# Concrete with a complex additive based on a superplasticizer and an organosilicon polymer

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**Absract.** Depending on the functional purpose, different requirements are imposed on the products. In particular, reinforced concrete products used in irrigation and drainage construction, along with increased strength and frost resistance, are required to have increased water resistance. For the water resistance of concrete, through macropores (filter capillaries) are dangerous, which are formed as a result of uneven thermal expansion of concrete components during heat treatment, as a result of plastic shrinkage and sedimentation during compaction. The relationship between the structure and impermeability of concrete is very complex.

## 1. Introduction

As a result of a multi-year study, it was proved that an increase in the physical and mechanical properties of concrete is achieved by controlling the process of structure formation, carried out both at the stage of concrete design, and at the stages of mixture preparation, product molding, and concrete hardening.

Concretes used in construction, depending on the functional purpose, have different requirements for products. In particular, reinforced concrete products used in irrigation and drainage construction, along with increased strength and frost resistance, are required to have increased water resistance.

The results of the study showed that, for the water resistance of concrete, through macropores (filter capillaries) are dangerous, which are formed as a result of uneven thermal expansion of concrete components during heat treatment, as a result of plastic shrinkage and sedimentation during compaction. The relationship between the structure and impermeability of concrete is very complex. Previously [1], it was noted that there are many dense, in terms of water resistance, concretes with significant porosity, for example, when air-entraining additives are introduced into the concrete mixture. When they are used, a highly dispersed emulsion, mineralized air bubbles appear in the concrete mixture, blocking through filtration channels and increasing the density of concrete, although its overall porosity may increase.

The use of superplasticizers on average makes it possible to increase the mobility of the concrete mixture from OK=2-3 sm to OK=15-20 sm, or in equally mobile mixtures to reduce water consumption by 20-30%. The paper notes that the use of superplasticizers in production conditions increases the strength of concrete by a grade, and in many cases by two grades, water resistance - by 3-4 grades.

At present, the most widely used superplasticizer S-3 based on sulfonated naphthalene-formaldehyde oligomer. The introduction of superplasticizer S-3 into the composition of concrete increases the mobility of the mixture from OK=2-4 sm to OK=8-20 sm, and water resistance from W4 to W6, i.e. for one brand, and for equally mobile mixtures - from W4 to W14 [2].

With the introduction of superplasticizer C-3 into concrete, the plasticizing effect is provided mainly as a result of a decrease in interfacial energy at the boundary of the solid and liquid phases and their adsorption on grains of binders and especially neoplasms.

According to the works [3] it is clear that the effectiveness of superplasticizers depends on the type and composition of the cement. Thus, the authors [4] note that the superplasticizer S-3 gives a greater effect on strength on medium-aluminate ($C_aA$=7.2%) cements, somewhat lower on high-aluminate ($C_aA$=5%) and the lowest indicator on low-aluminate ($C_aA$= 6%) cements.

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According to Krylov [5], the introduction of S-3 into concrete makes it possible to subject it to heat treatment at low temperatures without lengthening its cycle.
Currently, a search is underway for modified superplasticizers, the basis of which is C-3
Economic efficiency of superplasticizers in the manufacture of precast concrete products. So, according to Ivanova [6], the economic efficiency of the use of various types of superplasticizers largely depends on their cost and the value of the optimal dosage.
One of the types of chemical additives that increase the water resistance and durability of concrete is air-entraining additives.
The reasons for increasing the water resistance of concrete with air-entraining additives are explained as follows. There are many quite dense, from the point of view of water resistance, concretes with significant porosity. For example, increasing the water resistance of concrete with the help of foam concentrates, which cause the appearance of a highly dispersed emulsion in the concrete mixture, mineralized air bubbles that block through filtration channels. Thus, dense concrete is obtained in terms of water resistance, although its overall porosity may be greater.
It should be noted that any entrained air increases the water resistance of concrete, and the latter is achieved if the additive creates evenly distributed closed pores in its structure.
In our present time, the following types of air-entraining additives are mainly used: neutralized air-entraining resin (SNV), synthetic surface-active additive (SPD), saponified wood pitch (TsNIPS-1), saponified wood resin (SDO), sulfanol and tallow pitch glue (KTP).
In the United States, air-entraining additives are widely used to improve the sulfate resistance of concrete.
One of the types of additives that increase the water resistance and durability of concrete are organosilicon polymers.
The theoretical provisions for the use of organosilicon polymers in concrete technology is that when organosilicon compounds are combined with inorganic ones, the latter will enter into a chemical bond with the active centers of silicon polymers if there are active functional groups in inorganic compounds (such as -OH, - OMe -$NO_2$, etc.). Hydrogen-containing and alkoxy containing organosilicon polymers are of particular interest, since due to the very low bond of Si-H and Si-OR, it is possible to replace hydrogen and OR - groups with calcium and the porosity of the cement skeleton of concrete, released gas or entrained air, which, if these processes are properly controlled should improve water resistance and durability due to the formation of a system of small closed pores.
Influence of complex additives on the water resistance of concrete. It should be noted that the introduction of air-entraining or gas-forming additives into the composition of concrete can reduce the strength of concrete, therefore it is advisable to introduce them together with plasticizing additives, which will ensure a decrease in W / C and thus compensate for the decrease in concrete strength.
One of the effective types of organosilicon polymers is polyphenylalkoxysiloxanes (FES-50, FES-66). The introduction of organosilicon polymers such as polyphenylalkoxysiloxanes into concrete in an amount of 0.1-0.5% by weight of cement, its air content increases from 1.9 to 3.0%. The strength of concrete at a dosage of more than 0.1% by weight of cement is reduced, and frost resistance is F 300-500 cycles, depending on the dosage. In addition, the introduction of polyphenylalkoxysiloxanes into the composition of concrete gives it hydrophobic properties and thereby reduces water absorption and water permeability.
As can be seen, when air-entraining additives are introduced into the concrete composition, the structure of concrete changes, which is favorable for increasing water resistance and frost resistance and frost resistance, causing a decrease in its strength, which can be compensated by a decrease in W/C due to plasticizing effect additives.
Therefore, a number of specialists suggest introducing air-entraining additives into concrete in combination with plasticizers.
So use of SSB and START additives separately in the fabricated prefabricated reinforced concrete trays did not provide the necessary physical and mechanical properties of concrete. With the introduction of PRS and SNB in the complex in an amount of 0.1 ÷ 0.02% by weight of cement, the strength of concrete after heat treatment was 87% of the brand, and the frost resistance was F300 cycles.
The emergence of new types of plasticizing (superplasticizer) and air-entraining additives in the field of manufacturing technology for prefabricated reinforced concrete products opens up new promising ways of water resistance due to complex additives.

## 2. Materials and Methods

To reveal the mechanism of increasing the physical and mechanical properties of concrete with a complex additive of plasticizing and air-entraining action, superplasticizer C-3 and an organosilicon polymer oligoethoxy-2 - ethylhexoxysiloxane KE 119-215 were used [7]. The role of the latter is to hydrophobize the surface of pores and capillaries by chemical fixation of the organosilicon compound. Water repellent KE 119 - 215 works as a moderate microfoaming agent due to the alcohol released as a result of the reaction, which reduces the surface tension at the border of the concrete mixture - air.

The studies were carried out on concrete of class B20 without additives C:P:Sch = 1:2.01:3.29 and with the addition of C:11:1C = 1:2.09:3.39 (by weight). In all cases, the content of sand and aggregate mixture was r = 0.38, cement consumption was 350 kg/m. Portland cement grade 400 was used as a binder, and sand with a particle size modulus $M_{cr}$ = 1.88 was used as a fine aggregate. Granite crushed stone with a maximum fineness of 20 mm served as a large aggregate.

Determination of compressive and tensile strength (samples-cubes with an edge of 10 sm), water resistance (cylinders with a diameter of 15 and a height of 15 sm) and frost resistance (samples-cubes with an edge of 7 sm) were carried out by standard methods.

To study the effect of plasticizing and air-entraining additives and their combination on the technological properties of the concrete mixture, the mobility of the concrete mixture and the volume of entrained air were determined according to GOST 10181.

The water resistance of concrete was determined according to GOST 12730.5-84 "Concrete. Methods for determining water resistance" on samples-cylinders with diameters and a height of 150 mm. The samples were tested 10 days after heat and moisture treatment. Concrete samples were stored after heat and moisture treatment until equilibrium humidity was reached at an ambient temperature equal to tair 20+2$^0$C and relative air humidity φair=40+2%.

Each series of six specimens was kept in the laboratory for 24 hours before testing. The end surfaces of the samples were cleaned with a metal brush from the surface film of cement stone. Before testing, each sample was weighed.

Concrete was tested for water resistance by a certified laboratory of the Jizzakh Polytechnic Institute.

## 3. Results and Discussion

In the process of testing concrete samples for water tightness. Sealing was carried out by sealing the sample with a rubber hollow chamber with excess pressure in it, which was created using a water pump. The pressure in the chamber for the reliability of sealing was maintained at 3-4 atmospheres more than the pressure on the sample. For example, if the sample is 0.2 MPa, then in the chamber it was taken equal to 0.5-0.6 MPa, if the samples were 1.0 MPa in the chamber 3-4 MPa. (Figure 1).

The water pressure on the sample is increased in steps of 0.2 MPa for 1-5 minutes and maintained at each degree for 16 hours. The tests continue until signs of water filtration appear on the opposite surface in the form of drops or a wet spot.

The water resistance of each sample is evaluated by the maximum water pressure at which no water seepage was observed on four of the six samples.

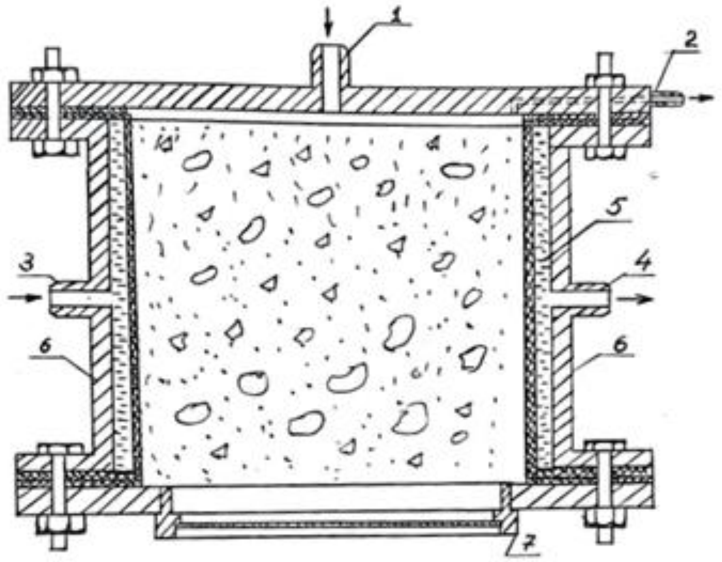


**Fig. 1.** Scheme of fastening and sealing of a concrete sample in a test nest: 1 - pipe for supplying water under pressure to the sample; 2- pipe for removing excess water; 3 - branch pipe for supplying water under pressure when sealing the sample; 4- branch pipe for water outlet after testing; 5- chamber for sealing a concrete sample; 6- test clip; 7- Removable lid with glass to observe the formation of a "wet spot"

After testing, the samples are removed from the nests using a special device with a vacuum pump.

The installation makes it possible to determine the water resistance of concrete up to W 16. If, even at a pressure of 1.6 MPa, signs of water filtration in the form of drops or a wet spot do not appear on the surface of the samples, the samples split and the depth of penetration of water into concrete (Nsm) is determined.

As can be seen from the research results (See Table No. 1), the introduction of superplasticizer S-3 to obtain equally mobile mixtures compared to concrete without additives made it possible to reduce water consumption by 16 ... 20%, while the volume of air involved in the concrete mixture was 2 ,8% It should be noted that although concrete mixtures with and without S-3 additive had the same mobility (O.K = 3.5 sm), the workability of the mixture with S-3 was better.

The introduction of KE 119-215 into the composition of concrete in the amount of 0.05; 0.07; 0.1; 0.3; 0,5% of the mass of cement at a constant dosage of 0,5% S-3 practically does not affect the mobility of the mixture. The volume of entrained air in the concrete mixture with an increase in the dosage of KE 119-215 to 0.1% of the mass of cement increases to 3%, and its further increase to 0.5% in combination with S-3 almost does not change the volume of entrained air, but can reduce mobility of the concrete mix.

**Table 1.** Results of studies of the introduction of superplasticizers into the composition of concrete

| Additive | Quantities, % mass of cement | W/C | O.K, sm | Volume of treated air,% | Waterproof |
|---|---|---|---|---|---|
| - | - | 0.53 | 3.5 | 1.2 | 4 |
| S3 | 0.5 | 0.53 | 2.2 | 1.2 | 8 |
| S3 | 0.5 | 0.44 | 3.5 | 2.8 | 12 |
| KE 119-215 | 0.05 | 0.53 | 2.5 | 2.2 | 8 |
| KE 119-215 | 0.07 | 0.53 | 2.0 | 2.0 | 8 |
| KE 119-215 | 0.1 | 0.53 | 2.0 | 2.4 | 10 |
| KE 119-215 | 0.1 | 0.53 | 1.7 | 1.8 | 8 |
| KE 119-215 | 0.5 | 0.52 | 1.4 | 2.0 | 6 |
| S3+KE 119-215 | 0.5+0.05 | 0.44 | 3.2 | 2.8 | 12 |
| S3+KE 119-215 | 0.5+0.07 | 0.44 | 3.0 | 2.6 | 12 |
| S3+KE 119-215 | 0.5+0.1 | 0.44 | 2.8 | 3.0 | 14 |
| S3+KE 119-215 | 0.5+0.3 | 0.44 | 1.8 | 2.6 | 12 |
| S3+KE 119-215 | 0.5+0.5 | 0.44 | 1.6 | 3.0 | 12 |

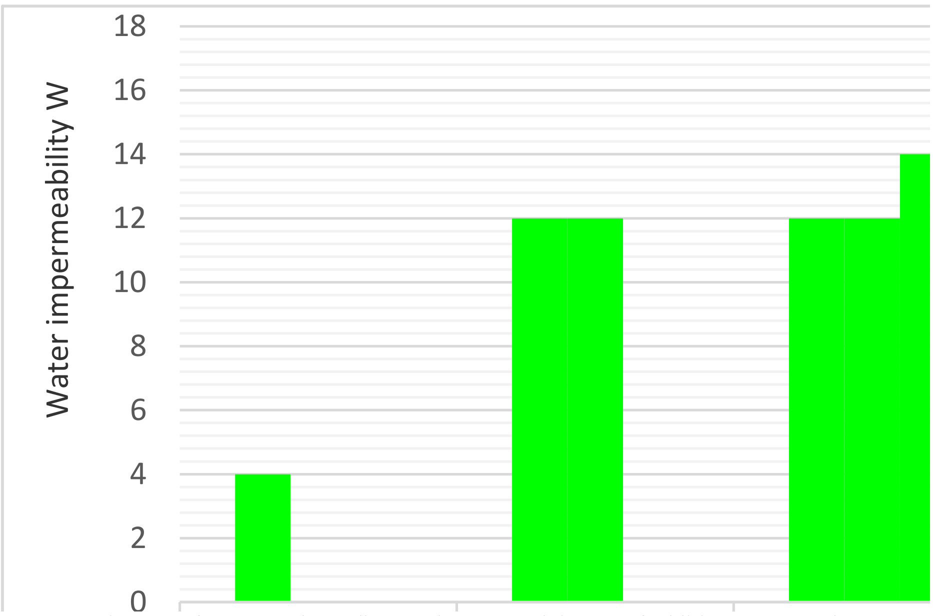


**Fig. 2**. Water resistance of concrete depending on the type and dosage of additives. 1-control; 2,3-s S-3, respectively, 0.5 and 0.7% of the mass of cement; 4…9-s S-3+KE119-215 respectively 0.5+0.05; 0.5+0.07; 0.5+0.1; 0.7+0.05; 0.7+0.07; 0.7+0.1% by weight of cement

As noted above, one of the main factors for increasing the durability of prefabricated reinforced concrete products of irrigation and drainage construction is increased water resistance. In this work [8, 9], the water resistance of the samples was determined 10 days after heat treatment. The introduction of superplasticizer C-3 into the composition of concrete without reducing water consumption increases water resistance by two grades. Studies of the water resistance of concrete with organosilicon polymers KE 119-215 were performed for the first time. The introduction of 0.05 and 0.07% KE 119-215 improves water resistance by three grades, and at a dosage of 0.1% of the mass of cement - by four. A further increase in the dosage of KE 119-215 to 0.5% of the mass of cement did not affect the increase in water resistance [10-11].

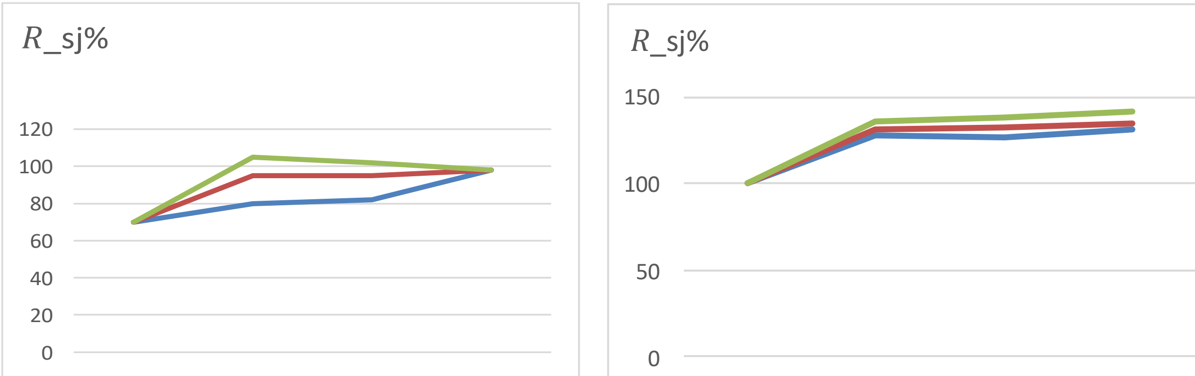


**Fig. 3.** Strength of concrete depending on the type and dosage of additives. a-after TVO; b-at the age of 28 days of normal hardening; 1-C-3; 2-0.5% C-3 + EC 119-215; 3-0.7% S-3+CE 119-215

With the introduction of C-3 concrete on equally mobile mixtures, the water resistance increases by four grades, and with the introduction of the complex additive S-3 + KE 119-215 in the ratios of 0.5 + 0.5 and 0.5 + + 0.07% of the mass cement received the same grades for water resistance W12, i.e. water resistance increased by four grades. The highest water resistance grade W14 was obtained with the ratio of the components of the complex additive 0.5 + + 0.1% of the mass of cement.

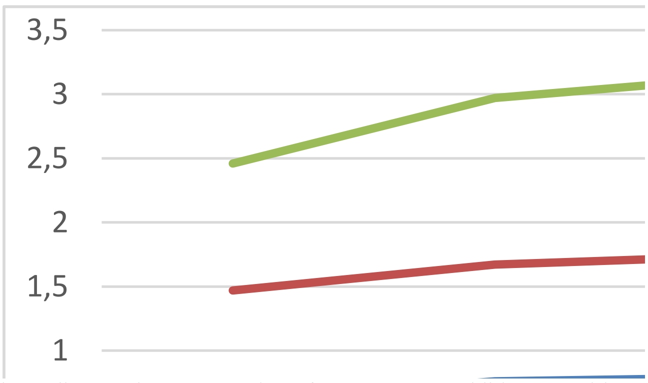


**Fig. 4.** Frost resistance of concrete depending on the consumption of cement: 1-no additives; 2-with a complex additive; 1.2-150 cycles; 2-300 cycles

## 4. Conclusion

Studies of the effect of the dosage of S-3 alone and in combination with the organosilicon polymer KE 119-215 on the water impermeability of concrete (Fig. 1) showed that an increase in the dosage of S-3 from 0.5 to 0.7% of the mass of cement practically does not change the water resistance, despite the fact that the W/C is decreasing. However, at 0.7% S-3 in combination with KE 119-215 and an increase in the amount of the latter to 0.1% of the mass of cement, water impermeability, compared with the addition of 0,5% C-3, increases by 2 ... 3 grades.

As can be seen from fig. 4, with an increase in the dosage of C-3 from 0.5 to 0.7% in the complex S-3 + EC 119-215, the strength of concrete after HTT increases slightly. Even with the introduction of S-3 separately, the strength of concrete after HTT decreases. With an increase in dosage from 0,5 to 0,7% of the mass of cement, the strength of normal-hardening concretes at the age of 28 days, individually and in the C-Z + EC 119-215 complex, increases.

The results of studies of frost resistance with a complex additive C-Z + KE 119-215 showed that it is higher compared to concrete without additives and depends on the consumption of cement. As can be seen from fig. 3, with an increase in cement consumption, frost resistance increases.

Thus, the organosilicon polymer KE 119-215 of the oligoethoxy-2-ethylhexoxysiloxane type is an air-entraining additive and promotes the formation of evenly distributed closed pores in the concrete structure.

The introduction of the organosilicon polymer KE 199-215 into the composition of concrete in combination with the superplasticizer C-3 increases the water resistance, frost resistance and strength of concrete.

As can be seen from the above, one of the effective methods for improving the water resistance of concrete is the introduction of complex additives that provide:

- plasticizing effect, which reduces the water content in the concrete mixture, due to which the density and uniformity of the concrete structure increase;
- air-entraining effect, due to which conditionally closed pores are formed in the concrete structure, clogging the direction of the filtering capillaries;
- hydrophobic effect, as a result of which hydrophobic layers are formed on the walls of the pores, which reduce water absorption;
- sealing effect due to neoplasms, which occurs as a result of the interaction of cement gel particles and sealing additives.

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