Influence of dispersion and content of mineral filler on the structure and properties of gypsum binder

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Abstract. The effect of dispersion on the structure and properties of gypsum binder and the content of mineral filler from industrial waste (15%) - crushed steel-smelting slag from the mass of gypsum binder was studied. With the introduction of the optimal amount of filler, in turn, it can significantly improve the macrostructure of the composite, increase the strength of the gypsum stone by 20%, despite the reduction in the consumption of gypsum binder up to 25%. At the same time, their strength characteristics are preserved, relative to the gypsum binder without filler. The resulting gypsum binder can be used in the manufacture of gypsum tongue-and-groove boards for the construction of partitions in rooms with normal humidity.

1 Introduction

Currently, gypsum materials and products are among the most advanced building materials due to the simplicity, economy, environmental friendliness and low energy consumption of gypsum binder production. At the same time, the scope of the gypsum binder is limited due to significant drawbacks, such as low strength and low water resistance, which makes it necessary to modify gypsum binders in order to improve their physical, technical and operational characteristics. A promising direction is also the development of composite gypsum binders and gypsum concretes based on them using industrial waste as modifiers [1-16].

In the Republic of Uzbekistan, in various years, such scientists as Adilkhodzhaev A.I., Atakuziev T.A., Akhmedov M.A., Glekel F.L., Takhirov M.K. were engaged in research in the field of obtaining effective building materials from local raw materials and industrial waste, Kasimov E.U. Kamilov Kh.Kh., Nabieva I.A. Tulaganov A.A., GazievU.A., Talipov N.Kh., Makhamataliev I.M., Tsoi V.M. and others. In their studies, the issues of using local raw materials and industrial wastes in the technology of various types of concrete, including the development of compositions and technology for the production of gypsum concrete, are highlighted [17-20].

The analysis of the conducted scientific research has shown that in our country the issue of developing compositions of composite gypsum binders with fillers, as well as the physical and technical performance properties of gypsum concretes based on them, is little

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studied. The effectiveness and expediency of modifying a gypsum binder with dispersed mineral fillers is explained by the results of studying complex physicochemical transformations that occur in the process of structure formation and the formation of a crystal lattice of a modified gypsum stone.

In this case, the modifying mineral additive (filler) plays the role of a substrate that diffuses into the neoplasm product. As a result of this process, the physical and mechanical properties of the gypsum binder are significantly improved due to the formation of so-called mixed systems. The above ratios of particle sizes of the mineral filler and binder contribute to the ordering of the structure and ensuring the solidity of the entire microstructure of the composite as a whole, reducing the number of microdefects and damage. This, in turn, makes it possible to significantly improve the macrostructure of the composite, increase the strength of the modified gypsum stone by 20%, despite the reduction in the consumption of gypsum binder from 18 to 25%. At the same time, their strength characteristics are preserved, relative to the compositions of the gypsum binder without filler [19, 20].

As you know, the basic principles of the polystructural theory of composite building materials (PT CSM) are based on the scientific research of materials scientists and the development of new modern technologies of composite building materials, including the technology of composite gypsum binders. According to the principles of PT KSM, the need for optimal filling of mineral fillers using industrial waste is predetermined and substantiated.

Based on the basic principles of PT KSM, the simplest and most accessible method that allows you to control the properties and structure formation of gypsum compositions in a predetermined desired direction is the use of dispersed mineral fillers [1-15].

From the results of the literature, a review of information on the use of a mineral filler from the Bekabad steel-smelting slag of Uzmetkombinat JSC in the composition of gypsum compositions, including data on the regularities of the influence of technological parameters of the filler on the properties and structure of the gypsum binder, is not contained in the published literary sources. There is also no information on the results of studies of the composition and properties of a gypsum binder using a mineral filler of industrial waste from the Bekabad JSC "Uzmetkombinat".

2 Objects and methods of research

In this article, the influence of the amount and dispersion of the filler from steel-smelting slag on the physical and technical properties of the gypsum binder was studied. As starting materials, the following were chosen: building gypsum of the Samarkand and Bukhara gypsum plants and Bekabad steel-smelting slag of Uzmetkombinat JSC. The characteristics of the starting materials are given in the tables.

Table 1. The chemical composition of gypsum stone

Content, %							
CaO	MgO	SO_3	H_2O	R_2O_3	O_2	Insoluble residue	$CaSO_4$*H_2O
Zirabulak-Kungurtau-Samarkand region							
30.97-32.92	0.0-1.32	41.26-46.6	18.44-20.82	0-1.42	-	0.2-7.24	95.0-98.0
Mamajurganty-Bukhara region							
31.84-32.85	0-0.62	40.68-46.31	20.69-21.24	-	0.1-1.48	0-2.4	90.04-99.57

Table 2. Properties of gypsum binder according to GOST 125

№	Name of building gypsum	Basic properties							
		Fineness of grinding (% residue on sieve 0.2)	Water demand, %	Setting time, min		Strength, MPa		Fineness class	brand
				Start	end	$R_{st.}$	R_b		
1.	Samarkand	2.3	70	5'30"	10'00"	6	3	II	G-6
2.	Bukhara	3.8	60	5'30"	8'30"	7.6	3.6	II	G-7

Table 3. Characteristics and chemical composition of the Bekabad steel-smelting slag of Uzmetkombinat JSC

Name of parameters	**Parameter value**	
	Conveyor № 11	**Conveyor № 3**
Sample fraction, mm	0-5	5-20
The test consists of: Iron metal, %	2.4	3.8
Slag with foreign non-metallic inclusions (clay, sand, etc.), %	97.6	96.2
The chemical composition of slag and foreign non-metallic inclusions:		
CaO,%	36.1	29.8
SiO_2,%	29.6	37.7
Al_2O_3,%	8.7	13.7
$FeO + Fe_2O_3$,%	7.9	7.2
MgO,%	13.7	7.2
MnO,%	4.5	3.5

The Bekabad steel-smelting slag of Uzmetkombinat JSC was previously ground in a construction ball mill before being introduced into the composition of the gypsum binder to a residue on sieve № 008 in quantities of 60, 30 and 0%. In this case, the dosage of the mineral filler was varied in the range from 5 to 25%.

3 Results and their discussion

An analysis of the results of experimental studies shown in Fig. 1 showed that an increase in the degree of filling of a gypsum binder with a mineral filler leads to an increase in its water demand.

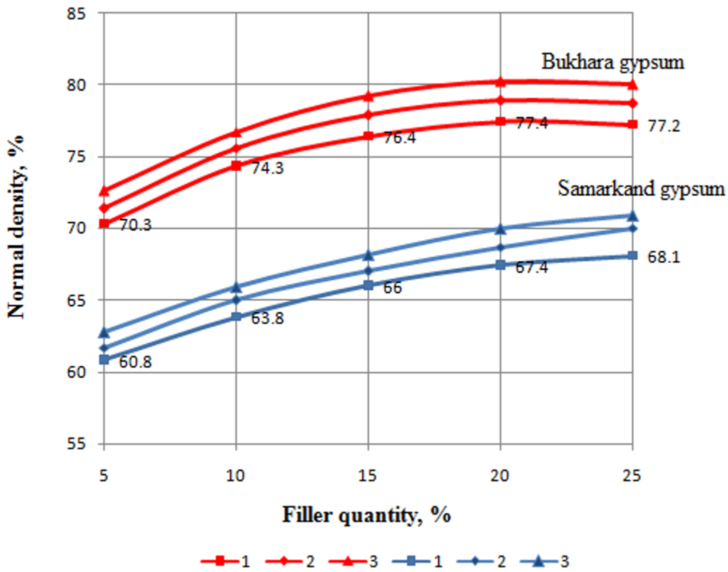

Fig. 1. Influence of the amount of mineral filler on the water demand of the gypsum binder at fineness of grinding: 1-60%, 2-30% and 3-0%, respectively (according to the residue on the sieve № 008)

So, if at a dosage of a mineral filler of 5%, the normal density of Samarkand gypsum is 63% (for a gypsum binder without an additive of 60%) with a fineness of grinding steel-smelting slag, to a level of zero residue on a sieve № 008, then with an increase in the amount of filler to 25%, the normal density Samarkand gypsum increased to 71%. With a dosage of mineral filler of 5%, the normal density of Bukhara gypsum is 73% (for a gypsum binder without additives 70%), then with an increase in the amount of filler to 25%, the normal density of Bukhara gypsum increased to 80%. From this it follows that the influence of the fineness of steel-smelting slag grinding on the water demand of the gypsum binder turned out to be insignificant on average. This means that an increase in the amount and degree of filling of the gypsum binder with steel-smelting slag leads to an increase in its water demand.

According to the results of experimental studies of determining the setting time when introducing into the composition of the gypsum binder mineral filler - ground steel-smelting slag shown in Fig. 2 and 3.

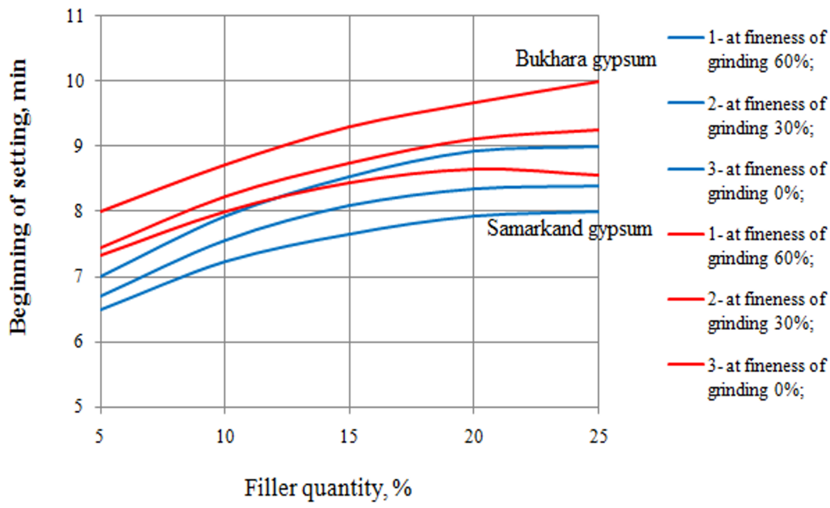

Fig. 2. Influence of the amount of mineral filler on the onset of setting of the gypsum binder at fineness of grinding: 1-60%, 2-30% and 3-0%, respectively
(according to the residue on the sieve № 008)

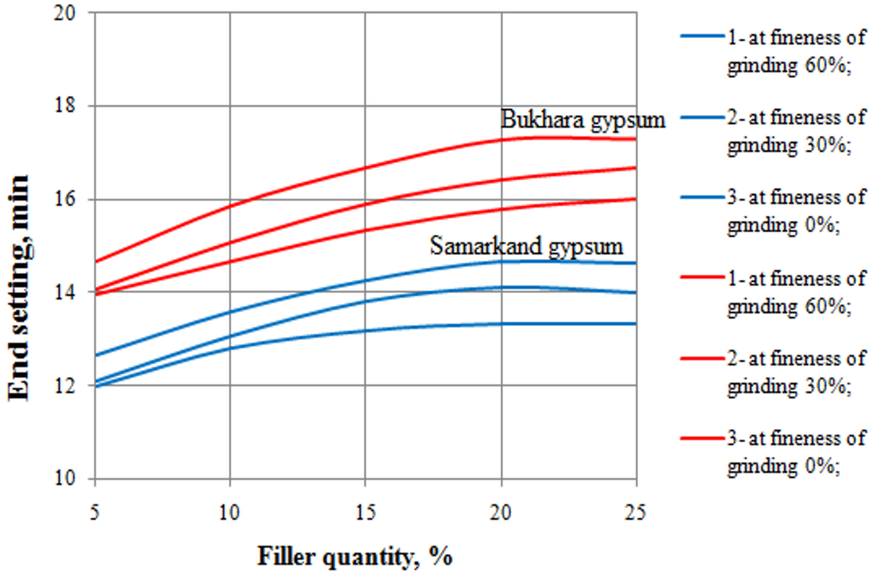

Fig. 3. Influence of the amount of mineral filler on the end setting of the gypsum binder at fineness of grinding: 1-60%, 2-30% and 3-0%, respectively (according to the residue on the sieve № 008)

The results of the experiments on the setting time at the amount of steel-smelting slag of 5%, the beginning of 7 minutes and the end of setting of Samarkand gypsum is 13 minutes, and for Bukhara gypsum, the beginning of 8 minutes and the end of setting of 15 minutes to the level of zero residue on sieve № 008 show that changes in the setting time gypsum binder is observed. At the same time, the introduction of ground steel-smelting slag into its composition with a sufficiently fine grinding and filler content has a certain effect on the setting time of the gypsum binder, even when it is introduced in an amount of more than 15%, the setting time of the gypsum binder slows down by no more than 2-4 minutes.

The degree of influence introduced into the ground steel-smelting slag on the compressive strength of the filled gypsum stone also depends on its quantity and fineness of grinding (Fig. 4.)

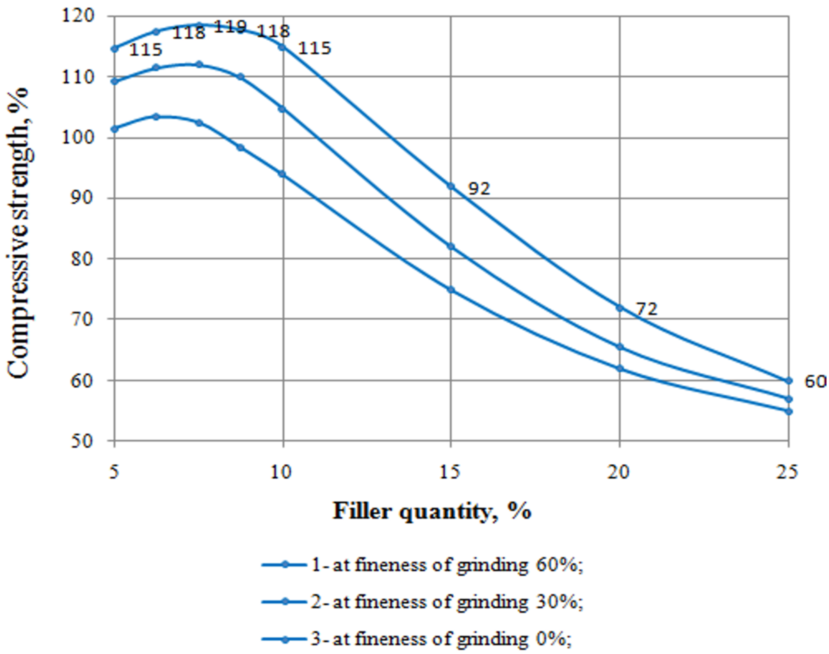

Fig. 4. Influence of the amount of mineral filler on the compressive strength of gypsum stone at a fineness of grinding: 1-60%, 2-30% and 3-0%, respectively (according to the residue on the sieve № 008).

The analysis of graphic dependences shows that the ground steel-smelting slag, when introduced into the composition of the Samarkand gypsum binder in the amount of 5% and dispersion of 60% (according to the residue on the sieve № 008), does not significantly affect the strength of the filled gypsum stone, and remains at the level of the composition without additives (control plaster). A further increase in the dispersity of the mineral filler contributes to an increase in the strength of specimens made of filled gypsum stone. In particular, with the same amount of ground steel-smelting slag and with a filler dispersion of 30%, the compressive strength of the filled gypsum stone increases by 9%. Finer grinding of the mineral filler, to the level of zero residues on the № 008 sieve, allows increasing the strength of the filled gypsum stone by 18% with the amount of mineral filler 5%.

From this it follows that the ultimate compressive strength of Samarkand and Bukhara gypsum stone also depends on the amount and fineness of steelmaking slag grinding.

The effect of mineral filler on the water resistance of gypsum stone was also studied. The results of experimental studies are shown in (Fig. 5.).

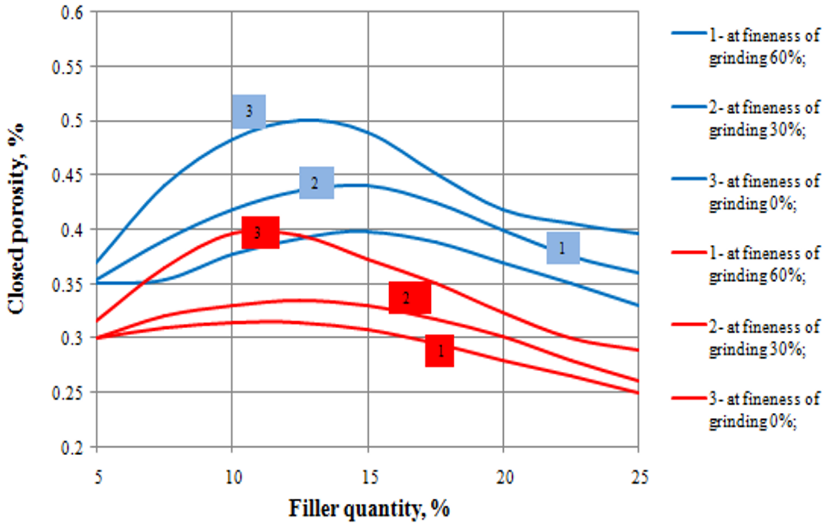

Fig. 5. Influence of the amount of filler on the water resistance of gypsum stone with grinding fineness: 1-60%, 2-30% and 3-0% respectively (according to the residue on the sieve № 008)

An analysis of the results of experimental studies to determine the degree of water resistance of filled gypsum stone showed that the mineral filler - ground steel-smelting slag with a dispersion of 30 and 60% (according to the residue on sieve № 008) does not significantly affect the water resistance of filled gypsum stone (the softening coefficient is within the range of 0.36-0.44 and 0.26-0.33 for the gypsum binder of the Bukhara and Samarkand plants, respectively). With an increase in the dispersion of ground steel-smelting slag (up to complete passage through a № 008 sieve), a significant increase in the softening coefficient of the filled gypsum stone is observed.

With the introduction of a finer until complete passage through the sieve of a dispersed mineral filler in an amount of 10%, the softening coefficient of the filled gypsum stone increases from 0.3 (for an additive-free composition) to 0.4 of the Samarkand gypsum binder and from 0.35 to 0.5 for the Bukhara plant respectively.

A further increase in the content of ground steel-smelting slag in the composition of the gypsum binder (from 15% to 20%) makes it possible to obtain a filled gypsum stone with a softening coefficient in the range of 0.29-0.36 and 0.4-0.5 for the gypsum binder of the Samarkand and Bukhara plants accordingly, however, no decrease in its strength is observed.

Such changes in the physical properties of the filled gypsum stone, in our opinion, occur due to changes in the characteristics of both the general and differential porosity of the material. At the same time, a change in the nature of the type of porosity of the filled gypsum stone is observed in the form of an increase in the proportion of closed pores in their total volume (Fig. 6).

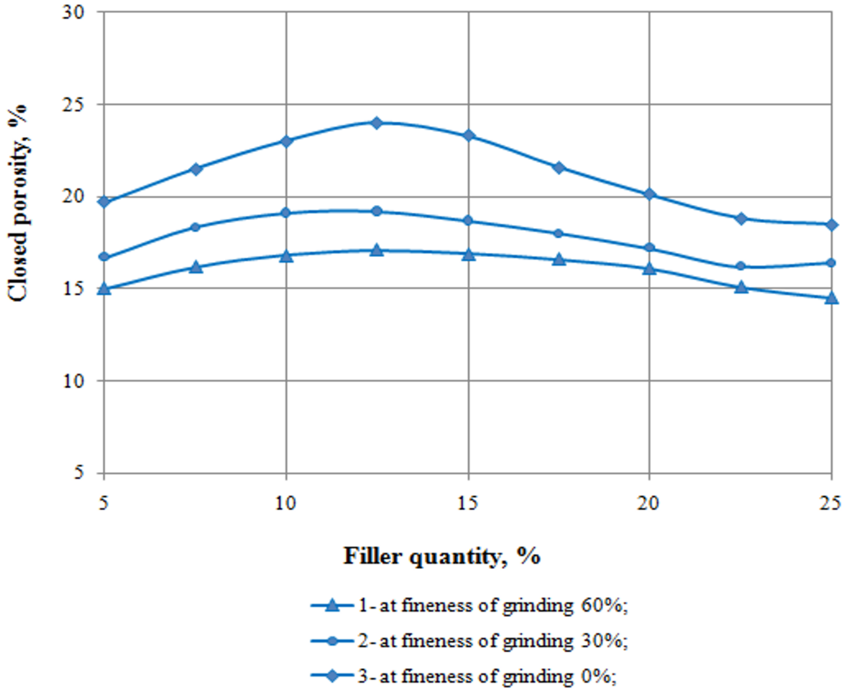

Fig. 6. Influence of the amount of mineral filler on the closed porosity of gypsum stone

4 Conclusions

Thus, it can be stated that on the basis of the above analysis of the results of experimental studies, the following ranges of variation of recipe-technological parameters were adopted: the amount of filling of the gypsum binder with steel-smelting slag is 15% and the fineness of the filler grinding to zero residue on a № 008 sieve.

With the introduction of the optimal amount of filler, in turn, it can significantly improve the macrostructure of the composite, increase the strength of the gypsum stone by 20%, despite the reduction in the consumption of gypsum binder up to 25%. At the same time, their strength characteristics are preserved, relative to the gypsum binder without filler.

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