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PRODUCTION OF LOW AND MIDDLE CLASS CONCRETE FROM ENVIRONMENTALLY FRIENDLY RAW MATERIALS

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Abstract

The prospects and relevance of research regarding the analysis of concrete mixtures composition and the analysis of the properties of gravel-sand concrete mixtures are confirmed by the presence of a huge natural resource base for obtaining modern concrete composites. The article is devoted to the actual problem of using sand and gravel mixtures (SGM) to obtain concretes of low and medium classes. As part of the research, the compositions of concrete mixtures were developed for the preparation of concretes of classes B7.5–B30 on bank SGMs. Using the cement content ratio, a comparative analysis of the effectiveness of the considered concretes on sand and gravel mixtures and normal concretes on standard aggregates from sand and crushed stone was carried out. The physicomechanical and deformative properties of various classes of concretes on SGM were studied; on the basis of the results obtained, a conclusion was made about the advisability of expanding the field of sand and gravel concrete mixtures and their application.

Keywords: Aging, concrete composites, complex binders, helioforms, materials, natural and technogenic raw, Portland cement

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1. Introduction

The prospects and relevance of research regarding the analysis of concrete mixtures composition and the analysis of the properties of gravel-sand concrete mixtures are confirmed by the presence of a huge natural resource base for obtaining modern concrete composites (Alaskhanov et al., 2019; Barinova, 2005; Bazhenov et al., 2019; Kurbatov et al., 2008; Lesovik, 2007).

2. Problem Statement

Since the composition of gravel sand mixtures includes two components – gravel and sand, then its properties are regulated by two GOSTs (all-Union State Standard in Russia): GOST 8267–93 “Crushed stone and gravel from dense rocks for construction work. Specifications” and GOST 8736–93 “Sand for construction work”.

3. Research Questions

From a wide variety of materials used in industrial, civil and individual construction, sand and gravel mixtures are the most affordable and demanded building materials. But, despite this, the analysis of literature sources and the research on the practice of industrial use of SGM indicate extremely scarce information about the scientific and production experience in the use of sand and gravel mixtures in the Russian construction industry.

4. Purpose of the Study

The results of the research proved the possibility of obtaining B7.5–B30 grade concretes, which fully comply with the requirements of the current norms and standards. Moreover, gravel-sand mixtures of river bank origin from the river beds of the mountainous regions of the Chechen Republic were taken as the research objects and samples.

5. Research Methods

The analysis of the results obtained indicates the absence of a unified methodology for designing the compositions of concrete mixtures for the recipes of the entire line of concretes under consideration. To substantiate the above, using the cement content ratio (Ccr), the ration of cement for obtaining a specific grade of heavy concrete on standard aggregates (crushed stone, sand) and SGM was compared.

6. Findings

As the results obtained (Table 01) have shown, with the transition to concretes of higher grades, starting with B20 and higher, in order to ensure their design strength, it is necessary to increase the cement ratio in comparison with the reference compositions on traditional local crushed stone and sand, i.e. apply an increased proportion of the binder, equal to 1.1–1.5. Moreover, the higher the grade of concrete, the greater the value of this proportion (coefficient).

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Table 1. Ccr value for various concrete compositions

No.	Filler (aggregate) state (SGM)	Design class (grade) of concrete	Consumption of materials for 1 m^3 of concrete mix, kg				Ccr
			C	SGM	Add	W	
	Unrefined (raw)	B7.5	195	2080	2	180	0.93
	Refined	(M100)	185	2095		176	0.88
	Unrefined (raw)	B12.5	243	2030	2.5	183	0.97
	Refined	(M150)	230	2045		180	0.92
	Unrefined (raw)	B15	295	1980	3.0	185	0.98
	Refined	(M200)	280	2000		181	0.93
	Unrefined (raw)	B20	350	1945	3.5	182	1.03
	Refined	(M250)	325	1975		178	0.95
	Unrefined (raw)	B22.5	390	1915	4.0	183	1.04
	Refined	(M300)	375	1930		180	1.00
	Unrefined (raw)	B25	465	1840	4.6	187	1.11
	Refined	(M350)	440	1870		184	1.05
	Unrefined (raw)	B30	515	1805	5,2	192	1.12
	Refined	(M400)	495	1830		190	1.08

Note: * – the cement content ratio is calculated relative to the reference non-additive concrete compositions presented in table 1, for which it is equal to 1.

However, it is important to note that the ratio of the binder for concretes on SGM of lower grades of compressive strength (B7.5, B10, B12.5 and B15) is below 1, which indicates the efficiency of obtaining such concretes suitable for non-critical structures.

To obtain concretes of higher classes (grades), starting with B20 and higher, we propose to refine the SGM by way of wet method, which makes it possible to reduce the content of flour (slimy), clayey and silty particles and clay balls to permissible values, or to get rid of them altogether. In this case, dry cleaning (beneficiation) will not be as effective as the wet method, since the SGM of the Vedeno field, extracted from the bottom of water or of high humidity, will not be cleaned of and/or separated from clay particles adhering (smeared) to the surface of the grains.

Thus, in order to save the most expensive component of concrete – a binder, we have carried out studies of the compositions of concretes obtained using refined (cleaned) SGM.

The use of refined SGM gives a cement-saving effect of up to 15%, and in combination with the chemical additive "Polyplast SP-1" this effect increases to 30% (Table 01).

Thus, the motivation for using refined SGM in concrete composites of relatively high compression grades has been experimentally proved. A chemical additive used as a plasticizer and structure modifier is recommended to be used in all compositions, regardless of the class or grade of concrete.

In this regard, studies aimed to determine the strength and deformation properties of the proposed concretes based on aggregates from SGM become even more reasonable and interesting.

It is commonly known that concrete is a multicomponent system, where, along with active components (cement and water), a significant volume is occupied by inert components – sand and crushed stone, or, as in this case, sand and gravel mixtures. Due to the fact that in order to obtain a dense monolithic structure of concrete, it is necessary to ensure a strong bond (adhesion) of inert components with a binder, GOST regulates the permissible amount of harmful impurities to obtain a high-quality

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mixture heavy and fine-grained concrete in 2012. Even a slight excess of their content will have a negative effect on the strength of contact area (zone) (Figure 01).

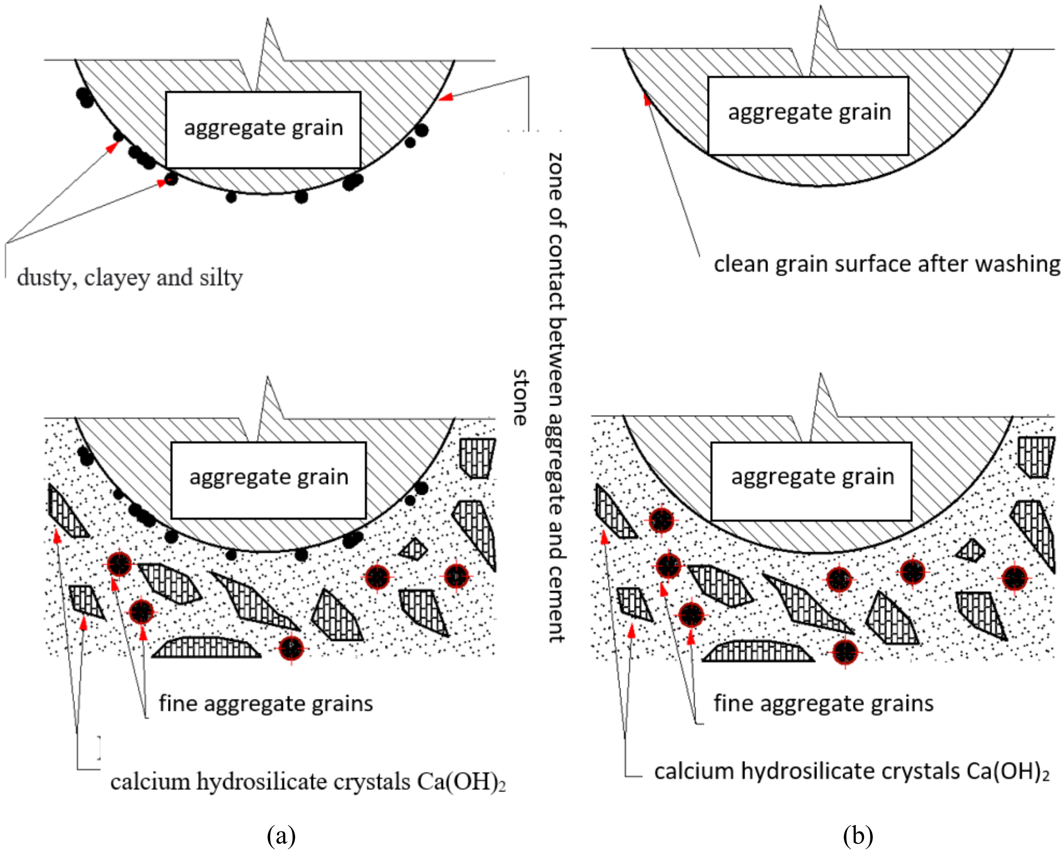

Figure 1. The contact area of the aggregate and cement stone when using unrefined (contaminated) aggregate (a) and refined (sleaned) aggregate with a clean surface (b)

It is generally accepted that the destruction of any material occurs due to the excess amounts of internal stresses arising from the action of an external load over the amounts permissible for a given type of material. In the known theory of concrete strength, three types of deterioration are presented: along the cement stone, along the aggregate, and the contact zone between the aggregate and the mortar part of the concrete (Bataev et al., 2017; Kharkhardin, 1994; Salamanova et al., 2019; Salamanova & Khadisov, 2019; Saidumov et al., 2019; Udodov & Charikov, 2020). For concretes developed on the basis of aggregates with a rounded surface (for example, gravel), the second picture (case) of concrete deterioration is relevant, i.e. destruction along the contact zone.

The quality of the resulting concrete composite is judged by its parameters such as design strength, durability, resistance to external influences (frost resistance and water resistance). The axial compressive and tensile strength at 28 days of age determines the class (grade) of concrete according to the type of impact considered.

When using an unrefined aggregate (Figure 01), the surface of which is contaminated with various clay and silty particles, the strength of the contact zone is significantly lower than when using a refined (cleaned) aggregate. Clay, silty and other undesirable particles in the composition of concrete, occupying

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positions between the surface of the aggregate and the cement stone, significantly reduces the strength of their adhesion, which affects the strength of the entire concrete.

In order to study the physicomechanical and deformative properties, studies of various classes of SGM concretes were carried out (Table 02).

Table 2. Physical, mechanical and deformative properties of various classes of SGM concretes

№ of composition from previous table	Filler (aggregate) state (SGM)	Design class (grade) of concrete	Actual strength (Rp28), MPa		Elastic modulus, E·103, MPa	Shrinkage of concrete, mm/m
			Rcomp	Rbend		
	Unrefined	B7.5 (M100)	10.5	0.9	10.8	0.46
	Refined		10.2	1.1	12.3	0.41
	Unrefined	B12.5 (M150)	18.3	1.3	14.3	0.52
	Refined		17.5	1.7	15.7	0.47
	Unrefined	B15 (M200)	21.6	1.5	17.5	0.62
	Refined		22.1	2.2	18.9	0.59
	Unrefined	B20 (M250)	26.8	1.8	21.4	0.76
	Refined		27.2	2.6	21.1	0,71
	Unrefined	B22.5 (M300)	31.7	2.2	24.5	0.89
	Refined		32.1	2.9	26.5	0,80
	Unrefined	B25 (M350)	34.7	2.8	28.8	0.93
	Refined		33.8	3.2	30.2	0.87
	Unrefined	B30 (M400)	40.2	3.2	35.5	0.98
	Refined		42.5	3.5	36.2	0.89

From table 2 it can be seen that the use of refined SGM contributes to the improvement of almost all indicators of concrete quality.

Naturally, concretes on SGM are characterized by low bending strength (Figure 02) in comparison with concretes on crushed stone, for which this indicator can be 3–7 MPa, depending on the class of concrete. Therefore, such concretes are recommended to be used to resist compressive forces.

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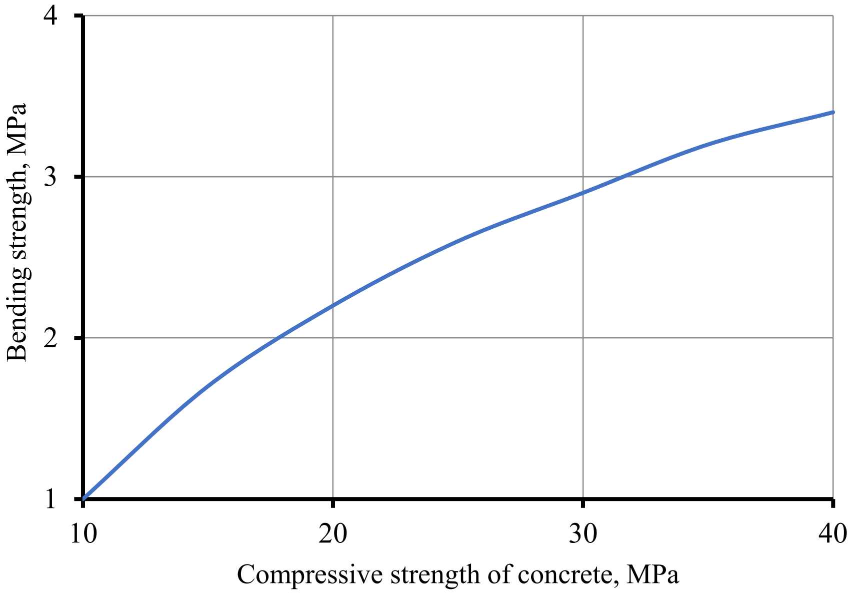

Figure 2. Dependence of concrete compressive strength on its bending strength

It was also found that with an increase in the strength and the proportion of binder in concrete, the shrinkage of concrete increases, but it does not exceed the maximum permissible values. Shrinkage, as a rule, ranges from 0.3 to 0.6 mm/m for normal concretes on crushed stone and natural sand.

The use of refined SGM helps to reduce concrete shrinkage (Figure 03).

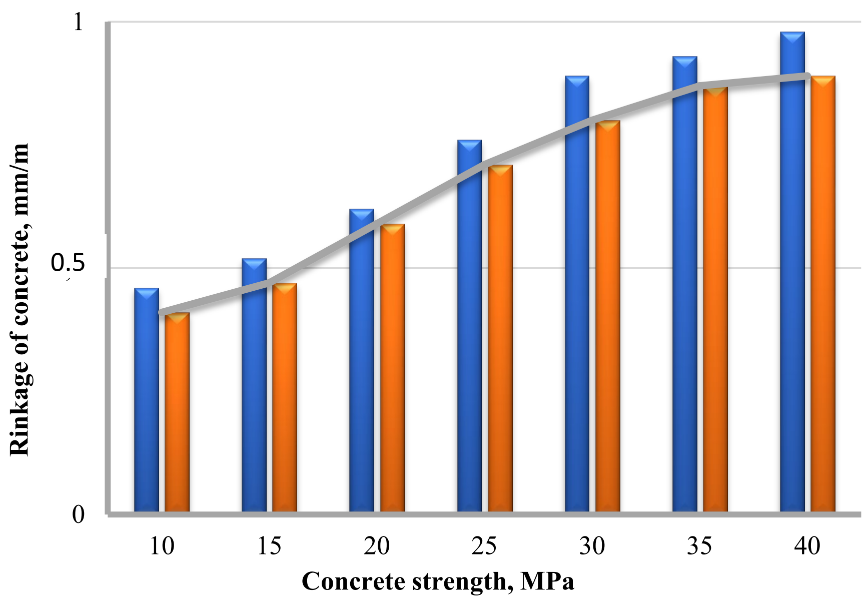

Figure 3. Dependence of concrete shrinkage on its strength and surface cleanliness of the aggregate from SGM

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7. Conclusion

The modulus of elasticity of concretes based on SGM is up to $36 \cdot 10^3$ MPa, depending on the class of concrete. Moreover, with an increase in the strength of concrete, the modulus of elasticity also increases. It should be noted that the modulus of elasticity of concrete on refined SGM is significantly higher in comparison with concretes on unrefined (contaminated) aggregate.

Thus, the studies carried out have convincingly proved that the design of low and middle class concretes on river bank sand and gravel mixtures is an urgent task of modern concrete science, the solution of which will significantly expand the raw material base of high-quality aggregates for obtaining concrete composites based on them with the required set of physical and mechanical and deformative properties.

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