Gypsum composites reinforcement

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Abstract. Wide distribution of gypsum materials and products, that contributes mainly to their good consumer properties and capacity of forming the most comfortable environment requires the increase in their technical parameters, mainly of mechanical and operational ones. Modern studies of gypsum bindings focus mostly on higher strength, water resistance, lower density and longer life. Existing method of improving the properties of gypsum bindings consists in wide use of mineral and organic modifiers capable of influencing various formation layers of gypsum stone structure. Multilayer reinforcement of composites can form the structure for modified stone of enhanced crack resistance. Reinforcement at atomic-molecular level is the most attractive, as most of known methods of modification with carbonic fullerenes complicate the technology, increase labor and energy expenditures, and, as a result, the price of articles. Reinforced dihydrate calcium sulphate contributes to stronger structure of composite high-strength bindings and improving their mechanical properties, which is achievable through the use of a mineral modifying complex and selecting of a grain composition.

Studies were made to understand how reinforcing mineral complex influences physical-mechanical properties of gypsum composite. It should be mentioned that samples based on gypsum binary mixture of optimum granulometry with an additive are stronger than gypsum mixes without additives. Use of mineral modifier contributes to changing in crystal morphology and forming stronger structure of gypsum stone, and this is confirmed by microstructural analysis of reinforced composite. Results obtained prove that modified gypsum composites may be used in making gypsum materials and articles of high strength.

1. Introduction

Wide distribution of gypsum materials and products, that contributes mainly to their good consumer properties and capacity of forming the most comfortable environment requires the increase in their technical parameters, mainly of mechanical and operational ones [1, 2, 3]. Modern studies of gypsum bindings focus mostly on higher strength, water resistance, lower density [4, 5] and longer life. Volumetric expansion is an important factor of modern high-strength gypsum bindings’ quality.

To improve the properties of the gypsum bindings, the researchers use mineral [3, 5] and organic modifiers [4], that influence various layers of gypsum stone structure forming [2,3,5]. Multilayer reinforcement of composites offers a different approach to cracks that form in the structure of modified stone [6]. Reinforcement of a fragile matrix in solidifying stone with nanoscale elongated crystalline hydrates that, because of their structural and morphological features are much stronger than bulky
crystals, assures multiple increase in technical properties of composite materials [6]. But, more often than not, such reinforcement complicate the technology, increase labor and energy expenditures, and, as a result, the price of articles.

Harder structure of composite bindings [7, 8, 9] and their improved mechanical characteristics are assured by nanoreinforcement [10, 11], including, for example, structures of calcium sulphate dihydrate [12, 13, 14] with crystals of tri-sulphate from of hydrosulphoaluminate. This method offers additional ‘self-strengthening’ of gypsum matrix at nanoscale level [15, 16] and helps in obtaining highly-effective construction composites on simplified technology based on traditional gypsum bindings.

Use of normalized granulometric composition of bindings affords further improvement of service properties of gypsum material obtained at the cost of directed forming of its inner structure [2, 17]. Computer modelling is appropriate for balancing the grainy composition of composite raw mix [18, 19, 20].

2. Materials and methods

Source material for work were gypsum bindings powders produced by StroyKomm OOO of Krasnodar Krai, in particular, α-modifications of G-19 grade having different milling fineness (compositions 1, 2), and their binary mixture. Granulometric composition of raw powders was estimated with laser microanalyzer Fritsch Particle Sizer Analysette 22. Distribution of gypsum powder particles size was researched by laser diffraction as per ISO 13320-1:2009 “Analysis of particles size. Laser diffraction methods”. Figures 1,2 show integral and differential size distributions of particles in gypsum powders of compositions 1 and 2.

**Figure 1.** Granulometry of gypsum binding G-19, composition 1.

**Figure 2.** Granulometry of gypsum binding G-19, composition 2.
Additives based on Al$_2$(SO$_4$)$_3$·18H$_2$O and Ca(OH)$_2$ solutions and their mixtures were used as mixers required for obtaining reinforced gypsum stone. Dependence of gypsum composite structural characteristics on the content of Al$_2$(SO$_4$)$_3$·18H$_2$O, Ca(OH)$_2$ – based solutions was estimated by the value of compression strength, average density and water adsorption found in standard samples shaped as cubes having 70.7-mm sides after their 3-day hardening under dry air. Density and water adsorption of reinforced composite were found by standard methods. Shape and size of crystals on the glass was estimated with digital microscope DM200-2 QIDDYCOME. Results of microscopic research were obtained from scanning electronic microscope TESCAN Mira 3.

3. Results and Discussion

During optimization of granulometric raw mixture based on gypsum binding powders of various technical parameters, granulometry was modeled by computer program complex, that was designed at the department for construction materials and products of Tver State Technical University [2, 21]. Results of calculation the granulometry of binary mixture in compositions 1 and 2 are shown in Fig.3.

Figure 3. Calculation of Granulometry for binary mixture of gypsum binding powders G-19 by StroyKomm OOO.

The second stage of research consisted in studies of dependence between structural and strength characteristics of gypsum composite and content of reinforcing additive.

Figure 4-7 show findings of research of Al$_2$(SO$_4$)$_3$·18H$_2$O and Ca(OH)$_2$ – based additive influence on the properties of gypsum composites.
Figure 4. Strength of reinforced gypsum stone vs. $\text{Al}_2(\text{SO}_4)_3\cdot18\text{H}_2\text{O}$ content:
1 – 0 %; 2 – 7 %; 3 – 8 %, 4 – 9 %.

Figure 5. Density of nanoreinforced gypsum stone vs. $\text{Al}_2(\text{SO}_4)_3\cdot18\text{H}_2\text{O}$ content.

It should be noted that samples based on gypsum binary mixture of optimum granulometry with $\text{Al}_2(\text{SO}_4)_3\cdot18\text{H}_2\text{O}$ added are much stronger than gypsum compositions without aluminium sulphate added (Fig.4). According to strength conditions, optimum content of aluminium sulphate in gypsum mixture makes 8 %. Further increase of additive might result in partial loss of strength, as the volume of pores is more than the volume of hydrosulphoaluminate: this is confirmed by density growing (Fig.5) against reducing strength of gypsum composite. Growing water absorption (Fig.6) is another indirect indication [22, 23] of intensive formation of reinforced gypsum composite in water-saturated environment [24, 25]. Use of $\text{Al}_2(\text{SO}_4)_3\cdot18\text{H}_2\text{O}$ and $\text{Ca(OH)}_2$ - based additive contributes to formation of tabular dihydrate calcium sulphate crystals and needle hydrosulphoaluminate calcium crystals, that is confirmed by microstructural analysis (Fig. 7).
Figure 6. Water absorption of reinforced gypsum stone vs. content of $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$.

4. Conclusions
The studies lead to the following conclusions:
1. Management of gypsum reinforced composites content provides for better structural and mechanical characteristics of the material obtained.
2. Offered compositions gypsum modified mixtures may be useful in making gypsum materials and products that assure high mechanical strength while keeping an adequate level of other operational parameters.
3. Analysis of gypsum material properties has proved that improvement of structural and mechanical properties of modified gypsum stone contributes to greater percentage of aluminium sulphate in the modifying complex and obeying the appropriate mode of technological process.
4. Modelling of gypsum reinforced composites geometry may employ the capacities of the computer-based software product designed at the department for construction materials and products of Tver State Technical University.

5. Acknowledgement

Findings of research were experimentally tested by the certified laboratory for construction materials of Tver State Technical University and are protected with the RF patent.

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