Transactions on Engineering and Computer Science

Research| Vol 2 Iss 1

Increasing the Early Strength of Concrete

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Received: February 09, 2021; Accepted: March 14, 2021; Published: March 22, 2021

Abstract

The early compressive strength of concrete is investigated. The influence of complex organic ions and molecules of a number of non-electrolytes, due to the inhibitory effect of dissolved particles on the translational motion of water molecules in a solution, has been established. It was found that these substances alter the formation of concrete strength. The rate of formation of concrete strength in the early stages increases due to the dissolution of cement particles with structured water. It was found that the effect of complex organic ions and molecules of a number of non-electrolytes on the strength of concrete exceeds the effect of solid nanomodifiers, in particular, carbon nanotubes, silicon oxide, and others. When using complex organic ions and molecules of a number of non-electrolytes as individual modifiers of water used for concrete preparation, their optimal amount is 8 10^{-4}...9 10^{-4}% of the cement mass. The increase in the strength of concrete at an early age reaches 170%, and at the age of 28 days - 35%. The mechanism of action of modifiers of this type is that they structure water due to hydrophobic hydration and the effect of "small doses".

Keywords: ***Concrete; Strength; Complex organic ions; Non-electrolyte molecules; Nanomodifier; Cement; Oleate; Sodium.***

1. Introduction

In recent years, a high rate of strength development has been considered an important indicator of modern concrete. Considering that in conditions of monolithic construction, concrete hardening is carried out without the use or with limited use of heat treatment, the question of accelerating the hardening and forming the strength of concrete on conventional cements becomes fundamental. The kinetics of an early increase in strength predetermines the time to reach the strength to remove the formwork, as well as the timing of removing the formwork, changing the tool and, in

Citation: Shyshkina A and Shyshkin A. Increasing the early strength of concrete. Trans Eng Comput Sci. 2021;2(1):220.

general, the duration of the building construction process. In [1] - [4], the results of the authors' research on the development of a method for accelerating concrete hardening without the use of special chemical additives for the manufacture of reinforced concrete structures without thermal moisture treatment are presented. As a result of the research, it was found that the introduction of hydrophobic surfactants into water, which is intended for the preparation of concrete, leads to an increase in the rate of formation of concrete strength and the value of this strength. It has been proven that hydrophobic surfactants of the aliphatic type are most effective. Cyclic hydrophobic surfactants do not provide the specified effect. The influence of the type of hydrophobic surfactant is explained by the mechanism of hydrophobic interaction in the system "water - hydrophobic surfactant" [1]. In general, water is a liquid with a high structure and partial retention of the ice tetrahedral openwork structure and the presence of unbound water molecules. The specific structure of water is the cause of hydrophobic interactions between non-polar molecules or radicals in an aqueous medium. According to A. Samoilov [5], hydrophobic hydration is designed to stabilize the structure of water with solute particles. The main reason for the resulting hydrophobic interactions arises from the structural changes that occur in water when hydrocarbons are dissolved in it. Thus, hydrophobic interactions occur only in aqueous solutions between polar water molecules and non-polar hydrophobic particles or radicals of molecules, in particular with radicals of surfactants. In studies [1] - [4] used hydrophobic surfactants, which are salts of alkali metals. In this case, a hydrophilic alkali metal (Na) ion is introduced into the water together with the hydrophobic carbon radical. The diagram of hydration of a hydrophobic surfactant molecule is shown in Fig. 1.

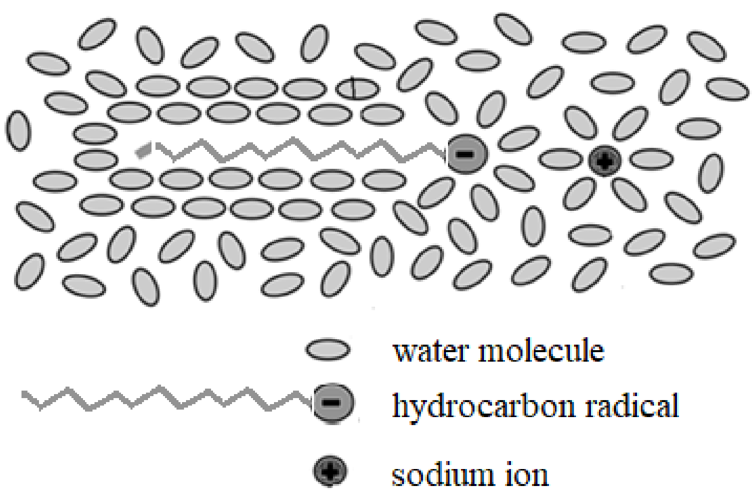

Fig. 1. Scheme of hydration of a hydrophobic surfactant molecule.

Therefore, in this case, part of the surfactant molecule is involved in hydrophobic hydration (hydrocarbon radical), and part of the molecule (sodium ion) is involved in hydrophilic hydration. It's the same with water molecules.

The presence of two types of hydration of the surfactant molecule obviously has a certain effect on the processes of cement hydration.

In [1] - [4], the effect of using non-polar hydrophobic particles was not studied. Therefore, the development of ideas about the early strength of cement stone and concrete, taking into account the mechanism of hydrophobic hydration, remains an unsolved scientific problem.

Based on the foregoing, the goal was set to evaluate the effect of using non-polar hydrophobic particles (molecules of organic substances) in the formation of the early strength of concrete, which was achieved during the research.

2. Materials and Methodology

2.1. Materials

Portland cement 42.5 “Heidelberg Cement. Kryvyi Rih "(Ukraine), as a fine filler - river sand with particle sizes from 0.001 to 2.0 mm. As a hydrophobic substance (MPAR), we used: sodium oleate (Simagchem Corp., China), sodium dodecanoate (Hinreakt, RF), a nonionic composite (Novokhim Company, Kharkov, Ukraine).

2.2. Methodology

All hydrophobic substances were dissolved in water to a concentration of 0.001. An aqueous solution of a hydrophobic substance in an amount calculated in accordance with the experimental plan was added to a container with a measured amount of water to prepare concrete. The concrete mixture was prepared in a 5 liter forced mixer. The components were dosed by weight, first mixing the dry components and then adding an aqueous solution of a hydrophobic substance or only water. The mixing time for one mixture was 3 minutes. Control samples 40x40x160 mm in size were formed on a standard laboratory vibrating table with an oscillation frequency of 50 Hz and an amplitude of 0.35-0.5 mm. The samples were stored at a temperature of (293 ± 2) K and a relative humidity of (95 ± 5) %, and the compressive strength was determined at an early age according to the requirements of the standards.

The disclosure of the mechanism of influence of colloidal hydrophobic surfactants on the structure was carried out through theoretical studies. Modeling of the structure of the water structure was carried out taking into account the known results of research, which were presented in the scientific literature. To confirm the results of theoretical research, measurements of the hydrogen pH and electrical conductivity of suspensions were performed.

3.Results and Discussion

3.1. Results

Fig. 2 shows the change in the relative compressive strength of an artificial stone formed as a result of hardening of the "cement - water - surfactant" system, depending on the type of surfactant.

First of all, it should be noted the presence of the greatest effect of increasing the strength of concrete, which was provided by sodium oleate, a modifier that contains ions, (an increase in the compressive strength of concrete at the age of 2 days to 67%).

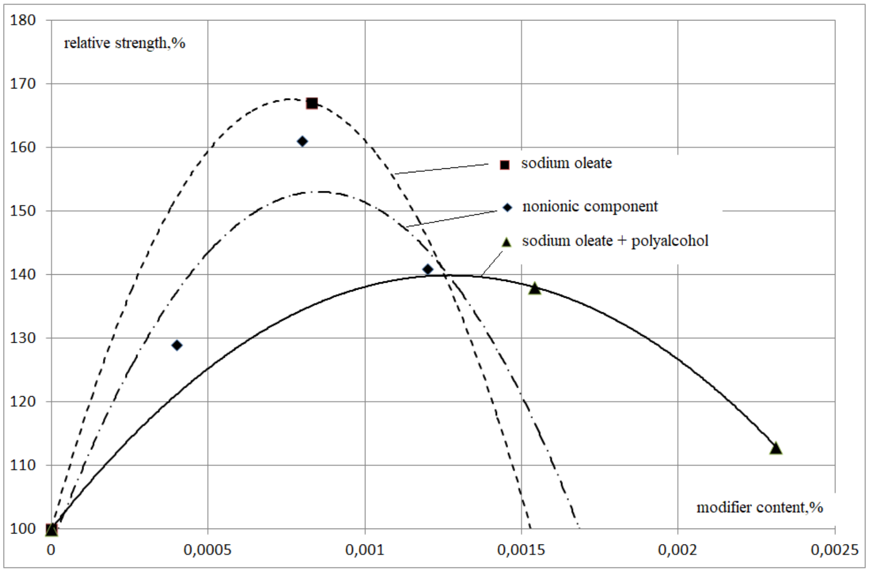

Fig. 2. Relative strength of concrete at the age of 2 days (the strength of concrete without additives is taken as 100%).

First of all, it should be noted the presence of the greatest effect of increasing the strength of concrete, which had a modifier containing ions - sodium oleate (increasing the compressive strength of concrete at the age from 2 days to 67%). At the same time, the use of a non-ionic organic substance as a modifier of the structure of water provides an increase in the strength of concrete at the age of 2 days by 61%, which corresponds to the effect of using a modifier containing ions. Thus, it was found that the type of hydrophobic modifier of the structure of water (ionic or non-ionic) has practically no effect on the change in the strength of concrete, both at an early age and at a later age (Fig. 3).

By processing the experimental results, regression equations were obtained, which made it possible to determine the value of the optimal content of modifiers:

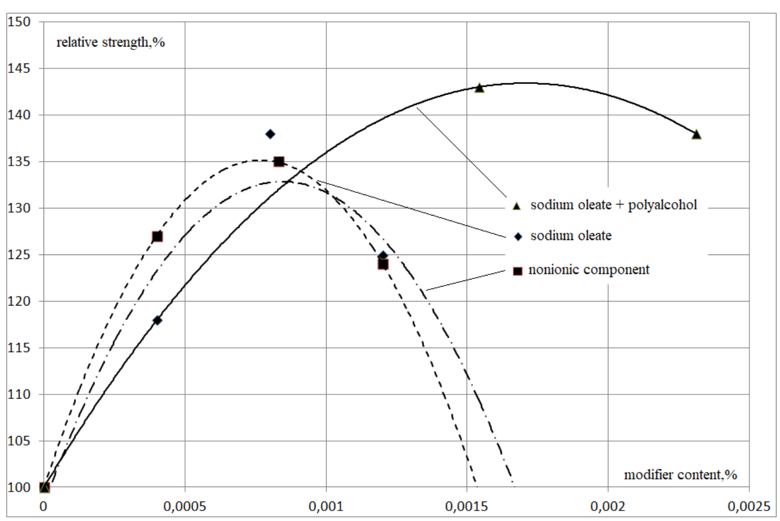

Fig. 3. Relative strength of concrete at the age of 28 days (the strength of concrete without additives is taken as 100%)

for a modifier that dissociates into ions:

$$y = -100000000 \cdot x^2 + 176460x + 100 \quad (1)$$

x_{opt} = 0,00088%.

For a modifier that does not dissociate into ions:

$$y = -80000000 \cdot x^2 + 130625x + 100 \quad (2)$$

x_{opt} = 0,00082%

Thus, the possibility of using organic substances containing a hydrocarbon radical for the modification of the structure of water has been established to increase the early strength of concrete.

This phenomenon can be explained on the basis of the fundamental principles of colloidal chemistry and physicochemical mechanics of dispersed systems [6], [7], considering the structure of cement stone [8], [9] as a dispersed system.

3.2. Discussion

Until now, many problems of the mechanism of the processes of hydration and hardening of cement are debatable, and there are no unambiguous answers to the questions that arise on these problems [6] - [10]. According to [11], [12], the consequence of plastic deformations during cement grinding is a number of experimentally observed irreversible transformations, which make it possible to record and measure some of its aspects: a decrease in density, polymorphic inversions, and amorphization of surface layers of particles. Such activated layers are characterized by abnormally high chemical activity and sorption capacity, as well as abnormally low diffusion resistance.

When mixing cement with water, according to [11], [12], the surface layers of cement particles activated during grinding interact intensely with molecules of the external environment - water, and undergo mechanical destruction. Water chemically binds to the amorphized cement minerals of the surface layers of its particles and penetrates deep into them. The diffusion rate in destructed layers of cement particles activated by plastic deformation is several orders of magnitude higher than the diffusion rate in ordinary crystals and glasses. This type of sorption and interaction, both in intensity and mechanism, is not substantially identical to physical (reversible) adsorption and classical chemisorption. As a result of these processes, active complexes "cement mineral - water" are formed. Since in this case water is structured by hydrophobic hydrocarbon radicals of activators as a result of hydrophobic hydration, and its molecules have an increased value of interaction forces, water molecules do not attach to the cement minerals (cement hydration in the solid phase). In this case, the water separates these minerals and they go into solution. Thus, there is an intensive dissolution of cement particles and their hydration in the solution, which leads to an increase in the rate of formation of the structure of the cement stone and, as a consequence, to the acceleration of the formation of its strength.

4. Conclusion

The results of the studies carried out allow us to draw the following conclusions.

Organic substances, which include a hydrocarbon radical or other hydrophobic elements, cause the structuring of water. Structured water, absorbed by a hyperamorphized layer that forms on the surface of cement particles during grinding, provides a high degree of dissolution of these particles and, as a consequence, an increase in the rate of their hydration. The maximum effect is achieved when the content of these substances is from $8 \cdot 10^{-4}$ to 10^{-6} % by weight of cement. At an early age, the strength of concrete increases by 70%, and at the age of 28 days - by 40%. The mechanism of action of water modifiers of this type and application is the structuring of water due to the process of hydrophobic hydration and the implementation of the "low dose effect". The effect of the amount of surfactant dilution to the desired concentration on the properties of concrete remained without research.

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