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Composite material based on recycled concrete.

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Abstract. The article presents the results of studying the problem of the accumulation and utilization of concrete scrap. It is noted that during the implementation of comprehensive programs, including the renovation of housing, a significant amount of concrete scrap has already been accumulated, and will continue to accumulate and its utilization is necessary now, and from 2020 will become mandatory. The study of methods of concrete scrap utilization provided an opportunity to justify the appropriateness of its use as a component of building materials. The theoretical foundations for the production of composite facing materials using ground concrete scrap are based on the applied aspects of the methodology of creating new building (composite) materials, the main positions of which were formulated by the scientists of the Moscow State University of Civil Engineering. This methodology has been tested in the development of compositions and technologies of acoustic and some types of heat-insulating materials: foamed gypsum and mineral wool products of a combined structure. The results of scientific research on the development of compositions of composite material based on fine-grained waste scrap concrete, mineral binder and linear polymers (with branching radicals) hardened as a result of chemical interaction with concrete components are presented. Polyurethane derivatives hardened as a result of reactions with water in the presence of catalysts with or without exposure to temperature were used as a polymeric component. The target of the research is the creation of scientific foundations of energy-saving technology of facing products based on concrete scrap. To achieve this target, it is necessary to solve the next tasks: - with the use of the foundations of the methodology for the creation of new building (composite) materials, to develop formulations and technological parameters for the creation of facade products with increased elasticity; - identify specific types of polymer compositions satisfying the conditions of curing and exploitation, elastic lining materials.

1. Introduction

Finishing materials in facade facing systems experience significant mechanical stresses associated with changes in the geometric characteristics of the foundation (shrinkage, movement, etc.), or with deformations of the suspension and fastening systems [1, 2]. If the facing product is rigid, then when a certain level of stresses in the structure is achieved, it becomes possible to destroy the products or to fall out of the fastening systems [3, 4]. For the design to remain intact, it is necessary that the products have a certain elasticity (flexibility), while maintaining all the performance characteristics at the level required by the standards.

On the other hand, as a result of the implementation of complex housing programs, a huge amount of construction scrap (including concrete) scrap has already accumulated on the corresponding sites, the utilization of which is necessary, and in the near future will become mandatory [5, 6]. In connection with the above, the development of recipes and technology of facing products based on concrete scrap is an urgent task.

Attention to the issue of re-use of concrete in the construction industry intensified in the 1990s due to the increased scarcity of natural fillers, the need to protect the environment and the increase in the number of old, morally and physically worn out buildings and structures made of reinforced concrete subjected to demolition.

Many years of experience in the processing of concrete is available in the United States. For more than 10 years, over 20 million tons of concrete products have been processed annually. According to a number of American firms, in the production of crushed stone from concrete, fuel consumption is 8 times less than when it is mined under natural conditions, and the cost of concrete on secondary crushed stone is reduced to 25% [7, 8].

The first studies on the use of scrap waste in the EEC member countries in construction were carried out in 1977 by Dutch scientists. Later experiments were conducted jointly by the scientists of the Netherlands, Belgium and Germany, who formed the Research Committee "Reuse of concrete and stone scrap" [9, 10].

The paper presents the results of the selection of compositions and technologies of composite materials based on fine-grained waste scrap concrete, mineral binder and linear polymers (with branching radicals), which are cured as a result of chemical interaction with mineral binder components under temperature exposure conditions.

2. Experimental section

According to the developed hypothesis, the increase in strength and durability of concrete can be achieved by improving the quality of the contact zone and the use of dimers, which increase the elasticity of the emerging contacts. This is achieved by pre-treatment of the aggregate with a complex additive. As such an additive, microsilica powder was used together with a hyperplasticizer ".

The preparation of the aggregate treatment solution was carried out in a concrete mixer. First, a part of the mixing water in an amount of 20-30% was mixed with a hyperplasticizer in an amount of 0.5-0.75%, after which microsilica was added in an amount of 10% by weight of the cement with simultaneous stirring for 30 seconds. Then, fine and coarse aggregates were fed to the concrete mixer and the mixture was mixed for 60 seconds. After that, cement and the rest of the water were fed and the concrete mix was mixed for 90 seconds.

Mathematical planning of the experiment is an important part of the solution of technological problems on the computer for finding the equations of mathematical models of technological processes or phenomena. The method of the Moscow State University of Civil Engineering (MGSU) was used as a basis. The statistical hypotheses were tested, the simulation, processing and optimization of the results were carried out in accordance with the methodology of the G-BAT-2011 software complex developed at the SMiM department of the NIU MGSU [11, 12]. The experimental conditions are shown in Table 1.

Table 1. Experimental conditions

Factor name	Symbol X_i	The mean value of the factor, $\overline{X}_i$	Variation interval, ΔX_i	Factor values at levels	
				-1	+1
Cement consumption, kg / m^3	X_1	400	50	350	450
Sand consumption, kg / m^3	X_2	650	50	600	700
Screenings consumption, kg / m^3	X_3	650	50	600	700
Hyperplasticizer consumption,kg / m^3	X_4	5.2	1.5	3.7	6.7

As variable factors, expenses of cement, sand, screening, hyperplasticizer are accepted. The consumption of water is set in accordance with the W / C and is not an independent factor. The experimental conditions are given in Table 1. The response functions are the strength of concrete in compression (Y1) and its average density (Y2).

3. Results section

Mathematical processing of the experimental results allowed obtaining regression equations for the average density (V2) and compressive strength (V1). The following mathematical models (polynomials) are obtained:
- for compressive strength

$$Y1 = 29.4 + 3.8X1 + 1.9X2 + 1.8X3 + 1.7X4 + 1.8X1X3-1.6X42$$

- for medium density:

$$Y2 = 1899 + 51X1-34X2 + 32X3 + 18X4 + 15X1X4-8X42$$

The obtained models were tested for adequacy by the Fisher criterion. The calculated values of the Fisher criteria are equal for the average density model F1 = 14.7 and for the compressive strength model F2 = 15.1. The tabular values of the criteria are respectively 19.2 and 19.3. The calculated values of the F-test do not exceed the tabulated value, and with the corresponding confidence probability (95%), the model can be considered adequate. This fact will be taken into account in the analytical optimization of mathematical models.

4. Discussion section

Analysis of the coefficients of the equation Y1 = f1 (X1, X2, X3, X4) shows that the strength increases with increasing portland cement, sand and drop-out rates in the intervals taken in the experiment (positive coefficients for X1, X2, X3.) With increasing hyperplasticizer costs first, there is an increase in strength, and then at high costs, a decrease is observed (the coefficients at X4 and X42), suggesting that the function Y1 = f1 (X1, X2, X3, X4) has a local extremum in X4, and analytical optimization is possible.

The analysis of the coefficients of the equation Y2 = f2 (X1, X2, X3, X4) shows that the greatest impact on the increase in concrete density is due to an increase in portland cement consumption and dropout (coefficients at X1 and X3). An increase in the consumption of sand leads to a decrease in density (coefficient at X2), and an increase in the flow of the hyperplasticizer contributes to an increase in density, initially intense, and at high costs, insignificant.

Analytic optimization is based on the fact that the functions Y1 = f1 (X1, X2, X3, X4) and Y2 = f2 (X1, X2, X3, X4) are mathematical and the methods of mathematical analysis can be applied to them, provided that they are not violated condition of adequacy. In the case considered, the following scheme is adopted:

- the equation V1 = f1 (X1, X2, X3, X4) is differentiated with respect to X4 and equated to zero, defining the extremum of the function V1 in X4;
- solve the functions Y1 = f1 (X1, X2, X3, X4) and Y2 = f2 (X1, X2, X3, X4) for X4 = opt
- solve the function Y2 = f2 (X1, X2, X3) at Y2 = 1960 kg / m^3
- Conduct a graphic interpretation of optimized functions.

Interpolation solutions on the whole range of factors X1, X2, X3 with the optimized value of factor X4 (hyperplasticizer consumption) can be represented graphically (Figure 1).

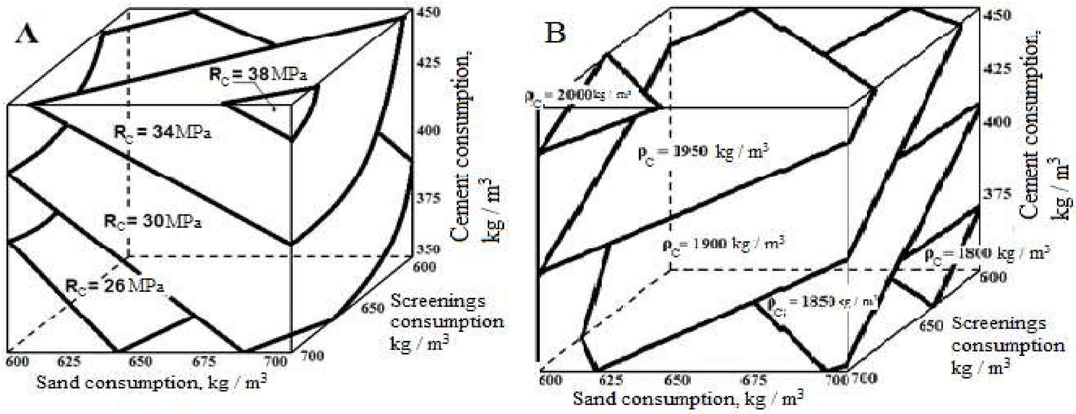

Figure 1. Graphical interpretation of interpolation solutions: A - dependence of strength of concrete on variable factors; B - the dependence of the average density of concrete on variable factors

The construction of the nomogram for the selection of the composition over the entire region of determining factors X1, X2, X3, X4 (Figure 2) was carried out using mathematical dependences for strength and density.

In the nomogram I sector, the strength of concrete (R, Y1) is dependent on the consumption of portland cement (Pc, X1) and the flow rate of the hyperplasticizer (Pp, X4):

$$Y1 = 29.4 + 3.8X1 + 1.7X4 - 1.6X42$$

The plots are plotted for plasticizer flow rates of 4 kg/m^3 and 6 kg/m^3, in coded form, respectively: -0.8 and 0.53 and then converted to a natural coordinate system.

In the nomogram II sector, the dependence of the concrete density (ρ, Y2) on the dropout rate (Po, X3) and the flow rate of the hyperplasticizer (Pp, X4) is used:

$$Y2 = 1899 + 32X3 + 18X4 + 15 - 8X42$$

The plots are plotted for plasticizer flow rates of 4 kg/m^3; 5 kg/m^3 and 6 kg/m^3, in coded form, respectively: -0.8; -0.13 and 0.53 and further their transformation into a natural coordinate system is carried out.

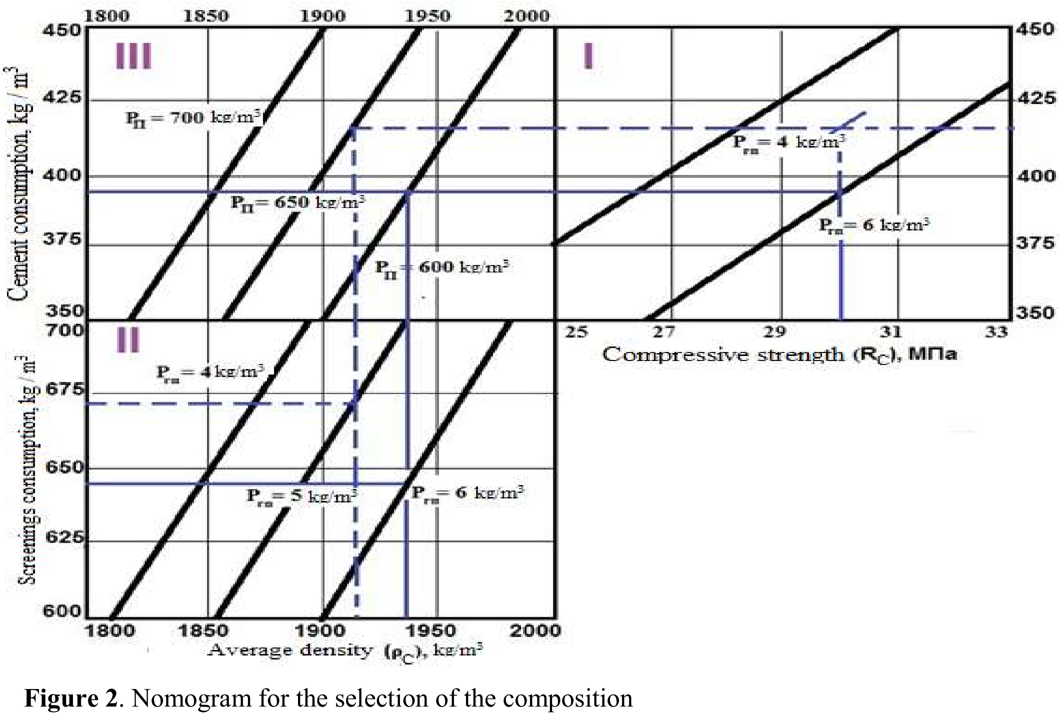

Figure 2. Nomogram for the selection of the composition

In the nomogram III sector, the density of concrete (ρB, Y2) is dependent on the consumption of portland cement (Pc, X1) and the sand consumption (Ps, X2): У2 = 1899 + 51X1 - 34X2

The graphs are plotted for the sand consumption of 600 kg/m^3, 650 kg/m^3 and 700 kg/m^3, respectively, in coded form: -1, 0, +1 and then converted to a natural coordinate system.

The nomogram can be used to predict the properties or the selection of the composition of the finishing concrete [13, 14]. For example, in order to obtain concrete with a strength of 30 MPa, then with a hyperplasticizer consumption of 6 kg/$m^{3,}$ the cement consumption will be 390 kg/m^3 (Sector I nomogram). At a sand consumption of 600 kg/m^3, this composition will correspond to a concrete density of 1930 kg/m^3 (sector II nomogram). The drop-out rate is 640 kg / m^3 (sector III nomogram).

If, with the same strength of concrete, we want to reduce the consumption of plasticizer (for example, up to 5 kg/m^3), then we will have to increase the consumption of portland cement to 420 kg/m^3 (dotted line). At the same time, when the sand consumption is 650 kg/m^3, the concrete density is 1920 kg/m^3, and the dropout rate is 672 kg/m^3. All component costs are adjusted based on the results of the trial mix.

5. Conclusion

In connection with the increasing volumes of demolition of five-story buildings, replacement of bridge structures and road surfaces, the problems of processing elements of destructible structures and structures with the purpose of obtaining secondary non-metallic building materials become extremely topical. The article presents the results of experiments, in the course of the realization of which the multifactor dependences of the strength and density of articles on the amount of cement, the consumption of the polymer component, and the ratio of sand and screening of crushing in the aggregate mixture necessary to optimize the production of facade concrete products are established.

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