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THE DETERIORATION OF STRENGTH AND THERMAL PROPERTIES OF AUTOCLAVED AERATED CONCRETE AS A RESULT OF CAPILLARY MOISTURE

POGORSZENIE WŁAŚCIWOŚCI WYTRZYMAŁOŚCIOWYCH I CIEPLNYCH BETONU KOMÓRKOWEGO W WYNIKU ZAWILGOCENIA KAPILARNEGO

Abstract

In modern construction there appear two parallel independent trends. On the one hand, large emphasis is put on raising durability of construction works implemented through the selection of appropriate materials with parameters tailored to the specific conditions occurring during the operation of the building. On the other hand, great importance is attributed to the problem of energy-efficient building design, which is reflected in the increasingly stringent records of existing legislation. In this paper some questions were raised concerning the both issues. The article presents the results of autoclaved aerated concrete studies, in particular, the deterioration of its strength and thermal conductivity due to moistness.

Keywords: capillary transport, thermal conductivity, strength, autoclaved aerated concrete

Streszczenie

We współczesnym budownictwie obserwuje się niezależne występowanie dwóch równoległych trendów. Z jednej strony kładzie się duży nacisk na podniesienie trwałości realizowanych obiektów budowlanych, poprzez dobór właściwych materiałów, o parametrach ściśle dostosowanych do specyficznych warunków występujących w trakcie eksploatacji obiektu. Z drugiej strony dużą wagę przywiązuje się do problemu energooszczędnego projektowania budynków, co znajduje swój wyraz w coraz bardziej restrykcyjnych zapisach obowiązujących aktów prawnych. W ramach niniejszego artykułu podjęto kwestie dotyczące obydwu zagadnień równocześnie. Przedstawiono mianowicie wyniki badań dotyczących betonu komórkowego, a w szczególności pogorszenia jego wytrzymałości i przewodności cieplnej w wyniku zawilgocenia.

Słowa kluczowe: przepływ kapilarny, przewodność cieplna, wytrzymałość, beton komórkowy

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1. Introduction

The economic, technical and ecological aspects tend to be the reasons for constructing the buildings which are distinguished by their satisfying durability as well as energy efficiency of used solutions, e.g. structural and material ones. Exterior walls of the buildings play a major part in fulfilling these requirements. Sensible choice of the appropriate building materials to be used for constructing the partitions requires full awareness of their physical and mechanical properties. These properties may undergo strong oscillations depending on the intensification of factors affecting them, e.g. moistness. Thermal conductivity and compressive strength of the building materials are the elementary parameters that determine the suitability of materials used to build the exterior partitions. Dry construction materials show, however, different characteristics when exposed to moisture. One of the major causes of the exterior partitions moistness is capillary rise. As a result of capillary forces water penetrates the pores of the material, causing deterioration of its physical and mechanical properties. Along with an increase of moistness the coefficient of thermal conductivity rises too, while the material's compressive strength concurrently falls [1, 10, 11].

This paper shows the elements of the process and the outcomes of a two-phased experiment focused on defining the matter exemplified by the autoclaved aerated concrete. In the first stage of the experiment a simulation was performed in which the partitions made of various kinds of autoclaved aerated concretes are exposed to a liquid water penetration as a result of capillary forces. Such situation may occur as a result of a bad project, leading to an appearance of condensation inside or on the surface of the partition. It may also emerge as a consequence of a faulty performance, such as lack of or improper installation of the waterproofing. It can also be caused by the installation failures or natural disasters, for example as an effect of flood waters [12]. After a 3 month simulation period, during which water spread through the pores of the tested material, an examination was performed. It established the basic stage of the experiment which aimed at testing on how water spreading through the partition thickness changed the distribution of strength and thermal parameters inside each wall made of concrete of a range of different densities.

2. Experiment

2.1. Testing of the capillary sorption coefficient

The experiment aiming at assessing an impact of capillary moisture on the thermal and strength parameters was conducted in an air-conditioned laboratory at the constant temperature of +20°C. Four samples of concrete blocks were selected for the purpose of conducting the experiment: 400, 500, 600, and 700 density class, produced by one manufacturer. They create a testing material, which was used as a basis for determining the coefficient of capillary sorption which was utilised as a measure of intensity of the process of a material porous structure water penetration. As described in [6] a selection of sorption measuring methods can be used. For the purpose of this study a mass method for sorption measurement was adopted.

Ill. 1. Measurements of water sorption coefficients

Four samples were prepared for the first stage of testing. The four samples were cuboids measuring 12 × 12× 24 cm each. The samples were insulated along their side walls by a silicon layer in order to ensure a one-way water transport, as well as to prevent it from uncontrolled drying up through the sides. With relation to all considered samples an initial mass, geometric measures and base volumetric density were established. Once prepared and inventoried, the samples were placed in a dish filled with distilled water (Ill. 1). Throughout the entire period of testing the samples remained submerged in distilled water to exactly the same depth that equalled around 2 mm. The research was conducted by a gravimetric analysis method and was based on systematic measuring of the mass of the samples which were weighted on the 0.01 g accuracy scales. The process run relatively fast in its initial stage, therefore the measurements of subsequently changing mass were taken once every hour. Along with the declining intensity of the process, the intervals between the consecutive measurements were increased to 4 h, 8 h and finally to 12 h.

2.2. Measurement of thermal conductivity coefficients

After the three month period of the experiment each sample, measuring 12 × 12 × 24 cm was cut in two to form two cubes measuring 12 × 12 × 12 cm. These were named respectively 'top' (the top cube exposed to a direct contact with surrounding air), and 'bottom' (lower cube exposed to a direct contact with water). Once prepared as per given description, the samples were first used to measure the thermal conductivity coefficient λ. It was a non-stationary method which was chosen to ensure a relatively quick accomplishment of the measurements, as opposed to long-lasting stationary measurements that could have had some impact on the changes of the tested samples moistness. The testing was conducted by the use of a portable measuring instrument ISOMET 2104 equipped with appropriately selected surface probes.

Each measurement was performed twice, and the result was automatically recorded by the measuring instrument, as shown in Ill. 2.

Ill. 2. Measurement of thermal parameters

2.3. Measurement of compressive strength

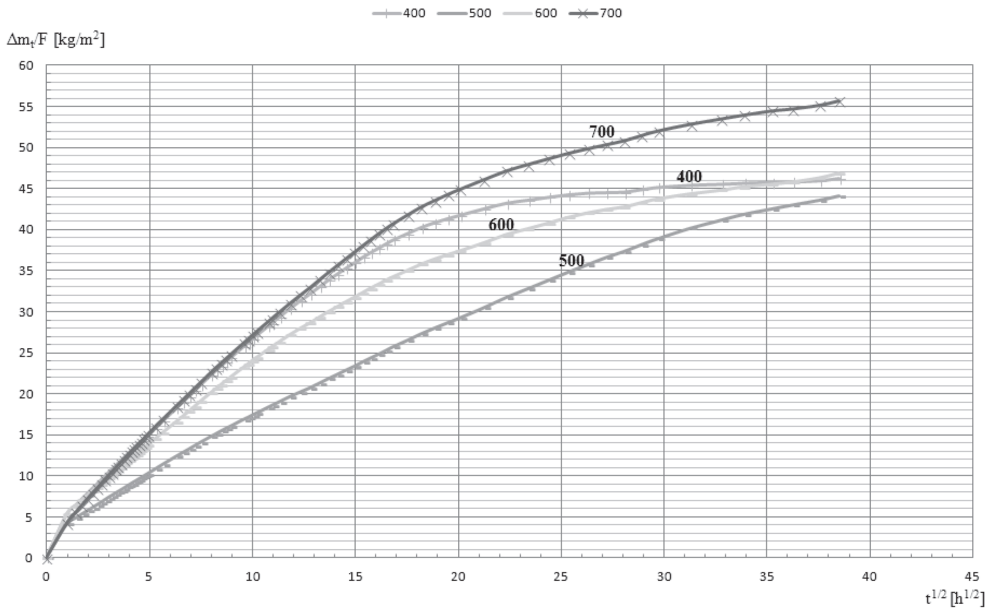
Soon after the measurements of the thermal parameters were completed, the measurements of the compressive strength commenced. In order to perform this experiment a material testing machine was used, as shown in Ill. 3.

Ill. 3. Measurement of compressive strength

Before the commencement of compressive strength testing each individual sample was weighted and measured. Next, each sample was one by one put inside the machine. The testing involved an even application of compressive force to each sample where the compression was set to have an axial and perpendicular orientation towards the surface. Strength, measured in N/mm^2 was then read from the screen of the machine. Compressive strength fb was being marked according to the standard [8].

2.4. Test results and analysis

Testing of the capillary sorption facilitated the preparation of graphical illustration of changes to the masses of individual samples in relation to the area of contact with water in a function of the square root of time. Ill. 4 shows a diagram containing four graphs prepared on the basis of average values recorded during measurement process of all four classes of autoclaved aerated concrete blocks.



Ill. 4. Diagram $m_s = f(\sqrt{t})$ for aerated concrete of 400, 500, 600, 700 kg/m^3 density

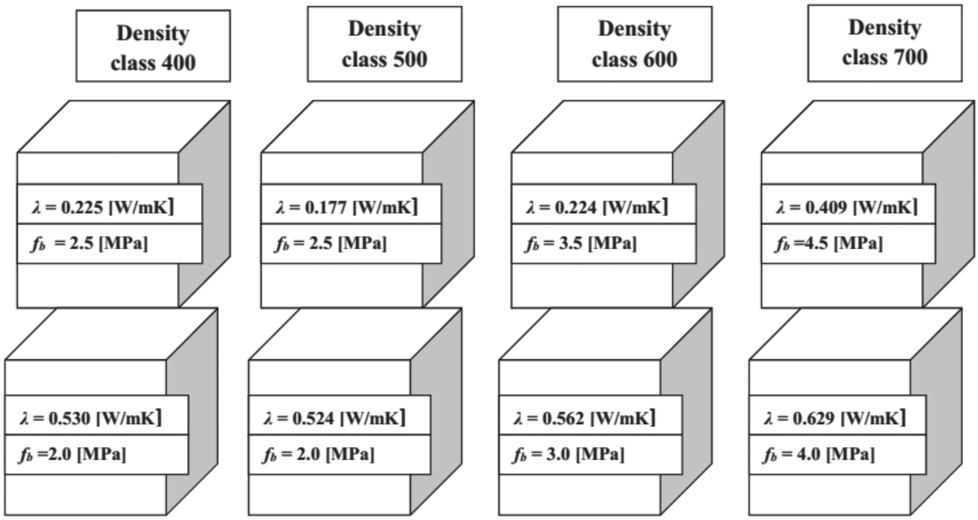
In accordance with PN-EN ISO 9346 standard [7] capillary coefficients of water sorption A was determined by using the following formula:

$$m_s = A \cdot \sqrt{t} \tag{1}$$

where: m_s is the mass of the absorbed water in relation to the area of contact of the sample and water ($\Delta m_t/F$), and t denotes time of the process.

Having analyzed the graphs, it was observed that for all tested classes of autoclaved aerated concrete blocks there occurred a high level of compatibility between the description illustrated by the formula (1) and actual course of the process. The occurrence of a linear correlation $m_s = f(\sqrt{t})$ was noted in a relatively long period of time. Similar results were obtained for all individual samples in a course of a 1 month long experiment [2, 5].

Measurements performed by means of using Isomet 2104 instrument and those conducted inside the material testing machine enabled to assess the impact of capillary moisture on the thermal conductivity and compressive strength within the group of the tested autoclaved aerated concretes. A range of factors which were tested in works, e.g. [3, 4, 7] influence the coefficient of thermal conductivity. Predominant value is assigned to moistness, in particular the one that penetrates the available porous space of the material in liquid phase. For this reason this work endeavours to assess a degree of the unfavourable impact of spreading capillary moisture on unwanted fall in strength and increase of thermal conductivity. The average values obtained from measurements of blocks of all concrete density classes are shown in Ill. 5.



Ill. 5. Schematic diagram of 12 × 12 × 24 cm AAC block division of cube samples 12 × 12 × 12 cm with their thermal conductivity coefficient λ and the compressive strength f_b in various water saturations

Every ‘bottom’ cube is characterised by decreased average compression strength in relation to the ‘top’ one. Nevertheless, the recorded falls in strength are located on a level of around 25% in the case of two concretes of the lowest density, at a level of 17% in the case of class 600 concrete, and at 12.5% in the case of the highest density concrete, 700. Moreover, the average value of thermal conductivity coefficient for the ‘bottom’ samples of autoclaved aerated concrete class 400 and 600, which was determined by the performed measurements, is 2.5 times greater compared to the ‘top’ samples; for class 500 it is three times greater and for class 700 it is 1.5 times greater.

3. Conclusions

The research proved that applying a load of capillary water to a partition wall affects negatively its properties by causing changes to its thermal insulating properties, as well as it causes a decrease of its compressive strength. It needs to be stressed that these regularities occur in relation to all tested density classes of autoclaved aerated concrete: 400, 500, 600 and 700.

In each case the thermal conductivity coefficients λ, obtained by the use of the non-stationary method show unequivocal tendency to increase thermal conductivity along with the increase of the material moistness. Greater moistness of the area located in a direct contact with water, compared with the opposite drier sides, leads to an increase of the thermal conductivity in a range from around 300% to around 150%. These unfavourable changes to the insulation parameters occur along with a decrease in the compressive strength in the range of 25% to 12.5%. The both lower limiting values relate to the autoclaved aerated concrete class 700 which was the least affected by destructing influence of capillary water. However, even in the case of the highest density concrete, the technical parameters determining energy-efficiency and durability of the partitions undergo a serious deterioration. It goes without saying that the utmost care should be taken when choosing suitable material and construction solutions in order to prevent the walls from the occurrence of water inside the partitions, regardless of its source.

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