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Analysis Of The Use Of Microfillers In Cement Materials

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Abstract: The article analyzes the influence of various microfillers on the properties of cement-containing materials using the example of the most effective microfillers - highly active metakaolin, microsilica, fly ash and aluminosilicates.
Keywords: highly active metakaolin, microsilica, fly ash, aluminosilicate, microfiller, cement, concrete, clay-soil mixture.

Анализ Использования Микронаполнителей В Цементных Материалах

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Аннотация: В статье проанализировано влияние различных микронаполнителей на свойства цементсодержащих материалов на примере наиболее эффективных микронаполнителей — высокоактивного метакаолина, микрокремнезема, золы-уноса и алюмосиликатов.
Ключевые слова: высокоактивный метакаолин, микрокремнезем, летучая зола, алюмосиликат, микронаполнитель, цемент, бетон, глинисто-грунтовая смесь.

Various types and grades of cement are used in basic engineering applications such as construction or prefabrication, as well as in a wide range of industries producing construction chemicals. The wide possibilities of modifying the base material and significant changes in the final composition allow creating almost any desired properties and satisfying any requirements. In addition, cementitious and non-cementitious binders are used in standard industries, for example, in the production of gypsum, lime plaster or anhydrite mortar.

Various dispersed mineral fillers affect the properties and structure of concrete, i.e. they help to strengthen the material, increase its strength, water resistance, and reduce water absorption.

The most popular microaggregates used in the production of concrete are: microsilica, fly ash, limestone flour and highly active metakaolin.

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Microsilica is a highly reactive pozzolanic additive, which is a dispersed powder and a by-product of silica smelting. It is intended for the production of concrete with high performance properties. The advantages include: good abrasion resistance, low permeability for gases and water, high bonding between the components of mixtures with microsilica, which do not stratify, reduced cement consumption, high strength of the material and increased corrosion resistance. The particle size of microsilica is 0.1–0.2 µm, which is approximately fifty times smaller than that of fly ash. Microsilica reacts with calcium hydroxide, and the high fineness and purity of the material contribute to its rapid and effective reaction. The average amount of microsilica in a concrete mixture is from 10 to 30% of the weight of cement.

Fly ash is a finely dispersed material with small particles and is used in the production of concrete without additional grinding. A characteristic feature of fly ash is the presence of unburned fuel and iron in its composition. The size of fly ash is less than 0.315 mm. Fly ash is formed by burning solid fuels in the presence of oxygen at temperatures around 800°C.

Fly ash is obtained from anthracite, coal and lignite. Ash can be acidic or alkaline depending on the calcium oxide content.

The use of fly ash increases the strength of concrete products, improves workability, reduces shrinkage, increases water resistance and increases fire resistance. Its main disadvantages: increased control of mixture components, decreased initial strength at low temperatures.

One of the most effective groups of additives is the aluminosilicate group. Their main components are sources of silicon dioxide (SiO_2) and aluminum oxide (Al_2O_3), such as slag, ash or activated clay, as well as alkali-activated components such as liquid glass or alkali and hydroxide solutions.

The use of aluminosilicates in the preparation of concrete mixtures leads to a change in the structure of the cement stone in the hardened concrete, that is, to its compaction. This effect is due to the fact that the average grain size of aluminosilicate additives is smaller than that of the binder, which is the effect of "micro concrete", i.e. intergranular voids are filled with active grains of mineral additives, which enter into chemical interaction with the hydration products of clinker minerals, as well as mixed alkali oxides, which leads to the formation of new dense water-insoluble formations.

The result of the interaction of aluminosilicates with the components of cement stone is a significant compaction of the structure of hydrated layers formed during the hardening of concrete, which increases the density, water resistance, corrosion resistance and strength of concrete. Since the introduction of aluminosilicate-based additives into the concrete composition interacts with hydrolyzed lime (portlandite), formed during the hydration of the main clinker minerals (alite and belite), as a result of hardening, the concrete not only increases in density, but also has high performance indicators, as well as high resistance to the main types of chemical corrosion of concrete.

Highly active metakaolin (HAMK) is an aluminosilicate material, which is an artificial putzsolan additive with the highest activity among active mineral additives. In particular, metakaolin has a lime binding capacity of approximately 2.5 times higher than microsilica, which is widely used in the construction industry.

Metakaolin is an aluminosilicate material obtained by calcining kaolin clay at temperatures from 650 to 900 ^{0}C. At these temperatures, chemically bound water is released and the process of decomposition of crystalline kaolinite into amorphous metakaolin occurs.

$$2SiO_2 \cdot Al_2O_3 \cdot 2H_2O = 2SiO_2 \cdot Al_2O_3 + H_2O,$$

Since kaolin cannot react with new cement stone derivatives and is an inactive filler that reduces the strength properties of the material. Metakaolin in concrete reacts with calcium hydroxide to form calcium silicate hydrates (CSH-gel) and forms crystalline products such as calcium aluminate hydrates and aluminosilicate hydrates, which replace calcium hydroxide and thereby help improve the microstructure of concrete.

$$Al_2Si_2O_2 + Ca(OH)_2 \rightarrow C-S-H,\ C_4AH_3,\ C_4AH_6,$$

The main distinguishing feature of metakaolin from microsilica is its chemical nature. Unlike microsilica, metakaolin is a mixture of active silica and alumina in almost equal proportions, that is, it is not a silicate, but an aluminosilicate pozzolan.

The properties of metakaolin are as follows:

- Light color from white to gray, which makes it an almost non-alternative material for modifying white and colored cement-based compositions to increase weather resistance, water resistance and, as a result, strength.
- In its form, metakaolin is a plate-like particle with an average size of 1-2 µm. These particles are an order of magnitude smaller than Portland cement particles, which allows for the finalization of their granulometry.

Thus, the inclusion of metakaolin in cement concrete allows:

- Increase the plasticity and workability of concrete mixtures.
- Significantly reduce the consumption of superplasticizers required to compensate for the thickening effect when introducing a finely dispersed additive into cement. In particular, with a reasonable choice of dosage of metakaolin and plasticizer, the workability of concrete with metakaolin can be even higher than the workability of concrete of the same composition with the same amount of plasticizer, but without metakaolin.

Areas of application of metakaolin:

- The above properties of metakaolin determine the following main areas of its application.
- Heavy concrete, including high-strength and self-compacting.

Reducing the dosage of cement in the production of concrete has always been a target task in the problem of optimizing the composition of the concrete mix. This is important both from an economic point of view, which is especially relevant in connection with the recent rapid growth of cement prices, and from the point of view of improving the properties of concrete, in particular, reducing their shrinkage and compression deformations.

In combination with the use of highly effective plasticizers, metakaolin allows to significantly reduce the cement content in concrete formulations, especially in concrete with high requirements for water resistance and frost resistance.

Thus, the conducted analyses showed that the most effective microfiller in terms of the effect of various microfillers on the properties of cement-containing materials is highly active metakaolin.

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