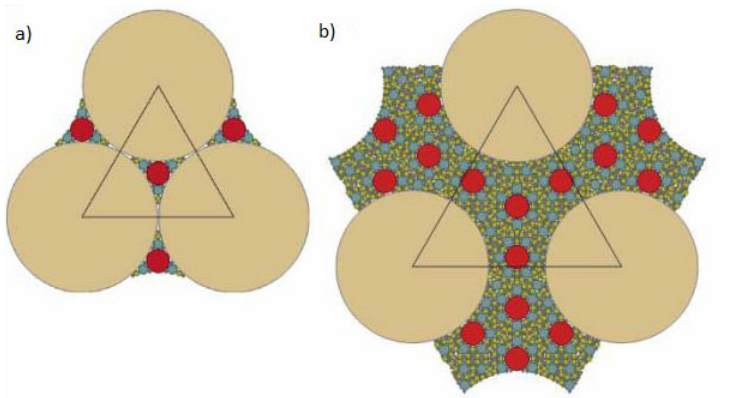

Figure 1. Compact packing (a) and Spacing packing (b)

Table 1. UHPC components

Component	Range of material quantity per cubic meter, kg	Typical material quantity per cubic meter, kg	Volume fraction, %
Sand	490-1390	991	38,80
Cement	610-1080	693	22,70
Microsilica	50-334	225	10,60
Crushed Quartz	0-410	208	8,10
Fibers	40-250	151	2,00
Superplasticizer	9-71	14,4	1,40
Water	126-261	159	16,50

Since there is no coarse aggregate in mixture, sand is the largest ingredient. Commonly is used quartz sand, because it is not chemically active and does not participate in hydration reaction also it gives additional compressive strength to hardened concrete (Porteneuve *et al*. 2002). Any type of Portland cement can be used to manufacture of UHPC. The most ideal cement is with large amount of C_3S, C_2S and minimum amount of C_3A. It is also desirable to use low shrinkage cement, because in mixture there is extremely high amount of cement, which lead to significant shrinkage of cement paste (Aïtcin *et al*. 2000). Also possible to use rapid hardening concrete, but in sulphate environment and areas where frost resistant needed it should be avoided (Vernet *et al*. 2004). The fact is that not all cement reacts during hydration so the part of cement (till 30 percent) can be replaced to: fly ash, blast furnace slag, glass powder, microsilica, metakaolin or in combination of several additives. Also could be used fibers but it is not compulsory. Fibers typically used two types: steel and polypropylene. It is necessary to estimate, that UHPC have very low porosity (approximate 1 % or less), so it is significantly sensitive to fire. In those places where is possible contact with the fire, required to use

polypropylene fiber (Schmidt *et al*. 2003). Any superplasticizer can be used, important that it would be based on polycarboxylate ether.

MATERIALS USED DURING THE RESEARCH

During the research used cement of UAB "Akmenė" CEM I 52.5 R with a mineralogical composition: C_3S-61%, C_2S-12%, C_3A-7%, C_4AF-13%, density 3100 kg/m^3, the specific surface - 370 kg/m^2, normal consistence paste - 27.3%, setting starts after 130 minutes compressive strength after two days - 30.6 MPa, flexural strength after two days of 6.0 MPa. These properties determined according to LST EN 197-1 standard.

During the research used AB "Anykščiai" quarry quartz sand with following characteristics: fraction -0/1; density - 2670 kg/m^3; bulk density - 1600 kg/m^3; clay and dust - 0.5%. Also used crushed quartz sand, with following characteristics: fraction 0/001; density - 2670 kg/m^3; bulk density - 1425 kg/m^3, clay and dust - 0.5%.

During the research used pozzolanic additive - microsilica. Mineralogical composition: SiO_2 - 92.08% Al_2O_3 - 1.16%, Fe_2O_3 -1.24%, CaO - 1.07%, MgO - 0.8%, SO_3 - 1.27%, K_2O - 0,67%, Na_2O - 1.13; granulometry, where particle size: <0.06 mm - 1.5%, from 0.06 to 0.08 mm - 2.5%, from 0.08 to 0.1 mm - 5%, from 0.1 to 0.15 mm - 19%, from 0.15 to 0.2 mm - 15%, from 0.2 to 0.3 mm - 22%, from 0.3 to 0.4 mm - 17%, from 0.4 to 0.5 mm - 8%,> 0.5 mm - 10%, average particle size 0.22 mm; physical properties: density - 2120 kg/m^3; bulk density (poured freely/compacted) - 255/329 kg/m^3; specific surface - 3524 m^2/kg, hygroscopicity - 158%; natural disintegration angle - 54 degrees.

During the research used chemical additive - superplasticizer Glenium ACE 30. It is a liquid consistency, dark brown liquid, reducing the W/C ratio without altering the strength of concrete, which has the following characteristics: density - 1.06 g/cm3, chlorides - 0.1% equivalent alkali content, expressed as Na_2O - 1.0% dosage (weight of cement) - from 0.3 to 3.0%, the optimal environmental temperature using superplasticizer - 20 º C, should be protected from freezing.

RESEARCH METHODOLOGY

Concrete mixture proportions are given in Table 2. In order to investigate properties of UHPC, in the laboratory was mixed with properly proportion 3 series of concrete mixtures and made 9 specimens. Mixing procedure is shown in Table 3. All proportions had different characteristics: SiO_2 microsilica content varied from 13.5 to 18% of the total cement quantity, crushed quartz content varied from 20 to 40% of the total aggregate volume. Concrete mixing was performed with a vibrating mixer. This mixer is especially suitable for concrete mixtures with very low W/C ratio. Mixer inside the drum has vibratory cylinder, that vibratory cylinder due to vibration rotates constituents particles to each other, in such way all constituents falling into the right places with minimum content of water. Vibration parameters are chosen according to the composition of the concrete mixture. Main mixers characteristics: frequency range varied from 30 to 500 Hz and barrel capacity 4 liters.

Table 2. Concrete composition

Specimens number	SiO_2 quantity, %	Concrete mixture volume	Water, l	W/C	C, kg	SiO_2, kg	Total amount of FA, kg	Sand, kg		SP,l
								0/001	0/1	
1	13,5	1m³	183	0,21	876	118	1230	221	1009	37,67
2	16,2	1m³	183	0,21	876	142	1201	216	985	37,67
3	18	1m³	197	0,22	876	158	1183	213	970	37,67

Explanation: SiO_2 – microsilica, W/C – water and cement ratio, C – the amount of cement; FA – total amount of Fine Aggregate: fraction 0/1 and 0/001; SP – Superplasticizer.

Concrete viscosity was determined using falling ball method. Falling ball method is based on modified Stokes law (Vaikasas *et al*. 2007). Viscosity was measured using 10 cm height tube, clock, steel ball and metal detector. Tube was filled with known density of concrete and ball is placed on the top of tube poured with concrete. When the ball reaches constant velocity, clock starts to measure time needed to reach bottom of the tube. Metal detector precisely shows when steel ball velocity is constant and it reaches the bottom. Dynamic viscosity calculated according to formula 1.

$$\eta = K \cdot (\rho - \rho_1) \cdot t, Pa \cdot s \tag{1}$$

Here:

ρ- Density of concrete mixture;

ρ_1 - Density of steel ball;

t - Steel balls sinking time;

K - Viscometer constant, shown in formula 2.

$$K = \frac{0{,}5 \cdot g \cdot d^2 \cdot \left[1 - 2{,}104 \cdot \frac{d}{D} + 2{,}09 \cdot \left(\frac{d}{D}\right)^3\right] \cdot 0{,}1}{9 \cdot Z}; \quad (2)$$

g - Gravity constant;
Z - Height, where steel ball sinking was constant;
d - Diameter of steel ball;
D - Diameter of viscometer;

Specimens were made cylindrical form (diameter 50 mm) and left 28 days for hardening according to LST EN 12390-2 standard. Concrete density and compressive strength was determined according to LST EN 12390-7 and LST EN 12390-3 standard. Specimens were polished to get absolutely parallel surface and compressed to determine compressive strength. Parallel surface determined according to LST EN 772-16 standard.

Table 3. UHPC mixing procedure

Time, s	Procedure
60	Homogenizing sand, microsilica and cement
30	Poured all water and 50 % superplasticizer
60	Homogenizing
120	Pause
30	The rest of the plasticizer dosage
60	Homogenizing

RESULTS OF RESEARCH

In research main issue was to determine, how microsilica effects water absorption, viscosity, relative water absorption and compressive strength. Results displayed in figures 2 - 5. Figure 2 shows that the more SiO_2 are in mixture, the greater amount of water needed to obtain the normal viscosity paste. That could be explained, because microsilica has a very high specific surface, the higher the surface the more needed water to moister grains and obtain normal viscosity paste.

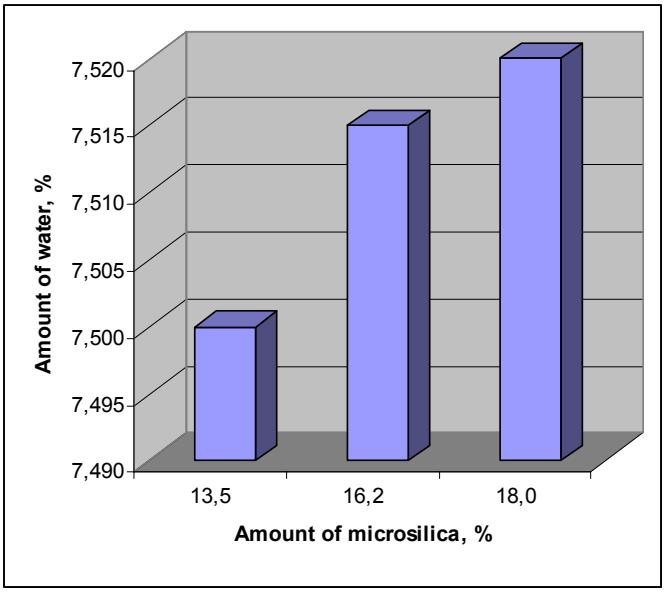

Figure 2. Microsilica influence on water content for normal consistence paste

Viscosity was determined for each specimen with different amount of SiO_2. Each specimen had the same W/C ratio. Viscosity increases, with increased amount of microsilica, it grows in proportion from 28 to 120 Pa·s (Figure 3). Due to increased quantity of microsilica in mixture, water penetration into the concrete decreases.

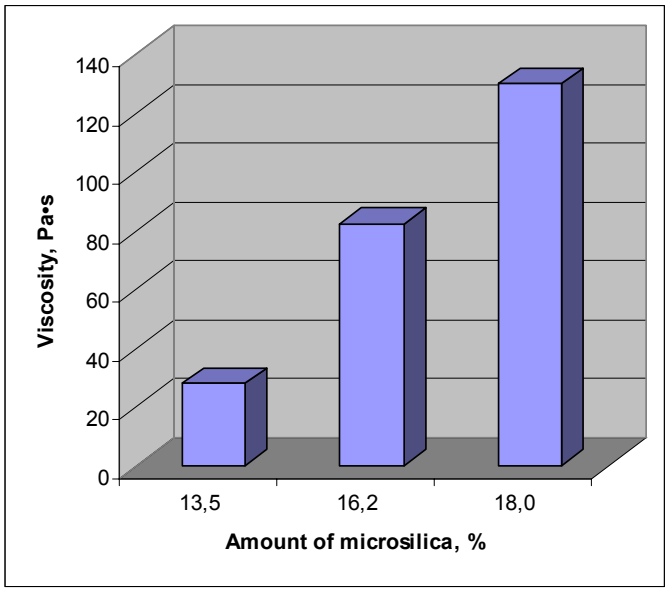

Figure 3. Viscosity of concrete mix dependence of the microsilica quantity

This means, that specimen with less amount of microsilica has larger capacity pores. The larger amount of pores gives better water penetration to concrete. Results are followings (Figure 4): when content of microsilica 13,5% - relative water absorption 3,69 %, when content of microsilica 16,2 % - relative water absorption 5,09 %, when content of microsilica 18% - relative water absorption 3,89 %.

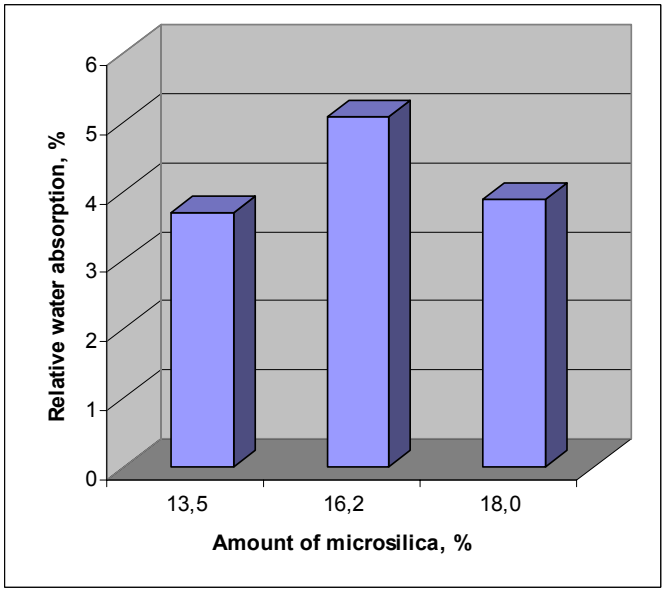

Figure 4. Relative water absorption of concrete with different quantities of microsilica

Figure 5 shows, that with increased amount of microsilica, compressive strength of concrete decreases. That could be explained that the compresive strength loss is due to worse components proportion also due to secondary hydration and molar ratio imbalance. Results are followings: when amount of microlisica 13,5 % compressive strength 140,16 MPa, when amount of microlisica 16,2% compressive strength 95,42 MPa, when amount of microlisica 18,0% compressive strength 105,00 MPa.

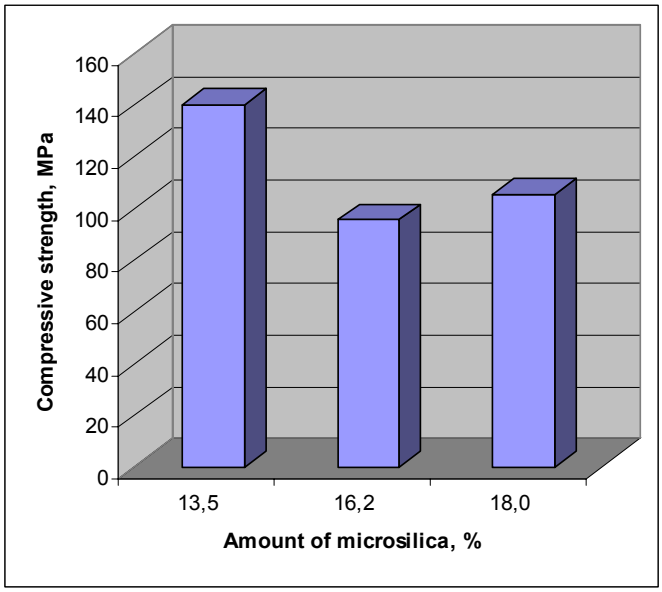

Figure 5. Concrete compressive strength with different amount of microsilica

CONCLUSIONS

Research founded, that with increased amount of microsilca requires higher amount of water to achieve normal viscosity paste.

Concrete mixture dynamic viscosity depends of microsilica content. Higher amount of microsilica increases viscosity of concrete.

Noticed, that with increased amount of microsilica water absorption is reduced. This could be explained, because in matrix formed less volume of pores.

Maximum compressive strength of UHPC achieved, when the SiO_2 is about 13%.

Use of microsilica makes more intensive hydration process, which makes more intensive crystallization process. During the chemical reaction porosity decreases, that has very positive effect for durability and mechanical properties of concrete. Further investigation shows, that there is no threat of alkaline corrosion.

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Investigation of Cement Hydration in the Presence of Permutite

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Abstract. Permutites, i.e. synthetic amorphous sodium aluminum silicates being capable of ion exchange and being of the approximate composition: $Na_2O \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O$; x- usually 5-6. These synthetic aluminosilicates chemical composition and properties are similar to natural zeolites. So, literature offers a lot of material of various aluminosilicate material additive usages in concrete systems, but there were no information, that zeolite like permutites were used like puzolanic additives in concrete technology. In the present work, a amorphous aluminosilicates, named generally as permutite, was used like additive in hardened cement paste and some properties as well as its influence on portlandcement hydratation was determinated. Initial studies of permutite admixture showed that at the portlandcement hydration time permutite reduces the quantity of free $Ca(OH)_2$ in hardened cement paste specimens and takes part in pozzolanic reaction with $Ca(OH)_2$, when secondary calcium hydrosilicates formed. The hardened cement paste specimen density when added permutite additive from 1 up to 10% remains similar even increases little when 5 % permutite is added. It can be stated that the admixture of permutite which has amorphous structure improves the strength of the hardened cement paste and added permutite additive in all cases there was an increase.

Keywords: permutite, cement hydration, pozzolanic materials.

INTRODUCTION

The incorporation of zeolite in cement contributes to the consumption of $Ca(OH)_2$ formed during the cement hydration and the formation of cement-like hydrated products. The pozzolanic reaction of the zeolite is rather is accelerated after the 28 days. Like other pozzolanic materials such as silica fume and fly ash, zeolite contributes to concrete strength mainly through the pozzolanic reaction with $Ca(OH)_2$ (Janotka *et al*. 2003, Poon *et al*. 1999, Kontori *et al*. 2009, Perraki *et al*. 2003). Zeolites are crystalline aluminosilicate based materials and containing large quantities of reactive SiO_2 and Al_2O_3. The main advantages of synthetic zeolites are that, they can be engineered with a wide variety of chemical properties and pore sizes, and they are stable at high temperatures but have some limitations too. The main limitations of synthetic zeolites are: relatively high cost. Synthetic amorphous aluminosilicagel, permutite are much cheaper materials.

Permutites, i.e. synthetic amorphous sodium aluminum silicates being capable of ion exchange and being of the approximate composition: $Na_2O \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O$; x- usually 5-6

The first aluminosilicate ion exchangers were synthesized in 1903 (Harms *et al*. 1903). They can be produced from the melt or from solutions at normal or increased temperature (Derleth *et al*. 1978). The cation-exchange material, an amorphous aluminosilicate permutite-like material, has an IEC of similar to 2.5 mequiv g(-1) (Pless *et al*. 2006). The data suggest that the IEC value of these amorphous aluminosilicates is dependent on the tetrahedrally coordinated aluminum (Pless *at al*. 2005). The simplest permutite is isostructural with the mineral sodalite, but there are hydroxyl ions in the 000, 1/2 1/2 1/2 positions instead of chlorine ions, and the oxygen atoms are somewhat displaced. The cell constant of permutite increases from 8.93 to 9.03 A, on heating to 850°. The permutite contain 10 molecules of water, of which two are in the form of hydroxyl while the remaining eight are in the form of zeolite water (Sakavov *et al*. 1963).

The relationship between amorphous geopolymeric products and zeolite crystals with the same overall chemical compositions was discussed. The infrared evidence shows that SiO_4 tetrahedra are partially bonded by AlO_4 during the hydration process of geopolymeric cement (Zhang *et al*. 2008). The mutual transformation between Geopolymeric cement products and the corresponding zeolite crystals would take place once the condition is suitable, which revealed that the Geopolymeric cement products are probably the amorphous equivalent of the corresponding zeolite crystals (Zhang *et al*. 2006).

The main product of reaction in the geopolymeric materials was amorphous alkali aluminosilicate gel. However, in the case of sodium hydroxide activator in addition to it, traces of chabazite, Linde Type A, Na-P1 (gismondine) zeolites and hydroxysodalite were also present. The type of zeolite present and composition of aluminosilicate gel were dependent on the curing history (Bakharev 2005).

In this study (Swanepoel *et al*. 2002), fly ash, a waste product of the electricity and petrochemical industries, was investigated as a basic ingredient of a new geopolymeric material. X-ray diffraction measurements show quartz as the main constituent with the largest part of the geopolymer structure being amorphous and glass-like.

Authors (Pacewska *et al*. 2002) report about the effect of waste material on cement hydration kinetics. In the presence of a aluminosilicate admixture, the $Ca(OH)_2$ content decrease in cement pastes due to the pozzolanic reaction is observed. The surface area of hydrated paste becomes higher and the strength increase.

The present investigation (Škvara *et al*. 2009).has been focused on the influence of temperatures ranging from 20 to 1000°C on properties of aluminosilicate polymers materials. The Na leaching declines in a very significant way after firing at temperatures above 600°C and the tendency to the formation of efflorescence disappears. Aluminosilicate polymer materials exhibit excellent material properties.

In this present paper (Fernández-Jiménez *et al*. 2009).discusses the technological fundamentals for producing high quality cement using industrial byproducts as prime materials (fly ash from a steam power plant, and granulated blast furnace slag). These new cements are particularly suitable for the precast industry: manufacture of railway sleepers, concrete blocks, and so on.

So, literature offers a lot of material of various aluminosilicate material additive usages in concrete systems, but there were no information, that zeolite like permutites were used like puzolanic additives in concrete technology. In the present work, a amorphous aluminosilicates, named generally as permutite, was used like additive in concrete and physical - chemical properties as well as its influence on portlandcement hydration was determinate.

MATERIALS AND METHODS

The Portland cement CEM I, 52,R (specific surface – 370 kg/m^2, paste of normal thickness – 27.3 %, initial setting time – 130 min, final set – 215 min) mineralogical composition C_3S = 50.7 %; C_2S = 18.5 %; C_4AF = 14.2 %; C_3A = 9.7 % was used this study.

Permuntite is one of the silica and aluminium rich raw materials. This material contain: Al_2O_3 = 24.6 %; SiO_2 = 40.8 %; Na_2O = 14.1 %; H_2O = 20.5 %. Its particle diameter was 277,5–389,0 μm, and a specific surface equal to S = 0,177 m^2/cm^3.

The X-ray diffraction analysis was conducted using DRON – 6 diffractometer. The investigation was carried out with a 2Θ angle range 4 - 70° with Ni - filtered the CuK_α radiation. Thermographic investigations have been carried out by using differential scanning calorimeter *STA 409 PC* of firm Netzsch. Maximal temperature was 1500 °C, and the velocity of the increase in temperature was 10 °C/min. IR spectra were recorded with Perkin Elmer FT-IR System spectrometer. For the IR analysis, 1 mg of the substance was mixed with 200 mg of KBr and compressed in a forming press under vacuum. A high resolution scanning electron microscope FEI Quanta 200 FEG with a Schottky field emission *gun* (*FEG*). Chemical compositions of permutite were investigated by an energy-dispersive X-ray spectrometer (EDS) with silicon type drift droplet detector. The size distribution and specific surface of the Mastersizer 2000 instrument Malvern's company determinate.

For the analysis of the effect of silicagel addition (5, 10, 15 % of mass) on the properties of cement stone, the series of hardened cement paste mixtures were chosen and mixed in a laboratory mixer. Samples were formed, i.e. prisms of 2x2x2 cm in size, that hardened for 28 days under the conditions regulated by the LST EN 196 standard. The compression strength of hardened cement paste was evaluated based on EN 196-1 standard. An automated and computerized ToniTechnik 2020 press was used to evaluate the compression strength of hardened cement paste.

RESULTS AND DISCUSSION

To get permutite, these materials where used as $SiO_2 \cdot nH_2O$, $Al(OH)_3$, Na(OH). In order to get permutite, analogical to zeolite X, composure according to literature the following mole ratios were chosen: Na_2O/SiO_2 = 1,2; SiO_2/Al_2O_3 = 10; H_2O/Na_2O = 23. Gel was formed when mixed sodium aluminate and sodium silicate solutions. Then gel was aged for 72h in room temperature. X-ray diffraction patterns analysis (Fig. 1, a) was performed (after 72h of aged) it shows that material was amorphous.

It can be seen that in IR curve there is absorption bands that are typical to Na-X zeolite: 983-1012 cm^{-1} asymmetric valence vibration region 450 – 465 cm^{-1} Si(Al) – O deformation vibration region. So, IR spectrum shows that in reaction products the majority of vibration section absorption bands are typical to Na-X zeolite (Fig. 1, b). In room temperature during aluminosilicate gel aging time chemical bonds are formed between atoms that are typical to crystalline Na-X zeolite. According to data it can be state that in aluminosilicate gels chemical bonds are instantly formed between atoms and its amount is increasing during aging time

During hydration process after 3 - 28 days of hydration, in the all investigated specimens curves of X-ray diffraction patterns analysis (Fig. 2) non-hydrated alite diffractive peaks, characteristic of the inter-plane

distances *d* – 0,304; 0,279; 0,275; 0,261 nm and others, were identified. This testifies the fact that this mineral does not fully hydrate in 28 days. The X-ray diffraction patterns of all the specimens also show the diffractive peaks of portlandite (CH), a product of hydration, (*d* – 0,491; 0,262; 0,193; 0,179 nm etc.). The most intensive diffractive peaks of portlandite were identified in the specimens of hardened cement paste without using the admixture of permutite (Fig.2, cr. 5). In the meantime upon adding from 1 or 10 % of the mentioned admixture to the specimens, the diffractive peaks of portlandite are less intensive in the X-ray diffraction patterns (Fig.2, cr 1 - 4) compared to those of the control specimen without any admixture.

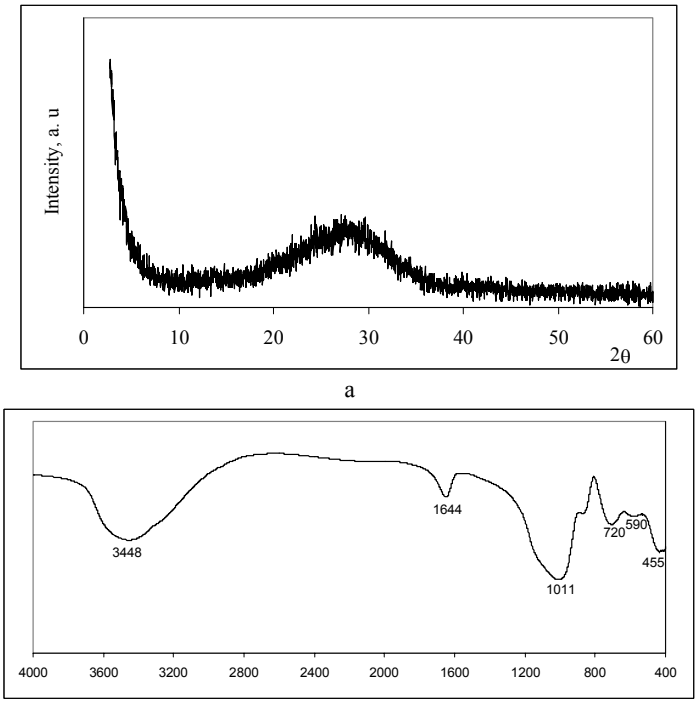
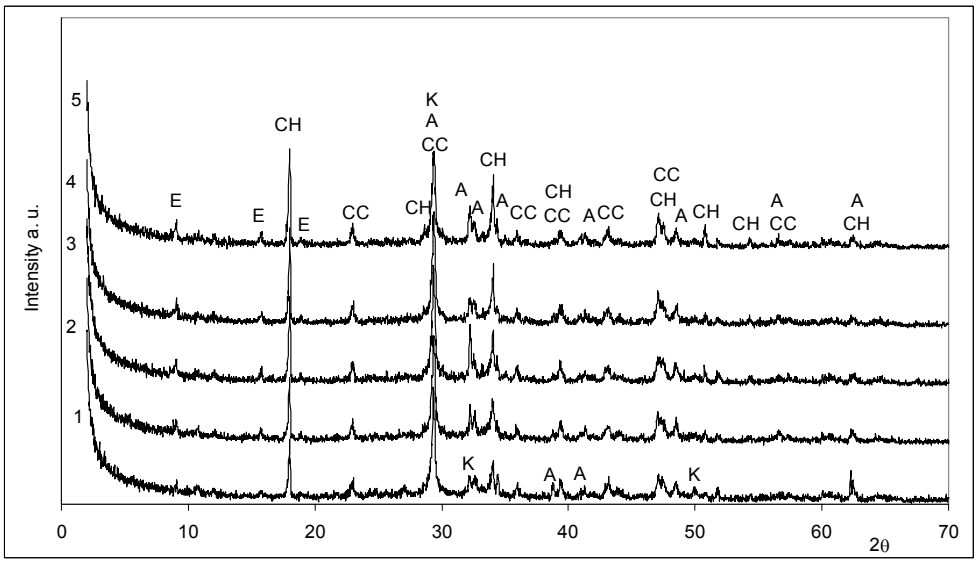
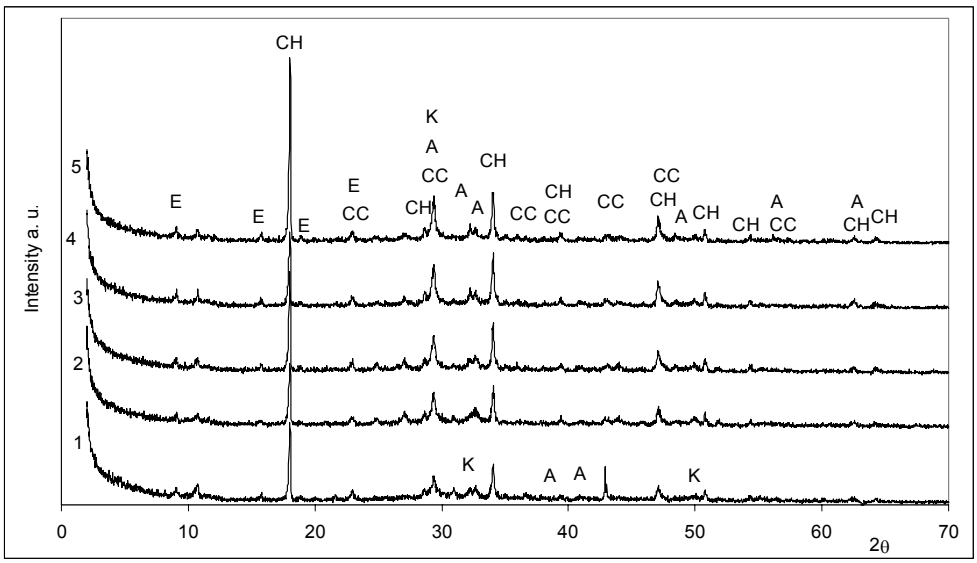


Figure 1. X-ray diffraction pattern (a) and IR curve (b) of aluminosilicate gel aged for 72h.

It can be stated that the admixture of permutite reduces the quantity of free $Ca(OH)_2$ in hardened cement paste specimens. The diffractive peaks of calcium hydrosilicate (*d* – 0,303; 0,279 nm), ettringite (*d* – 0,975; 0,563; 0,389 nm), and calcium carbonate (*d* – 0,304; 0,250 nm), which is formed when calcium hydroxide react with CO_2 in air, were also identified in the researched specimens.



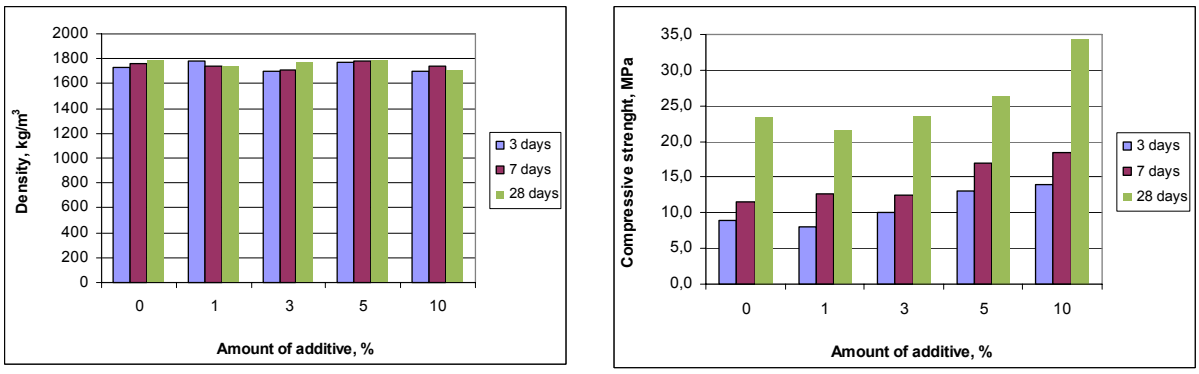
a



b

Figure 2. X-ray diffraction patterns of hardened cement paste after 3 days (a) and after after 28 days (b) containing: *1* – 10 %; *2* – 5 %; *3* – 3 %; *4* – 1 % and *5* – 0 % of permuntite. * Notes: CH – $Ca(OH)_2$; A – $Ca_{54}MgAl_2Si_{16}O_{90}$; K – C–S–H; CC – $CaCO_3$; E - $Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$

When hydration time of the specimens is elongated up to 28 days (Fig. 2, b), the same tendency remains: more permutite is in the specimens, the less portlandite and non hydrated alite peaks intensives. In all specimens after 28 days hydration X-ray diffraction patterns can be seen not grate portlandite peaks intensives increase that shows that alite hydration is in progress.



a b

Figure 3. Dependence of density a) and b) compressive strength of hardened cement paste on the additive amount

Hardened cement paste specimens density adding permutite additive from 1 up to 10% should decrease, because part of portland cement is replaced by fine dispersive permutite (Fig. 3, a), but density increasing additives amount remains similar and even increases, when 5% of permutite is added. This addition which has amorphous structure also improves the strength of the hardened cement paste. On the contrarily to density strength, when crushed after added permutite additive in all cases increased. Comparing concrete specimen, strength without additives with 10% permutite additive there was almost 40 % increase in strength (Fig. 3, b).

CONCLUSIONS

Initial studies of permutite admixture showed that at the portlandcement hydration time permutite reduces the quantity of free $Ca(OH)_2$ in hardened cement paste specimens and takes part in pozzolanic reaction with $Ca(OH)_2$, when secondary calcium hydrosilicates formed. The hardened cement paste specimen density when added permutite additive from 1 up to 10% remains similar even increases little when 5 % permutite is added It can be stated that the admixture of permutite which has amorphous structure improves the strength of the hardened cement paste and added permutite additive in all cases there was an increase. Comparing hardened cement paste specimens strength without additives and with 10 % of permutite additives there was an increase in strength about 40 %.

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Accident Trends in the Construction Companies of Lithuania

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Abstract. Construction is one of the most important industrial sectors that has a significant impact on the economic and cultural indicators of the country. This sector, however, is characterised by some of the poorest health and safety performance indicators in the entire region. Accidents at work continue to impose a social and economic burden. Accident data show the need for a comprehensive study that would allow an improvement in health and safety performance on constructions sites. To achieve this aim, the authors carried out an analysis of accidents at work and the hazard of construction site falls and falls from high rise structures. The work carried out on construction sites was monitored and health and safety violations were recorded.

Keywords: employee health and safety, accident, occupational disease, risk assessment, construction sector.

INTRODUCTION

Construction is one of the most important industrial sectors that has a significant impact on the economic and cultural indicators of the country. This sector, however, is characterised by some of the poorest health and safety performance indicators in the entire region. Compared with other EU sector workers, workers in the construction industry, on average, run twice as high a risk of non-fatal accidents at work (Liaudanskiene *et al.* 2010; Hola 2009; Liaudanskienė *et al.* 2009; Dėjus 2008; Stankiuvienė 2008; Lopez *et al.* 2008). It is because of the specific nature of construction as well as the type of business (frequent change of the nature and location of work, work involving high risk, and work carried out in various climatic conditions) that the management of work safety is more complicated and difficult than in other types of businesses. As a result, ensuring work safety in construction companies is a rather complex process that requires regular monitoring and accident analysis (Liaudanskienė *et al.* 2010; Dėjus 2009).

In order to prevent occupational accidents and diseases, improve work efficiency and job satisfaction, it is necessary to take measures to ensure work safety on building sites (Alinaitwe *et al.* 2009; Giretti *et al.* 2009; Hallowel *et al.* 2009; McDonald *et al.* 2009; Perera *et al.* 2009; Turskis *et al.* 2009; Idoro 2008). The various accidents are caused by failure to observe work discipline, violation of technical rules and internal rules of procedure, and the breakdown of technological processes and mechanisms; workers may cause or suffer injuries, fall ill with occupational diseases, cause damage or destroy material resources.

The accident data show that a comprehensive study is required to improve the health and safety performance of employees in the construction sector. Accidents are investigated using the following three main methods: statistical, monographic, and topographical. Statistical study of accidents involves division of accidents according to the branches of industry, professions, type of work, circumstances and causes or accidents, age and sex of workers, duration of sick leave, and other indicators. To achieve this aim, the authors carried out an analysis of accidents at work by visiting 22 construction sites and observing the work carried out on the sites, recording violations of health and safety requirements, and focusing on the hazard of construction site falls and falls from high rise structures.

DYNAMICS OF OCCUPATIONAL ACCIDENTS

The trend of occupational accident increases at work has been observed since 2000 after the Law on Social Insurance of Occupational Accidents and Occupational Diseases of the Republic of Lithuania came into effect. Prior to the coming into effect of this law, damage to health due to trauma or occupational illnesses were compensated by employers as prescribed in the Provisional Law on Compensation of the Damage due to Occupational Accidents or Occupational Diseases. Therefore, when the insurance contractor, i.e. the State Social

Insurance Fund Board started to compensate the employee when he was unable to work due to an insured event, the interest of the employer in the health and safety of his employees considerably decreased.

Another trend with respect to occupational accidents appeared when large numbers of workers immigrated to the older EU countries. Lithuania and particularly construction companies faced a serious problem with a shortage of a qualified workforce. As a result, the increasing scope of construction operations in this sector has become one of the most hazardous areas of economic activities (Table 1).

Table 1. Dynamics of occupational accidents

Occupational accidents	2006	2007	2008	2009
Total number in Lithuania	3581	3638	3293	2079
Processing industry	1230	1280	1142	586
Construction	661	694	588	268
Transportation	398	474	376	298
Agriculture and forestry	286	452	339	86

The analysis of the indicators of occupational accidents in the main areas of economic activities during the period of the study shows that the most dangerous activities are carried out in the processing industry and in construction companies (Annual reports of the State Labour Inspectorate of the Republic of Lithuania).

The necessity of preventing occupational accidents at construction companies in Lithuania is shown in Table 2 which presents the ratio of serious and fatal accidents at work in construction companies to the total number of serious and fatal accidents at work in all sectors in Lithuania.

Table 2. The ratio of serious and fatal accidents at work in construction companies to the total number of serious and fatal accidents at work in all sectors in Lithuania

Total number in Lithuania	2006	2007	2008	2009
Serious occupational accidents	228	194	150	106
Serious accidents in construction	70 (30.7 %)	66 (34.0 %)	33 (22.0 %)	20 (18.9 %)
Lethal occupational accidents	108	101	79	48
Lethal accidents in construction	29 (26.9 %)	23 (22.8 %)	27 (34.2 %)	10 (20.8 %)

The analysis of the figures provided in Table 2 shows that the largest number of serious accidents on building sites was recorded in 2007 and they accounted for 34% of all the serious occupational accidents in the country. The number of fatal occupational accidents at work was highest in 2006. There were 26 fatal occupational accidents in construction in 2006, yet in terms of percentage against the total amount of accidents in the country, the highest amount of fatal occupational accidents in construction was observed in 2008 and accounted for 34.2% of all accidents.

Up to the end of 2008, the amount of construction work increased rapidly in Lithuania. Due to the large amounts of work, short turn around times, and the lack of a qualified workforce, a trend of increasing occupational accidents was noted (Table 3).

Table 3. Data about the change in the amount of work and occupational accidents in construction sector

Indicators	2006	2007	2008	2009
Installation work (construction) (million LTL)	7.922	11.009	12.486	5.775
Trends of increase [+]/decrease [-] in installation work (construction) (percentage)	-	+39.0	+13.4	-53,7
Employees in construction sector (thousand)	104.0	115.5	119.7	86.9
A portion of all employees (percentage)	8.3	8.9	9.2	7.5
Total number of accidents in construction	661	694	588	268
Trends of increase [+]/decrease [-] of accidents in construction (percentage)	-	+5.0	-15.3	-54.4
The number of fatal accidents in construction	29	23	27	10
Trends of increase [+]/decrease [-] of fatal accidents in construction (percentage)	-	-20.7	+17.4	-63.0

The data provided in Table 3 show that the volume of work in the construction sector was responsible for both positive changes (an increase in the number of people employed) and negative changes (occupational

accidents). The analysis of the statistical data demonstrates that at that time the primary focus of the employers was the volume of work and the short turn around times of work completion. After Lithuania joined the EU, the phenomenon of permanent change in the workforce was observed in construction companies. The shortage of people led companies to reduce qualification requirements for new employees (the qualification, work experience, etc.). The same employee would do earthworks, lay concrete, plaster, paint, and lay the roof. No one seemed to care whether he was a qualified brick layer or a painter. The person was just a construction worker. As a result the employee had little knowledge of the work and sometimes would not have heard about health and safety requirements, in the best cases they would have signed paper stating that they had familiarised themselves with the requirements (Annual reports of the State Labour Inspectorate of the Republic of Lithuania).

Statistical analysis shows that every third employee who died at work or was seriously injured was an employee of a construction company. It has been observed that the majority of accidents occur in small and medium size companies. Employees with little experience or training or employees who have not been duly instructed are those who are most often injured. Such employees fail to assess the risk in a workplace and the possible factors/hazards that cause occupational accidents.

CAUSES AND FACTORS OF OCCUPATIONAL ACCIDENTS

Accidents at work continue to impose a social and economic burden. Accidents occur as a result of risk factors/hazards related to technical, social, and other conditions in the work environment (Figure 1).

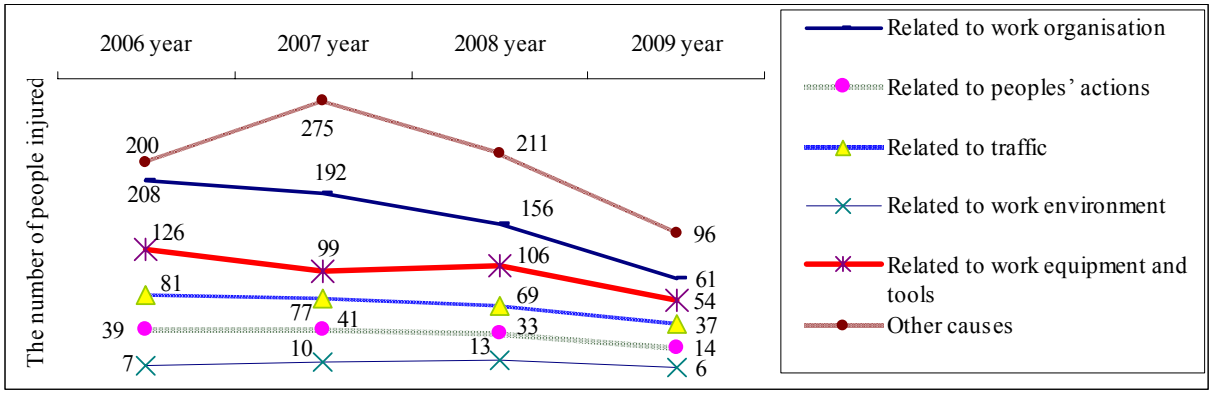

Figure 1. Causes of accidents in construction sector in Lithuania

The analysis of the accidents demonstrates that the majority of occupational accidents are due to peoples' actions, inappropriate organisation of work, and work equipment and tools. Accidents at work occur because employees have poor knowledge of or have not been instructed in safe work methods, they have not been familiarised with the work technology (procedures), and the collective protective measures are not adequate or are not used.

As a result of the analysis of the reasons and trends of occupational accidents, the main factors that have an impact on the possible occurrence of an occupational accident have been identified (Figure 2).

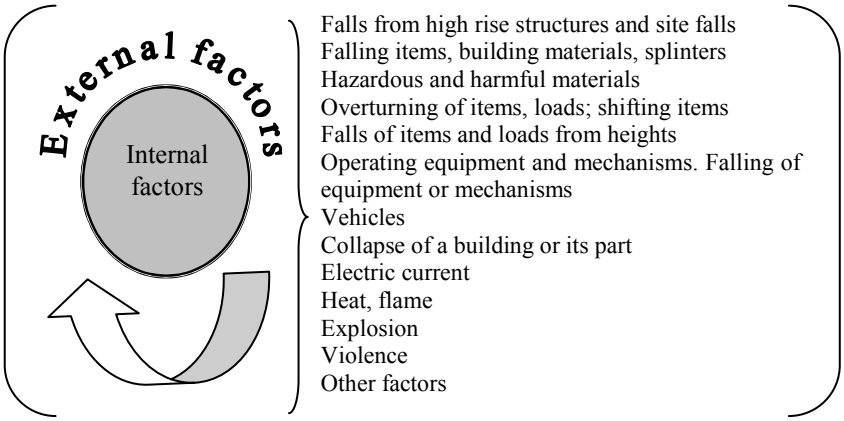

Figure 2. Accident factors in the construction sector in Lithuania

In recent years, vehicle accidents are responsible for one third of occupational accidents and falls from high rise structures and on site falls account for one seventh of all accidents. Even though accidents due to falls from high rise structures have decreased, this factor still remains one of the most hazardous, particularly on building sites. Falls from high rise structures and site falls are among those that cause most injuries. The consequences of these factors are particularly unacceptable as they most frequently occur as a result of these factors and are serious. To reduce the number of accidents at work due to falls from high rise structures and site falls, particular attention must be paid to the preparation for works on high rise structures.

THE HAZARD OF FALLS FROM HIGH RISE STRUCTURES AND SITE FALLS

There are human and economic stimuli in the construction industry for reducing the large number of occupational accidents. Falls from high rise structures and site falls, despite the fact that they are not the cause of the majority of accidents, are the most serious and costly.

During visits to sites to observe construction works, violations in the area of health and safety were noted. The main causes of injuries on sites include:

- Falls from tall ladders (4 cases recorded);
- Falls from scaffolding (10 cases recorded);
- Falls from the roof (5 cases recorded);
- Falls from high structures due to slipping, falling or tripping (3 cases recorded).

The risk of falls from high rise structures and site falls always exists during work involving roof installation, working in the building, on some structural elements, boarding, platforms, scaffolding, access roads, etc. The following protective measures are used to prevent falls from high rise structures and site falls: guarded scaffolding, protective shields, covers, roof ladder, and access elevators with work platforms, protective netting or safety harnesses.

During observation of the construction works, it was noted that the majority of accidents occur when working on scaffolding and laying the roof. Frequently, no safety harness was used when working on roof trusses or the roof cover, because this is a costly and time-consuming practice. Scaffolding that reduces the number of falls and therefore creates a better work environment is often replaced by a simple ladder. The use of such personal protective means as ropes that prevent falls from high structures are not used as much today due to technical progress. Thirty percent of all fall-related accidents while working on the roofs occur at a height of more than 3 metres [State Labour Inspectorate].

Another reason for fall-related accidents is due to the inadequate placing of the ladder. Falls from ladders account for a fairly large proportion of accidents in the construction industry [State Labour Inspectorate]. The situation can be improved only if the ladder is used less frequently and safe work means are opted for instead. This also creates the basis for developing an ergonomic work environment for construction works on high structures.

In many cases when observing construction work carried out on high structures, the following health and safety violations were recorded:

- absence of work technology (procedures) or work sequence instructions;
- absence of collective protective means for protection of workers from falling from high structures;
- workers are not provided with personal protective means (safety harness with a rope);
- the work carried out on high structures is organised inadequately and without considering the danger of falling;
- the work is carried out without the supervision of a foreman;
- hazardous zones are not marked with hazard signs;
- several contractors working on the site and their employees do not communicate on site;
- coordination is absent among companies working together, therefore the risk of injuries occurs due to their incompatible actions, construction works carried out by different contractors, and absence of organisational solutions.

Due to the specific nature of the construction sector, it is rather difficult to ensure work health and safety. When planning preventive measures, the problem areas mentioned above, the weakest areas of employee health and safety, the circumstances that may have the most serious consequences, and the existing probability, causes, and factors of accidents must be considered.

The statistics for occupational accidents in Lithuania is sad and discouraging. The loss of employees, however, has not yet taught managers of some companies to take a more serious approach to human health and safety. The level and condition of employee health and safety should be of concern no only to state institutions, but also employers.

CONCLUSIONS

1. It is because of the specific nature of construction as well as the type of business (frequent change of the nature and location of work, work involving high risk, and work carried out in various climatic conditions) that the management of work safety is more complicated and difficult than in other types of businesses.
2. Construction sector has become one of the most hazardous areas of economic activities in terms of employee health and safety.
3. After Lithuania joined the EU, the phenomenon of permanent change in the workforce was observed in construction companies in Lithuania. Employees with little experience or training or employees who have not been duly instructed are those who are most often injured. Such employees fail to assess the risk in a workplace and the possible factors/hazards that cause occupational accidents.
4. The majority of occupational accidents are due to peoples' actions, inappropriate organisation of work, and work equipment and tools.
5. Accidents occur due to hazardous factors related to technical, organisational, social, and other conditions in the work environment.
6. Falls from high rise structures and site falls are among those that cause most injuries. The consequences of these factors are particularly unacceptable as they most frequently occur as a result of these factors and are serious.
7. The problem of falls from high rise structures and site falls in construction companies requires permanent focus and preventive measures.
8. When planning preventive measures, the problem areas mentioned above, the weakest areas of employee health and safety, the circumstances that may have the most serious consequences, and the existing probability, causes, and factors of accidents must be considered.

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The Meaning and Measurement of Housing Affordability: Literature Review

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Abstract. There is an increasing need to gain a more encompassing understanding of housing affordability since there is still no common consensus on how best to define and measure it. This paper provides a critical review of the literature relating to housing affordability in order to clarify how the term has been defined and conceptualised by academics and policymakers. Traditional and modern methods for measuring housing affordability are also discussed.
This paper will be beneficial for policymakers, researchers and wider society as it combines the different understandings of what 'housing affordability' means, ultimately assisting in gaining a more consistent understanding of the concept. If we are to have more successful outcomes from housing policy it is important that policymakers, academics and other interest groups are on the same wavelength when they are conversing about affordability issues.

Keywords: Housing affordability, Affordable housing, Affordability definitions, Affordability measures

INTRODUCTION

The affordability of housing is a pressing problem that not only affects individual households but also has implications for the wider economy and environment, e.g. employment, health and sustainability. Thus, the affordability of housing is a major issue which has to be explored at local, regional and national levels to contribute to the government's sustainability agenda. Decent and affordable housing is said to be an important factor in contributing to the sustainability of communities (HM Government, 2005).

The housing affordability issue has received considerable attention for a number of years, both in the UK and across the globe. Yet, although there has been abundant talk of declining affordability, the theoretical foundations of the concept have received less attention (Gan and Hill, 2009). The literature studied highlights the fact that a specific definition of the concept of affordability is unclear and, subsequently, a specific and accepted measure of affordability is also uncertain.

THE MEANING OF HOUSING AFFORDABILITY

'Affordability' had become a common term in UK housing policy by 1990 (Whitehead, 1991) and it has continued to become an increasingly important policy issue. Yet although there is abundant talk of 'housing affordability' a specific definition of the concept is unclear. The ambiguity surrounding the concept of affordability was initially raised as a concern by researchers in the 1990's who suggested that the meaning of the term needed to be clarified or its use should be discontinued (Maclennan and Williams, 1990). Nonetheless the term is still continually used internationally, often without much consideration for its meaning. Stone (2005) suggests that both academic and policy environments are inconsistent with the notion of affordability. Accordingly there are many differing definitions, those at local, regional, national and international levels and those proposed by academic and policy environments.

MacLennan and Williams (1990) provided a widely quoted definition of affordability as being "concerned with securing some given standard of housing (or different standard) at a price or a rent which does not impose, in the eye of some third party (usually the government) an unreasonable burden on household incomes". Bramley (1990) advises more specifically that "households should be able to occupy housing that meets well established (social housing) norms of adequacy (given household type and size) at a net rent which leaves them enough income to live on without falling below some poverty standard" . Hancock (1993) also argues that "any rent will be affordable, which leaves the consumer with socially-acceptable standard of both housing and non-housing consumption after rent is paid". Chaplin *et al.* (1994) affirm that "...definitions of affordability must clearly take account not only of the cost of housing, but of housing standards and the price of other necessities of

life". Freeman *et al.* (1997) simply assert that "Definitions of affordability concentrate on the relationship between housing expenditure and household income and define a standard in terms of that income above which housing is regarded as unaffordable". Comparing the relationship between housing expenditure and household income is one of the most common ways to define housing affordability (Kutty, 2005; Whitehead, 1991). Conversely, Glaser & Gyourko (2003) believe that income should form no part of affordability considerations. They believe that the physical construction costs of housing are a more rational benchmark to compare with housing prices. It seems sensible to consider supply in defining housing affordability; however, surely income also has some relevance in the ability to 'afford' any good or service?

In contrast to academic definitions of affordability, in official UK policy documents affordability is simply defined as the 'ratio of lower quartile house prices to lower quartile earnings' (ODPM, 2005). International housing policy documents, in developed countries, also simply advocate that no more than a certain specified percentage of income (ranging between 25 to 35 percent) should be spent on housing for it to be considered as affordable (Affordable Homes Partnership, 2007; AHNRC, 2001; CLG, 2007; CMHC, 1991; Dacquisto and Rodda, 2006; Housing New Zealand Corporation, 2005). Such definitions have no regard for household size, composition, housing location or neighbourhood characteristics.

It seems that many academics and policymakers simply consider housing affordability to be the relationship between housing costs and incomes (Freeman *et al.* 1997; ODPM, 2005), whilst others also believe that non-housing costs should be brought into the equation (Bramley, 1990; Chaplin *et al*. 1994; Hancock, 1993; Stone, 2006b). Certain academics also touch on housing standards (Bramley, 1990; Chaplin *et al*. 1994; MacLennan and Williams, 1990). However, Bogdon and Can (1997) have criticised the existing literature for its focus on the price of housing rather than the condition, location and neighbourhood characteristics of supposedly affordable housing. Yet, even today day the majority of affordability definitions discussed still fail to consider housing location and neighbourhood characteristics. An exception is Fisher and her colleagues (2009) who suggest that a more thoughtful definition of affordability should consider the opportunity costs facing households due to housing location. The research "...calls for a broader discussion and refinement of the criteria by which society judges the suitability of affordable housing, especially with respect to schools and other local amenities" (Fisher *et al*. 2009).

MEASURING HOUISNG AFFORDABILITY

Contrasting views on how best to conceive and define housing affordability have consequently extended into how best to measure it. There are two methods of measuring affordability which are most commonly referred to and recognised internationally; one determines the proportion of income spent on housing costs (the ratio method) and the other looks at the amount of income remaining once housing and other essential cost of living have been paid for (the residual method).

The ratio measure of affordability is based on assumptions of what should be paid for housing (rent or mortgage). A household is said to have a housing affordability problem when it pays more than a certain percentage of its income to obtain housing. Thus, the measure relies on a 'rule of thumb' which suggests that any household that spends more than a certain percentage of its income on housing lives in unaffordable housing. This idea stems from initial studies on housing affordability, which date back to 19th century studies of the household budget, which commonly equated "one week's pay for one month's rent" (Hulchanski, 1995). However, this 'rule of thumb' approach is merely based on assumptions about what average households tend to spend or think they ought to spend on housing (Hulchanski, 1995). This subjective assumption has created much debate among academics since there appears to be no clear explanation of why such a rule of thumb is used or why a ratio that is deemed as 'affordable' changes (namely increases) at certain points in time (Stone, 2006b). However, despite the debate and lack of justification the rule of thumb approach is widely used as the basis of affordability standards internationally.

The ratio approach is extensively applied to measure affordability in the UK and other European countries, the US, Canada, Australia, China (Hui, 2001) and New Zealand (Housing New Zealand Corporation, 2005). It seems that international policy environments unquestionably adopt such a measure of affordability. This is not surprising since the ratio measure has the advantage of being easy to compute as it only relies on a few variables which are usually easily accessible. However, it is apparent that this approach is by no means consistently accepted among academics (Belsky *et al*. 2005; Hancock, 1993; Hulchanski, 1995; Stone, 1993). Despite its criticisms, the ratio measure is said to be a useful *indicator* for making comparisons over time or between areas (Bogdon and Can, 1997; Whitehead *et al.* 2009).

While the ratio approach focuses on what households actually pay for housing, the residual approach focuses on a household's ability to pay for housing (Ndubueze, 2007). The residual approach addresses the fact that many low income households cannot even afford to pay the commonly specified 30 percent of their incomes for housing. The residual method is based on the notion that housing affordability is the ability of households to meet the cost of housing whilst maintaining the ability to meet other basic costs of living, i.e. the income left

after paying for housing (Burke, 2004; Chaplin *et al.* 1994; Stone, 2006b; Whitehead, 1991). The notion of the residual approach is generally favoured over the ratio approach, although there has only been a limited adoption of the former in the assessment of housing affordability in the UK (Stone, 2006a). Many academics have called for the use of the residual measure as an alternative to the ratio approach (Bramley, 1990; Kutty, 2005; Stone, 2006a). However, several flaws have been highlighted with both measures.

LIMITATIONS OF TRADITIONAL AFFORDABILITY MEASURES

The ratio method is most frequently used to measure housing affordability due to its simplicity and ease of understanding (Stone, 2006a). Nonetheless, this simplicity is precisely what limits its effectiveness as a measure of affordability since it does not incorporate a number of factors that affect housing affordability. Hanckock (1993) argues that, "In a ratio definition, it is possible for individuals to be consuming very little of either housing or other goods and for the housing costs still to be considered affordable". Hulchanski (1995) also criticised the ratio measure as not logical for defining housing need or housing problems since it generalises households who spend more than a certain percentage of income on housing as having an affordability problem. A high ratio of housing costs to income might simply be due to a household's preference for high quality or large housing (Kutty, 2005). Thalmann (2003) indicates that the commonly specified affordable ratio standard of 30 percent is a very high burden for large low-income households, because it leaves them very little for other necessities. Gan and Hill (2009) also affirm that ratio measures can significantly understate affordability problems for households with low incomes.

While the residual measure addresses the fact that not all households can afford to pay a fixed percentage of income for housing, most of the other flaws concerning the ratio measure also affect the residual measure. The ratio measure fails to account for differences in housing costs that are the result of perceived higher neighbourhood quality (Bogdon and Can, 1997). The residual measure is also unable to account for such differences. Thus, households who have chosen to pay more for housing in order to live in a higer quality neighberhood are not identifed. Moreover, both ratio and residual measures require subjective third party benchmarking to set standards of affordability (Hui, 2001), e.g. the point when a house price to income ratio becomes 'unaffordable'. But how does one decide on the point when housing moves from being affordable to unaffordable by either measure? There is often no explicit basis for deciding on an affordable standard; such decisions are often made in a subjective way and may simply refer to past observations (Bramley, 1994). Furthermore, Gabriel *et al*. (2005) indicate that both residual and ratio measures are unable to distinguish between affordability problems arising from household choice and those arising from need. Some households may appear to have an affordability problem by definition, though such households may simply choose to spend a higher proportion of their income to obtain housing. Additionally, neither measure takes into account housing standards or quality of housing location. Belsky *et al*. (2005) highlight the fact that ratio and residual measures fail to take account of the trade-offs that households make in order to lower their housing costs, for example compromising on neighbourhood quality. The fact that a household is able to 'afford' housing in a certain location may, in reality, be due to its lower quality or neighbourhood deprivation. Households, especially those on limited incomes, make trade-offs between what they desire and what they can afford to pay for (Ndubueze, 2007). Additional costs may be imposed on households as a result of such trade-offs, both monetary and socio-economic costs, which are disguised by traditional measures of affordability.

MODERN AFFORDABILITY MEASURES

The National Housing and Planning Advice Unit (NHPAU) (2008) stress that we have recently seen the biggest fall in house prices since the 1990s as a result of the credit crunch, although by no means has housing become more affordable. The traditional measures of affordability can reveal that housing is becoming more 'affordable' simply because of such falls in house prices, when in reality the subsequent tightening of lending criteria and requirements of larger deposits has meant that affordability is still an issue for concern. Accordingly, additional measures are required to better reflect the true housing affordability problem.

The Roof affordability index has been developed to measure how difficult it is for a household to become a home-owner in England, unlike traditional measures the index uses average mortgage costs and thus takes account of variations in interest rates (Shelter, 2006). The NHPAU has also recently developed three new affordability indicators in an attempt to provide a fuller picture of housing affordability. The measures include the deposit measure, the mortgage costs measure and the rent measure (NHPAU, 2010). Although these new measures are more helpful than traditional measures at representing a household's financial situation, they still fail to represent what people get in return for what they spend on housing, for example neighbourhood and housing quality.

Belsky *et al*. (2005) suggest that an ideal affordability measure would account for tradeoffs that households make to lower housing costs, e.g. transportation and access to public services, health and safety. Only few academics have begun to develop such measures of affordability that look at the issue from a wider context than

simply focusing on the costs involved with owning or renting housing. The Housing and Transportation Affordability Index has been developed in the USA which takes into account not just the cost of housing, but also its location efficiency by measuring the transportation costs associated with place (CTOD and CNT, 2006). Housing may be considered affordable on a ratio scale, but location costs are often underestimated or ignored; the interaction between housing and location is believed to provide a more meaningful measure of affordability (CTOD and CNT, 2006). Fisher *et al*. (2009) developed a measure of affordability in the USA that looks at a bundle of attributes an area possesses - namely school quality, job accessibility and safety - and assesses whether taking implicit prices of such attributes into account makes a difference to whether an area can be regarded as affordable. The research recognises that house prices are affected by location, since the price includes the value of the services provided by the local amenities. The investigation concludes that focusing on price alone may lead to inaccurate conclusions about the affordability of an area (Fisher *et al*. 2009). Both studies from the USA (CTOD and CNT, 2006; Fisher *et al*. 2009) recognise the fact the affordability of housing is affected by more than simply housing costs and incomes. However, there are further locational factors that may also affect the affordability of housing. Fisher *et al.* (2009) focus on school quality, job accessibility and safety as the criteria for their affordability assessment, whereas CTOD and CNT (2006) focus exclusively on transportation. Such criteria could be combined into one assessment of affordability, along will additional locational criteria that also influence housing affordability.

CONCLUSIONS

The literature suggests that there is an increasing need to gain a more encompassing understanding of housing affordability since there is still no common consensus on how best to define and measure it. It is important that policymakers, academics and other interest groups are on the same wavelength when they are conversing about affordability issues; it seems that currently they are not. Having contesting views on the concept of housing affordability will create confusion over the issue, along with poor outcomes from housing policy. To have more successful outcomes from housing policy, both nationally and internationally, housing affordability must be more accurately and consistently defined and measured to gain a better understanding of the concept.

It is the view of the researchers that the way housing affordability is conceptualised and measured today must be reconsidered. Affordability is often conceived to be simply a problem of housing costs and incomes, especially by policymakers. However, providing affordable housing should not merely be about cheap homes, there is also a need to have regard for the neighbourhoods and communities in which such housing is situated (McDonald *et al.* 2009). The majority of affordability definitions and measures discussed and utilised today fail to consider housing location and neighbourhood characteristics. Yet, the location of housing and its subsequent neighbourhood characteristics may impose additional monetary and socio-economic costs on households, for example the cost of and ability to access schools, jobs, child care, shops, health services, etc. To assist in creating more affordable and also more sustainable communities it is important to move away from viewing housing affordability as a purely monetary issue and begin to have consideration for a broader range of factors that influence households and their quality of life (Maliene and Malys, 2009). Accordingly, it is important that further research is conducted into both the meaning of housing affordability and the criteria by which the issue is assessed.

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Technology of Cast-in-Situ Inclined Outer Walls Erection

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Abstract. The article deals with the results of theoretical and experimental research of concrete mix lateral pressure dispense on tilted formwork of exterior walls. The total lifting power on tilted formwork is determined. The experience of developing the formwork technology of erecting the cast-in-situ tilted walls is represented.

Keywords: research; inclined formwork; formwork technology; lifting force.

INTRODUCTION

A research of a thrust pressure on formwork during laying of concrete mix is a topical problem for the modern formwork technology of intensive erection of cast-in-place constructions. When designing and developing new formwork constructions, fixture elements, bearing and supporting formwork systems, it is necessary to take into account a concrete pressure low acting on formwork. Moreover, it is impossible to determine the main technological parameter - a speed of concreting in the formwork - without carrying out a research and determining a thrust pressure low of concrete mix along a formwork altitude.

In the building practice there are a lot of cases when a formwork having one or several inclined walls is applied. The current domestic and foreign normative documents don't have any formula for calculating a lateral concrete pressure on the formwork having an inclined wall. For this reason, it is very topical to carry out this research.

Estimation of concrete mix lateral pressure on inclined formwork of walls and columns

The existing local and foreign norms for calculation of concrete mix lateral pressure do not account for spatial location of formwork. German standard (DIN 18218) strictly stipulate that calculation method is valid for vertical formworks having vertical deviation no more than +/- 5 degrees.

In the construction practice inclined walled-formworks are frequently used. Such cast-in-situ structures are characteristic for complicated architectural projects, including unique structures. In this case one has to know not only concrete mix pressure distribution on the inclined formwork, but also forces exerted on arrangements and load bearing scaffolding that support the formwork.

Most complicated tasks seem to appear in evaluation of lateral pressure in complex shape formwork having spatial location different from the vertical. In this article we limit ourselves to consideration of two-side inclined formwork having parallel opposite walls.

Computable model is based on the rheological approach used in study of concrete mix lateral distribution on the vertical formwork. It is obvious that concrete mix lateral pressure depends not only on rheological parameters of the mix proper, formwork geometric parameters, but inclination of formwork itself.

Let's first consider the case for non-vibration concrete mix placement across the entire height of inclined rectangular formwork. Let's introduce coordinate system x, y, z having aligned axis x with formwork axis. Denote α – angle of formwork inclination. Let's consider equilibrium of concrete mix element located on depth x of the inclined formwork, limited by two horizontal planes (Figure 1) with distance dx between them and formwork walls.

We assume prerequisites and allowances similar to those used in works Markovsky, 2009. Differential equation of the equilibrium of concrete mix elementary layer having thickness of dx is written as:

$$\frac{d\sigma_x}{dx} = \gamma_{см} \cdot \sin\alpha - \tau \cdot \frac{P}{S}, \quad (1)$$

where σ_x – vertical pressure;

$\gamma_{см}$ – average density of concrete mix;

τ – shear stress;

P – formwork perimeter;

S – area of formwork horizontal cross-section;

α – angle of formwork inclination.

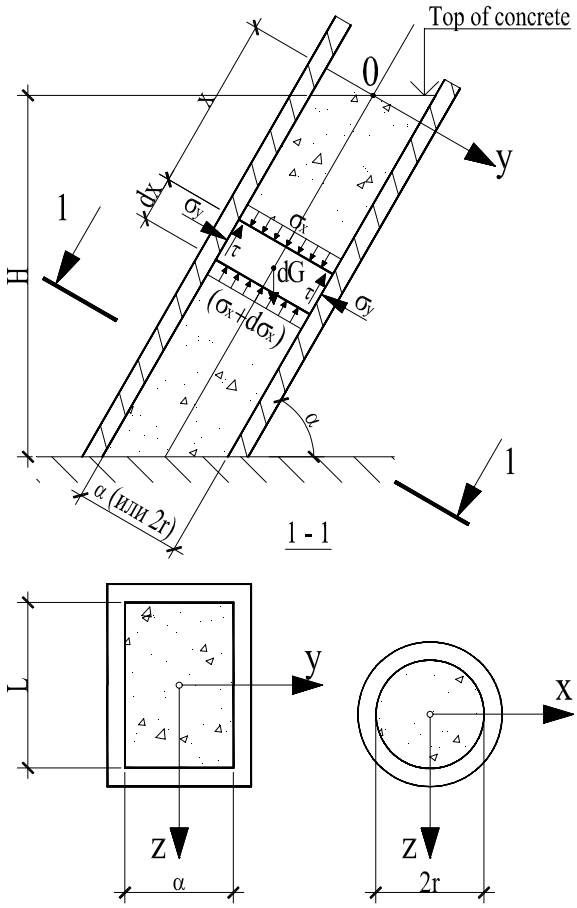

Figure 1. Loading diagram for determination of concrete mix pressure on the inclined formwork

General solution of the differential equation under boundary conditions assumes the form:

$$\sigma_y = \xi_o \cdot \left(\gamma_{см} - \frac{\tau_{o.n.c}}{\sin\alpha} \cdot \frac{P}{S} \right) \cdot H, \quad (2)$$

where $\xi_0 - \frac{\sigma_y}{\sigma_x}$ - coefficient of concrete mix lateral pressure;

$\tau_{o.n.c}$ – extreme shear stress of concrete mix in wall boundary layer at the initial placement stage;

H – height of placed concrete layer.

Lateral pressure of concrete mix is determined according to the following formulae:

for rectangular formwork

$$\sigma_y = \xi_0 \left(\gamma_{см} - \frac{2\tau_{o.n.c}}{\sin\alpha} \right) \cdot \left(\frac{1}{\alpha} + \frac{1}{L} \right), \quad (3)$$

for square column formwork

$$\sigma_y = \xi_o \cdot \left(\gamma_{\tilde{n}\grave{i}} - \frac{4 \cdot \tau_{\hat{i}.\ddot{i}.\tilde{n}}}{a \cdot \sin\alpha} \right) \cdot H, \tag{4}$$

for round column formwork

$$\sigma_y = \xi_o \cdot \left(\gamma_{cm} - \frac{2 \cdot \tau_{o.n.c}}{r \cdot \sin\alpha} \right) \cdot H, \tag{5}$$

for wall formwork

$$\sigma_y = \xi_o \cdot \left(\gamma_{cm} - \frac{2 \cdot \tau_{o.n.c}}{a \cdot \sin\alpha} \right) \cdot H, \tag{6}$$

In comparison with vertical formwork arrangement the lateral concrete mix pressure on the inclined formwork drops.

Let's then consider influence of the rate of mix placement on distribution of concrete mix lateral pressure in the inclined formwork. We assume rate of mix placement V_x along formwork axis x. Differential equation of the equilibrium of elementary mix layer in the formwork obtained by analogy with work Markovsky, 2009 assumes the form

$$d\sigma_y = \xi(t) \cdot \left[\gamma_{cm} \cdot \sin\alpha - \left(\tau_{o.n.c} + \frac{\alpha_t \cdot t}{t_E} \right) \frac{P}{S} \right] V_x \cdot dt, \tag{7}$$

where $\xi(t) = \dfrac{d\sigma_y}{d\sigma_x}$.

Pressure is determined accounting for change of the coefficient of concrete mix lateral pressure with time and rheological parameters of wall boundary layer only. Parameter of time influence t is included in the model on condition that lateral pressure coefficient reaches zero during time period t_E. Coefficient of concrete mix lateral pressure is assumed as per M. Specht,1975:

$$\xi(t) = \xi_0 \cdot \left(1 - \frac{t}{t_E} \right), \tag{8}$$

where ξ_0 – initial coefficient of concrete mix lateral pressure with t=0.

With permanent rate of concrete mix placement (V) by formwork height we can write:

$$dx = V \cdot dt, \tag{9}$$

In the initial solidification period before cement stiffening starts the behaviour of highly mobile concrete mixes in the wall boundary layer is approximated by Bingham law:

$$\tau = \tau_{o.n.c}(t) = \tau_{o.n.c} + \alpha_t \frac{t}{t_E}, \tag{10}$$

where $\tau_{o.n.c}(t)$ – extreme concrete mix shear stress in wall boundary layer during solidification t;

α - empirical coefficient accounting for rise of parameter $\tau_{o.n.c}$ with time.

After integration of equation (7) under boundary conditions we obtain:

$$\sigma_y = \xi_o \cdot V_x \cdot \left[\left(t - \frac{t^2}{2 \cdot t_E} \right) \cdot \left(\gamma_{cm} \cdot \sin\alpha - \frac{P}{S} \cdot \tau_{o.n.c} \right) - \alpha_t \cdot \frac{P}{S} \cdot \left(\frac{t^2}{2 \cdot t_E} - \frac{t^3}{3 \cdot t_E^2} \right) \right], \tag{11}$$

Maximum value of lateral pressure is set at $t=t_E$:

$$\sigma_y^{max} = \xi_o \cdot V_x \cdot \left(\gamma_{см} \cdot \sin\alpha - \frac{P}{S} \cdot \tau_{o.n.c} \right) \cdot \left[\frac{t_E}{2} - \frac{\alpha_t \cdot t_E}{6 \cdot \left(\gamma_{см} \cdot \frac{S}{P} \cdot \sin\alpha - \tau_{o.n.c} \right)} \right], \quad (12)$$

Mean rate of mix placement V_x is determined along axis x of formwork, i.e.:

$$V_x = \frac{x}{t}, \quad (13)$$

Recalculation for vertical placement rate (V), conventional for the vertical formwork is made by formula (14):

$$V_x = \frac{V}{\sin\alpha}. \quad (14)$$

Experimental researches

To approve the theoretical data used in determining technological formwork parameters and itself technology, examined before, also to research factual formwork deformability, a number of full-scale tests were carried out when an inclined wall was erecting on the level of 6th floor of the National Library of Belarus (Figure 2).

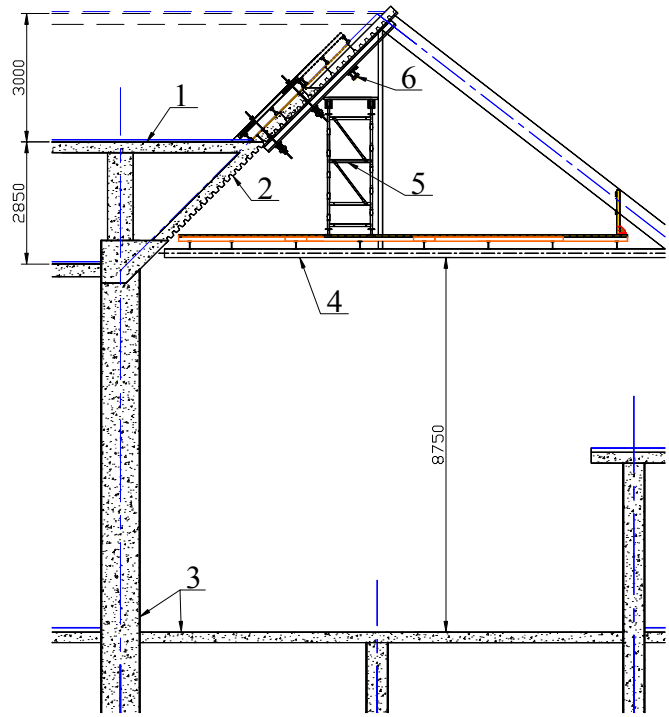

Figure 2. Encasing technology for inclined walls
1 – cast-in-place floor; 2 – inclined concrete wall; 3 – underlying cast-in-place structure;
4 – hanging platform; 5 – portable scaffolds for workers; 6 – inclined wall formwork

METHODS

At the first stage the formwork deflections during the concreting as far as erecting the construction are measured. The scheme of an experimental fragment with indication of the loading succession and data acquisition equipment locations are shown in the Figure 3. The location places for deflection indicators based on primary problems are appointed, which should be solved during researches.

The technique of natural tests consisted in synchronous fixation of indications of the sensor, registering the formwork deflections in the loading moment. Loading was made continuously at an unloading concrete mix

from a tub in volume $2m^3$. Additional technological loading was made by crew of concreters (5 persons) and equipment, in particular, vibrator.

At the second stage the immobile deflections of fixed formwork after the process of concrete mix curing are measured. The technique of tests consisted in fixing deflections in characteristic points on wave length of a professional flooring (a fixed formwork). If disregard "bunker" effect and formwork movement, and also resulting from this displacement of forces, we will receive final deflections, which have been recorded during the research.

At the same time, comparison of settlement and actual values of deflections according to schemes of loading in experiments causes scientific interest. That's why in a MicroFe program complex the computed model one of the closest reflecting work of construction on tests was created, and numerical experiment was made.

For calculation the lateral pressure of a fresh concrete mix detailed estimated values on height of a formwork on the basis of the premise stated earlier were accepted.

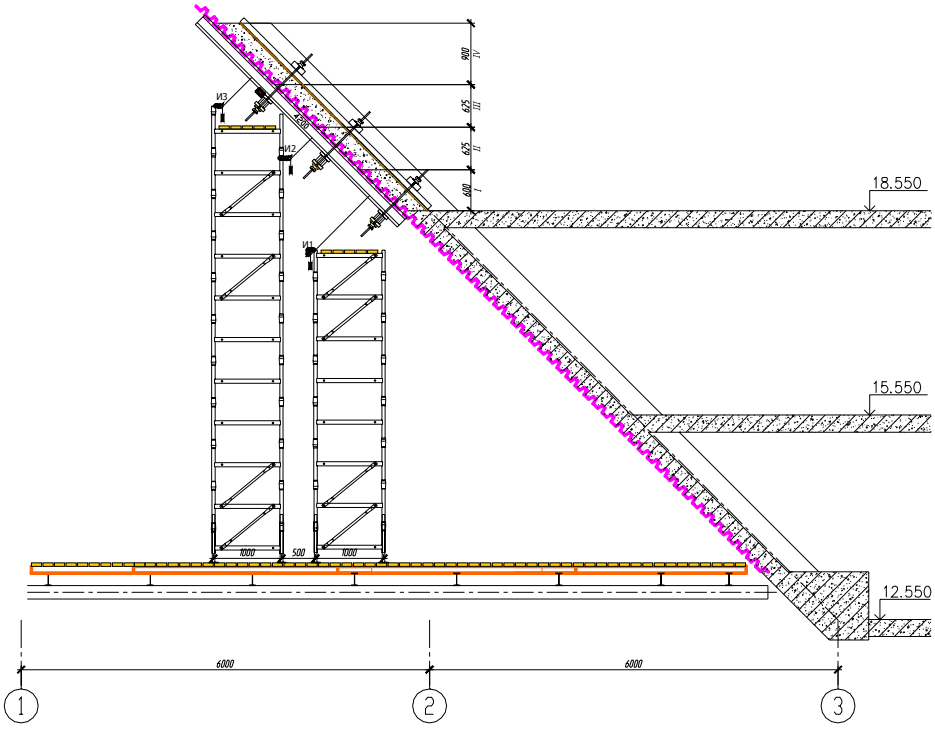

Figure 3. The basic scheme of full-scale investigation of formwork deformability at an erection stage

RESULTS

The quantitative picture reflecting growth of deflections by the results of tests and to the design data is presented on graphs (Figure 4).

Comparison of design values of deflections shows acceptable convergence with the experimental data, received during tests. Thus, during the experiment the deformations answering to real work at an erection stage of a construction when quasihydrostatic increase of concrete mix pressure takes place have been received.

THE RESULTS DISCUSSION

Analyses of realized researches demonstrated that the lateral pressure of immature concrete mix depends directly on a concrete hardening process. And an increase of angle of concrete internal friction depending of the time is proper for this process. Despite an increasing concrete altitude, some increase of pressure is occurring till the maximum value is reached.

A level and value of pressure for the formwork are mainly determined by a concreting speed and hardening process of a specific concrete mix having environmental conditions.

Then the value, distribution and temporal loading process are impacted by a number of external secondary factors. Moreover, a position and reinforcement density, for example, like a geometry-depending formwork cross section of lateral pressure, have an influence decreasing the pressure.

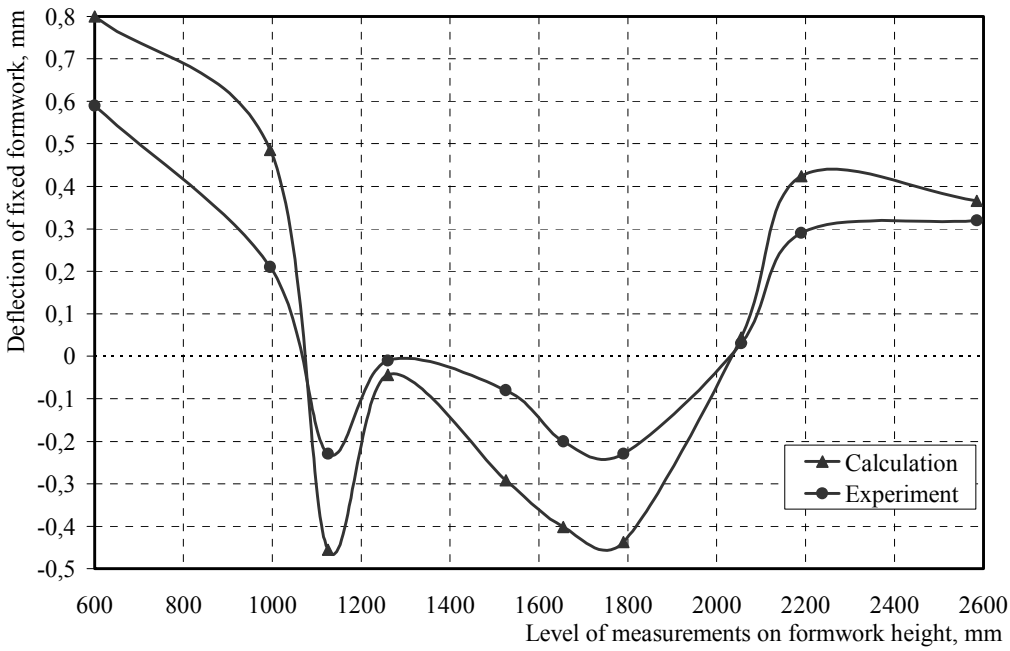

Figure 4. Deformations of a fixed formwork at an erection stage

As a result of an elasticity of tension bar and formwork deformation, some displacements in formwork pressure distribution appear that exert a specific influence when a formwork of bigger stiffness is applied.

A comparison of design values for deflections demonstrates an acceptable coincidence with the experimental data obtained in the course of researches.

CONCLUSIONS

The analytic formula for determining pressure on inclined formwork wall was obtained and from this it follows that the pressure depends on rheological parameters of concrete mix in volume, wall layer and geometrical parameters of the formwork.

The comparative analysis of results obtained in full-scale and numerical tests confirmed an accuracy of assumed theoretical preconditions and design model made on their base; it permits to apply the method used in developing the formwork technology for the erection of inclined cast-in-place walls of the National Library of Belarus. The assumed formwork technology for inclined wall erection considering a lateral concrete pressure provided the defect zero erection of cast-in-place constructions.

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Territorial Planning: a Tool for Implementing Sustainable Regional Development

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Summary: Implementation of sustainable regional development is among the most complicated tasks faced today. Territorial planning is one of the tools used to implement this objective. Territorial planning is a complex process of setting the directions for development of both the country and the specific territory, establishing the priorities and limitations for using the territory, the level of urbanization and expansion. It is an area where interests of certain entities involved in the planning of a territory compete, and their incompatibility together with territorial planning inconsistency have a negative effect on sustainable development and do not create favourable environment for investment. This article analyses territorial planning as a technique facilitating balanced and consistent development of all territories in a country. The article also reviews the territorial planning system and its problems.

Keywords: Sustainable development, territorial planning, sustainable regional development policy.

INTRODUCTION

Sustainable development is controversial; tools and techniques to achieve it are not clearly defined and intermingle with development inertia, market factors, and high demand for investment. Implementation of sustainable development policy is one of the most complicated tasks and challenges for entire community. Attempts to shift from sustainable development theory to decision making and to direct economic development towards the environment face several problems. One of them is the background of social problems entailing four different but interrelated elements: the real world, information, theory and model. M. Burinskienė and V. Rudzkienė (2009) in their studies have arrived at the conclusion that sustainable development analysis must be based on systematic approach.

Public influence on general plan solutions, its impact on common interests of the region is discussed. A question is posed as to which stages of general planning can be based on the reliability of population and experts' evaluation results and dependence on social and economic factors.

Lithuanian scientists doing research in territorial planning claim that this process has been floundering for a dozen of years. Z. J. Daunora (2005), M. Burinskienė (2009), D. Bardauskienė (2007), E. Staniūnas (2008), R. Čiegis (2008), V. Rubavičius (2008), P. Juškevičius (2008), R. Ginevičius (2009) et al. point out many areas in need of improvement. They miss clear strategy, priorities, stable legal framework, planning norms etc.

Lithuanian local authorities and academic community have noticed that not all local community groups understand the key solutions of sustainable development; they mistrust actions and decisions made by local authorities, thus giving rise to conflicts in the process of sustainable development strategic planning. That is mainly caused by methodology gaps and inaccuracies (R. Čiegis and D. Gineitienė, 2008).

Object of the study: territorial planning as one of the tools for sustainable regional planning. Goal of the study is to analyse the system of territorial planning and its problems in sustainable regional development. Objectives of the study are to analyse the principles of sustainable development in territorial planning, review territorial planning research problems. Method of the study is systematic literature review and summary.

IMPLEMENTATION OF SUSTAINABLE DEVELOPMENT IN THE REGION

The prime goal of regional development is the quality of life, and sustainable development is only a set of tools to reach this goal. Lithuania being a member of the European Union (EU) has to coordinate its regional development policy with EU policy, which aims at combining social and economic development by reducing disparities between the less developed regions. Regional development policy has been designed specifically to reduce the gap between the richest and poorest EU Member States or to raise the level of regional development

(R. Ginevičius and V. Podvezko, 2009). Regional imbalances are reduced using European structural assistance for regional development, by restructuring the industry, by strengthening the underdeveloped regions etc.

European regionalization policy not only provides the opportunity to start direct collaboration of regions, cities and municipalities, but also promotes the creation of new management models that would guarantee the partnership of authorities, the general public and business and facilitate the competitiveness of urbanized regions in global markets (V. Rubavičius, 2008). The EU policy is aimed at increasing the independence of urban regions strengthened by the partnership of local authorities, local community and business. A clear public policy is a prerequisite for strong cities and regions "which would form a certain basis for the relations of the state and towns following European urban development trends and changes in the nature of urban management, and which would also be used for setting the goals and benchmarks for national urban development" (V. Rubavičius, 2008).

Sustainable regional development poses a task to involve the public, local communities into renovation and urban development projects. The role of the public is extremely important for sustainable development programmes. Therefore, initiatives of local authorities and businesses based on social innovations aimed at meeting population needs, strengthening neighbourhood relations, providing opportunities for the public to act together with local authorities and businesses, improve life of local communities are promoted at EU level.

The awareness of sustainable development goals depends on the level of national social economic policy and prevailing attitudes. "The planning of sustainable development is understood as strategic and integrated territorial planning" (P. Juškevičius, 2005). Sustainable regional policy is implemented through a multifaceted strategy, where "social, economic interests are in harmony with environmental and cultural interests and progressive changes to encourage this process are envisaged" (R. Čiegis, 2001). Strategic planning becomes a challenge to the managers and administration of the region. The major benefit of strategic planning is concentration on major problems and the most promising objectives, when the present situation and perspectives for the future are well known. A public administration institution should abstain from domineering in the process of designing strategic development plans; it should unite other participants in the process and set an example by its actions.

A rational approach to integrated regional policy is sustainable and balanced social, economic, and environmental policy, human activity and care for landscape and environment. Regional policy priorities may be determined by the region's problems or the relative importance of regional development in the sectors, or by developing spatial structure and territorial distribution of certain elements in view of the future. Regional planning entails the following key areas: residential areas, maintaining the quality of the environment, protection of territories, demographic and social environment, economic environment, infrastructure, and the use of land (Figure 1)

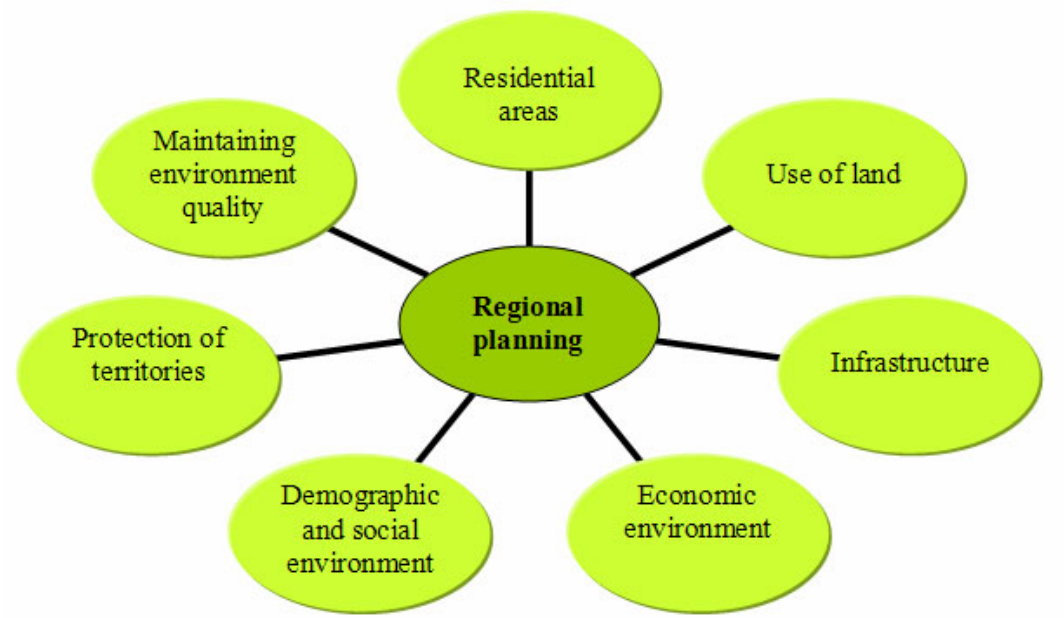

Figure 1. Areas of regional planning

Regional strategic development plans cover different areas, whereas local strategies should focus on the advantages of the region (R. Čiegis et al. 2005). Territorial development priorities depend on many external factors and criteria and lead to multifaceted and alternative solutions. Regional policy priorities may be set according to the problems of the region or relative significance of regional development in sectors, or by developing spatial structure and territorial distribution of certain elements in view of the future (P. Kavaliauskas, 2008). A drafted strategic development plan requires monitoring. "Meanwhile, the implementation of sustainable development principles is more a declaration or coincidence than the outcome of systematic efforts. Sustainable development can only be ensured by expedient management, the beginning of which is identification of the condition followed by planning and subsequent physical implementation" (P. Juškevičius, 2005). Sustainable regional development can be defined as "development providing guarantees that local population can reach and maintain the acceptable level of welfare, without causing threat to the possibilities of neighbouring populations" (J. Gailius and A. Draugelis, 2001).

The Law on Territorial Planning sets requirements to specific planning cases but it does not state the reason for the existence of territorial planning. The level of urban infrastructure development is not regarded to be so much fundamental; however, it is an important factor of economic attractiveness of a city. Infrastructure is one of urban development areas, the efficient management of which is in the hands of the public (E. Staniūnas, 2008). "Methodological gaps and inaccuracies also pose a risk of conflicts in the processes of sustainable development strategic planning" (R. Čiegis and D. Gineitienė, 2008)

TERRITORIAL PLANNING SYSTEM IN LITHUANIA

Territorial planning has an important role in the implementation of sustainable development in the region. Territorial planning is used for designing prospective territories providing for the development of residential, commercial, service or other type of environments, to ensure a balanced use of the country's territory and realizing the public interest by defending ecologically sensitive territories, cultural values. The Law on Territorial Planning defines territorial planning as follows: "Territorial planning is a process and procedure for regulating the general spatial concept of developing a territory, for setting priorities of land use, for defining environmental and historical heritage conservation and other conditions, for developing a system of land, forest land and water, residential areas, industry and infrastructure, for regulating population employment, and for determining the rights of natural and legal entities engaged in the development of the territory." (Republic of Lithuania Law on Territorial Planning)

Territorial planning is regulated not only by the Law on Territorial Planning but also by the Laws on Construction, Forests, Land, Protected Areas, Immovable Cultural Properties, Assessment of Planned Economic Activity and other acts of law as well as 30 secondary legislation acts: rules, regulations, procedures.

The Law on Territorial Planning determines four levels of territorial planning subject to the size of the territory and the level of solution elaboration (Figure 2).

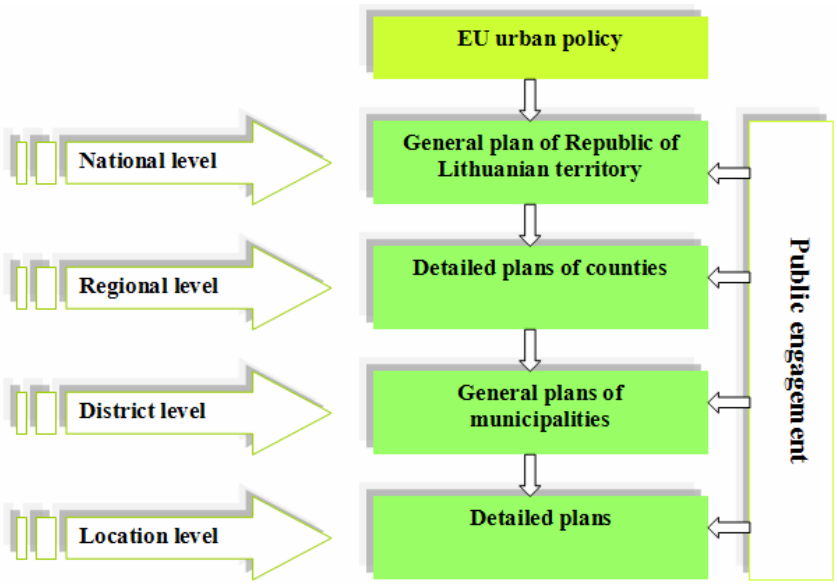

Figure 2. Lithuanian territorial planning system (modified according to the Law on Territorial Planning)

The following four levels of territorial planning are defined in the Law of Territorial Planning subject to the size of the planned territory and the level of solution elaboration:

- ✓ ***National level:*** a general plan for the entire territory of the state is designed. The designing of the general plan is coordinated by the Ministry of Environment and approved by the *Seimas* (Lithuanian Parliament);
- ✓ ***Regional level:*** general plans for the territories that have territorial, administrative and functional commonality. These general plans are organised by the Government authorized body and are approved by the Government;
- ✓ ***District level:*** general plans for the areas that have territorial, administrative (municipalities) and functional commonality in the region. These general plans are organised by directors of municipal administrations and are approved by local councils;
- ✓ ***Location level:*** detailed plans for plots or groups of plots. These detailed plans are organised by directors of municipal administrations, managers of state land, natural and legal entities; the plans are approved by local councils.

The system of territorial planning is based on the general (master) plan which sets forth the long-term strategy for the use and management of the country's territory. General (master) plans of the counties are designed with respect to the general (master) plan of the territory of the Republic of Lithuania. These plans are more detailed and of smaller scale, they set priorities and limitations for the development and use of territories in a county and municipalities belonging to the county. General plans for municipal territories are designed in accordance with the general and special plans of the county and the territory of the Republic of Lithuania, taking into account already designed or being designed general plans of bordering municipalities. These plans are designed in even smaller scale than the general (master) plan of the county and elaborate the priorities for the development of municipal territory, establish territory use limitations. Detailed plans are designed for a certain part of municipality's territory. They elaborate management and use regulations set forth in general and special planning documents. Special planning documents may be drawn on each level of territory planning. They are aimed at the planning of specific activity areas, e.g. forest land management, protected territories and the like.

Territory planning is arranged by various public administration entities, natural and legal entities taking into account the level and types of territorial planning. Applicable laws provide for the engagement of the general public in the entire process of territorial planning, irrespective of the planner, the level of planning or the type of the planning document. Community engagement in the preparation of territorial planning documents ensures the compatibility of public and private interests, enhances the transparency of territorial planning system, facilitates the implementation of sustainable development.

PROBLEMATIC REVIEW OF TERRITORIAL PLANNING SYSTEM

Certain obstacles are encountered on each level of territorial planning. One of them is imperfect legal framework of territorial planning. The authors have noted that legislation on territorial planning is often discordant, and in many cases stipulations of the laws are even contradicting, instead of being complementary and clarifying. The authors believe it results from frequent amendments to the laws and secondary legislation, where only certain parts are revised. A systematic and strategic revision of all territorial planning legislation has to be done by introducing substantial harmonized amendments and setting sustainable regional development as a goal.

This problem was analysed in the studies of P. Juškevičius and K. Jauneikaitė. The researchers have noted that major adverse effects are preconditioned by underdeveloped and unorganized system of territorial planning. The purpose, ways and manner of the use of land are not in line with the goals of urban planning, physical and functional variety of the objects. The problems of planning and systematic assessment of urban structures also undermine planning performance (P. Juškevičius and K. Jauneikaitė, 2008).

In view of the aforementioned problems it is safe to say that territorial planning system is inefficient. The planning hierarchy set forth in the Law on Territorial Planning is not complied with in practice. Very often lower level territorial planning documents are approved first and higher level documents are drawn and approved afterwards. Such a situation prevents the setting up of general directions for the development of the region and meeting the objectives of general territory planning. This, in turn, impedes the territory planning process, causes delays and failure to approve important territory planning policy documents in time, implementation of strategic projects is postponed and investment is not attracted.

The general plan reflects public interests of the entire region, city or district municipality and provides a possibility to seek sustainable development. Therefore, pooling of experts competent in different areas, making the community interested in development project, listening to people's expectations and needs is very important in designing general plans. Good results in view of sustainable development can only be achieved when experts in different disciplines, executive officers and staff of state institutions and the general public work together to put in practice the goals and objectives set forth in theoretical plane.

Today the notions of development and sustainability are paralleled when global, regional and local processes are examined (A. V. Rutkauskas, 2008). Not all local communities are aware of the basic principles of sustainable development and this lack of awareness leads to mistrust in the actions and resolutions of local authorities, and makes preparation and approval of territory planning documents more complicated.

One of the most important objectives of today's regional and urban planning is *to define the public interest with a view to urban development.* Therefore, public engagement in the approval of strategic development plans and territory planning documents is very important. Today "the voice of local communities in Lithuania is rather weak and unheard when large-scope territory planning documents are drafted and approved" (V. Rubavičius, 2008).

Regions are classified by their social and economic development level. There is a need to develop an integrated criteria system to evaluate social and economic development. Sustainable development has not been validated as a goal in Lithuanian territorial planning yet, and therefore there are no indicators identified. Most often public and experts' opinions are relied on, which differ a lot (D. Bardauskienė, 2007). A system of indicators is required for the implementation of sustainable development in the regions, municipalities or towns. This system would be used to determine and evaluate the sustainability level of a region, city or district municipality. Among all mechanisms in place today there is not a single technique to determine and evaluate the region's, city's or district municipality's situation, sustainability level and progress, to inform the general public and to identify its reaction (E. K. Zavadskas et al. 2005). The system of indicators, as a planning tool, is used very seldom today and only in single cases of a specific region, city or district municipality. This can be explained by the "absence of mandatory requirements or clear incentives to use them" (P. Juškevičius, 2005). Every municipality or planning entity has to design an individual set of indicators to be used for sustainable territorial planning. These indicators are often defined quantitatively by taking statistical data from the social, economic or environmental setting. Experts are commissioned to determine the relevance of indicators. Therefore, the evaluation of indicator relevance depends more on subjective factors and competence of commissioned experts.

The system of indicators could be a good planning tool not only for higher level planning but also for drafting territory planning documents of lower level. "Unfortunately, it is not possible yet not only due to the lack of adequate information or high cost" (P. Juškevičius, 2005). The system of indicators could be used as an alternative in drafting strategic plans, because usually the object of such planning is the entire territory of a region, city or district municipality, where no functional or another type diversification strategies are emphasized (E. K. Zavadskas et al. 2005).

SWOT analysis is often used for drafting higher-level territorial planning documents or strategies. It helps to identify strengths, weaknesses, opportunities and threats present in the region, city or district municipality at the current planning stage. SWOT analysis enables to review the condition of the region or municipality and to identify problematic areas, which, in turn, gives the possibility to examine sustainable development problems in the region or municipality. Problem analysis aims to gather information about the actual state and to determine the main obstacles and negative elements present in the region or municipality and the interrelation of these elements and direct goal of sustainable development of the region or municipality.

The review of the situation reveals that, most probably, the development of indicator system will be initiated by city or district municipalities willing to identify their position in the region, country or wider space of competition and collaboration, and their indicators will be developed sooner than a general national system of indicators for setting and implementing territorial planning goals is put in place (P. Juškevičius, 2005). As quantitative and qualitative development of Lithuanian territorial planning system is very slow, the timing for the development of such tool cannot be defined (E. K. Zavadskas et al. 2005).

Another issue to be noted is the absence of special information system for territorial planning needs, and the fact that very few city and district municipalities have their own GIS (geographic information system). The development of such system must be promoted and initiated. Administrative unit is the key object of official and accessible statistical system; however at present a common system of territorial units does not exist.

The development of indicator system could create long-term collaboration of the municipality, research institutions and private businesses and such collaboration would speed up the modernization of methodology. The complexity of territorial planning system, specific features of the region, city or district municipality, required competencies of the staff have to be taken into account when considering the intentions to develop a universal indicator system suitable for different municipalities and towns.

Another territorial planning system problem to be mentioned in this article is unavailability of planning norms. The normative framework of territorial planning is defined as a set of norms and rules for territorial design and planning. It indicates the need for social and cultural infrastructure, the principles of locating infrastructure objects in the urban structure, the permissible density and intensity of construction in the plots used for different purposes, obligatory areas of plot parts to be free of construction, obligatory distances from plot boundaries etc. (Z. J. Daunora, 2005). There are rules for drafting general, detailed and special plans,

however the norm that would facilitate urban planners in planning residential areas in view of sustainable development are not available yet. Planning norms should give exact definitions of the notions used in urban planning and clearly define priorities to ensure sustainable development of residential locations, to improve living and work conditions for people, to maintain ecologic stability in the territory, to protect the original design of urban systems.

Up to now little attention has been paid to the specificity, importance and complexity of tasks solved by urban planning, to EU approach on the formation of city and settlement systems, which should be also be defined at some level in the Law on Territorial Planning. All those notions and considerations are often missing in the solutions of general and detailed plans of regions or towns, although they should be clearly defined in town planning norms. In the absence of planning normative framework, the adoption of specific solutions turns into a tense competition among approving institutions, stakeholders, various councils, committees and local community groups, where pragmatic goals of business usually win over the priorities of cultural development. If territorial planning norms were present, they would prevent ill-founded investment ideas, unsound restrictions for development, limit possibilities of biased bureaucratic decisions, shorten project planning time (Z. J. Daunora, 2005).

Discrepancies between the city centre and the suburbs have to be reduced first of all in the implementation of sustainable regional development and formation of a planned spatial structure. Nowadays mathematical and multiple criteria assessment methods are already applied in territorial planning to facilitate the implementation of sustainable development. One of such methods was studied by D. Bardauskienė (2007). Mathematical methods were used for the first time in Lithuanian territorial planning for the drafting of Vilnius city general plan. These methods were used to evaluate the results of planning expert surveys. The study showed high compatibility of expert opinions and differences in attitudes of businessmen and the position of town planners, economists and scientists. Unlike businessmen, city dwellers are sceptical about new development and reconstruction opportunities in residential districts; however such a view is influenced by social and economic factors (age, dwelling in one place, living standards). "Mathematical methods can be used in cases where quantitative evaluation of the objects is applied." (D. Bardauskienė, 2007).

E. K. Zavadskas, J. Šaparauskas, A. Kaklauskas, Z. Turskis and T. Vilutienė (2005) have designed a unique system of twelve indicators in their studies to evaluate sustainability, which described business environment (economic indicators), quality of life (social indicators) and infrastructure (engineering and technical indicators). The values and relevance of indicators were determined from expert surveys and other sources of information. Game theory was applied for this task due to the complexity of the problem (E. K. Zavadskas et al. 2005)

In summary it is safe to say that solutions proposed by researchers to improve the territorial planning system would facilitate the implementation of sustainable development in the region, however more attention to this problem must be paid on the level of national and local governments.

CONCLUSIONS

Territorial planning in Lithuania often depends on subjective goals or priorities and not on public interests. Objective evaluation of the interests of different community groups and the compliance of planning proposals with public interests and sustainable development goals is difficult to achieve due to the absence of methodologies and evaluation indicators. Examination of the problems and perspectives of Lithuanian territorial planning system in a broader context has shown that the system, namely the methodological framework, legal framework and approaches to planning, has to be improved with a view to EU town planning policy, implementation practice and local experience.

When general territory plans aimed at complex planning of the territory are drafted, when key expansion and development directions and limitations are set, strategic plans must be linked to general plans of territories drawn in long-term perspective by aligning the measures of strategic plans to ensure the implementation of approved general plans. Directions for development must be set in accordance with research and monitoring data. Monitoring of general plans is a prerequisite for the implementation of sustainable development.

Planning norms are necessary for the preparation and evaluation of planning solutions. The prevailing feature of the Law on Territorial Planning of the Republic Lithuania is broad applicability of stipulations and lack of specificity: planning goals and objectives are applied to territories of different size and purpose, from a plot to entire territory of the country. They apply both for urban and rural planning.

The primary, although difficult, task is the development of a normative framework for territorial planning and design or adaptation of norms used in other countries for Lithuania. The normative framework is understood as a corpus of urban design and planning norms and rules. This task belongs to the sphere of scientific activity and requires adequate accumulation of qualified human resources and funding from the state.

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Construction in Lithuania: Challenges and Tasks

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Abstract. Lithuania as a member of European Union shares the same economical space with countries, which have longer experience of market economy. In that situation it is very important to know the European economical system and the peculiarities of construction market.
The dwindling construction volumes in Lithuania and Western Europe have increased competition and made the contractors review their operational strategies. More attention is paid to the export of construction activity. Large European construction corporations perform more than 50% of their operations outside their countries of origin. The essential economic transformation processes in Central European countries have created premises for growth in construction exports.
Internationalization processes in construction influence the business of Lithuanian contractors. The beginning of 21st century could be named as an intellectualization epoch of construction business, engineering and management solutions. The success of Lithuanian contractors will depend on international construction experience, competitive abilities and adaptation in changeable construction market.
How should all construction market participants adapt to the constantly changing market conditions? What is the current competitive situation in the Lithuanian, in the European and global construction sector?

Keywords: construction, management, engineering, construction project management.

INTRODUCTION

The construction sector is the leading industrial employer in Europe, representing 7.5% of total European employment and 28.1% of industrial employment in the European Union. The European construction sector comprises roughly 1.9 million construction firms, of which 97% have fewer than 20 workers and 93% fewer than 10 (Building & Construction, 2010).

Approximately 11 million workers are directly employed in the European construction sector. Employment in the sector has a very powerful multiplier effect on employment as a whole; one job in the construction industry generates two new jobs in the overall economy. A strong employment policy in the construction sector therefore has a positive impact on employment in general.

Compared with other industrial activities, the construction sector is by far the most labour-intensive industry. About 50% of turnover is achieved through the labour of the workers. For this reason the work force of construction firms constitutes the main economic lever for the future survivability of the sector. Productivity in the sector largely determines the competitiveness of building enterprises.

The beginning of 21st century could be named as an intellectualization epoch of construction business, engineering and management solutions. The success of European Union and Lithuanian contractors will depend on international construction experience, competitive abilities and adaptation in changeable construction market.

METHODS

The study concerns construction sector data review and analysis, bringing relevant construction problems in Lithuania and the possible alternative solutions.

RESULTS

The construction sector is strategically important for Europe providing buildings and infrastructure on which all sectors of the economy depend. It is the biggest sectoral employer and a major contributor to Gross Capital Formation in Europe.

In our work with this sector we cover the whole lifecycle of the economic activity, from the exploitation of the raw materials to the recycling of buildings or civil engineering works. Our activities can be divided into two major subsectors: the Construction Products and the Construction activity. The objectives, the tools and even the focus of our work and the treatment are different for each of them:

- As far as Construction products are concerned, the overall policy objective is to complete the Internal Market for such products mainly through the implementation of the Construction Products Directive, which will become the Construction Products Regulation in the near future. In practical terms, this is done through supporting the production of standards and European Technical Assessments and the development of the whole set of instruments foreseen for its implementation.
- Concerning the Construction activity itself, the focus is on the competitiveness of the sector, in particular by accompanying and encouraging actions from industry and Member States, not least in the field of sustainable construction and by promoting actions and supporting the development of common tools facilitating for companies and other actors to better adapt to the changes in the sector.

Safety in construction and the free movement of services, engineering and construction services, are also an important policy priority, which is developed through the promotion of the Eurocodes and their implementation by the Member States (The European Construction sector, 2010).

The establishment of the European Union and its further development is a natural result of the integration process. The Lithuanian Republic is also taking an active part in the process. Our country has good opportunities to present itself in the European economy and use both its advantages and potential to achieve its purposes. On the other hand, all economic subjects need to put more effort into retaining and developing their operations in a very competitive market. (Juodis, 2001).

The decrease in Western Europe construction sector have increased competition and made the contractors review their operational strategies. According to the latest construction forecasts, the European construction volume will recede by 4% in 2010 and slightly recover in 2011 and 2012. Despite large EU projects for the improvement of the infrastructure, the civil engineering sector will achieve a negative result the first time for years in 2010. In building construction, the general tendency will remain negative, though to a somewhat less extent than 2009. How will the sectors develop? 2010: only a short break for the European construction machine? In 2011 and 2012, the construction sector will regain strength again. Civil engineering investments will have to be heightened again after two years with a low level. Most probably, though, the Western 2012 construction volume will still be smaller than in 2009.

The role of construction in the economy is outlined by construction volumes and their comparative weight as part of the gross domestic product (GDP), as well as the number of people employed in construction. In 2009, construction work worth LTL 5279.6 million was carried out in Lithuania. Construction amounts to 5.77% of the Lithuanian GDP (Figure 1).

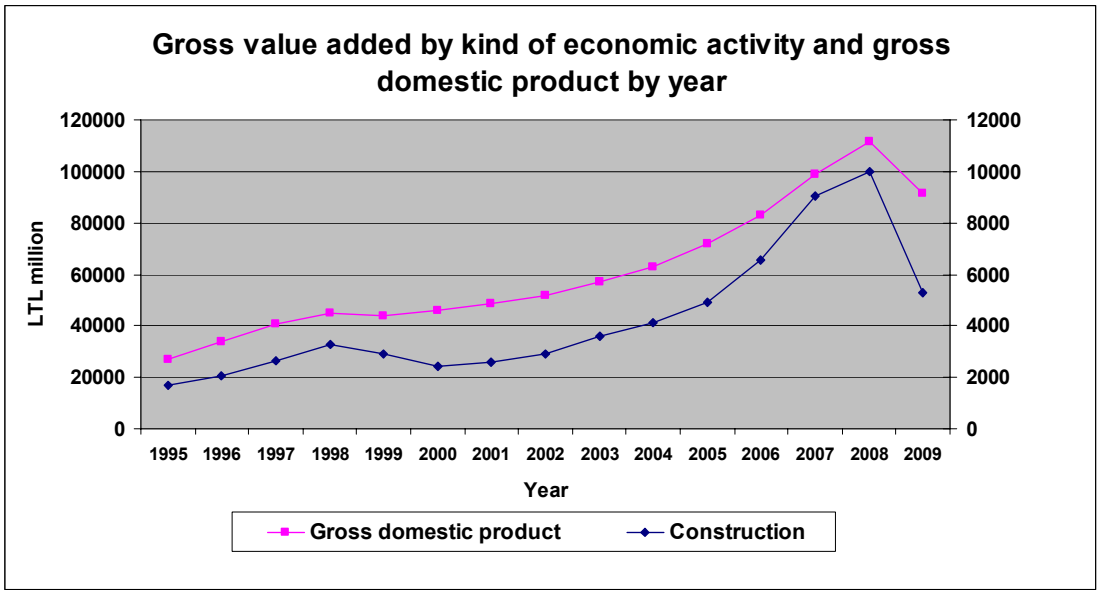

Figure 1. Gross value by kind of economic activity and GDP by year
(Data from the Department of Statistics Lithuania 2010)

Creating a job in construction allows creating two jobs in other sectors related to construction. In Lithuania 130223 people are employed in construction. This comprises 7.94% of all Lithuanian labour force in 2009. Annual construction volumes per head are around LTL 40543. More than 44% is new construction, 31% is reconstruction, 21% of construction volumes is repairs and restoration and 4% is other work (Figure 2).

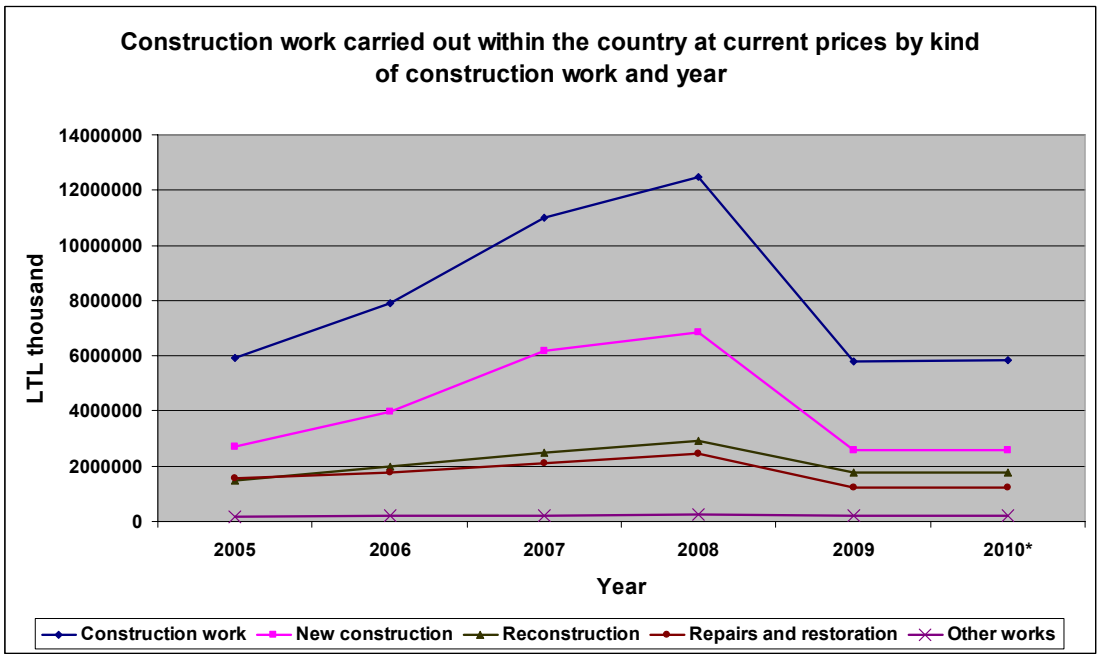

Figure 2. Construction work at current prices by year
(Data from the Department of Statistics Lithuania 2010)

The dynamics of changes building construction by classification of types of construction in Lithuania is provided in Figure 3.

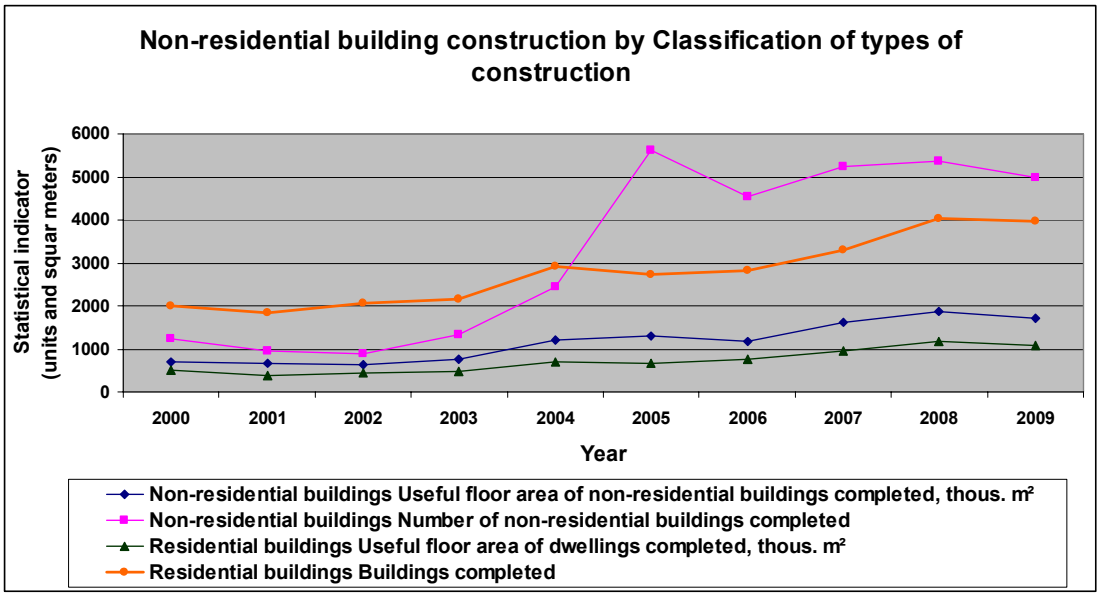

Figure 3. Building construction by classification of types
(Data from the Department of Statistics Lithuania 2010)

Rapid growth of investment in 2007 was slowed down by economic recession and unfavorable credit situation. In 2009, against 2008, investment decreased by 37%.

In 2009, the bulk of investment (69%) fell within construction; 29% of total investment allocated to the acquisition of long-term tangible assets. As compared with 2008, investment in building and civil engineering construction decreased by almost 28%. Investment in the purchase of real estate (land and buildings) decreased by 60%.

For the construction and purchase of residential buildings, LTL 2.6 billion was allocated (by 12% less than 2008) (Statistics Lithuania, 2010).

A lot of attention must be devoted to maintenance, modernization and renovation of existing structures (Juodis and Varnas, 2003; Juodis and Varnas, 2004).

The situation in the Lithuanian construction market depends on the construction juncture and the developmental dynamics of this sector of the economy. The juncture of construction shows a certain situation and reflects the specifics of construction operation within a certain time period. The juncture is determined by processes of market economics. Changes in juncture depend on numerous interdependent factors, such as the relationship of demand and supply in the market, monetary policy, technical advances, changes in regulation of economic activity, international and ecological situation etc.

Juncture changes in construction influence other economy sectors related to it. The following sectors are most sensitive to changes in construction: manufacturing of construction materials and products, construction equipment, wood processing industries, building engineering systems' production etc.

The negative impact of juncture fluctuation is decreased on the national level by regulating the size of public investment in the country. This enables to ensure more stable operation of not only the construction sector, but also the whole national economy.

Juncture information is used for setting the construction juncture policy. The supply of such information has not yet formed in Lithuania, although the demand for it by construction companies as well as those in other sectors is huge. In the absence of juncture information it is difficult to make correct construction strategic management decisions. The nature of juncture changes in the country's economy as well as in separate sectors is different. In many Western European countries, construction market and juncture research companies are already operating. They monitor the change tendencies in construction and disseminate information to all market participants. Such juncture information is used by construction companies for operational and strategic planning.

The development of construction is closely connected to the development of the economy as a whole. The process of economic development proceeds in S-shaped cycles. Lithuania was an independent country in 1918-1940; then it lost its independence and once again became independent in 1990. From1940 to 1990 Lithuanian economy experienced periods of deformed development with all the downsides of planned economy. Therefore the development of Lithuanian economy did not follow the classic S-shaped cyclical nature. However, there is not enough data available to carry out an extensive analysis of the dynamics of long cycles of the construction sector development. On the other hand, such construction sector juncture and development research are necessary for forecasting.

The economy of Lithuania was one of the fastest growing in the world. In the period 1998–2008 GDP growth rate was positive 9 years in a row. Since the year 2000 GDP has almost doubled with a growth rate of 77%. Rapid economic expansion has caused some imbalances in inflation and balance of payments. The account deficit to GDP ratio in 2006–2008 was in double digits and reached its peak at threatening 18.8% in the first quarter of 2008 (Bank of Lithuania. Statistics, 2010). This was mostly influenced by rapid loan portfolio growth as Scandinavian banks provided cheap credits in Lithuania. Consumption was affected by credit expansion as well. This led to high inflation of goods and services, as well as trade deficit.

The global credit crunch which started in 2008 affected the real estate and retail sectors. Lithuania was the last among the Baltic States to be hit by the economic crisis because its GDP growth rate in 2008 was still positive. In the third quarter of 2009, compared to the previous quarter, GDP again grew by 6.1% after five quarters with negative numbers. The rebound in Lithuania's economy in the third quarter was the fastest in the EU.

A heavy shock to consumers helped to balance the current account in 2009. Net external assets of the Bank of Lithuania are at a record height of EUR 5.46 billion (Bank of Lithuania. Statistics, 2010). Sectors related to domestic consumption and real estate are still suffering from the economic crisis. However, exporters have started making profits even with lower levels of revenue. The catalysts of growing profit margins are lower raw material prices and staff expenses.

During the recent years, a lot of construction project management companies have been established in Lithuania. The employees of such companies are former construction project managers, engineers, economists, specialists of informatics etc. Usually, a construction project management company has 5-7 employees. Such companies carry out the "turn key" solutions most efficiently. The construction project management companies devote a lot of attention to decision preparation, evaluation and selection, monitoring of project flow and expense control throughout all project stages. Companies that actively cooperate with universities show the best operational results. One of the best practices is cooperation with Kaunas University of Technology.

In this university, complex construction project management decision optimization research (both theoretical and applied) is carried out with the help of knowledge of various sciences: civil engineering, system engineering, applied mathematics, informatics, cybernetics, and construction economics. Information from Lithuanian construction companies is used in this research. Furthermore, questionnaires for carrying out special construction project management research are designed. This allows the analysis of a wide range of topics. The use of construction project methodology allows optimizing complex construction tasks, using mathematical

optimization methods and models, such as mathematical programming, inventory management, probability theory, series theory, game theory, correlation, artificial neural network and other models.

CONCLUSIONS

The crisis in the EU economic and other processes has a major influence on the transformation processes of Lithuanian economy. The construction sector is very important for the national economy. This sector is the fastest developing sector in the country's economy. However, considering the impact of internationalization processes, a strategic issue appears how to ensure the international competitiveness of the Lithuanian construction sector. An analysis of Western European construction experience has allowed us to estimate the level reached as well as the opportunities for increasing the sector's competitiveness, areas of relevant scientific research and construction improvement.

The beginning of the XXI century can be called the age of intellectualization of construction business engineering and management decisions. Knowledge and methods of various sciences are needed in solving complex construction project management problems. More efficient, and therefore competitive construction decisions can be prepared by using not only the knowledge of civil engineering, but also that of system theory, system engineering, applied mathematics, cybernetics, economics, informatics and psychology. Preparation of competitive construction decisions requires highly qualified specialists and more funds. However, the final positive result is much bigger than the expenses related to the preparation of efficient decisions and their implementation.

In this respect, important issues appear for universities which prepare civil engineering specialists and integrate studies with scientific work. The analysis of the best practices in such study programs and cooperation among universities can ensure competitive development of the construction sector on the national as well as the EU level.

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Engineering Preparations for Construction – Basis of Construction Planning

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Abstract. Construction works are financially expensive investments. The main goal of any constructional enterprise or organization is orientations towards good results. A competitive fight forces to improve continuously the construction business strategy as well as to look for the methods enabling to adapt at the maximum to the constantly changing situation in the construction market when the conditions are minimum. Each construction enterprise looks for methods that allow decreasing costs of construction works without impairing their quality, reducing execution duration of construction works, using constructional machinery as rationally as possible in order to develop a competitive construction project.

All this may be achieved if a construction enterprise is able to organize scientific planning of the construction works strategy in the engineering preparations for construction phase of a construction project.

Engineering preparations for construction is the base for planning the construction process. It may be defined as a complex of technical, legal, economic, technological and organizational measures able to ensure a consistent beginning of construction, rhythmic organization of the main construction works against the optimal technology.

In the course of engineering preparations for construction, there are great possibilities to work out rational design solutions of construction works execution using different techniques for their evaluation. In this case, the main role is assigned to mathematical methods.

Keywords: engineering preparations for construction, construction works, construction process, design solutions, construction project phase

INTRODUCTION

Construction is one of the key branches of economy. Construction development shows the general economic level of the country. Up until the end of 2008, the construction sector was one of the fastest-growing branches of Lithuania's economy. This was largely determined by various interacting micro- and macro-economic factors having a complex effect on the effectiveness of construction. Despite a slowdown in the pace of construction in the country, new construction objects are still in demand and this promotes competition in the construction market. Construction companies are forced to look for construction methods that would help to build in a more efficient, quality and, certainly, cheaper manner.

Construction companies performing construction works are forced to tackle a number of issues as to how to reduce construction costs at limited estimated construction prices, shorten the duration of construction works and use construction mechanisms and building materials more rationally in order to create a competitive and profitable construction project. All this can be achieved by a construction company planning a construction strategy in an engineering manner during the period of preparation for construction.

Engineering preparations for construction are the basis of construction planning. They can be defined as a set of technical, legal, economic, technological and organisational measures needed to ensure a smooth start of construction and measured organisation of the main construction works based on an optimum technology.

Skilled engineering preparations for construction create real preconditions for efficient construction activities. This work is done by highly skilled specialists, and this entails considerable costs. The costs of engineering preparations for construction and control account for 0.3-0.5% of construction cost. However, the ratio of the cost of this work to final construction efficiency results is 1:5 and higher (Juodis, 2001). This shows high importance and effectiveness of engineering preparations for construction.

Engineering preparations for construction provide great possibilities to prepare rational construction work design solutions, using various methods for their evaluation. The most important role here is played by mathematical methods. Mathematical methods facilitate more effective tackling of construction issues and preparation of rational construction work design solutions (Zavadskas and Kaklauskas, 1996),(Juodis and Janušaitis, 1998), (Juodis and Apanaviciene, 2003), (Viliuniene and Juodis, 2002), (Viliuniene and Viliunas,

2005, 2007) Practical implementation of such solutions during construction works would facilitate reduction of construction costs by 15–25%, the duration of construction by 16–30%, and construction company profit could reach 8–10% (Viliuniene and Viliunas, 2005). In addition, the accelerating development of computer technology facilitates not only faster preparation of rational construction work design solutions using mathematical methods but also their integration into special computer programmes designed for construction management.

The purpose of this article is to provide an effective construction process planning model enabling a construction company to plan the performance of construction works at the stage of engineering preparations for construction.

CONSTRUCTION PROCESS PLANNING MODEL AT THE STAGE OF ENGINEERING PREPARATIONS FOR CONSTRUCTION

For construction companies looking for ways to reduce essential construction project factors (costs, time), the authors of the article suggest the contractors to carry out engineering preparations for construction. The place of engineering preparations for construction at the stage of construction project management is shown in Figure 1.

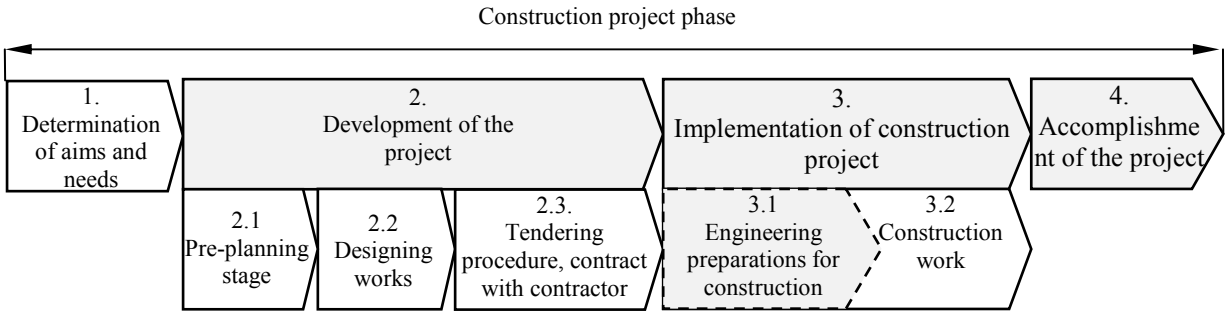

Fig.1. Construction project phase

They are performed by a building contractor or subcontractor after concluding a contract with the client. During engineering preparations for construction, construction companies prepare documents on the performance of construction works, which include technological solutions for the performance of construction works, timetables and arrow diagrams, resource demand and supply schedules, subcontractor work schedules, estimates and financial charts. Engineering preparations for construction include preparation of rational solutions that are reflected in the abovementioned documents.

The value of construction works makes up 65–80% of the total investment amount (Juodis, 2001). Therefore, engineering preparations for construction determine the course and effectiveness of construction processes. A block diagram of engineering preparations for construction is provided in Figure 2.

The stage of engineering preparations for construction in Lithuania is not regulated by the Law on Construction and therefore various definitions of this phase of construction can be found. The most common terms in literature are “preparatory work for construction”, “preparations for construction” and “engineering preparations for construction”. These terms are often confused. The term “engineering preparations for construction” does not have a universally-accepted definition yet. The absence of a precise definition impedes useful research into engineering preparations for construction.

According to foreign literature, in German-speaking countries, engineering preparations for construction (Arbeitsvorbereitung) is a separate stage of construction project management. This stage features systematic preparation, management and control of construction, construction processes and construction operations. It involves tackling tasks related to construction volume calculation, preparation of estimates, drawing up of cyclograms, timetables and arrow diagrams, construction cost analysis, determination of the need for and acquisition of materials and machinery, etc. In English-speaking countries, engineering preparations for construction are not treated as a separate stage of construction project management. Tasks related to engineering preparations for construction when contractors carry out an analysis of the impact of materials, equipment systems, construction methods and timetables on the duration and costs of a construction project are usually tackled in the pre-construction phase or in the construction phase. The phase in which issues related to engineering preparations for construction are tackled depends on the construction project implementation model.

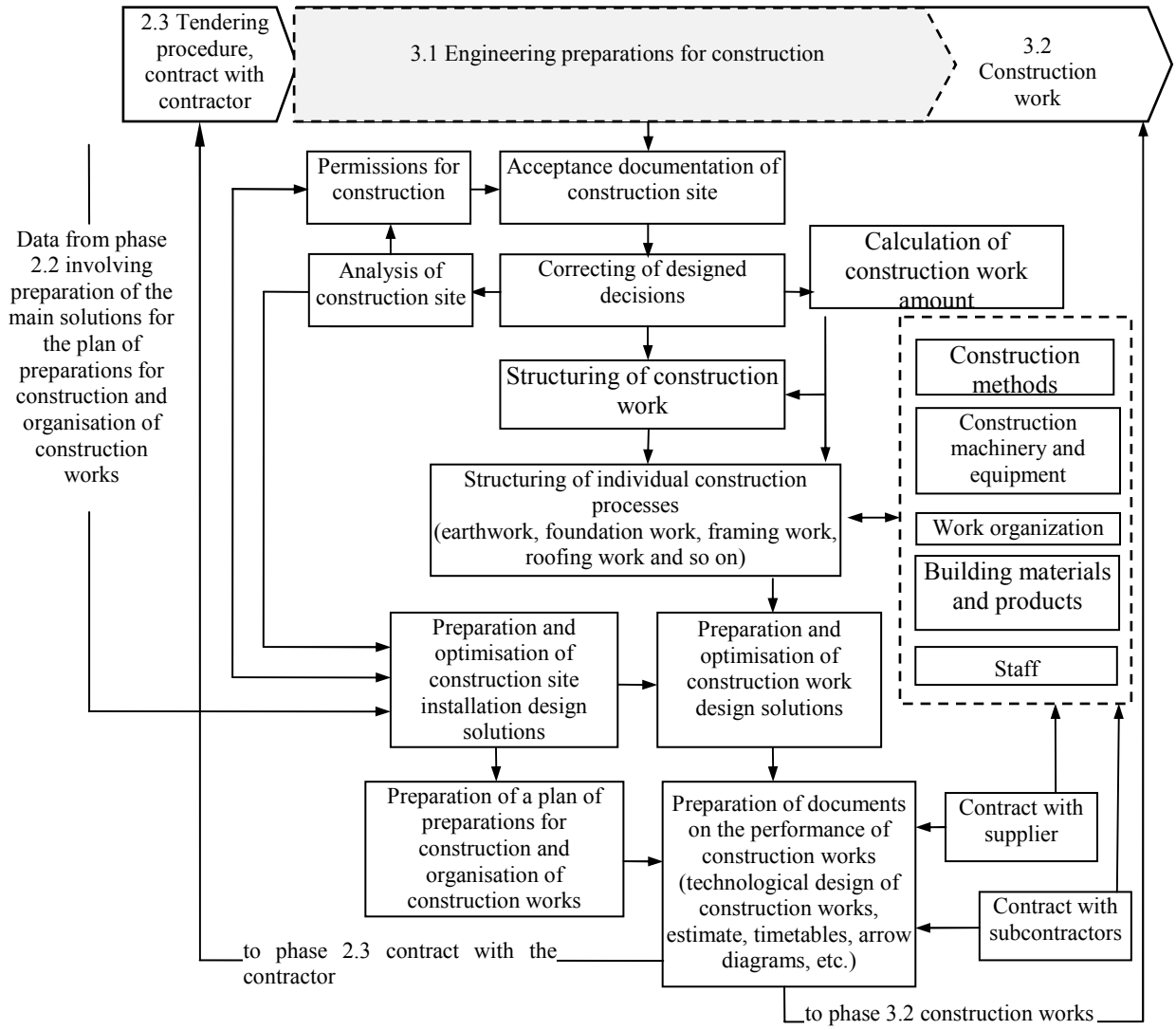

Fig 2. Structural scheme of engineering preparations for construction

In our case, construction process alternatives are analysed during engineering preparations for construction, they are evaluated and determined using economic-mathematical methods, with optimal solutions integrated into construction documentation (estimates, timetables, arrow diagrams, etc.). The entire process of engineering preparations for construction we have designed is computer-aided. This extremely facilitates building contractors' work, reduces the likelihood of errors and makes decision-making easier.

METHODOLOGY FOR THE PREPARATION OF CONSTRUCTION WORK DESIGN SOLUTIONS AT THE STAGE OF ENGINEERING PREPARATIONS FOR CONSTRUCTION

Preparation of optimum construction work design solutions consists of the following phases:

- Structuring of the performance of construction works;
- Preparation of alternative construction work design solutions;
- Evaluation of construction work design solutions using various mathematical methods;
- Creation of a complex economic-mathematical model of construction work design solutions;
- Integration of an optimum design solution into estimates, timetables and arrow diagrams.

A principal scheme of modelling of construction work design solutions is provided in Figure 3.

A system engineering methodology may be applied when preparing alternative construction work design solutions. In terms of system theory, any construction process consists of a set of complex, stochastic and determined processes that can be analysed, evaluated and optimised by dividing them into sub-processes, which are presented in the form of separate blocks. Each block is defined by specific design solutions that are

mathematically described and evaluated using various mathematical methods. Mathematical methods are best suited for modelling construction processes. The creation of a complex model of construction work design solutions involves evaluation of all specific features of the process, construction regulation requirements, technological links and sequence of sub-process variations as well as the duration of the processes and their costs.

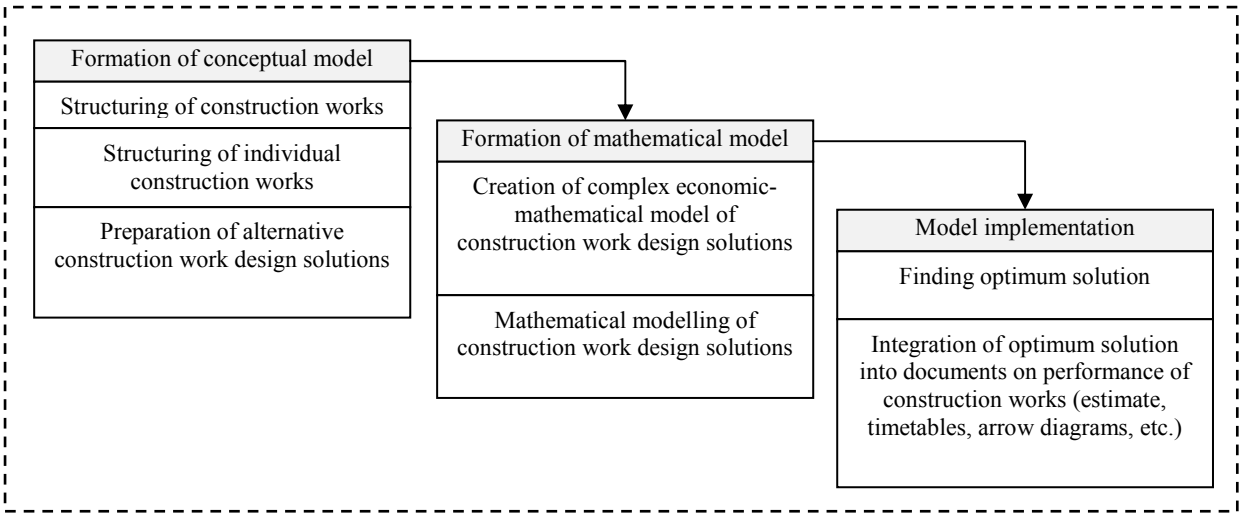

Figure 3. Principal scheme of modelling of construction work design solutions

This facilitates a better understanding of a task in question, a comparison of different solutions, and evaluation of the effect of changes in one variable on other variables. Optimum solutions obtained after evaluating construction work design solutions using various mathematical methods are integrated into the documents on the performance of construction works (estimates, timetables, arrow diagrams, etc.).

CONCLUSIONS

1. Careful and precise engineering preparations for the performance of construction works minimises costs and time spent of them, thus creating preconditions for efficient activities of construction companies and boosting of competitiveness.
2. Further scientific analysis of the issues of engineering preparations for construction and practical application of its results would facilitate boosting of the efficiency and competitiveness of construction companies, applying achievements in various areas of science in the search for an effective solution to these issues.
3. The accelerating development of computer technology facilitates faster preparation of rational construction work design solutions using mathematical methods, integrating them into special computer programmes designed for construction management.

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Heat Exchange in Ventilated Air Gaps of Lightweight Steel Roofs

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Abstract. The external and internal air temperatures are commonly used for calculations of roof's rated thermal parameters. However, in lightweight ventilated roofs the values of heat flows are determined by the difference between the temperatures of premises and roof's ventilated air gap, but not by the difference between the external and internal air temperatures. The temperature of roof's ventilated air gap is strongly influenced by the temperature of roof steel coating. This steel coating has low thermal receptivity, so its temperature quickly reacts to solar radiation, long-wave radiation from sky to surface and other climatic effects. The theoretical and experimental studies were done and in this paper the received data is presented on the heat exchange processes in lightweight roof's ventilated air gaps and regularities of their temperature's variations.

Keywords: lightweight steel roof, solar radiation, short-wave radiation, ventilated air gap, roof coating temperature.

INTRODUCTION

Technical decisions of lightweight ventilated roofs are based on the heat saving parameters during the cold period of the year. When the roofs are designed, the heat exchange processes (which take place during the summer period) are not considered. There is a problem of overheated premises under lightweight ventilated steel roofs in summer. Sun radiation is heating buildings surfaces, therefore the indoor temperature is rising up (Šeduikytė *et al*. 2008). Also, the surface temperatures of building envelope can easily reach 75-80 ^{o}C (Lee *et al.* 2009). During this period the coating of steel roof heats up due to intensive solar radiation and this causes surplus heat gains into premises. The calculation of values of these heat gains requires:

a) to estimate the temperature of roof coating, i.e. to evaluate the heat exchange between the external air, roof coating and ventilated air gap.
b) to estimate the temperature of ventilated air gap, i.e. to evaluate heat exchange between roof coating, ventilated air gap and roof construction taking place between ventilated air gap and premises.
c) to estimate the thermal behavior of roof construction taking place between ventilated air gap and premises, and the temperature differences between ventilated air gap and premises, i.e. to evaluate heat exchange through roof construction taking place between ventilated air gap and premises.

Usually, the calculations of the rated thermal parameters are done using the internal and external air temperatures. Heat flows values of lightweight ventilated steel roofs are determined by the temperature differences between premises and ventilated air gap, but not by the temperature differences between premises and the external air. The temperature of ventilated air gap is influenced by the temperature of roof steel coating. This steel coating has low thermal emissivity, so its temperature quickly reacts to solar radiation, long-wave radiation from the sky to surface and other climatic impacts. Daily climate impact's variation causes the significant temperature changes of steel roof coating. So, roof thermal analysis is often time dependent since the external temperature, wind speed and solar radiation vary with time (Al-Sanea 2002).

REVIEW OF LITERATURE REFERENCES

Before in-depth analysis of the research object, the overview of overheating problems was done during the hot period of the year in premises under ventilated tiling roofs. It was noticed, that premises under ventilated tiling roofs have no overheating problems. So, it was pointed, that roof coating could have an impact for values of heat gains into premises in summer. Therefore primarily the temperature of roof coating was analyzed due to climatic parameters' effect.

Besides the external air temperature effect, the temperature of roof coating is influenced by short-wave and long-wave thermal radiations, the angle of roof surface with the horizontal projection and the short-wave absorption coefficient of the surface and the long-wave absorption coefficient of the surface.

Thermal conductivity of roof coating external surface is defined as external heat transfer coefficient. The external heat transfer coefficient of roof coating is estimated from the sum of convective and radiative heat transfer coefficients (Фокин. 2006; EN ISO 6946:2008):

$$h_{se} = h_r + h_c, \tag{1}$$

The radiative component of heat transfer coefficient of roof surface is calculated according to equation (2):

$$h_r = 4 \cdot \sigma \cdot T_{AIR}^3 \cdot (\frac{1}{\varepsilon_{sky}} + \frac{1}{\varepsilon_{surf}} - 1), \tag{2}$$

where: h_r – the radiative heat transfer coefficient of roof surface, W/m^2·K; σ – Stefan-Boltzmann constant, σ=5,67051·10^{-8} W/(m^2·K^4); T_{AIR} – the external air temperature, ºK; ε_{sky} – emissivity of long-wave radiation from sky to surface; ε_{surf}– emissivity of long-wave radiation of roof surface.

The value of the convective heat transfer coefficient of roof surface is affected by wind speed v (m/s) (Фокин 2006) and is calculated according to equations (3.1, 3.2):

$$h_c = 7{,}34 \cdot v^{0{,}656} + 3{,}78 \cdot e^{-1{,}91 \cdot v}. \tag{3.1}$$

or by (Černe *et al.* 2007):

$$h_c = 3{,}1 + 4{,}1 \cdot v. \tag{3.2}$$

When solar radiation is active, the temperature of premise's surface raise up, but the effect of long-wave radiation from sky to surface reduces this temperature.

According (EN ISO 13790:2008), horizontal surfaces fully take over the long-wave radiation's effect, but these effects are twice less for vertical surfaces. Amendment for the estimation of the long-wave radiation's effect due to surface's lean angle is placed in (Kehrer *et all.* 2008: 207-212). So, the external surface's temperature of ventilated steel roofs $\theta_{rc.e}$ should be calculated according to constructed equation (4)

$$\theta_{rc.se} = \theta_e + \frac{I_{\Sigma.SOL} \cdot \alpha_{rc.se}}{h_{rc.se}} + \frac{\Delta L_{NET} \cdot \varepsilon_{rc.se}}{h_{rc.se}} \cdot (\cos(\frac{\beta}{2}))^2, \tag{4}$$

where: ΔL_{NET} – the balance of long-wave radiation (the long-wave radiation of roof coating surface minus the long-wave radiation from sky to surface), W/m^2; β - the angle of relative roof coating surface with horizontal plane.

In common with the thermal effects of climate for the roof coating external surface, heat exchanges take place and in an roof coating inner surface. These heat exchanges affect the temperature of the roof coating inner surface, so they need to be evaluated analyzing the consistent patterns of the roof coating temperature's variations (Figure 1).

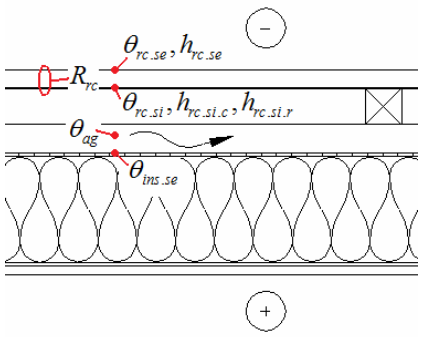

Figure 1. Elements used in calculation

To this end, the energy balance equation (5) can be used and the temperature of the roof coating inner surface $\theta_{rc.si}$ can be calculated from it (6):

$$\frac{\theta_{rc.se} - \theta_{rc.si}}{R_{rc}} = (\theta_{rc.si} - \theta_{ag}) \cdot h_{rc.si.c} + (\theta_{rc.si} - \theta_{ins.se}) \cdot h_{rc.si.r}\ , \tag{5}$$

$$\theta_{rc.si} = \frac{h_{rc.si.c} \cdot R_{rc} \cdot \theta_{ag} + h_{rc.si.r} \cdot R_{rc} \cdot \theta_{ins.se} + \theta_{rc.se}}{h_{rc.si.c} \cdot R_{rc} + h_{rc.si.r} \cdot R_{rc} + 1}, \tag{6}$$

where: $\theta_{rc.si}$ – the temperature of the roof coating inner surface, ºC; θ_{ag} – the temperature of ventilated air gap, ºC; $\theta_{ins.se}$ – the temperature of roof's thermal insulation's external surface, ºC; R_{rc} – thermal resistant of roof coating, $m^2 \cdot K/W$; $h_{rc.si}$ – the heat transfer coefficient of the roof coating inner surface, $W/(m^2 \cdot K)$.

Heat exchanges taking place in the roof coating inner surface are divided into convective and radiative heat exchanges. The convective heat exchange takes place between the roof coating inner surface and the air, which moves in ventilated air gap. When heat exchange is through ventilated air gap between its enclosed surfaces (i.e. between roof coating inner surface and roof's thermal insulation's external surface), the heat exchange is entitled radiative. In equations (5) and (6) the heat transfer coefficient of the roof coating inner surface $h_{rc.si.c}$, $W/(m^2 \cdot K)$, is calculated by equation (3.1), where the speed of moving air through ventilated air gap is used instead of wind speed. The heat transfer coefficient of the roof coating inner surface $h_{rc.si.r}$, $W/(m^2 \cdot K)$ is calculated according article (Barkauskas *et all.* 2000) as follows:

$$h_{rc.si.r} = \frac{(\frac{273 + \theta_{rc.si}}{100})^4 - (\frac{273 + \theta_{ins.se}}{100})^4}{\theta_{rc.si} - \theta_{ins.se}} \cdot \frac{C_o}{\frac{1}{\varepsilon_{rc.si}} + \frac{1}{\varepsilon_{ins.se}} - 1}, \tag{7}$$

The value of heat transfer coefficient depends on the speed of moving air through ventilated air gap. The characteristics of roof construction (which is below air gap) have no effect for the value of heat transfer coefficient. Meanwhile, following the equation (7), the radiative heat transfer coefficient of the roof coating inner surface is affected by the long-wave radiation's emissivity by enclosed surfaces of ventilated air gap and the temperature of these surfaces. The value of the radiative heat transfer coefficient can be increased and reduced by changing the long-wave radiation's emissivity by these surfaces. When the long-wave radiation's emissivity of these surfaces is reduced, the value of the radiative heat transfer coefficient also decreases and vice versa. One of decisions for reducing the radiative heat transfer through ventilated air gap is – to install a layer with low radiative emissivity in the lower surface of ventilated air gap. When the roof coating inner surface $\varepsilon_{rc.si}$=0,8, the lower surface of ventilated air gap $\varepsilon_{ins.se}$ is reduced from 0,9 to 0,1, the value of the radiative heat transfer coefficient can be reduced about 7 times. However, by this case, the part of radiative energy should reflect from this layer and this energy amount should increase the temperature of the roof coating inner surface. It is unknown how much this temperature could increase. In theory, according equation (7), when the temperature of the roof coating inner surface $\theta_{ins.se}$ is reduced; the radiative heat transfer coefficient also decreases. Then, the thermally recipient layer could be installed in the lower surface of ventilated air gap, which could accumulate the part of thermal energy. Or two ventilated air gaps should be installed instead of one and this could make presumptions for variations of the temperature of roof coating – but this question is also not explored.

The goal of this analysis was to determine the variation regularities of the temperature of roof coating, as well as using experimental studies to clarify the variation regularities of the temperature of roof's ventilated air gap and the temperature of thermal insulation's external surface depending on variation of the external air temperature and the temperature of roof coating.

OBJECTS OF EXPERIMENTS AND CONSTRUCTION OF EXPERIMENTAL CELLS

Generally used constructions of the lightweight ventilated steel roofs were chosen for experiments. Thermal insulation is usually installed between wooden frame's elements in such roof's types.

The experiment was done in real climatic conditions. Then, the climatic effects are different in separate experiments. If only one experimental cell was used for research, then separate times fixed experimental results would be complicated to compare. So, two experimental cells S1 and S2 of identical construction were made and their thermal characteristics were calibrated before the basic experimental process. When the cells' calibration was done (it was the first experimental stage) and the deduction was made that cells' thermal characteristics are identical, the construction of the cell S1 was left in constant conditions during all experimental period. The construction of the cell S2 was changed in other experimental stages in order to estimate the impact of thermal characteristics of roof layers placed below ventilated air gap for variation's dynamics of roof coating temperature, which forms due to climatic effects. The experimental results fixed in the cell S2 were compared with the results of the cell S1.

During the first experimental stage (during the cells' calibration) the roof construction of the cells S1 and S2 was made as represented in Figure 2:

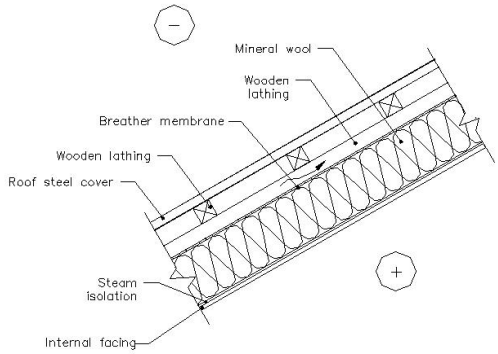

Figure 2. The basic design of lightweight steel roof construction when the breather membrane is used for wind insulation

The heat transmittance coefficient of the cells' walls is U = 0,16 W/(m^2·K), of the cells' floor is U = 0,18 W/(m^2·K), of the cells' roof is U = 0,16 W/(m^2·K). Waterproofing roof coating – profiled dark brown color steel leafs with a short-wave radiation's emissivity of external surfaces $\alpha_{rc.se}$= 0,7, a hemispherical long-wave radiation's emissivity of external surfaces $\varepsilon_{rc.se}$=0,88 and a hemispherical long-wave radiation's emissivity of internal surfaces $\varepsilon_{rc.si}$= 0,77. Wind proofing insulation is non conductive for air and conductive for the vapor breathing membrane of 0,6 mm thickness. The chipboard of 10 mm thickness is used for internal layer of the roof construction. On purpose to reach the maximum reduction of the external air infiltration into cells' inside, junctions of premises ant their separate layers were made airtight in both cells. The 200 mm thick expanded polystyrene foam panels were installed as layers of thermal insulation of the walls and the floor. The orientation of the roofs surfaces of both cells is identical – south direction and surface's lean angle is 2° in respect of horizontal projection. The values of the thermal conductivity coefficients of used constructional products were evaluated by experimentations due to EN 12667 (EN 12667) using device which meet ISO 8301 requirements. During the experimentation in the cells S1 and S2 all day the temperature was kept constant and lower than the external air temperature: 10±0,5 °C. The construction of the cell S2 was changed in other experimental stages as follows in Table 1.

Figure 3. The cells S1 and S2

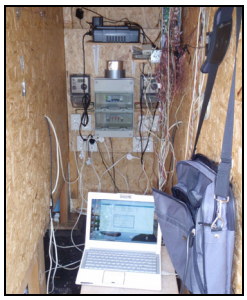

Figure 4. Data loggers, measurement, control and management devices

Figure 5. Digital meteorological station

Table 1. The cell's S2 roof's construction in different experimental stages.

Experi-ments	The cell's S2 construction changes in different experimental stages
2	The 0,3 mm thick heat reflective coating (its hemispherical long-wave radiation's emissivity coefficient ε = 0,09) was mounted over the breather membrane.
3	The 14 mm thick cement-sawdust board with heat reflective coating (its hemispherical long-wave radiation's emissivity coefficient ε = 0,09) was mounted over the breather membrane.
4	The 14 mm thick cement-sawdust board without additional coatings (its hemispherical long-wave radiation's emissivity coefficient ε = 0,80) was mounted over the breather membrane.
5	Additional layer was mounted over the breathing membrane. The layer consists of two air gaps separated by heat reflective coating with two heat reflecting surfaces. The hemispherical long-wave radiation's emissivity coefficients of separating coating surfaces is ε = 0,09. Air gap between the breather membrane and heat reflective coating is 35 mm high and air gap between the heat reflective coating and roof coating is 40 mm.

METEOROLOGICAL DATA

Digital meteorological station was set up near the experimental roof's cells. It registered these climatic parameters: diffuse and total solar radiation, long-wave radiation from sky to surface, external air temperature, relative humidity of external air, wind speed, wind direction and atmospheric pressure (Figure 5).

During the experiments the values of climatic parameters were fixed and they are presented in Table 2:

Table 2. Measured values of climatic parameters during the experiments and normative climate data of the test area

Parameters	*Exp. No.1*	*Exp. No.2*	*Exp. No.3*	*Exp. No.4*	*Exp. No.5*	*Measured in July*	*Normative climate data*
The average daily external air temperature, °C	22,5	21,5	22,8	23,3	20,2	18,7	17,4
The average wind speed during the day, m/s	2,3	1,2	1,8	1,9	1,3	1,7	3,1
The average daily total Solar radiation, W/m²	331	327	242	307	225	222	215
The average daily diffuse Solar radiation, W/m²	79	80	128	94	105	114	103
The average daily external air relative humidity, %	65	67	62	67	71	75	76
The average daily long-wave radiation from sky to roof top surface↓, W/m²	388	385	404	394	388	382	n/a
The average daily long-wave radiation from roof top surface to sky ↑, W/m²	438	438	439	442	428	416	n/a
The average daily long-wave radiation balance, W/m²	-50	-53	-35	-48	-40	-34	n/a
Daylight hours of a day τ_d, h	17,4	17,2	16,9	16,7	16,0	16,6	16,0
Night hours of a day τ_n, h	6,6	6,8	7,1	7,3	8,0	7,4	8,0

THE EXPERIMENTAL RESULTS

The experiment was done in July, because of the highest average monthly air temperature. In Lithuania (where experiment was done) in July the average daily amplitude of the external air temperature is 10,2 °C, and the maximum daily amplitude of the external air temperature is 18,7 °C (RSN 156-94). During the experiment the average daily amplitude of the external air temperature was 10,5 °C. So, it could be stated, that selected periods suited to permanent monthly amplitude of the external air temperature in the experimental location.

Table 3. Measurement data of the external air temperature and roof construction elements

Parameters	**Cell No.1 („S1")**			**Cell No.2 („S2")**		
	Day	***Daylight hours***	***Night hours***	***Day***	***Daylight hours***	***Night hours***
Experiment No.1 (calibration of cells)						
The external air temperature, °C	22,5	23,5	20,0	22,5	23,5	20,0
The temperature of roof coating inner surface, °C	29,9	34,8	17,0	29,7	34,6	17,0
Air temperature in ventilated air gap, °C	26,3	29,5	18,1	25,6	28,4	18,2
The temperature of thermal insulation's external surface, ºC	27,2	30,8	17,5	26,9	30,5	17,6
Experiment No.2						
The external air temperature, °C	21,5	22,5	18,8	21,5	22,5	18,8
The temperature of roof coating inner surface, °C	32,1	38,7	15,2	32,8	39,8	15,0
Air temperature in ventilated air gap, °C	27,2	31,4	16,4	27,0	31,1	16,4
The temperature of thermal insulation's external surface, ºC	28,8	34,0	15,6	23,7	26,6	16,2
Experiment No.3						
The external air temperature, °C	22,8	24,0	20,1	22,8	24,0	20,1
The temperature of roof coating inner surface, °C	28,7	33,7	16,9	29,7	35,2	16,8
Air temperature in ventilated air gap, °C	25,4	28,6	17,9	26,4	29,7	18,7
The temperature of thermal insulation's external surface, ºC	26,3	30,1	17,4	24,0	25,5	20,5
Experiment No.4						
The external air temperature, °C	23,3	24,5	20,5	23,3	24,5	20,5
The temperature of roof coating inner surface, °C	29,4	35,0	16,6	30,1	35,9	16,7
Air temperature in ventilated air gap, °C	25,7	29,1	17,8	25,8	28,9	18,5
The temperature of thermal insulation's external surface, ºC	26,6	30,7	17,1	27,3	30,9	18,9
Experiment No.5						
The external air temperature, °C	20,2	20,8	19,0	20,2	20,8	19,0
The temperature of roof coating inner surface, °C	27,9	34,0	15,8	28,5	35,3	15,1
Air temperature in ventilated air gap, °C	24,6	28,2	17,3	24,8	28,9	16,6
The temperature of thermal insulation's external surface, ºC	25,6	30,2	16,4	20,5	21,8	17,9

The experimental results shows, that during the experiments the average daily roof coating temperature was higher than the external air temperature between 5,9 and 11,3 °C, and the average roof coating temperature of daylight hours was higher than the external air temperature between 9,7 °C and 17,3 °C. In the night hours of a day, the average roof coating temperature was lower than the external air temperature between 3,2 °C to 3,9 °C due to long-wave radiation from sky to surface (Table 3).

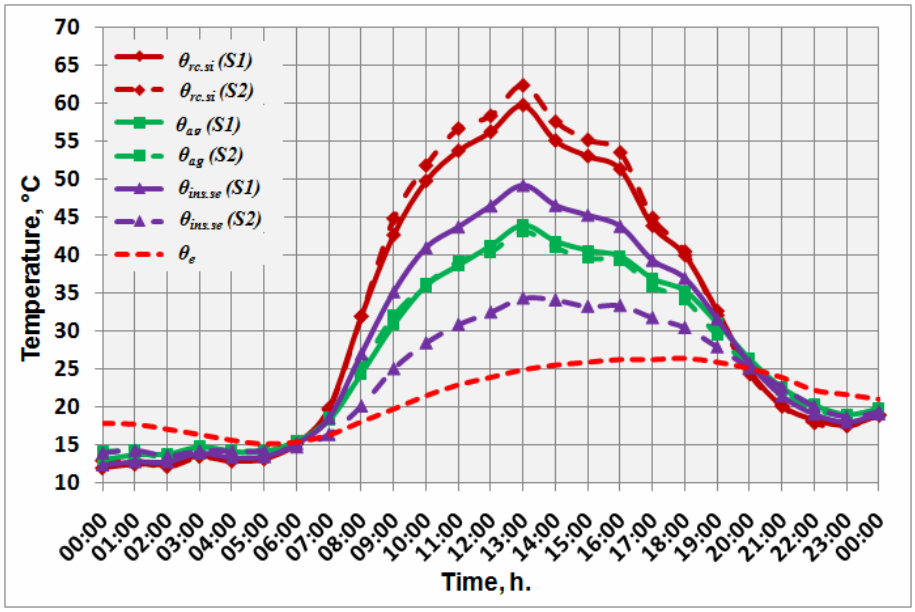

Figure 6. The experimental data of the roof elements and the external air temperature in Experiment No. 2

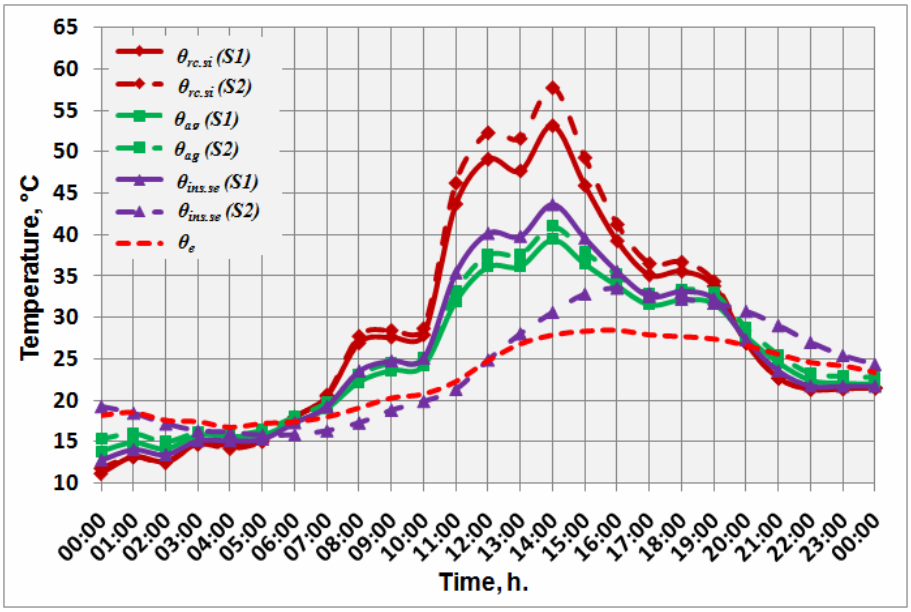

Figure 7. The experimental data of the roof elements and the external air temperature in Experiment No. 3

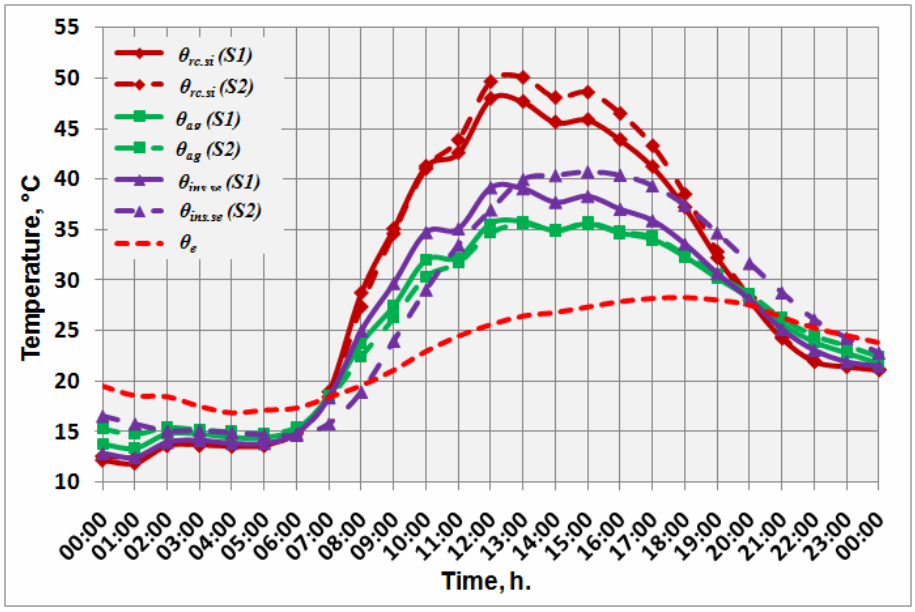

Figure 8. The experimental data of the roof elements and the external air temperature in Experiment No. 4

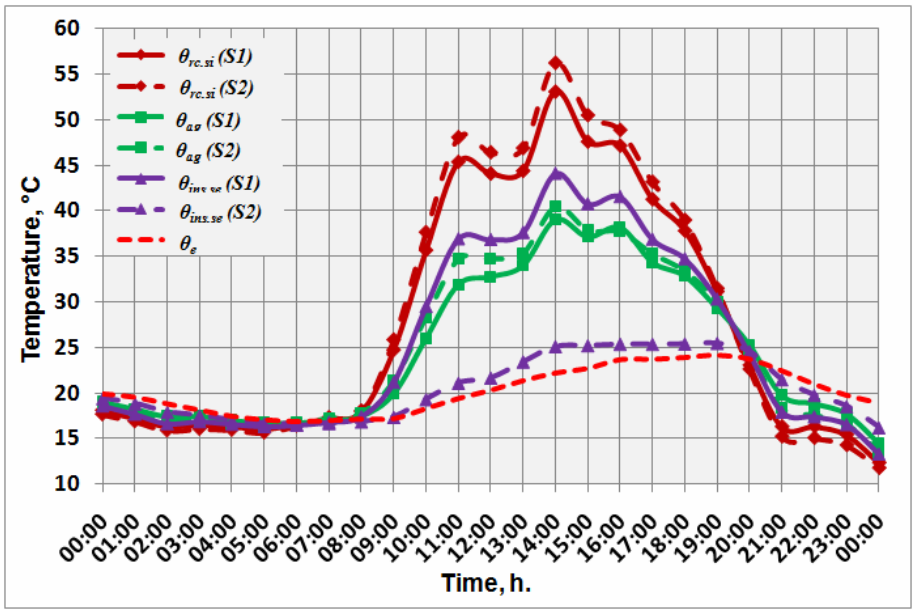

Figure 9. The experimental data of the roof elements and the external air temperature in Experiment No. 5

During the experiments, when the external air temperature was about 25 °C, the temperature of roof coating rose up till 60 °C and more in midday. Also, the temperature of ventilated air gap rose up till 45 °C. In midday the temperature of roof's thermal insulation's external surface was about 10 °C lower than the temperature of roof coating due to heat exchange between surfaces of ventilated air gap (in roof constructions as showed in Figure 2).

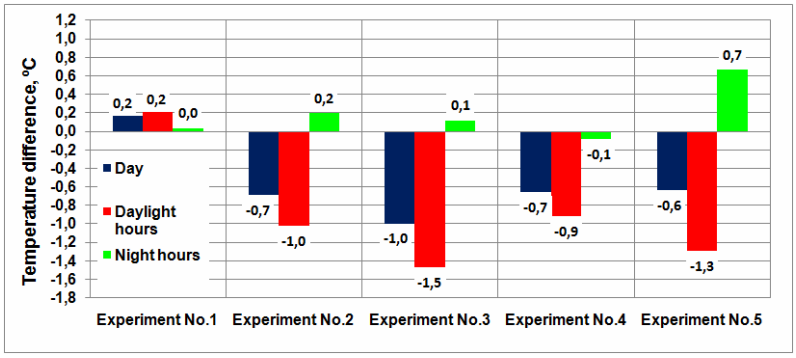

Figure 10. The temperature difference of roof coatings of the cells S1 and S2 during the experiments

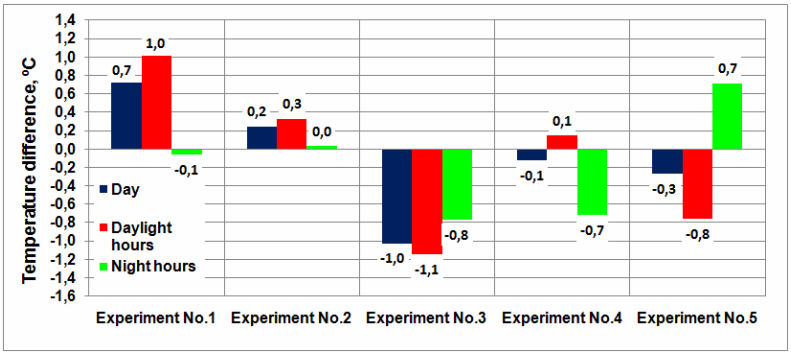

Figure 11. The temperature difference of the roof's ventilated air gaps of the cells S1 and S2 during the experiments

During the experiments it was determined, that in different experimental stages the difference between average daily roof coatings temperatures of the cells S1 and S2 was: 0,2 °C, -0,7 °C, -1,0 °C, -0,7 °C and -0,6 °C. In daylight hours these differences were from -1,5 °C till 0,2 °C, and in night hours: from 0,1 °C till 0,7 °C.

In different experimental stages the difference between average daily roof's ventilated air gaps temperatures of the cells S1 and S2 was: 0,7 °C, 0,2 °C, -1,0 °C, -0,1 °C and -0,3 °C. In daylight hours these differences were from -1,1 °C till 1,0 °C, and in night hours: from -0,8 °C till 0,7 °C. This means, that radiative heat transfers, taking place between surfaces of ventilated air gap, have almost no impact to the temperatures of ventilated roofs steel coating and ventilated air gap.

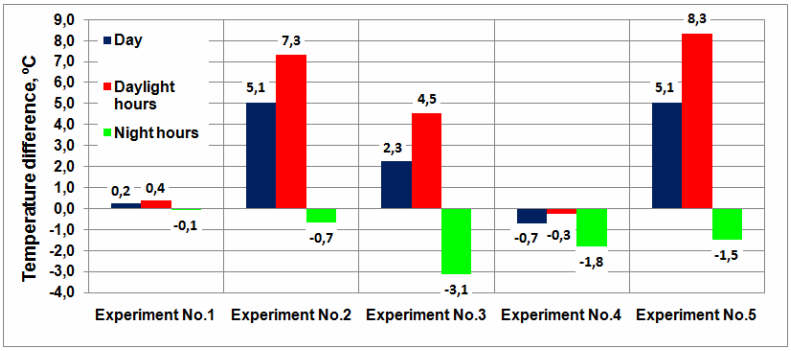

Figure 12. The temperature difference of the roof's thermal insulation's external surfaces of cells S1 and S2 during the experiments

In different experimental stages the difference of the roof's thermal insulation's external surface's average daily temperatures of the cells S1 and S2 was: 0,2 °C, 5,1 °C, 2,3 °C, -0,7 °C and 5,1 °C. In daylight hours these differences were from –0,3 °C till 8,3 °C, and in night hours: from -0,1 °C till -3,1 °C.

THE ANALYSIS OF EXPERIMENTS

Measured and calculated results of roof coating temperatures and inaccuracies of calculated temperatures are presented in Table 4.

It could be stated from presented data, that absolute inaccuracy of average daily roof coating temperature calculations is from -0,6 to +1,6 °C, when the calculations are made by equation (6).

For calculations made by equation (6) the experimental data was used relating to ventilated air gap's temperature, air moving speed in ventilated air gap (for convective heat exchange evaluation in surface layers) and the temperature of top surface of roof's thermal insulation. After that, according equations (4) and (6) calculated results was compared on purpose to evaluate the impact of heat exchange's intensity in roof coating inner surface for the temperature of this coating. It was fixed that these heat exchanges have the greatest impact when roof coating temperature is the highest. However, these heat exchanges reduce the temperature of roof coating inner surface just approximately 0,003 °C (this is a difference of calculation results according equations (4) and (6)). This means that heat exchange has no effect for ventilated steel roof coating temperature when heat exchange takes place in steel roof coating inner surface, and this type of roof coating extremely takes over the thermal climatic effects.

Table 4. Measured and calculated average daily temperatures of steel roof coatings.

Parameters	Experiment No. 1		Experiment No. 2		Experiment No. 3		Experiment No. 4		Experiment No. 5	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Measured average daily temperature of roof coating inner surface, °C	29,9	29,7	32,1	32,8	28,7	29,7	29,4	30,1	27,9	28,5
Average daily temperature of roof coating external surface calculated by formula (4), °C	31,2	31,2	33,7	33,7	29,1	29,1	31,0	31,0	28,1	28,1
Average daily temperature of roof coating inner surface calculated by formula (6), °C	31,2	31,2	33,7	33,7	29,1	29,1	31,0	31,0	28,1	28,1
Absolute calculation error - the difference between calculated temperature according to formula (6) and the measured temperature of roof inner surface, ° C	1,3	1,5	1,6	0,9	0,4	-0,6	1,6	0,9	0,2	-0,4

Note: S1 – *The cell No. 1,* S2 – *The cell No. 2.*

Daily dynamic temperature variation of roof coating is determined by the intensity of solar radiation's effect. In practice, it is important to evaluate how much time it takes for roof coating temperature to react to solar thermal effects. In Figure 13 the diagrams of temperature of roof coating internal surface and the total short-wave solar radiation are presented from Experiment No. 2. The data shows, that the steel roof coating quickly reacts to thermal effects of solar radiation and temperature variation due to low thermal emissivity, and these coatings repeats complexion of solar radiation's intensity variation. From other experiments the given data is very close to one presented in Figure 13.

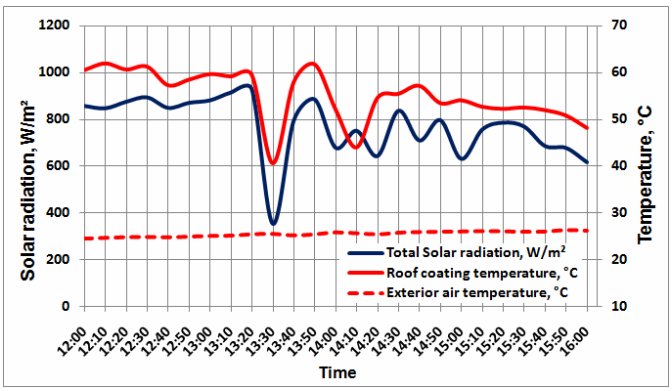

Figure 13. The temperature of roof coating inner surface and intensity of short-wave solar radiation during the Experiment No. 2 (10 minutes average)

When heat flows through roof constructions are designed and roof's thermal technical characteristics are calculated, the temperature of ventilated air gap is equated to the external air temperature according to standards. But during the experimentation, the temperatures variation of ventilated air gap and roof's thermal insulation's

external surface was changing due to the variation of temperature of roof coating and due to heat flow's density of the total solar radiation heat flow.

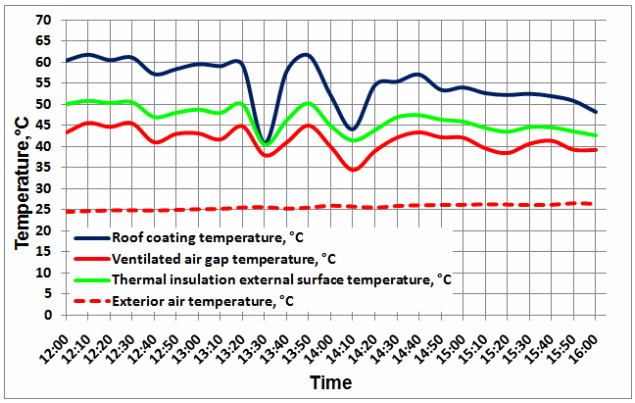

Figure 14. The cell's S1 temperatures of roof coating, ventilated air gap, thermal insulation's external surface and the external air during the Experiment No. 2 (10 minutes average)

CONCLUSIONS

1. The thermal solar radiation effects make quick influence to the temperature of steel roof coatings because of low steel roof thermal susceptibility. Also, the temperature variation of these coatings repeats complexion of solar radiation's intensity variation.
2. While radiative heat exchanges take place in ventilated steel roof coating inner surface, they have no impact to the temperature of ventilated steel roof coating and extremely take over climatic thermal effects.
3. During the day the variation of ventilated air gap's temperature repeats the variation of roof coating temperature, but not the variation of the external air temperature.
4. It was determined during the experimentation, that when solar radiation heat flow is maximum, the temperature of ventilated air gap could be reduced not more than 3 ºC by installing massive layer (~20 kg/m²) and/or heat reflective coating (ε=0.09) over roof's thermal insulation's external surface.
5. During the night hours (while there is no impact of solar radiation) the temperature of ventilated air gap is till 3 ºC lower than the external air temperature due to the impact of long-wave radiation between roof coating and sky.
6. During the day in lightweight steel roofs the temperature variation of thermal insulation's external surface repeats the temperature variation of ventilated air gap and temperature variation of roof coating, but not the temperature variation of the external air.

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Energy Demand for Heating and Ventilation in Museum Buildings Before and After Thermo Modernization – Numerical Analysis

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Abstract. Indoor environment quality of the museum premises influences the safety of the exhibits presented there. HVAC systems used in museums are designed mainly to create the comfortable indoor conditions for visitors that can be often different to the optimal conditions for the exhibition.
The numerical models of the selected museum building was built, giving the possibility to assess the energy demand in the heating season by simulation methods. The preliminary results of simulations by IDA and CONTAM software are validated by the measurements of the actual internal air temperature and relative humidity during the heating season in the rooms considered of the chosen museum.
The same software was used to analyze the possibilities to improve the indoor environment as a result of the thermal modernization of the museum building envelopes.

Keywords: Energy demand, simulation, museum buildings.

INTRODUCTION

Museum buildings belong to the special group of buildings where the indoor air quality (IAQ) is important. Particularly, the certain parameters, such as indoor air temperature, relative humidity and solar radiation decide on the IAQ. Ensuring the proper conditions in connection to the safety of the exhibits sometimes stands in contradiction to the primary function of museum – making the exhibits available for visitors. The large number of visitors can make the IAQ unsuitable because of the sudden growth of the internal heat gains and the air humidity that can be even dangerous for the exhibition (Ferdyn-Grygierek and Baranowski, 2010). Recommended parameters of the internal climate in museums are a relative humidity of 50 % and the temperature of 15÷ 25 ^{o}C. Deviations of ± 10 % for humidity are admitted, as well as deviations of temperature by ± 2 K (these ranges concern short fluctuations of the parameters due to instantaneous redundant gains and the non-homogenous environment – gradients of these parameters over the space of the museum). The conditions of the microclimate required to ensure the necessary comfort for the visitors have been determined rather precisely by both international and Polish standards (ASHRAE, 2005, ISO, 1994).

Additional difficulties to ensure the proper IAQ in the museum buildings results from their historical value. Very often those buildings are lack of the proper heating and ventilating installations, and because of their heritage importance there is no agreement for rebuilding and reconstruction of the HVAC system.

The paper presents the preliminary results of the investigations carried out within the frame of the research project which targets the identification and assessment of the energy demand for cooling and heating purposes in the museum buildings and points out the possible activities leading to the improvement of the indoor air quality. The research work was undertaken in the three museum buildings, differing one from another in the construction and HVAC installations. The research work comprises measurement campaign of the IAQ in the buildings under consideration as well as the simulation analysis of the energy consumption and ventilation air flows in those buildings.

BUILDING DESCRIPTION

The building under consideration was built in the beginning of the 20th century as a museum, nowadays the Upper Silesian Museum. It is a five-storey, double-winged building being in service since 1929 and comprising exhibition halls, storage rooms, offices and laboratories. The exhibition rooms are located on the first, second and the third floor. The building has mixed walls construction – partly made from reinforced concrete and partly from bricks. The thermal insulation of the external walls is below the contemporary requirements (Table 1).

The ventilation of building is realized only by the natural air infiltration through the windows leakages and there is no ventilation ducts except of the third floor where the two exhibition rooms are equipped with the supply/exhaust ventilation system with partially prepared air. The whole building is heated by the individual radiators supplied from the municipal district heating system.

Figure 1. Upper Silesia Museum

Table 1. Construction data and main values of the heat transfer coefficients

External walls: front wall: reinforced concrete 38 cm, back and side walls: bricks 38 cm	 U= 2.5 W/m^2K U= 1.5 W/m^2K
Ceilings: concrete slab 15 cm	U=2.75 W/m^2K
Windows: wood/aluminum/PVC, double glazed pane	U=1.8 W/m^2K

METHODS

The analysis of the energy demand and assessment of the indoor air quality were both performed by the numerical simulation. Thanks to the simulations the prediction of the building thermal performance for the different operation modes is be possible. On the other hand the simulation calculations are validated by the measurements of the indoor environment parameters and, after tuning, could be a reliable tool to predict and asses the energy consumption and IAQ in the different buildings (Baranowski and Ferdyn-Grygierek, 2009).

For the purpose of the thermal analysis the IDA ICE 3.0 software was used (IDA, 2002). The program enable to create and solve the heat balance equations for all simulated zones. Thus the following heat fluxes are calculated during simulation:

- heat from air flows,
- internal heat gains from occupants (including latent), appliances and electrical lighting,
- heat from room cooling and heating units (panels, radiators, chilled beams etc.),
- direct solar radiation,
- heat from window surfaces (including absorbed solar radiation),
- heat from walls and floors (heat stored in the structure, e.g. in the case of cooling ceiling).

Apart from items listed above the changeability of the operative and mean air temperature, air changes per hour, relative humidity, PMV and PPD indices, and the details of energy used by cooling/heating coils, local units, etc. are also calculated by the IDA code.

The important part of the heat balance is the energy demand for ventilation purposes. The calculations of the ventilation air flows within the considered building was made by CONTAM program. This program is designed for multizone analysis of the ventilation and indoor air quality in buildings (Walton and Dols, 2005). CONTAM can be applied to the global assessment of the ventilation effectiveness in the whole building, search for the time variation of the ventilation air flows in the particular zones or for checking the influence of building air-tightness on the air infiltration.

The research program comprises continuous measurement of the main indoor environmental parameters: air temperature and humidity and CO_2 concentration. The campaign has started in October last year and is carried out in all museum buildings considered in the project (Blaszczok et al. 2010). In the Upper Silesia Museum building all main exhibition rooms are equipped with measurement sensors located in selected points of every room. The local weather station provides the set of the meteorological data necessary for simulations.

MODELS

Two numerical models were built: the first one, CONTAM model was used to simulate the ventilation air flow in the building. The results of the simulation were used as the input data in the second model – IDA thermal model. Both models presented here are rough and preliminary. The experiment and measurement results make tuning them up possible.

Respectively the zoning was assumed in both models that was force out by the very complicated internal structure of the building. The stairwell located in the centre of the building is surrounded on all floors by the exhibition rooms and the auxiliary rooms (storerooms, cubbyholes and others). The topology of the numerical model is important, especially the assumptions about zoning. In the thermal calculation model (IDA) only the exhibition rooms were taken into account in the thermal balances. The walls between the neglected adjacent rooms were assumed as adiabatic so it was not necessary to include them into the thermal model. When the air flows in the building is calculated all air flow paths should be identified and balanced in particular zones. For

this reason in CONTAM model all rooms equipped with the windows were taken into account therefore the number of zones are greater than in case of IDA software. Also the stairwell (neglected in the thermal model) was modeled in CONTAM being the important flow path of the vertical air flows because of the thermal buoyancy which is formed in it.

All building walls were modeled according to the actual state (see Table 1). One of the biggest uncertainty is the value of the air infiltration coefficient which describe the air tightness of the windows - the assessment of these parameters based on the authors experience. Three type of windows were installed in the building: metal, wooden and PVC – all are weather-stripped, double glazed and some of them with the antisun layer. For the preliminary simulations the air infiltration coefficient was assumed to be equal 0.2 $m^3/m \cdot h \cdot Pa^{0.67}$. In the CONTAM the stairwell was modeled, being the important flow path in case when the ventilation is realized by natural way.

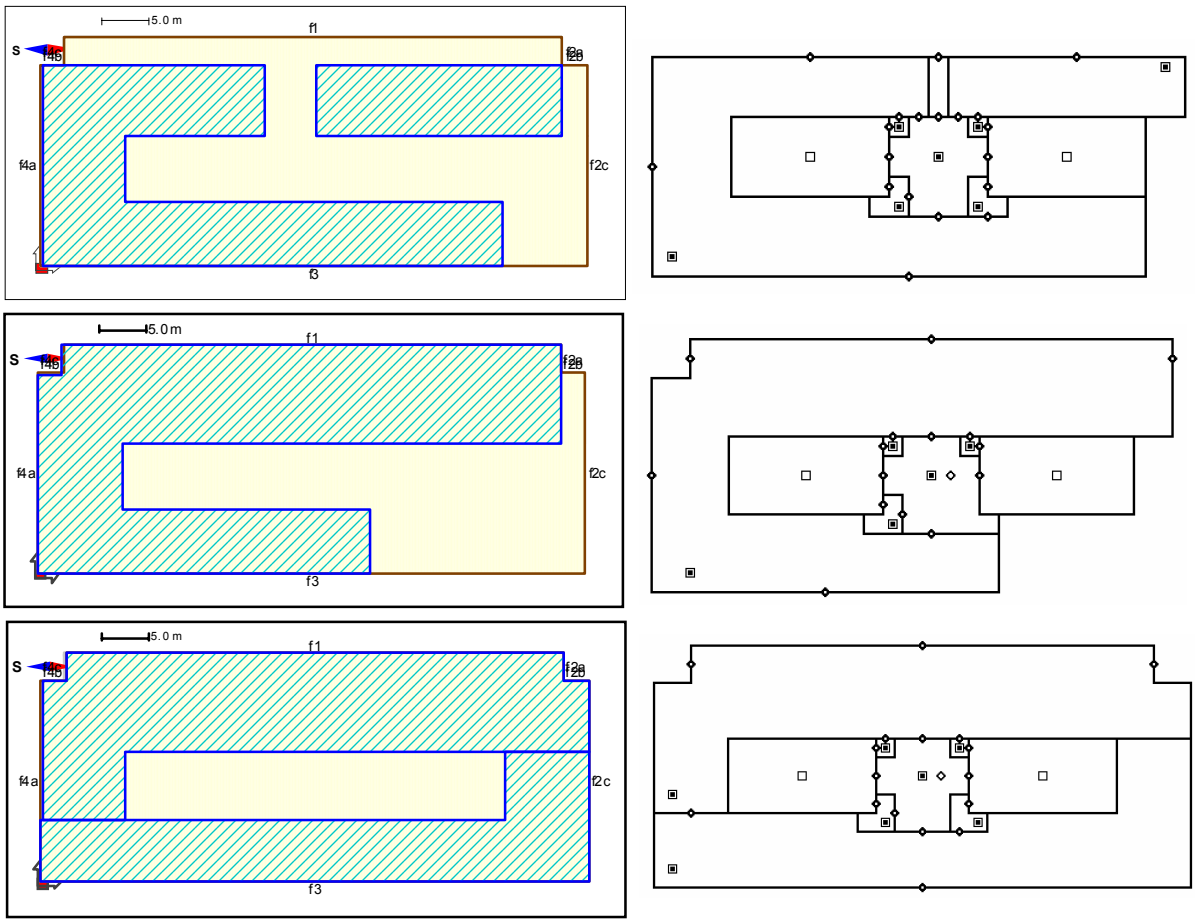

Figure 2. The sketchpad of IDA (left) and CONTAM (right) presenting the models of three floors of the museum building

Other assumptions in reference to the numerical models were as follows:

- lack of the external and/or internal window shadings (which exist in reality),
- the internal heat gains are the same for all zones and are not very precise: the lighting of the exhibition rooms is turned for 24 hours (no schedule), in every room there is only one person (rather staff than visitor)
- the air change rate calculated by CONTAM is used as the input data for the IDA program; the mean value from the period of simulation is taken into account: 0.3 1/h for the painting exhibition (with mechanical ventilation) and 0.1 1/h for other rooms,
- constant air temperature in the exhibition rooms is assumed: 21°C for the air flows simulation (CONTAM) and 21-25 °C for the thermal simulation by IDA.

Obviously, the presented numerical models are treated as the draft version. Using the measurement results the models will be improved and tune up which can help to give more precise and realistic results.

PRELIMINARY RESULTS AND DISSCUSSION

All simulations were carried out using the meteorological data recorded by the local weather station. The results of the simulation were obtained for the climate data of March 2010. For this period the additional measurements of the ventilation air flows in the painting exhibition room was made thus the comparison of the results was possible.

The run of variation of the air change rate in the painting and ethnography exhibition rooms is shown in the Figure 3. Because of the mechanical ventilation system installed in the painting room the air change rate is there approximately three times greater than in the ethnography exhibition.

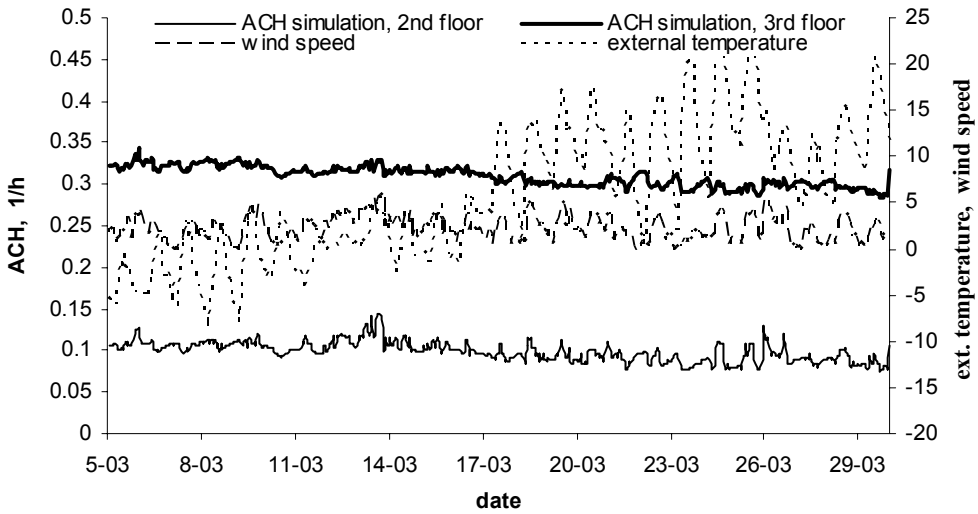

Figure 3. Air change rate simulation results for two exhibition rooms

The measurement of the exhaust air flow performed on 10th March in the painting room gave the air change rate equal to 0.32 1/h – this is very close to the simulation result. It can be noticed that the dependence of the air change rate (and consequently air infiltration) on the temperature difference is weak but on the wind speed is more noticeable. The reason of that is a lack of the ventilation ducts connecting the museum rooms with the ambient which creates the thermal buoyancy.

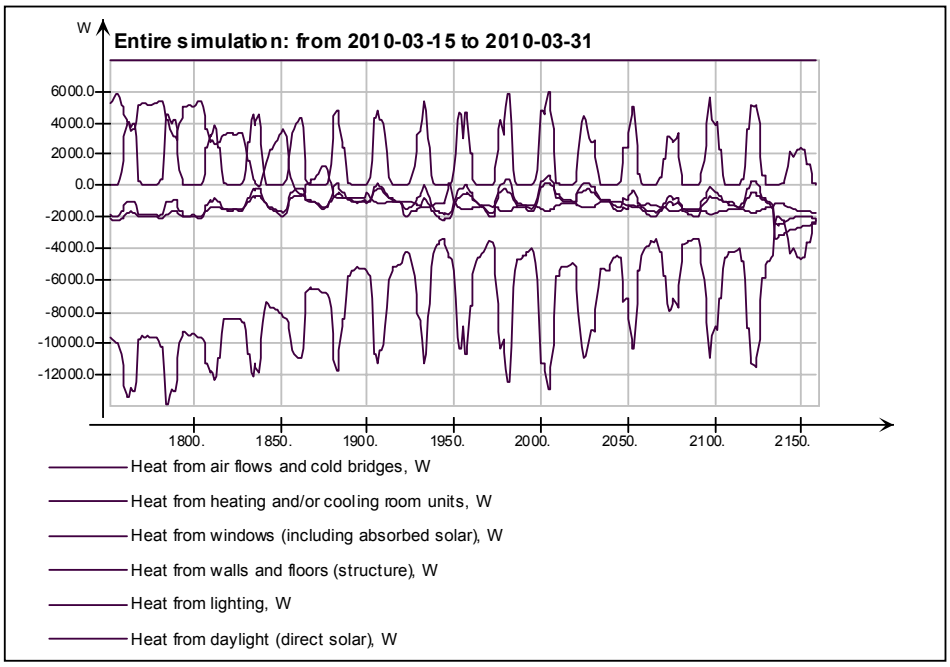

Figure 4. Graphical interface of the IDA simulation results

The thermal simulations performed by IDA program produce the complete, detailed set of data showing the courses of the particular heat fluxes for all zones of the considered building (Figure 4). The courses of the variation of the internal temperature in different museum rooms are presented in the Figure 5, 6, and 7. It appears that the trend of the changeability of the simulation results is quite satisfactory. The smaller dynamic in the amplitude - in comparison with the measurement - is probably from the incorrect modeling of the internal heat gains. This can be confirmed by the variation of the third curve in those charts that shows the changeability of the CO_2 concentration in the room. The sudden increase of the CO_2 arises likely because of the presence of people and the shape of this curve corresponds with the measurement of the air temperature. As it was mentioned previously the model of the internal heat gains was not very accurate – only one person in every zone was declared.

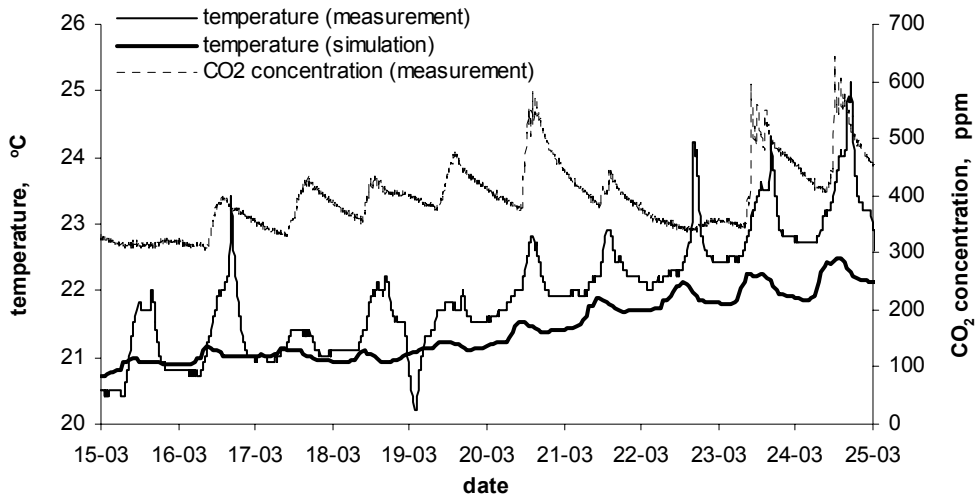

Figure 5. Variation of the air temperature in the exhibition room on the 1st floor

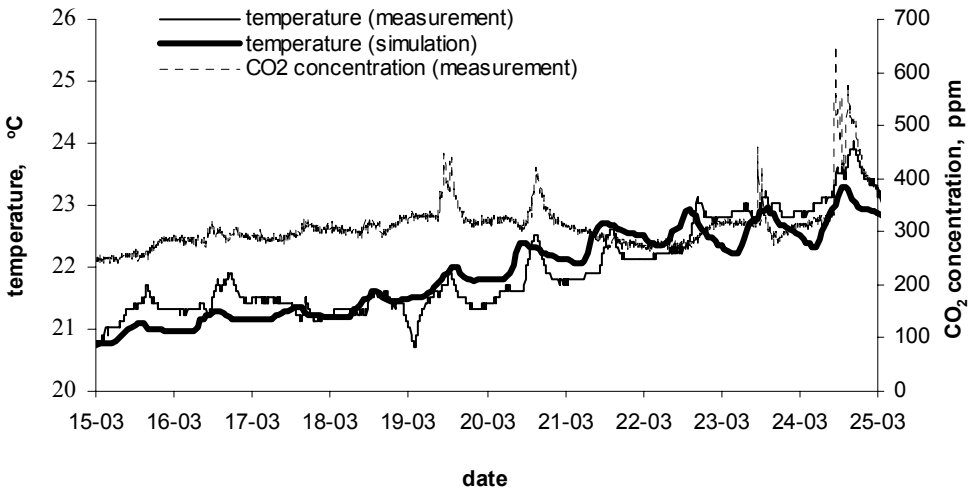

Figure 6. Variation of the air temperature in the exhibition room on the 2nd floor

As the last task the simple thermorenovation of the building was performed. It was assumed that all external walls are insulated with the mineral fibre. The thickness of the insulation was chosen to get the heat transfer coefficient decreased according to the domestic regulations to the value U = 0.25 W/m^2K - that means that the U-value reduced ten times. All other assumptions were the same as previously. The results of the simulation presented in the Figure 8 show that following the modernization energy demand for the assumed part of March was utilized only for cooling, although the outdoor temperature was sometimes near to 0 ^oC. Before modernization almost for the half of the time of the same period the actual heating demand reached even 6 kW. These results show the great potential of the energy saving in this museum building.

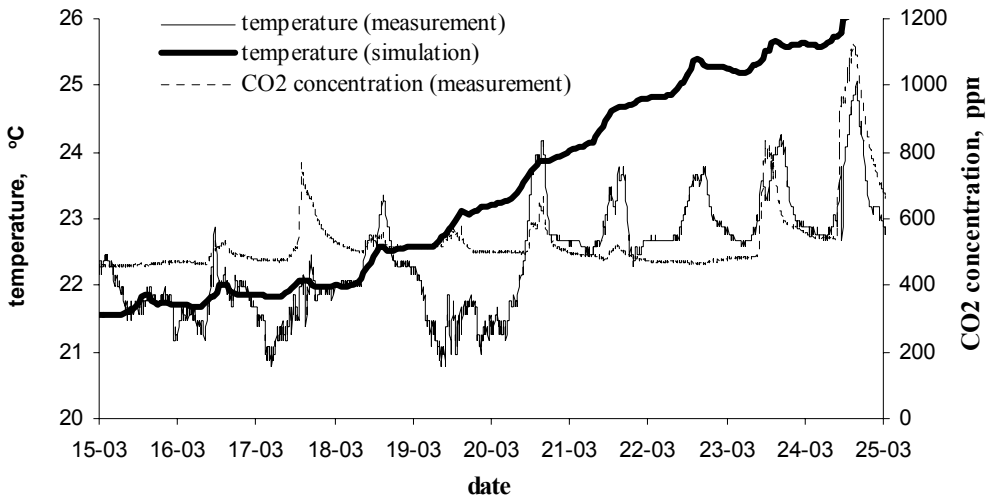

Figure 7. Variation of the air temperature in the exhibition room on the 3rd floor

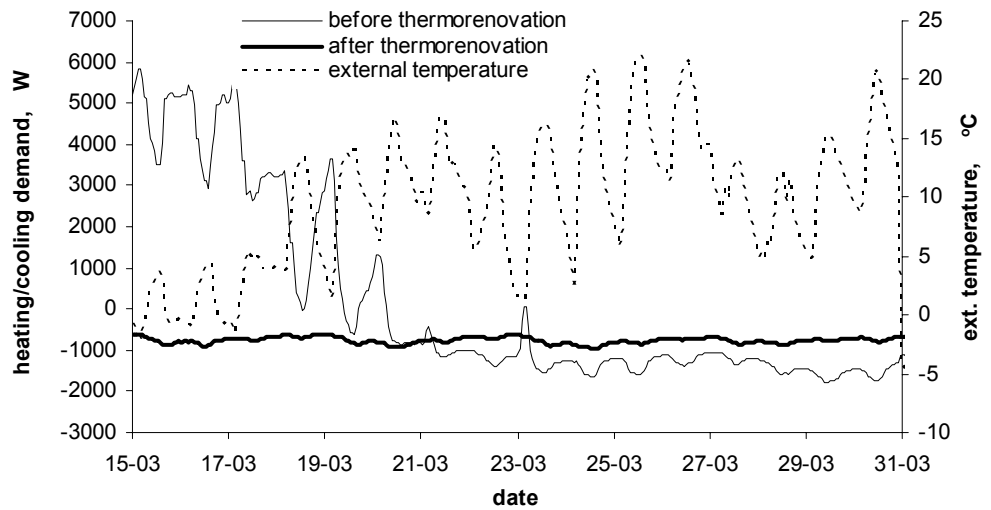

Figure 8. Actual heating or cooling demand in the exhibition room on the 1st floor before and after thermorenovation

CONCLUSIONS

The work performed gives only preliminary but quite satisfactory results. It was proved that even simple and rough numerical models can be a reliable basis for the initial analysis of the thermal behavior of buildings.

Buildings designed to serve directly as museums should meet the requirements concerning the heating and cooling demands and their ventilation in order to remove the excess of moisture. Based on these preliminary results some potential problems are indicated. The problem of this building is ventilation. Here in practice the system of ventilation for the whole building does not exist – neither mechanical nor natural. The air conditioning system installed in the painting exhibition room improve to some extent the air exchange only for this room but the rest of the museum rooms are in practice without any ventilation.

As the next step the numerical models presented here will be improved and adjusted, e.g. instead of the constant value of the internal heat gains the proper schedules related to the presence of people or switching on/off the lighting etc. will be applied.

The results presented in the paper concern only a very short period of time. The next simulations should shown the variation of the cooling/heating demand and air exchange in the building for a longer period, e.g. for heating season. The comparison to the measurement will allow to validate the software used and will confirm (or not) reliability of the simulation methods.

ACKNOWLEDGEMENT

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Comparison Between Results of Measurement and CFD Prediction of the Airflow in a Room with Mixing Ventilation

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Abstract. Many researches compare results from CFD simulation and airflow measurement results regardless of method of measurement of airflow. We can't forget about difference between the speed measured by omnidirectional anemometers and velocity measured by LDA anemometer or predicted by CFD simulation.

Keywords: speed - magnitude of velocity vector, velocity

INTRODUCTION

Computational Fluid Dynamics (CFD) becomes more and more widespread tool used for calculations concerning predictions of air movement in rooms, indoor air quality and thermal comfort. Comparison of the results from numerical calculation and the airflow measurement results is the most reliable method for validation of CFD predictions. Very important is to notice of difference between the speed, i.e. magnitude of velocity vector and velocity. The speed measured by omnidirectional low velocity thermal anemometers cannot be directly compared with velocity predicted by CFD simulation. The aim of the presented test was a CFD quality control by comparing the results obtained from the numerical calculation with the measurement results.

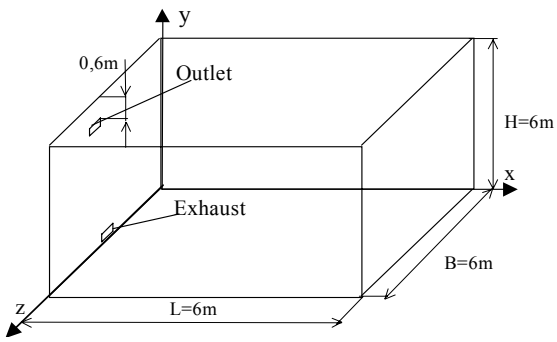

Figure 1. Enclosure geometry

METHODS

The airflow tests were carried out under isothermal conditions in an empty office room of the dimensions 6×6×3m (length × width × height). The jet was generated by a nozzle with the outlet dimensions 0.15×0.1m, (equivalent diameter D=0.138 m) positioned on the wall in the middle of the room width and at the distance of 0.65m from the ceiling. The air was supplied with the velocity W_o=5.2m/s. The exhaust had the same dimensions as the supply outlet and was positioned near the floor, on the same wall. The enclosure geometry is shown in Figure1.

The experimental tests were carried out in a scale model (1:5) of a room. The air was supplied to scale model with the velocity W_o=26.06m/s, according to the equality of the Reynolds number in the model and the prototype enclosure.

Laser Doppler anemometer (LDA) was used for the air velocity measurement in the jet. The axial mean air velocity component distributions were measured in 2 orthogonal axis, in the cross-sections of the jet, at distances from 5 to 40 equivalent diameters from the supply opening. Higher density of the measurement grid was used in the jet area, at the distances from 10 to 25*D* from the supply opening.

In order to identify the flow in the occupied zone measurements were performed with 8-channel low velocity thermal anemometer with spherical sensor (LVTA). Measurements of the mean speed, i.e. the mean magnitude of velocity vector, were taken at 200 points: 25 points in the 8 horizontal planes, in the space of the room from 0.1m above floor to the height 1.8m and 0.5m apart from the walls. The distances between measurement points in *x* and *z* directions were the same and equal to 1.25m; in the *y* direction they were equal to 0.24m (Figure 2).

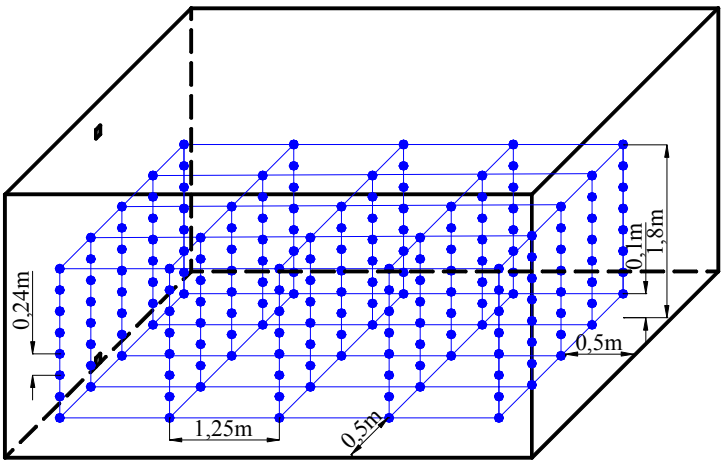

Figure 2. Location of measurement points in occupied zone

SIMULATION

Commercial CFD *k-ε* code with an orthogonal, Cartesian, discretisation grid was applied for the airflow calculation. Four numerical grids with different cell sizes were defined (Figure 3).

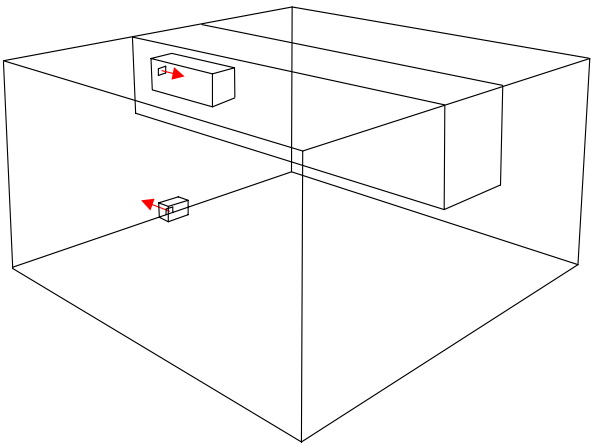

Figure 3. Regions with different size of grid cells

The cell size of the uniform base grid in the whole modelled space was 0.05×0.05×0.05m. The local grids with a higher density were applied for the jet region - the cell size equal to 0.05×0.025×0.025m: and nearby outlet and exhaust - the cell size equal to 0.025×0.0125×0.0125m. Boundary conditions were described directly in the supply opening.

CFD AND LDA RESULTS COMPARISON

To compare a distribution of longitudinal velocity component in a jet, the maps presented in Figure 4 were prepared. Because a laser anemometer was used to measure a velocity distribution in a jet, the measurement results could be compared directly with the numerical calculation results. Locations of further measurement sections were plotted on the maps, which facilitates to compare velocity distributions. The map based on the measurement results was generated owing to the use of model of axisymetric jet generated by a point momentum source, and therefore a velocity distribution was calculated starting from a distance 10d from the nozzle. The model is not able to represent the opposite wall interaction, and therefore the end of jet segment was not shown on the map. In consideration of the above, a comparison of the maps is only possible within the range 10-35d.

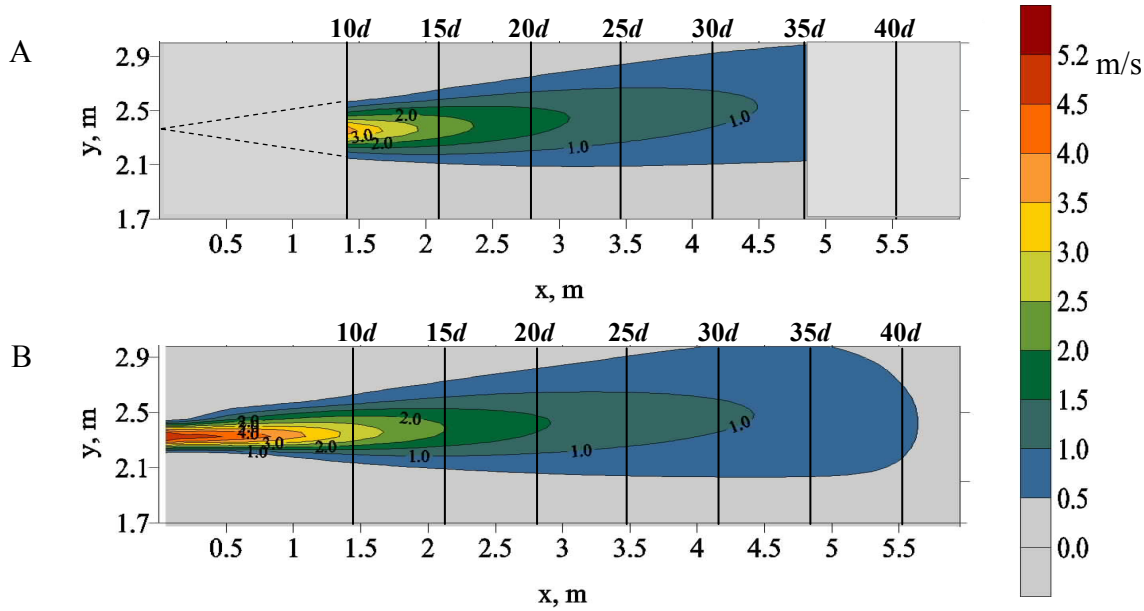

Figure 4. Comparison of velocity in a jet A- experiment, B CFD

An analysis of constant velocity isolines on the maps of jets makes it possible to conclude that the above 20d numerical calculations correctly predict velocities in a jet, but the jet profile width resulting from the CFD calculations is higher by 20% than the measurement profile, which will be reflected in air flows in the occupied zone.

To carry out a correct comparative analysis of the speed in the occupied zone, coming from the measurements with an eight-channel thermoanemometer set, with the CFD values, the velocity values obtained from the numerical calculation had to be recalculated into speed values. The method proposed by Popiolek and Melikov 2004 was used for that purpose. An omission of that calculation may lead to completely wrong conclusions. A comparison of the speed distribution maps based on measurements and velocities obtained directly from numerical calculations show quite big differences in a distribution of that parameter in the occupied zone (Figure 5).

An analysis of velocity distribution in a jet shows that higher values coming from the CFD compared to experiment values may be expected in the occupied zone. However, a direct comparison of the experiment results and numerical calculations suggests a completely opposite conclusion – the experiment values significantly exceed the calculation values. It results from an incorrect comparison of the distribution of two different quantities – the experiment speeds and the velocities coming form the CFD calculations. The use of recalculation and carrying out the following correct comparative analysis provides the conclusions that could be expected after the previous analysis of the velocity distribution maps in a jet – the speed values resulting from numerical calculations exceed the speed values measured, which is a consequence of the overestimated width of the stream profile and resulting overestimated average momentum value in the jet.

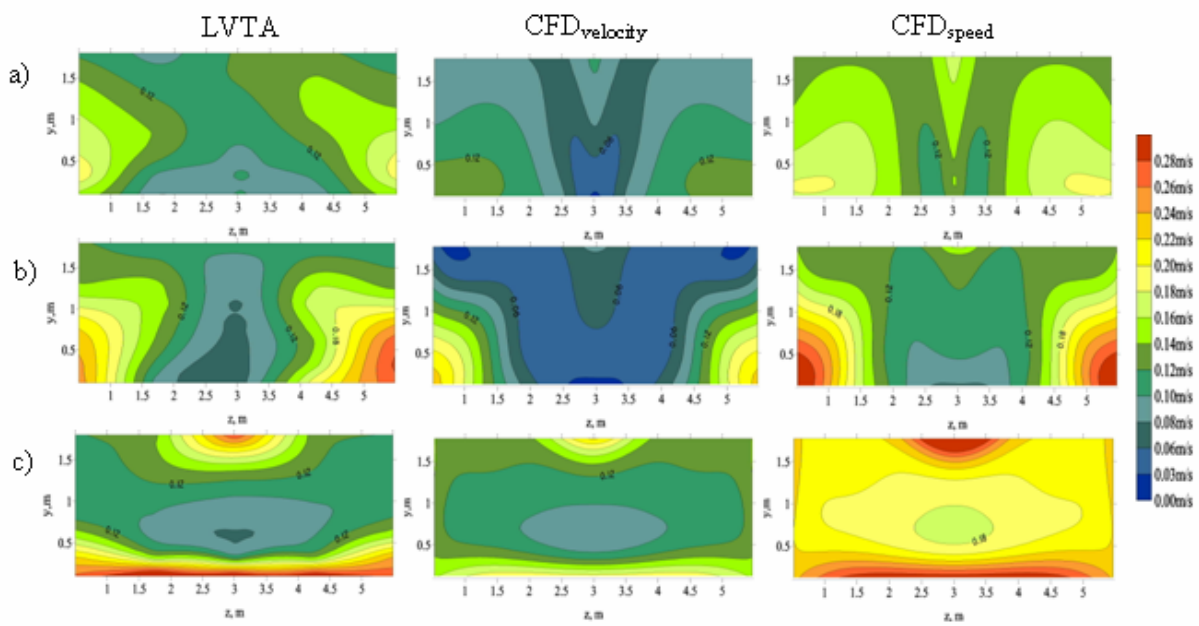

Figure 5. A comparison of the speed distribution maps in occupied zone

a) 0,5 m from inlet
b) 3,0 m
c) 5,5 m

The same error is observed in the case of comparison of average value of speed/velocity, resulting from the cumulative distribution function (Figure 6). A direct comparison of the experiment values and numerical calculations gives very similar average values, differing by only 2% between each other; however such a comparison is not correct because it refers to different quantities. Recalculation of the velocity values calculated numerically into the speed values make it possible to compare with the experiment values. In that comparison, significant differences in the average speed value resulting from not representing the momentum flux in the jet can be seen.

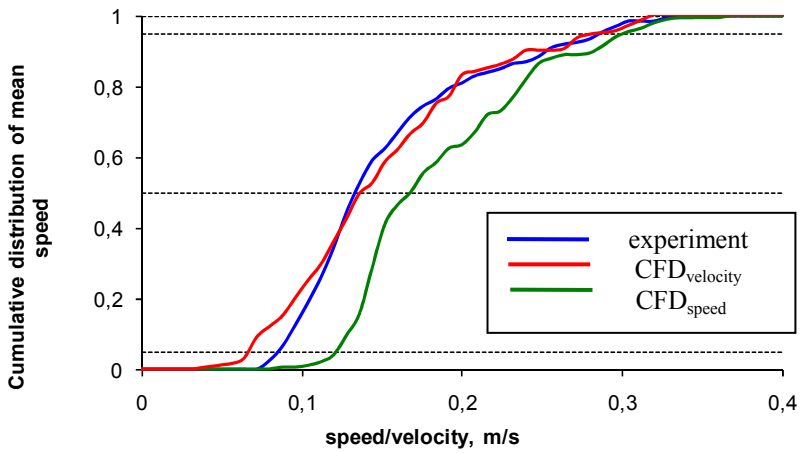

Figure 6. Measured and predicted cumulative distribution of mean speed in occupied zone

CONCLUSIONS

A distinction between a velocity and speed term and awareness of the measured value depending on the selection of a measuring instrumentation is extremely important because it makes it possible to correctly verify numerical calculations by using an experiment. An omission of that distinction may lead to incorrect conclusions, especially in the case of an analysis of turbulent flows that are predominant in the ventilation technique. An awareness of the difference between velocity and speed is a guarantee of correct verification of numerical calculations by means of experimental investigations.

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Specifics of Air Distribution in Multi-Storey Apartment Buildings

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Abstract. The main aim of ventilation systems in dwelling buildings is to ensure optimal comfort conditions and indoor air quality (IAQ) for inhabitants. While temperature and humidity level are crucial indicators for human comfort, CO_2 concentration is significant factor for human health.Since PVC windows have got wide expansion the problems with IAQ became more urgent. The air-exchange rates in dwelling buildings commonly are calculated by the same methods irrespective of the apartment's level.
This paper is devoted to modeling of air exchange rates and air distribution in multi-storey apartment buildings. A stack effect could be observed in the multi-storey buildings during the winter: the cold outdoor air infiltrates trough the lower levels of building and comes out through the upper levels. When internal walls and ceilings are not airtight, in addition to heat circulation, CO_2 circulation from building's lower levels to upper levels is also taking place. In such case the calculation methods of air-exchange rate should differ for upper and lower building's levels. The paper provides the results of monitoring of the IAQ features in multi-storey dwelling buildings paying particular attention to the influence of building's level on IAQ parameters.

Keywords: Indoor air quality, infiltration, CO_2 level, monitoring.

INTRODUCTION

Nine-storey apartment buildings are rather frequent for Latvian capital. Buildings constructed before 1990ies have been equipped with mandatory natural ventilation systems with stack effect. The inflow of fresh air in such buildings has been acquired through the gaps between window frame and window carcass. The exhaust – through the vents which are situated in kitchens and bathrooms.

Nowadays during the construction of new buildings and the renovation of the existing ones the mechanical exhaust from kitchens and bathrooms is commonly used and natural air supply is acquired through the simple air inlets in bedrooms. In many cases, after the renovation, the only natural exhausts persist in bedrooms, and the ventilation is possible only by opening the windows. The results of the research have shown that simple mechanical or natural exhaust cannot ensure optimal indoor air quality. In order to get information on indoor air quality in a whole building, the practical measurements of indoor air in different building's levels were done. The theoretical evaluation of infiltration and exfiltration influence on indoor air quality should be done in order to find the optimal air exchange rate and working principals of the ventilation system. It is incontestable that during the winter air infiltration is acquired through the lower levels of the building and exfiltration – through the upper levels.

The infiltration has a major impact on building's energy efficiency and its indoor air parameters, especially it concerns high rise buildings (Ross, 2004) and it should be taken into account for calculation heating system's capacity for lower floors. The existing researches (Olli Seppanen *et al.* 2000) on indoor air quality have shown that optimal CO_2 concentration in indoor air is up to 1000 ppm. The evaluation of indoor air quality in Netherlands (Wim Zeiler and Gert Boxem, 2008) has shown that allowed CO_2 concentration level was 1000ppm with a maximum value 1200ppm. The recommendations (ASHRAE 2004) also provide that indoor CO_2 concentrations should be maintained at or below 1000 ppm.

Latvian building code LBN 002 - 01"Thermal performance of building envelope"(LBN 002) provides only general requirements for buildings' air tightness: maximal air leakage for houses, hospitals and kindergartens is 3 $m^3/(m^2 \times h)$, at 50Pa; maximal air leakage for public buildings, - 4 $m^3/(m^2 \times h)$ at 50Pa; maximal air leakage for engineering buildings (factories) - 6 $m^3/(m^2 \times h)$ at 50Pa. When the air leakage is less than 3 $m^3/(m^2 \times h)$, building should be equipped by mechanical ventilation.

The airtight building has both – positive and negative properties. The positive impact of air tightness is possibility to create controlled air supply scheme and to reduce energy consumption for supply air heating. This positive effect could be reinforced by use of the ventilation systems with heat recovery.

The negative property is lack of natural air supply and additional costs for equipments and exploitation of mechanical ventilation. The negative property of non-airtight buildings is uncontrolled cold air infiltration which requires also additional heat in time than room is not occupied. For the existing buildings the level of air leakage could be evaluated by using a fan pressurisation method. At the same time there is now also common developed theoretical methodology of evaluation of impact of air leakage on building performance in building design stage.

At the moment there is a strict gradation for windows air leakage (*LVS EN 12207:2001, 2001*). But for external walls and roof structures theoretical evaluation of air leakage is problematic due to the lack of information on air permeance of building materials. The study presents data only for limited number of materials (Jacques Rousseau,*2001 and СП 23-101-2004,2004*).

METHODS

In the scope of this study the monitoring of indoor air temperature, relative humidity and CO_2 level was done in dwelling buildings. The measurements were done in sleeping rooms. For indoor air quality measurements the data loggers with the following parameters were used: temperature: -20^{0}C to 70^{0}C (±0.35^{0}C); relative humidity: 10% to 90% (±2.5%); CO_2 level: 0 to 10 000 ppm (±50 ppm or 5% of reading).

The level of infiltration and exfiltration in building depends on stack effect and wind pressure.
The stack effect can be expressed using the following equation (*Фокин К.Ф. et al., 2008*):

$$\Delta p = gh(\rho_e - \rho_i), Pa \tag{1}$$

The wind pressure can be expressed as:

$$\Delta p = \frac{\upsilon^2 \rho}{2} C_p, Pa \tag{2}$$

Total impact of stack effect and wind pressure on infiltration for first floor of buildings up to 14 floors can be found using the following equation (*Фокин К.Ф. et al.,2008*):

$$\Delta p = 0.8[\pm g(\rho_e - \rho_i)H \pm 0.6\frac{(n\upsilon)^2 \rho_e}{2}], Pa \tag{3}$$

or using (*Малявина,2007)* data:

$$\Delta p = 0.5H(\rho_e - \rho_i)g - h(\rho_e - \rho_i)g + 0.5\frac{(n\upsilon)^2 \rho_e}{2}]K(c_h - c_z), Pa \tag{4}$$

The impact of stack effect and wind pressure on infiltration level was calculated using the weather data from Latvian Building code (Table 1).

Table 1. The average Latvian climatic conditions

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Average temperature	-4,7	-4,3	-0,6	5,1	11,4	15,4	16,9	16,2	11,9	7,2	2,1	-2,3
Average relative humidity	85	82	79	73	69	72	76	78	81	83	86	86
Average wind speed	4,9	4,4	4,5	4,2	3,9	3,9	3,6	3,7	4,3	4,8	5,2	5,1

For the nine-storey apartment building the air pressure difference is shown in table 2.

Table 2. The air pressure difference for nine-storey apartment building for average Latvian climatic conditions

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1st floor	23	21	19	15	11	9	7	8	12	16	21	23
9th floor	-1	-3	-1	1	2	4	4	4	4	4	3	1

Typically dwelling buildings up to 16 floors are built from concrete panel with stone wood (or glass wood) insulation and with concrete external finishing. Basing on data (*СП 23-101-2004*) the resistance to infiltration can be calculated:

$$R_{\inf} = R_{\inf}^{concrete} + R_{\inf}^{insulation} + R_{\inf}^{ext.fin}, m^2 hPa/kg$$

where: $R_{\inf}^{concrete}; R_{\inf}^{insulation}; R_{\inf}^{ext.fin}$ – resistance to infiltration of concrete panel, insulation and external finishing, m^2hPa/kg (the values of resistance to infiltration for different building). The resistance to infiltration of a wall: $R_{\inf} = 39242 m^2 hPa/kg$.

Such high resistance to infiltration does not have any impact on total building's energy performance and quality of indoor air. The air tightness of windows still should be taken into account. The windows with resistance to air leakage R_{inf} = 0,65 kg/(m^2h) are typically used in Latvian market for dwelling building construction. The level of infiltrated air through the windows can be calculated (*Малявина, 2007*):

$G_0 = \frac{1}{R_{\inf}}\left(\frac{\Delta p}{\Delta p_o}\right)^{\frac{2}{3}}, kg/(m^2 h)$ For the first floor the level of infiltrated air will be:

$G_0 = \frac{1}{0.65}\left(\frac{23}{10}\right)^{\frac{2}{3}} = 2.68, kg/(m^2 h)$. For the 9th floor: $G_0 = \frac{1}{0.65}\left(\frac{1}{10}\right)^{\frac{2}{3}} = 0.33, kg/(m^2 h)$.

The infiltration level for 1st floor is eight times higher than for 9th floor.

RESULTS

For the purpose of practical evaluation of IAQ, two similar apartments were chosen in the same building. The measurements were done in the bedrooms on the 1st and 9th floor. The area of all analyzed rooms is 14m^2 and volume – 36m^3. The ventilation system consists of central mechanical exhausts from kitchens and natural air supply in bedrooms through regulated air inlets. The flow level through air inlets is regulated manually. The diameter of air inlet is 100mm. Each room is occupied by two adults and one infant. The roof exhaust ventilator was not operating at night during the study. All bedrooms' windows are situated on the northern facade.

The total amount of infiltrated air during the night:

$$L = G_0 F + L_{a.i}, m^3/h$$

where: $L_{a.i}$ – supplying air through air inlets, m^3/h, G_o – window's level of infiltration, kg/m^2h, F – window's area, m^2.

The theoretical evaluation of air distribution was done for nine-storey apartment building (Figure 1).

Amount of infiltrated air for the 1st floor through one window and one air inlets is L = 2.68*3+54= 62m^3/h. Amount of infiltrated air for the 9th floor is L = 0.33*3+2.5= 2.50 m^3/h. The theoretical air supply for the 9th floor is 25 times smaller than for the 1st floor. The exhausts ventilator capacity in 1st and 9th floor is 50m^3/h. Infiltrated air amount in 1st floor bedroom is 62m^3/h. The difference between infiltrated and exhaust air volume is 12 m^3/h. That means that 12 m^3/h from 1st floor exfiltrates through door to the staircases and communication shaft and under the stack effect goes to the upper floors.

During this study the windows on the 1st floor were closed and room in the 9th floor was regularly ventilated by opening windows during the day and before the night. Figure 2 and 3 present measurements in apartments on the 1st and 9th floors.

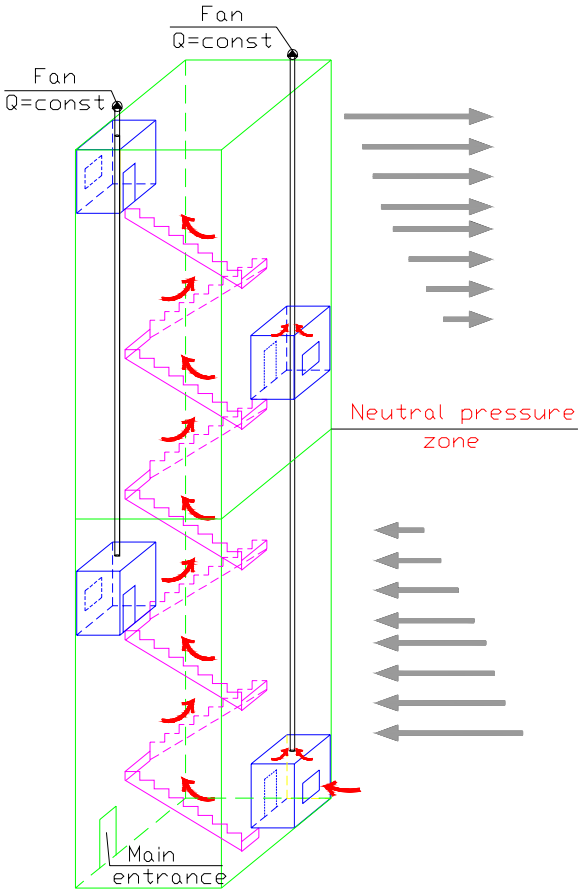

Figure1. Air distribution in for nine-storey apartment building

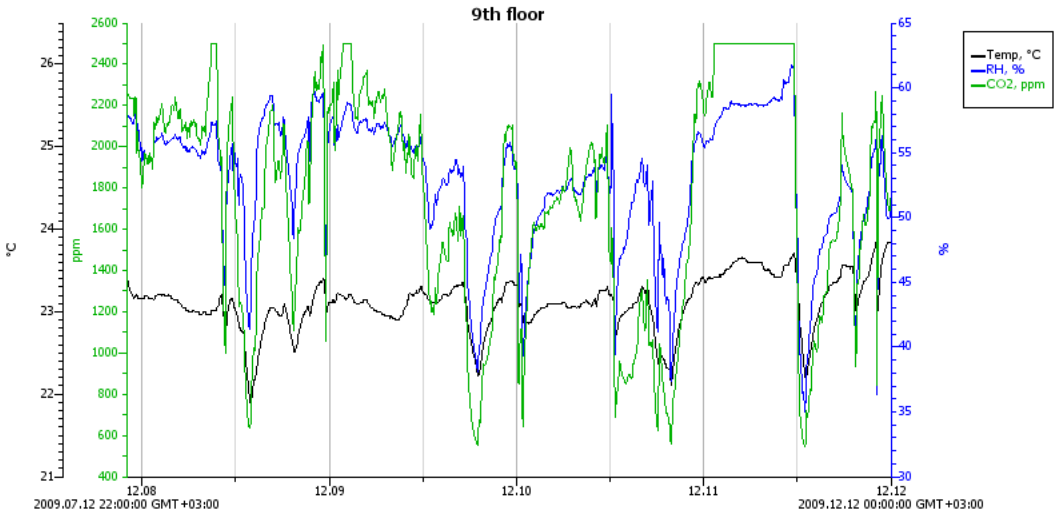

Figure 2. Indoor air parameter in 9th floor

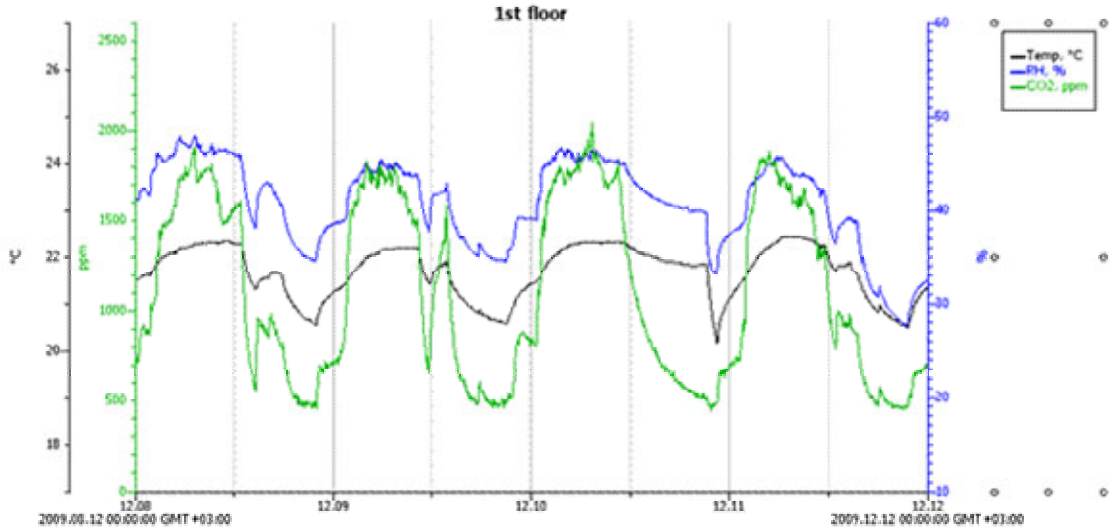

Figure 3. Indoor air parameter in 1th floor

As it could be seen from Figure 1 and 2 the CO_2 level on the 1st floor is significantly lower than on the 9th floor and does not exceed 1700ppm. On the 9th floor the CO_2 level during the night time is up to 2500ppm. The relative humidity on the 1st floor varies from 30% till 50%. The comparison of 24-hour fluctuation of CO_2 level is shown in Figure 4.

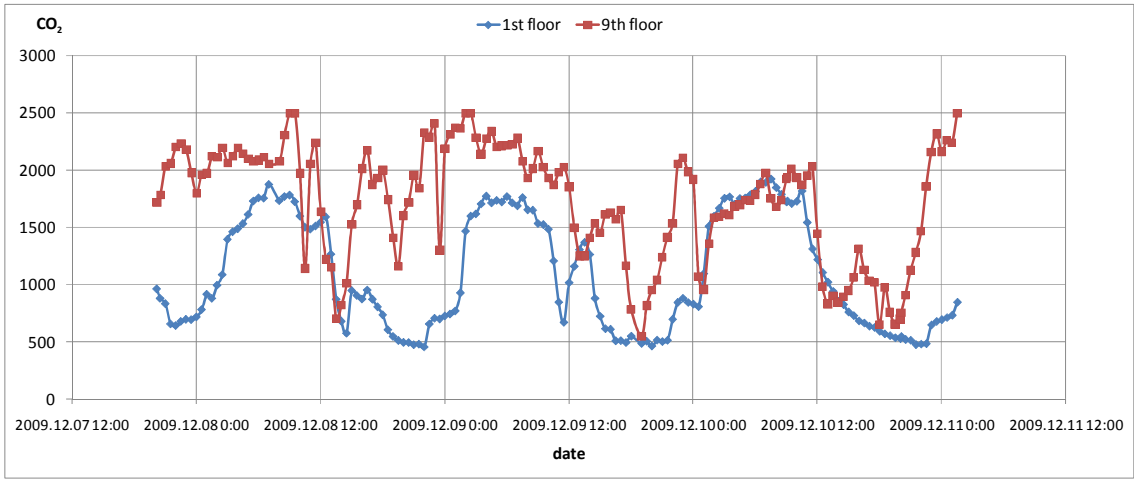

Figure 4. The comparison of 24-hour fluctuation of CO_2

As it could be seen form Figure 3 the CO_2 concentration on the 9th floor is much higher during the night time and it drops down after the opening of the window. The ventilation by means of window opening has significant shortcomings due to the high infiltration of cold outdoor air which can cause colds.

CONCLUSIONS

Usually in practice the HVAC systems and air exchange rates are calculated irrespective of the apartment's level. Although event in the 9th floor dwelling buildings the air pressure difference between 1st and last floor is 24 times.

Even the total balance between supplying air and exhausted air by ventilation system per apartment is calculated correct there is a risk of supplying air overflow due to infiltration. In this case excess air exfiltrates to the stair cases and raises up to the upper floors.

The impact of infiltration on energy consumption and indoor air parameters is very important for high-rise building as well as for 9store apartment buildings.

The further research will focus on evaluation of whole building taking into account not only one room as an example but also area of all apartments.

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Energy Consumption in School Buildings Before and After Thermomodernization

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Abstract. In Poland, most of the school buildings were built in 1960s and 1970s. These buildings are characterized by relatively high energy consumption. The increase in heating costs observed in 1990s showed how expensive the maintenance of such buildings was. For that reason, many of the school buildings have been recently renovated. The purpose of such renovation is to reduce the energy consumption by means of thermal insulation, windows replacement and central heating modernization.
The paper presents the results of the energy consumption analysis in a school buildings before and after thermomodernization. The results were compared with the standards. The analysis referred to two typical Polish elementary schools, that were built between 1950 and 1970.
The goal of analysis was to find the optimal solution of thermomodernization taking into consideration energy consumption and profitability of investments. The cost-effectiveness was estimated by SPBT (Simply Payback Time) indicator.

Keywords: Energy demand, thermomodernization, school buildings

INTRODUCTION

Regulations to energy efficiency of buildings in UE provides directive N° 2002/91/WE of European Parliament and Union Committee from 16 of December 2002. The detailed acts concerning standard of energy consumption, quality of buildings and heating, ventilation and hot water systems are published in the particular countries. A so-called "energy certificate" is required. Such certificates quote the calculated amount of energy consumed in the course of one year as well its annual cost and the amount of emissions resulting from the used heat, and in some countries also electricity. The principles of energy saving obligatory in the European Union have been valid also in Poland since January 4th 2006 (Dz. U., 2008, N° 201).

Pursuit of rationalization of central and regional government budget expenditures caused in recent years focusing on reduction of energy expenses in government facilities. Among them are public buildings such as schools.

In Poland, most of the school buildings were built in 1960s and 1970s. These buildings are characterized by relatively high energy consumption. Lis and Sliwowski (2003) gathered information concerning 134 school buildings, mainly in Warsaw. The heat consumption was contained within the range 100÷400 kWh/(m^{2}a), amounting mostly to about of 260÷280 kWh/(m^{2}a). Similar values have been quoted also by other Polish authors. Filipowicz (Filipowicz *et al*. 2001) suggest an average of 170÷250 kWh/(m^{2}a) for the city of Tychy, Gawin (Gawin *et al*. 2000) quotes values 145÷465 kWh/(m^{2}a) concerning schools in the region of Lodz, however Lis (2001) quotes an average of about 180 kWh/(m^{2}a) in the case of 50 schools in the region of Czestochowa.

For the comparison the index of heat consumption in Danish and German not modernized schools oscillates within the range of 200÷280 kWh/(m^{2}a) (Annex N° 36, 2003).

The presently assessed potential possibilities of saving energy only in Polish municipal economy amount to about 30÷40 % of the entire energy consumption (Gawin *et al*. 2000). Therefore an important element of the national policy is to stimulate investors implementing activities aiming at reducing the energy consumption.

Analyzing thermomodernization improvements, we may distinguish three such groups: modernization of the source of heat, modernization of the heating and ventilation systems, and modernization of the "shell" of the building (Filipowicz *et al*. 2001). The first-mentioned range of modernization tends to find a cheaper and more ecological way of heating the building. This range of changes is reduced to the modernization of the boiler-room equipment. The second group of modernization comprises the modernization of the internal systems: fitting the thermostatic valves, replacing same parts or even the entire systems. The third group of operation

comprises the insulation of external partitions and the replacement or sealing the windows. From the economical point of view, of much importance is the cost that must be paid for the purpose of saving 1 GJ of energy.

The report presented in the Annex N° 36 (2003) deals with the analysis of the thermomodernization improvements of as many as 25 educational buildings in 9 European countries, the resulting saving energy for heating them reaching 55 to 57 %. This indicates that this problem concerns not only Poland but the whole world.

Reduction of the energy consumption of already existing buildings, so very essential in the case of our budgets, may prove to be profitable already soon after the investments. Attention should be called to the possibilities arising from the legal act of November 21st, 2008, concerning thermomodernization and refurbishments (Dz. U., 2008 N° 223), which permits to obtain a bonus for the repayment of bank loan, granted for this purpose, provided that certain energy and financial conditions have been met. This way of financing can be applied if an energy audit of the given building has been carried out.

The paper presents the results of the energy consumption analysis in two typical Polish elementary schools, that were built between 1950 and 1970. The goal of analysis was to find the optimal solution of thermomodernization taking into consideration energy consumption and profitability of investments. The cost-effectiveness was estimated by SPBT (Simply Payback Time) indicator.

METHODS

The heat demand for the whole building was calculated with the use of computer program Audytor OZC, the latest version of which can calculate the design heat load of rooms and annual energy consumption the whole building basing on standards PN-EN 12831:2006 and PN-EN ISO 13790:2009. Each of the cases was calculated for a period of 9 months – the whole heating season (from September to May), using a weather test reference year. Factors of the internal heat gains from occupants, lightning and equipment were assumed according to the Polish standards. The temperature in rooms were between 16 ^oC and 20 ^oC depending on the function. The temperature was held on the same level throughout the day and night (including weekends).

In order to check the adequacy of the assumptions made for calculations, the difference between the measured and calculated heat consumption was analyzed.

Measured heat consumption was recalculated to standard conditions with equation (1).

$$Q_H^{st}=Q_H^{m}\cdot SD^{st}/SD^{m} \quad (1)$$

where:
Q_H^m – measured heat consumption,
Q_H^{st} – measured heat consumption for standard climate,
SD^{st} – degree days for standard climate,
SD^m – degree days for real climate.

Concerning the respective external partitions the thickness of the insulation was optimized. The criterion of this choice was the required minimum thermal resistance and SPBT indicator.

In compliance with the Decree of the Ministry of Infrastructure of March 17th, 2009 concerning the detailed scope and form of energy auditing (Dz. U., 2009 N° 43), the value of the thermal resistance after thermomodernization should be at least 4.0 $(m^2K)/W$ for the external walls and 4.5 $(m^2K)/W$ for the roofs and ceilings beneath unheated attic.

Annual heat demand for the loses of the heat transfer for the individual external partitions was calculated with equation (2).

$$Q_{0u}, Q_{1u} = 8.64\cdot 10^{-5}\cdot SD\cdot A/R \quad (2)$$

where:
Q_{0u} – annual heat demand before thermomodernization,
Q_{1u} – annual heat demand after thermomodernization,
SD – degree days,
A – area of partition,
R – thermal resistance before and after thermomodernization.

The costs of thermomodernization improvement have been assumed in compliance with the actually valid price list. These prices comprise the purchase and installation of the elements. The overall costs were increased by cost of the audit and required design works. The cost of the production of heat was calculated as the sum of the cost of fuel and the costs of servicing and maintenance.

RESULTS AND DISCUSSION

School building in Katowice

Firstly analyzed school building was built in 1950s (Fig. 1). This is two storey building with a basement storey under part of the building. Total cubature of the building amounts to 14 215 m^3, and usable heating area is 2 634 m^2.

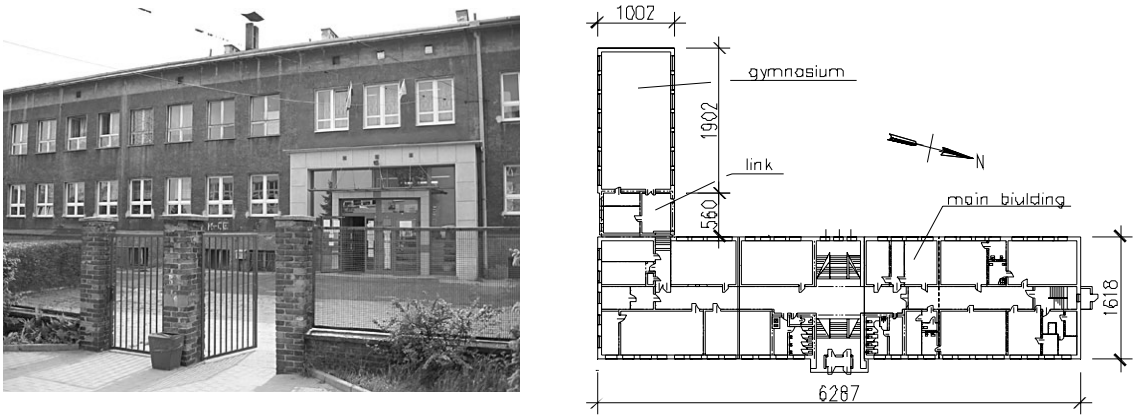

Figure 1. Analyzed school building – view of the entrance and plan of the ground floor. Dimensions in [cm]

Construction

The body of building with irregular outline of the external walls consists of two parts:

- the three-storey main building (including a partly heated basement) plus unused and unheated attic, containing: classrooms, kindergarten, offices, medical room, toilets, library, cloakroom, boiler rooms, kitchen, dining room, club and utility rooms,
- the ground floor building without the basement underneath, containing a gymnasium and a link between the main building and gymnasium.

Basement walls and ground floor walls are made of solid bricks. First floor walls are made of perforated bricks. External walls are not insulated. The ceiling over the first floor (under the unheated attic) is a beam-and-block floor insulated with 8 cm thick straw-clay mix. Gymnasium roof is a beam-and-block slab and a 5 cm thick wood cement sheet. Link roof is a non-ventilated flat roof without thermal insulation. Doors and windows are mostly replaced with the new ones (PVC double-glazed windows). Average value of the heat transfer coefficient (double glazed pane + frame) is estimated to 1.6 W/m^2K. Currently old type windows are in two rooms only.

Ventilation

Most of the rooms were equipped with gravitational ventilating ducts – from 1 up to 4 individual ventilating ducts (27×14 cm) connecting each room with the outlet on the roof. The gymnasium, kitchen and part of kindergarten's rooms are equipped with mechanical ventilation systems.

The ventilation was not found to be insufficient. The classrooms are ventilated during the breaks by opening the windows. The average weekly flux of the ventilated air was estimated as 6345 m^3/h, which gives a change of air amounting to 0.74 h^{-1}.

Heating

The building is equipped with a central water heating system, so far not modernized. The radiators are equipped with not adjustable cut-off valves. The pipes, situated of the outside of the wall, are not insulated.

Heat is produced in the boiler fired with eco-pea-coal. The boiler-room equipment was modernized in the year 2007, when two modern coal fired boilers with a thermal power of 150 kW and 200 kW were installed.

Preparation of the domestic hot water

Domestic hot water is prepared individually by means of electric boilers installed adjacent to the receivers. The annual heat demand required for the preparation of hot water amounts to 308.5 GJ/a. System is not planed for modernization.

Energy consumption

The external walls and the roofs of building do not meet the Polish standards of thermal isolation. The heat transfer coefficients for external partitions are presented in Table 1.

Table 1. The heat transfer coefficients for external partitions of building before and after thermomodernization

Type of building envelope	U [W/m^{2}K]		
	Before thermomodernization	After thermomodernization	Polish standard
External walls			
Basement			
Solid brick 77 cm/64 cm	0.820/0.952	0.211/0.219	0.30
Ground floor			
Solid brick 38 cm/51 cm	1.404/1.135	0.237/0.228	0.30
First floor			
Perforated brick 38 cm/51 cm	1.202/0.960	0.230/0.220	0.30
Ceiling beneath unheated attic	1.742	0.214	0.25
Gymnasium roof	1.176	0.215	0.25
Link roof	1.491	0.221	0.25
Windows	1.6/3.0	1.6	1.8
Ceiling over unheated basement	1.305	0.304	0.45

The design heat load is 317.8 kW. Annual energy demand for heating without taking into account energy efficiency of heating system is equal to 1608.5 GJ/a. It is 169.6 kWh/a per square meter of heating area.

Energy efficiency of heating system in existing state is estimated to 0.65 (Tab. 2). With energy efficiency of heating system taken into account, annual energy demand per square meter of heating area is calculated to value of 259.1 kWh/(m^{2}a).

Table 2. Efficiency of heating system

Heat generation	0.88
Heat transfer	0.93
Control	0.80
Storage of heat	1.00
Total efficiency of heating system η_{tot}	**0.65**

In order to check the adequacy of the assumptions made for calculations, the difference between the calculated heat consumption and measured heat consumption in the winter season of 2008/2009 was analyzed. The consumption of fuel amounted to 92.44 t. Assuming that the net calorific value of eco-pea-coal on the level 25 MJ/kg the consumption of heat amounted to 2311 GJ/a. The actual consumption of heat was recalculated from the relation (1) to standard conditions, the result being 2513 GJ/a. It is 265.0 kWh/a per square meter of heating area.

The difference between the measured heat demand (converted to the seasonal standard conditions) and the calculated seasonal heat demand amounts to 2.3 %.

Proposals of thermomodernization improvements

The analysis comprised the assessment of the effectiveness of the following improvements: the insulation of external partitions, the insulation of the floor above unheated part of the basement and the modernization of the heating system.

List of the optimum improvements and their costs are presented in Table 3.

Table 3. List of the optimum thermomodernization improvements in order of the growing SPBT indicator

N^o	**Type of thermomodernization improvement**	**Planned costs zl[1)]**	**SPBT**
1	Mounting thermostatic radiator valves and changes in boiler room allowing for decrease in temperature of the supply water in pipe system which in consequence increased the efficiency of the heating system to value **ηtot =0.76**	42 380	4.3
2	Insulating the ceiling beneath unheated attic – mineral wool 16 cm (λ[2)]= 0.039 W/(m·K))	45 474	4.8
3	Insulating the roof of link - granulated mineral wool 15cm (λ= 0.039 W/(m·K))	2 911	6.2
4	Insulating the external walls of link – polystyrene 14 cm (λ= 0.04 W/(m·K))	3 546	14.2
5	Replacement of the glass brick in link	1 588	15.7
6	Insulating the roof of gymnasium - polystyrene 15 cm (λ= 0.04 W/(m·K))	21 255	16.7
7	Insulating the external walls, ground and first floor of the main building - polystyrene 14 cm (λ= 0.04 W/(m·K))	130 181	19.3
8	Insulating the external walls of gymnasium - polystyrene 14 cm (λ= 0.04 W/(m·K))	36 516	22.2
9	Insulating the external walls of basement - polystyrene 14 cm (λ= 0.04 W/(m·K)) and replacement of the remaining 6 old type windows	30 741	28.9
10	Insulating the ceiling of coal storage room - polystyrene 10 cm (λ= 0.04 W/(m·K))	11 625	38.0

1) 1 zl=0.24 EURO
2) λ - Thermal conductivity

The best economical effects were obtained in the case of modernization of the heating system. Fitting the thermostatic valves as well as minor changes in the boiler room secure a payback of the investment costs already after three years and six months. Works related to the insulation of the external partitions will prove to be most effective in the case of insulating the roof under the unheated attic. The least effective investment was the insulation of the ceiling of unheated coal storage room, where the investment payback time is 38 years. As the ceiling cannot be insulated by a layer exceeding a thickness of 10 cm (due to the outfit of this room) these works are economically not feasible.

Basing on the values of the SPBT indicator, further stages of modernization were created. Table 4 presents the annual savings achieved in the heating of the building in the course of subsequent cases of thermomodernization.

Table 4. Savings in heating costs for all cases of the thermomodernization improvements

Case	N° of thermomodernization improvement	q_H 1)	Q_H 2)	η_{tot}	Q_H/η_{tot}	Costs of heating	ΔQ_H	Savings	Investment costs 3)	SPBT
		MW	GJ/a		GJ/a	zl/a 5)	GJ/a	zl 5)	zl 5)	
1	1+2+3+4+5+6+7+8+9+10	0.2198	729	0.76	958	27 399	1 499	42 871	339 216	7.9
2	1+2+3+4+5+6+7+8+9	0.2204	737	0.76	968	27 685	1 489	42 585	327 591	7.7
3	1+2+3+4+5+6+7+8	0.2266	789	0.76	1 036	29 630	1 421	40 641	296 350	7.3
4	1+2+3+4+5+6+7	0.2353	837	0.76	1 099	31 431	1 358	38 839	259 335	6.7
5	1+2+3+4+5+6	0.2673	1 092	0.76	1 434	41 012	1 023	29 258	127 654	4.4
6	1+2+3+4+5	0.2735	1 128	0.76	1 482	42 385	975	27 885	106 398	3.8
7	1+2+3+4	0.2740	1 131	0.76	1 486	42 500	971	27 771	104 810	3.8
8	1+2+3	0.2754	1 140	0.76	1 498	42 843	959	27 427	100 764	3.7
9	1+2	0.2777	1 155	0.76	1 518	43 415	939	26 855	97 854	3.6
10	1	0.3178	1 609	0.76	2 113	60 432	344	9 838	52 380	5.3
0 4)		**0.3178**	**1 609**	**0.65**	**2 457**	**70 270**				

1) design heat load
2) annual energy demand for heating without taking into account energy efficiency of heating system
3) costs of the thermomodernization improvements increased with the cost of the audit and required design works
4) building before thermomodernization
5) 1 zl=0.24 EURO

A complex renovation of the outer shell and the modernization of the heating system resulted in a reduction of the design heat load by 31 %, and the annual consumption of heat by 61 %. Attention should be drawn to the fact that the building is in its present state already provided with mostly modernized windows. The achieved energy consumption of the building amounts to 101 kWh/(m^2a); the reimbursement of the costs of investments will require no more than 8 years. 46 % of the entire consumption of heat is used for the purpose of ventilation. Previous to modernization the share of heat consumption for ventilation amounted to 27.2 % (the flux of ventilated air was the same during all the stages of modernization).

The share of heat losses through the modernized external partitions (walls, roofs and ceiling under unheated attic) dropped from 49.5 % to 15.8 %. The best result is achieved by insulating the ceiling under unheated attic. The losses of heat are then decreased from 861.2 GJ/a to 145.4 GJ/a; this means that before the modernization the share of the ceiling constitutes 30 % of the total consumption of heat, whereas after its insulation it amounts merely to 8.6 %.

In relation to the saving of heat to the total energy consumption for heating and preparation domestic hot water (domestic hot water system was not modernized) the saving of energy amounts to 54.2 % (Tab. 5).

Table 5. Total energy consumption for heating and preparing of the domestic hot water and rate of the energy savings to the state before thermomodernization

Case	1	2	3	4	5	6	7	8	9	10	**0**
Total energy consumption (heating and domestic hot water), GJ/a	1267	1277	1345	1408	1743	1791	1795	1807	1827	2422	**2766**
Savings of energy consumption, %	54.2	53.8	51.4	49.1	37.0	35.3	35.1	34.7	34.0	12.4	

According to the requirements of the decree concerning the promotion of thermomodernization (Dz. U., 2008 N° 223) the investor may apply for a bonus if the energy demand has been reduced by a least 15 %. This condition is satisfied in all cases, except case 10.

School building in Oswiecim

The second analyzed building was built in 1960s (Fig. 2). This is two storey building without basement. Total cubature of the building amounts to 6 248 m^3, and usable heating area is 1 352 m^2.

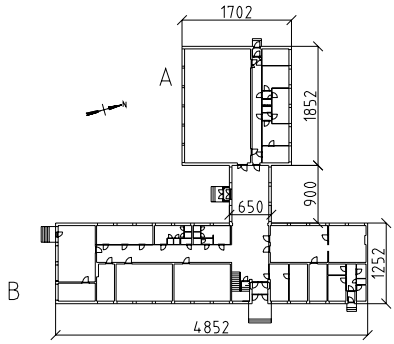

Figure 2. Analyzed school building in Oswiecim – view of the entrance and plan of the ground floor. Dimensions in [cm]

Construction

The body of building consists of two parts and link between them:

A – the two storey building containing classrooms, office, medical room, toilets, kitchen, dining room, club and utility rooms,

B – the one storey building containing a gymnasium, cloakrooms and library.

The building was built by the mean of large panel technology. All external walls are 38 cm thick, are made of reinforced concrete slabs and aerated concrete slabs. The roof of building is an non-ventilated flat roof. Doors and windows are mostly replaced with the new ones. Average value of the heat transfer coefficient (double glazed pane + frame) is estimated to 1.6 W/m^2K. Currently old type windows are in gymnasium and two classrooms.

Ventilation

The school was equipped only with gravitational ventilating ducts. The classrooms are ventilated during the breaks by opening the windows, like in the school in Katowice. The average weekly flux of the ventilated air in the school in Oswiecim was estimated as 2490 m^3/h, which gives a change of air amounting to 0.57 h^{-1}.

Heating

The building is equipped with a central water heating system, was modernized in 2002. Within the framework of a modernization was replaced old cast-iron radiators by steel radiators with thermostatic valves and replace old ductworks. Heat is produced by coke-fired stove localized in boiler room in adjacent building. The boiler was modernized in the year 2002, coke fired boiler with a thermal power of 130 kW was installed.

Preparation of the domestic hot water

Domestic hot water in toilets is heated individually in a boiler. The annual heat demand required for the preparation of hot water amounts to 163.7 GJ/a. System is not planed for modernization.

Energy consumption

The heat transfer coefficients for external partitions are presented in Table 6.

Table 6. The heat transfer coefficients for external partitions of building before and after thermomodernization

Type of building envelope	U [W/m^2K]		
	Before thermomodernization	After thermomodernization	Polish standard
External walls	0.966	0.21	0.30
Roof of gymnasium	0.595	0.17	0.25
Roof	0.619	0.16/0.17/0.19	0.25
Windows	1.6/2.6	1.7	1.8

The design heat load is amount to 178.7 kW. Annual energy demand for heating without taking into account energy efficiency of heating system is amount to 721.4 GJ/a. It is 148.2 kWh/per square meter of heating area.

Energy efficiency of heating system in existing state is estimated to 0.66 (Tab. 7). With energy efficiency of heating system taken into account annual energy demand per square meter of heating area is calculated to value of 224.5 kWh/(m^2a).

Table 7. Efficiency of heating system

Heat generation	0.82
Heat transfer	0.95
Control	0.85
Storage of heat	1.00
Total efficiency of heating system η_{tot}	**0.66**

The consumption of coke in the winter season 2008/2009 was 37.5 t. Assuming that the net calorific value of coke is on the level 27 MJ/kg the consumption of heat amounted to 1012.5 GJ/a. The actual consumption of heat was recalculated from the relation (1) to standard conditions, the result being 1092.0 GJ/a. Than difference between the measured heat demand (converted to the seasonal standard conditions) and the calculated seasonal heat demand amounts to 0.3 %.

Proposals of thermomodernization improvements

In school located in Oswiecim replacement old windows, insulating external walls and roofs was assumed. The list of the optimum improvements and their costs are presented in Table 8.

Table 8. List of the optimum thermomodernization improvements in order of the growing SPBT indicator

N°	Type of thermomodernization improvement	Planned costs zl[1)]	SPBT
1	Replacement of windows	61 855	16.9
2	Insulating external walls– polystyrene 15 cm (λ[2)]= 0.04 W/(m·K))	119 782	17.9
3	Insulating roof of part A of school polystyrene 18 cm (λ= 0.04 W/(m·K))	13 566	25.4
4	Insulating roof of part B of school polystyrene 17 cm (λ= 0.04 W/(m·K))	71 074	26.4
5	Insulating roof of link - polystyrene 14 cm (λ= 0.04 W/(m·K))	6 494	31.4
6	Insulating roof of gymnasium - polystyrene 17 cm (λ= 0.04 W/(m·K))	24 441	33.3
7	Adjustment of heating system	7 000	

1) - 1 zl=0.24 EURO
2) λ - Thermal conductivity

The best economical effects in school in Oswiecim were obtained in the case of replace old windows and insulating external walls. The least effective investment was the insulation of the roof of gymnasium.

The adjustment on central heating system wasn't considered separately because of the fact it is the effect of the adaptation to changed conditions of heat requirements. Basing on the values of the SPBT indicator, further stages of modernization were created. Table 9 presents the annual savings achieved in the heating of the building in the course of subsequent cases of thermomodernization.

Table 9. Savings in heating costs for all cases of the thermomodernization improvements

Case	N° of thermomodernization improvement	q_H[1)]	Q_H[2)]	η_{tot}	Q_H/η_{tot}	Costs of heating	ΔQ_H	Savings	Investment costs[3)]	SPBT
		MW	GJ/a		GJ/a	zl/a[5)]	GJ/a	zl[5)]	zl[5)]	
1	1+2+3+4+5+6+7	0.1293	348	0.66	526	19 094	563	20 437	311 211	15.2
2	1+2+3+4+5+7	0.1324	369	0.66	557	20 219	532	19 312	286 770	14.8
3	1+2+3+4+7	0.1334	375	0.66	566	20 546	523	18 985	280 277	14.8
4	1+2+3+7	0.1444	457	0.66	690	25 047	399	14 484	209 203	14.4
5	1+2+7	0.1467	473	0.66	714	25 918	375	13 613	195 637	14.4
6	1+7	0.1698	649	0.66	979	35 538	110	3 993	75 855	19.0
0[4)]		**0.1787**	**721**	**0.66**	**1 089**	39 531				

1) design heat load
2) annual energy demand for heating without taking into account energy efficiency of heating system
3) costs of the thermomodernization improvements increased with the cost of the audit and required design works
4) building before thermomodernization
5) 1 zl=0.24 EURO

A complex renovation of the outer shell and adjustment of the heating system resulted in a reduction of the design heat load by 28 %, and the annual consumption of heat by 52 %. In the building under consideration most of the old windows are replaced by new windows. As a result achieved energy consumption of the building amounts to 97.6 kWh/(m^2a); the share of heat losses through the modernized external walls dropped from 22.3 % to 7.6 % and through the roof from 16.6 % to 6.8 %.

In relation to the saving of heat to the total energy consumption for heating and preparation domestic hot water (domestic hot water system was not modernized) the saving of energy amounts to 44.9 % (Tab. 10).

Table 10. Total energy consumption for heating and preparing of the domestic hot water and rate of the energy savings to the state before thermomodernization

Case	1	2	3	4	5	6	0
Total energy consumption (heating and usable hot water), GJ/a	690	721	730	854	878	1143	1253
Saving of energy consumption, %	44.9%	42.5%	41.8%	31.9%	29.9%	8.8%	

CONCLUSIONS

The analysed buildings represent typical Polish schools. Both of them were built within the action called "Thousands of schools for the 1000-anniversary of Poland". The construction of these schools buildings was based on one of several standard projects.

The present analyses described in the paper show, that complete thermomodernization of such school buildings may result in decreasing of heat consumption even up to approximately 50÷60 %. Attention should be drawn to the fact that the buildings are in its present state already provided with mostly modernized windows, and heating systems in schools were partly modernized. In the case when the school buildings have not been modernized earlier the energy saving effect can be even better.

Energy consumption for heating after complete thermomodernization of school buildings are reduced to 101.0 kWh/(m^2a) in school in Katowice (before thermomodernization 259.1 kWh/(m^2a)) and to 97.6 kWh/(m^2a) in school in Oswiecim (before thermomodernization 224.5 kWh/(m^2a)). The greatest energy saving effect was obtained after insulation of the external partitions. As the result of insulating the external walls and roofs the percentage of heat losses through them decreased from 49.5 % to 15.8 % and from 38.9 % to 14.4 %, respectively.

Estimation of profitability of the investment by simple payback time shows that the thermomodernization improvements are cost-effective in both buildings. SPBT indicator is below 8 years for school in Katowice and about 15 years in Oswiecim. A bit higher payback time for school in Oswiecim is caused by relatively high investment costs, especially costs of the insulation of the roof in this building.

The minimum required energy effect (decrease of energy consumption about minimum 15 %) to get "the thermomodernization bonus" was obtained for either investments. After thermomodernization energy consumption for heating and preparation of the domestic hot water was reduced about 54 % in school in Katowice and about 45 % in school in Oswiecim.

The analysis of particular options of thermomodernization allowed to determine the most profitable scope of work and estimate the savings due to thermomodernization can bring. In the case of lack of sufficient funds schools can pick the most profitable improvements.

In the cases dealt within this paper the ventilation system in the building had not been analyzed. In the classrooms we encounter merely gravitational ventilation. The classrooms are ventilated additionally during the breaks by opening the windows and, in the opinion of users, the applied ventilation is satisfactory. Our investigations based on these assumptions. However, during periods of low outdoor temperature it can cause dramatic decrease in the indoor temperature even below 10 ^{o}C (Ferdyn-Grygierek, 2005). For this reason, in future the modernization of the ventilation system (installation of the mechanical ventilation systems) should be considered.

ACKNOWLEDGEMENT

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Assessment of Indoor Climate Conditions in Multifamily Buildings in Lithuania Before and After its Renovation

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Abstract. There are over 18 thousand multifamily apartment houses built from prefabricated reinforced concrete blocks in Lithuania. Renovation of these buildings is under way as most of the housings of this type are not meeting today's standards from technical, functional, architectural and social point of view. Two field studies performed in order to evaluate indoor climate conditions in two similar buildings in Kaunas before and after renovation are presented in this paper. Air temperature, relative humidity and carbon dioxide concentration were measured in the living rooms of the apartments and the questionnaire survey was carried out in order to determine most critical microclimate parameters and sick building syndrome (SBS) symptoms. Field studies revealed that air temperature in the rooms is usually low or too low and CO_2 concentration measurements indicated poor ventilation in both buildings. Subjective investigation indicated that such problems as changing temperatures, too low temperatures and draught could be solved by building renovation. However, complains related to stuffy and dry air increased after the renovation. The identified SBS symptoms were less frequent in renovated house compared to the not renovated one.

Keywords: multifamily apartment houses, renovation, indoor air quality, thermal comfort, SBS symptoms.

INTRODUCTION

From 50's to 70's most European countries experienced a large housing shortage due to the consequences of the war, economic migration, and fast population growth. These shortages were tackled with a high level of building activity, the emphasis being on quantity at the expense of quality. There are over 18 thousand multifamily apartment houses built from prefabricated reinforced concrete blocks in Lithuania. Most of these buildings were erected till 1980. Lithuanian household sector currently consumes more than one third of the final energy production.

Building renovation is an important topic from the energy conservation as well as quality of life point of view. Concentration of many pollutants is often higher indoors than outdoors. Moreover, people spend 80 – 90 % of their lives indoors, therefore poor indoor air quality (IAQ) may have a significant effect on health. Starting from 1970 there has been increasing knowledge of health problems and complains related to non-industrial settings. Sick building syndrome (SBS) symptoms were defined in 1982 by the World Health Organization experts. SBS describes a constellation of symptoms that have no clear etiology and are attributable to exposure to a particular building environment. A lot of studies, where carpet was present were related to increasing intensity of SBS symptoms (Wargocki *et al.* 1999, Seduikyte and Bliudzius 2005). Norwegian study indicated that the presence of PVC and other plasticizers containing surface materials in homes increases the risk of bronchial obstruction during the first two years of life carpeting, particle boards and new furniture (Jaakkola *et al.* 1999, Jaakkola *et al.* 2002). The emission of pollutants from linoleum is stronger if dampness from the building structure is involved (Wolkoff *et al.* 1995).

Lithuanian national Strategy for Sustainable Development (approved on the 11th of September, 2003) emphasizes integration of environmental concerns into the household sector as well as minimization of impact from this sector to environment. In 2007 National Strategy for Energy was approved. The main goals in the Strategy related to the household sector were following: to ensure effective use of existing houses, their renewal and modernization; to use EU funds for the renovation of the multifamily apartment houses and public houses while increasing energy efficiency. In 2009 National Programme of Multifamily Building Modernization was complemented with the new financing model.

Some investigation of the refurbishment process in Lithuania has already been performed in terms of sustainability (Seduikyte and Jurelionis, 2009) and necessity of energy savings (Stankevicius *et al.* 2007).

The aim of the study presented in this paper is to investigate conditions of the multifamily apartment houses before and after the renovation from the indoor climate point of view.

METHODS

Two five storey multifamily buildings were selected for the study, both built in Kaunas in 1977 of prefabricated reinforced concrete blocks. One of these buildings was renovated in 2008, another one remains unrenovated apart from minor refurbishment of heat substation and some window replacement implemented by the flat owners. Two methods for the evaluation of indoor climate were used: objective (measurements of indoor microclimate parameters) and subjective (questionnaire survey). The aim of the investigation was to evaluate indoor air quality and thermal comfort conditions in flats as well as to obtain subjective information and complaints from the apartment owners concerning indoor climate conditions and SBS symptoms in the building.

Questions presented in the questionnaire survey were purposeful to identify SBS symptoms, air quality and visible pollution sources, mould growth and perception of thermal environment in residential places.

Four apartments were selected in both buildings to investigate carbon dioxide concentration variation during the day. CO_2 concentration was selected for the study as an indicator of ventilation efficiency (CEN Report 1752:1998). Air temperature and relative humidity were measured in thirteen apartments total within two months (March and April, 2009 and 2010). Observation of the parameters during these months gives the understanding of average indoor conditions during the year. March is a heating season month in Lithuania, while in the beginning of April district heating is turned off.

RESULTS

Air temperature and relative humidity in the apartments were averaged according to the period of the measurement: when the heating system was still on, and when it was off. Results are presented in the Figures 1 and 2. Apartments labeled as "B.1" were located in the not renovated building and "B.2" in the renovated building respectively.

According to Lithuanian standard HN 42:2004, air temperature in the rooms of residential buildings should be in the range of +20 – +24 °C (thermal comfort conditions) and down to +18 °C (moderate thermal environment conditions). Measurement results showed that average air temperature in the living rooms of both buildings was about +19,2 °C during the heating period. Yet in some apartments it drops down to +16°C (the apartment on the top floor of the not renovated building).

Relative humidity values should be in the range of 40-60 % according to the standard mentioned above for thermal comfort conditions and 30-70% for moderate thermal environment. 45 % was the average relative humidity in both buildings dropping down to 30 % in some cases.

Related humidity in rooms was mostly within the comfort range, therefore there were 29 % of inhabitants having complaints due to dry air. Previous studies revealed that low relative humidity values (30% or less) may cause complaints about dry air from approximately 60 % of building occupants (Seduikyte and Paukstys, 2008).

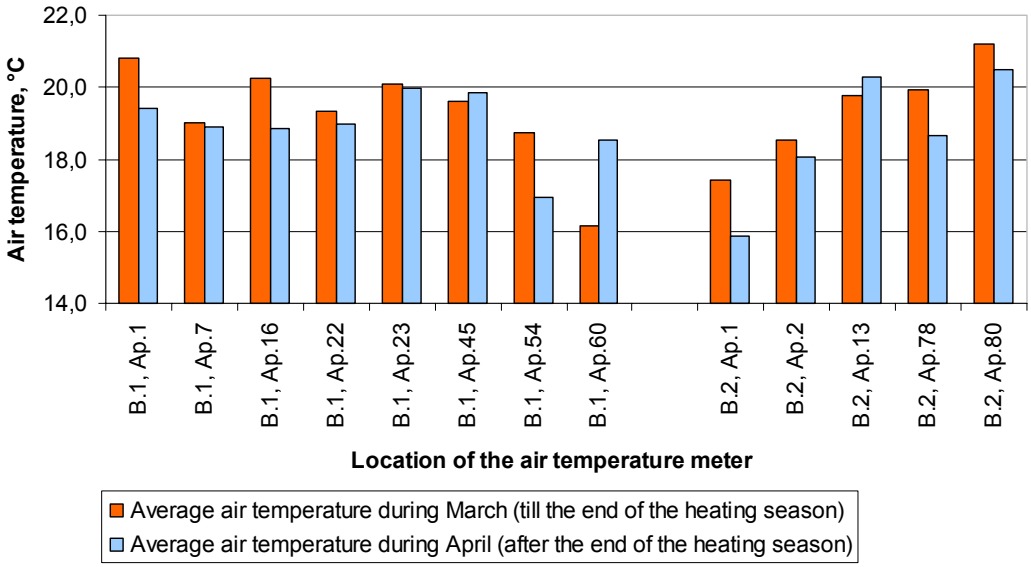

Figure 1. Average air temperature in the apartments

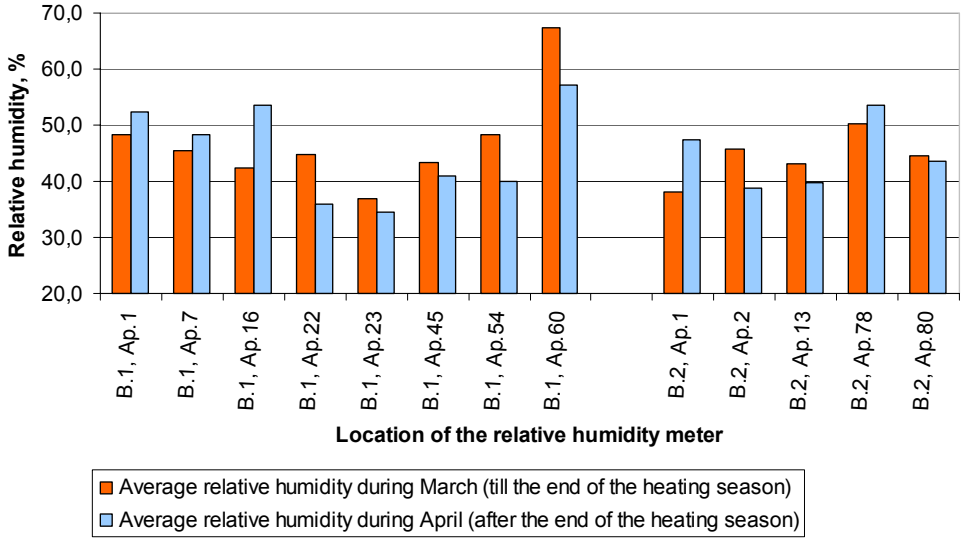

Figure 2. Average relative humidity in the apartments

Four apartments were selected in each building to investigate carbon dioxide concentration variation during the day. New sealed windows were installed in all of the investigated apartments. Carbon dioxide concentration variation during the day in those apartments is presented in Figures 3 and 4. There was no possibility to control or document the occupation of the rooms where the CO_2 measurement equipment was installed precisely. Rooms, which were occupied intensively, can be outlined easily from the peak carbon dioxide concentrations. CO_2 concentrations close to 1000 ppm were usually observed in the apartments when the whole families were at home irrespective of people location in the apartments. Nevertheless, if the occupants were staying in the same room as the measurement equipment, CO_2 concentration reached up to 2500 ppm (not renovated building) and 3000 ppm (renovated building). These peak concentrations outline insufficient ventilation in both buildings.

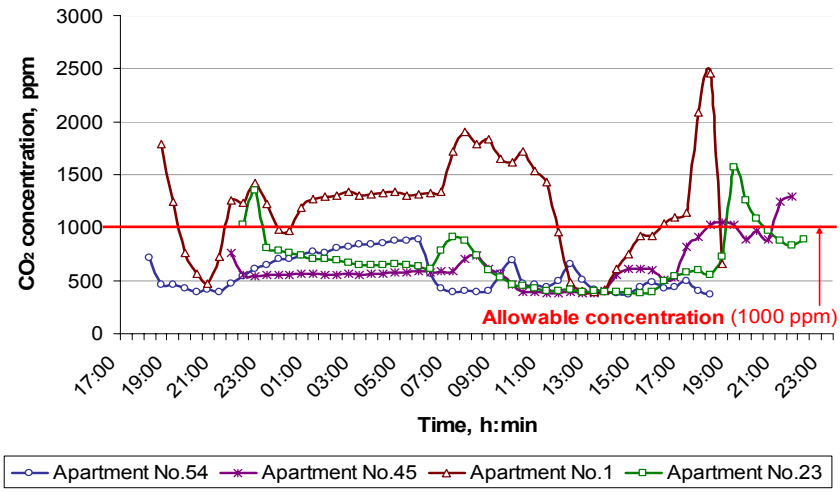

Figure 3. Variation of carbon dioxide concentration in the apartments of the not renovated building

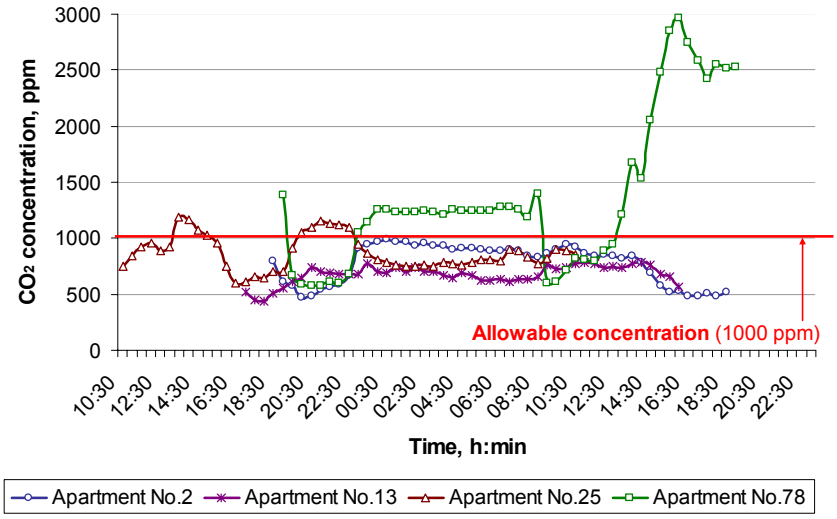

Figure 4. Variation of carbon dioxide concentration in the apartments of the renovated building

Subjective investigation of the indoor air quality and thermal environment was carried out by means of the questionnaire survey. The owners of the apartments identified most critical microclimate related problems (Figures 5 – 6) as well as most common SBS symptoms (Figure 7). Average number of the occupants in the apartments of not renovated house was 2,6 person per flat and the average age of the respondents was 44,5 years. Average number of the occupants in the apartments of renovated house was 1,4 person per flat and the average age of the respondents was 63,4 years.

71 % of the occupants living in not renovated house are disturbed by noise from other apartments several times during the week, 88 % of respondents living in renovated house identified this complain. Of changing temperatures there were 41 % of complaining residents in the not renovated house and 14 % of the renovated one. Complains of too low air temperatures were identified by 71 % of the respondents living in not renovated house and by 14 % respondents living in the renovated house. Of stuffy air there was 18 % complaining residents of the not renovated house and 64 % of the renovated one. Of dry air – 29 % and 69 % respectively.

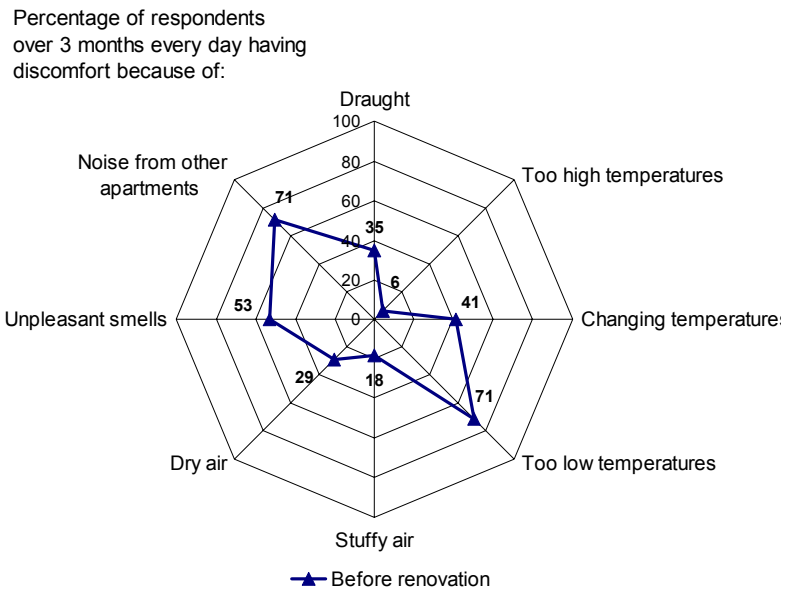

Figure 5. The frequency of complains related to the living environment (in the not renovated house)

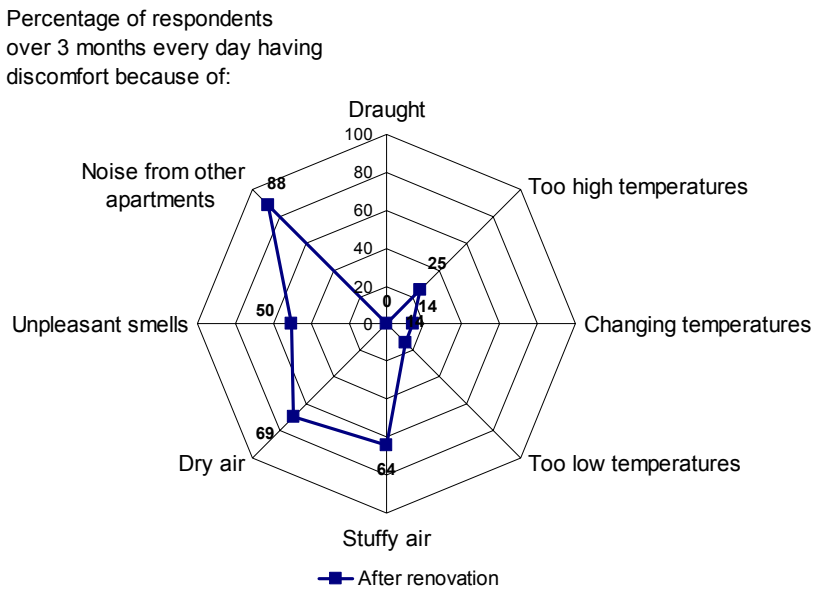

Figure 6. The frequency of complains related to the living environment (in the renovated house)

Most frequent SBS symptoms felt by the apartment owners are presented in Figure 7. More then 50 % of residents living in the not renovated house identified the following SBS symptoms: tiredness, sense of dryness, cough, irritation of eyes. More then 50 % of residents living in the renovated house identified sense of dryness and cough. These symptoms could be related to thermal environment and IAQ. Such complaints are usually related to air pollutants emitted by materials (building materials, furnishing), combustion processes (tobacco smoke, flue gas), equipment, biological sources (people, plants, fungi, microbial growth).

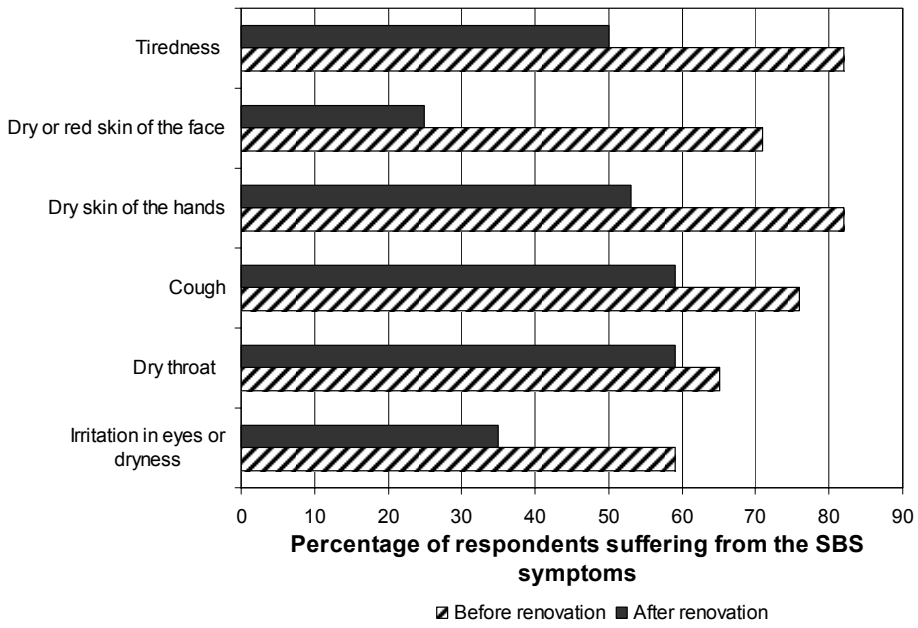

Figure 7. SBS symptoms identified during the field survey

CONCLUSIONS

Field studies showed that both air temperature and relative humidity in the rooms are either low or too low in both buildings. Yet, these parameters depend more on the location of the apartment in the building and less depends on the fact that renovation action was performed or not.

CO_2 concentrations much higher than 1000 ppm in some apartments showed that ventilation of rooms is not appropriate. However, many apartment owners of the not renovated building indicated mould growth on the external walls or ceiling causing unpleasant smells in the rooms.

Subjective investigation indicated that such problems as changing temperatures, too low temperatures and draught could be solved by building renovation. However, after the renovation process, complaints related to stuffy and dry air increased. This could be explained by the fact, that ventilation system was not refurbished, so new windows and insulated walls decreased air infiltration creating more stuffy conditions. This statement is confirmed by measurements of CO_2 concentrations, which indicated that carbon dioxide may reach 3000 ppm in the apartments of the renovated building in case of regular occupation. Furniture and floor coverings may also contribute to increasing these problems.

All SBS symptoms identified during the field survey in the renovated house were lower then in the not renovated one.

Questionnaire survey revealed that renovation of multifamily apartment houses is not only solving existing problems but also creating new ones, when all aspects of healthy environment are not taken in to account.

ACKNOWLEDGEMENT

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Cooling Effect of Locally Increased Air Movement at Elevated Room Temperature

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Abstract. The study investigates impact of local air movement on thermal comfort of sedentary occupants in rooms with temperatures higher than these recommended by standards. Twenty two human subjects participated in two 80-minute long experiments. Experiments were conducted in a climate chamber under two operative temperatures 28 and 30 °C. During the first 25-min of experiment subjects become acclimatized to the conditions. For the remaining time subjects were exposed to the increased air movement directed to the face. Any time during the experiment subject were able to regulate the velocity. Results identify that the individually controlled increased local air movement toward the face improves occupants thermal conditions. Both whole body and local thermal sensation was significantly decreased by the elevated velocity. Local air movement, however, was not able to compensate entirely for the increase of temperature up to 30 °C. Application of systems generating air movement may allow to increase the room temperature in summer period when mechanical cooling is needed, thus leading to energy savings.

Keywords: thermal comfort, air movement, local environment.

INTRODUCTION

The thermal environment is an important element of indoor environment, because its quality is one of the most important factors determining comfort of occupants. Thermal discomfort can affect people's health and performance. Present standards and guidelines prescribe appropriate levels of environmental parameters for comfort of the occupants. Based on the dissatisfaction level and corresponding thermal sensation the categories of environment were derived (EN 15251). The categories I, II, III correspond to 6, 10 and 15 % of dissatisfied occupants. This corresponds to the thermal sensation votes of ±0.2, ±0.5 and ±0.7, as rated on a 7-point thermal sensation scale. Additionally for spaces outside these categories, i.e. the dissatisfaction higher than 15%, the category IV was established.

Thermal sensation perceived by people is a result of a heat balance between the body and the environment. The sensation depends on the environment that people stay in as well as on the clothing they wear and the activity they perform. The activity level is the major factor defining the amount of heat produced internally by a person during the metabolic combustion processes. The clothing insulation determine the heat loss from the body to the environment. There are four environmental parameters affecting the heat balance that are responsible for the perception: air temperature, mean radiant temperature (often combined with air temperature and expressed by operative temperature), relative humidity and air velocity.

The operative temperature of 26 °C has been recognized in the guidelines and standards as the upper limit for the thermal comfort of sedentary occupants (EN ISO 7730 2007, ASHRAE 55 2004). The indoor temperature during summer may often exceed this limit. This can often occur in buildings without mechanical cooling. An option to offset the elevated air temperature in such spaces is to increase the heat exchange by an increased air movement.

Air velocity in indoor environment is considered mainly as the sources of occupants' discomfort. Elevated air velocity may cause draught discomfort at low room air temperature, but at higher temperature it will improve occupants' thermal comfort. The increased air velocity intensifies convective heat transfer from the body to the surrounding air. When the air temperature is high the convection heat exchange is limited, but air movement increases evaporation of the sweat secreted and thus providing additional cooling effect. The positive effect of air movement on the occupants' thermal comfort was also acknowledged in the recent updates of the standards. ASHRAE 55 and ISO 7730 specify the necessary air velocity increment to offset temperature increase above 26 ºC. Air velocity of up to 0.82 m/s is suggested to be used in rooms with air temperature above 26 °C, when occupants are provided with individual control of air movement.

People differ as regards their preferences for thermal environment. Large individual differences in the preferred air velocity were observed in several studies (Toftum *et al*., 2002, Melikov *et al*., 1994a, b). Fountain *et al*. (1994) studied the preferred air movement generated by three devices: a desk fan, a desk-mounted diffuser and a floor-mounted diffuser. At a temperature of approximately 25.5°C the selected velocities ranged from less than 0.1 m/s up to almost 0.9 m/s. With an increased air temperature, a trend towards selecting higher velocities was observed. An experiment on the air velocity preferred at temperatures from 26.0°C up to 29.5°C performed under laboratory conditions also showed large individual differences in the selected velocities (Toftum *et al*., 2003). At the highest temperature tested the selected velocities varied from 0.35 to 1.7 m/s. Recently a strong preference for more air movement even at a temperature of 22.5°C was observed in a field study (Arens *et al*., 2009).

The air movement can be generated by a free standing cooling fans, ceiling fans or by other devices. An efficient cooling with vertical air jets was demonstrated in case of a workplaces with a standing workers (Melikov *et al*., 1994a, b). For a sedentary occupants several designs of localized ventilation devices or task ambient conditioning systems have been developed and tested. Some localized systems which provide clean, ventilation air directly to the occupant's breathing zone were named personalized ventilation. Such personalized ventilation serves both to provide clean air and to cool the occupant. Different designs of air terminal devices (ATDs) and various operating strategies of personalized ventilation (clean outdoor air, re-circulated room air, different air supply temperatures) have been studied (Kaczmarczyk *et al*., 2004, 2006) and the positive effects on thermal comfort, perceived air quality and general health (intensity of 'Sick Building Syndrome' symptoms) was proved. Tests of different designs of ATDs showed that air movement towards the face, i.e. a cooling of the face, is preferred over an air movement towards the abdomen (Kaczmarczyk *et al*., 2006). These tests were performed in the temperature range from 20 to 26 °C. Cooling fans as well localized ventilation systems provide occupants with the ability to control the velocity level and the direction of the flow. Due to individual control the different preferences for the thermal environment can be accommodated.

The purpose of the present paper is to document human response to individually controlled air velocity applied locally toward the face in rooms with temperatures above the upper limit recommended by standards for thermal comfort.

METHODS

Experimental facilities

The experiments were conducted in a climate chamber. Due to a special construction (inner chamber located in an outer chamber) it was possible to avoid radiant asymmetry and maintain the mean radiant temperature equal to the air temperature. Temperature in both chambers was maintained at the same level by air conditioning systems. The inner chamber had dimensions 2,5 x 3,5 x 2,8 m^3. One workstation equipped with a system for supplying air was built inside this chamber. The system consisted of air terminal device (ATD) mounted on a duct and a fan supplying the air. The opening dimension of ATD was 16 cm. More details on the ATD construction and performance is given by Kaczmarczyk and Nawrat (2010). The air supplied with ATD was recirculated air from the chamber with a maximum target velocity of 2 m/s. The fan worked with a constant speed and the airflow rate was regulated by changing the regulation knob that controlled the damper built in the duct. The workstation with a person taking part in experiments is shown in Figure 1.

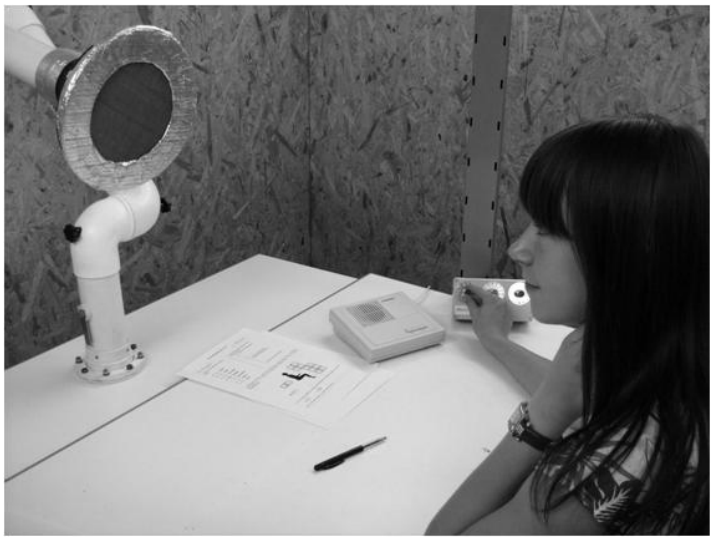


Figure 1. Subject at the workstation during experiment

Subjects

Twenty two subjects, fifteen women and seven men, participated in two experiments. Subjects were students and volunteered to participate in both experiments. An average age of subjects was 23.1 years. All subjects participated in both experiments.

Experimental conditions

Experiments were performed in the chamber with operative temperatures of 28 °C and 30 °C. The relative humidity was not controlled, but was recorded during experiments. Subjects experienced each temperature on different days. The order of temperatures that subjects were exposed to was randomized.

Experimental procedure

During experiments subjects performed light sedentary work, such as reading and writing. Each of the two experiments lasted 80 min and consisted of two stages. During the first 30-min period subjects became adapted to the thermal conditions and did not use any cooling system. For the remaining 50 min subjects sat by the workstation equipped with the system for supplying the air toward the face. The air was supplied by the ATD located approximately 40 – 45 cm from subject's face. In the beginning of this period the system was set to the maximum airflow rate and subjects were encouraged to adjust the local velocity by regulating the damper setting according to their preferences. The damper settings were recorded continuously in 1-s intervals by a computer program.

Questionnaires

Subjective responses regarding whole body thermal comfort as well as other judgments were collected by means of questionnaires four times during the experiment: at the end of the acclimatization period (25 min) and three times during the period when ATD was in use, i.e. at 30, 55 and 80 minute. The overall thermal sensation was evaluated using the standard 7-pont ASHRAE thermal sensation scale. The acceptability of this sensation was evaluated on the acceptability scale. Both scales are shown in Figure 2. Numbers on the left side of the scales represent codes given to individual ratings and used for further analysis.

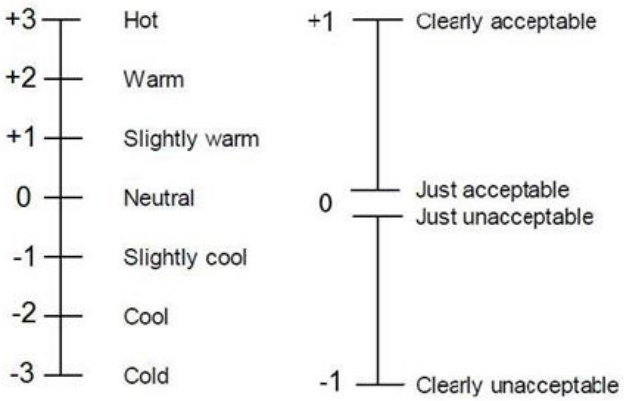


Figure 2. ASHRAE thermal sensation scale (left) and acceptability scale (right)

Subjects rated also their local thermal sensation for the selected body parts and its acceptability. Additionally they answered questions on perceived air quality and other aspects of the environment. Subjects were also asked to give their opinion on the system tested.

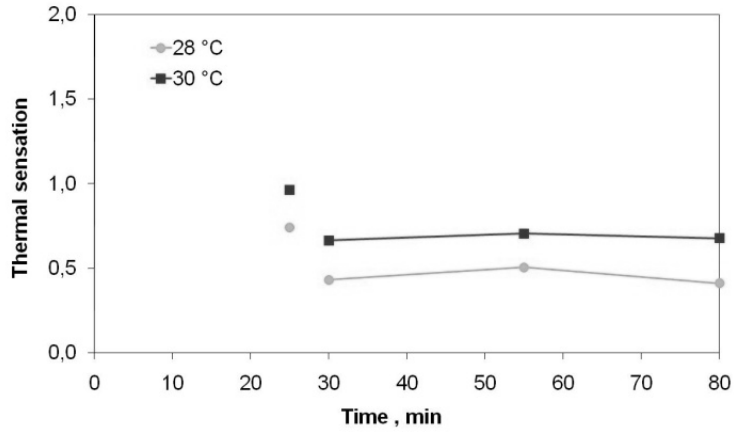
The data collected in questionnaires were coded, as indicated in Figure 2, and analyzed with program Statistica 8.0. Normally distributed data were subjected to analysis of variance ANOVA. Data with other distributions were analyzed with non-parametric Friedman ANOVA and Wilcoxon Matched Pair Test.

RESULTS AND DISCUSSION

Experiments have shown that the operative temperatures studied (28 and 30 °C) indeed result in thermal sensation votes higher than these recommended by standards. The average thermal sensation votes are shown in Figure 3. During the acclimatization period, when the air velocity was low, at 28 °C the average thermal sensation rate was 0.7 (close to "slightly warm") on 7-point ASHRAE thermal sensation scale. At 30 °C subjects felt "slightly warm" (vote 1.0 on the scale). As expected the thermal sensation was rated higher at 30 °C than at 28 °C, however, the difference observed was not significant (p=0,16). According to EN 15251 space with so high operative temperature is classified to the worst category IV, which could only be accepted for a very limited time during a year.

Implementation of the local air movement applied facially by the ATD was able to decrease the overall thermal sensation to the sensation closer to thermal neutrality. As shown in Figure 3, at both temperatures

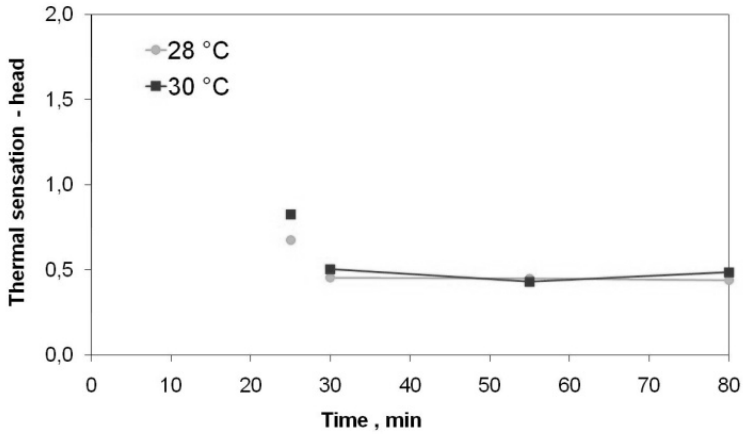
studied subjects felt significantly warmer without local air movement (votes in 25th min) than at any time later, when the use of the local system was allowed ($p \leq 0{,}018$ at 28 °C, $p \leq 0{,}024$ for 30 °C). At the end of the experiment (80th minute) thermal sensation reached 0,4 for the temperature 28 °C and 0,7 for temperature of 30 °C. Differences between the responses at both temperatures reached significant levels at 30 and 80 minute ($p \leq 0{,}048$). This finding indicates that the air movement improved the thermal sensation, but at 30 °C its cooling effect was not sufficient to bring the sensation to the level registered at 28 °C with air movement. The degree to which the increased velocity was able to improve (decrease) the whole body sensation was similar under both conditions studied.



Thermal sensation 0: neutral, 1: slightly warm, 2: warm

Figure 3. Whole body thermal sensation under two temperature conditions

The local thermal sensation of the head region was affected by the air movement to a greater extent than the whole body (Figure 4). This was due to the fact that mainly the head region was directly exposed to the air flow. An interesting finding is that the airflow setting used by subjects resulted in the same thermal sensation of c.a. 0.4 for both temperatures studied.



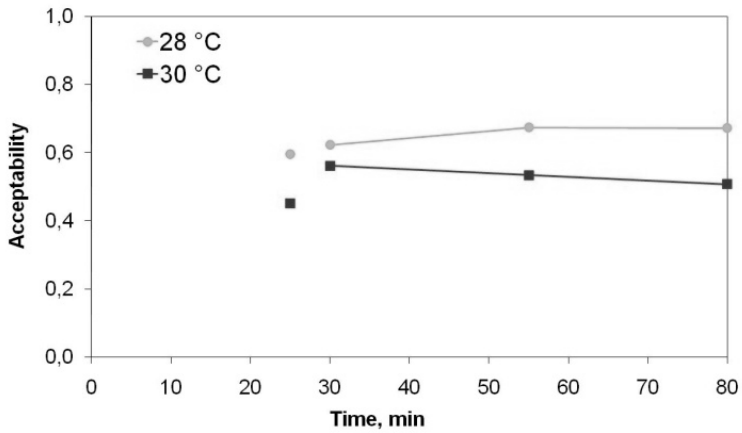
Thermal sensation 0: neutral, 1: slightly warm, 2: warm

Figure 4. Local thermal sensation for the head under two temperature conditions

The results documented that the local air movement directed towards the face positively affects thermal sensation of the whole body in rooms with higher temperature. The data show also that the improvement expressed by the overall and the local thermal sensation votes did not significantly change in time when the local air movement was applied. The duration of the exposure to the air velocity was limited to 50 min only, but it is expected that in case of a longer exposure this sensation would also remain constant. People were able to change the velocity and thus to adjust it to obtain the thermal sensation preferred.

The votes of overall and local thermal sensation correspond with the acceptability votes. The condition with lower ambient temperature obtained higher acceptability ratings than votes during both exposures (with and without air movements) at higher room temperature. As shown in Figure 5, the acceptability of thermal sensation

in case of 28 °C increased systematically from 0.6 in the 25th minute to 0.67 in 80th minute. The difference is not large. This means that the subjects felt relatively comfortable, but also that the local air movement did not cause any nuisance. Statistically significant improvement in acceptability was observed only between the first and the last votes (p=0.016). At 30 °C without air movement the acceptability was significantly lower. Introduction of the air movement substantially improved the acceptability at the immediate response, but in time became less evident. This result underlines the fact that at high temperature cooling of the body with local air flow is insufficient.



Acceptability 0: just acceptable, 100: clearly acceptable

Figure 5. Acceptability of thermal sensation under two temperature conditions

Analysis of the airflow rate settings used during the experiment showed that all subjects used the possibility to control the velocity. Individual settings ranged from 0.1 up to 2.1 m/s. These velocities were measured at a place of subject while the workstation was unoccupied. The experimental procedure implemented a step-change in conditions, i.e. exposure to the increased local velocity was after exposure to still environment for 25 min. In order to assure the same "starting" velocity for all subjects the local system was preset to provide the maximum velocity of ca. 2 m/s at the beginning of the exposure. Therefore subjects first experienced the maximum velocity and then were able to adjust it according to their individual needs. Natural tendency among most of the subjects was to decrease the velocity during the initial several minutes. As the time elapsed number of changes substantially decreased. At the end of the exposure subjects, on average used lower then allowed velocities. The median velocity at the target area was slightly higher 1.9 m/ at 30 °C than at 28 °C 1.67 m/s. This difference was expected as more cooling is needed at the higher room temperature. The air velocities selected in this study were much higher than the maximum velocities suggested by the standards (EN ISO 7730 2007, ASHRAE 55 2004). The standards, however, do not take into account nonuniformity of the velocity field. It should be noted that the ATD, but also a typical desk fan, creates very nonuniform velocity field where the highest velocity is observed only at a small area of several cm^2. Examples of velocity profiles generated by the system tested are shown in the literature (Kaczmarczyk and Nawrat, 2010). The higher velocity applied to a small body area (the face) may equalize the cooling effect caused by the lower velocity but applied to the whole body.

Present results confirmed that at higher room temperatures, especially when the air temperature becomes close to the body temperature, the convective cooling is less efficient. In such case cooling due to increased evaporation of sweat secreted play main role. The cooling due to evaporation is driven by the difference in partial water vapor pressure. The higher the relative humidity of surrounding air is the less evaporation and thus smaller cooling effect can be achieved. In the present experiments the relative humidity was moderate and ranged from 31 to 46 % (in both temperature conditions), thus the evaporative cooling was not disturbed. Nevertheless, the results obtained indicate that the cooling ability of the locally applied air movement is limited, especially at the higher temperature. The device tested was not able to compensate for the increased temperature up to 30 °C. In order to increase the cooling capability several solutions can be considered. Increasing air movement above 2 m/s may be only a temporal solution as too high velocity may result in excessive mucous membrane drying and may lead to eye irritation. Furthermore high air velocity may disturb some sedentary work, for instance blowing papers off the table. An option may be increasing the area of the increased velocity, so that larger body area will be affected. Another solution for increasing cooling ability is to decrease the temperature of the supply air, as it was suggested for the use of personalized ventilation (Melikov, 2004).

Allowing the room temperature to increase above the recommended limits and increasing the local air movement may lead to energy savings. Schivion and Melikov (2008) performed calculations based on the

suggestions for increased velocity given in the standard and indicated cases when such savings can be obtained. Present result, obtained with people, show that the ability to improve the thermal conditions only by increased locally air movement to the category II as suggested by standard (EN 15251) may be impossible to achieve.

CONCLUSIONS

Based on the results obtained the following conclusions can be drawn:

- increased air movement toward the face improved both whole body and local thermal sensation
- local air movement was not able to compensate entirely for the increase of temperature up to 30 °C

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Improvement of Energy Efficiency of Office Building in Belgrade by Application of PV Modules

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Abstract. The main concern of the paper is to present different models of energy efficiency improvement of the office building in Block 26, New Belgrade, Serbia, by application of active solar system to the building envelope, more exactly by integration of PV modules into the facade structure. The paper shows hypothetical models of the office building energy improvement for Belgrade climate conditions. The building's energy efficiency is defined according energy necessary for cooling, lighting, equipments and other needs settled with electric energy. Models of PV modules integration into the facade structure are discussed by aspects of energy efficiency.

Keywords: Improvement of energy efficiency, Active solar systems, Building integrated PV modules.

INTRODUCTION

In Belgrade, as well as in Serbia, construction of energy efficient office buildings is still not in practice. For heating, cooling, lighting and equipment operation, most of existing office buildings consumes lot of energy. The main target on which this paper is directed is achieving energy savings through building refurbishment; more exactly possibilities for reduction of electric power consumption by application of photovoltaic (PV) modules are discussed. Different models of integration of PV modules into the facade of corner lamella of office building in Block 26 (Figure 1), New Belgrade, are proposed and their efficiency estimated.

Figure 1. Location of office building in Block 26

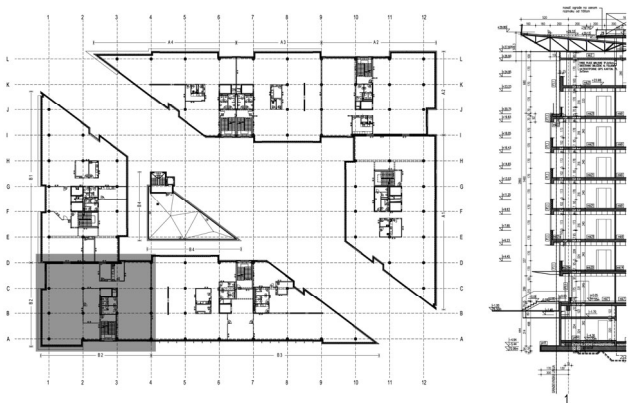


Figure 2. Corner lamella of office building in Block 26

The corner lamella of office building in Block 26 is the 8-storey building (Figure 2). The main facades are southeast and southwest oriented. Significant roof extension to the plane of the facade causes partial overshading of the last two floors. Therefore, facade areas from second to forth floor are considered as favorable for PV modules application. The facade is light structure, suspended facade (curtain wall) leaned against the building structure and suspends in front of it. PV modules can be integrated into the most of the contemporary suspended facade systems; photovoltaic facade is type of glazed facades (Krstic-Furundzic, 2007). Different solutions of PV modules integration into the suspended facade system are proposed as hypothetical models of building facade improvement.

METHODS

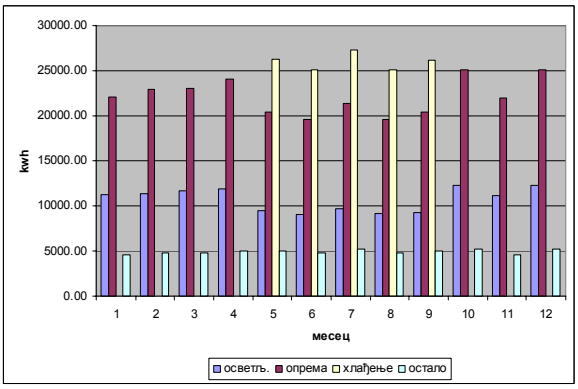
The analysis in the paper is hypothetical and it aims to show benefits of active solar systems, PV modules application on office buildings in Belgrade climate conditions. Methodological approach includes analyses of characteristics of both the existing building and hypothetical improved models of the building regarding electric energy consumption, and comparative analyses of obtained results. The building's energy efficiency is defined according energy necessary for cooling, lighting, equipments and other needs settled with electric energy.

Electric energy consumption of the existing building

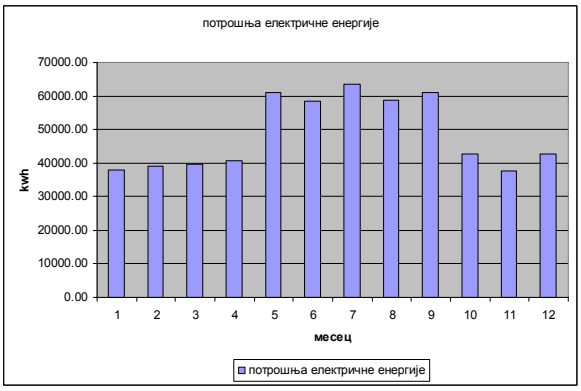
Monthly and annually electric energy consumption of the existing building is presented in the Table 1 and Figure 3.

Table 1. Monthly and annually consumption of electric energy

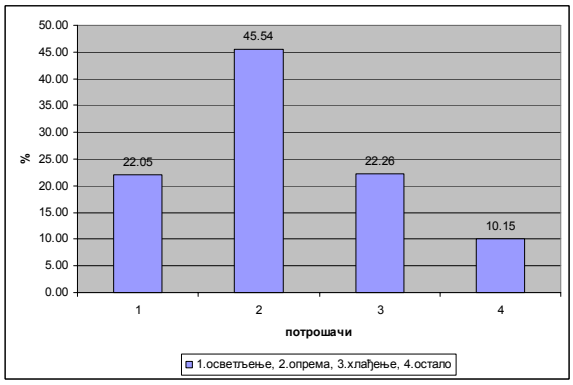
Month	Lighting [kWh]	Equipments [kWh]	Cooling [kWh]	Other needs [kWh]	Total [kWh]
1	11296.00	22045.00	0.00	4572.00	37913.00
2	11349.60	22952.00	0.00	4800.60	39102.20
3	11637.60	23062.00	0.00	4800.60	39500.20
4	11835.20	24024.00	0.00	5029.20	40888.40
5	9433.62	20467.15	26213.20	5029.20	61143.17
6	9051.21	19555.95	25053.60	4800.60	58461.36
7	9702.63	21331.60	27294.80	5257.80	63586.83
8	9164.61	19602.70	25131.60	4800.60	58699.51
9	9320.22	20420.40	26135.20	5029.20	60905.02
10	12320.80	25096.00	0.00	5257.80	42674.60
11	11152.00	21990.00	0.00	4572.00	37714.00
12	12320.80	25096.00	0.00	5257.80	42674.60
	128584.29	**265642.80**	**129828.40**	**59207.40**	**583262.89**
%	22.05	45.54	22.26	10.15	100.00



a)Individual monthly consumption [kWh]



b) Total monthly consumption [kWh]



c) Monthly consumption in %

Figure 3. Monthly consumption of electric energy for cooling, lighting, equipments and other needs
(Figure a-legend: lighting - the 1 column, equipments - the 2 column, cooling - the 3 column and other needs - the 4 column)

Architectural Integration of PV modules

The case study shows different models of energy efficiency improvement of the office building in Block 26, New Belgrade, by integration of PV modules into the envelope.

The design of integration of solar systems was defined consequently according to the actual characteristics of (Krstic-Furundzic and Kosoric, 2009):

- The building location – the context (considering urban planning, social, climatic and geographical aspect),
- The building (considering the compatibility in respect to the building construction type, building materials, the shape, the function, the style and design of the building),
- The facade and roof (considering the building physics characteristics, mounting, physical and appearance characteristics of solar systems).

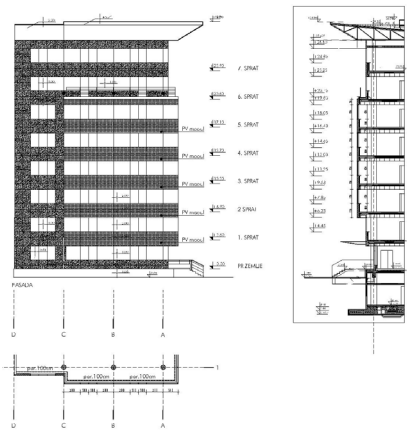


Figure 4. PV modules in parapets

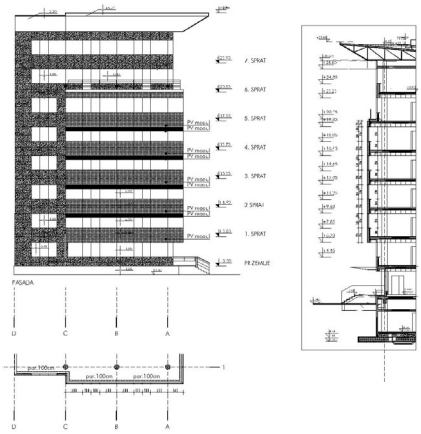


Figure 5. PV modules in parapets and upper part of windows

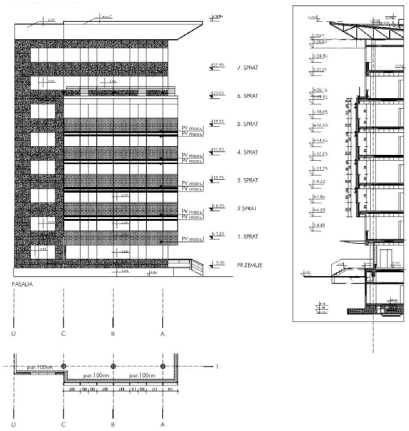


Figure 6. PVmodules in parapets and sun shadings (2 lines)

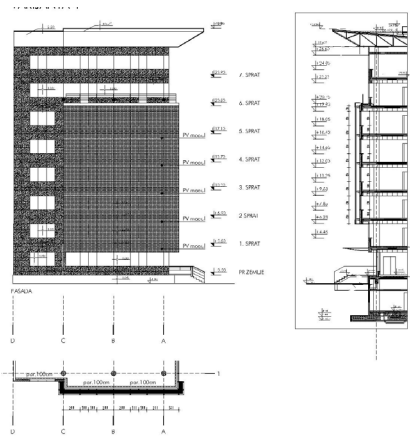


Figure 7. PVmodules in double skin facade

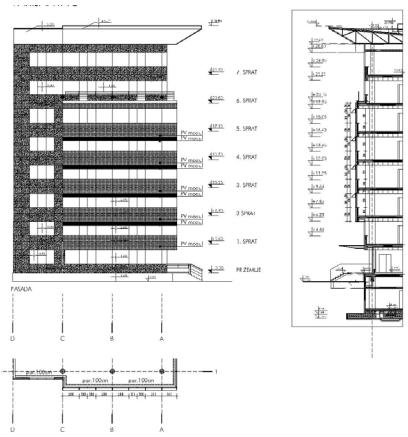


Figure 8. PV modules in parapets and sun shadings (one line)

For analysis five distinctive variants of position of PV modules on building facades were selected:

- I Design Variant: parapet 90˚, not transparent PV modules, area of 238 m^2 (Figure 4) - vertical position of solar panels,
- II Design Variant: parapet 90˚, not transparent PV modules, and upper part of windows 90˚, transparent (50%) PV modules, area of 308 m^2 (Figure 5) - vertical position of solar panels,
- III Design Variant: parapet 90˚ and two lines of sun shadings 45˚, not transparent PV modules, area of 308 m^2, (Figure 6)
- IV Design Variant: whole double skin facade, transparent (50%) PV modules, area of 238 m^2, (Figure 7)- vertical position of solar panels,
- V Design Variant: parapet 90˚ and one line of sun shadings 45˚, not transparent PV modules, area of 336 m^2, (Figure 8).

RESULTS

Calculations and simulations of PV systems for all design variants were done in PV* sol 2.6 (Krstic-Furundzic *et al.* 2009). The standard modules with polycrystalline cells were used for calculations. PV modules location and area and annually production of electric energy by PV modules are presented in Table 2, while the review of monthly production of electric energy is given in Figure 9.

Table 2. PV modules location and area related to annually production of electric energy

	PV modules location	PV modules area [м^2]	Energy from inverter [kWh]	Energy from PV modules [kWh]
Variant 1	Parapet (90˚)	238.00	24627.00	25578.00
Variant 2	Two lines in parapet	308.00	29164.00	30605.00
	parapet 1 (90˚)	238.00	24627.00	25578.00
	upper part of windows (90˚)	70.00	4537.00	5026.00
Variant 3	Parapet and 2 lines of sun shadings	336.00	40694.00	43680.00
	parapet (90˚)	238.00	24627.00	25578.00
	sun shadings 1 (45°)	49.00	9153.00	10377.00
	sun shadings 2 (45°)	49.00	6914.00	7724.00
Variant 4	Whole double skin facade (transparent,90˚)	238.00	12892.00	14339.00
Variant 5	Parapet and 1 line of sun shadings	336.00	33773.00	35577.00
	parapet (90˚)	238.00	24627.00	25578.00
	sun shadings (45°)	98.00	9146.00	9999.00

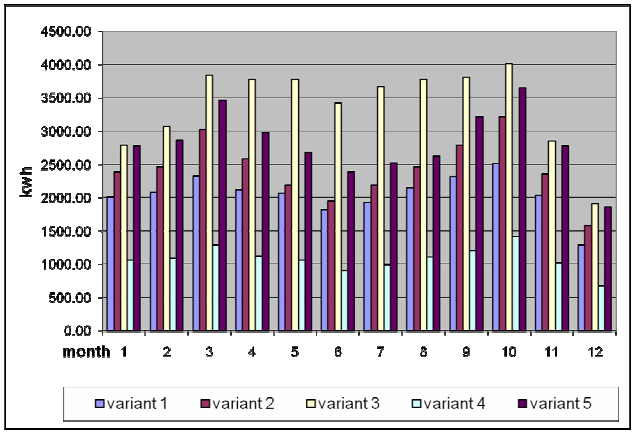


Figure 9. Monthly production of electric energy

For cooling, lighting, equipments and other needs settled with electric energy, annually electric energy consumption of the existing building is 583262.89 kWh (Table 1), while the electric energy production is for Variant 1 – 24627.00 kWh, Variant 2 – 29164.00 kWh, Variant 3 – 40694.00 kWh, Variant 4 – 12892.00 kWh and Variant 5 – 33773.00 kWh (Table 2). Electric energy production is subordinate to PV modules location, as well as to available area.

Comparative analyses of obtained results regarding monthly and annually amount of electric energy consumption and production by PV modules are carried out. Results are presented in Table 3 and Figure 10. Also, comparative review of monthly and annually consumption of electric energy and percentage of monthly

and annually energy demands satisfaction by PV models is carried out and results are shown in the Table 4 and Figure 11.

It is evident that different locations of PV modules give different results regarding electric energy production:

- PV modules integrated in the parapets (90˚) can produce monthly electrical energy from min 1280.0 kWh in December to max 2510.0 kWh in October; they can meet demands from min 3.0 % in December to max 5.88 % in October;
- PV modules integrated in the parapets and upper part of window (90˚) can produce monthly electrical energy from min 1585.0 kWh in December to max 3210.0 kWh in October; they can meet demands from min 3.71 % in December to max 7.65 % in March;
- PV modules integrated in the parapets (90˚) and two lines of sun shadings (45˚) can produce monthly electrical energy from min 1910.0 kWh in December to max 4010.0 kWh in October; they can meet demands from min 4.48 % in December to max 9.72 % in March;
- PV modules integrated in the whole double skin facade (90˚) can produce monthly electrical energy from min 670.3 kWh in December to max 1410.0 kWh in October; they can meet demands from min 1.57 % in December to max 3.30 % in October;
- PV modules integrated in the parapets (90˚) and one line of sun shadings (45˚) can produce monthly electrical energy from min 1855.0 kWh in December to max 3650.0 kWh in October; they can meet demands from min 4.35 % in December to max 8.76 % in March.

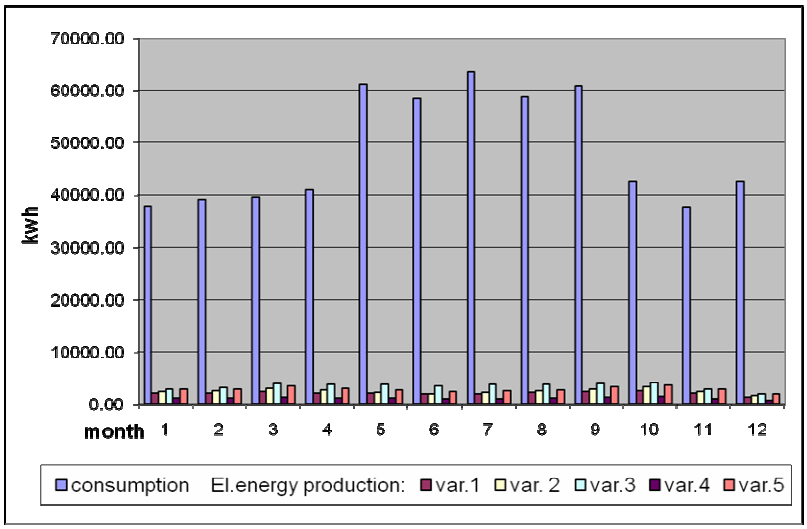


Figure 10. Comparative review of monthly consumption and production of electric energy

Table 3. Comparative review of monthly and annually consumption and production of electric energy in kWh

		Variant 1	Variant 2	Variant 3	Variant 4	Variant 5
Month	Consumption [kWh]	El.en. from inverter[kWh]	El.en. from inverter[kWh]	El.en. from inverter[kWh]	El.en. from inverter[kWh]	El.en. from inverter[kWh]
January	37913.00	2005.00	2380.00	2792.00	1052.00	2780.00
February	39102.20	2080.00	2464.00	3065.00	1085.00	2855.00
March	39500.20	2320.00	3022.00	3840.00	1280.00	3460.00
April	40888.40	2113.00	2580.00	3775.00	1120.00	2980.00
May	61143.17	2069.00	2183.00	3775.00	1055.00	2680.00
June	58461.36	1820.00	1950.00	3420.00	903.00	2380.00
July	63586.83	1930.00	2185.00	3665.00	985.00	2523.00
August	58699.51	2150.00	2460.00	3782.00	1102.00	2620.00
September	60905.02	2310.00	2790.00	3810.00	1210.00	3210.00
October	42674.60	2510.00	3210.00	4010.00	1410.00	3650.00
November	37714.00	2040.00	2355.00	2850.00	1020.00	2780.00
December	42674.60	1280.00	1585.00	1910.00	670.00	1855.00
	583262.89	24627.00	29164.00	40694.00	12892.00	33773.00

Table 4. Comparative review of monthly and annually consumption of electric energy and % of energy demands satisfaction by PV models

		Variant 1	Variant 2	Variant 3	Variant 4	Variant 5
Month	Consumption [kWh]	% of energy demands satisfaction	% of energy demands satisfaction	% of energy demands satisfaction	% of energy demands satisfaction	% of energy demands satisfaction
January	37913.00	5.29	6.28	7.36	2.77	7.33
February	39102.20	5.32	6.30	7.84	2.77	7.30
March	39500.20	5.87	7.65	9.72	3.24	8.76
April	40888.40	5.17	6.31	9.23	2.74	7.29
May	61143.17	3.38	3.57	6.17	1.73	4.38
June	58461.36	3.11	3.34	5.85	1.54	4.07
July	63586.83	3.04	3.44	5.76	1.55	3.97
August	58699.51	3.66	4.19	6.44	1.88	4.46
September	60905.02	3.79	4.58	6.26	1.99	5.27
October	42674.60	5.88	7.52	9.40	3.30	8.55
November	37714.00	5.41	6.24	7.56	2.70	7.37
December	42674.60	3.00	3.71	4.48	1.57	4.35
	583262.89	4.22	5.00	6.98	2.21	5.79

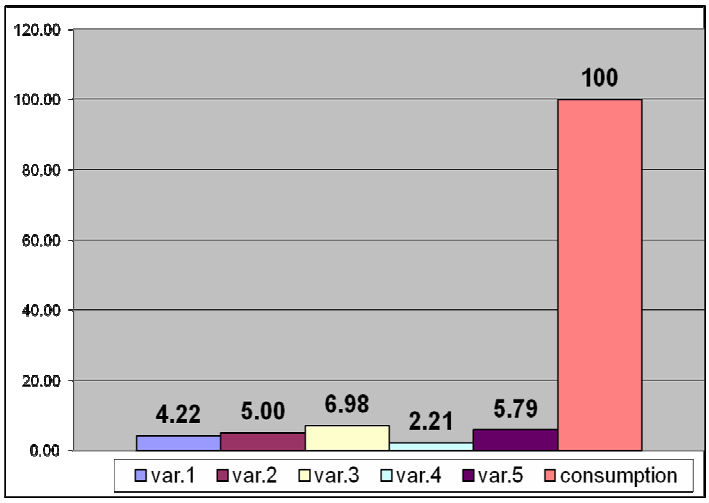


Figure 11. Percentage of annually energy demands satisfaction by different variants of PV models integration

DISCUSSION

Significant differences in the amounts of electric energy production related to variants of PV modules location are noticeable. In relation to total annually electric energy consumption, the following percentages of annually energy demands satisfaction by different variants of PV models integration are determined: Variant 1 – 4.22%, Variant 2 – 5.00%, Variant 3 – 6.98%, Variant 4 – 2.21% and Variant 5 5.79%, which points out that Variant 3, sloped PV modules (45˚), is the most efficient. Achieved results are corresponding to prior knowledge, which confirms that important electric energy production, i.e. energy savings by application PV modules in the building envelope cannot be yet provided.

CONCLUSIONS

It can be concluded that for cooling, lighting, equipments and other needs settled with electric energy, office buildings spend significant amounts of electric energy. According to analyses presented in the paper following conclusions can be made:

- Due to internal thermal gains, office buildings spent lot of energy for cooling.
- Percentage of annually energy demands satisfaction by PV models integration is too small.
- However, some energy savings can be obtained resulting in CO_2 emissions reductions, which should not be disregarded.
- Facades with sloped PV modules are favorable in sense of energy efficiency. Modules can also be used as shading devices.

- New aesthetic potentials in refurbishment of the existing buildings can be obtained by application of PV modules. PV modules can significantly contribute to office building appearance.

ACKNOWLEDGEMENT

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Analysis of Internal Heat Gains Occurrence and Their Impact on Heat Loads in Buildings

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Abstract. The paper presents time functions of internal heat gains in apartment and office buildings. Assumed hourly functions have been used as input data for development of a simulation program concerning dynamics of heat requirements and the operation of central heating systems with thermostatic valves. Concluding remarks may be applied to influence analysis of internal heat gains in the tested buildings.

Keywords: Internal heat gains; Occupation profiles; Heat balance of the rooms; Efficiency of the heat gains use; Apartment and office buildings.

INTRODUCTION

For a correct estimation of the internal load, the most important thing is a correct and as accurate as possible determination of the sources of heat present in the studies of building. The main sources of internal load are occupants, lights and electric appliances. The paper presents two principal problems – identification and analyses of internal heat gain profiles in apartment and office buildings as well as the impact of these gains on heat demand in these buildings. The aim of the work was the elaboration of time functions of inner heat gains in analysed buildings and the qualification of the influence of the above-mentioned gains on heat balance of these buildings. To elaborate profiles (Dziekońska, 2003), (Papakostas and Sotiropoulos, 1997) hourly time-courses of the sojourn of persons in rooms were used as well as activities undertaken by them, and also own research in this range. Assumed hourly functions have been used as input data for development of a simulation program concerning dynamics of heat requirements and the operation of central heating systems with thermostatic valves. The results are occupation patterns, use of electric appliances, and occupants activities influencing the generation of heat in dwellings and office buildings. The impact of internal heat gains on heat demand in the tested buildings are presented too. The results can be used for the calculation of heating and cooling loads in analysed buildings or for the estimation of heat gains in a building energy model.

SOURCES OF INTERNAL HEAT GAINS IN BUILDINGS

Main sources of heat gains from internal sources in buildings are:

- occupants,
- lighting,
- equipment in rooms (household equipment, TV sets, radios, computers),

and in apartment buildings additionally:

- use of hot water,
- preparation of meals.

Occurrence of internal heat gains and their value depends on the kind of room (or building). The literature study (Lubina, 2004) shows that the only unknown in determining heat gains from internal sources in buildings is a time profile of those gains. Most frequently it depends on the presence of people (lighting, use of equipment, preparation of meals, etc.). Data concerning the average value of heat flux emitted by sources mentioned above and their nominal quantity can be found both in standards or handbooks and in literature (ISO 9164:1989), (Fanger, 1974), (McIntyre, 1980), (Recknagel *et al*. 1994), (Liébard and De Herde, 1996), (ASHRAE Handbook, 1997).

TIME-COURSES OF INTERNAL HEAT GAINS

Considering different purposes of particular types of buildings and, in the result, time profile of the variability of occurrence of gains mentioned above, the analysis should be done separately for apartment and office buildings.

In case of apartment buildings the evaluation of power of heat gains sources in particular hours has been based on the analysis of statistics, based on the schedule of presence of residents (men, women in paid employment and not in paid employment, children, elderly people, etc.) and activities undertaken by them, connected with the use of household equipment or lighting in presented works (Papakostas and Sotiropoulos, 1997), (Dziekońska, 2003). Hourly profiles of people's presence and other heat gains, connected with the use of rooms developed in this way, has been adjusted to Polish conditions (on the basis of Statistical yearbook): an average number, age and position of people, occupying an "average" apartment and it's equipment (Figure 1 and Figure 2).

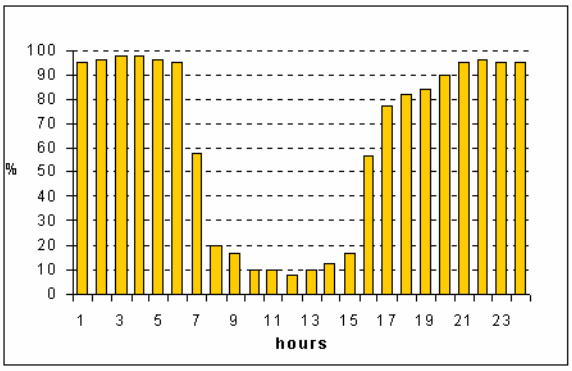

Figure 1. Example of hourly profiles of people's presence – men in working days

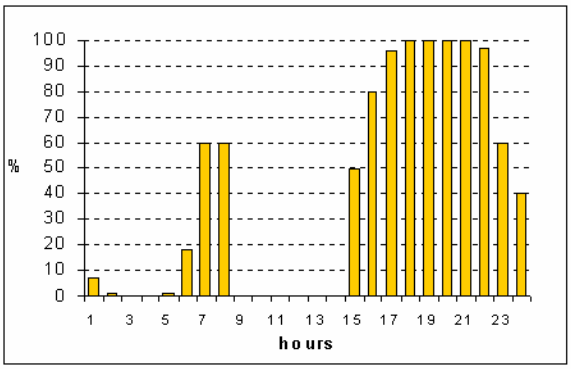

Figure 2. Hourly profile of the use of lighting in flats

Since available standards and guidelines (PN-B-02025:2001), (ISO 9164:1989), (PN-B-03406:1994), (PN-EN 832:2001) provide only average daily values of heat gains per apartment to check the correctness of representation of the achieved time profiles, an average daily flux of heat gains per apartment for analyzed and acknowledged typical families was determined and compared with the available data (Figure 3 and 4).

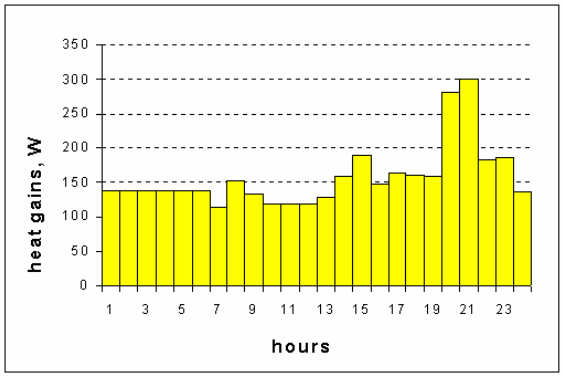

Figure 3. 24 hour profile of total heat gains from people in apartment building

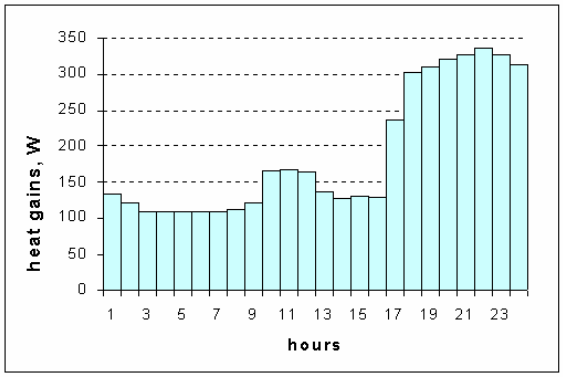

Figure 4. 24 hour profile of total heat gains from others sources

For office buildings the identification of time profiles of internal sources heat gains occurrence was done on the basis of the study of electric energy consumption, connected with the use of lighting and other office equipment in the building daily (with the time step equal 2 minutes) in particular days of week.

Histograms of electric power demand achieved this way (Figure 5) and research in situ of people's presence, use of lighting and computers, allowed to create hourly runs of variability of internal heat gains in analysed rooms (Figure 6). Those observations also show that profiles of the use of lighting and computers may be considered constant during the day (also during lunch break) (Lubina, 2001).

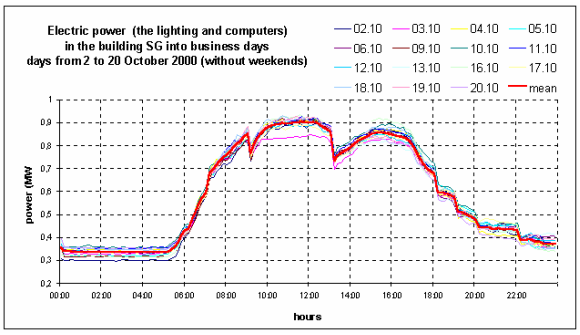

Figure 5. Profile of electric power demand in building Justus Lipsius in working days in October 2000

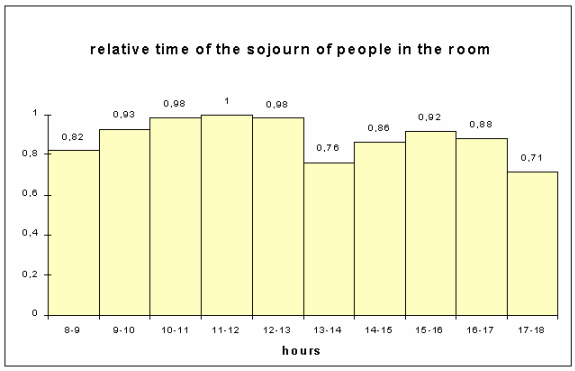

Figure 6. Average profile of the people's sojourn in building Justus Lipsius – October 2000

EXEMPLARY RESULTS OF SIMULATION – MONTHLY BALANCES

Considering time profiles of the occurrence of heat gains from internal sources in apartment and office buildings, simulations of heat balances of chosen flats in apartment buildings and offices for each month of heating season were carried out with the use of programs DYNINST (Foit and Lubina, 2002) and ESP-r (ESRU, 1999). For the analysis 3 flats on repeatable stories (II floor) in a small multiple dwelling (4 stories, 3 flats on each) and a part of office building, consisting of 2 rooms (first for 2 persons, second for 1) and a piece of hall were chosen.

In calculations average monthly runs of external climate with a time step of 1 hour for Sulejów (chosen from years 1966-1995) were used.

Furthermore:

- a constant number of air changes rates in buildings was analysed (0.75 h-1 for flats, 1.0 h-1 for offices), as well as variable in time number of air changes, coming from a real amount of air, flowing into building,
- monthly heat balances of the flats and offices were analysed for the averaged daily runs of rooms exploitation, and variable in time profiles of rooms exploitation,
- different orientation of rooms and flats was analysed,
- the heat accumulation in internal partitions in office buildings was not included in analysis.

Analysing the results of simulation for each month of heating season (October-April) for chosen rooms, one can notice that heat gains in the rooms, both from the sun and internal sources, start to have important influence on heat balances of analysed rooms and working conditions of internal installations (Lubina *et al*. 2005).

Relative, referred to heat losses, share of internal heat gains for different flats, oscillates from 10 % (January) to 32 % (October) in cases of west-oriented rooms. Heat gains from the sun in balances of particular rooms oscillate from 12 % (December) to as much as 72 % for west-oriented rooms in April. In general, for apartment buildings, heat gains from internal sources make from 13 % to 24 % of heat losses balance in analysed flats (with a low insulation of building envelop), and were compared with the amount of heat gains from sun radiation (especially in winter months). Gains from the sun have dominant influence on heat burdens only in the edge months of heating season (Figure 7).

In cases of office rooms an average share of internal heat gains was even bigger (22-36 %). For winter months their influence was decisive for heat burdens (Figure 8).

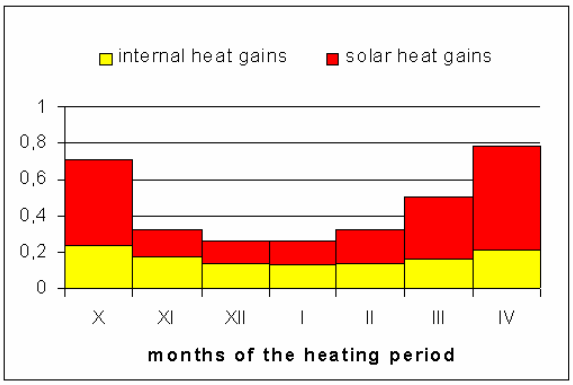

Figure 7. Relative (referred to heat losses) share of internal heat gains for analysed flats in the apartment building

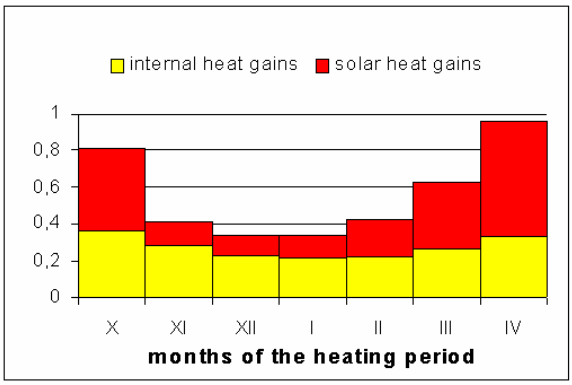

Figure 8. Relative (referred to heat losses) share of internal heat gains in analysed office rooms

Heat gains from sun radiation predominate in autumn and spring (although not in north-oriented rooms, nor in some east-oriented rooms). No matter what the orientation of the room is, relative, referred to heat losses, share of internal heat gains oscillates from 20% (January) to 39 % (October) in cases of office rooms for two persons. Orientation of the room has a great influence on the amount of heat gains from the sun.

An average efficiency of the use of heat gains in analysed buildings, specified according to PN-B-02025, oscillates from 0.65 to 0.97 (Figure 9), depending on the month of heating season and function of the room type, although predominating here is the share of gains from sun radiation, which corresponds with coefficient GLR (relation between gains and losses) at the level from 0.9 to 0.25.

The range of fluctuation of efficiency value of heat gains use for analysed apartment buildings is 0.63 (west-oriented flats in April) to 0.99 (for winter months). In cases of office rooms this range is similar (from 0.59 for west-oriented offices in April to 0.96 for northern or eastern rooms in December and January), but it's level is lower. Above results prove that, in edge months of the heating season, only the small part of gains can be used for reducing heat efficiency of heaters. In those periods rise of internal air temperature was noticed of more than a planned value of 20 %, especially in offices.

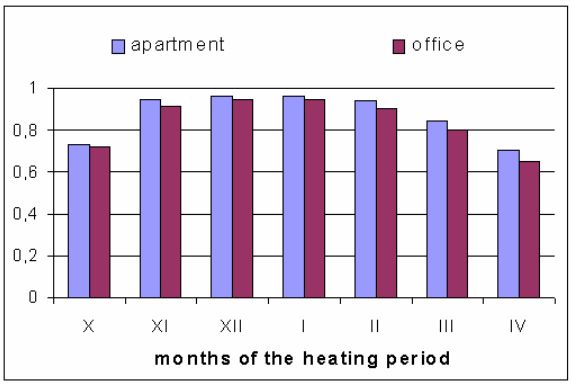

Figure 9. Average efficiency of the utilization of heat gains in analysed buildings

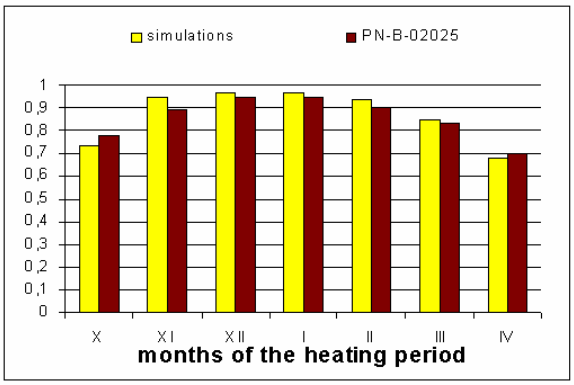

Figure 10. Comparison of the efficiency of heat gains utilization in individual months during heating season – the dynamic simulations and the algorithms according to PN-B-02025

The results of dynamic simulations for analysed flats (lack of the proper input data for public utility buildings, concerning ventilation and internal heat gains) were compared with results of calculations performed according to algorithms, consistent with PN-B-02025. The comparison is illustrated in Figure 10.

The achieved results for analysed flats show high convergence, what indirectly confirms the correctness of the use of the worked out time profiles of people's presence in rooms, and the use of flats, and may suggest the possibility of formulating requirements of proper input data, concerning internal heat gains in public utility buildings.

INFLUENCE OF ROOMS USE ON HEAT BURDENS OF BUILDINGS

As all the standards and guidelines for design give rough and averaged values of internal heat gains, it was decided to check, whether using the average daily runs of rooms use and variable in time profiles of rooms use, may affect monthly heat burdens of analysed cases. The problem concerns especially rooms used in particular time ranges, which means mainly office buildings.

The results confirmed the difference in total heat balance of analysed rooms, depending on whether constant or variable profile of internal heat gains occurrence was considered. For apartment buildings the differences were small (lack of heat gains from people during the day was compensated with sun radiation). For office buildings, however, especially in edge months of the heating season, the differences were more visible (Figure 11). Average monthly heat demand in those months, considering time profile of gains occurrence was, even for south- and west-oriented rooms, 50 % bigger than in case when constant value of heat flux from internal sources was considered (Figure 12).

In the analysed case room orientation does not affect the result of calculations in winter months (November-February), but it is visible in the remaining months of heating season, especially in the edge ones. The use of constant occurrence profiles (which means: those, fixed in standards) results in the reduction of heat demand for heating purposes of the building in autumn-spring period (Figure 11).

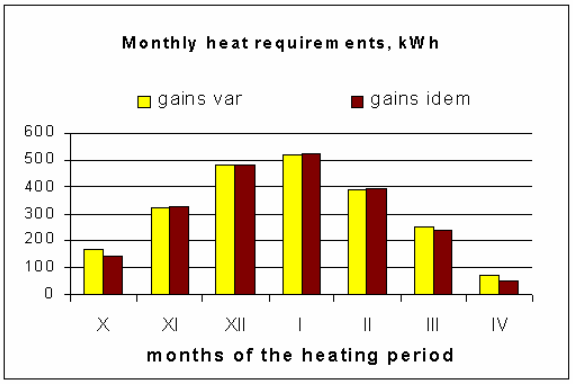

Figure 11. Comparison of the thermal balances for analysed office rooms – constant and variable profiles of the internal heat gains occurrence

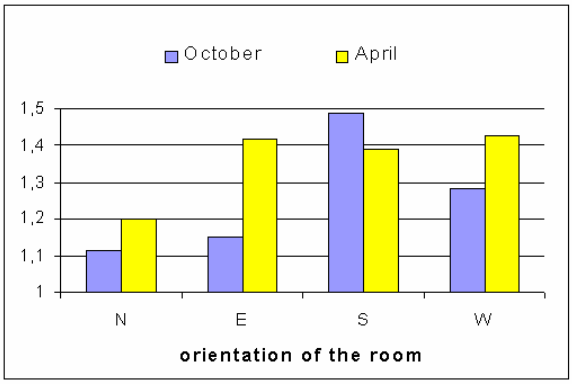

Figure 12. Relative growth of heat demand (in relation to calculations with obtained constant profile of room occupation) for office rooms of different orientation in extreme months of heating season

CONCLUSIONS

Carried out tests and analysis of time profiles of internal heat gains variability allow to formulate the following conclusions:

- Results of the in-situ observation, research and the statistical analysis of time-courses of internal heat gains (people, lightning and equipment of rooms) confirmed the dynamic character of changes of these components of the heat balance (Lubina, 2004),
- Heat fluxes, emitted by people and the office equipment for the analysed cases, achieve values from 300 to 650 W; similar amounts of heat gains can be found in analysed flats,
- The presented profiles of people's presence in the rooms, and the use of those rooms, correspond well the real occurrence of internal heat gains, and may become a basis for the calculations of the living heat gains variability for dynamic simulations of living heat gains variability for dynamic simulations of apartment buildings, as well as office buildings.

General conclusions from the analysis of influence of internal heat gains on heat balance of rooms can be presented in a few points:

- Internal heat gains make from 13% to 24% of heat losses balance of the analysed apartment buildings (with a low insulation of the building envelop), and for office buildings from 22 to 36 %,
- An average efficiency of the heat gains use oscillates from 0.70 to 0.97, depending on the month of the heating season and the function of the room (but here the predominating factor is the presence of gains from sun radiation),
- There are differences, especially in edge months of the heating season, in a total heat balance of the analysed rooms or flats, depending on whether the constant or variable profile of the internal heat gains occurrence was assumed (this concerns, first of all, office buildings),
- Assuming constant (average in the period of a day) values of heat gains from living sources, results in the reduction of heat demand for heating purposes of the office building,
- In case of apartment buildings the knowledge of time profiles of people's presence in rooms and the use of those rooms is not of so great importance in the simulation of heat burdens in longer time periods. The knowledge of the people's presence profile is growing in cases of dynamic simulations of particular rooms or in shorter time periods (e. g. 24 hours).

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The Influence of the Fiber Orientation with Respect to the Acting Force Direction on Dynamic Stiffness of Resilient Materials Before and After Compressibility Test

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Abstract. This research was inspired by the interest to determine the influence of orientation of the fiber inside mineral wool board with respect to the direction of applied dynamic force on its dynamic stiffness value. The nine specimens of stone wool of the density 111 kg/m^3 with identical dimensions of 200x200x200 mm (cubes) were prepared for that purpose. The orientation of the fiber inside the wool board always coincides with conveyor movement direction during its production. Compressibility test was performed on every three specimens in three different directions: „A“ direction –seemingly perpendicular to the fiber orientation, „B“ - direction – seemingly tangential to fiber orientation and „C“ direction – seemingly alongside to fiber orientation. The dynamic stiffness was measured in all three directions (mentioned above) of the each specimen before and after mechanical deformation (compressibility test). The dynamic stiffness of the specimens after its mechanical deformation in “A” direction decreased in percentile considerably in “A” and “B” directions and insignificantly in “C” direction. After compressibility tests performed in “B” and C” directions the dynamic stiffness in all three directions decreased insignificantly or had not changed at all.

Keywords: mechanical deformation, compressibility test, acting force direction, fiber orientation, dynamic stiffness

INTRODUCTION

The impact noise is the most common kind of the structure borne noise in dwellings. The different floating floors constructions are usually used for the impact sound insulation. The floating floors reduce noise level to rooms below. These floors mostly consist of three main layers: upper floor (“float”), base floor (concrete slab) and elastic interlayer between them. The impact sound insulation of the floating floors depends from this interlayer’s properties. Different resilient materials are used for these interlayer’s. The fiber structure materials as stone and glass wool are most common resilient materials used for that interlayer. The dynamic stiffness is the main descriptor used for characterization of these resilient materials. Different authors (Gnip *et al*. 2009; Kim *et al*. 2008; Schiavi *et al*. 2005; Schiavi *et al*. 2007a; Schiavi *et al*. 2007b; Seddeq, 2006; Stewart *et al*. 2000; Vermeir *et al*. 2006) who studied the mechanical properties of the resilient materials have not investigated mechanical deformation influence on dynamic stiffness values of the resilient materials and how dynamic stiffness depend from direction of the fiber orientation with respect to applied force. The previous research (Dikavicius, 2009) showed that after mechanical deformation (compressibility test) the dynamic stiffness of fiber structure resilient materials significantly decreased. This led us to perform measurements of deformed materials to check the fiber orientation influence to change of dynamic stiffness values of the resilient materials.

METHODS

The specimens from stone wool board of 111 kg/m^3 density (from the market of the Lithuania) were prepared. The dimensions of the specimens were selected 200x200x200 mm (cubes) that the equal conditions for the measurements of the dynamic stiffness for all fiber orientation directions with respect to the acting force would be assured. Compressibility test was performed on every three specimens in three different directions (Buska, 2007): „A“ direction –seemingly perpendicular to the fiber orientation, „B“ - direction – seemingly tangential to fiber orientation and „C“ direction – seemingly alongside to fiber orientation. (Figure 1). For each measuring were used 3 specimens.

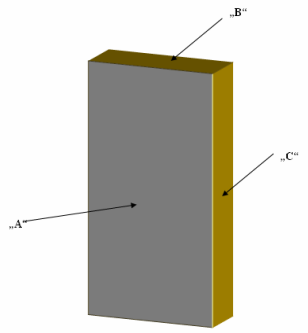

Figure 1. Directions of acting force with respect to seemingly fiber orientation

The compressibility test was performed according to the standard EN 12431. The universal test machine Zwick/Roell BT1-FB050TN was used for this purpose (Figure 2). The measurement accuracy of the universal test machine is ± 1 %.

Figure 2. Zwick/Roell BT1-FB050TN

The dynamic stiffness was measured before and after compressibility test of the same specimens. The dynamic stiffness was measured in all three directions (“A”, “B” and “C”) independent of the applied force direction during compressibility test. Dynamic stiffness was measured by special system DYPS 3 (Figure 3). The measurements were performed according to the standard EN 29052-1. The measurement accuracy of the system is ±2 % in the 10 Hz – 100 Hz frequency range and is ±3 % in the 100 Hz – 200 Hz.

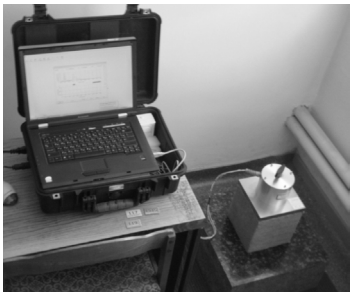

Figure 3. DYPS 3 system

The resonance frequency has been determined by varying excitation frequency (from 10 Hz up to 180 Hz) and excitation force level from 0.1 N up to 0.4 N (than dynamic stiffness is ≤50MN/m^3) and from 0.4N to 0.8N (than dynamic stiffness is >50MN/m^3) and calculating the mobility transfer function between the input signal from the force transducer and the output signal from the accelerometer.

The dynamic stiffness per unit area s' of the specimen was calculated by formula:

$$s' = s_t^{'}, \text{ (MN/m}^3\text{)} \quad (1)$$

where $s_t^{'}$ is the apparent dynamic stiffness per unit. Apparent dynamic stiffness per unit area was calculated by following formula:

$$s_t^{'} = 4\pi^2 m_t^{'} f_r^{'} \text{ , (MN/m}^3\text{)} \quad (2)$$

where $m_t^{'}$ is the mass per unit area of the load plate; $f_r^{'}$ is the resonance frequency of mass-spring system (measured).

RESULTS

In Figure 4 - 6 are shown comparison of the measured dynamic stiffness values before and after compressibility test. In Figure 4 are shown dynamic stiffness values when force was applied in "A" direction and dynamic stiffness was measured in all three ("A", "B" and "C") seemingly directions of fiber orientation, accordingly in Figure 5 are shown dynamic stiffness values when force was applied in "B" direction and Figure 6 are shown dynamic stiffness values when force was applied in "C" direction.

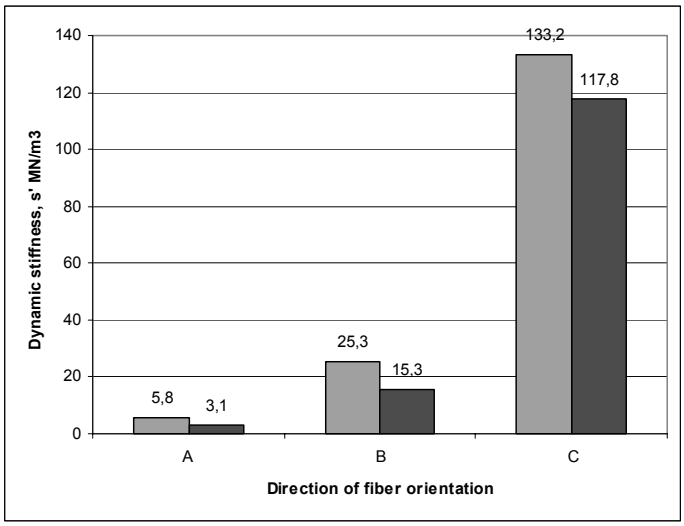

Figure 4. Comparison of the dynamic stiffness values of specimens before and after compressibility test when force was applied in "A" direction

Form the Figure 4 we can see that dynamic stiffness mostly decreased in "A" direction comparing with values before compressibility test it is in the same direction as acting force was applied. The decrement is 47 % (from 5.8 MN/m^3 to 3.1 MN/m^3). Also significant decrement was in "B" direction – 39 % (from 25.3 MN/m^3 to 15.3 MN/m^3) and the lowest decrement was in "C" direction – only 12 % (from 133.2 MN/m^3 to 117.8 MN/m^3).

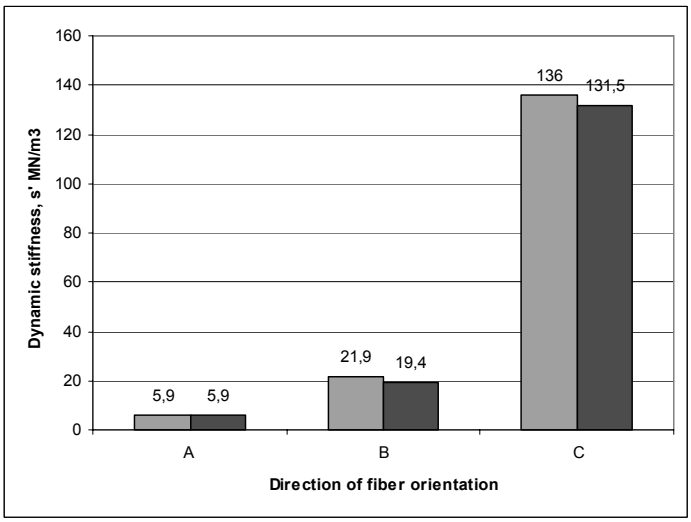

Figure 5. Comparison of the dynamic stiffness values of specimens before and after compressibility test when force was applied in "B" direction

Form the Figure 5 we can see that mechanical deformation has less influence in this case (force acting "B" direction) on dynamic stiffness than in the first case (Figure 4). The dynamic stiffness had not changed in "A" direction comparing with values before compressibility test. The decrement is only in "B" and "C" directions. The dynamic stiffness significantly decreased in "B" direction 21 % (from 21.93 MN/m^3 to 19.43 MN/m^3) and in "C" direction dynamic stiffness decrement was insignificant only 3 % (from 136.0 MN/m^3 to 131.5 MN/m^3).

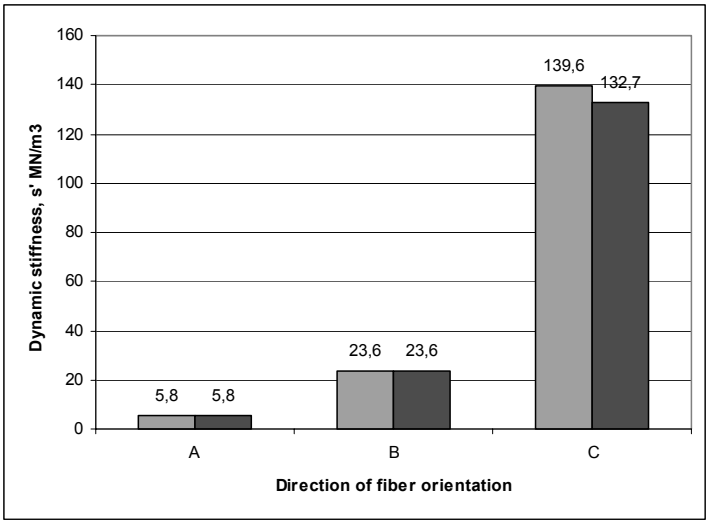

Figure 6. Comparison of the dynamic stiffness values of specimens before and after compressibility test when force was applied in "C" direction

Form the Figure 6 we can see that mechanical deformation practically has no influence on dynamic stiffness values. The dynamic stiffness had not changed at all in "A" and "B" directions comparing to the values before compressibility test. Only insignificant decrement (5 %) was got in "C" direction (from 139.6 MN/m^3 to 132.7 MN/m^3).

DISCUSSION

From the results presented above (Figure 4-6) we can see that mechanical deformation has different influence on dynamic stiffness values of the fiber materials depending on the seemingly orientation of the fiber. After compressibility test the dynamic stiffness mostly changes in that direction in which the force had been applied. This is very typical in "A" direction case when deformation was performed perpendicularly to fiber orientation. In this case the mechanical deformation influence is also significant in other directions ("B" and "C"). The decrement of dynamic stiffness shows that in this direction (deformation direction) the fiber materials mostly change its structure and also loses its structural stability it comes more elastic to the acting force. In the other deformation directions ("B") the dynamic stiffness has not changed significantly and this shows that in this direction the fiber materials deforms very little. In the other directions ("A" and "C") the dynamic stiffness practically had not changed when deformation was performed in "B" direction. When deformation was performed in "C" direction the dynamic stiffness also changed insignificantly and in other directions ("A" and "B") it had not changed at all. This shows that mechanical deformation in this case had not changed the fiber materials structure. From this we can say that the significant decrements of the dynamic stiffness values can be achieved when fiber are orientated perpendicularly to the acting force.

CONCLUSIONS

The research showed that mechanical deformation has influence on dynamic stiffness of resilient materials and this influence depends from seemingly fiber orientation with respect to the acting force direction.

The research showed that the mechanical deformation has significant influence only when fibers are orientated seemingly perpendicular to acting force direction (the dynamic stiffness in this case decreased by 47 %).

The mechanical deformation has no influence on dynamic stiffness when force is applied on the specimen tangentially and alongside to fiber orientation.

Appropriately chosen direction of applied force enables to change dynamic stiffness of fiber materials (to lower dynamic stiffness values from 3 % to 47 %).

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The Optimal Fourier Number on Calculation of an Unsteady Heat Transfer of Building Walls

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Abstract. With the temperature change at any side of building enclosure, the heat flow diffuses through enclosure and changes until the steady state condition is reached. In real terms, the heat exchange process in buildings is a dynamic process, consequently varying in time. Volatility of the heat exchange process is influenced by oscillating of external temperature, internal heat gains, solar radiation and other factors that affect the heat balance of building. While calculating unsteady heat exchange, it is important to divide the materials of enclosure into a right number of conditional layers. A conditional layer is a material's thickness, in which an assumed process of steady heat transfer takes place. The time step is the second parameter which affects the accuracy of calculation of unsteady heat transfer. This parameter defines time during which temperature diffuses step by step through the conditional layer. Thermal diffusivity is the last parameter, which defines the equalization speed of the temperature in conditional layer. A combination of all these parameters is expressed by the Fourier number.
Our research has shown that in order to get the best accuracy of calculation, the most rational value of Fourier number is 0.25, when performing the calculation of an unsteady heat transfer by explicit discretization scheme.

Keywords: unsteady heat transfer, Fourier number, finite differences, explicit time stepping, stability criterion.

INTRODUCTION

It is assumed that for heating of building it is consumed about 80% of the total energy consumption of building. One of initiatives to reduce energy consumption is the EU Directive 2002/91/EC Energy performance of Buildings, which makes it obligatory (Wargocki *et al.* 2008). The production of thermal energy by use of regular liquid, solid or gaseous fuels generates negative impact on the environment – by releasing of carbon dioxide. Also an increase in the price of thermal energy is very important to the least possible use of thermal energy for building's heating while maintaining the regulated indoor climate parameters. One of the ways for saving of thermal energy is an intermittent space heating (Valančius *et al.* 2005).

A relevant issue is to assess the time till heating system's freezing, when the accident cut of energy happens in the district heating networks. The identification of how much additional heating power is needed to restore normative temperature for various time intervals is also important for intermittent heating. In order to forecast the following questions it is needed to know the cooling and heating accumulation rates of building enclosures (Juodvalkis, 2008) as well as furniture and other heat accumulating should be considered inside the building (Hensen *et al.* 2001).

Obviously that under real conditions heat transfer processes in buildings are always unsteady (Valančius *et al.* 2005).

Unsteady heat transfer can be characterized by the concept of heat transfer when heated (frozen) material's temperature varies continuously in time. In examining a simple case where the heat flow moves in one direction only, the differential heat conduction equation is expressed applying the finite difference method (Фокин, 2006; Claesson, 2003; Stankevičius *et al.* 2000; Богословский, 1982):

$$\frac{d\Theta}{dt} = a\frac{d^2\Theta}{dx^2}, \tag{1}$$

where: $d\Theta$ – change of temperature over a time step, [°C]; dt – time step, [s]; dx – thickness of layer, [m].

For the solution of this equation the homogenous flat wall is divided into elementary Δx layers of equal thicknesses (Stankevičius *et al.* 2000). When the planes separating the layers are marked using numbers *n–1 ; n ; n+1* and the time is divided to the equal ranges Δt, the equation is expressed as follows (Фокин, 2006; Stankevičius *et al.* 2000; Богословский, 1982):

$$\frac{\Theta_n^{t+1} - \Theta_n^t}{\Delta t} = a \cdot \frac{\Theta_{n+1}^t + \Theta_{n-1}^t - 2 \cdot \Theta_n^t}{\Delta x^2}. \tag{2}$$

A general formula for temperature's calculation in any plane at time interval Δt, when temperatures in the same plane and two surrounding planes in the preceding time Δt are known (Nevriva *et al.* 2009) is:

$$\Theta_n^{t+1} = \Theta_n^t + \frac{a \cdot \Delta t}{\Delta x^2} \cdot \left(\Theta_{n+1}^t - 2 \cdot \Theta_n^t + \Theta_{n-1}^t\right). \tag{3}$$

Fourier number in building physics is defined as dimensionless parameter which characterizes the heat transfer. This number shows the similarity of thermal processes in conditional layers before and after of time step and is to be used for calculations of enclosures for unsteady heat transfer. This is a dimensionless time, which together with the Biot number characterizes transient heat transfer problems (Wang, 2009; Shevchuk, 2006). The expression of the Fourier number:

$$F_O = \frac{a \cdot \Delta t}{\Delta x^2}, \tag{4}$$

where: a – thermal diffusivity [m^2/s]; Δt – time step [s]; Δx – thickness of layer [m].

By the case of unsteady heat transfer, in any plane the temperature is determined by the following formula:

$$\Theta_n^{t+1} = \Theta_n^t + F_O \cdot \left(\Theta_{n+1}^t - 2 \cdot \Theta_n^t + \Theta_{n-1}^t\right) \tag{5}$$

According to scientists' publications (Фокин, 2006) the value of the Fourier number equal to 0.5 is the permissible maximum. Higher value of this number affects significant errors in the calculation of temperature. The best accuracy is achieved, when F_o = 1/6 = 0.1666, but as it is less, the size and time of calculation are increasing.

While calculating unsteady heat transfer, in each time step differences between calculated and exact values always take place. In general case, three groups of „errors" exist (Hensen *et al.* 2001):

1. Truncation errors – this type of errors is given when the fluxions of differential equation (1) are changed into the finite elements. They can be reduced by reducing the time step Δt and increasing thickness Δx of conditional layer;
2. Rounding errors - which arise in calculating a significant number of decimal places. These errors can be reduced by using double precision arithmetic;
3. History errors – which are given due to errors, introduced in preceding solution steps. This type of errors has the greatest influence to the accuracy of calculation. The error of the first time step affects the second time step calculation of temperature.

In this paper these problems are investigated:

a. What numbers of inaccuracies are possible with large Fourier numbers (F_o > 0,5)?
b. What are the optimal values of Fourier number?

THE EXPERIMENTAL RESEARCH OF THERMAL PARAMETERS OF COMPOSITE PANEL'S MATERIALS

The experimental research was performed in the accredited laboratory of building physics by using of certified equipment. The medium-weight composite panel was chosen, consisting of two 25mm thickness wood fiber boards (MDF) and one 50 mm thickness expanded polystyrene foam board (EPS) (Figure 1). For determination of the thermal conductivity λ of these materials the lambda apparatus has been used, whose principle is based on the constant heat flux over the whole area of the sample. The density ρ was determined by measuring weight and volume; the ratio of these parameters shows the density. Specific heat capacity c has been determined by measurement of cooling rate which was measured by calorimeter.

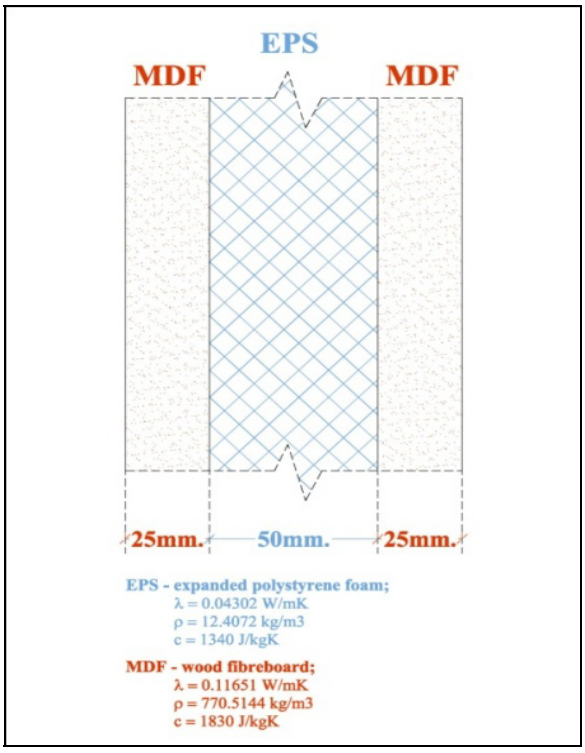

Figure 1. Cross-section of investigated panel in a „Hot box“

Experimental research of composite multilayer panel in a „Hot box“

Experimental research on composite multilayer panel has been performed in a „Hot box” (Figures 2 and 3) in order to estimate and verify the unsteady heat transfer calculation composed by the spreadsheet.

Figure 2. General view of a „Hot box“

Figure 3. Sample installed in surround panel of a „Hot box“

During the research heating, cooling and their combinations were used on both sides of the sample panel, and the temperatures at characteristic planes in the central area of sample were measured, such as: cold side ambience air (Θ_e), cold side surface (Θ_{se}) cold interface between MDF and EPS materials (Θ_1), warm interface between MDF and EPS materials (Θ_2), warm side surface (Θ_{si}), warm side ambience air (Θ_i) (Figure 4). The measured temperatures were recorded in time step of 3 minutes.

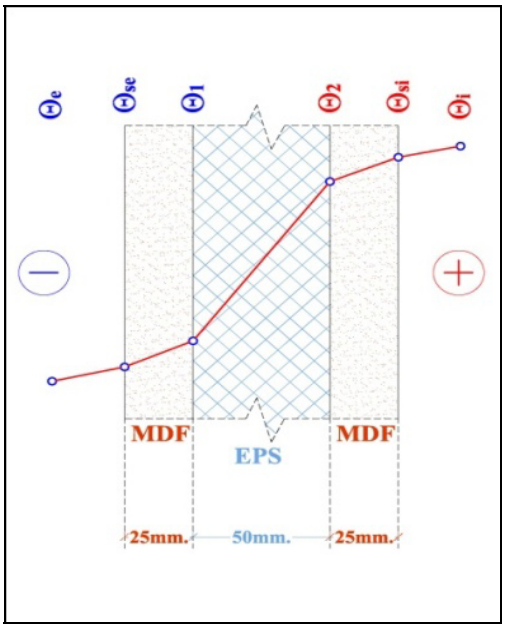

Figure 4. Characteristic planes of multilayer panel

The research has been performed by use of three heating modes:

1. Using the first heating mode, the warm side ambient temperature of the sample was kept by 20.5 ± 0.5 °C, the other – cold side ambience – has been cooled down and kept by –15.5 ± 0.5 °C temperature. When steady state condition through the sample has been reached, the heating and cooling was shut down and the temperature change was recorded at characteristic planes of the sample (Figure 5).
2. Using the second heating mode, one side ambient temperature of the sample was kept by 20.5 ± 0.5 °C, the other side - cooled down and kept by –15.5 ± 0.5 °C temperatures. Then the cooling on this side was shut down and the temperature change recorded at characteristic planes of the sample (Figure 6).
3. Using the third heating mode, one side ambient temperature of the sample was kept by 20.5 ± 0.5 °C, the other side's ambient temperature was reduced from 20±0.5 to –15.5±0.5 °C (Figure 7).

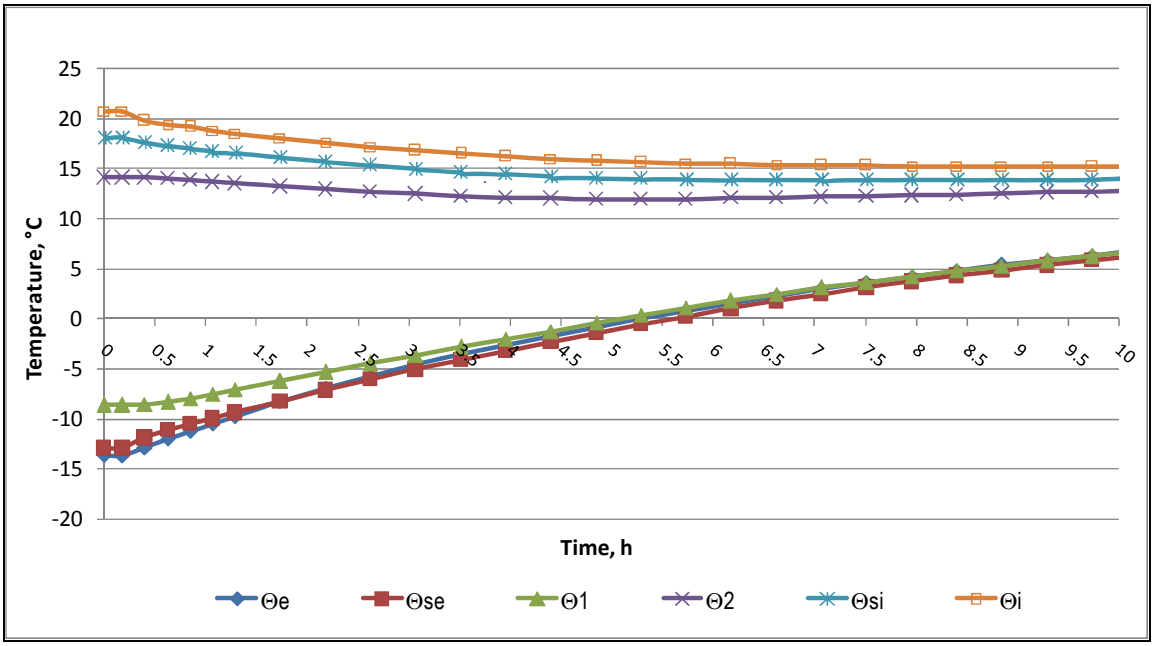

Figure 5. First heating mode, here: Θ_e – cold side ambient air temperature, Θ_{se} – cold side surface temperature, Θ_1 – cold interface temperature, Θ_2 – warm interface temperature, Θ_{si} – warm side surface temperature, Θ_i – ward side ambient air temperature

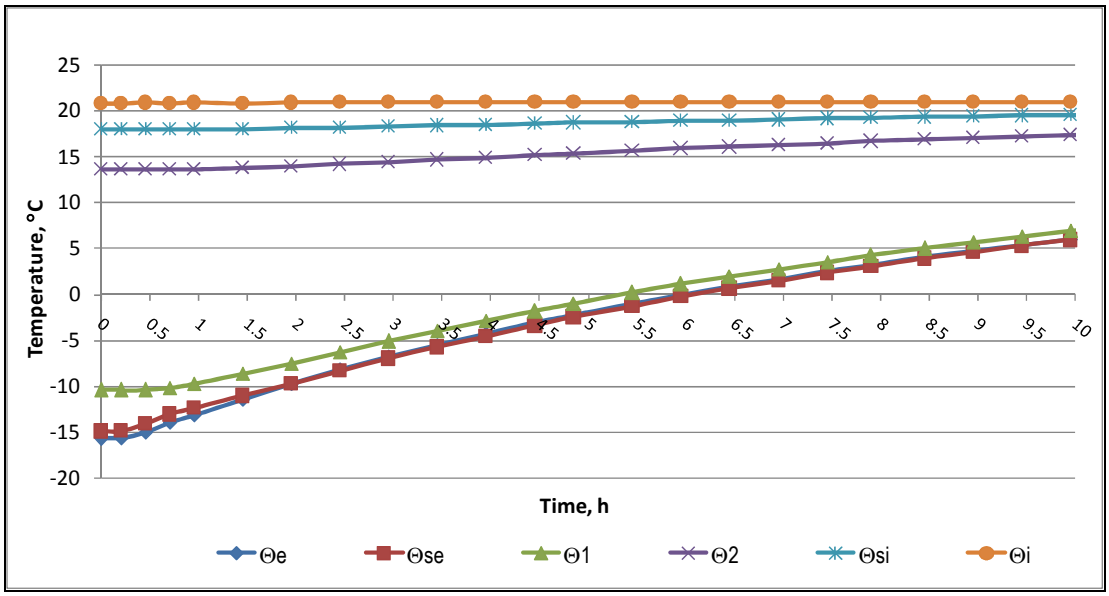

Figure 6. Second heating mode, here: Θ_e – cold side ambient air temperature, Θ_{se} – cold side surface temperature, Θ_1 – cold interface temperature, Θ_2 – warm interface temperature, Θ_{si} – warm side surface temperature, Θ_i – ward side ambient air temperature

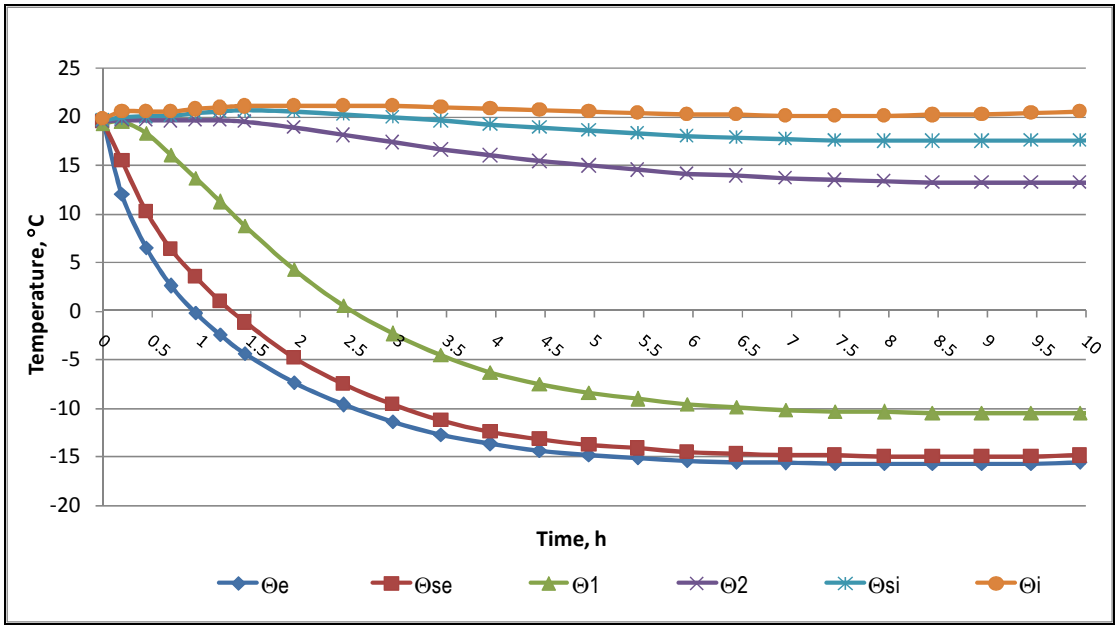

Figure 7. Third heating mode, here: Θ_e – cold side ambient air temperature, Θ_{se} – cold side surface temperature, Θ_1 – cold interface temperature, Θ_2 – warm interface temperature, Θ_{si} – warm side surface temperature, Θ_i – ward side ambient air temperature

Spreadsheet of unsteady heat transfer

The calculation of unsteady heat transfer was performed with program in Excel environment according to experimental research in a "Hot box" and the mentioned above heating modes, which can be divided into three groups: double-sided defrost, one-sided defrost and one-sided cooling down. In each case of heating mode, the spreadsheet was divided into three groups according to the thicknesses of conditional layers:

1 layer of MDF (wood fibreboard) + 1 layer of EPS (expanded polystyrene foam);

3 layers of MDF (wood fibreboard) + 1 layer of EPS (expanded polystyrene foam);

5 layers of MDF (wood fibreboard) + 2 layers of EPS (expanded polystyrene foam).

By changing the time step of calculation in spreadsheet we can observe that values of calculated temperature curves varies.

The accuracy of calculation was estimated by changing the time step of calculation and by comparing the calculated and measured temperature curves between each other. Conditional layers of construction's materials are split into the parts in order to find the optimal Fourier number.

The calculation was done for each case of the heating mode by calculating the temperatures at surfaces Θ_{si}, Θ_{se}, materials interfaces $\Theta_{EPS/MDP}, \Theta_{MDP/EPS}$, conditional layers $\Theta_{EPS/MDP/1}, \Theta_{MDP/EPS/1}$; $\Theta_{EPS/MDP/2}, \Theta_{MDP/EPS/2}$ etc.

To ensure the reliability of calculation, the spreadsheet was supplemented with calculation results describing air temperatures Θ_i, Θ_e and their influence to the convective heat transfer coefficient's values h_{si}, h_{se}. After comparison of calculated temperatures, including cold and warm side air temperatures Θ_i, Θ_e and without these air temperatures, it was decided to analyze the results of the spreadsheet without air temperatures as a more applicable case.

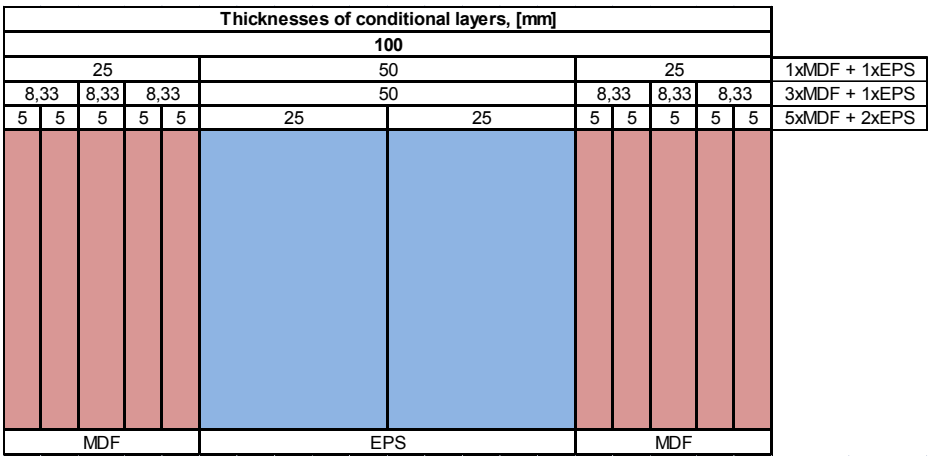

Figure 8. Cross-section scheme of calculation

COMPARISONS OF RESEARCH RESULTS

The accuracy of calculation and relevant choice of calculation parameters are estimated by comparing the results of experimental measurements with calculated ones. To achieve this goal, results of experimental measurements were loaded into the spreadsheet and compared with calculated values of temperature. The result of comparison is expressed as the temperature's calculation average error. This parameter is expressed by formula (6) and symbol *M*. Calculated temperature average error *M* – this is a comparison of the results of experimental measurements and calculated temperature values, by summing the modulus of these temperature differences and calculating the average of them:

$$M = \frac{\sum_{i=1}^{n} \left| \Theta_{\exp} - \Theta_{cal} \right|_i}{n}; \tag{6}$$

where Θ_{exp} – measured value of the temperature, (°C);
Θ_{cal} – calculated value of the temperature, (°C).

The dependence of the calculated temperature average error *M* on Fourier number F_o is shown in Figure 9, where nine curves define nine variants of calculation.

At the first heating mode the best accuracy achieved with panel's division in 2xEPS + 5xMDF number of conditional layers, as Fourier number values till 0.56 shows calculation error till 0.3°C. If the value of Fourier number exceeds 0.56, average calculation error of temperature increases up to 4°C and more. A similar trend, but in a larger scale is obtained by dividing in 1xEPS + 1xMDF and 1xEPS + 3xMDF number of conditional layers. At the second heating mode the best accuracy is achieved with division into 2xEPS + 5xMDF number of conditional layers. In this case of calculation there are obtained very accurate results (average calculation error *M* till 0.1°C) as F_o ranges from 0.15 to 0.45. As F_o is less than 0.15, temperature's calculation average error *M* enlarges up to about 0.5°C; and as F_o reaches 0.45, calculation error *M* jumps up till 1.5°C. The results of the first and the second heating modes have a lot of similarities to the third heating mode. At the third heating mode the best accuracy is achieved with division of panel into 2xEPS + 5xMDF number of conditional layers, but if the value of Fourier number reaches 0.68, calculated temperature average error jumps up to 16.8°C.

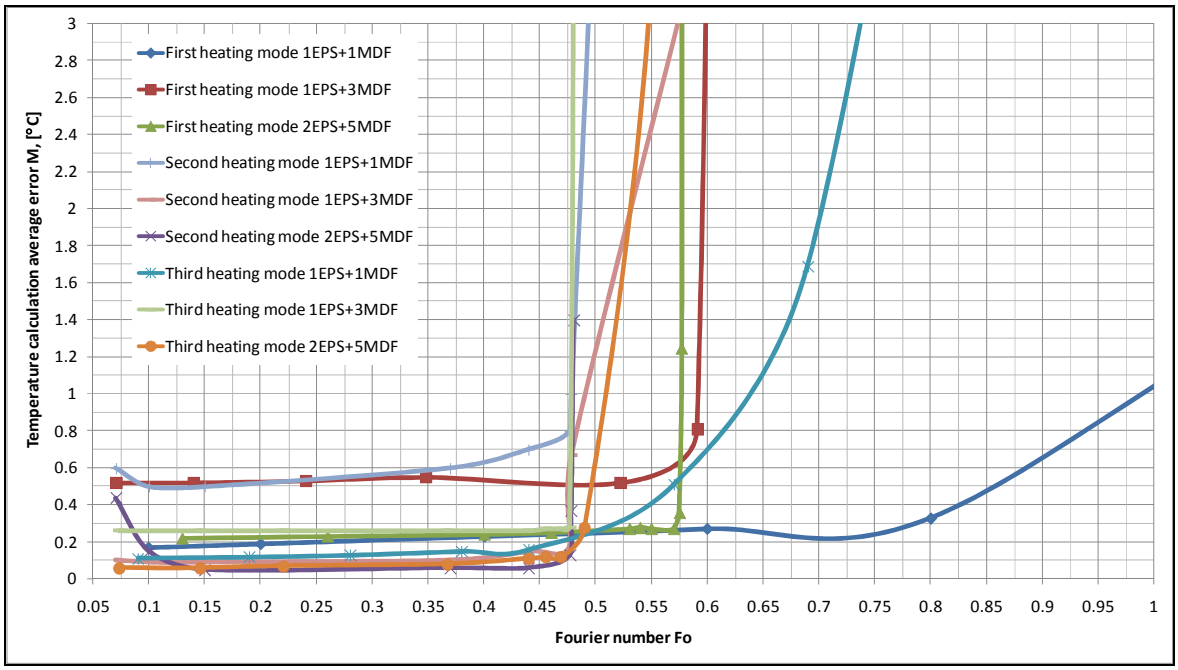

Figure 9. The dependence of temperature's calculation average error M on Fourier number F_o (scale to 3°C)

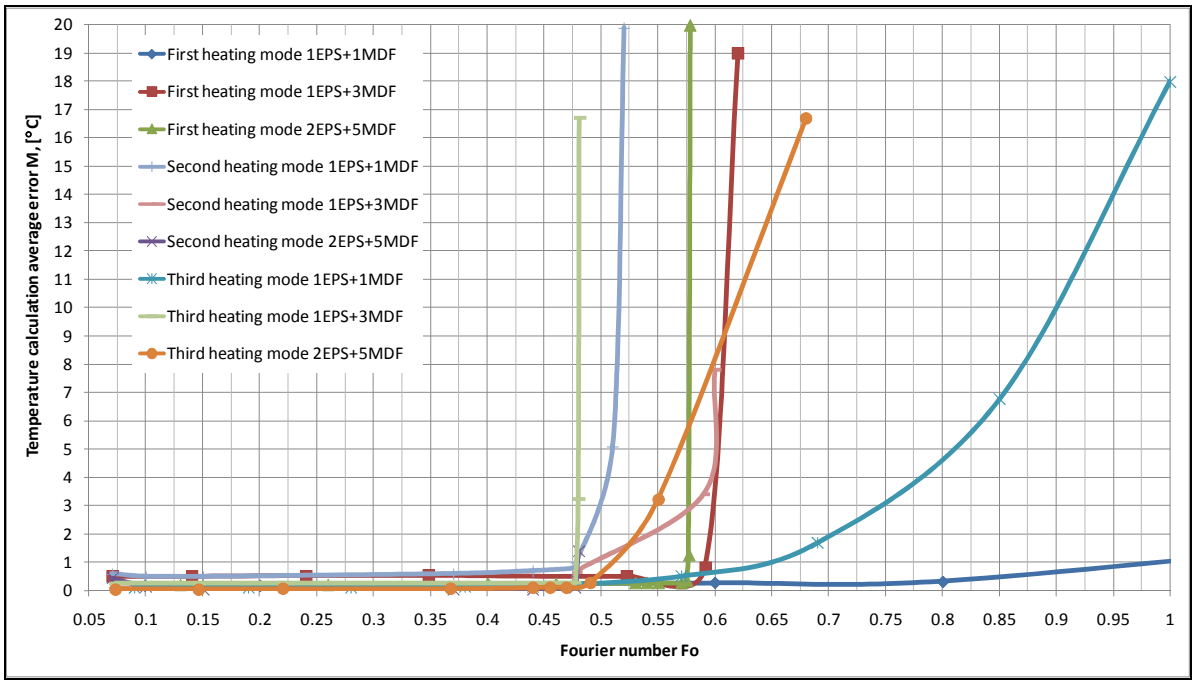

Figure 10. The dependence of temperature's calculation average error M on Fourier number F_o (scale to 20°C)

CONCLUSIONS

1. Our research has shown that optimal Fourier number on calculations of unsteady heat transfer through building walls is around 0.25.
2. The value of Fourier number of 0.5 not always ensures the needed accuracy of calculations of unsteady heat transfer. For example, at the third heating mode where sample plate is divided into 1xEPS + 3xMDF number of conditional layers, when Fourier number reaches 0.48 value, the average error of calculation of temperature M increases up to 16.7°C.
3. The value of Fourier number of 0.5 is very risky. For example, at the second heating mode where sample plate is divided into 1xEPS + 1xMDF number of conditional layers, when Fourier number reaches 0.52 value, the average error of calculation of temperature M increases up to ~20°C.

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The Advanced Construction of Facades. The Relations Between the Quality of Facades and the Quality of Buildings

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Abstract. The scope of the paper is the presentation of the results of quality analyses conducted by the author in several university buildings, of which two are intelligent. The analyses were focused on detecting the relations between the architectural solutions of facades and the performance of the building in practice. The studies included questionnaires and interviews with the users and facility managers. The results of the evaluation indicated that many problems, especially connected with the microclimate of the interiors, stem from the absence of advanced technologies in the facades of modern buildings.

Keywords: facades, users, quality analyses.

INTRODUCTION

Facades are important elements of buildings, influencing both the quality of their interiors and their surroundings. However, the form and look of the façade also exerts on impact on the functional quality of the interiors. The type of partition (full, transparent), the size and arrangement of windows, the inclination angle of external wall surfaces – these are just some elements determining: natural lighting, acoustics, energy consumption, feeling of comfort or discomfort of the users inside buildings. The aesthetic solutions of facades have functional and economic consequences. Also, furnishing and technical equipment play an important role.

Nowadays, in view of the availability of new technical and technological solutions the design of the external skins of buildings has become a complex, interdisciplinary process. The external wall has become an interactive partition, making it possible to incorporate the concept of energy efficiency and ecology. The message sent by the building is no longer limited to symbolic codes embedded in its architectural form and details, but it is rather a multimedia projection on its façade. the building. Instead of traditional durability and stability of form- there is movement, transience and dematerialization.

So far the above mentioned trends may be found in unique buildings designed by renowned architectural studios, setting trends in the art of construction. Innovative solutions of the external skins of buildings are put on equal footing with breakthroughs in such fields as genetics or cosmic engineering. However, we should be aware that, in consideration of the current dynamics of changes, which also refer to the field of architecture, what is now regarded as a novelty may be a standard in the nearest future.

In the discussion of new technologies in architecture it is important to separate the design stage from the occupancy stage. At the first stage, there are daring ideas, sometimes even requiring non-existent technical, material or structural solutions from the design team. It is only in this way that an idea can be materialized. Such buildings are talked about even before they are constructed. Novel facades are admired and commented in professional publications, in the media, in the internet. For example, the construction of "Bird's Nest" stadium in Beijing (designed by Herzog & de Meuron, 2002-2008) (Makowska and Kosik, 2008) required the creation of steel with new properties, and the buildings of the City of Culture in Santiago de Compostela, Spain (designed by P. Eisenman, since 2000 in the course of works) required the use of new concrete mixes of special density, preventing it from flowing down the skin of the building as it has the inclination of 50 %. In the case of "extreme" realizations multiple experiments or tests on special models are needed, increasing the construction costs and causing delays in delivery. Yet, such measures are necessary to secure the expected high technical quality of the building.

Sometimes, however, the designed technical solutions fail. In the phase of occupancy and usage of the building faults and defects are revealed, also in facades. For example, the first "living green wall" of a public utility building in Great Britain (designed by Marie Clarke, 2006) is dying off. The facades of Walt Dysney Concert Hall, modeled by means of state-of-the-art software, act like parabolic mirrors and direct the sunlight to

the windows of the neighboring buildings. The problem with facades did not spare the most famous Polish office building- Warsaw Metropolitan, designed by Foster's studio. Cracks appeared on characteristic granite slabs which weigh over half a ton each, and are suspended horizontally to the surface of the façade. Invisibly fastened tailor-made slabs with T-letter trusses had to be replaced. Conversely, train travelers to Krakow are welcomed by the disfigured facade of Krakow Gallery, where, after the breaking of glass sheets from the façade, all defectively fastened modules were removed. The expertise revealed design errors in the manner of fixing the glass sheets- disregarding the thermal expansion of the sheets and the wind pressure. The sheets were mounted too rigidly, which could have contributed to incorrect distribution of the forces acting on the building and, in consequence, caused glass cracking. Such problems are not usually discussed in professional publications, but are known from local reports published in newspapers and their internet versions available all over the world.

Figure 1. The façade of Krakow Gallery in the course of disassembly

Technical faults pose threats to the safety of users. But there are other problems involved in modern technologies. Behind beautiful facades there are interiors and users. It may be stated that modern technologies should create comfortable and luxurious conditions and support all activities performed in the building. The author made a decision has decided to confirm the above thesis on the bases of questionnaires carried out among the users of university buildings, both traditional and intelligent ones.

The objective of the studies, the results of which are presented in the paper, was to confirm the relation between the façade solutions and the performance of the whole building, including its technical quality and the microclimate of the interiors. It should be emphasized that the studies were of a pilot nature and the revealed problems should be analyzed profoundly.

METHODS

The research methods employed in the studies are typical of quality evaluation analyses- a field of knowledge that is well developed worldwide, yet in Poland followed in a very limited and fragmentary range. The methodology of quality analyses is popular mainly in social sciences. Unlike quantitative analyses, resulting in numerical data subjected to statistical treatment, qualitative analyses render answers to the questions: "How", "In what manner", "Why"? They also constitute a preparatory stage to quantitative analyses. The following quality analyses methods were used in the study: observations, questionnaires, interviews with the users and administrators of the examined buildings (Konecki, 2000), (Gruszczyński, 1999).

The scenario of the research entailed at least two visits to each investigated building. The first one was a round of the building with its administrator (facility manager). The obtained information and observations revealed certain malfunctions, yet without diagnosing their causes. On the grounds of general knowledge about the building and in cooperation with a sociology professor, questionnaires addressed to different group of users were created. The results made it possible to explain the causes of the problems. Several comparative studies of different buildings facilitated a diagnostic estimation, indicating recurrent errors in the buildings of the same type, such errors or malfunctions should have been eliminated at the stage of programming their functional and spatial layouts and solutions of new buildings (Tymkiewicz, 2008).

The study used some elements of POE-Post Occupancy Evaluation - devised in the 1980s by American scientists (Preiser at al. 1988) and further developed in the 1990s by research teams from many countries. POE is a method of a total evaluation of the quality of an architectural object from the technical, functional, behavioral, organizational and economic points of view made in the course of occupancy, after users moved in. The studies of the facades were focused on one category- behavioral quality, as this feature depends on the architect's decision to the highest degree. The following elements combine the behavioral quality: aesthetic issues,

emotional reception- including the designation of functions, connotations and symbolism, the creation of the feeling of safety and orientation in urban space and in the building itself. The questionnaires and interviews also included questions concerning the closest, and, as it turned out, most important problems for the users, i.e. the relation: "the external walls and the ergonomics of the interiors", exposing the impact of architectural and material solutions on : air quality, natural lighting, noise and rooms arrangement. The above mentioned problems were presented in the aspect of the users' subjective feelings. Attempts at making the studies objective by taking measurements of the parameters of the internal environment in cooperation with research staff from the Faculty of Environmental Engineering, Silesian University of Technology, encountered technical problems involving the logistics of the equipment and the research methodology. Transport of expensive equipment and the necessity of taking multiple measurements on specific days and seasons turned out to be impossible in many buildings. However, it was possible to conduct the measurements in some rooms inside the building of the Faculty of Environmental Engineering. Their results certified the deviations from the values assumed in the relevant standards.

RESULTS

The following university buildings located in Gliwice and Katowice were studied: 3 traditional buildings erected in the 1970s (Faculty of Mechanical Engineering, Faculty of Environmental Engineering, Faculty of Social Sciences, Faculty of Physics), and 4 new buildings functioning for only a few years. Among the 4, two are intelligent, equipped with BMS (Building Management Systems) – Faculty of Law and Administration, Faculty of Theology, and the remaining two are new but less technologically advanced (Exhibition Gallery of the Academy of Fine Arts, the so called: "Art Round About") and Foreign Languages College located in Gliwice.

Figure 2. Exhibition Gallery of the Academy of Fine Arts, Katowice

The studies revealed certain relations. In the traditional buildings the external walls have open window modules. Inside the buildings there are unfavorable microclimate conditions, mainly regarding the temperature in the rooms. Depending on the orientation of the buildings to geographical directions, the interiors are overheated or too cold. But the users easily deal with such inconveniencies. The access of daylight is regulated by rolling down internal blinds and excess heat by turning on fans in summertime; whereas in wintertime they use additional heaters and air humidifiers.

Surely, these appliances increase the operating and maintenance costs. In some rooms air conditioning is installed, the elements of which disfigure the façade. Yet, in the face of poor quality of the whole building, the users accept it without difficulty. The questionnaires disclosed that some users do not even notice the external look of the building, focusing their entire attention on the workplaces and their ergonomics. In case of necessity, the users introduce their own ad-hoc simple solutions (for example: in the absence of blinds they cover the windows to reduce sunlight penetration).

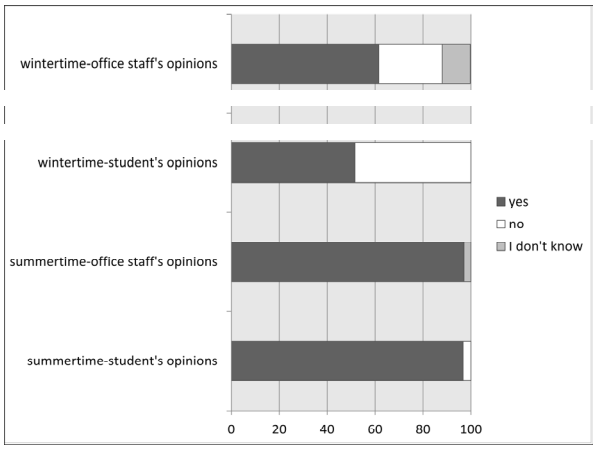

Figure 3. Traditional building (Faculty of Mechanical Engineering, Faculty of Environmental Engineering) - The need for additional technical equipment (in student's and office staff's opinions)

In the investigated intelligent buildings, equipped with air conditioning, the external skin is sealed and the windows cannot be opened. Theoretically, a computer system should control the regularity of the microclimate. Practically, however, it is otherwise. For various reasons (high costs of air conditioning operation) the maintained parameters do not provide comfort to the users and they feel helpless: it is stuffy and too hot, but the windows cannot be opened to air the rooms. In the office rooms, where there is an option of individual control of setting up the air conditioning, the problem is not so acute- about half of the respondents assessed the internal environment conditions at the workplace as adequate. Yet, this problem often appeared in students' comments in open questions contained in the questionnaires: "you need the key to open the window", "air-conditioning, even if it works, makes the rooms too hot and the windows cannot be opened", "the temperature is often not well adjusted, the windows cannot be opened", :because the windows cannot be opened, we open the doors", "it is too noisy and there is no fresh air", "it is stuffy- because the windows cannot be opened". The quotes are taken from the questionnaires carried out in the most technologically advanced building of the Faculty of Theology, where as many as ¾ of the respondents expressed their negative views. Similar opinions can be found concerning other facilities with air conditioning and sealed external skin. The users also pointed out to the disturbing noise from the air conditioning. As far as the new building of the Faculty of Theology, some other disquieting comments were made: "separately air-conditioned rooms cause temperature differences, that's why people get sick", "the air is too dry and it causes conjunctivitis".

Figure 4. Front façade of the Faculty of Theology building, University of Silesia, Katowice

Intelligent buildings should have intelligent facades, reacting to changing conditions of the external environment. This is not the case of the investigated buildings. The Faculty of Law and Administration building had a chance for an intelligent façade, as it is equipped with external blinds system. The blinds on the back façade are movable, rolled down mechanically and individually by the users. Unfortunately, the blinds on the front façade were not equipped with actuators and remain immovable, providing no opportunity of controlling the access of daylight to the interiors, which resulted in the installation of internal vertical blinds by the facility

manager. The effect: a view from the window obscured by a grate of vertical internal blinds and horizontal external blinds and the necessity of using artificial light even at daytime.

Figure 5. Back façade of the Law and Administration Faculty building, University of Silesia, Katowice

Seen in the aspect of energy efficiency, the use of artificial light at daytime is a disadvantage. The same problem was also observed in the Foreign Languages College building in Gliwice. The top floor of this building is glazed and contains conditioned rooms with the windows shielded by mechanically locked external blinds, which are the only protection against excess light penetrating the interiors oriented to the east and west. However, rolling down the blinds stops any access of natural light to the rooms, making it necessary to turn on artificial light. Conversely, in the "Art Round About" building there is no form of protection against sunlight, which makes the performance of many functions of the building difficult, including, for example, the arrangement of exhibitions or multimedia presentations.

Another problem is the operation of technical equipment. In the above mentioned "Art Round About" building, due to its characteristic form of a semi-cupola, many glazed surfaces and complicated heating system (it requires expertise, intuition and experience to operate)- the temperatures prevailing in the interiors during its first winter season fell down to 13 C. In the successive years, the problem was addressed. Equally, the questionnaires carried out in the Law and Administration Faculty building and Theological Faculty building revealed that failures of the air conditioning system happen: "the air conditioning system breaks down", "it is not on", "it gets too stuffy with many people around, they can't control the parameters". One of the students who conducted the questionnaire among the users of the Theology Faculty building expressed her impressions/ conclusions: "The architectural form of the building is positively perceived, but there is a problem with the operation of the microclimate; also, some of the respondents seemed to be a little afraid of this building".

Figure 6. Front façade of the Foreign Languages College building in Gliwice

The users seem to treat all novelties connected with the technology of an intelligent building with certain caution and fear, experiencing such feelings especially in the initial occupancy stage as an additional obstacle, rather than convenience. For example: the necessity of opening the door by means of a magnetic card in strictly

coded time, instead of "simple" key collection from the lodge, or of choosing one of the many options of "lighting arrangement" in a lecture room, instead of simply turning on the light. The users need time to get familiar with the new solutions and to learn how to use all the facilitations.

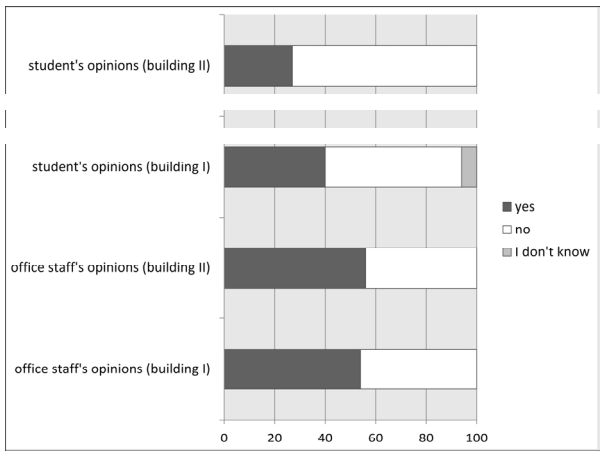

Figure 7. Intelligent buildings: Satisfaction of indoor environment conditions in student's and office staff's opinions; building I - the Law and Administration Faculty; building II - the Faculty of Theology

DISCUSSION

The opinions on the internal environment referred to in the paper constituted only one of many other factors analyzed in the investigated buildings. On the bases of the users' comments added to the open questions, a conclusion may be drawn that as far as a subjective feeling of comfort is concerned, the studies of traditional and intelligent buildings did not confirm the thesis set forth at the beginning of the paper- the users do not feel better surrounded by new technologies. The most acute inconvenience is no access to "fresh air" in air-conditioned rooms or buildings. This problem is nothing new. Hermetically closed shield glass walls were first used in the 1950s (Lever Brothers Building, SOM), but they necessitated artificial ventilation or air conditioning. In the face of the 1970s energy crisis, tightly sealed glass "containers" (Schittich, 2006) underwent a lot of criticism. New solutions were sought to protect the interiors from the external conditions and to take active advantage of the elements of the natural environment: the sun, the wind – to make buildings more energy-efficient and environmentally friendly. Since the erection of Commerzbank building in Frankfurt upon Main (designed by Norman Foster in 1997) there has been a trend to ventilate buildings in a natural way, even very big facilities (Michałek, 2005). Hybrid ventilation systems may offer a good option (Mierzwiński, 2002).

Likewise, the problem of the inefficiency of immovable external blinds that occurred in the Law and Administration Faculty building is not unique. For example, The Occidental Chemical Center in Niagara Fall, USA (1980), the first double-skin façade building in the USA, which received many awards for energy-efficiency and, at a certain time, was considered a pattern to be followed, also had a problem with the blinds mounted in the inter-skin space, which, after some time were set in the horizontal position due to their poor technical condition. Thus, they provided only half of the assumed protection against sunlight, the consequence of which was the introduction of vertical blinds by the users (Harrison and Meyer-Boake, 2005), (Michałek, 2006).

An option of controlling the access of daylight to the building is particularly important in glazed buildings, in which the sunlight protection solution should be incorporated into the project of the arrangement and aesthetics of their façades. If these issues are not taken into account at the design stage, sometimes it becomes necessary to change the architectural concept. Such was the case of the National Library in Paris, designed by Dominique Perrault, where the initially assumed transparency of the glazed towers was ruined by the necessity of introducing a blinds system, otherwise the building would not function (Fierro, 2003).

Double-skin facades which contribute to the creation of favorable microclimate of the interiors are rare in Poland and can only be found in commercial buildings, mainly in Warsaw. Although the information about such buildings is given in official presentations published in professional literature, we still do not know how they really perform and how their users feel inside them. Beside unique buildings, there are still be many traditional buildings, many of them will have to be modernized to function properly, as well as new facilities equipped with advanced intelligent technologies, usually functioning as office workplaces, public administration units, schools and universities.

The problem of facades is underestimated. In architectural journals facades are considered only in terms of aesthetic issues, possibly energy-efficiency issues. At the same time, buildings do not perform properly: the interiors are overheated or under-heated, too dark or too bright (especially for computer work stands), sometimes

they do not prevent the sun dazzle. The rooms are difficult to arrange, users suffer from noise and drafts, the costs of maintenance are increasing. Users, facility managers and architects do not link these problems with the quality of the exterior walls and, during renovation works do not try to rectify the problems in a complex manner. Usually facades are thermally improved and the internal rooms furnished with additional technical equipment that should improve the quality of performance (air conditioners, fans, heaters, humidifiers). Such equipment contributes to increased maintenance and operational costs, not to mention higher energy consumption. Newly erected buildings reveal typical functional problems. These issues are a subject of discussion and publications among engineers of different specialties (Ferdyn-Grygierek, 2008) (Lis, 2009), (Heim at al. 2009). Unfortunately, the information flow among scientific circles and interdisciplinary cooperation still encounter many obstacles.

CONCLUSIONS

Participative studies, involving users, are a routine procedure applied several months after the building is commissioned to occupancy and have a potential of providing evidence in disputes between architects and investors. In Poland, users' surveys are still a novelty, approached with distrust and conducted in a very limited range.

In should be mentioned in this place that within research projects run at the Chair of Design Strategies and Modern Technologies, Faculty of Architecture, Silesian University of Technology, quality analyses based on the POE method have been conducted for several years in buildings serving different functions. The research tools and procedures are still being tested and corrected, but even at this stage it may be concluded that more valuable and unambiguous information may be derived from direct interviews rather than from questionnaires.

The studies of the facades in all the investigated buildings were run complementary to the studies of other aspects- mainly focused on functional and organizational quality of the interiors. The incorporation of facades into the whole program of estimating the quality of buildings was well received and better understood both by facility managers and by the users. It was observed that the questions limited only to facades evoked some kind of "insufficiency" in the respondents, and a wish to share their opinions about other essential problems in the performance of the building. On the other hand, while answering the questions apparently not related to the external walls, problems were expose , the cause of which were definitely façade solutions. Thanks to such approach, students of the Faculty of Architecture who helped in the studies also had the opportunity to get more insight into the buildings and their performance. The table 1 presents the most important conclusions.

Table 1. Traditional and intelligent buildings - conclusions

	TRADITIONAL BUILDINGS	INTELLIGENT BUILDINGS
external walls	have open window modules	the windows cannot be opened, the skin is sealed
microclimate	the interiors are overheated or too cold (depending on the orientation of the buildings to geographical directions)	computer system should control the regularity of the microclimate
costs	additional heaters and air humidifiers - increase the operating costs of the building	high costs of air conditioning operation; maintained parameters do not provide comfort to the users
blinds	internal louvers, manual or mechanical control	external or internal louvers (manual or mechanical control); lack of electronical control
technical equipment	simple handling	complicated handling; equipment failures
users	easily deal with microclimate inconveniencies by opening windows, rolling down internal blinds, turning on fans (in summertime) or using additional heaters and air humidifiers (in wintertime)	don't know what to do, when it's stuffy and hot; want to open the window
	introduce their own ad-hoc simple solutions	feel helpless

The studies conducted in the university buildings were a valuable experience not only for the author, but also for the surveying students-future architects. They had an opportunity to learn that at the end of the entire design process there are users, with their own opinions about the building. Their views should not be ignored, as they may lead to the detection of malfunctions and faults in the performance of the building, to the improvement of the existing condition, and to the application of such experience in the designs of new facilities of similar functions. To recapitulate, it seems relevant to quote J. Flitch: "in architecture there are no spectators, there are only participants" (Bańka, 1999).

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Problems and Tasks of Facilities Management in Lithuania

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Abstract. The goal of the facility management approach is to carry out as little maintenance as possible as infrequently as possible while at the same time preserving the availability of the services facilities, the building elements and the whole building. In other words, maintenance should be carried out only when necessary to ensure the continued, safe and profitable use of the building at acceptable levels of satisfaction or when there is the possibility of extending the useful life of the elements of the building. Finding an appropriate maintenance strategy is the most difficult task facing maintenance management in determining an optimal approach to reducing the financial expenditure and total life cycle costs.

Most enterprises and organizations in Lithuania carry out the maintenance of constructions by their own potential. Common industrial or added costs are used for this purpose, which makes up the greatest part of total expenses and adversely affect the competitiveness of the main activity of the enterprise.

Moreover, the quality of services is often insufficient as all works are usually done in the method of "fire fight". This means that defects are eliminated too late, i.e. only when they appear, and this requires much higher expenses.

Keywords: facilities management, non-residential buildings, supporting activities.

INTRODUCTION

Lithuania as a member of European Union shares the same economical space with countries, which have longer experience of market economy. In that situation it is very important to know the European economical system and the peculiarities of construction market.

Internationalization processes in construction influence the business of Lithuanian contractors. The beginning of 21st century could be named as an intellectualization epoch of construction business, engineering and management solutions. The success of Lithuanian contractors will depend on international construction experience, competitive abilities and adaptation in changeable construction market.

METHODS

The study concerns facilities management researches review and analysis, bringing relevant facilities management problems in Lithuania and the possible alternative solutions.

RESULTS

The term facilities management comprises the object, its structure, operation functions and the whole operation system. The effective activity of facilities management allows creating optimal conditions for the implementation of the main activities, the rational maintenance, repairing and modernization works of buildings; it also allows reducing operational costs of buildings as well as using efficiently the investments to ensure the modernization and necessary functionality of buildings.

The easiest way to cut maintenance costs is to stop doing maintenance. This approach is simple, but the long-term results are usually very costly.

Non-residential buildings that are built in Lithuania before 2000 and not renovated are poorly managed. Their engineering services, for example, may fail to provide the intended quality of service or comfort, a deficiency which in turn directly affects occupant businesses and stakeholder benefits in facility operations. This failure often lies in a lack of integrated knowledge of the built environment, stakeholder relations and facility performance. In order to provide successful facilities management in any class of building, it is necessary to primarily explore the position of the building in the context of business and its supporting resources as shown in Figure 1.

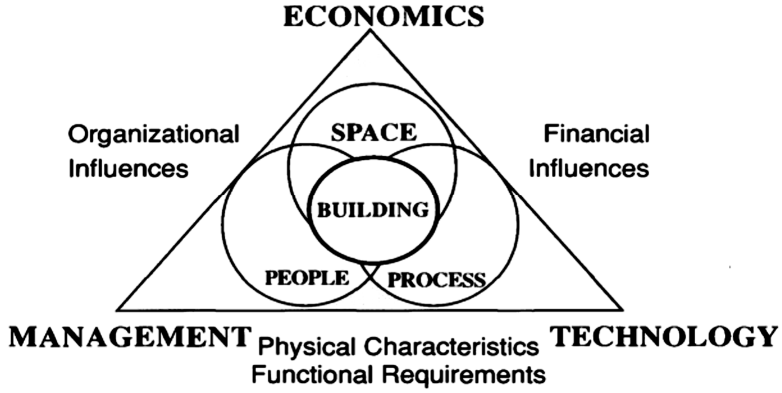

Figure 1. The Positioning of Building in Business (McGregor *et al.* 1999)

This figure illustrates not only the scope for appraisal in meeting the dynamics of the work environment in which businesses must operate, but also explains that the built environment is conducted within a framework of economics, management and technology. The aim is to optimize organizational and financial influences as well as physical characteristics and functional requirements. A successful building is thus an amalgam of people, process and space.

Real estate development is the continual reconfiguration of the built environment to meet society's needs. Development presents an integrated factor among estate traders, investors, designers and building firms. Development differentiates from the classic building industry since its products – buildings - are not dedicated to particular client but for an unknown client in the real market. The aim of the development process is the creation of a building, where it can either be rented by future unknown users or sold in the real estate market.

The activities, which create the conditions for the successful process of the core business, are the supporting activities (services). They involve first of all administration of building, the planning of its reconstruction, other services such as cleaning, post, safety, inventory, etc. These supporting activities must be managed. A new method of management is used in the development firm – a facility management. Facility Management is the unique planning and control of all supporting activities within the firm. It appears as a support-services management method. There are three possible ways of managing the supporting activities. The first is where the firm manages everything on its own. The second one is outsourcing – a supply firm manages the supporting activities, while the third relies on a combination of the developer and a supply firm managing the supporting activities. Outsourcing is usually offered by firms, which the core business is the facility management.

To enable the business to fulfill the formulated goals, it manages the corporate activities that may be defined as:

- Primary – core business (processes)
- Secondary – supporting activities (processes).

Main activity (core business) may be characterized as dominant, functional process, performed by the company in order to fulfill its primary function. Business entities perform main activities in order to fulfill fundamental goal of the business – profit.

Supporting activities are mainly all the other activities that are do not belong to the main functional process of business activity but they create conditions for successful running of the core business. Among supporting activities we can mention finances, human resources, informatics and telecommunications, technical and other processes. In the production sphere these include mainly the administration of the entity, operation, and maintenance, planning of reconstruction, services like cleaning, alimentation, mail, and lease of spaces, moving services, equipment and administration of real estates.

Costs related to the realization of supporting services often mean the evaluation to the total business costs, i.e. total costs for main and supporting activities not a negligible sum. In spite of this fact, leading workers in business entities do not enough emphasize the management of supporting services.

Their capacity is fully used by the core business. From the point of view of the corporate management it is an ineffective time. Such a time "loss" may consequently result in minimization of the corporate management effects; business entity loses dynamics, quality workers, and profit.

Core business (fundamental activities) optimization is continuous and, the activity of the management is fully centered on it. The main goal of the management should be firstly the maximal effectiveness of the core business. Focusing of corporate attention to the core business is possible only when the management has a programmed separation of the supporting activities from the core business.

Facility Management method enables the Quality management of the supporting activities. It is expected to control and to optimize the supporting activities (processes) in entities with the goal of effective running of the core business.

International organization called International Facility Management Association (IFMA), associating more than 18000 members from 50 countries defines the Facility Management as: a method that within the organizations mutually harmonizes the workers, the working activities, and the working environment integrating the principles of business administration, architecture, human and technical sciences. Facility management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology (International Facility Management Association, 2010).

Another broader definition provided by IFMA is: "The practice or coordinating the physical workplace with the people and work of the organization; integrates the principles of business administration, architecture, and the behavioral and engineering sciences."

In the UK and other European countries facilities management has a wider definition than simply the management of buildings and services. The definition of FM provided by the European Committee for Standartization (CEN) and ratified by BSI British Standards is: “Facilities management is the integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of its primary activities”.

The British Institute of Facilities Management has formally adopted the CEN definition but also offers a slightly simpler description: "Facilities management is the integration of multi-disciplinary activities within the built environment and the management of their impact upon people and the workplace" (British Institute of Facilities Management, 2010).

In Australia, the term *Commercial Services* has replaced facilities management in some organizations. Commercial services can also define services other than just looking after facilities, such as security, parking, waste disposal, facility services and strategic planning.

The term *construction project management* appeared in scientific and practical terminology in Lithuania about 15 years ago. The term *facilities management* started to be used about 10 years ago, because since then the construction project was understood and analyzed only until the onset of the operation period of a building.

Scientists of Lithuania and other countries give the following suggestion for the analysis of the facilities management: the problem is to be analyzed in administrative, technical, spatial (accommodation) and other services management aspects (Zavadskas, Kaklauskas et al., 2001).

The effective activity of facilities management allows creating optimal conditions for the implementation of the main activities, the rational maintenance, repairing and modernization works of buildings; it also allows reducing operational costs of buildings as well as using efficiently the investments to ensure the modernization and necessary functionality of buildings (Oesterle, 1999; Henzelmann, 2001; Braun, Oesterle, Haller, 2004).

Non residential buildings built in recent years Lithuania is increasing. In last years this increase was corrected by economic difficulties. Growing of such buildings construction, increasing effective facilities management solutions to such buildings need.

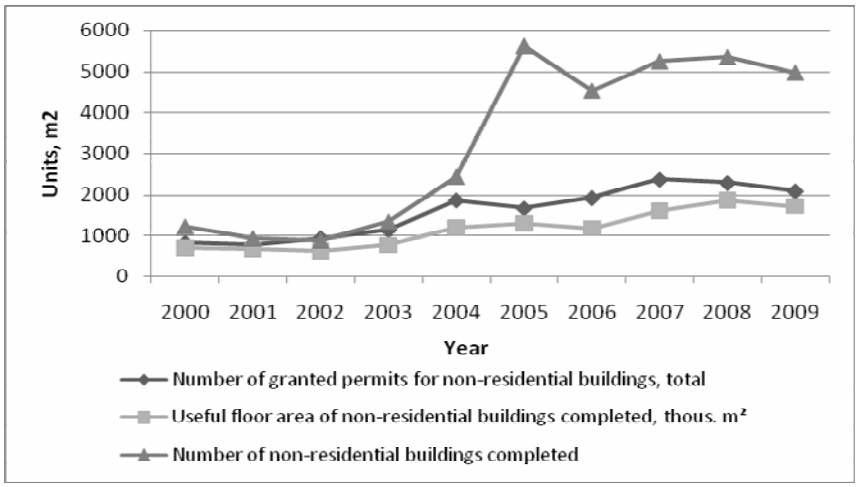

Figure 2. Non-residential building construction in Lithuania
(Data from the Department of Statistics Lithuania 2010)

In Lithuania the maintenance of non-residential buildings is carried out in two ways: 1) the enterprise or owners of the building carry out all works by their potency or 2) facilities management services are provided by another enterprise according to the contract. Most enterprises and organizations in Lithuania carry out the maintenance of constructions by their own potential. Common industrial or added costs are used for this purpose, which makes up the greatest part of total expenses and adversely affect the competitiveness of the main activity of the enterprise. Construction maintenance departments are functioning inefficiently in the enterprise therefore this leads to higher expenses, compared to the costs needed for specialized construction maintenance enterprises.

Moreover, the quality of services is often insufficient as all works are usually done in the method of "fire fight". This means that defects are eliminated too late, i.e. only when they appear, and this requires much higher expenses.

Foreign scientists have extensive experience in academic research in facilities management. They proposed a classification of such research (Figure 3).

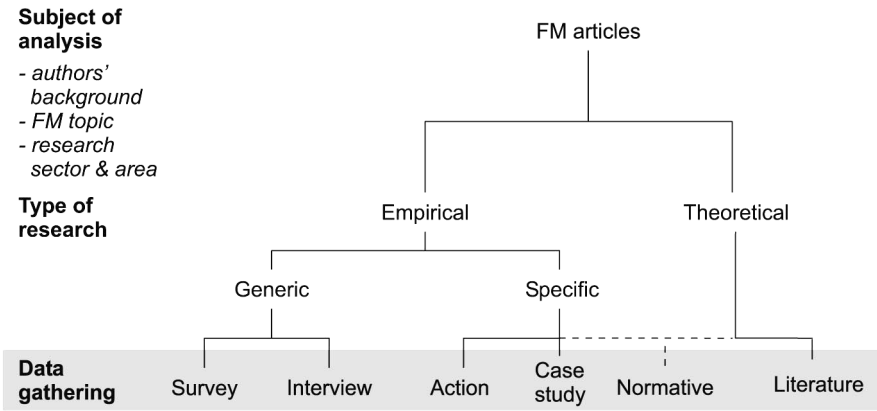

Figure 3. Classification of academic research in facilities management (Ventovuori *et al.* 2007)

To summarize the scientific researches and practice of constructions maintenance in Lithuania, facilities management problems and tasks might be divided into several groups (Fig. 4).

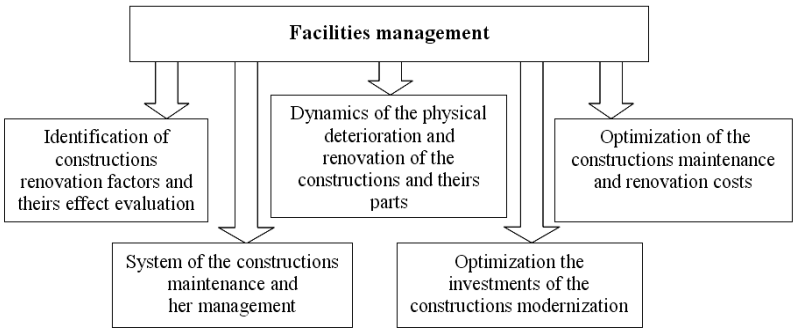

Figure 4. Possible reasons for the renovation of constructions in Lithuania

The dynamics of physical deterioration and reparation of constructions and their components makes the strongest impact on facilities management work structure the amount of necessary costs. During the construction operation period those costs and investments make up to 75% of total expenses during the construction lifetime period. The amount of the costs depends on the solutions of a construction project and the effectiveness of facilities management activity during the construction operation time (Fig. 5). Having analyzed the dynamics of physical deterioration and reparation of constructions and their components, an optimal facilities management functioning model can be created.

The model of construction maintenance and reconstruction allows optimizing the amount of necessary costs and demand of investments during the construction operation period.

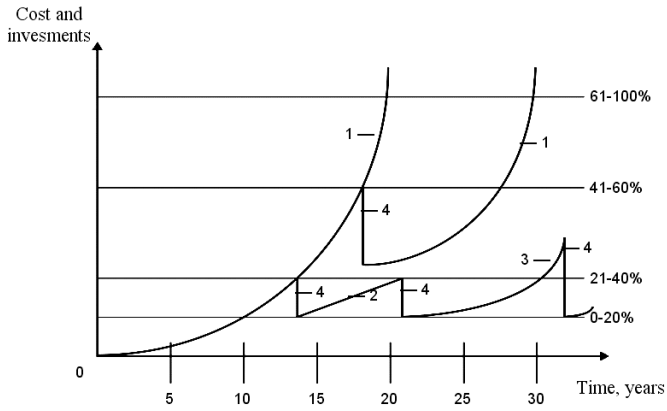

Figure 5. Changes in costs and investments during the construction operation period

Fig. 5 shows possible changes in costs and investments depending on the maintenance and reconstruction model of a building. Here: 1 – curve of natural deterioration of the construction; 2 – curve of construction deterioration when effective maintenance is performed; 3 – curve of construction deterioration when maintenance is performed; 4 – repair works of the construction.

Construction maintenance system and its management make a strong impact on the efficiency of construction operation. Therefore the creation and practical implementation of the management model of this activity has a strong practical and educational significance.

The transformation of management systems is strongly affected by the development of different studies and the practical application of their results. Facilities management cybernetics model might be created on the basis of the achievements in theory, applied mathematics, informatics and economics studies. Practical application of the facilities management cybernetics model determines the purposeful, reliable and effective functioning of an enterprise. However, in practice this management model of an enterprise might be implemented only with sufficient normative, methodological, informational and legal resources of the management system.

The changes in functions and structure of Lithuanian economy determine the demand for certain specialists. As the experience of certain European countries shows, economical results and living standards may be achieved even without any material resources. In such case topical issues become education system and preparation of different specialists.

Internationalization processes give more freedom for capital exchange and people movement as well as creates better possibilities for the development of economics and other fields of activities. On the other hand, it also sets new requirements for the professional training level of specialists and the application of scientific achievements in practice. This will be a top issue when determining the competitiveness of national economical systems in the international market (Juodis, 2001).

The Facility Manager's job requires integrating business management and other disciplines. Specific tasks can vary substantially depending on the organization, but their duties fall into several broad categories: operations and maintenance, real estate management, project planning and maintenance, finance, quality assessment, technology integration, and management of human and environmental factors. Specific tasks can include architectural planning and design, budgeting, workplace planning, purchase and sale of real estate, lease management, and renovations. Facility Managers may oversee renovation projects to ensure the facilities meet government regulations and environmental, health, and security standards. Facility Managers also monitor the facility to ensure that it remains safe, secure, and well-maintained.

What is the task of the Facility Manager in the design phase of the non-residential buildings development process? The design phase can start after the developer has signed the contracts (he has decided on a general contractor, determined general rent or sales requirement). The architect as a member of the development team – beyond assisting in basic planning – provides basic services. Some of them are: schematic and final design, preparation of construction documents, administration of the agreements between the developer and the builder, etc. The design process is characterized by many iterations. Step-by-step the building assumes its final shape.

In the design process, there is an opportunity to minimize the possible market risk, that is, the inability to be competitive (to keep the space competitive in an evolving market, minimize operating costs, maintenance costs, costs for repair or innovation, energy costs, etc.). Facility Manager should significantly co-operate with his or her operating experience in this period of time. They are not a competitor or opponent to the architect in the preparation phase, but rather their partner. The leading task in the project phase is up to the architect, the Facility Manager should economically and operationally develop suggested individual versions and present their pros and cons. Final decision should always be up to the designer as well as the developer.

CONCLUSIONS

1. The demand for facilities managers in Lithuania is constantly increasing, and more attention is paid for the maintenance, modernization and reconstruction of new and existing non-residential buildings.
2. Enterprises of different business activities are trying to develop their competitiveness by reducing the functional costs of their activities. Such cost reducing possibilities might be detected in the buildings maintenance and management system. Research of the enterprises development show, that those functions are often transmitted to certain specialized companies.
3. Lithuanian enterprises and construction developers have a not enough effective practices in facilities management of non-residential buildings.
4. The effective functioning of facilities management is mainly determined by the selection of an optimal technical maintenance model as well as efficient application of investments for the modernization of buildings. To solve those problems, scientific studies need to be performed and best practical recommendations are needed.

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Impact of Digital Level Errors Investigations on Construction Engineering Measurements

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Abstract. Modern constructions distinguish for the size of construction objects, complexity of engineering structures and high precision of connectors and nodes of structural elements. These peculiarities and highly increased mechanization level caused changes in construction technology and character of engineering equipment of construction objects. Demand for precision has greatly increased. Construction work starts and finishes with geodesic measurements, therefore geodetic measurements and labeling are the most important components of mounting and installation work in constructions. Digital automatic levels are a precise instruments used for precise leveling. Operation of digital levels is based on the digital processing of video indications of a coded staff. Changes in leveling methodology and sources of specific errors occur using digital levels for precise levelling. The scope if this work includes resort of digital automatic levels and impact of their accuracy on construction measurements.

Keywords: coded staff, digital leveling, leveling error.

INTRODUCTION

Digital automatic levels are a precise instruments used for precise leveling. Operation of digital levels is based on the digital processing of video indications of a coded staff. At the beginning of measurement a visual pointing of the instrument into the surface of leveling meter is performed. After that the instrument automatically points the focus of its optical system on the surface of the meter and then a rough correlation calculation is performed followed by the precise correlation. According to the data received in the processor of the instrument an exact distance from the axes of the instrument to the surface of the level meter is calculated. According to the information received by decoding the data from the photoelectric matrix the height of the level placing is calculated in the processor. During this operation the coded view of the meter is compared with information that saved in the memory of the instrument. The scope if this work includes resort of digital automatic levels and impact of their accuracy on construction measurements. Construction work starts and finishes with geodetic measurements, therefore geodetic measurements and labeling are the most important components of mounting and installation work in construction.

The digital levels represent a breakthrough in leveling techniques using the innovative concept of reading a bar coded staff. Optical readings are not longer needed. Experience shows that with digital levels there is up to a 50% time saving when compared with conventional levels. The main reasons are the faster data capture as well as the shorter time and safer means of data processing, due to the possibility of saving measured data on storage devices. Digital levels measure and save the height and the distance to the staff at the press of a button, and calculate the height of the point. Advantages are that no readings are required, no copying or writing down and no calculation by hand (Becker *et al*. 2007).

Precision investigations of a particular model of levels and coded staffs and digital leveling are necessary. The investigations of technical, geometrical and methodological parameters of instruments are also needed. The scope of this work includes resorting to digital automatic levels and impact of their accuracy on construction measurements (Becker, 1999).

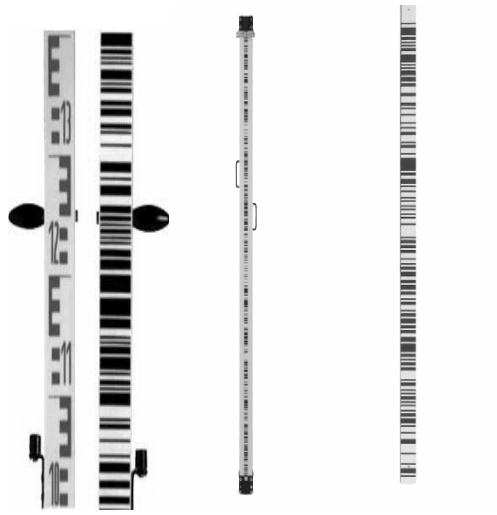

Figure 1. Models of the leveling staffs

DETERMINATION OF THE COLLIMATION ERROR OF THE DIGITAL LEVELS

A digitals levels automatically compensates for the collimation error digitally performing readings in coded staffs, if such error is defined and saved in the memory of the instrument. They have the absolute collimation error *absColl* and the variable error *collDif*, which depends on meteorological conditions. Initial value of the *absColl* set by a manufacturer is equal to zero seconds. The collimation error of these levels can be adjusted using maintenance program CHECK&ADJUST. By setting up this program, readings are automatically compensated for the Earth curvature errors. Checking is made by repeating the leveling of a 45–50 m length site line AB, which is fixed by metal poles. The line is divided into three equal sections. The line contains points 1 and 2, which are locations of the leveling stations (Figure 1) (Krikstaponis, 2000, 2002).

In the station 1, reading a_1 and distance d_1 are set to the closer-standing staff. Then, reading a_2 and distance d_2 are set to the further-standing staff. Measurement sequence in the station is as follows: b_2, d_3 and a_2, d_4. If *absColl* = 0 and during the checking *collDif* = const ≠ 0, then two height differences can be calculated:

$$h_{AB} = (a_1 - b_1) - tgcollDif, (d_1 - d_2) \quad (1)$$

$$-h_{AB} = (b_2 - a_2) - tgcollDif, (d_3 - d_4) \quad (2)$$

Starting the checking, i.e. putting into the program CHECK&ADJUST, *absColl* value from the memory of the level can be seen in the instrument display. After performing measurements in both stations, the variable collimation error *collDif* and the new absolute collimation error *absColl* are calculated. Both values, in seconds, are shown in the display. The new absolute collimation error is equal to the sum of the old and the newly determined variable collimation error. The absolute collimation error *absColl,* taking into account *collDif* value, can be set to a new value or left as the old value. If the *absColl* value is too large (>20”), it can be reduced or removed by adjusting the position of the middle horizontal reticle. After confirming the adjustment of the reticle position, the level calculates the correct reading a_2’. Visual reading to the staff with centimetric steps placed in point A is made without moving the level standing in the point 2. If the instrument is well adjusted, the calculated and the visually set readings are identical. If the difference between the readings is larger than 3 mm for the 30 m distance (*collDif* ≈20”), horizontal reticle should be adjusted. After the adjustment of the horizontal reticle, the collimation error is check again.

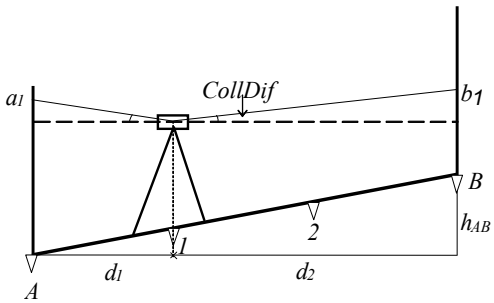

Figure 2. Checking of collimation error

During the normal measurement conditions, standard deviation of the error is about ± 2” (Aksamitauskas *et al*. 2007).

Investigations of *collDif* daily variations of the digital levels NA3003 No.92426 and No.92432 were performed at Vilnius Gediminas Technical University.

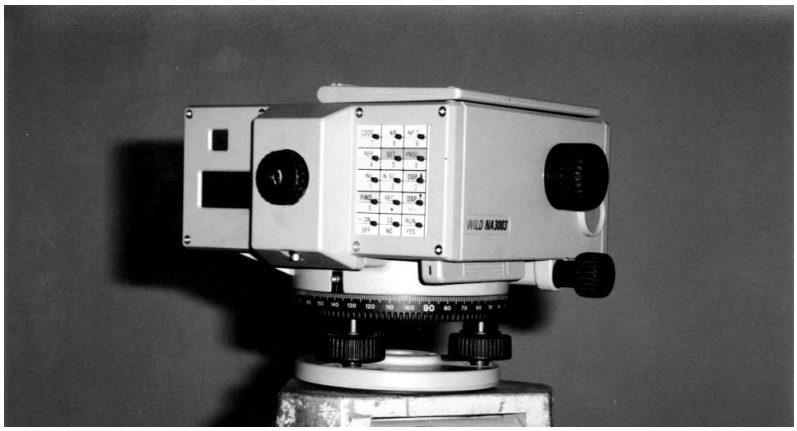

Figure 3. Digital level NA3003

Two instruments, previously used by Institute of Geodesy for the leveling of the geodesic vertical grid, were used for these investigations. The methodology developed by Krikštaponis was applied. A base AB of 45 m was selected. The end points of the base were fixed using metal stakes where coded staffs were fixedly (using supports) installed. The base was then divided into three equal sections. Both levels were placed at points 1 and 2. Measurements were performed every half an hour. Ten measurement cycles were made changing placement of the level without moving the tripod. Air temperature, measured in the shade by a thermometer H-200, varied up to 4 ºC. In order to achieve as uniform measurement conditions and objective results as possible, the measurements using both levels were performed sequentially at the same consistency. The measurements of one cycle by each level lasted about 5 minutes. The largest temperature variation during one cycle did not exceed 0.5 ºC.

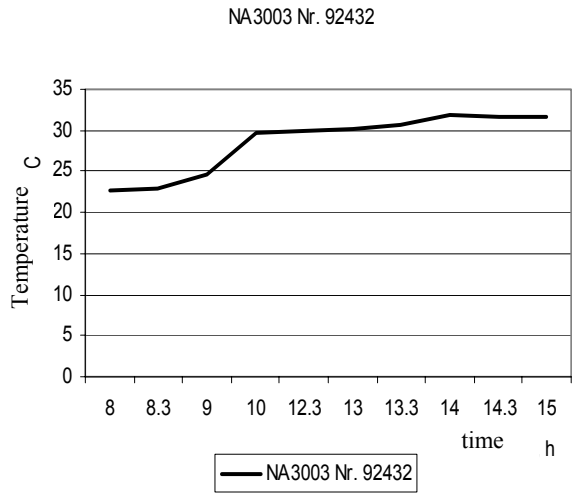

Figure 4. Temperature variations during *collDif* measurements by the level NA3003 No.92432

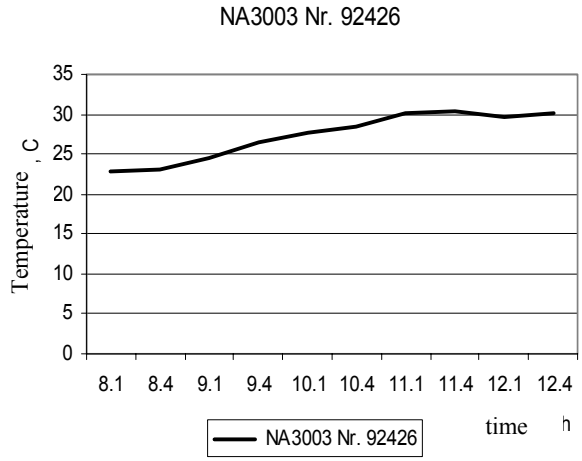

Figure 5. Temperature variations during *collDif* measurements by the level NA3003 No.92426

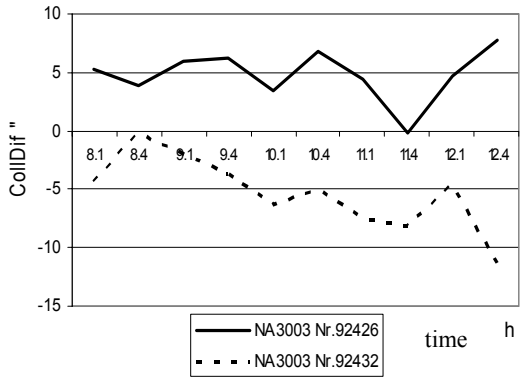

Figure 6. *collDif* variation during a day

The *collDif* values change; therefore, if the surrounding air temperature changes, a new absolute collimation error *absColl* should be set and saved in the memory of the instrument. In order to reduce the impact of the collimation error for the measurement results, the error values should be set at temperature closest to an average air temperature at which the further measurements will be made.

During the measurements in a station when all distances to the staffs are absolutely equal and *collDif* value is stable, *collDif* does not have any impact on the measured height difference.

INVESTIGATION OF THE INCOMPLETE TILT COMPENSATION OF THE DIGITAL LEVEL

Incomplete compensation of a level was examined leveling the same station with lying and angled levels. For this purpose the level was placed strictly in the middle between the staffs that were fixed on built poles, and the height difference was measured at the following bubble position of the spherical level (Figure 7) (Krikstaponis 2001).

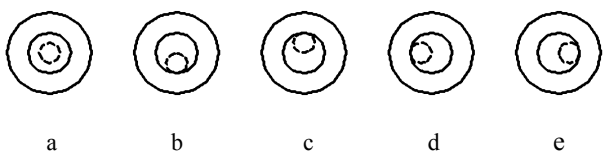

Figure 7. Positions of the spherical level bubble while testing a level compensator: a – bubble in the middle of the ampoule, b and c - at the longitudinal inclination, d and e - at the transverse inclination

The Δh of the averages of height differences for the level used in the first class leveling should not exceed 0.5 mm or 0.05 mm per level tilt minute (Krikštaponis, 2001). Incomplete compensation of the level tilt was investigated when the distance between the staffs was 32.95 m and 15.63 m. A reading obtained by digital levels is an average of several (in this case 5) readings. In this investigation, four measurement sections were made in

total while changing the level height with each section. The results of the measurements are given in Table 1. The averages of the height differences and the differences of these averages Δh from the average of the height difference obtained at the bubble position in the middle of the level ampoules were calculated (Krikstaponis 2000).

Table 1. Investigation of the incomplete tilt compensation of the digital level.

Section No.	Height differences				
	bubble in the middle of the ampoule	at the longitudinal inclination		at the transverse inclination	
		–5	+5	–5	+5
Level NA3003 No. 92426		s = 32.95 m			
1	1.51178	1.51211	1.51277	1.51285	1.51289
2	1.51176	1.51213	1.51281	1.51283	1.51297
3	1.51179	1.51211	1.51280	1.51286	1.51388
4	1.51179	1.51212	1.51284	1.51277	1.51289
5	1.51178	1.51210	1.51275	1.51284	1.51300
Average	1.51178	1.51211	1.51279	1.51283	1.51293
h (mm)		+0.33	+0.01	+0.05	+0.15
					s = 32.95 m
1	1.06246	1.06240	1.06248	1.06244	1.06243
2	1.06248	1.06241	1.06244	1.06240	1.06238
3	1.06246	1.06246	1.06246	1.06237	1.06240
4	1.06245	1.06248	1.06246	1.06241	1.06245
5	1.06243	1.06243	1.06243	1.06238	1.06242
Average	1.06245	1.06244	1.06245	1.06240	1.06242
h (mm)		–0.01	0.00	–0.05	–0.03
Level NA3003 No. 92432			s = 32.95 m		
1	1.51183	1.51277	1.51285	1.51286	1.51275
2	1.51180	1.51288	1.51298	1.51290	1.51291
3	1.51179	1.51290	1.51293	1.51289	1.51284
4	1.51183	1.51277	1.51301	1.51284	1.51292
5	1.51190	1.51280	1.51280	1.51283	1.51286
Average	1.51183	1.51282	1.51292	1.51286	1.51286
h (mm)		–0.01	+0.09	+0.03	+0.03
					s = 32.95 m
1	1.06246	1.06234	1.06246	1.06242	1.06237
2	1.06246	1.06240	1.06242	1.06243	1.06240
3	1.06236	1.06245	1.06243	1.06243	1.06241
4	1.06243	1.06235	1.06246	1.06240	1.06238
5	1.06241	1.06236	1.06245	1.06240	1.06235
Average	1.06242	1.06238	1.06244	1.06242	1.06238
h (mm)		–0.04	–0.02	0.00	+0.04

It was found that these digital levels meet the requirements for the first-class instruments. The obtained *Δh* (in Table 1) of the averages of height differences did not exceed 0.5 mm or 0.05 mm per level tilt minute.

CONCLUSIONS

The variability profile of *collDif* for both instruments, i.e. NA3003 No.92432 and NA3003 No.92426, was similar, although the angle values differed up to 6". A slight impact from air temperature for *collDif* variations was also observed.

The *collDif* values change; therefore, if the surrounding air temperature changes, a new absolute collimation error *absColl* should be set and saved in the memory of the instrument. In order to reduce the impact of the collimation error for the measurement results, the error values should be set at temperature closest to an average air temperature at which the further measurements will be made.

During the measurements in a station when all distances to the staffs are absolutely equal and *collDif* value is stable, *collDif* does not have any impact on the measured height difference.

Studying the incomplete tilt compensation of the digital levels NA3003 it was found that these digital levels meet the requirements for the first-class instruments. The obtained *Δh* of the averages of height differences did not exceed 0.5 mm or 0.05 mm per level tilt minute.

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