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DETERMINATION OF PARAMETERS OF DRY BUILDING MIXTURES BASED ON GYPSUM AND POLYMER ADDITIVES FOR FINISHING WORKS

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A study was conducted on the properties of raw materials and dry building mixtures based on gypsum according to the current regulatory documents of Ukraine. A series of investigations were carried out on multicomponent building compositions in terms of their rheological and physico-mechanical properties of the finished coating. Additive modifiers were considered as components that influence the necessary properties of the final material. The most rational dosages of components that affect the properties of the working mixture and the finished construction coating were provided. The main parameters of the technology for performing finishing works using building mixtures based on gypsum and polymer additives were determined.

Keywords: gypsum, plaster, dry building mixture, crack resistance.

Introduction. Among modern composite materials, dry building mixtures based on gypsum, various fillers, and polymer additives hold a special place. This type of material occupies a distinct niche in the building materials market. Gypsum-based building mixtures significantly differ in properties and applications from dry building mixtures based on cementitious materials. This is evident from the fact that developing cement compositions does not encounter difficulties in adjusting the kinetics of strength development, unlike gypsum materials. Despite this, materials based on gypsum and polymer additives have gained widespread use due to their convenience and ease of use. Gypsum materials have several advantages: fire resistance, high environmental friendliness, thermal insulation, and sound absorption. These characteristics make gypsum materials ideal for repair and finishing works.

The total content of gypsum binder in dry mixtures often ranges from 60-90% by mass, so the properties of gypsum largely determine the quality of the gypsum mixture solution. The behavior of such chemically retarded gypsum is characterized by a rather long initial setting time but a very short strength gain period. This hardening feature chemically delays the ability of building gypsum to harden and creates certain difficulties when processing plaster mortar applied to the wall surface. The main challenge is ensuring that the kinetics of strength development of the gypsum composition align with all technological operations during finishing works [1, 2].

Dry construction mixtures based on gypsum have different compositions and various applications in construction. Therefore, engineers face numerous tasks in selecting the types and quantities of raw materials, especially concerning modifier additives. Currently, there are many such additives, but information about their usage results may be protected by law as commercial secrets or be unknown, making this an interesting area for further research. The classification of dry building mixtures based on gypsum is shown in Table 1.

Main Material Presentation. The properties of gypsum mortars are significantly influenced by the strength characteristics of gypsum binders. Additives based on superplasticizers of the polycarboxylate

or polyacrylate type, as well as quicklime and slaked lime, are often used. Complex modifiers using superplasticizers based on polyacrylate or polycarboxylate polymers and lime additives significantly extend the setting time of gypsum binders. It is this combination of complex chemicals with lime that allows achieving the necessary smooth strength development, which is essential for aligning the kinetics of strength development of the material with all the required technological operations [3].

In the course of several studies, construction gypsum, ground chalk, slaked lime, and the polycarboxylate-type additive Sika ViscoCrete 225 were used. It was found that the Sika ViscoCrete 225 additive imparts hyperfluidity to the gypsum mixture and is unstable under low-temperature conditions. When using cold water (work was carried out in winter in an unheated room), the gypsum mixture "flows" and becomes unsuitable for application to walls. In other words, this material, in its characteristics and appearance, resembles "enamel" paint more than gypsum mortar. Under proper conditions, such an additive can be used in the production of other types of products like "putty," "grout," etc.

To improve the processing of plaster mixtures, lightweight fillers and limestone flour are often added as mechanical thickeners. The characteristics of the solution mixture can vary significantly depending on the type of dry gypsum mixture. These characteristics include the amount of water required to mix the gypsum mixture to achieve the necessary workability; the tensile strength of the hardened mixture in a dry state; and the adhesion strength of the mixture to the base surface.

Table 1

Classification of Dry Gypsum-Based Building Mixtures

Gypsum mixtures for plastering works	Gypsum, lime, fillers, polymer modifying components, setting retarders, and other additives.
Mixtures for surface preparation	Mineral binders, fillers, and various additives.
Dry mixtures for flooring	Mineral binders, aggregates, and fillers, and various additives, including those that enhance crack resistance, abrasion resistance, frost resistance, and water resistance of the mixtures.

For putty mixtures, the fineness of the binder material is crucial, specifically the residue on a 0.2 mm sieve. This parameter is particularly important when selecting a binder for finishing putty mixtures, where microcalcite with a maximum grain size of 150 microns is often used as a mineral filler. It should be noted that for gypsum mixtures, compressive strength is not the primary parameter. For plaster mixtures, it is essential to test the binder for effective interaction with retarders like tartaric or citric acid, as these are the most accessible and well-known.

In the production of dry gypsum mixtures, additives that regulate setting times, mixture workability, and coating strength are essential components. Gypsum binders set quickly, and solving the issue of extending usability involves the correct selection of special additives – setting retarders.

According to DSTU B.V. 2.7-126:2011, modified dry building mixtures should meet the following requirements: mobility - 7 ± 2 cm; compressive strength - 5 (2.5) MPa; flexural strength - 1 (0.4) MPa; crack resistance (7 days, 3 mm layer); vapor permeability - 0.07 mg/m \times h-Pa; shrinkage - 0.5 mm/m; adhesion strength - 0.3 MPa. The properties of gypsum binders are presented in Table 2.

Table 2

Properties of Gypsum Binders

Gypsum Binder Manufacturer	W/G Ratio	Start of Setting, min	End of Setting, min	Flexural Strength, MPa	Compressive Strength, MPa
Kamianets-Podilskyi, LLC "Gypsovyk"	0,52	6	9	3,0	7,4
Ivano-Frankivsk, TM "Krumix"	0,56	12	26	2,9	5,6

Table 3

Physical and Mechanical Characteristics of Gypsum Beam Samples

Component Ratio	W/G Ratio	Start of Setting, min	End of Setting, min	Flexural Strength (1 day), MPa	Compressive Strength (1 day), MPa
Gypsum : Chalk = 70/30	0,52	14	26	2,6	3,2
Gypsum : Limestone = 70/30	0,42	6	9	2,4	3,8

This table shows the properties of gypsum binders produced by two different manufacturers. The key parameters include the water-to-gypsum ratio (W/G), initial and final setting times, flexural strength, and compressive strength. These properties are critical for determining the suitability of gypsum binders for various construction applications.

When analyzing Table 2, it was found that the gypsum from Kamianets-Podilskyi, LLC "Gypsovyk," is "richer" and requires less mixing water compared to the gypsum from Ivano-Frankivsk, TM "Krumix," which is "leaner" and requires more mixing water. Additionally, the gypsum from Ivano-Frankivsk, TM "Krumix," is more reactive, as it heats up to 60-70°C during the hydration process, which is also a favorable characteristic. However, the use of plasticizers like *Melment* and *Melflux*, recommended by modifier suppliers, in combination with this gypsum is ineffective because this gypsum is considered "lean". The addition of these plasticizers to the gypsum from Ivano-Frankivsk, TM "Krumix," results in excessive fluidity, making the mixture unsuitable for use.

Plasticizers like *Melment* and *Melflux* are more suitable for use in cement systems – concretes and mortars – in terms of their plasticizing effect. Introducing such additives into gypsum binders is ineffective. New-generation additives like *Melment* and *Melflux*, which are widely advertised as gypsum dispersants, as well as superplasticizers based on polyacrylate and polycarboxylate polymers, have also not shown high efficiency in gypsum mixtures. Based on these considerations, it is proposed to mix hyperplasticizers based on polyacrylate or polycarboxylate polymers with lime in a rational proportion, which significantly reduces the water demand of the gypsum binder [6,7,8].

During laboratory work, the most rational Binder: Filler ratios were determined, and their main physical and mechanical characteristics were identified, as shown in Table 3. Ground chalk or limestone is most commonly used as fillers for gypsum compositions in amounts of 0-30%. The difference between these two types of fillers is that chalk has swelling properties and a white color, which is a significant advantage, while limestone hardly swells and has a color ranging from light cream to brown, limiting its use as a component for finishing materials [9,10].

In the current conditions, dry building mixes based on gypsum produced in Turkey are accessible and popular among Ukrainian consumers. The fundamental difference between the products of Ukrainian and Turkish production lies in the quality of the primary raw material component - gypsum. Both countries use gypsum from local quarries. Gypsum from Turkish deposits is bright white and has low strength indicators, whereas gypsum from Ukrainian deposits is stronger but does not have such a bright white color. Due to their low strength, Turkish-made gypsum materials are easier to sand, smooth, and handle with other similar operations, but not all consumers are satisfied with the low strength of the coating. This is why there are supporters of dry building mixes based on Ukrainian gypsum. The approximate composition of plaster based on gypsum from the Ivano-Frankivsk quarry, TM "Krumix", and plaster produced in Turkey is shown in Table 4.

The Ukrainian market features a range of products that are in high demand. Therefore, during laboratory research, the main properties of the products from the most well-known Ukrainian manufacturers were established. The results of the laboratory studies are presented in Table 5.

In developing our own product, the results presented in Table 4 were used as a benchmark to determine the main requirements for each type of gypsum mixture and the target values for the final product's properties. An image of the gypsum plaster coating using plasticizer additives is shown in Fig. 1. As seen in Fig. 1, the use of additives such as *Melment* and *Melflux* has a positive effect—the finished coating does not crack, has a more uniform and robust structure, and is more resistant to aggressive environments and mechanical impacts. The technological process of applying gypsum plaster is depicted in Fig. 2.

Table 4

Approximate Composition of Plaster Based on Gypsum from the Quarry in Ivano-Frankivsk, TM "Krumix" and Plaster Manufactured in Turkey

Dry Building Mix Based on Gypsum TM Krumix and Polymer Additives (Ukraine)*		Dry Building Mix Based on Gypsum and Polymer Additives (Turkey)	
Component	Amount, %	Component	Amount, kg
1. Gypsum	60,0	1. Gypsum	40-60
2. Chalk	40,0	2. Anhydrite	30-40
3. Perlit	2,0	3. Hydrated Lime	1-3
4. Hydrated Lime	1,0	4. Limestone 0-1 mm	0-10
5. Dispersion Powder	0,2	5. Perlit 0-1 mm	3-5
6. Cellulose Ether	0,15	6. Tylose MH 60017 P4 or MHS 150003 P4	0,23- 0,28
7. Starch Ether	0,03	7. Hostapur OSB	0,005 -0,03
8. Tartaric Acid	0,03	8. Tartaric Acid	0,005-0,03
		9. Genepol PF 80 Powder	0,01-0,02

*All components less than 2% are given over 100%

Table 5

Main Characteristics of Products from Well-Known Ukrainian Manufacturers of Dry Building Mixes Based on Gypsum and Polymer Additives

Product Name	W/G Ratio	Flowability, cm (Suttard Apparatus)	Start of Setting, min	End of Setting, min	Flexural Strength (1 day), MPa	Compressive Strength (1 day), MPa
1. Knauf Start	0,6	15...17,5	20...25	25...31	9,5	11,0
2. Knauf Finish	1,1	10,5...12	40	45	10,4	13,6
3. Knauf MP 75	0,6	9	> 90	-	8,4	14,6
4. Knauf Rodband	0,9	10,8	> 60	-	7,0	8,4
5. Майстреп Start, Odesa	0,6	18	10	21	1,0	1,1



(a)



(b)

Fig. 1. Gypsum Plaster Coating: (a) without additives such as Melment F10 or Mellflux 2651F; (b) with additives such as Melment F10 or Mellflux 2651F



Fig. 2. Technological Process of Applying Gypsum Plaster by Machine Application Method

Ukraine has sufficient reserves of high-quality gypsum raw materials. The quantity is enough to produce the necessary products not only for the needs of the domestic population but also to focus on the export of such materials. In some cases, Ukrainian products can compete with well-known foreign manufacturers. However, there are fundamental aspects related not only to the nature of gypsum as a material but also to the fact that gypsum raw materials from different deposits have their own characteristics and require solutions tailored to the properties of gypsum from a specific deposit. Therefore, any unique set of raw material components requires research and justification for the chosen composition of components, manufacturing conditions, and the product's application.

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ВИЗНАЧЕННЯ ПАРАМЕТРІВ СУХИХ БУДІВЕЛЬНИХ СУМІШЕЙ НА ОСНОВІ ГІПСУ ТА ПОЛІМЕРНИХ ДОБАВОК ПРИ ПРОВЕДЕННІ ОПОРЯДЖУВАЛЬНИХ РОБІТ

Виконано дослідження властивостей сировини та сухих будівельних сумішей на основі гіпсу згідно з діючими нормативними документами України. У ході лабораторних досліджень було визначено реологічні та фізико-механічні властивості самого будівельного гіпсу з двох кар'єрів. Було визначено принципову різницю між цими двома видами матеріалів та обґрунтовано доцільність використання кожного з них як з точки зору якості, так і з точки зору доступності кожного з матеріалів. Проведено ряд досліджень багатокомпонентних будівельних композицій як за реологічними так і за фізико-механічними властивостями готового покриття без використання добавок-модифікаторів (композиційна система «в'язуча речовина - заповнювач»). Було розглянуто взаємодію двох видів в'язучої речовини з двома видами інертних наповнювачів природного походження (крейда, вапняк) окремо або їх комбінацію. Добавки-модифікатори були розглянуті як компоненти, які мають вплив на необхідні властивості готового матеріалу. Розглянуто добавки-модифікатори в залежності від спектру їх дії, зроблено висновки щодо доцільності їх використання, визначено умови при яких вони є необхідними компонентами композиційної системи. Подано найбільш раціональне дозування компонентів, які мають вплив на властивості робочої суміші та готового покриття. Проведено лабораторні дослідження властивостей продукції найбільш відомих виробників сухих будівельних сумішей на основі гіпсу, які використовують українські споживачі (виробництво України та Турції). Подано результати досліджень та зроблено порівняльний аналіз отриманих результатів. Наведено інформацію щодо якості сировинних матеріалів, які використовують ці виробники. Визначено основні параметри технології виконання внутрішніх опоряджувальних робіт з використанням будівельних сумішей на основі гіпсу та полімерних добавок згідно всіх технологічних операцій при ручному та машинному нанесенні гіпсового покриття. Визначено принципові моменти, які пов'язані з плавністю набору міцності готової будівельної композиції. Подані рекомендації щодо використання регуляторів процесу набору міцності матеріалів на основі будівельного гіпсу.

Ключові слова: гіпс, штукатурка, суха будівельна суміш, тріщиностійкість.

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DETERMINATION OF THE PARAMETERS OF DRY BUILDING MIXTURES BASED ON GYPSUM AND POLYMER ADDITIVES DURING CARRYING OUT FINISH WORKS

The properties study of raw materials and dry building mixtures based on gypsum was carried out in accordance with the current regulatory documents of Ukraine. In the course of laboratory studies, the rheological and physico-mechanical properties of construction gypsum from two quarries were determined. The fundamental difference between these two types of materials was determined and the expediency of using each of them was justified both from the point of view of quality and availability of each of the materials. A number of studies of multi-component building compositions have been carried out, both in terms of rheological and physical-mechanical properties of the finished coating without the use of additives-modifiers (composite system "binder - aggregate"). The interaction of two binder types with two types of inert fillers of natural origin (chalk, limestone) separately or their combination was considered. Modifier additives were considered as components that have an impact on the required properties of the finished material. Additives-modifiers are considered depending on the spectrum of their action, conclusions are drawn regarding the expediency of their use, the conditions under which they are necessary components of the composite system are determined. The most rational dosage of components that influence on the properties of the working mixture and the finished coating is provided. Laboratory studies of the product's properties of the most well-known manufacturers of gypsum-based dry construction mixtures, which are used by Ukrainian consumers (produced in Ukraine and Turkey), were conducted. The research results are presented and a comparative analysis of the obtained results is made. Information is given on the quality of raw materials used by these manufacturers. The main parameters of the technology for performing internal furnishing works with the use of building mixtures based on gypsum and polymer additives according to all technological operations during manual and machine application of gypsum coating are determined. The fundamental points related to the smoothness of strength gain of the finished building composition have been determined. Recommendations for the use of regulators of the process of gaining the strength of materials based on building gypsum are presented.

Ключові слова: gypsum, plaster, dry building mixture, crack resistance.

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Гаркуша В.С., Симонов С.І., Сергієнко Ю.В., Годун Т.М., Пузачова Г.С. **Визначення параметрів сухих будівельних сумішей на основі гіпсу та полімерних добавок при проведенні опоряджувальних робіт** // Опір матеріалів і теорія споруд: наук.-тех. збірн. – К.: КНУБА, 2024. – Вип. 113. – С. 345-351.

Виконано дослідження властивостей сировини та сухих будівельних сумішей на основі гіпсу згідно з діючими нормативними документами України. Проведено ряд досліджень багатокомпонентних будівельних композицій з точки зору їх реологічних та фізико-механічних властивостей готового покриття. Добавки-модифікатори були розглянуті як компоненти, які мають вплив на необхідні властивості готового матеріалу. Подано найбільш раціональне дозування компонентів, які мають вплив на властивості робочої суміші та готового покриття. Визначено основні параметри технології виконання опоряджувальних робіт з використанням будівельних сумішей на основі гіпсу та полімерних добавок.

Табл. 4. Іл. 2. Бібліогр. 10 назв.

Harkusha V.S., Simonov S.I., Sergienko Yu.V., Hodun T.M., Puzachova H.S. **Determination of the parameters of dry building mixtures based on gypsum and polymer additives during carrying out finish works** // Strength of Materials and Theory of Structures: Scientific-and-technical collected articles. – К.: KNUBA, 2024. – Issue 113. – P. 345-351. – Ukr.

A study of the properties of raw materials and dry building mixtures based on gypsum was carried out in accordance with the current regulatory documents of Ukraine. A number of studies of multi-component building compositions from the point of view of their rheological and physico-mechanical properties of the finished coating have been conducted. Modifier additives were considered as components that have an impact on the required properties of the finished material. The most rational dosage of components that have influence on the properties of the working mixture and the finished coating is provided. The main parameters of the execution technology of furnishing works with the use of building mixtures based on gypsum and polymer additives have been determined.

Tabl. 4. Figs. 2. Refs. 10.

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