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STRENGTH AND DESTRUCTION OF BRICK MASASONRY BASED ON MODIFIED CEMENT MORTARS

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The article investigates the strength and deformability of brick masonry based on clinker-effective buikding mortars modified by additives of air-entraining action. Comparative studies have determined the physical and mechanical properties of mortar based on composite Portland cement CEM II / B-M 32.5R and masonry cement MC 22.5. It is shown that mortar on the basis of modified low-emission zeolite-containing cement MC 22.5 with additives of air-entraining action provides reduction of stress-deformed state of brick masonry. It is established that the increased strength of adhesion (0.73 MPa) of the mortar in the brick masonry without cracking is provided by the use of modified low-emission masonry cement MC 22.5. Increasing the efflorescences resistance of brick masonry is achieved by surface modification of hydrophobic substances and the use of clinker-efficient mortar.

Key words: brick masonry, modified building mortar, ceramic brick, strength.

Introduction

Monolithicity, crack resistance of brick masonry, its resistance to bending and tensile forces with uneven settling of foundations, change in temperature have a decisive influence on the durability of enclosing structures. The main reasons for the stress-strain state of the brick masonry are the heterogeneity of the mortar, the difference between the deformation properties of the ceramic brick and mortar, the presence of vertical seams in the masonry, etc. (Fic et al., 2013, Gotz et al., 2016;). During the operation of brick structures, due to changes in temperature and humidity, there are defects that significantly impair the architectural expressiveness and adversely affect on the physical and technical properties of the masonry facades. Destructive impact on masonry is largely caused by the high porosity of the ceramic facing brick and mortar. It leads to intense penetration and tightening of moisture and causes migration of salts with the crystals formation in the form of local white spots, different degrees of prevalence and intensity, also reduces its technical and decorative properties (Sukhanov et al., 2016; Sanyskyy et al., 2014). Therefore, improving the performance properties and increasing the durability of the brick masonry of buildings and structures determines the topicality of this work.

Review of scientific sources and publications

Ceramic facing brick is widely used for external constructions, building of architectural constructions, repairing or reconstruction of residential and public buildings. This artificial stone is a heterogeneous and porous material (Varshavets et al., 2014). This causes to moisture penetration into the deep layers of the masonry during operation, destroying it, especially during the impact of negative temperatures. On the other hand, salts are washed out and taken to the surface of the material, which also leads to the loss of the aesthetic appearance of the building (Zhu et al., 2014; Mahyuddin et al., 2012; Kropyvnytska et al., 2018).

The stone construction is prone to vertical and extra-center compression, bending, shearing and stretching at the same time. The main causes of stress-strain state of masonry are the heterogeneity of the mortar and the presence of vertical seams in the masonry, as well as a significant difference in the deformation properties of the brick and mortar. Due to the local heterogeneity of the mortar composition, the conditions of hardening in the seam, sections of the mortar are formed in the masonry, which are significantly different from each other at an average density and strength (Solodkyy, 2008). In addition, the values of deformation parameters of mortar are greater than in bricks. Tensile forces occur in the brick, compressive forces – in the mortar in the tense state, The magnitude of the load depends on the mechanical properties of the brick, the construction of the masonry and the deformative properties of the mortar, that is, the type of mortar and its service life (masonry age). With the increase of the latter the deformability of the mortar decreases. The time of occurrence of the first cracks depends on the quality of the horizontal seams and the average density of the mortar (Fic et al., 2013).

Nowadays, complex masonry mortars are widely used to build the brick masonry of the exterior walls of buildings and structures. They are characterized by sufficient density, adhesion strength to the base and design strength mark. However, due to the increased water absorption in the seam of the masonry, a dehydrated layer of mortar can be formed, which leads to the appearance of hair cracks and the integrity of the masonry. In order to improve the technological and technical properties of masonry mortars, air-entraining additives are used in the mortar, which act as “stress dampers” and create a system of small closed pores in the mortar matrix (Kropyvnytska et al., 2017). Closed pores prevent the propagation of cracks deep into the solid, their development is inhibited in the air pore. Thus, small closed pores interfere with the process of destruction of the material. The stress drops very quickly from high values on the surface of the pores to low values in its internal parts.

Effective ways to increase the performance properties of brick masonry are the use of multicomponent cements with additives of pozzolanic action and the use of modern hydrophobic substances, which reduces the water absorption of porous wall materials, increase the vapor permeability, abrasion resistance and improve the appearance of building structures (Sanytskyy et al., 2010; Pushkareva et al., 2014). In this regard, building technology requires a new approach to the modification of ceramic facing bricks at the nano- and sub-microlevels by hydrophobic action and masonry mortar based on multicomponent cements with the additives of plasticizing and air-entraining action.

The aims and objectives of the study

The aim of the study is to investigate the strength and deformability of the brick masonry using clinker- efficient building mortars modified by additives of air-entraining action.

To achieve this goal the following tasks were solved:

– physical and chemical properties of ceramic facing brick and mortar on the basis of composite Portland cement CEM II / B-M 32.5R EN 197-1 and masonry cement MC 22.5 EN 413-1 were investigated;

– the strength and deformation properties of the brick masonry were determined using the samples “ceramic facing brick – a complex mortar based on Portland cement CEM II / B-M 32.5R” and “ceramic facing brick – modified masonry cement MC 22.5”.

Materials and methods

Ceramic facing brick Grade MW, Type FBS, Average compressive strength 16.81 MPa (EN 771-1:2003) are used for investigation. Building mortars based on Portland cements CEM II / B-M 32.5R EN 197-1 and masonry cement MC 22.5 EN 413-1 are used for researches. Building lime and modifier of air-entraining action Master Air 81 (BASF) are applied as plasticizing additives. Water-repellent of penetrating complex action (Megatron-K) was used to treat the brick masonry surface.

The determination of the physical, technical and operational properties of ceramic bricks and mortar was carried out in accordance with the applicable national and European standards. The resistance of ceramic bricks to the efflorescence formation was tested according to DSTU B V.2.7-171:2008, frost resistance – DSTU B V.2.7-42-97.

The compressive strength of the brick masonry was determined according to EN 1052-1. The sizes masonry samples are given in table 1. The masonry samples were subjected to a uniform load during the test.

Table 1

Sample sizes to test the compressive strength of masonry

The dimensions of the masonry elements		Sample size brick masonry			
l_u= 250 mm	h_u= 65 mm	l_s= 515 mm	h_s= 545 mm		t_s= 120 mm
≤ 300	≤ 150	≥ (2 l_u)	≥ 5 h_u	≥ 3 ts i ≤ 15 t_s i ≥ l_s	≥ t_u

To determine the modulus of elasticity, the masonry samples were fitted with measuring devices for measuring height change. The compression force was applied in no less than three steps until half of the maximum possible value was reached. After the last stage, the compression force was increased to a constant value until destruction. The modulus of elasticity of the masonry isample was defined as the mesh modulus from the average strain value at the four measurement points at loading equal to one third of the maximum possible value. The adhesive strength of the brick masonry was determined in accordance with DSTU B.V.2.6-174:2011.

Results of investigation

Physical and mechanical properties of mortars based on cement CEM II / B-M 32.5R with the lime additive and MC 22.5 (Cement – 280 kg per 1 m^3 of sand) were investigated. The research results show that complex mortars based on CEM II / B-M 32.5R (W/C = 0.93) are characterized by an average density of the mortar – 1970 kg/m^3, water-holding capacity – 93.1–96.7 %, stratification – 8.2–5.4 %; strength mark – M100. The modified cement mortars based on masonry cement MC 22.5 reach the mark of the strength M75 at an average density of 1840 kg/m^3. The total porosity is 21.21 % (open – 11.76 %, closed – 9.45 %) for the complex mortars, for modified – 33.15 % (open – 13.42 %, closed – 19.73 %). The modified mortars are characterized by slight shrinkage deformations (0.31 mm/m), adhesion of 0.3–0.5 MPa, frost resistance F100 and the ability to harden without significant expansion deformation in winter conditions. The modulus of elasticity for such mortars decreases from 29.7 to 16.35 GPa in comparison with the complex mortars. The Poisson's ratio increases from 0.14 to 0.17, which reduces the possibility of cracking and improves the quality of masonry.

The nature of the masonry destruction and the degree of influence of numerous factors on its strength explain the features of its stress state in compression. According to DSTU B V.2.6–207:2015, the destruction of ordinary brick masonry in compression begins with the appearance of separate vertical cracks. The appearance of cracks depends on the quality of the horizontal seams and the average density of the mortar. The compressive strength of the masonry was determined by the strength of small samples of masonry loaded to destruction (Fig. 1). The results of the tests according to DSTU B EN 1052-1:2011 show that the compressive strength is 8.5 N/mm^2, the modulus of elasticity – $29.8 \cdot 10^3$ N/mm^2 for the masonry sample (modified mortar based on cement MC 22.5 – class M10,0). It should be noted that brick masonry based on a complex mortar based on CEM II / B-M 32.5R is characterized by higher elastic modulus ($E = 33.2 \cdot 10^3$ N/ mm^2).

Fig. 1. Determination of compressive strength of masonry

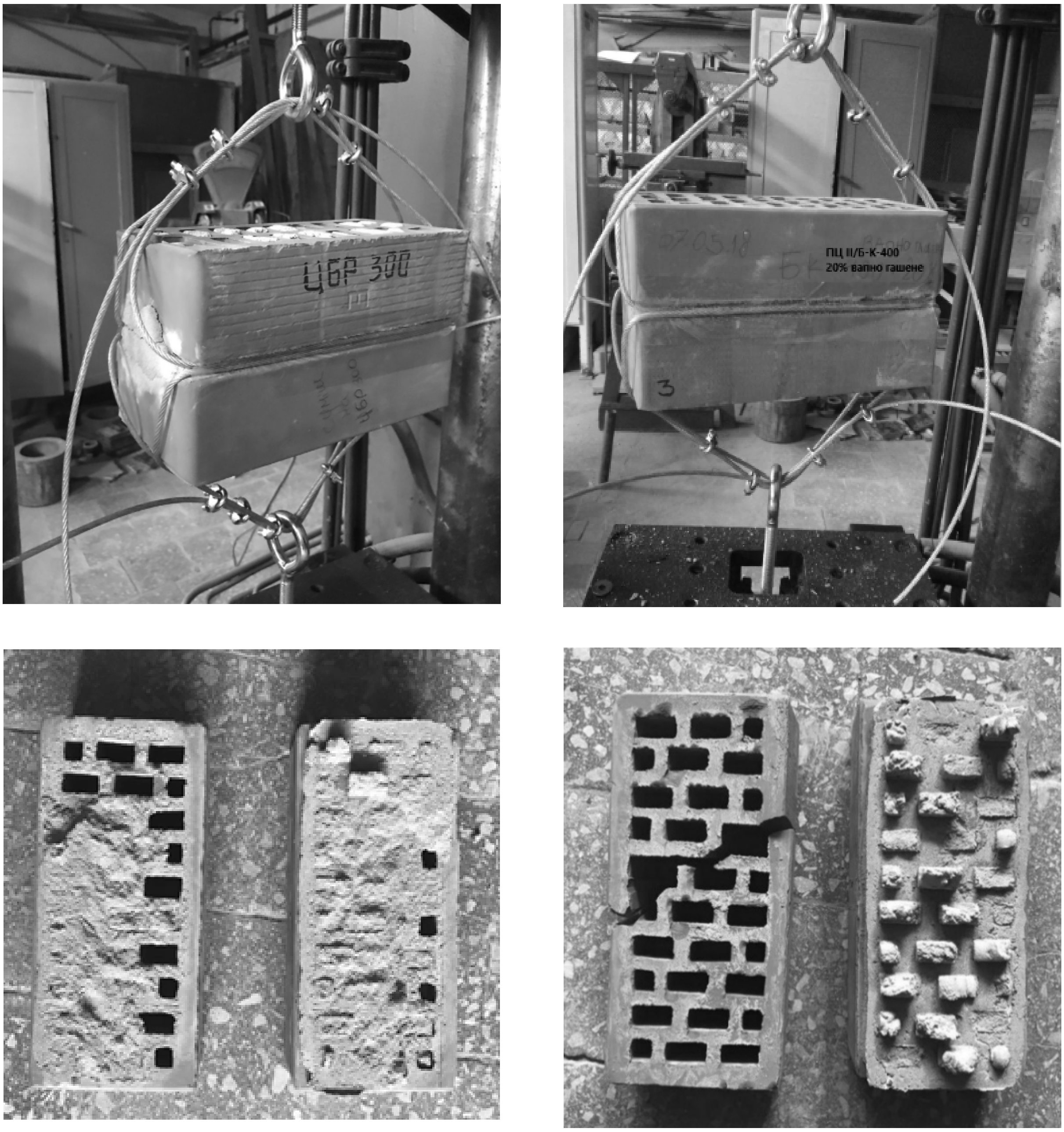
According to DSTU B.V.2.6-174:2011, the adhesion strength in masonry using a ceramic facing brick and modified mortar based on masonry cement MC 22.5 and Portland cement CEM II / B-M 32.5R was determinated. As indicated in the table. 2, the adhesive strength of the modified mortar in the brick masonry (separation area 240 cm^2, the value of the tear-off load 1500 N) is 0.73 MPa. While the adhesive strength of the complex mortar in the brick masonry (separation area 240 cm^2, the value of the tear-off load 900 N) is 0.31 MPa.

Table 2

Indicators during the test adhesion strength of the mortar in the brick masonry

Type of mortar	Compressive strength, MPa	The value of the tear-off load, N (kgf)	Separation area, cm^2	Adhesive strength, MPa	Characteristics of the separation area, %	
					By mortar	By brick
Complex building mortar	14.9	900	240	0.31	95	5
Modified building mortar	10.8	1500	240	0.73	60	40

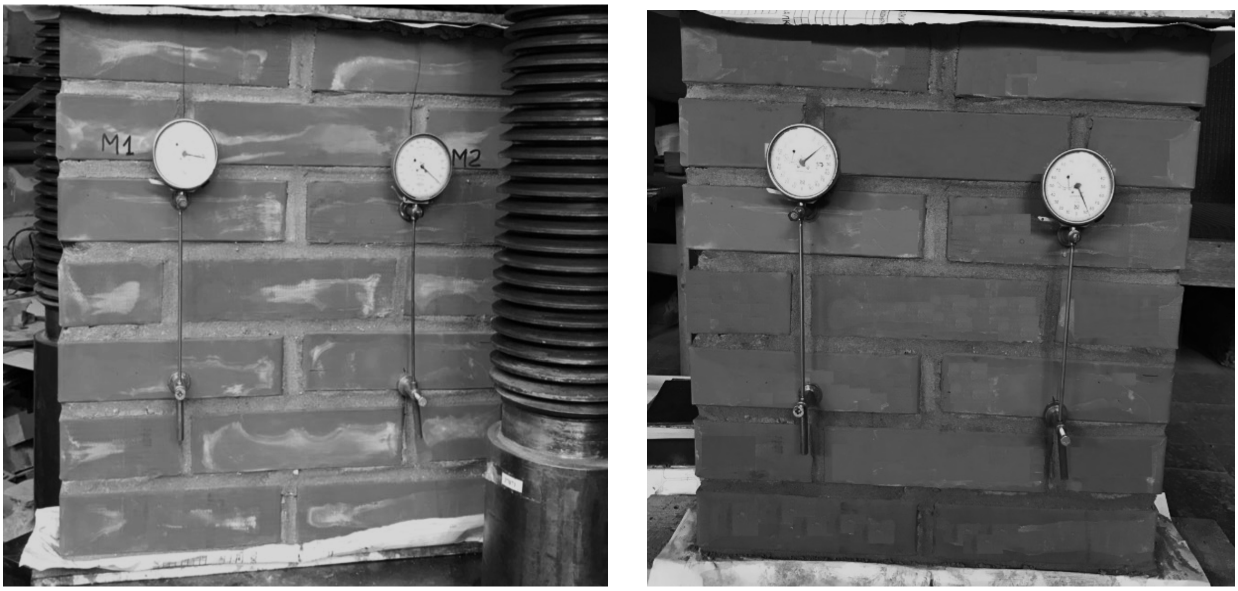
As can be seen from Fig. 2a, samples of brick masonry using a modified mortar based on masonry cement MC 22.5 are characterized by an optimum separation area. Masonry sample using a complex mortar based on Portland cement CEM II / B-M 32.5R is characterized by 95 % of the separation area by mortar with splitting of the brick (Fig. 2b).



a *b*

Fig. 2. Determination of adhesion strength of masonry
a – masonry on the basis of a modified mortar with MC 22.5;
b – masonry on the basis of a complex mortar with CEM II / B-M 32.5R.

Experimental studies have found that, ceramic facing brick is characterized by high porosity (21 %) and water absorption (16.5 %). The studies of the efflorescence formation have established the presence of efflorescences on the ceramic facing bricks surface after 7 days of testing. It is established that the selected samples of efflorescences from the masonry surface are characterized by high content of SO_3 (51.2 mass.%) and alkaline oxides Na_2O (36.7 mass.%) and K_2O (12.4 mass.%). In particular, salts of Na_2SO_4 and K_2SO_4 are formed. To prevent efflorescences formation, a surface treatment of a water-repellent of penetrating complex action (Megatron-K) was carried out. As can be seen from Fig. 3a, traces of efflorescences in the form of white spots appear for the masonry sample using a complex mortar. At the same time, for brick masonry, the elements of which are fastened with modified mortar on the basis of zeolite-containing cement MC 22.5 and the surface of which is covered by hydrophobic substance, the formation is not observed (Fig. 3b).



a *b*

Fig. 3. Samples of brick masonry based on:
a – complex building mortar; b – modified building mortar.

Thus, due to aeration, the modified masonry mortar is characterized by less water absorption, more resistant to atmospheric influences and repeated freezing cycles, since freezing water in the capillaries can be pressed into empty bubbles, which prevent cracking by acting as a damper.

Conclusion

The tests of brick masonry using a clinker-effective mortar based on modified masonry cement (f_m = 10.8 H/mm^2) according to DSTU B EN 1052-1:2011 have found that the compressive strength after 28 days of hardening is 8.5 N/mm^2, the modulus of elasticity is 29.8 GPa.

The use of clinker- efficient mortar based on modified masonry cement MC 22.5 with additives of air-entraining action provides the increased strength of adhesion (0.73 MPa) of a mortar in a brick masonry without efflorescences formation and cracking.

Modifying the surface of brick masonry and using an effective mortar based on modified masonry cement MC 22.5 provides improved operational reliability of the external walls of buildings and structures.

References

Fic, S., Vyrovoy, V., & Dorofeev, V. (2013). Procecy samoorganizacji struktury kompozytowych matrialow budowlanych. *Politechnika Lublenska*, 143.

Gotz, V., Pavlyuk, V., & Shylyuk, P. (2016). Betony i budivelni rozchyny: pidruchnyk. K.: Osnova, 568.

Sukhanov, V., Vyrovoi, V., & Korobko, O. (2016). Struktura materyala v strukture konstruktsyy. Monohrafiya, “POLIHRAF”, Odessa, 244.

Sanytsky, M., Kropyvnytska, T., & Kotiv, R. (2014). Modified plasters for restoration and finishing works. *Advanced Materials Research*, *923*, 42–47. doi: 10.4028/www.scientific.net/AMR.923.42.

Varshavets, P., Svidersky, V., & Chernyak, L. (2014). Peculiarities of the structure and hydro physical properties of face brick. *European applied sciences, Stutgart, Germany: ORT Publishing*, *1*, 106–110.

Zhu, H., Wang, P., Wang, R., & Zhang, G. (2014). Effects of Two Redispersible Polymer Powders on Efflorescence of Portland Cement-based Decorative. *Mortar Materials science*, *20*, 345–350. doi: https://doi.org/10.5755/j01.ms.20.3.4053.

Mahyuddin, R., & Amin, A. T. (2012). Effects of polymer modification on the permeability of cement mortars under different curing conditions: a correlational study that includes pore distributions water absorption and compressive strength. *Construction and Building Materials*, *28*, 561–570. doi: 10.1016/j.conbuildmat.2011.09.004.

Kropyvnytska, T., Sanytskyy, M., Semeniv, R., & Kaminskyy, A. (2018). Pidvyshchennya ekspluatacijnykh vlastyvostej ceglyanoj kladky zovnishnikh stin ogorodzhuvalnykh konstrukcij. *Naukovyj visnyk budivnyctva*, *91*(1), 146–151. doi: 10.29295/2311–7257–2018–91–1–146–151.

Solodkyy, S. (2008). Trishchynostijkist betoniv na modyfikovanykh cementakh, Lviv: Nacionalnyy universytet “Lvivska politehnika”, 144.

Kropyvnytska, T., Semeniv, R., & Ivashchyshyn, H. (2017). Increase of brick masonry durability for external walls of buildings and structures. *MATEC Web of Conferences*, *116*, 01007. doi: 10.1051/matecconf/201711601007.

Sanytskyy, M., Sobol, Kh., & Markiv, T. (2010). Modyfikovani kompozycijni cementy, Lviv: Vydavnytstvo Lvivskoj politehniky, 132.

Pushkareva, E., Sukhanevich, M., & Bondar, E. (2014). Gidroizolyacionnye pokrytiya pronikayushchego dejstviya na osnove shlakosoderzhashchikh cementov, modificirovannykh prirodnymi ceolitami. *Eastern-European Journal of Enterprise Technologies*, *3*(6(69)), 57–62. doi:http://dx.doi.org/10.15587/1729-4061.2014.24879.

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МІЦНІСТЬ І РУЙНУВАННЯ ЦЕГЛЯНОЇ КЛАДКИ З ВИКОРИСТАННЯМ МОДИФІКОВАНИХ БУДІВЕЛЬНИХ РОЗЧИНІВ

Досліджено міцність та деформативність цегляної кладки на основі клінкер-ефективних будівельних розчинів, модифікованих добавками повітровтягувальної дії. Порівняльними дослідженнями визначено фізико-механічні властивості будівельного розчину на основі композиційного портландцементу CEM II / B-M 32,5R та низькоемісійного цементу для мурування MC 22,5. Показано доцільність використання багатокомпонентних цементів із підвищеним вмістом активних мінеральних добавок гідравлічної та пуцоланічної дії, що дає змогу ефективно управляти процесами структуроутворення цементуючої матриці розчину та отримувати матеріали з наперед заданими властивостями. Встановлено, що будівельний розчин на основі модифікованого низькоемісійного цементу MC 22,5 з добавками повітровтягувальної дії забезпечує зниження напружено-деформованого стану цегляної кладки. Характерно, що дрібні повітряні пори запобігають поширенню тріщин у глибину твердого тіла, оскільки напруження дуже швидко спадає від високих значень на поверхні пори до низьких значень у її внутрішніх частинах. Це і визначаєте, що замкнені пори перешкоджають процесу руйнування матеріалу. Випробуваннями зразків кладки з використанням модифікованого будівельного розчину показано, що границя міцності при стиску через 28 діб становить 8,5 Н/мм^2, модуль пружності – 29,8$\cdot$10^3 Н/мм^2. Підвищена міцність зчеплення (0,73 МПа) розчину в цегляній кладці, без тріщиноутворення, забезпечується шляхом застосування модифікованого цементу для мурування МС 22,5. Дослідженнями висолоутворення згідно з ДСТУ Б В.2.7-171:2008 встановлено наявність висолів на поверхні цегляної кладки з використанням складних будівельних розчинів. Підвищення висолостійкості цегляної кладки досягають застосуванням клінкер-ефективних будівельних розчинів та поверхневого модифікування гідрофобізуючими речовинами.

Ключові слова: цегляна кладка, модифікований будівельний розчин, цемент для мурування, міцність.