Improving the mixtures preparation technology for in-situ concrete

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Abstract. Modern ways of improving the mixtures preparation technology for in-situ concrete, delivered to the construction site by concrete mixers and supplied to the installation place using concrete pumps, are considered. A two-stage method for preparing concrete mixtures has been developed, which allows improving the concrete mixtures’ technological properties and increasing the physical and mechanical properties of hardened in-situ concrete without additional investments.

Introduction

In modern construction, in the construction of hydraulic, energy and transport facilities, industrial, civil and other objects, in-situ concrete is widely used. In-situ concrete itself has been used since ancient times and its technology is constantly being improved as scientific and technological progress develops.

In our country, due to the rapid development of precast and reinforced concrete from the second half of the last century, attention to in-situ concrete has been somewhat weakened. However, the issues of improving the technology of in-situ concrete are currently becoming increasingly relevant.

Most often, in-situ concrete is economically more effective than prefabricated products and structures in the underground parts of buildings and structures, in hydraulic engineering and road construction and especially in precast-monolithic structures.

The most important task in the concrete mixtures preparation for in-situ, as well as for other types of concrete, is to ensure the mixture components’ distribution in order to achieve the required system uniformity. At the same time, a complex of complex physical and chemical interactions between the various phases of the multicomponent system starts developing in the mixed concrete.

In accordance with the modern ideas about the cement stone and concrete formation structure, clinker minerals hydration during the composition mixing is accompanied by chemical dispersion of poly-mineral composition cement grains. The occurrence of this process is promoted by the adsorption hardness lowering phenomenon (according to P.A. Rebinder) of cement grains upon wetting their surface with mixing water. The resulting cement paste is enriched with colloidal particles of neoplasms. The smallest cement particles in water tend to unite into flocs under the influence of the molecular attraction Vander-Waals forces.

Main part

Water is not evenly distributed inside the separate flocs as well as between them. All measures to increase the water distribution uniformity in cement and deflocculation during the composition mixing
lead to the more uniform coagulation structure formation of the hardening cement grout. This provides an improvement in the technological properties of the concrete mixture and an increase in the hardened concrete quality.

In parallel with the clinker cement minerals’ dissolution, crystallization processes occur in the hydrated tumors’ nuclei.

The most favorable substrate for the neoplasms’ crystallization is the hydrophilic surface of quartz sand grains. It is the contact zone between the surfaces of sand grains and the hydration products of clinker cement minerals that often determines the strength properties of hardened concrete [1, 2]. If the sand grains are covered, as is often the case, with the finest dusty-clay films, it is they that prevent the formation of a strong contact zone.

In the process of mixing the concrete mixture due to multiple collisions of the aggregate grains, as well as their friction against each other in the presence of the mixture liquid phase, the total area of the dust and clay films decreases. This, in turn, leads to the hardened concrete’s physical and mechanical properties improvement.

In view of the foregoing, the technological process of mixing concrete composition should not be considered only as a means of achieving an averaged content in the volume of the starting components’ obtained material. The technological mixing operation should serve the purpose of ensuring the optimal conditions for the flow of not only the concrete mixture technological properties physical and chemical processes formation, but also the required physical and mechanical properties of the hardened concrete. Today, mixing concrete mix is almost always carried out in various concrete mixers, the classification of which according to Yu.G. Khayutinu [3], is presented in Figure 1.

![Figure 1. Classification of concrete mixers](image)

It is important to note that with any mixing method, the resulting concrete mixture should meet certain technological requirements.

In particular, taking into account the fact that the concrete mixture prepared at the factory to the place of its laying is delivered, as a rule, by motor transport, it should not be delaminated during transportation and maintain the required workability at the beginning of concreting. When the delivery distance of the concrete mixture is relatively small, it is advisable to load concrete mixers ready for concreting with concrete mixture. However, as the transportation distance increases, especially on the roads with poor pavement or with a high load and the risk of downtime in traffic jams, the delivery of finished mixtures to the place of laying becomes problematic.

Currently, in the in-situ concrete production, intra-site pipeline transportation of concrete mix is
becoming more widespread. It is especially convenient when supplying large volumes of concrete mixture to concrete structures, which are difficult or impossible for vehicles to access, there is no way to supply the mixture with cranes, etc.

However, when using concrete pumps in pipeline transport, with high advantages, there are specific requirements for the concrete mixture for its pumpability.

In the technical and patent literature there is the data on the studies’ results aimed at improving the technological properties of concrete mixtures for monolithic housing construction. For example, there is a known method [3] of transporting so-called shrink concrete in concrete mixer trucks. Shrink concrete is a mineral component of a concrete mix mixed with a small amount of water. The resulting mass of earthy-moist consistency can be transported, without prejudice to the final product quality, at the distances significantly greater than those for the finished concrete mixture. However, due to the implementation complexity, this technological scheme is not widely used.

Based on the analysis of defects that occur during the reinforced concrete monolithic structures’ construction, a generalized classification of defects is given in [4], the main reasons for their occurrence are given, the generalized suggestions for reducing the defects are given, the methods for their assessment [5] and a two-stage technology for concrete mixture preparation developed by the author [6] is described.

The most recognized solution to the problem of reducing the defects of in-situ concrete and reinforced concrete is the use of self-sealing concrete mixtures (SCM). However, due to the relatively high cost and SCM preparing complexity, their use does not exceed 2-5% of the concrete work total volume. According to the author [6], the two-stage technology proposed by him can serve as an alternative to SCM. In the first stage of this technology, cement, a mineral additive and a plasticizer are mixed in a ball mill. On the second - the resulting complex binder is mixed with water and aggregates using the existing equipment at the concrete mixing plant.

The implementation of this proposal requires significant investment costs for organizing and equipping an additional processing line for the complex binder preparation.

A method for preparing concrete mixture for in-situ concrete [7], which does not require additional investments, was developed, the essence of which is that cement, aggregates and a part of the mixing water are preliminarily mixed in the factory to obtain a concrete mixture with a 2 - 4 cm cone precipitation, then the resulting mixture is transported in a concrete mixer to the place of use and no later than two hours after preparation add an aqueous solution of superplasticizer with the remaining estimated amount of mixing water and finally mix the concrete mixture for at least three minutes.

The disadvantage of this method is the difficulty in ensuring sufficiently accurate dosing of expensive superplasticizer in concrete mix outside the factory conditions. In addition, this method does not provide for the possibility of reducing the total flow rate of mixing water with respect to its calculated value.

The issues of improving the concrete mixtures preparation quality were solved by the authors of this work in the studies [8, 9]. The objective of this work is to increase the manufacturability and accuracy of dispensing superplasticizer in concrete mix for monolithic construction, as well as to reduce the total flow rate of mixing water without reducing the mixture mobility by the monolithic structures’ concreting time.

The essence of the developed technology for the concrete mixture preparation is that it includes two-stage cement mixing, aggregates, superplasticizer and mixing water, while in the first stage, cement, aggregates, superplasticizer and a part of the mixing water are mixed at the factory before the concrete mix with sludge is obtained a cone, equal to 10-12 cm, then the resulting mixture is transported with a concrete mixer to the monolithic structures’ concreting place, where an additional part of mixing water is needed to obtain the required mobility, and the concrete mixture is finally mixed in a concrete mixer.

Polycarboxylate-based chemical additive is used as a superplasticizer.

The concrete mixture obtained at the first stage is loaded into a concrete mixer truck and transported to the place of concreting of a monolithic structure. Directly at the construction site, an additional amount of mixing water is added to the concrete mixer, which is necessary to obtain the concrete mix of the required mobility grade, and the concrete composition is finally mixed. At the same time, the
manufacturability and accuracy of superplasticizer dosing, which is carried out at the factory, is increased in comparison with the introduction of superplasticizer into the mixture directly at the construction site, according to [7].

This is especially evident when the large volumes (up to 10 m\(^3\) and above) of concrete mixture delivered with concrete mixers to the place of concreting. In such cases, it is necessary to directly inject 50 - 80 l of superplasticizer solution into the concrete mixture directly at the construction site without proper equipment.

In addition, the introduction of a superplasticizer into the mixture at the factory at the first stage of the concrete mixture preparation according to the proposed method improves the conditions for its transportation from the point of view of mobility preservation, which reduces the total consumption of mixing water.

As a result of reducing the total mixing water flow rate, the strength indicators of concrete increase and its permeability decreases, which helps to increase the concrete structures’ service life.

The additive ST 5.0 is used as a superplasticizer in the proposed method - a complex superplasticizer based on polycarboxylate, manufactured by SkyTrade LLC according to Engineering Specifications (ES) 5745-001-94590966-2011 and intended for the ready-mixed concrete, as well as for the reinforced concrete structures. The optimal dosage of ST 5.0 is determined empirically depending on the materials and preparation conditions.

The proposed method is illustrated by the following example.

Commodity concrete mix of brand P4 for mobility for concreting monolithic structures with a design class of concrete in strength B 25 was adopted as the initial one.

Portland cement grade PC 500 – D0-H GOST 10178-85 manufactured by JSC “Sebryakovcement” was used as a binder. Quartz sand of the Dugino deposit in the Rostov Region with a fineness modulus Mf=1.3, bulk density 1330 kg/m\(^3\), meeting the requirements of GOST 8736-2014 was used as a fine aggregate.

Crushed stone with 5-20 mm fraction, produced by LLC “Donskoy Kamen”, Rostov Region, which meets the requirements of GOST 8267-93 was used as a coarse aggregate.

The composition of the concrete mixture with cement consumption 390 kg/m\(^3\) characterized by the components’ ratio (parts by weight): cement: sand: crushed stone = 1: 1.9: 2.7.

The superplasticizer additive in the amount of 0.25% by weight of cement, calculated on the anhydrous additive substance, was introduced into the concrete mixture by the proposed method and [6].

The cubes samples with a rib of 100 mm were formed from the prepared concrete mixtures, which were subjected to strength tests according to GOST 10180-2012 after 28 days of hardening under normal conditions, as well as the standard cylinder samples with a diameter of 150 mm to determine water
resistance according to GOST 12730.5-84. The test results are presented in the Table 1.

Table 1. Test Results

| test no. | The concrete mixture preparation method | Mixing water consumption, l/m³ | Cone draft, cm | Concrete strength after 28 days. hardening, MPa | Concrete waterproof of grade |
|----------|----------------------------------------|-------------------------------|---------------|-----------------------------------------------|------------------------------|
|          | at the stage of preliminary mixing      | at the stage of final mixing | total in two stages | after premixing | 1 h after stage I |                             |
| 1        | according to [7]                        | 150                           | 40            | 190                                           | 4                            | 20                           | 41.6/100                     | W4                           |
| 2        | Proposed                               | 155                           | 35            | 190                                           | 6                            | 18                           | 42.0/101                     | W4                           |
| 3        |                                       | 160                           | 25            | 185                                           | 10                           | 20                           | 44.1/106                     | W6                           |
| 4        |                                       | 160                           | 20            | 180                                           | 10                           | 21                           | 46.2/111                     | W8                           |
| 5        |                                       | 165                           | 20            | 185                                           | 12                           | 20                           | 44.9/108                     | W6                           |
| 6        |                                       | 170                           | 20            | 190                                           | 14                           | 19                           | 42.4/102                     | W4                           |

As it can be seen from the data presented (experiments №№ 3, 4, 5), the proposed method of preparing the mixture with the introduction of superplasticizer in the first stage allows to reduce the total consumption of mixing water, which increases the concrete strength and its water resistance. At the same time, the introduction of a superplasticizer additive into a mixed concrete mixture at the 1st stage at the factory increases its dosage accuracy compared to the field conditions. Reducing the total flow rate of the proposed method and increasing the water resistance of concrete contributes to an increase in its durability during the structures’ operation in aggressive environmental conditions.

Summary

1. The method for the in-situ concrete mixtures preparation, which allows to improve the technological parameters of the concrete mixture and the physical and mechanical properties of hardened concrete has been developed.
2. The proposed method does not require technical re-equipment of existing production or additional investments for its implementation.

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