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The Influence of the Chalcedony on the Properties of Autoclaved Aerated Concrete

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Abstract

Autoclaved aerated concrete (AAC) is commonly used in Europe due to its high utility values and high economic efficiency of the manufacturing process. In spite of the undeniable advantages of autoclaved aerated concrete, it has some less desirable qualities, therefore new solutions are being sought to improve its properties. One of the solutions aimed at improving the AAC fundamental parameters, resulting in the increased compressive strength and reduced water absorption, is the modification of its composition. The paper presents the effect of chalcedony on the phase composition and physical and mechanical properties of the autoclaved aerated concrete products. The modified product was subjected to X-ray phase analysis and to the tests of bulk density, water absorption and compressive strength. The investigation results presented hereby refer to the explanatory experiments. The research will be continued since the results reveal a clear improvement, albeit a slight one, of the AAC primary parameters.

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Keywords: autoclaved aerated concrete; chalcedony; microstructure; modification; phase composition;

1. Introduction

Chalcedonite is a sedimentary siliceous rock included into a group of unique rocks because it can only be found in limited areas. In Poland, chalcedonite is to be found in the following deposits: Dęborzynek, Gapinin, Lubocz and Teofilów in the area of Tomaszow Mazowiecki and Nowe Miasto. At present, chalcedonite is only excavated at Teofilów. Chalcedony is the main component of the rock, which contains also small quantities of quartz, opal, hydroxides of iron, pyrite, manganese compounds and clay minerals. The mineral composition of chalcedonite by

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volume is as follows: chalcedony, opal and autogenous quartz: 68.3-95.4%, quartz and other terrigenous ingredients: 0.3-6.6%, free and filled pores: 2.0-24.7%. With regard to the chemical composition, chalcedonite is a uniform rock due to the fact that the content of the silica exceeds 94% by weight. Chalcedonite contains smaller amounts of the oxides of iron, aluminium, alkaline elements and alkaline soil elements as well as organic substances and water [3,5].

2. Preparation of samples

In order to perform laboratory tests on the AAC concrete modified with chalcedonite, samples with dimensions of 100 x 100 x 100 mm and containing varying amounts of chalcedonite were prepared under laboratory conditions in the aerated concrete manufacturing unit. The samples of the traditional ACC were also prepared in order to verify the effect of the additive.

Autoclaved aerated concrete with the bulk density of 500 kg/m3 was produced in the SW technology. In this technology, the ground sand is mixed with water to form a slurry. Ground quick lime and cement (without additional grinding in the manufacturing plant) serve as the binder. The dosage of lime, cement, gypsum, sand slurry and additional water into the mixer was done by weight. The pore-forming agent and the surface active agent were prepared in the form of the powder suspension in water. The transfer and mixing of the ingredients in suitable proportions (sand and gypsum – approx. 72% of the product by weight, lime and cement – approx. 20% and water – approx. 7%) took about 6 minutes.

In the next stage, the appropriate quantity of the powdered additive was introduced into the mix. The additive used in the laboratory testing was selected on the basis of the initial multi-criteria technical-economic analysis. The conducted test performed full one-factorial experiment. Six parallel tests were performed for each value of the input factor (additive content in the sample on the percentage basis in relation to the sand and gypsum content in the sample). Table 1 presents the mix composition in particular samples on the percentage basis.

Table 1. The percentage of the additive in the individual samples.

Sample	Chalcedony (% of the sand with gypsum)
A	0
B	10
C	20
D	30

When the process was completed, the mix was poured into three-part forms. The forms with the mix were placed in the pre-curing chambers, in which they stayed at this density for three hours at the temperature of 60 °C. During this step, tricalcium aluminate reacts with sulphate feedstock and ettringite is formed. In this time, the samples attained the strength permitting their removal from the forms.

In the further stage, the samples were subjected to autoclaving at 190 °C and to the water vapor pressure of 1.2 MPa. The autoclaving was performed for 13 hours. This process gives the aerated concrete appropriate qualities such as strength, frost-resistance and durability [2,6].

3. Tests results and analysis

3.1. Dry state density

The dry state density was determined according to the PN-EN 772-13:2001 standard [10]. It defines the ratio of the autoclaved aerated concrete to its volume (including pores) after being dried to a constant weight. With respect to this standard, prior to the determination of density, the samples were dried to a constant weight at 105 °C. The value of the dry state density is shown in Fig. 1 as the arithmetic mean of the obtained values.

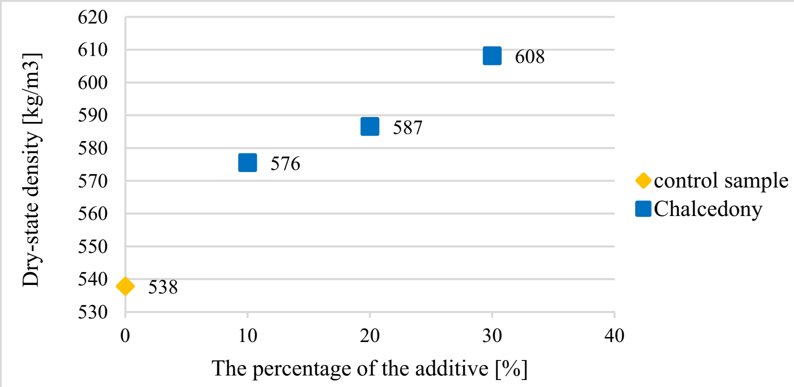

Fig. 1. Dry state density of the tested material.

The analysis of the obtained results shows that the additive of chalcedonite caused the growth in the density of the examined material. It was found that the increase in the density grows together with the rise in the additive percentage in the AAC. The samples containing 10%, 20% and 30% addition of chalcedonite revealed a density increase by 7%, 9% and 13%, respectively.

3.2. Compressive strength

Compressive strength was determined according to the PN-EN 772-1:2011 standard [7] by testing the samples on the press located in the laboratory of the Kielce University of Technology.

In accordance with the standard, prior to the examination, the samples were seasoned through drying at 70 °C until a constant weight was achieved. The compressive strength test results are presented in Fig. 2 as the arithmetic mean of the obtained values.

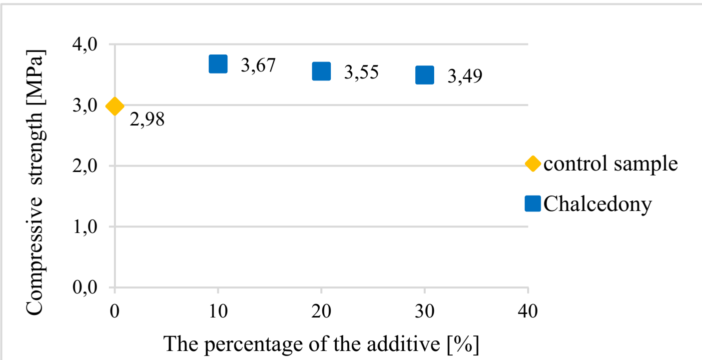

Fig. 2 Compressive strength of particular materials.

The results analysis shows that the additive of chalcedonite causes the increase in the compressive strength of the examined material. The sample containing 10% of the additive yielded the highest value of the compressive strength. The obtained result was 3.67 MPa, which is 23% higher than the compressive strength of the control sample.

On the basis of the results, it can also be concluded that as the percentage of the additive in the sample rises the strength value becomes gradually lower than the highest one. Thus, the samples containing 20% and 30% of the additive revealed the compressive strength that was 19% and 17% higher than that of the control samples.

3.3. Water absorption

Water absorption was determined according to the PN-EN 772-11:2011 standard [9]. In accordance with the standard, prior to the examination, the samples were subjected to seasoning through drying at 70 °C until a constant weight was achieved. Pursuant to the PN-EN 771-4:2012 standard [8], the examination of water absorption was performed after 10, 30 and 90 minutes. The resultant values are presented in Figure 3 as the arithmetic mean of the obtained results.

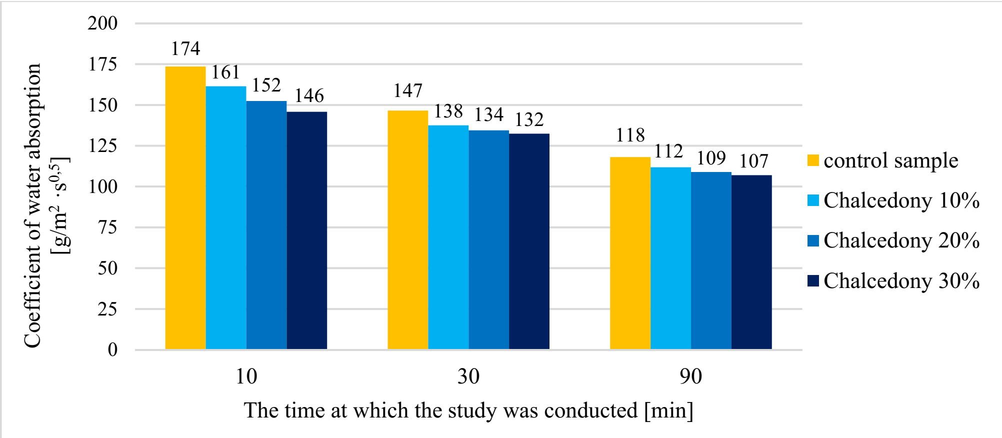

Fig. 3. Water absorption of the examined material.

The analysis of the obtained results shows that the addition of chalcedonite reduces the coefficient of water absorption. The sample containing 30% of the additive yielded the lowest water absorption coefficient in all the three measurements. This sample yielded a value that was lower than the control sample's result by 9% to 16%.

Samples containing 10% and 20% of the additive yielded a lower water absorption coefficient as compared to the control sample, the value amounting to 7% and 12% in the first measurement and 5% and 8% in the last one, respectively. The study shows that the increase in the additive content is accompanied by the decrease in the water absorption coefficient.

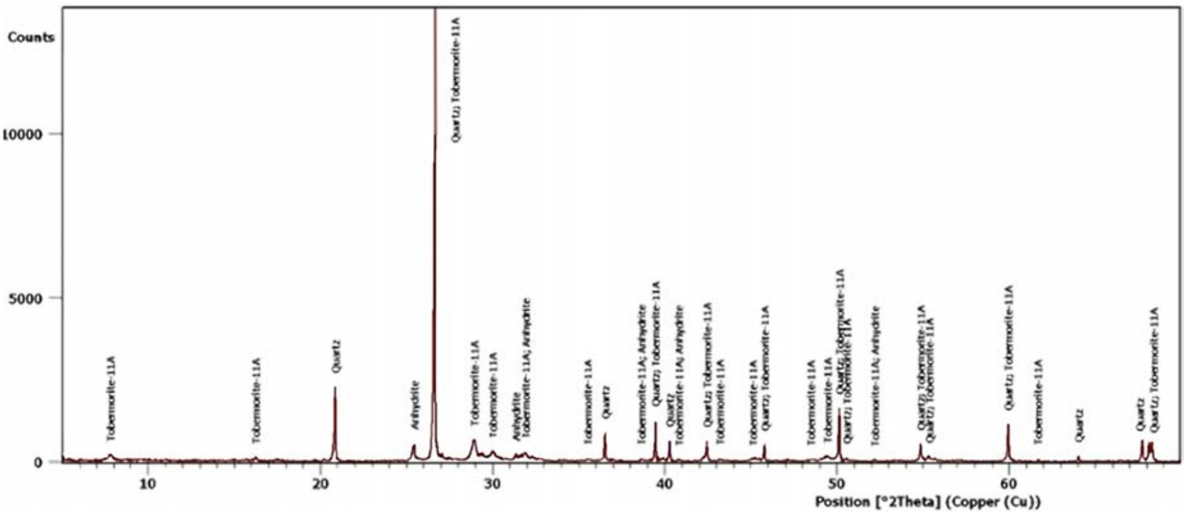

Fig. 4. X-ray diffraction pattern of the modified autoclaved aerated concrete.

3.4. Phase composition analysis

The phase composition analysis of the autoclaved aerated concrete was performed using X-ray diffraction (XRD). According to the reference sources, the basic phase components of the autoclaved aerated concrete are hydrated calcium silicates C-S-H and tobermorite, with smaller quantities of hydrogrenades and anhydrite and small amounts of scawtite, xonolite and pectolite [1, 4, 6]. One of the series of the diffraction patterns is shown in Fig. 4.

The results of the XRD study of the autoclaved aerated concrete modified with chalcedony revealed the presence of numerous phases of tobermorite. The material examination also revealed the presence of smaller quantities of anhydrite. Additionally, it was found that the modified material contains numerous crystalline phases, i.e. quartz.

4. Conclusions

Based on the presented study it can be concluded that the addition of chalcedonite has a beneficial effect on autoclaved aerated concrete and improves its qualities.

The 10% addition yielded the highest compressive strength results and increased its value by 23% compared to the traditional autoclaved aerated concrete. Moreover, autoclaved aerated concrete modified with chalcedonite has a reduced absorption coefficient. With the 30% addition of chalcedonite into the tested material, the final measurement revealed that the value of the water coefficient was reduced by 16% compared to the traditional product. Although there was an increase in bulk density (by 9.5% on average) of the modified aerated concrete, the growth value is not significant in comparison with the traditional product. The conspicuous improvement in the properties of ACC renders it advisable to undertake further studies and to modify its composition.

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