УДК 691.3

СУХАЯ СТРОИТЕЛЬНАЯ СМЕСЬ ДЛЯ РЕСТАВРАЦИИ И ВОССТАНОВЛЕНИЯ ЗДАНИЙ

С.В. Перевозчикова, В.В. Белов

София Валерьевна Перевозчикова
E-mail: ya.sonya1995@yandex.ru
Владимир Владимирович Белов
E-mail: vladim-bel@yandex.ru

Кафедра производства строительных изделий и конструкций, Тверской государственный технический университет, наб. Аф. Никитина, 22, Тверь, Российская Федерация, 170026

В работе отражается актуальность проблемы реставрации и восстановления архитектурных элементов на фасадах зданий. Также отражены результаты экспериментальной работы по подбору оптимального состава смеси для облегченных архитектурных элементов, в состав которой входит белый цемент, полые стеклянные микросферы, модифицирующие добавки и доломитовая мука в качестве микронаполнителя. Представлены результаты микроскопического анализа структуры материала

Ключевые слова: *сухая строительная смесь, реставрация, полые стеклянные микросферы, облегченные конструкции*

Для цитирования:
Перевозчикова С.В., Белов В.В. Сухая строительная смесь для реставрации и восстановления зданий. Умные композиты в строительстве. 2021. V. 2. No 1. P. 14-19 URL: http://comincon.ru/index.php/tor/V2N1_2021

DOI: *10.52957/27821919_2021_1_14*

UDC: 691.3

DRY MIX MORTAR FOR RESTORATION OF BUILDINGS

S.V. Perevozchikova, V.V. Belov

Sofia V. Perevozchikova
E-mail: ya.sonya1995@yandex.ru
Vladimir V. Belov
E-mail: vladim-bel@yandex.ru

Department of Construction Products and Structures Production, Tver State Technical University, Naberezhnaya Af. Nikitin, 22, Tver, Russia, 170026

The paper reflects the relevance of the problem of restoration of architectural elements on the facades of buildings. It also reflects the results of experimental work on the selection of the optimal mix for lightweight architectural elements, which includes white cement, hollow glass microspheres, modifying additives, and dolomitic powder as a microfill. The paper shows the results of microscopic analysis of the structure of the material.

Key words: *dry mix mortar, restoration, hollow glass microspheres, lightweight structures*

For citation:
Perevozchikova S.V., Belov V.V. Dry mix mortar for restoration of buildings. Smart Composite in Construction. 2021. V. 2. No 1. P. 14-19 URL: http://comincon.ru/index.php/tor/V2N1_2021

DOI: *10.52957/27821919_2021_1_14*

The restoration of buildings bears both cultural and common significance for the development of the country and the nation as a whole. The attractive appearance of cities promotes tourism, which contributes significantly to the well-being of the country.

Repair and restoration are the second most important tools, after the construction of new buildings to maintain and improve the appearance of Russian cities [1].

The restoration and repair of buildings largely depends not only on the technology used for this [2, 3], but also on the materials that are used. At this stage in the development of the building materials industry there are a large number of different mixtures and compositions used for repair work. Every year the requirements for these materials are becoming stricter. This contributes to a more thorough analysis of the materials developed and a positive final outcome.

Despite of this, the problem of developing building materials, the characteristics of which meet the requirements of modern realities of economic and physical - chemical indicators, is not solved [4]. There is still the question of the compatibility of restoration materials of old and new times. High-strength α-modification gypsum, which has an average density of 1900 kg/m^3, is the most often used material in restoration work [5]. However, the use of such gypsum in compositions can destroy the old wooden ceilings of restored monuments and other objects when restoring the ceiling elements. Authors [6] believe that the introduction of a certain amount of hollow glass microspheres in a restoration composition can lead to reduction in the weight of the element by almost half without loss of strength.

Gypsum composites are not as durable in an environment where they are exposed to precipitation, as cement-based composites, which in this case have a significant role, as the intended composite will be used for exterior finishing of buildings and restoration of architectural monuments.

The working life of materials used in restoration is determined by the influence of precipitation and temperature changes. These conditions clearly cause deformations in the finishing layer. Condensation leads to the delamination between the layer of the building envelope and the element to be restored [7]. The behavior of materials with a porous structure depends directly on the process of mass transfer within these materials [8, 9].

According to the previous studies we can say that the main disadvantage of lightweight cement composites is the reduction of strength by reducing the density. The use of hollow glass microspheres, which are durable fillers but with low density, solves this problem and makes it possible to obtain a material with the compact particle packing. In this material, the cement stone is a thin bonding layer, which makes it possible to obtain a material with a conglomerate type of structure [10].

During the repairs, it is necessary to choose the appropriate mixture to ensure compatibility of materials [11]. It is necessary to consider the activity of the outer layer in its interaction with the environment because the surface layer of the material has a structure different from that of the inner layer [12].

The paper [13] proposes the following mortar for civil and industrial purposes, including repair work. Mortar includes cement, sand, modifiers, water, and active mineral additive containing aluminosilicate microspheres (cenospheres), amorphous silicon dioxide (microsilica) and high calcium ash, with the following ratio of components, %: cement 25.0-40.0, sand 5.0-30.0, active mineral additive 35.0-60.0, modifiers 0.2-2.0.

The authors [14] initially studied the structuring of the cement matrix when ash microspheres were introduced into it. The second part of the study consisted of mechanical activation of ash microspheres. The microspheres were ground in a ball drum, which made it possible to achieve more active hardening of the composition at the boundary between the cement matrix and ash microspheres. The formation of calcium hydrosilicates and hydroaluminates proceeds more intensively due to the formation of mechanically activated microspheres of the base sheet 14]. This indicates the increase of structural density and leads to the improvement of the cement-containing material properties. Thus, the results obtained by the authors [14], when using in concrete mechanically activated particles of 15% of the weight of the cement, showed fairly good results: water resistance grade increased from W10 to W16, strength reached 75 MPa, and frost resistance increased by two steps.

The compositions of building mortars contain fill materials in the form of spheres such as fine-dispersion fillers based on calcium silicates, which are used for acceleration of the lime composites structure formation [15-17].

In this regard, the development of lightweight cement mortars with hollow glass microspheres for the restoration of architectural monuments is a pressing issue.

During the experiment there were the compositions of mortars selected to evaluate the effect of carbonate microfillers, the ratio of hollow glass microspheres and PVA on the strength, density, frost resistance and water absorption of the mortar. The quantity of water was taken according to the optimal plasticity of the mortar.

To obtain the complex characteristics of this mortar there were molded sample cubes 100x100x100 mm. The size of the samples is important for measurement of thermal conductivity. The sample cube of 70,7x70,7x70,7 mm serves for measuring of frost resistance, water absorption, softening factor; 20x20x20 mm serves for measuring of porosity, density, compressive strength. The standard methods require larger samples to obtain these characteristics, but it was decided to characterize the material by smaller samples for economical use of the expensive materials. Replacing large samples with smaller ones did not distort the results because the structure of the developing material does not have the coarse filler and is fine grained. The characteristics were determined by standard methods.

Data on the complex analysis of samples are shown in summary table 1.

The material has a fine-grained structure with the inclusion of pores of significant size. Approximately, these pores may have resulted from the mortar undervibration.

The hollow microspheres should prevent undesirable shrinkage of the material. They prevent the material from being destroyed by precipitation. This hypothesis can be confirmed by microscopic analysis. Photomicrographs of the structure on the sample bent fracture were made in the laboratory of Research Institute of Synthetic Fiber with the Pilot Plant (VNIISV), Tver, Russia. The material sample was a fragment of a cement monolith separated by brittle fracture.

Table 1. Complex characteristics of the optimal composition

Characteristics	*Average value of one sample set*
Compression strength, MPa	*16.0*
Average density, g/cm^3	*1.4*

True density, g/cm³	*1.8*
Moisture, %	*24.4*
The water absorption by mass, %	*20.4*
Total porosity volume, %	*26.3*
Thermal conductivity, W/ (m-K)	*0.502*
Softening factor	*0.40*

The surface of the fragment for observation in an electron scanning microscope was coated with a film of aluminum by vapor sedimentation method in vacuum. Photomicrographs were obtained by using a Hitachi-S450 electron scanning microscope. The accelerating potential was 10 kV, the photos were obtained on secondary electrons.

Fig. 1 shows photos with increasing magnification of the cleavage of surface. It can be seen that the glass microspheres (as well as traces of fallen out microspheres) are chaotically distributed throughout the material. The size of the microspheres varies greatly. The protruding part of the surface of the microspheres is almost flat (Fig. 2) and bears no traces of interaction with the cement. As microspheres pass through a crack in the material (see Fig. 2), they separate from one of its edges, usually without being subjected to fracture.

Fig. 3 shows a photomicrograph of a crack and a dimple caused by the microsphere. It can be seen that there are no fragments of the microsphere wall in the dimple. The contact surface is the same as the microsphere surface, i.e., the contact of the microsphere with the cement mass occurs almost over the entire surface, but without the formation of persistent bonds.

Based on the data obtained in Table 1 and Fig. 1-3, we can draw conclusions about the characteristics of the developed material.

One of the important characteristics of this composite is the resistance of the cement stone in the material to periodical moistening and drying-out. Frequent moistening and drying-out leads to accumulation of permanent deformations and material wear. But in contrast to laboratory tests, where temperature and humidity were high enough, in real conditions the composite is not dried to zero humidity so its values can be taken from 10 to 100%. It means that it is impossible to remove water completely from the composite.

Also, the average density of the sample is quite low (1400 kg/m³) for the restoration composition. According to the paper [5], the average density of high-strength gypsum alpha-modification used for the restoration should be 1900 kg/m³. Further density reduction is possible by introducing an additional amount of hollow glass microspheres but may have a negative effect on other physical and mechanical properties of the composite, such as average strength, softening factor.

As the material is expected to be used in an environment and will be subjected to precipitation, alternating freezing and defrosting, these pores may give rise to micro-cracks in the material due to the expansion of water at low temperatures. It could affect the durability of the material. Thus, the mixture has to be compacted more thoroughly to avoid the formation of large spores.

The softening factor is the water resistance of the material related to water absorption and the nature of the aggregate substance. The water absorption is related to the porosity and structure of the material. The same factors determine the frost resistance of the filler. The material is not expected to be used in an aqueous media (the coefficient of softening of the material should not be less than 0.8), the value of 0.4 can be considered satisfactory.

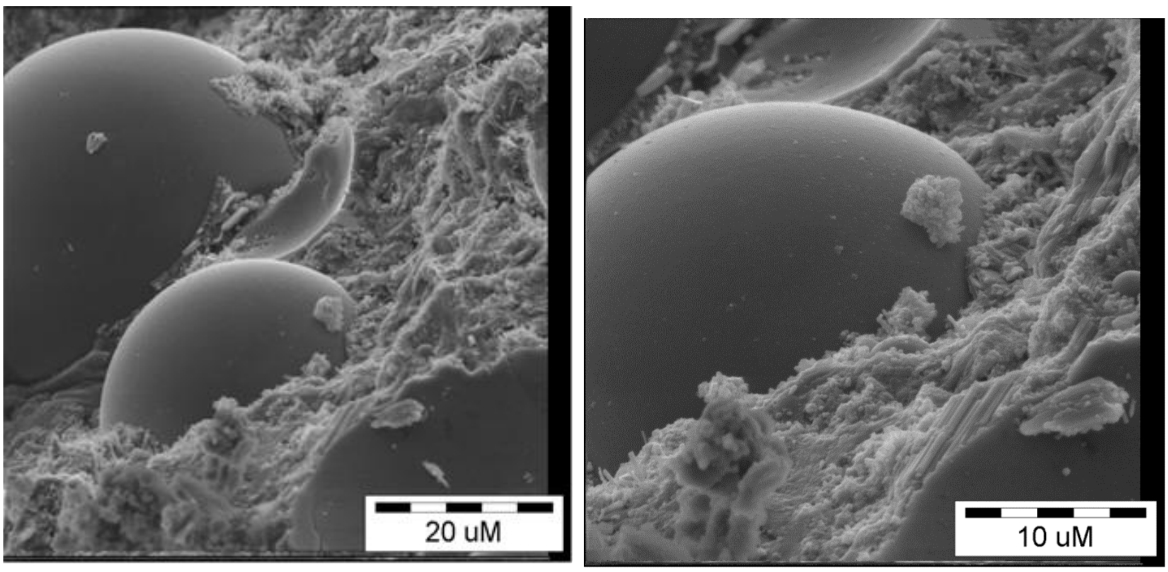

Fig. 1. The surface of the glass microsphere at high magnification

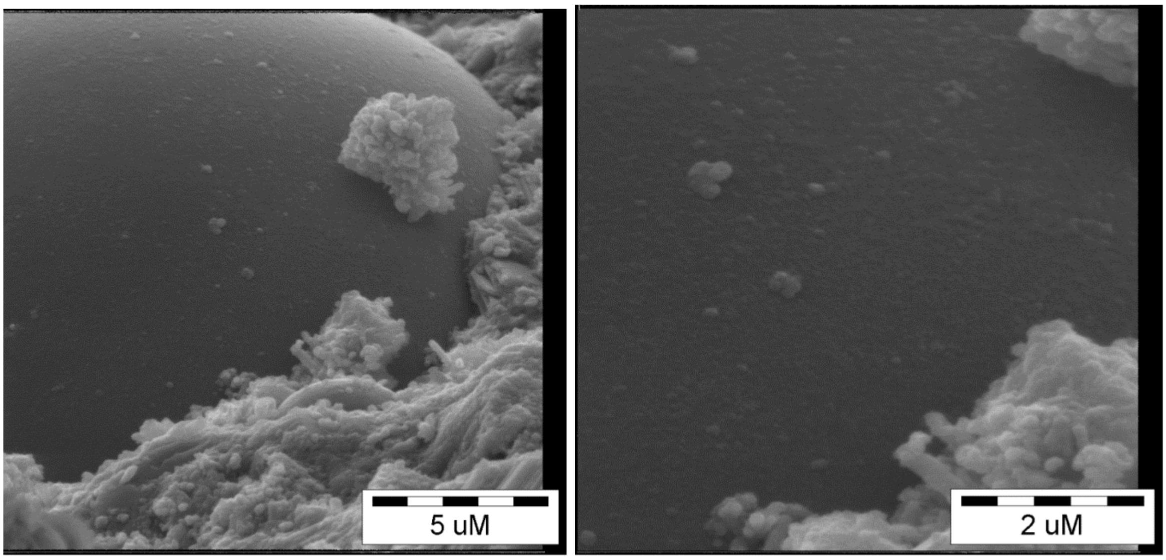

Fig. 2. The surface of the glass microsphere at high magnification

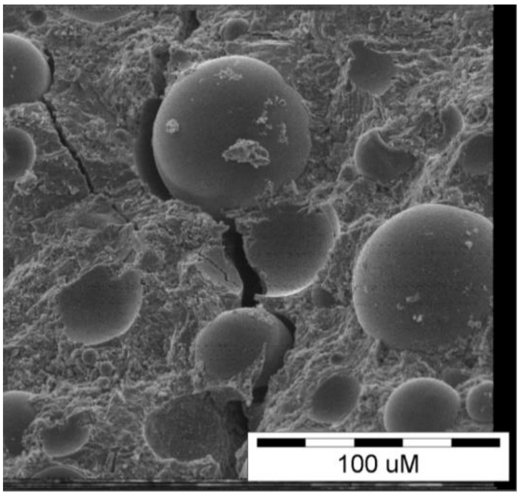

Fig. 3. Morphology of the material in the crack passage zone

Microspheres are used to reduce the weight of finished products. This can lead to a reduction in labor costs to perform reconstruction and will reduce the load on the wooden structures of historic buildings or obsolete parts of stone products. A stable pore structure can also be created. The proper spherical shape of the filler makes it possible to use a smaller number of binders for wetting, which leads to a reduction in viscosity and shrinkage. The microspheres act as a «damping» additive.

The use of natural carbonates as an additive has a positive effect on the regulation of the water - solid ratio of the gypsum molding plaster. This additive has the plasticizing effect which can significantly reduce the water - binder ratio and increase the strength of the final product. Also, the positive effect on the formation of the material structure can be achieved. Reducing the amount of water will reduce the number of capillary pores, thereby increasing the frost resistance of the material.

CONCLUSIONS

The lightweight corrosion-resistant dry mix mortar including hollow glass microspheres used to create, repair and restore architectural elements. Also, it will increase the crack resistance of products due to the "damping" effect and microspheres themselves serve as a framework for the cement matrix, which prevents its undesirable shrinkage. In addition, the presence of hollow glass microspheres in the material reduces its alkalinity and makes it more resistant to aggressive media.

Development of composition and production technology for lightweight corrosion-resistant dry mix mortar with a density of 900 kg/m^3 and compression strength of 5.0…10.0 MPa (grades 50, 75, 100) will allow to improve the quality of repair and restoration work and durability of architectural elements and facades of buildings so as improve their appearance.

The paper is published with the support of the Innovations Assistance Foundation, UMNIK-2019 program.

REFERENCES

1. ***Egorova O A.*** *Restoration of architectural monuments and the problem of facadeism. Vestnik grazhdanskih inzhenerov. 2017. N. 1(60). P. 16-22. (in Russian).*
2. ***Alfkhar MA, Osama E.*** *Problems of reconstruction of architectural monuments. Interaktivnaya nauka. 2017. N 12. P. 153-155. (in Russian).*
3. ***Krokhina A.A.*** *Problems of restoration of architectural monuments in the context of modern urban planning (legal aspect). SHag v nauku. 2019. N 3. P. 30-32. (in Russian).*
4. ***Korovyakov V.F.*** *Gypsum binders and their use in construction. Rossijskij himicheskij zhurnal. 2003. V. XLVII. N 4. P. 18-25. (in Russian).*
5. ***Khaev T.E., Tkach E.V., Zemlyanushnov D.YU. Solov'ev V.I.*** *Restoration work using lightweight plaster systems with hollow glass microspheres. Sovremennye tendencii razvitiya nauki i tekhnologij. 2017. N 2-2. P. 116-118. (in Russian).*
6. ***Oreshkin D.V.*** *Lightweight and ultra-lightweight cement mortars for construction. Stroitel'nye materialy. 2010. N 6. P. 34-37. (in Russian).*

7. ***Lesovik V.S., Zagorodnyuk L.Kh., Chulkova I.L.*** *The law of the affinity of structures in materials science. Fundamental'nye issledovaniya. 2014. N 3. P. 267-271. URL: http://fundamental-research.ru/ru/article/view?id=33621 (in Russian)..*
8. ***Vatin V.I.*** *Influence of physical, technical and geometric characteristics of plaster coatings on the moisture regime of homogeneous walls made of aerated concrete blocks. Inzhenerno-stroitel'nyj zhurnal. 2011. N 1. P. 28–33. (in Russian).*
9. ***Kornienko S.V., Vatin N.I., Petrichenko M.R., Gorshkov A.S.*** *Assessment of the moisture regime of a multilayer wall structure in the annual cycle. Stroitel'stvo unikal'nyh zdanij i sooruzhenij. 2015. N 6. P. 19–33. (in Russian).*
10. ***Isaeva Yu.V., Velichko E.G., Kasumov A.SH.*** *Optimization of the structure of ultra-light cement slurry, taking into account the geometric and physical-mechanical characteristics of the components. Stroitel'nye materialy. 2015. N 8. P. 84. (in Russian).*
11. ***Krasnitskaya A.A., Shamanov V.A***. *Aspects of the selection of effective building mixtures for the repair and restoration of reinforced concrete tanks for special purposes. Sovremennye tekhnologii v stroitel'stve. Teoriya i praktika. 2019. V. 2. P. 334-339. (in Russian).*
12. ***Ryzhikh V.D.*** *Designing compositions of repair mixtures taking into account the law of affinity of structures. Prirodopodobnye tekhnologii stroitel'nyh kompozitov dlya zashchity sredy obitaniya cheloveka: materialy II Mezhdunarodnogo onlajn-kongressa, po-svyashchennogo 30-letiyu kafedry stroitel'nogo materialovedeniya izdelij i kon-strukcij. Belgorod. 2019. P. 246-250 (in Russian).*
13. ***Vanshteidt L.D.*** *Pat. RU N 2708138; Bul. 2019. N 34. (in Russian).*
14. ***Zimakova G.A., Solonina V.A., Zelig M.P.*** *Ash mechanically activated microspheres are a component of highly efficient concrete. Mezhdunarodnyj nauchno-issledovatel'skij zhurnal. 2016. N 12(54). P. 90-94. (in Russian).*
15. ***Frolov M.V.*** *Structural formation of lime composites in the presence of a modifying additive. Sovremennye nauchnye issledovaniya i innovacii. 2015. N 7. Part 1. URL: http://web.snauka.ru/issues/2015/07/56191 (in Russian).*
16. ***Pyshkina I.S., Zhegera K.V.*** *The effectiveness of the use of amorphous aluminosilicates and calcium hydrosilicates in lime dry building mixtures. Regional'naya arhitektura i stroitel'stvo 2017. N 4. P. 24-28. (in Russian).*
17. ***Loganina V.I., Petukhova N.A., Akzhigitova E.R.*** *Development of an organomineral additive for dry building mixtures. Vestnik BGTU im. V.G. SHuhova. 2011. N 3. P. 8-12. (in Russian).*

Received 08.02.2021
Accepted 01.03.2021