UDC 666.972.16

PROSPECTS AND HYPOTHESES: MULTICOMPONENT SYSTEMS AND TARGETED STRUCTURE MANAGEMENT

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Abstract: The article is dedicated to a promising direction in concrete technology - the use of binary and multicomponent aggregate systems. A scientific hypothesis about the targeted control of the microstructure by combining fillers with different surface activity has been substantiated. The principle of dense packing of particles is considered.

Introduction. The current trend in cement technology development is the transition from mono- to multicomponent systems. The use of two or more types of finely dispersed fillers allows achieving a synergistic effect exceeding the result of their separate application and creating materials with fundamentally new properties.

Scientific hypothesis of targeted management of the structure

The prospective approach is based on the hypothesis of the need to combine fillers with different surface activity:

1. **Fillers with high surface activity ($Fn \geq Fv$):** For example, microsilica or metakaolin. Their particles serve as highly active crystallization centers, intensively accelerating hydration in the early stages and contributing to the formation of a strong matrix framework [1].

2. **Fillers with low surface activity ($Fn < Fv$):** For example, finely ground limestone or sand. These particles, when embedded in the structure, reduce internal stresses at the interface boundaries of the phases, contributing to the formation of a more ordered and stable microstructure, minimizing the risk of microfracture formation at the later stages of hardening [2].

By combining such fillers, it is possible to control the structure formation processes separately at different stages: achieving high early strength and simultaneously ensuring high durability.

Principle of dense packing of particles

The effectiveness of multicomponent systems is also explained by a fundamental physical principle - achieving the maximum density of packaging of particles of different sizes. Particles of aggregate, cement, sand, and gravel form a multimodal system, where smaller fractions fill the voids between larger ones [3,4].

• Crushed stone voidiness ~45%.

• When sand is added, the void content decreases to ~25%.

• The introduction of finely dispersed cement fractions and microfillers allows for a reduction in voidiness to 10% or less.

This leads to the creation of a super-dense matrix with minimal porosity, which is the key to high strength, low permeability, and consequently, the exceptional durability of concrete [5].

Examples of synergetic systems

• Limestone + Microsilica: Limestone provides good early strength and improves the rheology of the mixture, while microsilica, by entering into the pozzolan reaction, provides high final strength and durability.

• Ash removal + Metakaolin: Ash removal reduces heat generation and cost, while metakaolin compensates for delayed strength gain in early stages and increases sulfate resistance [6].

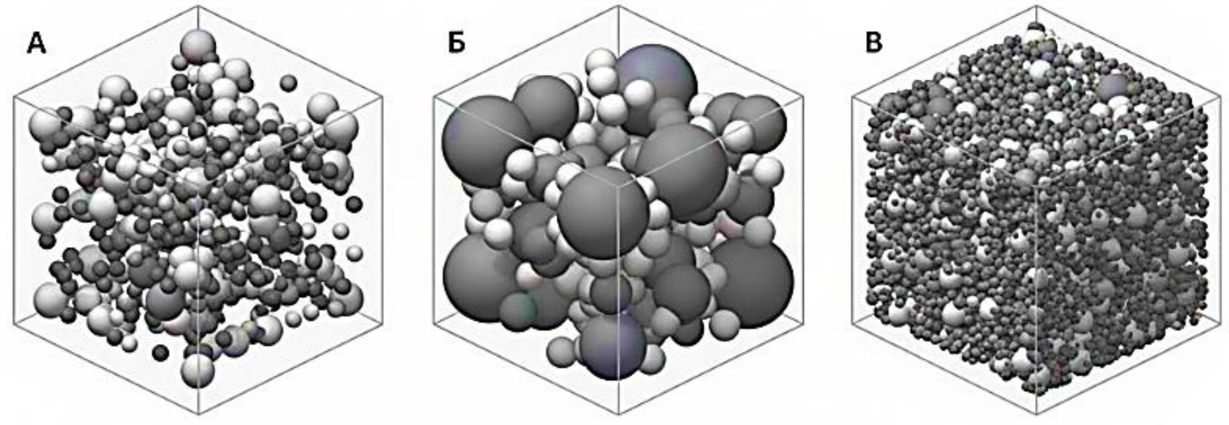

Figure 1. Spatial-structural topology of a binder

A - Dispersity of mineral filler higher than cement dispersity; B - The dispersity of the mineral filler is significantly lower than the dispersity of cement; B - The dispersity of binary mineral filler is greater and less than the dispersity of cement (optimal packaging).

Conclusion and prospects. The development of cement composites based on multicomponent filler systems represents a transition from empirical selection to precise engineering design of materials with specified properties. Further research in this area will allow for the creation of highly effective and environmentally friendly concretes capable of meeting the most complex requirements of modern construction, from skyscrapers to structures in aggressive environments.

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