Development of technology for obtaining polymer cement glue (PCG) with use of chemical additives and industrial waste

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Abstract. The article presents the results of a study on the production of polymer cement glue with the use of chemical additives and industrial waste, as well as the influence of the amount and fineness of the filler grinding on the properties of polymer cement glue and the possibility of obtaining polymer cement glue PCG using water-soluble POLIMIX technology dry construction mix (DBM).

1 Introduction

Polymer cement adhesive (PCG) with resin superplasticizer "POLIMIX" is a mixture of Portland cement, filler, and polymer additive in its form or with a hardening catalyst and water. This paper aims to substantiate the possibility of obtaining polymer-cement adhesive PCG for gluing products from cellular and dense concrete. It follows that in one case, a low-strength adhesive is needed; in the other - a high-strength one. This goal is achieved by varying the structure-forming compounding and technological factors for obtaining polymer cement adhesive PCG.

Portland cement is the main astringent and structure-forming component in polymer cement adhesive PCG. The degree of influence on the processes of structure formation and properties of polymer cement adhesive PCG will depend on the content of POLIMIX resin, the type of filler, its dispersion and quantity, as well as the method of preparation.

The need to use mineral fillers to produce polymer cement adhesive PCG is dictated by technical, economic, and environmental considerations. However, the literature has limited information on using fillers for polymer cement glue PCG. One paper is devoted to the issue of the use of filler for the production of polymer-cement concrete with the addition of POLIMIX [3]. Based on this, it seems appropriate to consider the prerequisites for using local fillers to produce polymer-cement adhesive PCG using POLIMIX. The following factors will influence the choice of filler for polymer cement adhesive PCG.

1. Economic. Minimization of cement consumption due to the constant increase in energy and cement prices.

2. Technical. Maximizing the potential activity of Portland cement and improving its properties.

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3. Environmental. Environmental protection through the use of industrial and electric power waste.

Justification and choice of filler, taking into account the listed factors, should be made based on the intended purpose of polymer-cement adhesive PCG. In our opinion, to obtain low-strength polymer-cement adhesive PCG, to minimize the consumption of cement and, in general, its efficiency, it is advisable to use fly ash as a filler.

2 Research methods

The compressive strength of the hardened adhesive samples was determined on a universal machine EDM-10/90 (GDR) at room temperature and a loading speed of 15 MPa/min. The strength of the samples was studied on cubes measuring 20x20x20 mm.

The kinetics of strength gain of polymer cement adhesive samples was studied for 180 days. The samples were tested under normal conditions after 1, 3, 7, 28, 90, and 180 days of hardening.

The destructive stress was determined during static bending at room temperature on the MII-100 breaking machine. The cohesive bending strength of adhesive compositions was studied on beams measuring 40x40x160 mm [16].

The automatic multifunctional device PSX-10M is designed to determine the specific surface area, average particle size, and gas permeability of dispersed materials.

The operation of the device is based on the method of gas permeability of the Goat and Pocket. The measurement method determines the time of passage of a fixed air volume through the sample layer. This method has proven itself well in various industries.

The readings of the PSX-10M device comply with GOST, ASTM, DIN, and ISO standards.

The PSX-10M device contains the following improvements:

- automatic height measurement;
- stabilization of the transients of the pneumatic system;
- increase the accuracy of height measurement;
- optimization of pressure and time measurement algorithms;
- availability of self-diagnosis functions.

On the front panel of the PSX-10M device, there is a convenient keyboard for entering parameters and a wide informative display. This allows the device to be operated autonomously [20]; no computer is required for its operation. The interface of communication with the operator is designed in a modern style and greatly simplifies the work with the device (Fig. 1).

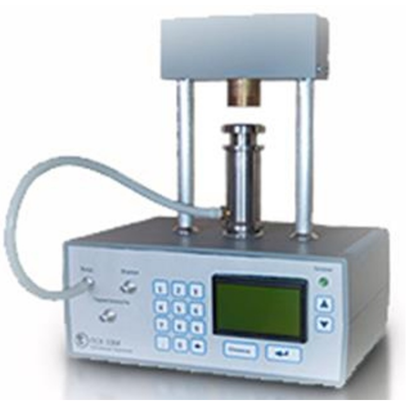

Fig. 1. PSX-10M device

3 The main part

The traditional technology of obtaining polymer cement adhesive PCG is based on adding mortar and concrete mixtures of aqueous dispersions of polymers or water-soluble resins to the mixing water at the place of their preparation [4, 5, 6, 7, 12]. This technology is relatively complex and does not meet modern requirements for intensifying construction processes. As already noted, in modern construction, dry building mixes (DBM) are expanding, the advantages of which are proven by world experience in their use.

Therefore, to obtain PCG with water-soluble POLIMIX resin, we investigated the possibility of using the technology of DBM dry building mixes.

In the previously performed works, two methods for obtaining dry building mixes of DBM [4,5] were proposed:

a) mixing dried sand (with a humidity of not more than 0.5%) and other overdosed components (binder, additives) in a forced mixer until a homogeneous dry mixture is obtained, followed by packing in paper or plastic bags;

b) grinding in a mill of dried sand, cement, and a special additive, dosed strictly according to the composition of dry building mixes and bag packing.

In the first method, a dry mixture of ordinary mortar without filler is obtained, which does not meet the resource-saving requirements in producing semi-finished construction products [8].

The second production method is more effective since dry building mixes of DBM contain 50% of the sand filler, and its components are activated during the grinding process [9].

However, with the second method of obtaining dry DBM building mixes, it is almost impossible to determine the specific surface of the filler. And, as it was noted, following the polystructural theory, in composite materials, each type of filler should have its optimal dispersion. At the same time, this requirement cannot be fulfilled in the case of fly ash, which may have the same or higher dispersion than cement in its natural state. In addition, as shown in [10], the activity of fine mineral binders and fillers decreases rapidly when in contact with air due to the hygroscopicity of their particles. Therefore, it becomes necessary to activate the PCG components when mixing them with water. In this regard, we have proposed a two-stage activation of components upon receipt of PCG. In one case, at the first stage, the overdosed components of the PCG (cement, fly ash, and POLIMIX) are mixed in a ball mill and packed into bags. In the second stage, the DBM is mixed with water in an activator mixer at the work site, and a PCG of the appropriate composition is prepared [18].

Thus, during the research, it was necessary to establish a rational duration for obtaining dry building mixes of DBM and mixing it with water in an activator mixer. To this end, the experiments were carried out in several stages.

In the first stage, as a result of preliminary experiments, the content of fly ash for the production of dry DBM building mixes, and the limits of varying the dosage of POLIMIX resin were determined.

PCG preparation was carried out manually by sequential mixing of overdosed water, resin, cement, and fly ash. The Wюююю/C was taken from the calculation of obtaining a PCG with a flow rate of 160 mm on the Suttard device. The limits of the change in the content of POLIMIX resin and filler are adopted based on previously performed works [1,2,10,11].

The experimental data shown in Fig. 2 show that low-strength PCG can be obtained with a fly ash content of 70-80% and POLIMIX resin-0.5-0.9% by weight of cement.

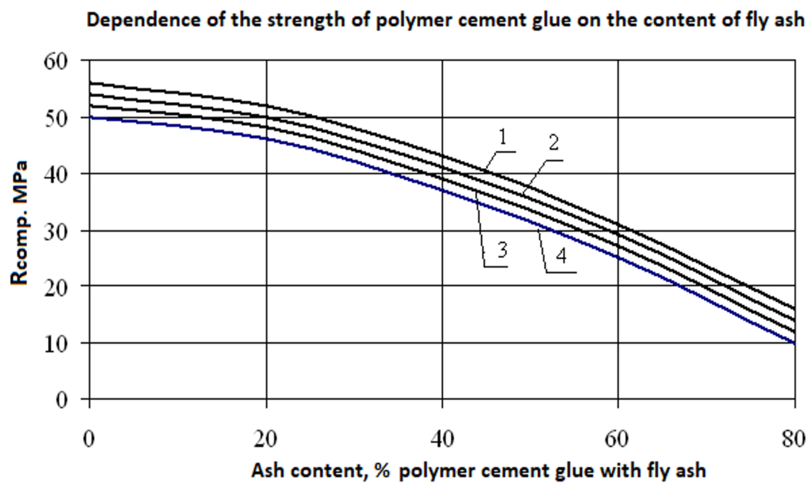

Fig. 2. Dependence of the strength of polymer cement glue on the content of fly ash: cohesive strength of polymer cement adhesive with a POLIMIX content of 0.9; 0.7; 1.1 and 0.5 cement weight

In the second stage, the effect of the duration of production and the content of POLIMIX resin on the specific surface of dry DBM building mixes and the water demand of PCG during preparation in a turbulent-type activator mixer for 30, 60, and 90 seconds was investigated. The rotation speed of the working body was 350 rpm; dry building mixes of DBM with fly ash and the addition of POLIMIX resin were obtained in a ball mill for 20, 30, and 40 minutes of mixing. The results of the performed studies are shown in Tables 1-4. With a constant ratio of cement and filler, with an increase in the duration of production and the content of POLIMIX resin, the specific surface area (Sud) of dry DBM building mixes naturally increased [20]. At the same time, the POLIMIX resin served as an intensifier for grinding the dry mixture. So, if the density of dry DBM construction mixes with fly ash without the addition of POLIMIX resin increased by 7-24 in 20-40 minutes of mixing, then with the addition of 0.5-1.1% resin -14-30 and 33-49%. (Table 1).

Table 1. Change in specific surface area of dry building mixes of DBM from duration of production

Composition of dry building mixes, %			Specific surface area of dry building mixes of DBM, m^2/kg, depending on product, receiving, min			
cement	Fly ash	POLIMIX	0	20	30	40
25	75	0	300	322	351	372
		0.5	-	341	372	390
		0.7	-	364	393	411
		0.9	-	383	401	422
		1.1	-	399	420	448

The consequence of the increase in the dispersion of dry construction mixtures of PCG with fly ash is an increase in the water demand of PTSC, which is confirmed by the data in Table 2. A comparison of the data shows that with the increase in the dispersion of dry construction mixtures of PCG and an increase in the duration of production, there is a natural increase in the water demand of PCC with fly ash. At the same time, with an increase in the dosage of POLIMIX resin and the plasticizing effect, the water demand of dry PCG building mixes decreases [19].

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Table 2. Dependence of I/C on content of additive and duration of obtaining dry building mixes of PCG

Composition of dry building mixes, %			W/C depending on duration of grinding, min			
cement	Fly ash	POLIMIX	0	20	30	40
25	75	0	0.39	0.4	0.42	0.445
		0.5	0.37	0.38	0.395	0.42
		0.7	0.35	0.36	0.375	0.4
		0.9	0.33	0.34	0.355	0.385
		1.1	0.32	0.33	0.345	0.375

There are two reasons for this. Firstly, when obtaining dry building mixes of PCG with fine ash, the Sud of cement also increases. It should also be noted that in this case, the PSX-10M device was used, which allows determining the density of dispersed fillers only considering particles' geometric shapes. In fact, as already mentioned above, due to the porosity of the particles, the entrainment ash is much higher. Therefore, the water demand for dry PCG construction mixtures with fly ash is higher. Secondly, the plasticizing effect of POLIMIX resin is greater the higher the cement content and the dosage of the additive and the larger the filler particles.

Experiments have shown that with a constant content of filler in dry PCG building mixes, with the activation of an aqueous suspension, the cohesive strength of the PCC in a solidified form changes extremely with the max index for the duration of mixing the mixture of 60 s. (Table 3).

Table 3. Dependence of cohesive strength of W/C on duration of mixing of dry building mixes of PCG with water

Duration of mixing, s	Ash content, %	R^{28}_{comp}, MPa
30	75	14
60	75	20
90	75	16

The greatest indicators of the cohesive strength of PCC are achieved with the duration of obtaining dry building mixes of PCG 30 and 40 minutes, the content of the POLIMIX resin additive 0.7% in the composition with fly ash (Table 4).

Table 4. Dependence of cohesive strength of PCC on duration of obtaining dry building mixes of PCG, content of additives, and ash

Content, %		PCC depending on duration of obtaining dry building mixes PCG, min		
POLIMIX	Fly ash	20	30	40
0.5	75	10	12	14
0.7	75	16	20	23
0.9	75	14	18	22
1.1	75	12	15	18

The data analysis in Table 3, 6 also shows that to obtain a low-strength PCC, the fly ash content should be 75%.

Considering the studies carried out, technological schemes for obtaining dry building mixes of PCG are proposed (Fig. 3).

Technological scheme for obtaining dry building mixes of PCG with fly ash Storage bins

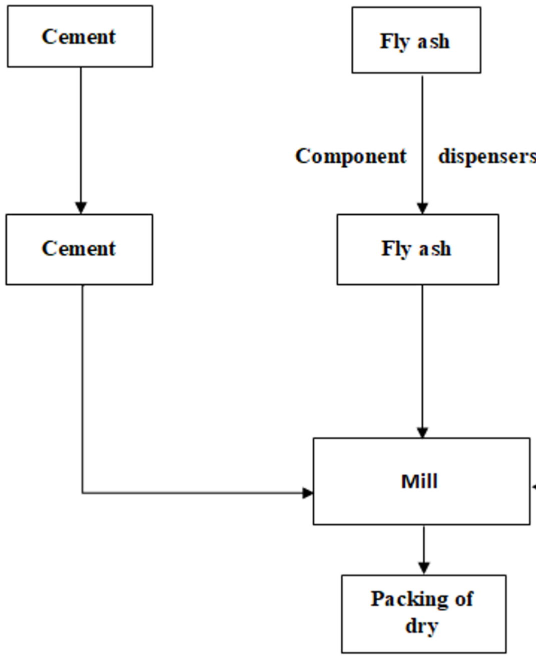

Fig. 3. Technological scheme for obtaining dry building mixes of PCG with fly ash Storage bins

Thus, the conducted studies have shown the possibility of obtaining PCG using water-soluble POLIMIX resin using the technology of dry PCG building mixes. In this regard, it is interesting to study the effect of two-stage activation on the structure formation and hardening of polymer cement glue [20].

4 Conclusions

1. A two-stage technology for obtaining PCC is substantiated. In the first stage, the technology of dry activation of components of dry PCG building mixes is proposed, and the second is the activation of an aqueous suspension of dry PCG building mixes in a high–speed mixer of a turbulent type. Rational durations of obtaining a dry mixture (30 min) and high-speed mixture preparation (60 s.) have been established.

2. It is shown that with a fly ash content of 75%, and POLIMIX resin of 0.7%, it is possible to obtain low-strength PCCs with the required cohesive strength.

3. The influence of dispersion, the amount of filler, and the content of POLIMIX resin on the properties of PCC have been established. It is shown that POLIMIX resin additives have a stabilizing effect on the coagulation and an accelerating effect on the crystallization periods of PCC hardening.

5. The positive effect of the two-stage activation of the mixture on the value of the cohesive strength of the PCC is shown.

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