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ADHESIVE ABILITY OF GYPSUM-CONTAINING PLASTER COMPOSITIONS

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Abstract. The traditional material for the construction of buildings in the Northern Black Sea region is a cheap local stone – limestone-shell rock. Most of the buildings in the central part of the city of Odesa, which are of historical and architectural value, are constructed of this material. With proper care and maintenance, these structures can perform their functions for hundreds of years, but as a result of shell rock moisture due to negligent operation and a number of other reasons, the supporting structures are damaged, followed by the collapse of the building. In many cases, the direct cause of the destruction of load-bearing walls is the damage or absence of the outer plaster layer. Repairing walls with cement compounds exacerbates the problem. The article discusses some aspects of the possible use of gypsum-based composite materials for repairing damaged walls of limestone-shell rock buildings. The requirements for the repair composition are formulated. The expediency of using gypsum as a binder for the repair plaster mixture for exterior repairs is substantiated. An ash-gypsum-cement composition was used to increase the water resistance of the plaster. Sufficient water resistance and vapor permeability of the proposed composition were confirmed. This paper presents the results of studying the adhesive strength of the contact of the developed composition with the surface of various materials. Methods and measuring equipment developed at the ODABA were used. The adhesion strength of the proposed mixture with the surface of shell rock is close to the standard strength. The use of the adhesive additive Ceresit CC 81 increases the adhesive strength of the joint of the proposed composition with shell rock by 1.5 – 2 times. The optimal amount of the adhesive additive to be introduced will be determined by the results of a multifactorial experiment to study the effect of a complex of chemical additives of different functional purposes on the properties of the proposed repair composition.

Keywords: limestone-shell rock, plaster layer, ash-gypsum-cement mixture, water resistance, vapor permeability, adhesion.

Introduction. Many old buildings in the Black Sea basin are made of cheap local building material limestone-shell rock. This environmentally friendly natural stone has become widespread in the Odesa region due to its good technical and operational properties [1–3]. A significant disadvantage of this material is the loss of strength when it is moistened. As a result of improper and negligent exploitation, cases of destruction of limestone buildings have recently become more frequent. One of the reasons for soaking the walls is the damage or absence of a plaster layer on the exterior surfaces. Repairs to shell rock walls with cement-sand mixtures accelerate the destruction of structures for a number of reasons [4]: chemical incompatibility of materials; greater strength of the plaster compared to the main layer; different deformational properties; and, finally, lower vapor permeability of the plaster layer. The use of imported restoration mixtures recommended for the repair of historic buildings raises certain doubts for a number of reasons:

– the chemical composition of the plasters is unknown, which makes it impossible to conclude that they are compatible with shell limestone;

– short experience of using these materials does not allow us to judge the durability of both the plaster layers and the plastered structures;

– the high cost of imported restoration compositions increases the cost of repair work.

In view of the above, the development of domestic limestone-compatible repair compositions that can compete with foreign, much more expensive analogues is an urgent task. The main requirements for the properties of the plaster composition being developed can be summarized as follows. The mixture must be:

– chemically compatible with the limestone-shell rock material;

– water resistant;

– have sufficient strength;

– have high vapor permeability;

– have good adhesion to shell rock;

– moisture deformations of the hardened plaster layer should be consistent with the characteristics of the main wall;

– should be cost-effective.

Analysis of recent research and publications. For the correct selection of the basis of the repair composition for the walls of buildings made of limestone-shell rock, it is necessary to take into account the technical data of plasters with different types of binders (Table 1) [5].

Table 1 – Technical data of plasters with different types of binders

Characteristics of of the plaster mixture	Types of plasters		
	Gypsum	Cement	Cement-lime
Layer thickness (wall)	50 mm	20 mm	20 mm
Layer thickness (ceiling)	20 mm	—	—
Grain size	1 mm	0.8 mm	0.8 mm
Compressive strength	1-2 MPa	0.9 MPa	0.9 MPa
Adhesion	0.5 MPa	0.4 MPa	0.3 MPa
Vapor permeability	0.15 mg/m·h·Pa	0.07 mg/m·h·Pa	0.07 mg/m·h·Pa
Consumption per 10 мм/м^2	9-12 kg/m^2	15-20 kg/m^2	15-20 kg/m^2

According to Table 1, gypsum-based plasters have the best characteristics. Particularly noteworthy are the large thickness of the layer applied in one pass, high vapor permeability and economical consumption of the mixture per unit area of the treated surface. An extremely important feature of gypsum plasters is the short curing time, which helps to increase the productivity of repair work. However, all these advantages leveled by the low water resistance of gypsum, which makes it impossible to use it in its pure form for exterior facade work. The issues of increasing the water resistance of gypsum compositions are discussed in many publications [6–10]. Promising methods of increasing the water resistance of gypsum ae: the creation of mixtures based on gypsum and cement with the addition of components with pozzolanic activity, the use of hydrophobizing additives, the use of complex additives with ground fillers (for example, expanded clay dust), and others [11, 12].

As a result of analyzing the available information on ways to increase the water resistance of gypsum, this study adopted a gypsum-cement mixture with the addition of thermal power plant ash as a pozzolanic additive as the binder base of the plaster composition. The studies confirmed the sufficient water resistance of the proposed compositions [13]. The softening coefficient of the proposed composition approached 0.8, which already makes the mixture waterproof with the possibility of further increasing water resistance due to hydrophobic additives.

An important criterion for choosing a plaster mixture for shell rock walls is the vapor permeability of the plaster layer and its consistency with the base material. This condition is of particular importance for maintaining the normal moisture state of the building envelope and

preventing excessive moisture accumulation in the walls during operation, which leads to a loss of structural strength and their possible destruction. Measurements of the transfer properties of the proposed ash-gypsum-cement compositions by the "dry cup" method showed that their vapor permeability exceeds the vapor permeability of limestone-shell rock [14], i.e., the plaster layer will not prevent the escape of vaporized moisture from the wall to the outside.

The strength of adhesion of the plaster layer to the wall base-shell rock – is also an important factor to consider when designing a repair composition. Adhesion refers to the adhesion of materials of different composition and structure, which is due to their physical and chemical properties. The adhesion of building and finishing materials is carried out mainly on the principle of mechanical and chemical bonding. The mechanism of mechanical bonding consists in the penetration of the applied substance into the pores of the outer layer or connection with a rough surface. With the chemical adhesion mechanism, the bond between materials, in particular those of different densities, occurs at the atomic level [15].

As can be seen from Table 1, gypsum plaster is characterized by higher adhesion compared to cement and cement-lime plaster, but the type of surface to be treated is not specified here. For ash-gypsum-cement compositions, there is no data on adhesion to limestone at all.

Purpose and objectives. The aim of this study is to evaluate the adhesion ability of the proposed compositions for plastering the walls of limestone-shell rock buildings and the possibility of increasing it, for which it is necessary to choose a method and device for measuring the adhesion strength, perform the necessary measurements and evaluate the effect of the adhesive additive on the adhesion strength between the plaster layer and the shell rock.

Research methods and materials. Measurements of the adhesion of the developed compositions to surfaces of different nature are carried out by the "tear-off method". The device for measuring adhesion (Fig. 1) developed at the PATBM Department of OSACEA.

Fig. 1. Device for measuring adhesion by the tear-off method (top view)

The test specimen is a system of a ring filled with a mixture connected to a base plate due to the adhesion of the mixture to the surface. The prototype is prepared as follows. A threaded cone ring is placed on a dust-free support surface of a plate made of the selected material and filled with the test mixture (Fig. 2). The samples are kept for 7 days. The principle of adhesion determination is to measure the force of detachment of the ring with the test mixture from the plate surface.

The test specimen is fixed in a collapsible cassette with a hole for the ring. The cassette is self-centering thanks to a ball joint with a bracket fixed through a load cell to the massive base of the device. The ring is connected to the movable pneumatic cylinder rod by a threaded coupling. The ring is detached from the surface when the rod moves under the action of compressed air from the pneumatic compressor. The loading speed is controlled by a valve. The result of the adhesion measurement is determined with an accuracy of 0.01 MPa by the built-in computing device as a fraction of the maximum tear-off force divided by the contact area (the area of the ring's inner hole in contact with the plate surface) and is recorded on the digital display of the device.

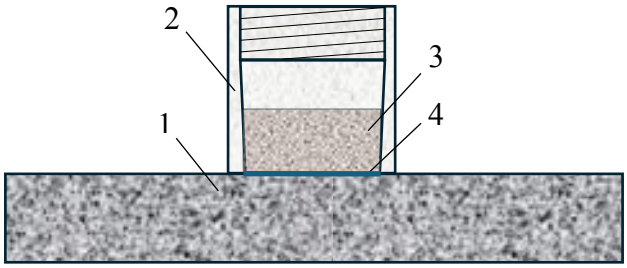

Fig. 2. Schematic of a specimen for testing the adhesive properties of a mixture:
1 – a plate made of real or model material; 2 – a metal conical ring with internal thread; 3 – the tested mixture; 4 – the zone of adhesive contact of the tested mixture with the supporting surface of the plate

The condition of the supporting surface has a significant impact on the adhesion measurement results. In previous measurements of the adhesion of repair mixtures to shell rock, a significant variation in results was observed depending on the quality of the surface (the presence of heterogeneities, cracks, cavities, etc.). Therefore, it was decided to use two types of surfaces: real – plates sawn from limestone blocks, and conditionally model – homogeneous surfaces of ceramic facing tiles, and to increase the number of measurements for samples of each composition (at least five). The surfaces of the shell rock plates were prepared according to the requirements [16, 17].

The investigated samples of ash and gypsum cement mixtures were made in accordance with the three-factor plan B_3 [18], which varied the type and amount of raw materials. After constructing and analyzing mathematical models of a set of properties, including strength, water resistance, and vapor permeability, the basic composition of the repair mixture for further experiments was determined: 60 parts of ground clinker cement and 40 parts of ash per 100 mass parts of G5 gypsum. The amount of water for the mix was selected according to the normal flow of the mixture.

Ceresit CC 81 was used as an adhesive additive, an additive designed for the preparation of manually or mechanized mixtures with enhanced adhesive properties [19]. To measure the adhesion, three batches of 5 samples were made: control without additives, with an adhesive additive in the amount of 3% by weight of dry components, and with an adhesive additive containing 10%.

Research results and their interpretation. The adhesion of the proposed additive-free composition to the surface of shell rock, averaged over five measurement results, is characterized by a tear-off force per unit contact surface of 0.25 MPa. The adhesion of the same composition to the surface of ceramic tiles is 0.30 MPa.

Qualitatively, the effectiveness of the adhesive additive, depending on its content, can be visually assessed by the traces of contact between the mixture and the tile surface (Fig. 3): at a 3 percent additive content, tearing occurs on the tile surface, and at 10 percent – on the mixture itself, which indicates that in this case the adhesive strength of the contact exceeds the cohesive strength of the mixture.

Fig. 3. Features of detachment of samples with different content of adhesive additive from the surface: a – 3%; b – 10%

When the Ceresit CC 81 adhesive additive was introduced into the mixture in an amount of 3%, the adhesion strength of the plaster mixture with the surface of shell rock increased by 1.3 times compared to the non-additive mixture, and when 10% of the additive was introduced, it increased by 2 times (Fig. 4).

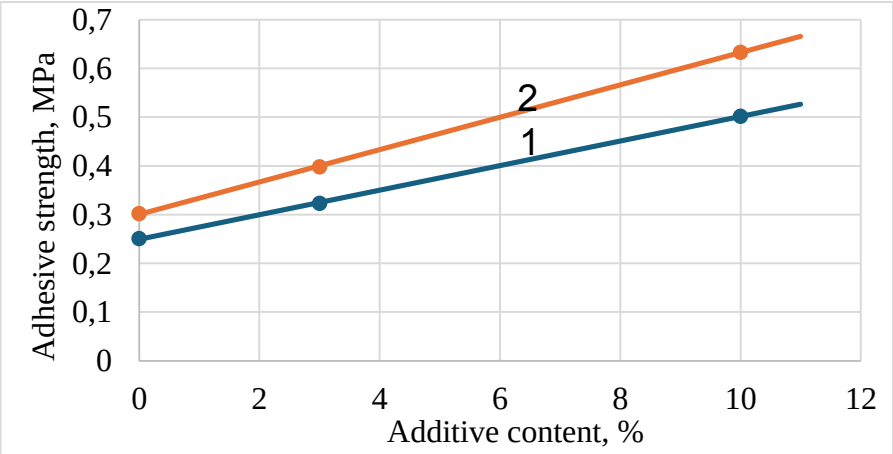

Fig. 4. Changes in the adhesion of the proposed plaster composition to shell rock (1) and ceramic surface (2) depending on the content of the adhesive additive in the mixture

The relative change in the adhesive strength of the contact between the mixture and the ceramic surface with the introduction of 3% of the additive was 1.3 times compared to the additive-free mixture, and with the introduction of 10% of the additive – 2.1 times, however, in absolute terms, the adhesion to tile is expectedly higher than that to shell rock under any conditions.

The graphs (Fig. 4) clearly show a proportional increase in adhesive strength, depending on the amount of additive to any surface, at least in the studied interval of 0 – 10%. The linear nature of the dependence makes it possible to extrapolate this trend to some area outside the experiment, but the selected interval for varying the amount of additive is already quite large, and further increasing the additive content in general construction mixtures is economically inexpedient.

Conclusions. Thus, it can be concluded that the use of the Ceresit CC 81 additive is effective in increasing the adhesion of the proposed plaster mixture to the main shell rock wall. Reasonable limits of the amount of adhesion additive to be introduced will be established based on the results of the planned experiment, in which, in addition to the specified additive, other chemical additives, in particular plasticizing and hydrophobizing additives, will be introduced into the mixture. These additives are known to be capable of increasing adhesion to a certain extent.

However, increasing adhesion is a separate task of the broader task of creating a plaster mixture with a given set of properties for the walls of limestone-shell rock buildings. At this stage of this task, all strength (including adhesion) characteristics of the composition should be ensured at the highest possible level in order to further bring them in line with the properties of the material of the main wall – limestone-shell rock by introducing inert fillers, for example, screening out shell rock sawing products, which will significantly reduce the cost of plaster mix for the repair of historic buildings.

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АДГЕЗІЙНА ЗДАТНІСТЬ ГІПСОВМІСНИХ ШТУКАТУРНИХ СКЛАДІВ

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Анотація. Традиційним матеріалом для будівництва будівель в Північному Причорномор'ї є дешевий місцевий камінь – вапняк-черепашник. Більшість будівель в центральній частині міста Одеси, які представляють історичну та архітектурну цінність, побудовані саме з цього матеріалу. При правильному догляді та обслуговуванні ці споруди здатні виконувати свої функції протягом сотень років, але в результаті зволоження черепашника через недбалу експлуатацію і ряду інших причин відбувається пошкодження несучих конструкцій з подальшим обваленням будівлі. У багатьох випадках безпосередньою причиною руйнування несучих стін є пошкодження, або відсутність, зовнішнього штукатурного шару. Ремонт стін цементними складами загострює проблему. У статті розглядаються деякі аспекти можливого застосування композиційних матеріалів на основі гіпсу для ремонту пошкоджених стін будівель з вапняку-черепашника. Сформульовано вимоги до ремонтного складу. Обґрунтовано доцільність використання гіпсу як в'яжучої основи ремонтної штукатурної суміші для зовнішніх ремонтних робіт. Для підвищення водостійкості штукатурки використовувався зологіпсоцементний склад. Підтверджено достатню водостійкість і паропроникність запропонованого складу. У даній роботі наведено результати дослідження адгезійної міцності контакту розробленого складу з поверхнею різних матеріалів. Використовувалися методи та вимірювальне обладнання, розроблені в ОДАБА. Адгезійна міцність зчеплення запропонованої суміші з поверхнею черепашнику наближається до нормативної. Застосування адгезійної добавки Ceresit CC 81 підвищує адгезійну міцність з'єднання запропонованого складу з черепашником в 1,5 – 2 рази. Оптимальну кількість адгезійної добавки, що має вводитись, буде встановлено за результатами багатофакторного експерименту з вивчення впливу комплексу хімічних добавок різного функціонального призначення на властивості запропонованого ремонтного складу.

Ключові слова: вапняк-черепашник, штукатурний шар, зологіпсоцементна суміш, водостійкість, паропроникність, адгезія.

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