International Journal of Advanced Research and Development
www.multidisciplinaryjournal.net
ISSN: 2455-4030
Received: 12-12-2022, Accepted: 28-12-2022, Published: 14-01-2023
Volume 8, Issue 1, 2023, Page No. 4-6

Methods to reduce water absorption of cement-containing materials based on highly active metakaolin with glass waste

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Abstract
The paper studied the basic properties of cement-containing materials and considered the problems that occur during the operation of concrete products in case of exposure to adverse conditions, aggressive environments, and water. The most known methods of fighting the impact of water on products have been studied, and the influence of different microfilters on the properties of cement-containing materials has been analyzed; based on the analysis, the most effective microfilter, highly active metakaolin, has been selected.

Keywords: highly active metakaolin, aluminosilicate material, cement-containing materials, fast-hardening cement CEM I 42.5 B, glass waste, Sika hyperplasticizer

Introduction

In modern construction, cement-containing materials are the main materials used in a variety of qualities, for example, building and decorative materials that resist high temperatures and high forces. All this makes them the most versatile building material. Concrete is obtained by curing and compacting a mixture of solid fillers, water, binder plasticizers, and additives which provide the properties of a particular brand or class[1]. The geography of the application of concretes with high physical and mechanical properties is permanently growing, and the development of technologies in the field of materials science contributes to an increase in demand for such materials.

A wide variety of cement types and grades are used in major engineering applications such as building construction or prefabricated parts, and a wide range of construction chemicals industries. A wide range of base material variations and a wide range of final compositions allow almost any desired properties and requirements [2].

In many cases, other binders are used if changed general conditions or special requirements obligate to create new material properties. Environmental considerations, physiological classifications, or market trends are included in these.

Different dispersed mineral fillers [3] affect the characteristics and structure of concrete, namely, they contribute to the strengthening of the material, increase its strength, and water resistance and reduce water absorption [4].Consider the most known microfilters that are used in the manufacture of concrete, they include: silica fume, fly ash, limestone flour, and highly active metakaolin.Highly active metakaolin (HMC) is an aluminosilicate material, it is an artificially made pozzolanic additive with the highest activity among the active mineral additives available on the market. In particular, metakaolin is able to bind lime approximately 2.5 times more than micro silicawidely used in the construction industry [5].

Metakaolin is an aluminosilicate material obtained by calcining kaolin clay at a temperature in the range of of 650 to 900 ºC. At these temperatures, chemically bound water is released and the process of decomposition of crystalline kaolinite into amorphous metakaolin occurs [6].

$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$, (1.2)

Hence, kaolin cannot react with new formations of cement stone and is an inactive filler, reducing the material's strength properties. Metakaolin reacts with calcium hydroxide to form calcium silicate hydrates (CSH-gel) in concrete, along with crystalline products such as calcium aluminate hydrates and aluminosilicate hydrates, they replace calcium hydroxide, thereby contributing to the improvement of the microstructure of concrete.

$Al_2 Si_2 O_7 \cdot Ca(OH)_2 \cdot C \cdot S \cdot H, C_4 AH_3, C_4 AH_6$, (1.3)

The main distinctive feature of metakaolin from microsilica is its chemical nature. In the comparison with micro silica, metakaolin is a mixture of active silica and alumina in almost equal proportions, that is, it is not silicate, but aluminosilicate pozzolan.

Features of metakaolin include

Light color from white to cream, which makes it a practically uncontested material for modifying compositions based on white and colored cement in order to increase their weather resistance, water resistance, and, as a result, durability [7]. The above features of metakaolin determine the main areas of its application.

To study the effect of highly active metakaolin on the characteristics of water absorption and porosity of fine-grained concrete, the following materials were used: Portland cement CEM I 42.5 B without additives; glass waste was used as a fine aggregate. Highly active metakaolin VMK - 45 of white color was added in dry form from the mass of cement in the amount of 6%, 8%, 10%, and 15%. Samples of fine-grained concrete of series 1 were made in a cubic form with dimensions of 70 × 70 × 70 mm.

Samples of series 1 were kept for 7 and 28 days under normal curing conditions. Some of the samples after stripping were subjected to heat and moisture treatment, keeping a mild hardening regime - the temperature did not exceed 80°C, and the temperature drop did not exceed 25°C/h. Data on the decrease in water absorption of samples in 28 days from 7 days are summarized in table 1.

Table 1: Decreased water absorption of concrete samples at the age of 28 days in relation to the water absorption of samples at 7 days

№ parties	Number of IUDs	Curing conditions	Humidity reduction, %
2	0%	Normal conditions	11
		Steaming	13
3	6%	Normal conditions	15
		Steaming	12
4	8%	Normal conditions	20
		Steaming	11
5	10%	Normal conditions	27
		Steaming	13
6	15%	Normal conditions	37
		Steaming	7

According to the results, there is a fall in the water absorption of concrete samples with a rise in the concentration of the additive of highly active metakaolin. For samples aged under normal hardening conditions, the best results are observed in cases where the additive content is 10%, 15%.

In order to determine the effectiveness of the use of a hyper plasticizer in the concrete mixture and further evaluate its effect on water absorption and porosity of concrete, batches were made without the addition of a hyper plasticizer.

Concrete samples of series II were made in a cubic form with dimensions of 70×70×70 mm. The samples were kept for 7 and 28 days under normal hardening conditions, some were subjected to steaming in compliance with the mild hardening regime, but at the same time, an increase in the water absorption of samples containing highly active metakaolin without a plasticizer is observed, compared with control samples that do not contain metakaolin and hyper plasticizer.

It was established that the effect of temperature on concrete samples of the 2nd series had a negative effect, because of which the water absorption of concrete samples increased.

A sharp rise in water absorption can be observed when using the VMK additive with glass waste without a hyper plasticizer. The rise in water absorption when using highly active metakaolin without a plasticizer under normal conditions at the age of 28 days is on average 26%, and when steaming 42%.

The conducted studies show that the use of a highly active metakaolin additive with glass waste without the addition of a hyper plasticizer adversely affects the ability of concrete to absorb water.

Conclusion

1. The introduction of an additive of highly active metakaolin with glass waste into a concrete mixture can significantly reduce the porosity and water absorption of concrete products has been experimentally established.
2. With an increase in the addition of highly active metakaolin with glass waste to 15%, a drop in open porosity and water absorption of concrete is observed. The decrease in water absorption and open porosity of concrete with an increase in highly active metakaolin in its composition is explained by an increase in the amount finely dispersed additive in the composition of cement, which contributes to the creation of a microcapillary structure and a decrease in microcapillaries.
3. It has been established that the introduction of 15% VMK with glass waste into cement makes it possible to reduce the duration of heat-moist treatment of concrete by 2 hours compared to concrete without additives.
4. It has been established that concrete with the addition of VMK has the highest strength after 6 and 8 hours of steaming. Concrete with a content of 15% HMC has a strength of 10% higher compared to concrete without additives at the age of 28 days.
5. It has been established that VMK with glass waste contributes to an increase in the strength of concrete at an early age during steaming and an increase in the final strength of the product.
6. The necessity of the use of addition of highly active metakaolin together with a hyper plasticizer in the manufacture of concrete which helps to reduce a water demand of concrete mixture and the rise of strength of finished concrete products has been proved.

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