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Concrete based on low-strength carbonate rocks

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Abstract:

The patterns of formation of the main technical and operational characteristics of concrete produced on the basis of carbonate rocks and modified with various chemical additives have been established. The study considered the effect of the superplasticizer Glenium®51 and the hydrophobic-plasticizing additive SDO on the properties and performance characteristics of concrete mixtures and hardened concrete. The influence of the additives on the workability of concrete mixtures, strength characteristics, frost resistance, and the consumption of coarse aggregate and cement was investigated.

When using the SDO additive, the gravel content in the concrete compositions ranged from 0.9 to 0.7 m³. It was established that the introduction of an optimal amount of the SDO physicochemical modifier, equal to 0.03% of the cement mass, into vibroconcrete compositions with a cement content of 350 kg/m³ makes it possible to obtain concrete with a compressive strength of 35 MPa and a frost resistance grade of F150. The obtained results indicate that the optimal dosage of the SDO modifier for concrete compositions with a cement content of 350 kg/m³ is 0.03% of the cement mass, which ensures the required combination of strength and frost resistance characteristics.

It has also been established that concrete compositions containing the Glenium®51 superplasticizer make it possible to obtain concrete with a compressive strength of 35 MPa using vibration-free technology. The use of the superplasticizer contributes to improving the technological properties of the concrete mixture and provides the required strength characteristics without the need for vibration compaction. When the gravel content is reduced to 0.3–0.4 m³ per 1 m³ of concrete, the introduction of carbonate filler makes it possible to reduce cement consumption while maintaining the required performance characteristics of the concrete.

The conducted research made it possible to establish the optimal parameters of concrete compositions based on carbonate rocks, reduce the content of coarse aggregate, and optimize cement consumption. The obtained results confirm the effectiveness of using chemical modifiers and carbonate fillers for the production of concrete with improved technical and operational characteristics and contribute to the more efficient use of local raw materials in concrete production.

Keywords:

carbonate rocks, crushed stone, concrete, superplasticizer, Glenium®51, SDO, modifier, strength, frost resistance.

1. Introduction

Currently, great attention is being paid to the rational and integrated use of local mineral resources in construction, reducing the cost of construction projects, and the production and distribution of environmentally safe construction products. Due to the widespread distribution of sedimentary carbonate rocks in many regions of the Russian Federation, the task of their comprehensive use is relevant [3; 6]. The relatively low strength and high heterogeneity of the composition often complicate and limit the use of this environmentally friendly mineral raw material, including in concrete production as a large aggregate [2]. At the same time, the use of imported large aggregates leads to a significant increase in the cost of produced concrete and construction objects as a whole.

Research into the raw material base of Mari El Republic (RME) carbonate crushed stone shows its high heterogeneity not only in strength and density but also in mineralogical

composition. Specifically, tests of RME carbonate rocks showed that their density can range from 1570 to 2710 kg/m³, and their compressive strength from 10 to 100 MPa. At the same time, the average compressive strength value in the cylinder does not exceed the 400 mark. The content of Mg (CO)₃ in carbonate rocks within a single deposit differs by tens of percent [4]. This hinders the use of local carbonate rocks in the production of lime, cement, and silicate products.

The research is aimed at finding ways to increase the efficiency of using RME carbonate rocks in concrete production. Taking into account the low strength of carbonate rocks, a hypothesis was formulated regarding the possibility of increasing their application efficiency in concretes by limiting the amount of carbonate crushed stone, provided that surface-active modifiers are additionally used to reduce the water demand of the concrete mixture and improve the structure of the concrete's mortar part [1; 5].

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2. Research methodology

The objective of the study was to study the influence of carbonate crushed stone and modifying additives (SDO and Glenium®51) on the formation of concrete's physical and technical properties—compression strength, water resistance, and frost resistance.

As a large filler, carbonate crushed stone from the RME Korkatovsky quarry was used in the form of a mixture of two fractions: 10-20 mm fractions - 60% and 5-10 mm fractions - 40% by mass, respectively. The mineralogical composition of the crushed stone used was characterized by the presence of 59% dolomite and 40% calcite. Impurities within the range of 1% were represented by quartz and feldspar minerals. Natural quartz sand from the RME Studentovsky quarry with a modulus of 2.07 was used as a fine aggregate.

Previous studies have shown that with a maximum volume content of carbonate crushed stone close to 1.0 m³ per 1 m³ of concrete and reduced only by the size of the grain displacement coefficient of the coarse aggregate, the water resistance coefficient of the concrete decreases to a critical value of 0.8.

An analysis was conducted on the dependence of the concrete's water resistance coefficient on cement consumption within the range of 250 to 450 kg per 1 m³ of concrete and the volume content of carbonate crushed stone, respectively, from 0.7 to 0.9 m³. The water flow rate was selected experimentally and corresponded to the production of uniformly movable mixtures with a stiffness of 20 s. The

water resistance of the concretes was evaluated using the softening coefficient based on the ratio of concrete compressive strength in the water-saturated state to concrete strength in the dry state.

As a result of the conducted experiment, concrete with a compressive strength of 25 to 45 MPa was obtained. All compositions demonstrated high water resistance within the range of 0.98-1.0.

The influence of reducing the gravel content from 0.9 to 0.7 m³ per 1 m³ of concrete in the presence of the SDO modifier from 0 to 0.06% of the cement mass on the properties of concrete obtained from uniformly mobile mixtures with a stiffness of 20 using the vibration compaction method at a vibration frequency of 50 Hz and an oscillation amplitude of 0.5 mm was investigated. Concrete mixtures were prepared in a laboratory vibro-mixer for 3 minutes. The SDO supplement was administered with isolation water. Samples—cubes measuring 100×100×100 mm—were molded from concrete mixtures. The physical and technical properties of the concretes were determined at 28 days of solidification under normal conditions.

At a constant cement flow rate of 350 kg/m³, the influence of the content of carbonate crushed stone and the modifying additive SDO on the formation of concrete strength, capillary-open porosity, and frost resistance was studied. The influence of concrete composition on the formation of compressive strength R_{cs} , MPa, is presented in Table 1.

Table 1

Influence of concrete composition on compressive strength

№ experience	Experiment Matrix		Material consumption per 1 m ³ of concrete				Compression strength limit, R_{cs} , MP
	Gravel, m ³	SDO, %	Cement, kg	Gravel, kg	Sand, kg	Water, liter	
1	0,9	0,06	350	1000	810	195	34,8
2	0,9	0,00	350	1000	810	210	34,1
3	0,7	0,06	350	780	1010	205	30,4
4	0,7	0,00	350	780	1010	220	28,8
5	0,9	0,03	350	1000	810	190	36,6
6	0,7	0,03	350	780	1010	210	31,8
7	0,8	0,06	350	890	910	195	35,8
8	0,8	0,00	350	890	910	210	34,0
9	0,8	0,03	350	890	910	200	36,4

It has been established that the surface-active modifier SDO in an amount of 0.03% reduces the water requirement of uniformly mobile concrete mixtures by an average of 5%. Further increasing the amount of the added additive to 0.06% of the cement mass slightly reduces water demand. In the absence of the SDO modifier, a decrease in the volume content of carbonate crushed stone from 0.9 to 0.7 m³ per 1 m³ of concrete leads to a decrease in the strength of the compositions from 34 MPa to 28.8 MPa. The introduction of the SDO additive contributes to a 5-7% increase in the strength of the compositions. The reduction of the volume content of carbonate crushed stone to 0.7 m³ per 1 m³ of concrete is recognized as statistically significant for the compressive strength limit of concrete modified with SDO with a 95% confidence level.

The influence of the SDO modifier and the volume content of crushed stone at a cement consumption of 350 kg/m³ on concrete frost resistance was determined using the accelerated structural-mechanical method in accordance with GOST 10060.4-95. At the same time, capillary open porosity and the strength increase coefficient of concrete during single freezing in a water-saturated state were monitored.

It has been established that across the entire range of gravel content variations, the modifier SDO in an amount of 0.03% of cement mass has the best effect on reducing the volume of capillary open pores in concrete. Thus, with a constant volume content of 0.9 m³ of crushed stone per 1 m³ of concrete, the presence of a 0.03% SDO additive from the cement mass reduces the capillary-open porosity of the



concrete from 14.4% to 13.4%. An increase in SDO content to 0.06% does not lead to a further decrease in capillary open porosity.

Figure 1 shows the dependence of concrete frost resistance on the content of carbonate crushed stone and the amount of SDO modifier.

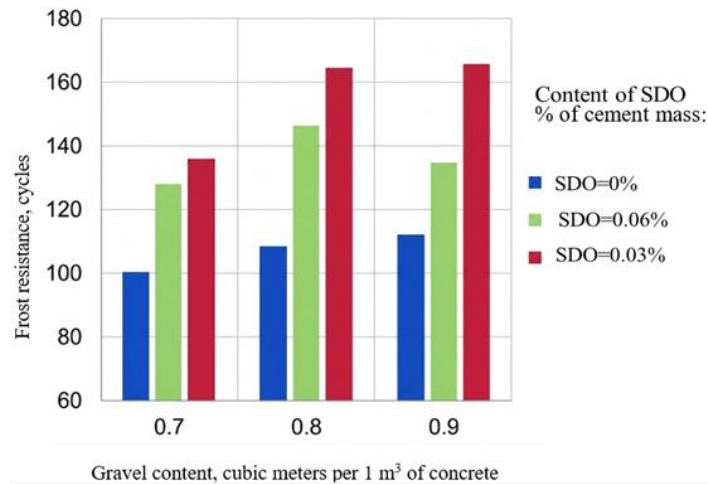


Fig. 1. Dependence of concrete frost resistance at a constant cement consumption of 350 kg/m³ on carbonate crushed stone consumption and the content of SDO additive

Based Analysis of the influence of crushed stone and SDO modifier content on frost resistance showed that a rational SDO modifier content of 0.03% of cement mass with a rational crushed stone content of 0.8-0.9 m³ increases concrete frost resistance from grade F100 to grade F150. Comparison of the data shows that the increase in concrete compressive strength is consistent with the results of determining its frost resistance and capillary-open porosity.

Self-compacting concrete mixtures are manufactured using compositions containing no more than 0.5 m³ of coarse aggregate per 1 m³ of concrete. Within the framework of vibration-free technology for self-compacting concrete mixtures in the presence of the Glenium®51 superplasticizer based on polycarboxylate ether, the influence of reducing the carbonate gravel content from 0.5 to 0.3 m³ per 1 m³ of concrete on its strength formation was investigated. The following were selected as variable factors in the experiment: the content of carbonate filler and the content of 5-10 mm fraction carbonate crushed stone.

Carbonate filler with a specific surface area of 350 m²/kg was obtained by grinding siftings from the crushing of carbonate rocks. At the same time, the calculation of the introduced amount of carbonate filler was performed based

on the condition that the total content of cement and mineral filler (C+H) in the mixtures was 540 kg per 1 m³ of concrete. Based on this, the content of mineral filler in the studied compositions ranged from 30 kg to 170 kg per 1 m³ of concrete. Crushed stone was added in an amount of 30-50% of the bulk volume. Based on preliminary tests, the content of the Glenium® 51 superplasticizer in all compositions was taken as 2% of the total weight of the cement and carbonate filler. The compressive strength limit of concrete was determined by testing 100*100*100 mm cube samples after they had solidified for 28 days under normal conditions.

The results of the compression strength study for self-compacting concrete are presented in Figure 2.

Analysis of the obtained results showed that the effect of partially replacing cement with carbonate filler is advisable when the gravel content is within the range of 30-40%. For these compositions, the use of carbonate filler contributes to cement savings. Overall, it has been established that concrete compositions with carbonate filler, when Glenium® 51 superplasticizer is added to the formula in an amount up to 2% of the total mass of cement and carbonate filler, allow for the production of concrete with a compressive strength of 34 to 46 MPa using vibration-free technology.

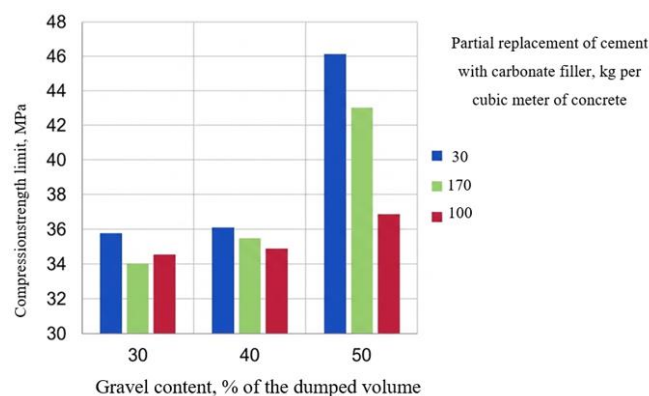


Fig. 2. Effect of partial replacement of cement with carbonate filler on the strength of self-compacting concrete



3. Conclusion

It has been established that concrete on carbonate crushed stone, with its content in the concrete within the range of 0.9 to 0.7 m³, has water resistance. From the perspective of forming strength and frost resistance at a constant cement consumption of 350 kg, concrete compositions containing 0.03% SDO and at least 0.8 m³ of carbonate gravel per 1 m³ of concrete are recommended.

Self-compacting concrete compositions that are economical in terms of cement consumption can be obtained based on the Glenium® 51 superplasticizer and carbonate filler with a volume content of carbonate crushed stone within 0.4-0.3 m³ per 1 m³ of concrete.

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