APPLICATION A DOLOMITE WASTE AS FILLER IN EXPANDED CLAY LIGHTWEIGHT CONCRETE

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Abstract: Manufacturing of cement based building materials incorporating alternative filler, obtained as a waste from industrial process, nowadays becomes more and more actual. It could be related not only to the cheaper expenses of the production if to compare with adequate products made of conventional raw materials, but also to the efforts to improve the quality of environmental. Investigations were carried out to explore the suitability of dolomite waste as fillers in expanded clay lightweight concrete by partly substituting of conventional quartz sand.
The goal of the study is to examine expanded clay lightweight concrete mechanical and physical properties by making a comparison between traditional expanded clay lightweight concrete and units which containing different amount of dolomite waste.
Physical properties such as density, porosity and absorption were determined. Tests were also performed to determine mechanical properties. Frost resistance and durability were tested.

Key words: dolomite by-product, lightweight concrete, utilization of waste, mechanical properties, physical properties, expanded clay

1. Introduction

Study of the cement mortar compositional material with different carbonate additives is very perspective field for investigations at the concrete material science. Nowadays, increased attention to such materials is observed owing to the large volume of waste by-product materials left at open dolomite stone cast mines and lime stone pits after technological production of building materials: gravel and fractioned crushed stones. Crushed stones are produced by crushing large parent mass of rock. Thus, many secondary unwanted tiny aggregates (powders, sands) are developed with many features depending on the parent rock properties (e.g., chemical and mineralogical composition, specific gravity, hardness, strength, physical and chemical stability, pore structure and color).

In recent years, huge quantities of technological waste such as very tiny crushed dolomite sands, which need to be recycled with maximum efficiency, have accumulated in Latvia. For example, production of the crushed dolomites leaves a lot of dolomite by-product materials in the open cast mine at Plavinas. Dolomite sand by-product has been accumulating during recent decades, and its quantity has reached a million of tons. Dolomite waste quantity is increasing very rapidly as well in other open cast mines. Produced waste mostly remains unused at quarries occupying space and multiplying overall technological costs. Such situation requires the integrated approach to recycling of the produced waste [1-4].

There are many ways and possibilities of using dolomite by-product. It can be used in agriculture as lime substitute for soil treatment, as quartz sand equivalent in the building industry, etc. Herewith, we offer utilizing dolomite sand waste at the concrete production technology. This work starts continuous investigations which aim is preparation and testing of different concrete materials with dolomite by-product as filler.

This publication focuses on dolomite material usage as the perspective aggregate for lightweight concrete production, substituting traditional (quartz based) sands. The aim of the work is to develop production technology of such lightweight concrete materials with the equivalent or even enhanced set of properties. Primarily, the structure-property regularities of the produced material have been determined, as being vitally important. Considering the complicated nature of dolomite by-product, mineralogical composition of the chosen materials have been extensively investigated as well as grading analysis of the materials. All these properties have an important impact on the quality of fresh and hardened concrete. The composition of the produced concrete material was changed by modifying initial quantities of the dolomite sand additive in the composition. The goal of the study is to examine expanded clay lightweight concrete mechanical and physical properties by making a comparison between traditional expanded clay lightweight concrete and units which containing different amount of dolomite waste. Physical properties such as density, porosity and absorption were determined. Tests were also performed to determine mechanical properties. Frost resistance and durability were tested.

2. Experimental Methods

2.1. Materials

Dolomite based sand fraction 0/4 mm was taken from the open cast mine at Plavinas and Remina, Latvia (Fig.1). Dolomite sand was remixed for homogeneity and dry conditioned in closed oven at 105±5 ^{0}C as preliminary preparation for the investigations. Drying conditions of the dolomite material are chosen in conformity with the preliminary grading determination and investigations by DTA-TGA analysis and X-ray diffraction method.

Fig. 1. Dolomit querry (on left) and sand obtained from dolomite by-product and traditional sand (on right)

2.2. Testing of materials

The specimens of selected dolomite waste have been investigated by using several experimental methods. The particle size parameters of the materials have been investigated by grading analysis with additional washing. The grading analysis has been carried out in conformity with LVS EN 933-1:1997. Standard sieve set equipped with the mechanic vibration table has been used.

Mineralogical structure of dolomite sand specimen has been examined by the Wide Angle X-ray Diffraction analysis method (WAXD). The X-ray diffraction measurements have been carried out on the Bruker diffractometer at the temperature of 20 ^{0}C. CuK_α - monochromatic radiation with the wavelength of λ= 0.154 nm at the range of diffraction angles 2θ from 4 to 50 ^{0} have been used. The scanning rate was 2 deg/min.

Chemical and physical properties of the raw materials have been investigated by the differential thermal analysis (DTA-TGA). The specimens weighting about 10 mg have been heated at the rate of 10 °C/min at the temperature range from ambient to 1000 °C on the Paulig/Paulig equipment. Thermal stability of the dolomite material has been evaluated by the weight-loss curves.

2.3. Testing of samples

Various specimens of expanded clay lightweight concrete filled with ether quartz or dolomite based sands were prepared. Consistency of the concrete mixes was determined by means of cone slump and cone flow [5, 6]. Vibrocompression technology has been applied for manufacturing of the blocs. The mixtures were half-dry with low wetness. The concrete blocs have been demolded immediately after preparation. The samples have been subjected to normal hardening conditions until complete solidification.

Three kinds of concrete have been prepared for the investigation: lightweight concrete with low strength (~20 MPa), lightweight concrete with middle strength and lightweight concrete with high strength (~70 MPa).

Following properties of lightweight concrete have been determined: density of concrete, water penetration, compression strength, tension strength, absorption of water, frost resistance

The specimens of concrete have been tested in accordance with LVS EN 12390-3:2002 [9]. Uniaxial compressive strength has been checked on the compression testing machine with accuracy $\pm$1%. A set of three samples was tested for each composition after the 7- and 28-day ageing period.

Water penetration has been measured according to LVS EN 12390-8:2002 [10]. The specimens have been placed into the experimental testing equipment and aged at the pressure of 500 kPa for 72 hours. Frost resistance test has been performed by freezing and thawing cycles in 5% NaCl solution in accordance with the standard ГОСТ 10060.2-95 [11].

3. Results and Discussion

3.1. Dolomite by-product properties

Mineralogical composition of dolomite waste has been obtained by X-ray diffraction. The pattern shown at the Fig. 2 indicates that the main components of the investigated composition are dolomite $CaCO_3{\cdot}MgCO_3$ and small amounts of quartz SiO_2– 2.5% and calcite $CaCO_3$ – 1.5%. There is no evidence of clay minerals being present in the mix. It is obvious that dolomite by nature is kind of the primary sediment mineral and has the wide spread geologic distribution [7]. The chemical formula of dolomite is $CaCO_3{\cdot}MgCO_3$ with the averaged chemical composition. Results were obtained from the chemical analysis according to LVS EN 1744-1 which shows that dolomite is 92 %, oxides – CaO ~31 %, MgO ~17 % and the other oxides which in total are less than 1 % of the weight of the raw material – Fe_2O_3 - 0.34 %, Al_2O_3 - 0.64 %, Na_2O - 0.82 %, K_2O - 0.76 %, SO_3 - 0.05 %.

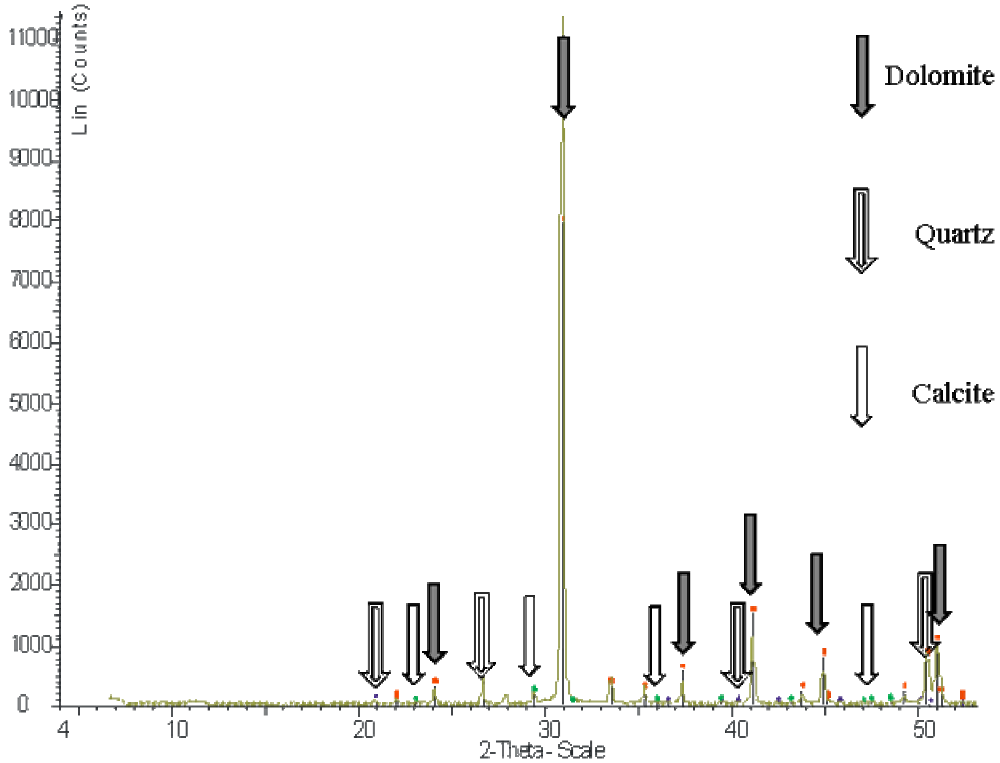

Fig 2. X-ray diffraction data of the Plavinas dolomite material

The DTA-TGA analysis shows typical decomposition process of dolomite (water physical adsorption and water chemical debonding from material and separating up of the material into constituent parts) increasing the temperature. The resolving process of dolomite occurs at the temperature interval from about 590 ^{0}C to 900 ^{0}C, which is presented by the endothermic reaction peaks at DTA curve. The maximum weight loss reaches 45% what is attributed to emission of CO_2. The products of dolomite decomposition are MgO, CaO and CO_2. This process is accompanied by the following chemical reaction [3, 4]:

$$CaCO_3{\cdot}MgCO_3 \xrightarrow{730\text{-}740^{o}C} MgO + CO_2\uparrow + CaCO_3 \xrightarrow{900^{o}C} MgO + CaO + 2CO_2$$

The X-ray diffraction analysis as well as DTA-TGA results is related to Plavinas' by-product sand. Remina's materials have the same characteristics.

3.2. The mix design

Different types of lightweight concrete have been designed and manufactured: S1 and S2– traditional compositions with quartz sands, D1 and D2 with dolomite sand, KM, KR3 and KRM high strength lightweight concrete with expanded clay, which contain dolomite and traditional quartz sands varying from 0 till 100%. The compositions S1 and D1 are developed as low strength lightweight concrete, S2 and D2, as middle strength lightweight concrete and KM, KR3 and KRN as high strength lightweight concrete. The compositions (kg/m3) are presented in Table 1 and Table 2.

Table 1 Compositions of the lightweight concrete with expanded clay

	S1	D1	S2	D2
Portlandcement	344	344	385	385
Expanded clay FIBO 4/10 mm	121	121	213	213
Expaded clay FIBO 10/20 mm	110	110		
Expanded clay Filtral 2/8 mm				
Quartz sand 0/4 mm	673		612	
Quartz sand 0/0.5 mm			94	
Dolomite powder			111	
Dolomite waste 0/4 mm		673		817
Water	220	220	205	205
Superplastificator	2.1	2.1	2.1	2.1
Mikrosilica				

Table 1 Continue

	KM	KR3	KRM
Portlandcement	422	422	422
Expanded clay FIBO 4/10 mm			
Expanded clay FIBO 10/20 mm			
Expanded clay Filtral 2/8 mm	422	422	422
Quartz sand 0/4 mm	844	844	563
Quartz sand 0/0.5 mm			
Dolomite powder		50	281
Dolomite waste 0/4 mm			
Water	215	204	239
Superplastificator	5	5	5
Mikrosilica	50		50

3.3. Fresh and hardened concrete properties

The analyzed data results show that concrete filled with dolomite sand has additional water content. Therefore the water/cement ratio has been changed, keeping the necessary technological parameters: mortar concrete yielding and cone slump.

Physical and mechanical properties of the hardened lightweight concrete are shown at the Table 2. Density of the concrete compositions D1-D2 and S1-S2 remains unaffected with regards to the dolomite content. Compression strength of the D1-D2 concretes are increased on 11-12.5% between 7 and 28 day aging period; Compression strength of the S1-S2 concretes are increased on 3-14.1% between 7 and 28 day aging period. Differences between lightweight concrete D1-D2 and S1-S2 are in the range 1.5-5.3%. It proofs that the cheaper dolomite waste can successfully replace traditional quartz sands without sacrificing the strength properties. All compositions at the range D1-D2 show that water uptake of the investigated concretes is not dependant on the composition and changes inconsiderably.

Compression strength of the compositions KM, KM3 and KRM are increased on 23-34% between 7 and 28 day aging period. Despite of higher water cement ratio in dolomite sand filled concrete KRM, what could be an effect of the dolomite additive to the fresh concrete mortars due to changes of the qualitative and quantitative characteristics of the concrete stone structure formation during the intrinsic hydration reaction process. Some authors presuppose development of the novel hydration complex phase on the interface of the cement and dolomite particles possible, that is featured as the semicrystalline high adhesion and the density complex epitaxial phase [13, 14]. Tension strength are very close for composition with and without dolomite waste at the same group of lightweight concrete. Water penetration is less for concrete with dolomite waste for low strength lightweight concrete and deeper for middle strength lightweight concrete. Experiments show that compositions filled with dolomite sand have the same frost resistance as compositions with traditional sand.

Table 2. Hardened concrete properties

	S1	D1	S2	D2
Density, kg/m^3	1506	1534	1589	1643
Compression strength after 7 days, MPa	17.0	17.5	24.8	21.9
Compression strength after 28 days, MPa	19.4	19.7	25.6	24.3
Tension strength after 28 days, MPa	1.60	1.73	2.17	2.04
Water penetration, mm	35	29	16	25
Content of expanded clay, %	38.8	38.8	32.6	32.6

Table 2. continue

	KM	KR3	KRM
Density, kg/m^3	2006	1970	1935
Compression strength after 7 days, MPa	53.4	53.9	45.6
Compression strength after 28 days, MPa	66.1	61.1	61.3
Tension strength after 28 days, MPa	-	-	-

Water penetration, mm	-	-	-
Content of expanded clay, %	21.0	21.4	21.8

The frost resistance tests have been performed for lightweight concrete with dolomite waste in the composition. The one cycle of the test are presented in fig.3. Destroyed specimen after 25 cycles is shown in fig. 4. Results of the testing are presented in table 3.

Fig.3. One cycle of the frost test

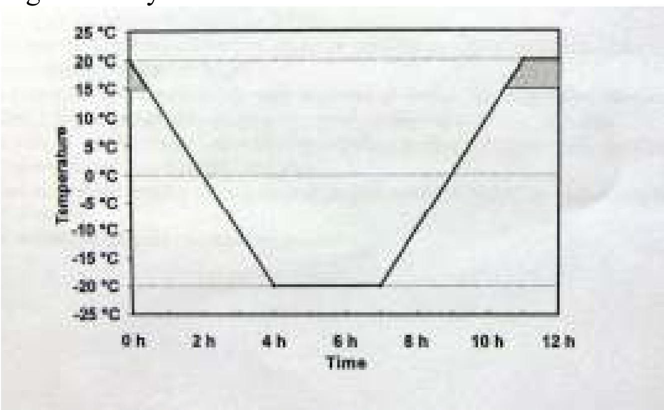

Fig. 4. Specimens of the lightweight concrete with dolomite sand after 25 frost cycles

Table 3. Results of test for absorption of water and frost resistance

	D1	D2	S1	S2	IIS1	IIS2
Absorbtion of water, %	7.2	6.0	6.1	5.5	3.7	4.4
Amount of remains m_{25}, g/m^2	58.3	65.8	22.1	22.2	4.44	4.22

Conclusions

The lightweight concrete composition with content of dolomite waste is more mobility and improve moulding of the blocks.
The compression strength of hollow lightweight blocs with dolomite waste is very close to compression strength of the blocks made from traditional compositions. Differences between strengths are 2.9-11.8% for 7 days age and 1.5-5.0% for 28 days age of concrete.
Dispersion of strength for one set of the specimens may be issued by creation agglomerate from dolomite powder.
The investigated dolomite sand waste can be used as equivalent of quartz sand to produce lightweight concrete having the compression strength, water uptake, density being equal to those of the traditional lightweight concrete filled with quartz sand.
The mechanical and physical properties of the lightweight concrete with dolomite waste can be improved by using the admixtures for decreasing amount of water in the composition

Acknowledgement

The financial support of Ministry of Education and Science of Republic of Latvia and Riga Technical University is acknowledged.

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