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The Effects of Modifying Additives Used for Concrete in Constructing Monolithic Reinforced Concrete Buildings

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Abstract **– The article is devoted to the use of modifying additives into the concrete mix during the construction of multi-storey buildings. Additives accelerating concrete hardening allow it to quickly build upper floors, but increase the cost of concrete mixes. Thus, reduction of the holding time will not be cost-effective if concreting is not a leading process in scheduling. To determine the effectiveness of additives, the schedule of construction of a multi-storey building with a reinforced concrete frame was optimized. The main optimization methods are changes in the construction technology taking into account the use of various types of additives (superplasticizers, waterproofing additives; season; the method of lifting concrete mix to the floor). Relamix-M2 and Penetron - Admix" reduce the concreting time by 37%; the cost of one m^3 of concrete decreases by 2.5%.**

Keywords – modifying additives; scheduling; multi-storey reinforced concrete buildings.

I. Introduction

Analysis of the effectiveness of modifying additives for concrete is one of the most relevant tasks.

Modifying additives can reduce the time of concrete hardening, lower the temperature of its pouring, increase plasticity of the mixture, improve waterproofing and mechanical properties.

Studies of structures made of modified concrete are relevant both in Russia and abroad.

Thus, the effect of the rubber fiber powder (RFP) on concrete was investigated. 5, 10, 15, 20, and 25% of rubber fiber powder was added into the concrete mixture, while reducing the weight of the injected cement. It was found that the strength and porosity of the concrete slightly decreased, while the corrosion resistance increased [1].

The use of nano-metagline as an additive to ultra-high-performance concrete showed that the compressive strength of concrete increases [2].

The use of industrial waste products identified improvement in the quality of concrete. Ash sludge (PSA), fly ash (FA), silica dust (SF) and metakaolin (MK) of various proportions (5%, 10%, 15%) were used. PSA significantly improved the mechanical properties of concrete at the initial stage; FA and MK improved its quality at the later stages (90 days) [3].

The use of coconut fibers (2% of the mass of concrete) slightly improves the mechanical properties of concrete [4].

Anti-foaming impurity (AFA 1 and AFA 2) when used as an additive in ultra-high-performance concrete reduces the pore volume, and improve the mechanical properties of concrete [5].

In Russia, scientists often tested modified concretes using certified additives.

I.E. Seskin and A.E. Baranov found that adding C-3 superplasticizer along with intensive pressing of concrete increases the strength of the original cement stone twice, that of the cement-sand mortar - three times and concrete - 1.5 times [6].

V. S. Izotov and R. A. Ibragimov found that with the use of the complex additive based on the Odolit-KW hyperplasticizer and sodium sulfate [7], the consumption of cement decreases by 28% and the time of isothermal heating of reinforced concrete products reduces by 4 hours; the quality of products improves, the turnover of forms increases. The economic effect due to the reduced consumption of Portland cement and thermal energy is about 300 rubles / m^3.

R. Sh. Valeev and I. G. Shaykhiev experimentally determined that the rational amount of the C-3 additive in the composite gypsum binder (modified with recyclable sludge), which meets GOST 125-79 for the strength characteristics of gypsum stone and setting time is 0.5% [8]. The use of sludge as a filler composite gypsum binder reduces the cost, energy production, and the amount of gypsum binder required.

The authors [9] developed and investigated a quartz-sand-based additive combined with a plasticizer C-3 whose mass fraction was 1% of the mass of the entire material. With an increase in the content of the complex microadditive, the water absorption of fine-grained concrete decreases; with 15% water content, it decreases 4 times. It is proved that the introduction of the additive in the age from 1 to 7 days accelerates the concrete holding, increases density and frost resistance, as well as reduces water absorption from 5.1 to 1.4%.

Yu.G. Barabanshchinok and M.V. Komarinsky found that some additives are not combined with certain types of cements: they do not show required properties [10]. In this regard, it is necessary to select the type of an additive depending on the type of cement.

The results of the experiments show the possibility of obtaining waterproof and frost-resistant extruded artificial stone materials based with cement consumption of 10 ... 20%, compressive strength of 25.0 ... 30.0 MPa using Penetron Admix based on the technology providing immersion of samples in the water environment 72 hours after molding. [11].

"Penetron-Admix" changes the structure of the tobermorite gel, increases the cross section of the plates, the distance between the plates, changes the direction of development of adjacent plates causing them to open like a fan. In addition, conditions for crystallization of calcium hydrosilicate in the form of brushes of needle-like crystals that fill cavities between the grains are created. As a result, with the same mass of tobermorite gel using “Penetron-Admix”, the volume of the gel grows in comparison with the gel of the cement stone solidified without an additive. The gel is looser, fills cavities between the grains, reducing the transverse size of the cavities, pores, and capillaries of the cement stone [12].

The higher values of density of fine-grained concrete modified with Penetron Admix (consisting of monocalcium aluminate, calcium dialuminate, gypsum hemihydrate, clinker minerals C3S and C3Al, and Ca (OH) 2) can be explained as follows: as a result of cement hydration, reactions between the components of this additive and ionic complexes of calcium and aluminum, oxides and metal salts contained in the cement stone, calcium hydrosilicates, calcium and hydrosulfoaluminate and calcium hydrocarboaluminates are formed [13].

II. METHODS AND MATERIALS

The effectiveness of additives was proven in the laboratory. The construction of the building involves selection of the most efficient material and development of a construction organization system to use materials with the best properties For example, the accelerated hardening of concrete is not required for works with long technological breaks or simultaneous work organization.

To assess the effectiveness of modifying additives, the schedule of the construction of a twenty-storey residential building in Rostov-on-Don was optimized.

The designed residential building is made is frame-monolithic. The walls are self-supporting, multi-layered; the outer layer is made of terracotta and yellow facing bricks (Fig.1).

Fig. 1. The front façade of the building

The spatial stiffness is provided by monolithic diaphragms and stiffener cores which are the staircases and elevator shafts operating in both directions. In the horizontal plane, the rigidity is provided by monolithic reinforced concrete floors, rigidly connected with the columns and cores of rigidity. The foundations of the building are slab reinforced concrete plates. The thickness of the base plate is 1.5 m.

The building frame consists of reinforced concrete monolith columns, staircase walls, elevator shafts, and slab reinforced concrete floors.

All monolithic structures are made of concrete V25 of the frost resistance grade F50.

The main indicators of the object of schedule optimization are presented in Table 1.

Since the building is of considerable size and height, concreting takes a long time, especially at lower temperatures.

The time for concrete strength development depends on the ambient humidity and air temperature. The strength curve for V25 is presented in Fig. 2.

TABLE I. MAIN PARAMETERS OF THE BUILING

No	Parameters	M.u.	Values
1	Building footprint area	m2	1506,35
2 3	Structural volume	m3 m3	115004,6 11881,8
4	Superstructure volume	m3	103119,8
5	Building area	m2	31219,5
6	Area of the residential building	m2	26544,5

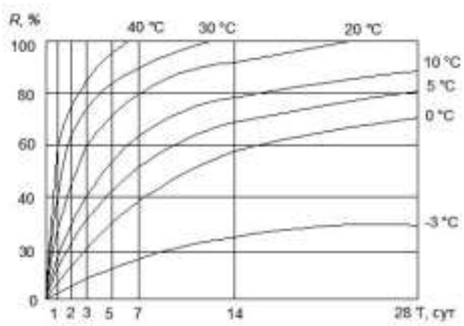

Fig. 2. The curve of V25 strength development

The demolishing strength of concrete is 70% of its full strength.

According to Fig. 2, when performing works without additives:

- in the summer period (at 25º-30º), the striking time is 4 days;
- in the autumn period (at 10º-15º), the striking time is 7 days;
- in the autumn period (at 4º-10º) and in the winter period when the concrete is heated, the striking time is 10 days.

The additives improve properties of the concrete mix.

When adding Relamix-M2:

- mobility of the concrete mix increases from P1 to P5 with a simultaneous increase in the concrete strength;
- the amount of mixing water is reduced by 20% or more;
- the final strength increases by 20% or more (in equal-moving mixtures);
- the strength at the age of 1 day increases by 30% or more (in equal mixtures);
- cement consumption is reduced by 18% for V 25 when using Relamix-M2:

Taking into account the use of additives:

- in the summer period (at 25º-30º), de-scraping occurs after 1 day after pouring;
- in the autumn period (at 10º-15º), the striking time is 3 days;
- in the autumn period (at 4º-10º) and in the winter period when the concrete is heated, the striking time is 5 days.

Since foundation slab waterproofing is performed simultaneously with basement wall construction, the waterproofing does not affect the time for the construction of the foundation.

Labor capacity is 503.1 man-cm using "Penetron Admix" and 539.0 man-cm without the use of additives (using the waterproofing). Concreting with the use of Penetron Admix is the most efficient method.

The method for lifting the concrete mix to the floor is also taken into account. Since the concrete pump of an internal diameter of 180 mm has to be located at a feed distance of up to 250 m horizontally and 40 m vertically, the concrete mix can be supplied only to the 13th floor (mark +39.300). An erection tower crane is used to supply the concrete mix to the upper floors. The mix is lifted in skips.

The scheduling results depending on the time for concreting and a leading mechanism (a pump or a crane) are summarized in Table 2.

TABLE II. DURATION OF CONCRETING OF ONE FLOOR, DAYS

Additives	**Pump concreting**			**Crane concreting**		
	summer	***autumn***	***winter***	***summer***	***autumn***	***winter***
Relamix-M2	17	21	21	24	31	31
Without additives	23	29	31	30	39	41

Since the design of the collective schedule should take into account the season and the mechanism used, the duration of the work was calculated in a tabular form (table).

The duration of concreting works is 529 working if modifying additives are used.

The duration of frame concreting is 385 working days if additives, accelerating hardening and superplasticizers are used.

III. RESULTS

Thus, reduced time of the monolithic construction due to the use of modifying additives (superplasticizers, waterproofing, hardening accelerators) is: (529-385) / 385 = 37%.

Taking into account the cost and consumption (0.6% of the cement mass used in concrete) of Relamix-M2, the economic benefits are 2.5% of the cost of 1 m^3 of V25.

TABLE III. DURATION OF CONCRETING OF ONE SECTION WITH ADDITIVES – HARDENING ACCELERATORS

Floor	Beginning of works	End of works	Duration, days	Mechanism	Season
1	10.05.18	27.05.18	17	Pump	Summer
2	28.05.18	15.06.18			
3	16.06.18	03.07.18			
4	04.07.18	21.07.18			
5	22.07.18	09.08.18			
6	10.08.18	27.08.18			
7	28.08.18	15.09.18			
8	16.09.18	02.10.18	21	Pump	Autumn-winter
9	03.10.18	24.10.18			
10	25.10.18	16.11.18			
11	17.11.18	09.12.18			
12	08.12.18	28.12.18			
13	03.01.19	24.01.19			
14	25.01.19	25.02.19	31	Erection crane	Autumn-winter
15	26.02.19	25.03.19			
16	26.03.19	25.04.19			
17	26.04.19	20.05.19	24	Erection crane	Summer
18	21.05.19	15.06.19			
19	16.06.19	10.07.19			
20	11.07.19	05.08.19			

IV. CONCLUSION

A twenty-storey frame-monolithic building in Rostov-on-Don was used as an object for analysis of the effectiveness of modifying additives. The schedule was built and optimized taking into account the use of various additives, working temperature (depending on the season); ways of lifting concrete mix to the floor (a pump or an erection crane).

It was identified that when using superplasticizers, concrete hardening accelerators and waterproofing additives, the time of construction of reinforced concrete structures of the aerial part is 385 working days which reduces the construction period by 37%.

It was revealed that the use of additives does not increase the cost of concrete mix due to the use of superplasticizers.

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