RESEARCH OF HEAT TRANSFER PROCESES IN WALLS MADE FROM NEW GENERATION AUTOCLAVED AERATED CONCRETE

JAUNĀS PAAUDZES GĀZBETONA SIENU SILTUMA PLŪSMAS PĒTĪJUMI

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Introduction

We elaborated in the previous publication one part of experimental data and also in this one we would like to share our latest results. The mentioned experiment is performed in Tallinn Technical School, where an experimental building with openings in northern and southern facades was constructed. In the end of 2004 these openings were filled with ECOTERM blocks (depth 375mm) with capacity mass $\leq$400 kg/m^3 forming joints with glue mortar. Since the year of 2005 regular measurements were performed in order to determine the calorific features of the walls. Of course, such experiments are not performed for the first time [1; 2; 5; 7], but in contrary to the similar researches which were performed before, in this case the wall fragments are being tested in the under the conditions, specific to the construction of individual dwelling houses in the Baltic region with wet climate mode. For instance, in the former tests no external and internal decoration tasks were applied. But in the current test, approximately a year after finishing the wall fragment, both interior and exterior decoration from materials [12] by company Maxit was performed. In effect also the calorific indicators of the wall have changed and more detailed information will be delivered in the next parts of publication.

Thermal conductivity coefficient

In order to establish the value of wall thermal conductivity coefficient U, the heat flow was measured with help of device ALMEMO – 2290-8 with feeders FQA017C and FQA019C. The surface temperature of both experimental walls was also measured, using HOBO type logger. Loggers of this type permit to determine the temperature and moisture of the surrounding air and that allows to perform a comprehensive analysis of acquired data and get substantiated results. Performed wall surface temperature measurements are gathered and displayed in Fig.1. Since the temperature deflections of inner surface within a year is not observable, only southern and northern wall surface temperature difference is plotted.

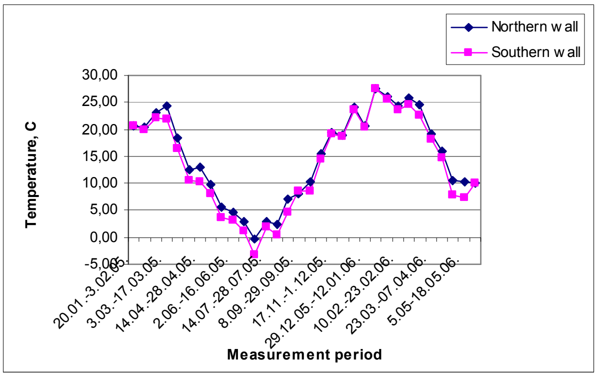

Fig.1. Temperature of external surface of aerocrete wall

Performed heat flow measurements are gathered and displayed in Fig.2. While analyzing the acquired experimental data, it can be calculated that heat flow through aerocrete wall is directly related to the temperature of external surface of the wall. Temperature fluctuations during the experiment were insignificant, therefore we can deduce that sun activity notably affects the heat flow. As it was mentioned before, the temperature fluctuation of inner surface of the wall is not significant; therefore the wall's external surface temperature difference is largely affected by the very activity of sun. It is due to the sun activity that surface temperature of the external wall depends on and in its turn affects both the process of wall drying and total heat flow through aerocrete wall.

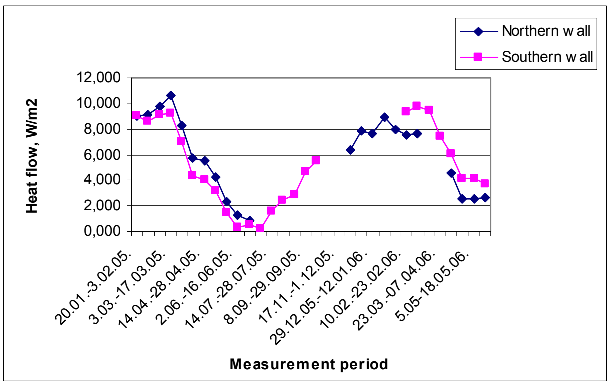

Fig.2. Heat flow through aerocrete wall

The value of thermal conductivity coefficient is determined by applying the data, acquired in the experiment, to the formula, $U_k = Q/(\tau_s - \tau_v)$, where Q – heat flow ($W/m^2$), τ_s – surface temperature of inner wall (^0C), τ_v – surface temperature of exterior wall (^0C).

Comparing the acquired experimental graphics, presented in Fig. 1, 2 and 3, it is observable that they are of similar nature. Obviously it means that certain congruence among thermal conductivity coefficient, wall's external surface temperature and heat flow through aerocrete wall exists. When analyzing the data, provided in the Fig.5., very important conclusion can be derived – even in the wintertime conditions the wall which is not yet dried and whose moisture is 24-14% coefficient U value corresponds to the standard LBN 002 – 01 requirements.

Calculating the theoretical U value with formula $U = 1/R$ (where $R = R_s + d/\lambda + R_v$; R_s – heat resistance of inner surface; R_v – heat resistance of external surface) it can be seen that theoretical calculations do not match with experimental results. It can be explained with aerocrete's capacity to accumulate heat and material thermal inertia. Questions which are connected with aerocrete wall thermal inertia we will view in further publications.

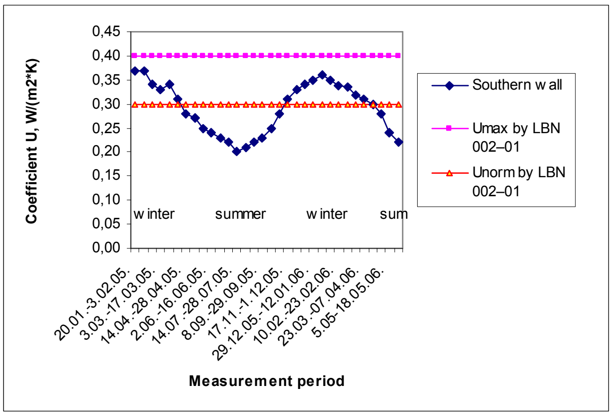

Fig.3. Thermal conductivity coefficient of aerocrete wall

In order to feel comfortable in the premises both in winter and in summer, it is also of importance to have a good microclimate. It is considered that wooden log buildings provide optimum healthy environment with a natural humidity regime. Thus, aerated concrete also has a number of qualities guaranteeing in the premises equal condition as one will find in log houses. Thanks to the porous structure, aerated concrete absorbs the excessive amount of humidity and in the result of water vapour diffusion discharges it, i.e. outside the building.

For ensuring good microclimate for a room, it is of importance that temperature fluctuations of the inner surface of the external wall would be minimum, if the temperature fluctuations of the outer surface of the external wall are considerable. It is particularly important in our weather conditions when the temperature of the external surface can drastically change both in winter and in summer, whereas the temperature changes of the inner wall are small.

The experimentally determined temperature changes outside and inside (in the premises) the wall are provided in Fig.4. By red line there is shown temperature fluctuation of wall outside surface, but with blue line - temperature fluctuation of wall inside surface. The small thermal conductivity and good heat accumulation capacity (heat inertia) provide permanent temperature in the inner rooms. Therefore, in buildings with homogeneous aerated concrete walls there is a pleasant chill on hot summer days and homely warmth on cold winter nights. Such effect cannot be achieved in buildings with external wall construction mass smaller than 100 kg/m^2, as for example wooden carcass buildings with mineral wool heat insulation.

By analysing the results of the experiment, it can be concluded that in case of considerable temperature fluctuations (in range of 70°C) of the external surfaces of the walls, the temperature of the inner surface varies only within 2°C. During experiment there is find out, that displacement of the maximum temperatures of inner and external surfaces reached 7 hours.

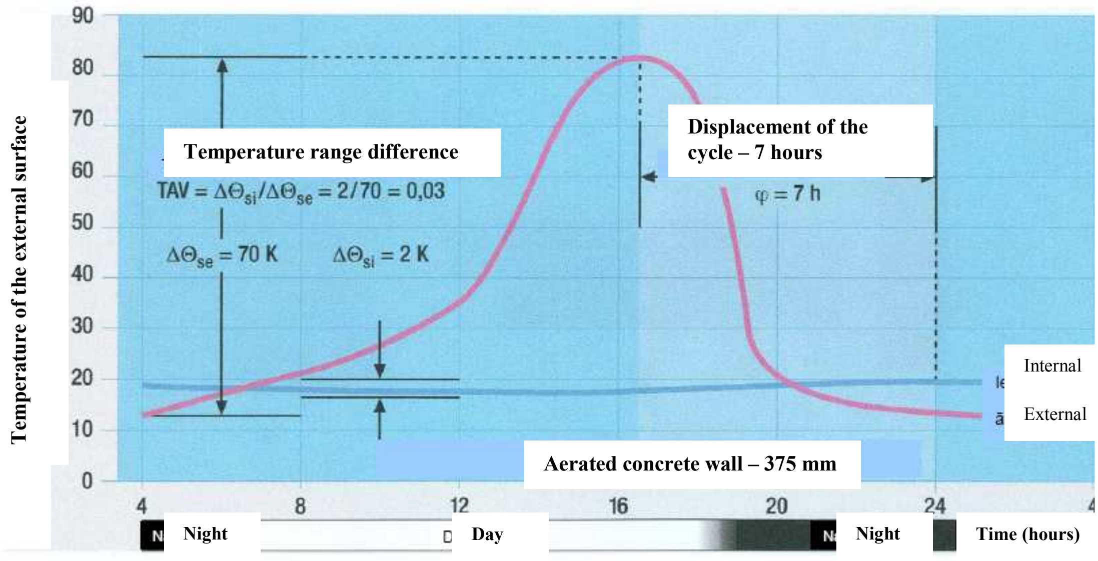

Fig.4. Heat inertia of aerocrete wall

After completion of the external and internal finishing layer, for the scope of the experiment, thermography of the wall was performed by means of the Thermovision 350 Standard equipment. The thickness of the external decorative layer is 3–4 mm, and the inner surface fill layer is 1–2 mm.

As seen in Fig.5, after completion of the external and inner surface finishing level, no heat losses through the vertical joints were observed and the temperature difference in the entire area of the wall is within 1,5 °C. The results of the thermography show that in case of 2 mm thick glue mortar joints and a finishing layer on both sides of the aerated concrete block wall, practically the joints leave no impact upon heat permeability and therefore, by performing thermotechnical calculations, the correction coefficient, which regards the distinctive heat permeability of the glued joints, is not to be taken into account.

An analogue thermographic analyses was performed in the complex of multi-apartment buildings "Mārupīte", Ropazu street, Riga. For construction of the external walls in the object "Mārupīte" were used the EcoTerm 375 mm blocks with the average volume weight 375 kg/m^3 and the reinforced lintel with average volume weight 480 kg/m^3. The constructed external walls are homogeneous, without additional insulation. For boarding the front of the house were used the Classic 250 mm blocks with additional insulation (Fig. 6). The blocks of the external walls were joined by glue mortar – the thickness of the glue mortar joints is 2 mm in average.

The thermographic analyses of the object was performed during the second heating period, approximately a year and a half after putting the building into operation. Comparing to previous thermographic measurements, heat losses through the outer surface of the wall i.e heat losses in the front part (elevation) of the building were established in the "Mārupīte" object.

The scope of the thermographic analyses was:

1. to check parts of elevation where heat losses are the largest;
2. to check whether external walls without additional heat insulation provide even distribution of temperature through the horizontal and vertical joints;

3. to check whether temperature distribution in reinforced lintel places is the same as on external walls;
4. to check whether soaking of the wall in separate places during the construction period has left an impact on temperature distribution on the external wall.

The conditions for thermographic analyses were very favourable. The outside temperature was –22 °C, what gave the opportunity to exactly establish places of heat loss in the elevation (Fig. 7). In figure there shown not only temperature fluctuation in elevation, but exactly in line LI01 and LI02, that were marked in facade fragment and as diagram in the right corner of figure.

In result of the test it was established that:

1. The largest heat losses come from windows, the spaces in between the floors in the level of ceiling and base level. Heat losses through windows are always larger than through outer walls; the above is also admitted in the Latvian construction norm LBN 002-01. Heat losses in base and in between floor level are attributable to insufficient quality of construction work during installation of heat insulation.
2. All the measurements confirmed that in aerocrete outer walls the temperature distribution is uniform with the lowest outer wall temperature. It does not mean that there are no heat losses for glued mortar joints in the thickness of 2 mm, as it is inevitable the case for standard mortar joints 10–12mm thick. It assures once again that the EcoTerm outer wall blocks joined with glue mortar fully ensure compliance with heat insulation requirements without additional insulation;
3. In aerocrete reinforced lintel places (the width of the lintel corresponds to the width of the wall) the temperature distribution is the same as in the outer walls, what evidences that on lintel places no cold bridges are created.

Irregular soaking of the wall due to precipitation during the construction period after approximately year and a half maintenance of the building has left no impact on the temperature distribution on the wall. It gives proof that the wall has dried and that the external surface has reached the balance moisture.

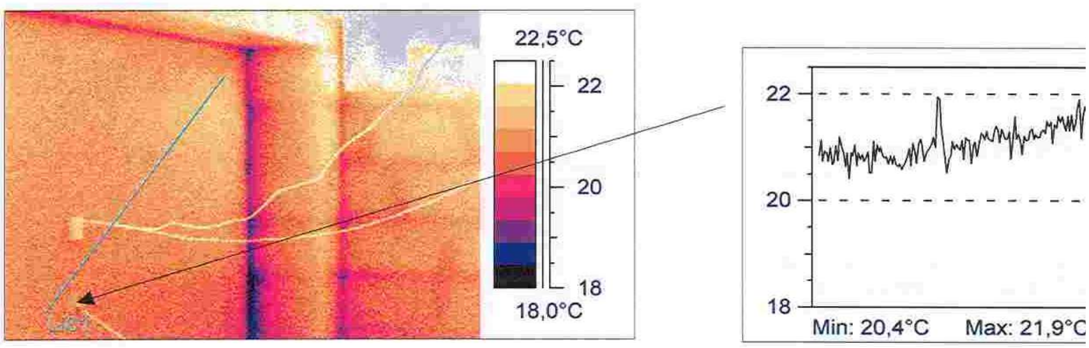

Fig.5. Aerated concrete block wall fragment thermography results after completion of inner and outer finishing layers

Fig.6. Fragment of elevation, object "Mārupīte"

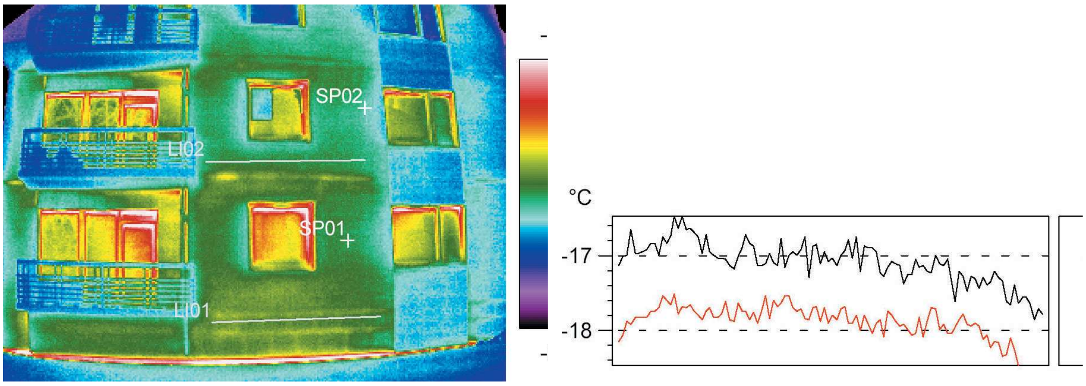

Fig.7. Results of the thermography for the aerocrete wall fragment

Conclusions

Acquired results show that certain congruence among thermal conductivity coefficient, wall's external surface temperature and heat flow through aerocrete wall exists. In the wintertime conditions the aerocrete wall which is not yet dried and whose moisture decreased from 24 to 14% coefficient U value corresponds to the standard LBN 002 – 01 requirements.

Calculating the theoretical U value we find out, that theoretical calculations do not match with experimental results. It can be explained with aerocrete's capacity to accumulate heat and material thermal inertia. Questions which are connected with aerocrete wall thermal inertia we will view in further publications

Aerated concrete block outer walls have a good thermal inertia (temperature fluctuations per day of the inner wall do not exceed 2 °C).

In this experiment we get great amount of measurements, that could extend information about thermal qualities of autoclaved aerated concrete walls construction built on Baltic region climatic conditions.

ESF reference

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Vilnītis M., Noviks J. Jaunās paaudzes gāzbetona sienu siltuma plūsmas pētījumi.
Iegūti eksperimentāli rezultāti par siltumtehniskajiem procesiem ārsienās veidotās no jaunās paaudzes gāzbetona blokiem. Eksperiments tiek veikts Tallinas Tehniskajā skolā, kur ir uzbūvēta eksperimentāla māja ar ailām ziemeļu un dienvidu fasādēs no EcoTerm blokiem ar biezumu 375 mm, tilpummasu ≤400 kg/m^3, izveidojot šuves ar līmjavu. Sākot ar 2005. gadu tiek veikti regulāri mērījumi lai noteiktu sienu siltumtehniskās īpašības. Lai noteiktu sienas siltuma caurlaidības koeficenta U vērtību tika mērīta siltuma plūsma izmantojot ierīci ALMEMO – 2290 – 8 ar devējiem FQA017C un FQA019C. Tāpat tika

mērīta arī abu eksperimentālo sienu virsmu temperatūra ar HOBO tipa logeriem. Analizējot eksperimentālos datus var secināt, ka siltuma plūsma mainās atkarībā no sienas ārējās virsmas temperatūras. Tieši no saules aktivitātes lielā mērā ir atkarīga sienas ārējās virsmas temperatūra, kura būtiski ietekmē gan sienas žūšanas procesus, gan kopējo siltuma plūsmu caur gāzbetona sienai. Var izdarīt secinājumu, ka eksistē savstarpēja sakarība starp siltuma caurlaidības koeficentu, sienas ārējās virsmas temperatūru un siltuma plūsmu gāzbetona sienās. Jau ziemas apstākļos vēl neizžuvušai sienai (w samazin;as no 25 – 14%) U vērtība atbilst normatīva LBN 002 – 01 prasībām. Aprēķinot siltuma caurlaidības koeficenta U vērtību redzams, ka teorētiskie aprēķini nesakrīt ar eksperimentāliem rezultātiem. Tas ir izskaidrojams ar gāzbetona spēju akumulēt siltumu un materiāla siltuma inerci. Jautājumus, kuri saistīti ar gāzbetona sienu siltuma inerci mēs apskatīsim turpmākajās publikācijās.
Ir zināms, ka iekštelpu mikroklimats ir tiešā veidā atkarīgs no temperatūras svārstībām uz sienas ārējās un iekšējās virsmas. Jo mazākas ir ārsienas iekšējās virsmas temperatūras svārstības pie ievērojamām tās ārējās virsmas temperatūru svārstībām, jo labāks veidojas telpu mikroklimats. Eksperimenta rezultātā tika noskaidrots, ka gāzbetona ārsienas iekšējās virsmas temperatūra izmainās par 2°C, ja tās ārējās virsmas temperatūras svārstības ir ievērojamas. Iegūtie termogrāfijas rezultāti parāda, ka, veidojot 2 mm biezas līmjavas šuves un veicot gāzbetona bloku sienas apdari no abām pusēm, šuves praktiski vairs neietekmē sienas siltumcaurlaidību, tāpēc, izdarot sienu siltumtehniskos aprēķinus, labojuma koeficients, kurš ņem vērā līmējuma šuvju atšķirīgo siltumcaurlaidību, nav jāņem vērā. Līdzīgs eksperiments tika veikts arī dzīvojamo māju kompleksā „Mārupīte". Ārsienu termografēšana tika veikta pēc aptuveni pusotra gada no objekta nodošanas ekspluatācijā otrās apkures sezonas laikā. Laika apstākļi šāda eksperimenta veikšanai bija ļoti labvēlīgi, jo ārējā gaisa temperatūra sasniedza –22°C, kas deva iespēju ļoti precīzi noteikt siltuma zudumu vietas ēkas fasādē. Eksperimenta gaitā ir iegūta apjomīga rezultātu datu bāze, kura sniedz pilnīgāku priekšstatu par gāzbetona norobežojošo konstrukciju siltumtehniskajiem rādītājiem ekspluatācijas apstākļiem, kuri raksturīgi Baltijas republiku reģionam.

Vilnītis M., Noviks J. Research of heat transfer proceses in walls made from new generation autoclaved aerated concrete.
Acquired results of heat transfer processes in walls made from new generation autoclaved aerated concrete. Two experimental walls, on the northern and southern part of the building, were built in Tallinn Technical school by imitating real living space in between. For construction of the walls was used autoclaved aerated concrete blocks EcoTerm 375 mm in thickness, volume weight ≤ 400 kg/m^3, glued together with a 2 mm thick layer of glue mortar. Starting from year 2005 there was carrying out various thermal measurements on regular basis. In order to establish the value of wall thermal conductivity coefficient U, the heat flow was measured with help of device ALMEMO – 2290-8 with feeders FQA017C and FQA019C. The surface temperature of both experimental walls was also measured, using HOBO type logger. It can be calculated that heat flow through aerocrete wall is directly related to the temperature of external surface of the wall. It is due to the sun activity that surface temperature of the external wall depends on and in its turn affects both the process of wall drying and total heat flow through aerocrete wall. Acquired results show that certain congruence among thermal conductivity coefficient, wall's external surface temperature and heat flow through aerocrete wall exists. In the wintertime conditions the aerocrete wall which is not yet dried and whose moisture decreased from 24 to 14% coefficient U value corresponds to the standard LBN 002 – 01 requirements. Calculating the theoretical U value we find out, that theoretical calculations do not match with experimental results. It can be explained with aerocrete's capacity to accumulate heat and material thermal inertia. Questions which are connected with aerocrete wall thermal inertia we will view in further publications. For ensuring good microclimate for a room, it is of importance that temperature fluctuations of the inner surface of the external wall would be minimum, if the temperature fluctuations of the outer surface of the external wall are considerable. By analysing the results of the experiment, it can be concluded that in case of considerable temperature fluctuations of the external surfaces of the walls, the temperature of the inner surface varies only within 2°C. The results of the thermography show that in case of 2 mm thick glue mortar joints and a finishing layer on both sides of the aerated concrete block wall, practically the joints leave no impact upon heat permeability and therefore, by performing thermotechnical calculations, the correction coefficient, which regards the distinctive heat permeability of the glued joints, is not to be taken into account. An analogue thermographic analyses was performed in the complex of multi-apartment buildings "Mārupīte". The thermographic analyses of the object was performed during the second heating period, approximately a year and a half after putting the building into operation. The conditions for thermographic analyses were very favourable. The outside temperature was –22 °C, what gave the opportunity to exactly establish places of heat loss in the elevation. In this experiment we get great amount of measurements,

that could extend information about thermal qualities of autoclaved aerated concrete walls construction built on Baltic region climatic conditions.

Вилнитис. М. Я., Новикс Ю. А. Исследование процессов теплопередачи стен из газобетона нового поколения.

Приведены экспериментальные результаты процесса теплопередачи стен из газобетона нового поколения. Исследования проведены в Таллинской Технической школе, где построен дом со стенами на южном и северном фасадах из газобетонных блоков EcoTerm толщиной 375 мм со средней плотностью ≤400 кг/м^3. Кладка производилась на клею с толщиной шва ~2 мм. Начиная с 2005 года ведутся постоянные измерения с целью определения различных теплотехнических характеристик газобетонных стен. Для определения значения коэффициента теплопередачи U были произведены измерения теплового потока в обеих экспериментальных стенах с помощью прибора ALMEMO – 2290 – 8 с датчиками FQA017C и FQA019C. Также проводились и измерения температуры и относительной влажности помещения и наружного воздуха и температуры внутренней и внешней поверхности опытных стен с помощью регистрирующего устройства HOBO. Анализируя полученные данные можно константировать, что тепловой поток изменяется аналогично температуры внешней поверхности стен. Именно солнечное излучение определяет температуру внешней поверхности стены, которое, в свою очередь, значительно влияет на процесс высыхания стены и тепловой поток через газобетонную стену. Это указывает на взаимную связь между коэффициентом теплопередачи, температурой наружной поверхности стены и тепловым потоком через газобетонную стену. Для невысохшей стены, когда влажность стены составляет 25 – 14%, значение коэффициента теплопередачи U соответствует требованиям норматива LBN 002 – 01. Теоретическое значение коэффициента теплопередачи U не совпадают с экспериментальными данными. Это можно обяснить способностью газобетона акумулировать тепло и тепловой инерцией материала. Вопросам, связанным с тепловой инерцей стен из газобетонных блоков, мы уделим внимание в следующих публикациях. Для обеспечения хорошего микроклимата в помещении важно, чтобы температурные колебания внутренней поверхности наружной стены были минимальны при максимальных колебаниях температуры внешней поверхности. Анализ полученных результатов привел к выводу, что в случае больших колебаний температур внешней поверхности стены температура внутренней поверхности стены колеблется всего лишь в пределах 2°C. Полученные результаты термографии показывают, что при толщине шва клеевого раствора толщиной 2 мм и отделки стены из газобетонных блоков с обеих сторон швы практически перестают влиять на теплопроводность стены, поэтому при теплотехнических расчетах стен коэффициент поправок, учитывающий влияние теплопроводности клеевых швов, можно не принимать во внимание. Аналогичная термографическая проверка проводилась также в комплексе многоквартирных домов «Mārupīte» в Риге. Термографическая проверка проводилась во второй отопительный сезон после примерно полутора лет эксплуатации. Условия для термографической проверки были крайне благоприятными. Температура наружного воздуха составляла –22°C, что позволило точно определить места потерь тепла на фасаде. Полученные экспериментальные данные дают более точное представление о теплотехнических характеристиках газобетонных стен в условиях, максимально соответствующих условиям эксплуатации наружных стен в регионе Прибалтики, которому характерны влажные климатические условия.