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INFLUENCE OF SELECTED PARAMETERS OF AUTOCLAVED AERATED CONCRETES ON THEIR DRYING

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Abstract

The paper presents an analysis of the influence of the moisture content in autoclaved aerated concretes on their drying. The tested material consisted of 60 cubic samples (10 x 10cm) of fly ash aerated concrete and sand aerated concrete, types 400 and 600. The analyzed physical parameters of the samples, such as specific density, bulk density, porosity, tightness and absorbtivity, were presented in the paper. The tests revealed that the rate of autoclaved aerated concrete drying depends in the first place on its structure and the moisture content. The drying period of samples soaked with water was the shortest for the sand aerated concrete type 600. The longest drying period was observed for the samples of the fly ash aerated concrete type 600. The results of conducted analyses allowed for distinguishing two phases of autoclaved aerated concrete drying: the first – up to 10 days, when an intensive decrease in mass wetness takes place, and the second – from 10 to 25-40 days, when a slow decline in mass wetness is observed.

Keywords: autoclaved aerated concrete, drying, building envelopes moisture

INTRODUCTION

Autoclaved aerated concrete (AAC) has been currently one of the most frequently used building materials for wall construction in modern housing facilities. The main reason for growing interest in this material is a pursuit of assuring appropriate hygrothermal conditions of building envelopes, which should be designed in order to ensure reducing energy consumption by a building and the right internal microclimate (Nawalany *et al.* 2015, Garbalińska and Bochemek 2011, Radoń and Künzel 2006). Manufacturers of autoclaved aerated concrete found a reasonable compromise between the lightness and strength with simultaneous thermal insulation. The choice of autoclaved aerated concrete as the material for constructing building envelopes of housing facilities was considerably influenced by its low heat transfer coefficient. Single-layer walls made of autoclaved aerated concrete of appropriate thickness meet the requirements stated in the Regulation of the Minister of Transport, Construction and Maritime Economy of 5 July 2013 amending the regulation on the technical conditions which buildings and their location must fulfill (Polish Journal of Laws of 2013, item 926) and the regulation of the Minister of Infrastructure of 2 July 2014 on the methodology of estimating energy performance of a building or dwelling or a part of the building constituting an independent technical and usable entity and the method of preparation and samples of their energy performance certificates (Polish Journal of Laws of 2014, item 888). Researchers conduct numerous studies in order to optimize the composition of blends used for the production of AAC better. The use of perlite may be an example, as it contributes to the reduction of the thermal conductivity by 15% (introduction of perlite waste up to 10% by weight) (Różycka and Pichór 2016). However, good properties of the aerated concrete may worsen as a result of the material moistening. In this area the researchers carried out numerous studies aiming at achieving the exact value of sorption isotherms of the autoclaved aerated concrete and other building materials (Siwińska and Strzałkowski 2015, Plagge *et al.* 2006, Scheffler *et al.* 2006). Water permeates into a highly absorptive material, such as aerated concrete, and may increase its heat transfer coefficient even 6-fold. This phenomenon may be caused by strongly capillary and porous structure of aerated concrete – it absorbs great amounts of moisture very quickly, since it is inadequately protected,. An average drying time of the building element in which an excessive moisture accumulated may last even several years. The length of the drying period depends mainly on the density of the material. External walls made of AAC with a lower density dry faster (Romanowski *et al.* 2003*)*. Unfavorable results of material moistening may contribute to higher energy expenditures on building heating or a serious worsening of its interior microclimate (Suchorab and Barnat-Hunek 2011).

THE AIM AND SCOPE OF INVESTIGATIONS

The aim of the work was to analyze the influence of selected parameters of autoclaved aerated concretes (AAC) on their drying. The scope of work comprised measuring of specific density, bulk density, porosity, tightness and absorbtivity of the samples, as well as determining the drying time of selected aerated concretes.

MATERIAL AND METHODS

Samples of fly ash and sand aerated concrete, types 400 and 600, were used for the tests. A total of 60 samples of sizes 10 x 10 x 10 cm were prepared, the test material was checked for damages, such as cracking or chipping. Subsequently, selected physical properties were determined (specific density, bulk density, porosity, tightness and absorbtivity) according to the obligatory standards. The data obtained during the preparation of a MSc thesis under the author's supervision were used in the paper (Majchrowicz 2008).

After the analysis of the above mentioned physical parameters, the samples were soaked until the moment of their full saturation with water. Then the soaked samples were placed on plastic stands, keeping an appropriate distance from other objects to ensure free air movement. The internal air temperature was maintained at the level of 20±2°C, while the air relative humidity was 50±5%. An ongoing control of the temperature and internal air relative humidity was conducted. The weight of the drying samples was measured every 24 h until the constant sample weight. A comparative analysis of individual aerated concrete samples drying was conducted on the basis of their mass moisture, calculated according to the following formula:

$$w_m = \frac{m_w - m_s}{m_s} \cdot 100\ [\%] \tag{1}$$

where:
m_w – wet sample weight, [kg],
m_s – dry sample weight, [kg].

The fly ash aerated concrete samples originated from manufacturers I-III, while the sand aerated concrete samples from manufacturers IV-VI (Table 1).

Table 1. Division of tested samples according to their origin, variety and type

Manufacturer	I	II	III	IV	V	VI
Aerated concrete variety		Fly ash			Sand	
Type of aerated concrete	600	600	400	600	400	600
Number of samples [pcs.]	10	10	10	10	10	10

RESULTS AND ANALYSIS

The samples originating from the manufacturer III revealed the highest water absorption by weight (91.1% – fly ash aerated concrete, type 400), whereas the lowest value of water absorption by weight was noticed for a group of samples from the producer IV (54.2% – sand aerated concrete, type 600). The research results show that the aerated concrete type 600 revealed a considerably lower water absorption by weight than the aerated concrete type 400. The results of the analysis of selected physical properties for the researched aerated concretes were presented in Table 2.

Table 2. Physical parameters of selected aerated concrete samples

Physical parameter	Unit	Manufacturer					
		I	II	III	IV	V	VI
Specific density	[kg·m^{-3}]	2327.6	2388.1	2244.2	2470.0	2263.6	2279.9
Bulk density		616.5	565.3	431.1	606.6	381.4	586.1
Tightness	[%]	26.5	23.7	24.6	25.7	16.9	19.2
Porosity		73.5	76.3	75.4	74.3	83.2	80.8
Water absorbtivity by weight		76.7	67.7	91.1	54.2	77.4	59.5

Drying of the tested aerated concretes was presented graphically in Figure 1.

The greatest decrease in absorbtivity by weight in aerated concretes type 600 occurred during the first 10 days of drying. Considering the samples of aerated concretes type 600, those originating from the manufacturer II were drying at the fastest rate. A decline in their moisture reached 50.0% during the first 10 days of drying. Also in the case of the concrete samples from manufactures I, IV and VI the decrease in absorbtivity by weight was considerable during the first 10 days of drying, reaching respectively 47.8%, 40.2% and 43.3%.

The results of aerated concrete type 400 drying tests demonstrated that the decline in moisture on the first day of drying of the samples from the manufacturer III was twice higher than for the samples from the producer IV. Like in the case of aerated concretes type 600, the highest drying intensity was observed during the period of the first 10 days. The test results showed the greatest decline in the moisture content during the same period, reaching 69.1% for the samples from the manufacturer III. The average moisture content in the samples from the manufacturer V decreased by ca. 60,0% during the first 10 days of drying.

Figure 2 shows a comparison of average moisture content by weight for the tested samples in the selected periods of drying.

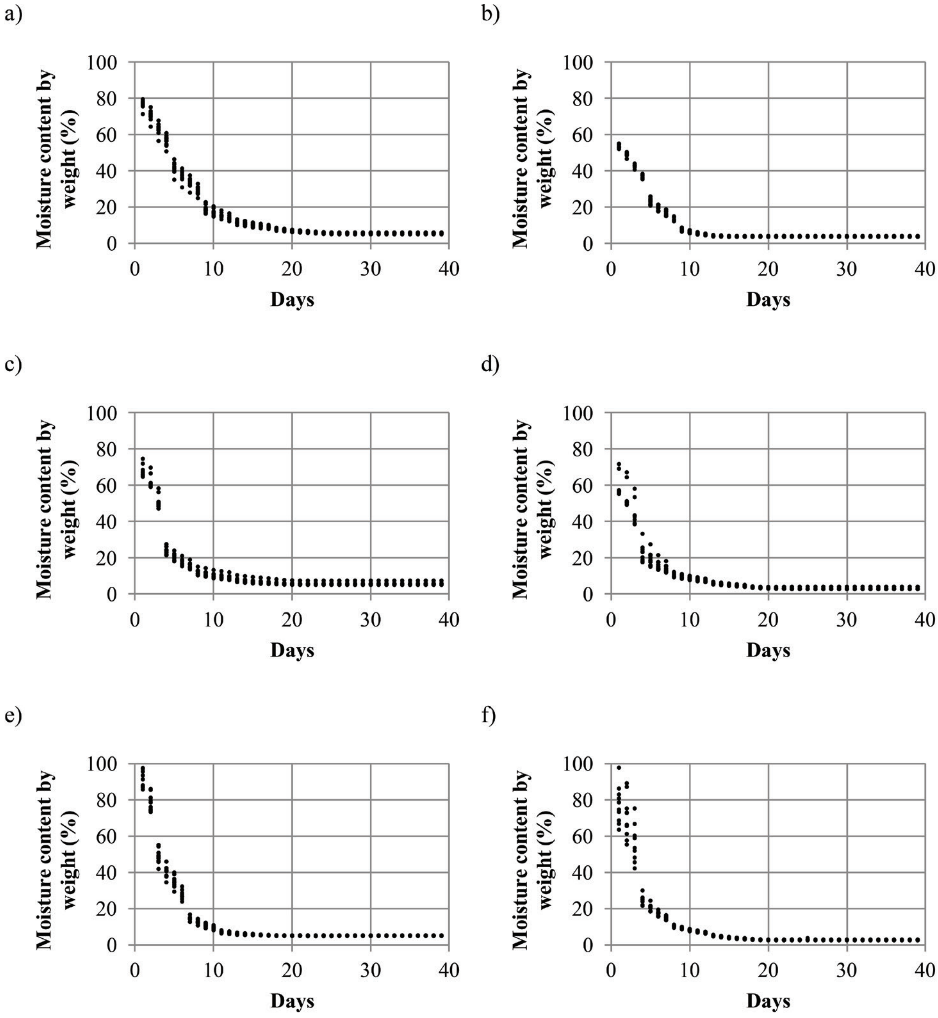

Figure 1. Moisture content by weight in aerated concrete samples: a) fly ash aerated concrete, type 600, manufacturer I; b) sand aerated concrete, type 600, manufacturer IV; c) fly ash aerated concrete, type 600, manufacturer II; d) sand aerated concrete, type 600, manufacturer VI; e) fly ash aerated concrete, type 400, manufacturer III; f) sand aerated concrete, type 400, manufacturer V.

Research on the period of drying for individual sample groups revealed a considerable diversification of time after which the sample reached unchanging values of moisture content by weight. The shortest period of drying was observed for the samples from the manufacturer IV (25 days), whereas the longest for the samples from the producer I (39 days). The other samples originating from producers II, III, V and VI were characterized by an approximate period of drying 30-32 days.

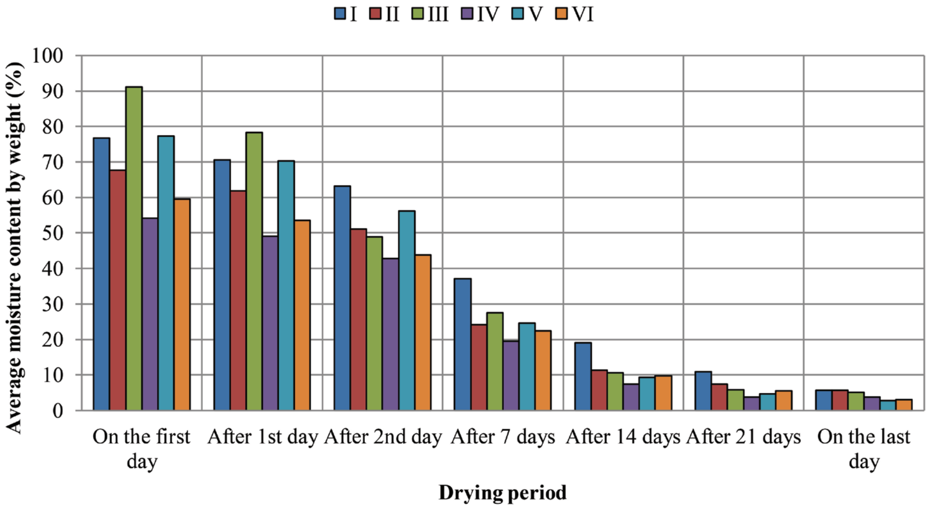

Figure 2. Average moisture content by weight of samples during the selected periods of drying

Due to a considerably higher volume of constructing elements of building envelopes in comparison to the tested samples, drying of autoclaved aerated concrete elements used in building envelopes may last much longer. According to Suchorab and Barnat-Hunek (2011) the period of drying of aerated concrete used for constructing building envelopes may last even several years.

a) b)

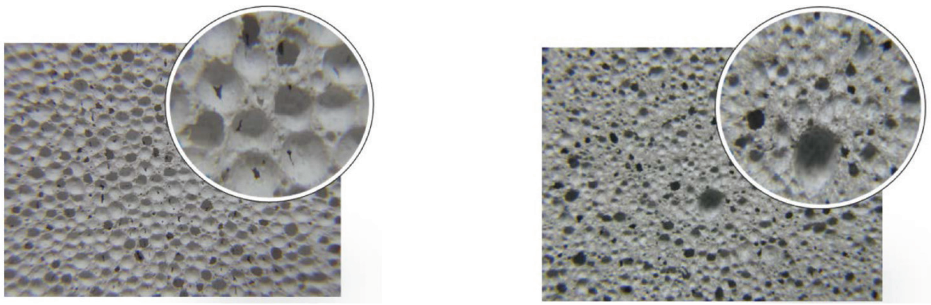

Figure 3. Structure of tested aerated concretes: a) sand aerated concrete, b) fly ash aerated concrete

The rate of aerated concrete drying is influenced by its structure. Studies revealed that in the case of aerated concrete with bigger pores (Fig.3a) the drying process is faster (25-30 days). In the case of aerated concrete with smaller and irregular pores (Fig.3b), drying process is slower (31-39 days).

Results of the analysis revealed that the highest average moisture content by weight (21.8%) exhibited the samples from the manufacturer I (fly ash aerated concrete, type 600). The highest standard deviation for this parameter was observed in the group of samples from the producer III. Table 3 shows a basic statistical analysis of moisture content by weight in samples in the individual groups.

Table 3. Basic statistics of moisture content by weight of tested samples

Manufacturer	I	II	III	IV	V	VI
Minimum moisture content w_{min} (%)	5.7	5.7	5.1	3.8	2.8	3.1
Maximum moisture content w_{max} (%)	76.7	67.7	91.1	54.2	77.7	59.5
Average moisture content $w_{śr}$ (%)	21.8	15.0	17.1	12.5	13.8	12.3
Standard deviation (%)	21.3	16.9	22.5	15.0	20.2	15.2
Median (%)	10.9	7.5	5.8	4.0	4.6	5.6

CONCLUSION

Inadequately protected building envelopes made of aerated concrete are especially susceptible to moisture. Depending on the degree of their dampness the period of drying of the building envelopes made from aerated concrete is different and the rate of the process depends mainly on the structure (the bigger the pores, the faster the drying process is). Considering the tested samples, the shorter drying period of only 25 days was recorded for the sand aerated concrete type 600, originating from the producer IV. The longest drying period, 39 days, was observed in the case of the fly ash aerated concrete type 600 from the producer I. Results of tests demonstrated that there are two drying phases: the first lasting up to 10 days, when an intensive decline in the moisture by weight occurs, and the second from 10 to 25-40 days, when a low decline in the moisture by weight is observed. Drying of analyzed aerated concretes was the fastest during the first 10 days, when the moisture by weight of the tested samples decreased to about 10%. The results of basic physical parameters measurements showed that the moisture content by weight in the natural state was about twice lower for sand aerated concretes than for fly ash aerated concretes. Bulk density of the aerated concrete type 400 samples ranged from 381.4 to 431.1 kg·m^3, while for type 600 samples between 565.3 and 616.5 kg·m^3. Absorbtivity by weight of the tested samples varied from 54,2% to 91.1%, whereas their porosity ranged from 73.5% to 83.2%.

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