Change in the strength properties of modified concrete over time

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Abstract. To date, there is no data on the change in the strength of hyper - compacted concrete. The conducted field observations summarize the data of a long-term period and allow us to draw a number of conclusions.
As shown by numerous studies, the nature of the development of the strength of concrete over time depends mainly on the type of cement, the composition of the concrete mixture, the temperature and humidity conditions of hardening, and also on many other factors.
Obtaining highly efficient building materials is possible by modifying the structure of cement stone and concrete. Consequently, the modification of the concrete structure in this direction is intended to improve the technological properties of the material. By modifying it is possible to change the kinetics of the growth of physical properties and the final values of the strength of concrete.
Without considering the physico-analytical mechanism for changing the structure formation of concrete, we note that it is primarily aimed at reducing the amount of water - a mixing agent per unit volume of the material. However, various studies have shown that in the initial period, the structure formation of cement stone develops in the optimal direction only at certain volumetric water content. The limiting reduction in water content complicates the process of hydration of the binder, limiting the final strength properties of the material. At the same time, the final strength properties of the material are improved by reducing the volumetric water content of the mixture in every possible way. In all cases, the modification of concrete assumes its composition to be unchanged from the mixing of the mixture to the final stage of the formation of the concrete structure.

1 Introduction

The dependence of the strength and water resistance of concrete on W / C follows from the physical essence of the formation of the concrete structure. The study of the process of cement hydration showed that cement, depending on the quality and hardening time, binds only 15...25% of water from its mass [1-5]. During the first month, at least 20% of water by

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weight of cement binds. At the same time, to impart plasticity to the concrete mixture, to improve the conditions for hydration of the binder, a significantly larger amount of water is introduced, since at $(W/C)_{beginning} = 0.20$ the concrete mixture remains practically dry and it is impossible to lay, mold and compact it with high quality. Excess water, without entering into chemical reactions with cement, remains in the concrete in the form of water pores and capillaries or evaporates, leaving air pores. Undoubtedly, this is the main reason for the decrease in the strength and water resistance of concrete.

To optimize the properties of concrete, to obtain ultimate strength, it is necessary to remove excess mixing water. The physical and mechanical properties of concrete in this case will be directly dependent on the amount of residual mixing water [6]. If the concrete mixture is compacted by squeezing out a certain amount of free water, then the concrete strength will be inversely functionally dependent on the residual W / C, since it determines the porosity of the cement stone and concrete. Therefore, in order to obtain concrete of extremely high strength and density, the pre-laid mixture must be additionally compacted under conditions of maximum concrete dehydration.

For a preliminary identification of the factors affecting dehydration, let us consider the process of compaction of a concrete mixture placed in a mold representing a cylinder with a solid wall. Let us assume that the mixture is subjected to compression by normal pressure applied to the piston. If the volume of cement mortar $(V_{c.m})$ present in the concrete mixture is less than the volume of pores (V_{pore}) between the grains of a coarse aggregate, then the normal pressure will be perceived only by the coarse aggregate, and the cement mortar will not perceive any pressure in this case. The influence of vibro-impact-peristaltic pressing in these cases is likely to be negative, since under the action of normal force there may be cases of fragmentation of individual grains of a large fraction, which leads to a decrease in the strength of concrete.

If $(V_{c.m}) = (V_{pore})$between the grains of coarse aggregate, then the normal pressure will be perceived by the grains of all components of the concrete mixture. Under these conditions, the effect of vibro-peristaltic pressing will be unstable. If $(V_{c.m})$ is greater than (V_{pore}) by a certain value, then the normal pressure will be perceived only by the cement mortar, and the effect of vibro-peristaltic pressing will depend on the ability of the cement-sand mortar to deform. The mortar will deform if the amount of cement paste is greater than the pore volume of the fine aggregate. Under these conditions, the entire load must be taken up by the cement paste. With an excess amount of water in the cement paste, the entire load will be taken up by water.

2 Methods

The process of squeezing the liquid and gaseous phases from the molded material is the main process of structure formation and modification of concrete properties. The reason for the removal of liquid and gas from concrete is the pressure drop across the wall thickness of the molded product towards the perforated surface of the formwork. The removal of liquid and gaseous media from the concrete mixture is an exfiltration process, i.e. removal of liquid and gaseous fluids from the material into the environment [7].

The main role in the formation of a particularly dense structure of concrete is played by the process of concrete dehydration. The extraction of excess mixing water from the concrete mixture under the action of the applied normal pressure is a filtration process [1]. An important role in it is played by the difference in the chemical potentials of the interacting phases and various gradients that arise in the system depending on the type of energy source, under the influence of which free water moves. The movement of free water under the action of a moisture gradient occurs in the direction of less moistened pores until the moisture is completely equalized.

Therefore, in order to remove free mixing water from the concrete mixture under pressure, it is necessary to perform work (energy consumption) to overcome the forces of water bonding with cement particles and to move it in the system. Naturally, the main task of studying the transfer of excess mixing water from a concrete mixture is to determine the dependence of the parameters of vibro-peristaltic action and filtration rate on various technological parameters and normal pressure.

3 Results and Discussion

Let us consider the general patterns of increase in the strength of concrete under normal temperature and humidity conditions of the environment (ϴ=90...100%, t=20°C). Thus excluding the influence of external factors on the hydration process, we compare the potential possibilities for increasing the strength of ordinary, high-strength and hyper-compacted concretes depending on their individual qualities. High-strength, hyper-compacted concretes are characterized by the fact that they are produced on highly active cements and have low W/C values [1, 5, 8]. However, it is rather difficult to quantify their total effect in most cases, especially since concrete of a given strength can be obtained with a wide variety of combinations of these technological parameters.

With an increase in the activity of Portland cement or a decrease in W / C, in particular, as a result of water extraction, the increase in the strength of concrete, other things being equal, as a rule, accelerates. Therefore, the influence of both factors on the increase in the strength of concrete (for a given grade) should at least compensate for each other. Taking into account these considerations, one can try to estimate the joint influence of these factors on the growth rate of concrete strength through its nominal grade strength R_c. Although this kind of assessment is rather tentative, it is convenient in that it allows us to proceed from the generally accepted characteristics of the quality of the material. Yu.N. Khromets and E.N. Shcherbakov [2] proposed the following empirical expression for assessing the growth of concrete strength over time:

$$\frac{R_\tau}{R_c} = 1 - \frac{100-\tau}{5\cdot(100+R_c)} \cdot lg\frac{28}{\tau} \quad (1)$$

where R_τ is the cubic strength of concrete when loaded at an arbitrary age $3< \tau < 180$ days; R_c is the cubic strength of concrete at 28 days of age.

Further studies conducted by E. N. Shcherbakov have shown that high-strength concretes (grades up to 1000) also obey regularity (1) quite well. This can be seen from the analysis of the data of numerous researchers given in [9-15].

This also applies to experimental data on hyper compacted concretes, although they lie in a separate area, but they are subject to general laws. Therefore, dependence (1) can be accepted as valid for hyper compacted modified concrete. Figure 1, on which the values of the ratios R_τ/R_c (τ= 3.7 and 90 days) for ordinary and high-strength concretes are entered as a function of grade strength R_c at 28 days of age.

The hyper compacted concretes used in the experiments hardened under normal temperature and humidity conditions. The composition of mixtures and the individual properties of Alite Portland cements varied over a wide range. Nevertheless, the location of the experimental points in the entire considered range of R_c satisfactorily obeys the regularity (1).

For concretes of early age (τ = 3 days), a slightly increased scatter of experimental points is noticeable, but the general character of dependence (1) is preserved. For concretes of mature age (τ ≥ 180 days), it is more difficult to check the nature of this dependence, since there is not enough experimental data. However, the increase in the strength of concrete on alite Portland cements at τ ≥ 180 days, as a rule, is small, therefore, expression (1) actually describes the region of the highest values in time of strength R_τ.

High-strength hyper-compacted concretes are characterized by a more intensive increase in strength at an early age (τ < 28 days) and a less significant increase in strength beyond 28 days of age (Fig. 1). This was also noted in [8, 9] for high-strength concretes.

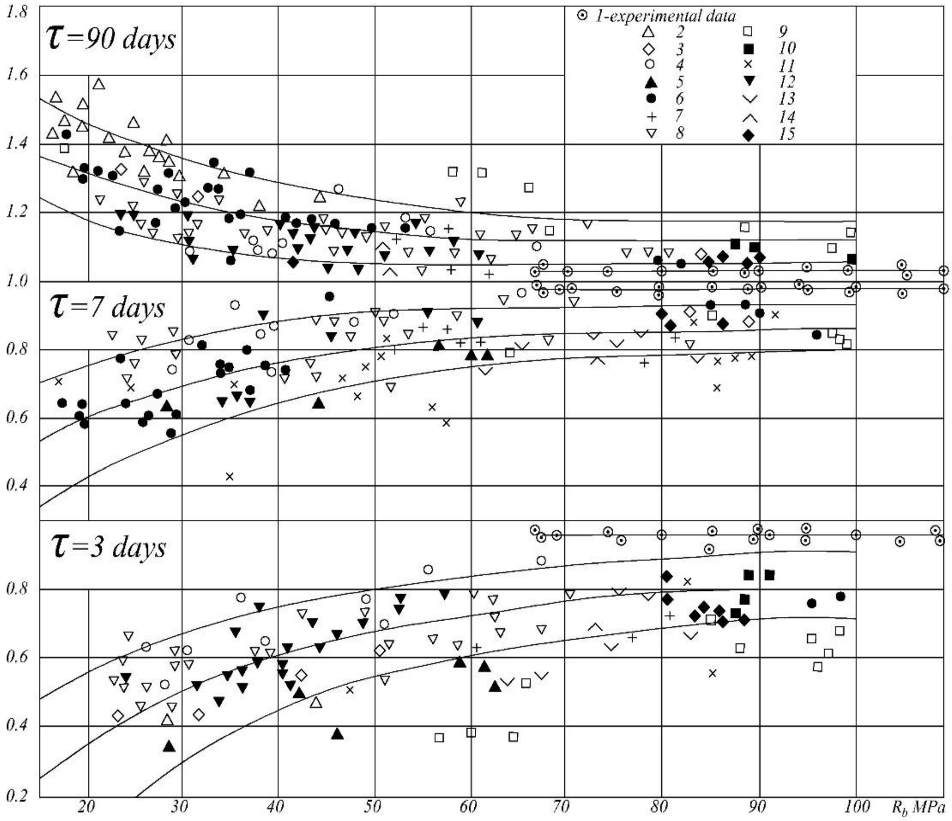

Fig.1. The development of the strength of concrete over time, depending on their grade strength. Alite Portland cements 40 different batches: 1-experimental data; 2-Dutron [18]; 3-Hummel; 4-Kiselev; 5-Meyer; 6-Vishers; 7-Ceylon; 8-Kwao; 9-Sytnikov and Ivanov; 10-Pisanko and Golikov; 11-Berg, Pisanko and Hromts Yu.N.; 12-Bonzel and Dams; 13-Pinus; 14-Rokach and Kochetkov; 15-Berg and Rozhkov; (-) according to O.Ya. Berg [9].

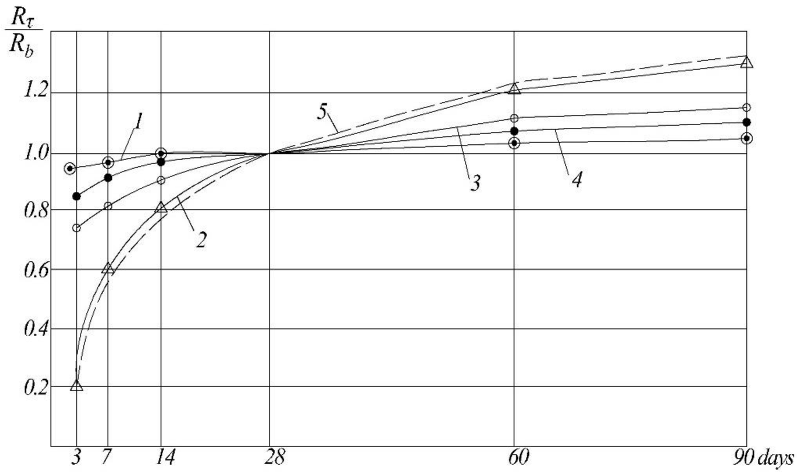

Fig. 2. The nature of the development in time of the strength of various heavy concretes on alite Portland cements: 1 - hyper-compacted concrete; 2 - concrete grade 200; 3 - the same, 600; 4 - the same, 1000; 5 - according to the logarithmic dependence, (curves 2, 3, 4, 5 - data of O.Y. Berg).

Expression (1) is more general in comparison with other well-known formulas of this type. In particular, for concrete of low grades, it is close to the known logarithmic dependence, and with increasing grade, it deviates more and more from this dependence. As can be seen from Figure 2, as a result, the rate of growth in the strength of ordinary and high-strength concretes can differ quite significantly. This feature of hyper-compacted, high-strength concrete is one of the important advantages that makes it possible to reduce the time for manufacturing structures, and in some cases, for example, in the climatic conditions of Uzbekistan, to abandon the use of heat and moisture treatment.

At the same time, one should be more careful when considering the possible increase in the strength of this concrete beyond the 28-day age. For the experimental type of concrete, R_{28} should be taken as the ultimate strength level. At the same time, no strength drops were observed during the observation period.

4 Conclusions

1. It has been confirmed by experimental data that the greatest strength of concrete is provided with $(W / C)_{rest}$ close to the normal density of the cement paste and the use of concrete mix compositions with a cement consumption of 10 ... 12% higher than the minimum binder consumption, which ensures optimal conditions of deformation, hyper consolidation and mixture modification.

2. According to the testing of experimental cylinders and drilled cores with a diameter of 150 mm, the strength level reaches 80 ... 110 MPa on ordinary cements (R_c - 42 ... 44 MPa) and carbonate aggregates, when using a vibro-peristaltic wave of hyper compaction up to 20 MPa.

3. The level of modification of the concrete mix, determined by the ratio $(W/C)_{rest}$ / $(W / C)_{beginning}$, depends on the value of the initial W / C and the mode of vibro-impact pressing.

4. An extensive analysis of various experimental data on the change in the strength of various concretes over time was performed, which made it possible to establish the area of placement of experimental data for hyper-compacted concrete in the range from 3 to 90 days.

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