Methodology for the selection of the composition for the production of products of hard-pressed concrete with industrial wastes

Yelizaveta Lotoshnikova[1], *Khungianos* Yavruyan[1*], *Spartak* Edilyan[1], and *Alexei* Gaishun[1]

[1]Don State Technical University, 1, Gagarin square, 344003 Rostov-on-Don, Russia

Abstract. The article presents a method of designing and assigning the composition of the molding sand, which is based on the calculation and experimental approach to determining the composition, taking into account the quality of raw materials used and the requirements for the properties of the concrete produced products. The main technical characteristics of small-size rigidly pressed products and requirements to them are given. The methodology of selecting the composition of the molding sand is discussed in detail. The method of nominal composition of molding sand is developed and presented in the form of flowchart. A step-by-step description of the flowchart is presented. Low water-consumption binder, man-made wastes - ash microspheres as a damping additive, traditional coarse and fine aggregates are used as raw materials. To determine the physical and mechanical properties of concrete in the products were tested for compliance with the requirements of regulatory documents. When carrying out researches, there were used generally accepted rules of evaluation of geometric sizes and indices of outer appearance of products, average density, water absorption and strength properties of concrete, abrasion of face layer surface of products, rules of assignment of requirements to frost resistance. Production of products according to the proposed composition and the recommended method of calculation of the molding sand will contribute to environmental protection, since the production waste is used in their manufacture. Keywords: selection methodology, raw mix, grain composition, concrete, freshly compacted mix, small products, hard pressing, block diagram

1 Introduction

The methodology for assigning the nominal composition of the molding sand for the manufacture of small products from hard-pressed concrete with damping additives is developed on the basis of experimental studies and semi-production refinement of the modes of manufacturing products from cement-mineral compositions according to GOST 26633 "Concretes of heavy and fine-grained. Technical conditions" with damping additives. Products are made by vibrocompression on pallets or by rigid pressing with their subsequent laying on the pallets. Products are designed for the device elements of road surfaces with

* Corresponding author: khungianos@mail.ru

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high traffic (crossings over the railroad tracks, lifts and descents, highways, etc.) and floors in the premises of industrial buildings under severe operating conditions of coatings (shock, chemical effects, etc.), can be used in the device sidewalks and landscaping paths. Products must be manufactured in accordance with the requirements of GOST 17608 "Concrete sidewalk slabs. Technical Conditions", and other normative and technical documents, as well as in accordance with the technological documentation approved in the prescribed manner and the basic requirements for the initial raw materials, formulations, technological parameters and modes of mixing, shaping and hardening, control and safety rules in the manufacture of products. Technical characteristics of the products are presented in Table 1.

Table 1. Technical characteristics of "cobblestone".

Product name	**Geometric dimensions**			**Reference mass, kg**	**Number of items in 1m^2 coating, pcs.**
	length	**width**	**height**		
Stone cobblestone	200	200	100	4.5	48
Stone cobblestone	200	50	100	2.3	95

Designing the production of products should be carried out taking into account SP 130.13330 and the norms ONTP 07-85.

Modes and parameters of the production of products are specified depending on the quality of materials used and the specific conditions of its manufacture at the technological complex. Products shall meet the requirements of GOST 17608, which are given in Table 2.

Table 2. Basic requirements for small concrete products.

Product designation	**Class concrete strength at compressive strength**	**Standardized tempering strength, % of design strength**		**Concrete grade by frost resistance**	**Water-absorption by mass, %, not more**	**Abrasion resistance of concrete, g/cm^2, no more**	**Impact strength, kg cm/cm^3, not less**
		Summer	**In winter**				
The device of crossings, raises, descents and other surfaces with heavy traffic	B 40 – B 50	70*	90*	F 150 – F 300	5	0.5	not regulated
Installation of sidewalks and garden paths	B 30 – B 40	70*	90*	F 100 – F 200	6	0.7	not regulated

* By agreement between the manufacturer and the consumer, the normalized tempering strength may be reduced by up to 50%.

2 Methods and materials

This refinement shall not impair the modes and parameters established by these regulations. All deviations from them shall be justified by technical and economic calculations or experimental data.

Products may be unpainted and colored. Colored products may have volumetric coloring or a colored coating layer. Mineral or organic pigments are used for their production.

Technical and economic efficiency of products made of cement-mineral compositions with damping additives is determined by the possibility of using local raw building materials and waste products.

The method of designing and appointing the composition of the molding sand is based on the results of research and design-experimental approach to determining the composition, taking into account the quality of raw materials used and the requirements for the properties of the concrete produced products.

Block diagram of determining the nominal composition of a molding sand using a low-water-consumption binder and ash microspheres as a damping additive is shown in Fig. 1.

At the first stage (blocks 1-3) normative requirements to the material of articles are determined by analyzing normative or design documents, where class of concrete is normalized by compressive strength (B), upper limit of water absorption by mass ($Wm \leq 5$ %), by abrasion ($And \leq 0.5$ g/cm^2), frost resistance in sodium chloride solution and impact strength (depending on operating conditions) [1, 2, 3].

Evaluation of the quality of raw materials is carried out by the methods of the relevant regulatory documents. When testing the binder of low water consumption, we determine its activity, fineness of grinding, setting time and the uniformity of volume change during curing.

3 Results

To determine the properties of dense aggregates (screenings of natural and artificial sand), we use the methods of GOST 8735. The grade of the rock is evaluated by the crushability of gr. 5-10 mm, we also determine frost resistance, grain composition, the content of weak grains and harmful impurities [4, 5, 6, 7, 8]. On a sample of ash microspheres we determine their grain composition, bulk density and hollowness.

After evaluating the grain composition of each component of the mixture of dense aggregates, we calculate the ratio between them in such a way that the dispersion curve of this mixture was as close as possible or located in the shaded area in Fig.

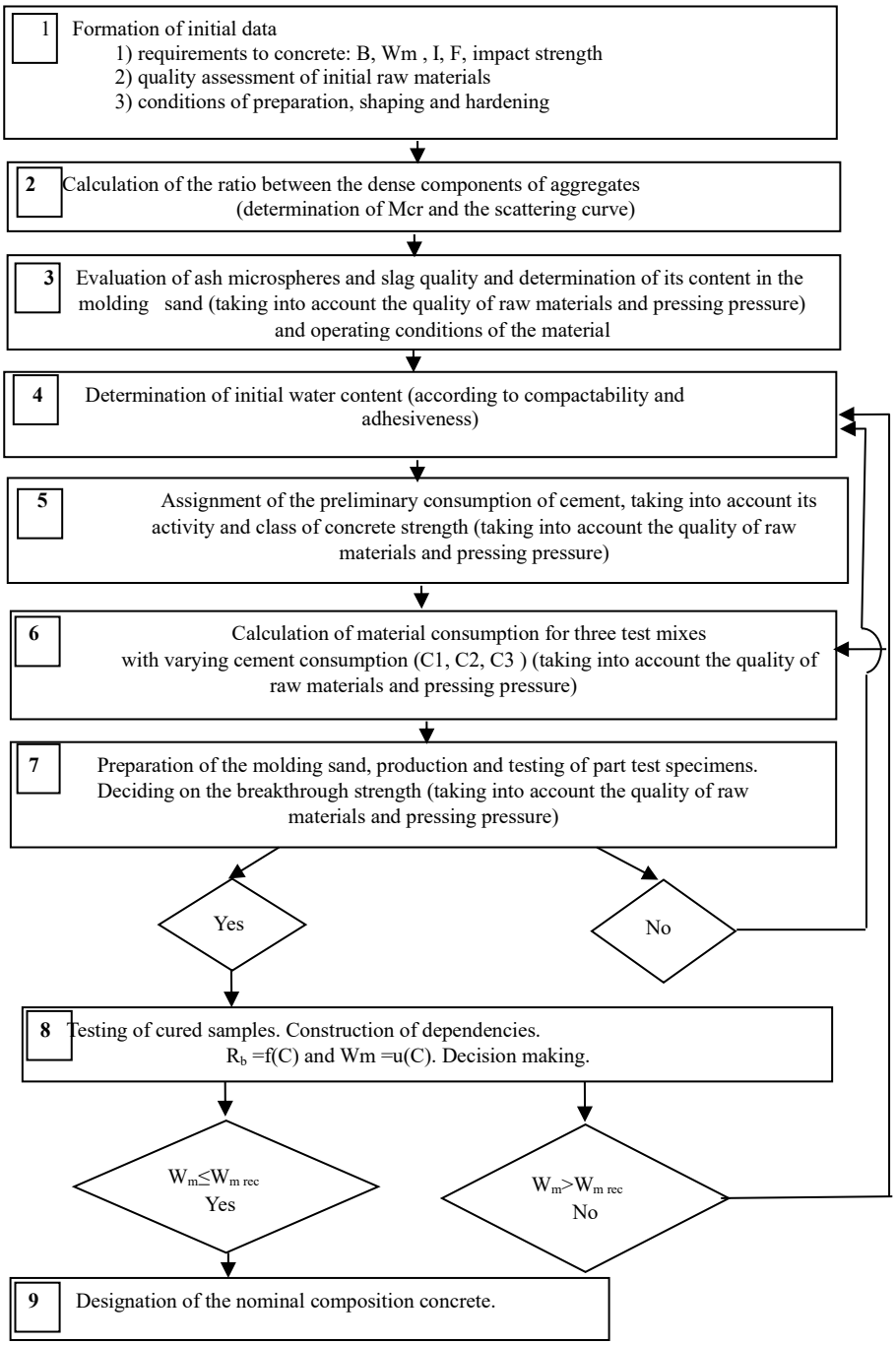

Fig. 1. Block diagram of the nominal composition molding sand.

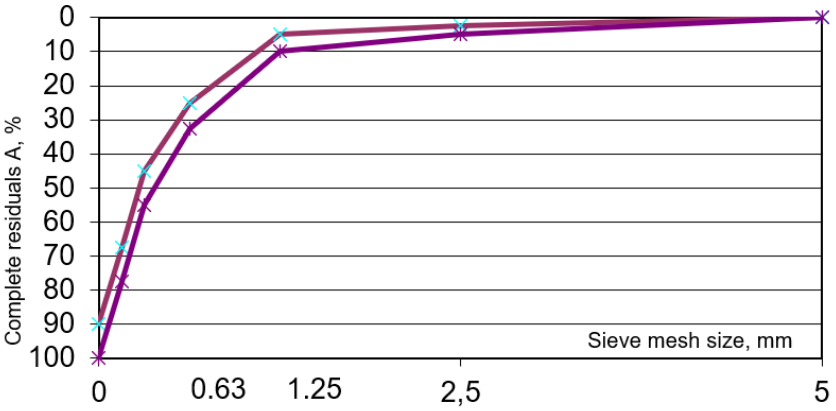

Fig. 2. Recommended boundaries of grain composition of raw components.

The content of ash microspheres in the composition of molding sand is within 3-10 % of the mass of dense aggregates with recalculation on the equivalent volume. The lower limit of ash microspheres is taken for concretes with high strength requirements (B50 and higher). The upper limit can be recommended for the manufacture of paving slabs with higher requirements for the resistance of concrete. In this case, with a small overspending of cement can provide stringent requirements for water absorption by mass, frost and corrosion resistance of concrete [9, 10].

To select the initial water content of the molding sand (block 4), the recommendations of research work [11] were used.

Indirect attributes of the optimal water content of the molding sand are its non-stickiness to the working bodies of the mixer and the absence of water separation at the selected pressing pressure [12, 13].

At the second stage of design (blocks 5-8), taking into account the design class of concrete in terms of compressive strength and activity of the used low-water-consumption binder (Fig. 3), the preliminary content of low-water-consumption binder (LWC) in the molding sand is assigned.

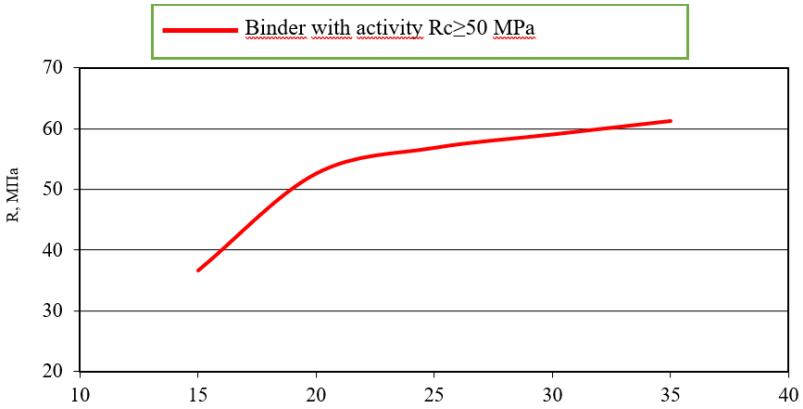

Fig. 3. Dependence of concrete strength on the amount of binder.

Then we carry out the calculation of three compositions, in which the binder consumption is taken at three levels: preselected and 2-4% below and above the selected. Range of variation depends on the accuracy of determining the activity of the cement [14, 15]. Then prepare three experimental mix, each of them is formed not less than six samples, cylinders

with a diameter and height 7.07 cm in accordance with the methodology. Compaction of molding sand is carried out at a specific pressure, corresponding to the pressure of pressing on the molding press. When manufacturing road products, it is recommended to set the value of pressing pressure within the range of 38 - 40 MPa.

Moulded samples of each series are divided into two groups. The first group is tested immediately after molding. According to the test results, the compaction coefficient, the average density of the freshly compacted composition and its break-up strength are determined [16]. Then a decision is made on the adequacy of the breakout strength: if it exceeds 0.7 MPa, then the selection continues, if less, then we return to block 4 and reduce the water content of the mixture. At the third stage, the second group of fabricated specimens is cured under normal conditions until the age of 28 days. Matured samples are dried, measured, weighed and placed in water according to the method of GOST 12730.3 "Concretes. Methods for determination of water absorption. Water-saturated samples are weighed and determine water absorption. Then they are dried again and tested in compression [17].

The results obtained allow to build dependences Rb = f(C) and Wm = y(C), the analysis of which makes it possible to decide on the quality of the hardened concrete and to specify the required cement consumption in the molding mixture.

Calculation of the nominal composition of the molding sand is made in reverse order: knowing the required cement consumption, water content of the molding sand, the accepted dosage of ash microspheres and dense aggregates (in % by weight) on the experimental average density of freshly compacted sand, determine the cost of raw materials for 1 m^3 of products [17]. Calculations are conducted with the main technical requirements for the concrete products themselves, the products themselves, the raw materials, as well as the requirements for labeling and packaging of products, rules of acceptance, quality control methods of raw materials, semi-finished and finished products, the rules of storage and transportation of products, as well as recommendations for the device coatings of products with increased impact resistance of concrete, information on the appointment of products and parameters of their use in practice, road and municipal construction, the rules of conditionally designed and manufactured products.

To determine the physical and mechanical properties of concrete in the products the following tests were conducted: compression, water absorption and abrasion tests of slabs and samples-cubes with rib 7 cm, cut from the body of slabs. The tests were conducted according to the methods of GOST 10180, GOST 12730.2 and GOST 13087.

Additionally, taking into account the results of the experimental studies carried out in this research work, the requirements for the impact strength of concrete are given, the results of studies on the influence of the type of binder, grain composition and properties of aggregates on the formation of the structure and properties of rigid pressed concrete with damping additive of ash microspheres and other porous additives are taken into account. Methods and regimes of accelerated hardening of concrete are recommended.

There are used generally accepted rules for evaluation of geometric dimensions and indicators of the appearance of products, average density, water absorption and strength indicators of concrete, abrasion of the surface layer of products, the rules of assignment of requirements for frost resistance, the rules of coatings and work performance are given, the implementation of which will help to achieve a significant increase in the operational reliability of the coating under operating conditions. Their content is set in accordance with GOST 13015 "Concrete and concrete products for construction. General technical requirements. Rules of acceptance, marking, transportation and storage" and by analyzing numerous normative documents defining the requirements for products of similar purpose (GOST 17608 for sidewalk slabs, GOST 32018 for curbstone, etc.).

4 Discussion

When developing the rules of acceptance of products, the need to ensure the normalized properties of concrete, the content of incoming and operational control, acceptance and periodic tests is taken into account. Unlike other similar normative documents there are established the rules of acceptance of products by the impact strength of concrete which was estimated by using the materials of researches done in the present research work.

Products made according to the recommended calculation of the nominal composition of the molding sand is an environmentally friendly product, and at the same time during their manufacture wastes are used, which contributes to the protection of the environment.

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