



## PHYSICOCHEMICAL PROPERTIES OF COLLOIDAL SYSTEMS AND THEIR SIGNIFICANCE IN THE TECHNOLOGY OF MODERN CEMENT-BASED COMPOSITE MATERIALS

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**Abstract:** This thesis discusses the physicochemical properties of colloidal systems, their role in the formation of cement-based composite materials, and their significance in modern construction technologies. Based on scientific literature, it analyses the hydration process that occurs when cement interacts with water, interparticle interactions, the degree of dispersion, and the effects of chemical admixtures. The control of colloid-chemical processes is considered in relation to opportunities to improve the workability and setting behavior of cement mixtures, as well as the final strength of the hardened material.

**Keywords:** colloidal system, cement, dispersed phase, hydration, composite material, superplasticizer, physicochemical properties.

### INTRODUCTION

Today, improving the quality of construction materials, extending their service life, and using resources efficiently in production are important scientific and practical objectives. Studying the principles of colloid chemistry is particularly important for addressing these objectives, because the properties of many construction materials depend on particle size, surface structure, interparticle interactions, and their state in a liquid medium.

When cement is mixed with water, complex physicochemical processes begin. The mineral compounds in cement react with water to form new hydrated compounds. During these processes, particles may approach one another, aggregate, and develop a spatial structure. As a result, the initially fluid mixture gradually hardens and becomes solid cement stone. Therefore, studying cement systems from a colloid-chemical perspective provides a theoretical basis for controlling their properties.

### MAIN BODY

Colloidal systems are complex systems in which very small particles of one substance are dispersed in a medium consisting of another substance. Their principal characteristics include a large specific surface area of the particles, a pronounced influence of surface phenomena, attractive and repulsive interparticle forces, and stability that depends on the physicochemical properties of the medium.

During the preparation of a cement mixture, a system of solid particles dispersed in water is formed. Interactions between the particles affect the mixture's flowability, thickening, and the gradual development of its structure over time. If particles approach one another and form



aggregates, the mobility of the mixture may decrease. More uniform particle dispersion, by contrast, can improve the mixture's workability.

When studying the physicochemical properties of cement systems, water plays a fundamental role. As demonstrated by Ridi et al. (2018), water acts as an essential probe of the colloidal properties of cement, providing key insights into the interfacial phenomena and interactions occurring at the particle surface.

The hardening of cement cannot be explained solely by the evaporation of water. It is primarily caused by the chemical reactions of the mineral compounds in cement with water—that is, by hydration. As highlighted by Scrivener et al. (2015), this process produces calcium silicate hydrates (C-S-H) and other hydration products, which play a crucial role in developing the microstructure and mechanical strength of cement stone. The formation and growth of hydration products strengthen the bonds between particles and lead to the development of a coherent structure.

Chemical admixtures play an important role in improving the properties of modern cement-based composite materials. Polycarboxylate-based superplasticizers, synthesized via radical polymerization, adsorb onto cement-particle surfaces and significantly affect particle aggregation (Karimov and Ismailov, 2025; Sha et al., 2020). As a result, particle dispersion improves, making it possible either to increase the flowability of the mixture or to maintain a similar level of workability while using less mixing water (Sha et al., 2020). Furthermore, Abdullaev et al. (2024) emphasize that the application of complex admixtures, superplasticizers, and fillers in cement concretes substantially enhances their technological and operational performance.

When examining cement systems, factors such as particle size distribution, surface charge, medium pH, water-to-cement ratio, and hydration rate must be comprehensively evaluated to control the rheological behavior, setting kinetics, and ultimate strength of the material.

## CONCLUSION

Studying the physicochemical properties of colloidal systems makes it possible to gain a deeper understanding of the processes involved in the formation of cement-based composite materials. Interactions between cement particles, surface phenomena, hydration, and the effects of chemical admixtures are critical factors that determine the workability of fresh mixtures and the performance characteristics of hardened materials.

An analysis of the scientific literature indicates that controlling colloid-chemical processes provides a robust theoretical foundation for optimizing modern cement technologies. Further experimental research into the dosage and impact of mineral additions and superplasticizers, alongside the correlation between physicochemical parameters and mechanical strength, remains highly relevant.

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