Methods of increasing the initial strength of winter concrete

R T Brzhanov[1], G A Pikus[2], M Traykova[3]

[1]Department of Building, Caspian State University of Technology and Engineering named after Sh. Esenov, 32 Microdistrict, Aktau 130003, Republic of Kazakhstan
[2]Department of Building Construction and Structural Theory, South Ural State University, 76, Lenin Avenue, Chelyabinsk 454080, Russia
[3]Department of Building Construction Reinforced Concrete Structures, University of Architecture, Civil Engineering and Geodesy, 1 Hr. Smirnenski Blvd., Sofia 1046, Bulgaria

E-mail: brzhanov@mail.ru

Abstract. The article analyses the stages of hardening and reaction of cement hydration. The relationship between the rate of hydration of cement minerals and the initial strength of concrete has been established. The initial strength of concrete plays a very important role in winter concreting. From the strength of concrete to freezing depends the course of destructive processes in solid concrete. Minerals, the products of cement hydration, have a different rate of formation and different strength. So, weak minerals are formed at the very beginning of hardening and have a low strength. And these weak minerals of cement screen inhibit the formation of stronger minerals. The technological method of destruction of weak bonds of cement minerals is re-vibrating the concrete mixture. Repeated vibration will destroy these new formations of cement, with the possibility of the formation of more durable minerals of cement. The number of weak neoplasms during the hydration of cement depends on its mineralogical composition. The period and intensity of re-vibrating to optimize the strength of winter concrete is set individually, depending on the type of cement and climatic conditions of construction. The results of comparative experiments on the influence of the amount of vibration of a concrete mixture on the strength of winter concrete are presented.

1. Introduction

The urgency of the problem lies in the need to improve the durability of materials and products obtained from multicomponent chemical compounds. Concrete and reinforced concrete, in fact, are products of chemical transformation of dry, loose components in a firm rock, after big interaction with each other in the presence of water. And how will the reaction between the components of concrete, and whether it will, first of all, depends on external influences. Centuries-old construction practice, based on the use of different materials, has developed a number of special technologies that meet the relevant changes in the environment [1] this is especially true for the construction of monolithic reinforced concrete buildings.

This technology increases the efficiency of construction, it becomes possible a variety of architectural expressive and spatial planning solutions. These and other advantages of concrete are not fully realized, since the patterns of interaction that make up the singularity of these systems are based on deformability, strength characteristics, insufficiently studied in early freeze concretes.

The properties of the finished monolithic concrete structure are due to the effect of temperature, humidity, and the possibility of hydration of cement at negative temperatures. When hydrating cement, various minerals are formed [1-3]. Minerals of new cement formation have different strength and speed of formation. The weakest cement minerals [4-6] are formed at the initial moment of hardening of concrete and shield the formation of the most durable minerals of cement [7]. In addition, the initial temperature of the concrete mix and the ambient temperature have a significant effect on the quality of the finished monolithic concrete.

2. Analytical solution of the problem

It has been established that the main factors influencing the strength are the different ability of concrete to make up chemical reactions depending on the temperature and humidity of the environment and the time of exposure of these conditions to hardening concrete. The degree of influence of technological and operational influences on the properties of prepared concrete and mortar is determined at experimental determination of strength, thermal properties and analytical dependencies compiled on the basis of research. The conditions for creating the required concrete properties and for solving the technological impact are determined [8]. The features of the state of concrete after short-term and long-term recruitment freezing are determined, their compressive strength and stretching after thawing. The dependence for calculation of external applications of negative temperatures is formalized. The dependence of the compressive strength and tensile strength with chemical additives has been revealed [9].

The most important parameter of the technology of winter concreting is the duration and period of vibration of the concrete mixture. However, many authors have been considering the vibrating of a concrete mixture only as a method of compacting and laying concrete [10-12]. Vibration is not considered as a factor in the activation of cement.

3. Purpose and objectives of research

The aim of the study is to develop ideas for hardening early-freezing concrete by breaking down weak cement minerals by repeated vibrations. To achieve the goal of the study, it is necessary to solve the following tasks: set the time of repeated vibration impact on the concrete mix. The re-vibration time must be related to the rate of formation of such hydrosilicates and calcium hydroalumates such as calcium hydroalumates $4CaO * Al_2O_3 * 19H_2O$ and $3CaO * Al_2O_3 * 3CaSO_4 * 31H_2O$, oxenite $CaO * 2SiO_2 * 2H_2O$. Repeated vibration will destroy these new formations of cement, and it becomes possible to form stronger cement minerals such as gilebrandite $2CaO * SiO_2 * 1{,}17H_2O$, phoshagite.

4. Research methodology

Methods are known for compacting a concrete mixture by vibrating and re-vibrating to maximize its compaction. A drawback of the known methods is the low strength of concrete in the initial period of its hardening [13].

The technical result is achieved by the fact that the repeated vibration of the concrete mix destroys the rapidly hydrating and weak minerals of cement, thereby enabling the hydration reaction of stronger cement minerals.

As shown in Figure 1, the concentration of binders in the solution always passes through a maximum, and can be considered as an intermediate stage of a sequential hydration process. Consequently, by the time variation of the concentration of the initial binder, dissolved in the liquid phase, it is possible to determine when and which of the processes - the dissolution of the astringent or the release of tumors - as the slowest limit the entire course of hydration as a whole.

All mineral binders can be divided into two types: fast-hardening (for example, calcium sulfate hemihydrate) and slow-hardening (silicate components of Portland cement), for fast-hardening binders, the dissolution rate of which is very high, for a sufficiently long period (up to 20-30% of the total hydration time), the rate of the process limits the crystallization of the new phase.

This is evidenced by the presence of a plateau on curve 1 (Figure 1), whose height, in this case corresponding to the solubility of the binder, does not depend on the hardness of the water even when it significantly changes. The process of dissolution for such binders becomes limiting only after their concentration in the solution begins to decrease as a result of the crystallization of the substance per unit time exceeds the amount of material entering the liquid phase at the same time due to dissolution of the initial binder.

For slow-hardening binders, the maximum on the concentration change curve (curve 2 in Figure 1), corresponding to the condition $dCmax / dt = 0$ is achieved in a time $t_0 < tr_{kr}$.

Is incommensurable before the process of hydration of the bulk of the binder is completed. This means that during most of the main hydration period, the kinetics of this process is limited by the binder dissolution stage, as the slowest, and the dissolution process itself proceeds in the diffusion region. The maximum concentration of the substance in the liquid phase for slow-hardening binders, as a rule, does not correspond to their solubility. In any case, one can never be sure that the concentration of a monomineral binder that corresponds to the solubility of this metastable phase is reached.

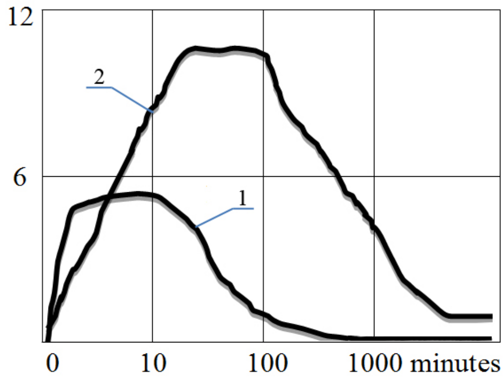

Figure 1. Kinetics of the change in the concentration of the substance in solution. 1. Calcium sulfate hemihydrate ($CaSO_4$), C*104Ca_2SiO_4, mol/l; 2. Two-calcium silicate (Ca_2SiO_4), C*102 $CaSO_4$, mol/l.

The peculiarities of the hydration processes of binders of the two types should be taken into account because in their kinetics there are some quantitative (but by no means qualitative) differences. Thus, for fast-hardening binders, a well-known theoretical equation gives an adequate approximation. Kolmogorov, derived on the assumption that crystallization proceeds from the liquid phase, the rate of nucleation of the centers and the linear rate of their growth remain constant all the time, and the crystals grow at the same speed in all directions, maintaining a spherical shape until the moment of contact with other crystals.

We investigated the methods of increasing the strength of concrete with the technological parameters of the preparation of concrete mix, re-vibrating. The theoretical basis for performing the experiments was the position known from the chemistry of cement that the minerals of cement clinker have different rates of hardening. And the weakest minerals crystallize faster and screen hardening of stronger minerals. Multiple vibrations of a concrete mixture tear off a film of hydrated neoplasms and accelerate the hydration processes of the most durable minerals of cement [13].

When the vibration is repeated, weak cement minerals (three calcium ferrite and four calcium alumoferrite) that destroy the hardening of the stronger minerals of cement (alite and belite) are destroyed and, in the final analysis, the strength of the concrete rises, all other things being equal.

In the experiments, the following materials were used: cement of grade PC-400D, crushed stone granite size of 10-20 mm, sand river with an average size modulus. Consumption of materials on $1m^3$ concrete mix: Cement - 300 kg; Sand - 680 kg; Crushed stone - 1325 kg; V/C = 0.5.

The concrete mixture was prepared for the entire volume of the experiment. Three series of samples were prepared for 9 samples in each series. All samples were vibrated on a laboratory vibro-site for 20 seconds, then 1 set of samples was placed in a normal hardening chamber and a refrigerating chamber, and the remaining samples were vibrated once again 0.5 hours from the start of mixing of the concrete mix with water and 3 series were vibrated for the third time in 1.0 hour from the beginning of mixing. The most suitable duration of vibration is 10-30 seconds.

The concrete strength test was performed after 28 days of normal hardening and in frozen at minus 20 °C, which were kept for 1 day in normal conditions before testing. The results of the experimental work are given in Table 1.

Table 1. Results of comparative tests.

No.	Age (day)	Strength, MPa (kg/cm^2)			Strength of control samples, MPa (kg/cm^2)
		Number of vibrations			
		1	2	3	
1		11.0(110)	12.0(121)	13.4(134)	13.4(134)
2	3	11.3(113)	12.3(123)	13.6(136)	14.6(146)
3		11.7(117)	12.7(127)	13.2(132)	13.2(132)
4		11.8(118)	15.8(158)	15.2(152)	15.2(152)
5	7	12.5(125)	14.5(145)	16.0(160)	15.0(150)
6		12.8(128)	14.5(145)	14.8(148)	16.8(168)
7		13.9(139)	24.0(240)	27.7(277)	28.2(282)
8	28	13.7(137)	23.7(237)	28.4(284)	28.7(287)
9		14.2(142)	24.8(248)	28.7(287)	28.5(285)

The results of the experimental work are presented in Figure 2. The results of the early freezing concrete strength test show that, three vibrations do not affect the strength gain of the frozen samples. Re-vibrating the concrete mix before freezing increases the initial strength of the concrete. And in such concrete at freezing there are less destructive processes.

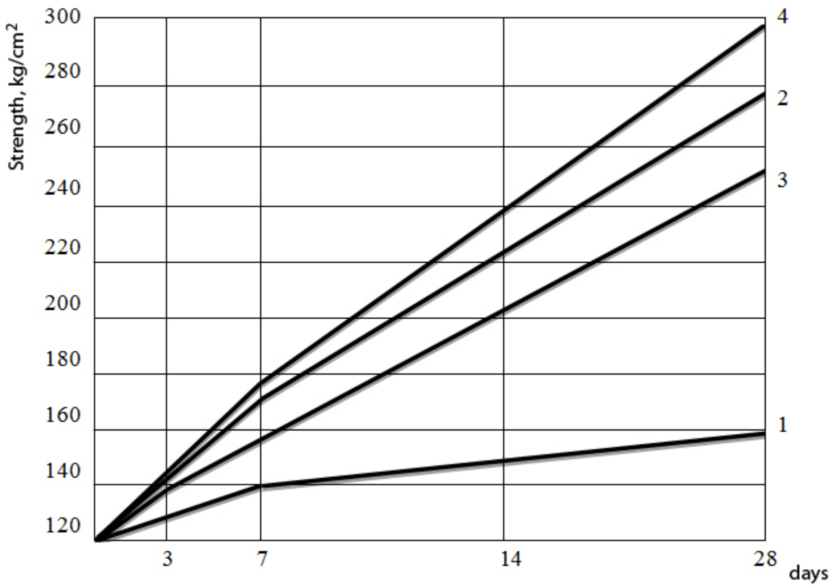

Figure 2. The results of strength tests of concrete when re-vibratings: 1 - concrete re-vibrating 1 time, 2 - concrete re-vibrating 2 times, 3 - concrete re-vibrating 3 times, 4 - control samples not subjected to freezing.

5. Conclusions

1. Executed experiments allow you to save cement with the correct appointment of a time of re-vibrating to 20%.
2. The time of re-vibrating is determined by the properties of the initial cement. According to the normal density of cement testing, the Vic's device sets the time for hydration of the cement paste clinkers.
3. The optimal time for re-exposure to the concrete mixture is within 0.5-1.5 hours, depending on the mineralogical composition of the cement.

4. The necessary duration of vibration depends on the massiveness of the concrete construction and the characteristics of the vibrator.

5.1. Discussion of the results and prospects for further research

Increasing the initial strength of concrete, re-vibrating is actual. But there are issues that need to be addressed in further research.

1. The re-vibration period depends on the mineralogical composition of the cement, so the re-exposure period is wide, it is required to set the re-vibration time for concrete types of cement.
2. To provide the minimum necessary for resistance to destructive phenomena of strength, concrete during early freezing can be subjected to repeated vibrations.

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