

ABSTRACT
for the PhD dissertation of Adlet Muzafaruly Zhagifarov entitled
“Improving the Operational Reliability of Self-Compacting Concrete Using
Various Modifiers,” submitted for the degree of Doctor of Philosophy (PhD) under
the educational program 8D07305 - “Construction and Production of Building
Materials and Structures.”

Relevance of the Study. Modern architectural and civil engineering practices impose increasingly stringent requirements on the strength, reliability, and long-term performance of concrete structures, particularly in relation to resistance to cracking, corrosion, and exposure to severe environmental actions. In this context, self-compacting concrete (SCC) occupies a significant position, as it is capable of forming a dense and homogeneous structure without the need for mechanical vibration. This characteristic makes SCC especially suitable for complex structural elements and reinforced members with densely arranged steel bars, where conventional compaction methods are difficult to apply or prove ineffective.

Despite the evident technological advantages of SCC, its application in Kazakhstan and other CIS countries remains limited. One of the key reasons lies in the specific features of the local strongly continental climate, characterized by sharp seasonal and diurnal temperature fluctuations, which impose higher requirements on freeze–thaw resistance and overall thermal stability. Furthermore, there is currently a lack of practical guidelines regarding the use of mineral and chemical modifiers tailored to local raw materials and construction conditions.

International research demonstrates that the incorporation of silica fume, fly ash, metakaolin-based additives, and modern high-range polycarboxylate-based superplasticizers contributes to densifying the cementitious matrix, reducing capillary permeability, and enhancing the corrosion resistance of reinforcing steel. These factors are particularly critical for Kazakhstan, where reinforced concrete structures are frequently exposed to freeze–thaw cycles, meltwater, and salt-induced degradation.

In light of the above, the purpose of the present study is to develop and experimentally validate a modified self-compacting concrete formulation aimed at enhancing its operational reliability and long-term durability under the climatic conditions of Kazakhstan.

Research Aim and Objectives

The primary aim of this study is to develop optimized mix designs for self-compacting concrete incorporating various chemical and mineral modifiers. It is assumed that an integrated approach to mix design will not only enhance the technological performance of the material but also ensure improved operational reliability during long-term service, including under adverse climatic conditions and aggressive environmental exposures. Ultimately, the research is directed toward creating a concrete that is capable of maintaining stable performance characteristics under real operating conditions.

To achieve this aim, a system of research objectives was formulated, each reflecting a specific stage of experimental design and implementation:

1. To develop a methodological framework for the comprehensive evaluation of the effects of various modifiers on the properties of self-compacting concrete. Particular attention is given to the integration of laboratory procedures and assessment criteria that enable an objective determination of admixture effectiveness.

2. To determine the rheological characteristics of self-compacting concrete mixtures incorporating different types and dosages of modifiers, thereby enabling the assessment of their influence on flowability, structural stability, and the material's capacity for self-compaction.

3. To investigate the physico-mechanical and operational performance of the modified mixtures, including compressive strength, frost resistance, water tightness, and other key parameters that govern the long-term durability of concrete.

4. To evaluate the influence of chemical and mineral additives on cement hydration, microstructural formation, and the density of the hardened matrix, which will allow the establishment of correlations between microscopic mechanisms and macroscopic operational performance.

Object of the study

The object of the study comprises self-compacting concrete mixtures and hardened concrete specimens modified with various mineral and chemical admixtures.

Subject of the study

The subject of the study is the set of regularities governing changes in the rheological, physico-mechanical, and operational properties of self-compacting concrete under the influence of silica fume, fly ash, and polycarboxylate-based superplasticizers.

Scientific novelty

- The regularities governing the influence of various mineral and chemical modifiers on the hydration process and the formation of the microstructure of self-compacting cementitious matrices have been identified and evaluated.

- Experimental results demonstrate that the combined use of silica fume, fly ash, and polycarboxylate-based superplasticizers leads to a measurable improvement in the operational reliability of self-compacting concrete.

- An optimized self-compacting concrete composition is proposed. Compared with the control mixture, the modified concretes exhibit increased frost resistance and water impermeability, while chloride-ion penetrability is reduced by more than 30%.

Research methodology

The methodological framework of the study is based on a comprehensive approach that combines theoretical analysis of current scientific literature and standards with full-scale experimental investigations. The applied methods include:

- Calorimetry – determination of exothermic heat release during cement hydration;
- Rheometry – assessment of rheological behaviour of fresh mixtures;
- Scanning Electron Microscopy (SEM) – microstructural characterization of cementitious matrices;

- X-ray Fluorescence (XRF) spectroscopy – determination of elemental composition;

- Standardized testing methods for compressive strength, frost resistance, water impermeability, and corrosion resistance.

Practical significance

The research outcomes substantiate optimized self-compacting concrete mix designs suitable for construction conditions in Kazakhstan. The developed recommendations can be applied in the design and construction of transport, civil, and industrial infrastructure, as well as in the production of precast reinforced concrete elements. Implementation of the proposed compositions enhances structural durability, reduces long-term maintenance costs, and supports the adoption of principles of sustainable construction.

Approbation of the Research

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