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ON THE PROPERTIES OF CEMENT-SAND MORTARS PLASTIFIED WITH CARBONATE CLAYS

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Abstract

The use of cement-sand mortars plasticized with carbonate clays in earthquake-resistant construction has been demonstrated in experimental tests. The compositions and physical-and-mechanical characteristics of these mortars have been identified for the first time, allowing for a reduction in cement consumption of up to 40% as well as a complete elimination of the costly lime while enhancing the mortar's strength. The use of cement-sand mortars plasticized with carbonate clays has been suggested for performing earthquake-resistant construction from local sawn limestone. The experiments' findings were put to the test and put into practice in Nagorno-Karabakh's construction complex. The study's finding s are in line with research and regulatory documents for cement-clay mortars for masonry.

Keywords: masonry, sawn limestone, masonry mortar, cement, carbonate clay, strength characteristics, seismic resistant.

Introduction

The formation of the strength of the mortar and its adhesion to the stone depend mainly on the water-holding capacity of the mortar and the absorption properties of the stone.

The ability of the mortar to retain water and the stone's ability to absorb moisture are the two key factors that determine the strength of the mortar and its ability to adhere to the stone.

Stones with high absorption properties, which include the local saw limestone of Nagorno-Karabakh, suck out moisture from the solution, which leads to dehydration of the masonry mortar and a decrease in its strength, as well as the solidity of the masonry.

The local saw limestone of Nagorno-Karabakh are among the stones with strong absorption qualities that absorb moisture from the mortar, dehydrating the mortar and reducing its strength as well as the stability of the construction. Thus, one of the main ways to increase the seismic resistance of stone structures made of sawn limestone is the use of masonry mortars with high strength and water-holding capacity.

The use of cement-sand mortars plasticized with carbonate clays in earthquake-resistant construction, the reserves of the latter are widespread in Nagorno-Karabakh, was demonstrated through an analysis of studies, normative documents on masonry, and physical-and-mechanical properties of materials for masonry mortars [1–5]. In particular, the favorable effect of cement on the physical and mechanical properties of clays of the most diverse genesis and granulometric composition is indicated in the works of Babkov B.F. and Bezruk V.M. who revealed that calcium silicates moistened with water, which make up up to 75% of Portland cement, turn into new compounds that, interacting with clay particles, form a strong, water-resistant mass with high water-holding capacity. Additionally, it has been demonstrated that depending on the chemical and mineralogical makeup of the clays themselves, these processes can be sped up.

Therefore, the cement-clay mortar hardens more quickly, has a higher level of strength, and can hold more water when carbonate clays are used.

At the same time, carbonate clays have a pronounced heterogeneity, and the use of these clays in masonry mortars without laboratory tests can lead to a decrease in the strength characteristics of the masonry and, accordingly, to a decrease in the solidity of stone structures. However, because carbonate clays exhibit significant heterogeneity, using them in masonry mortars without first subjecting them to laboratory testing runs the risk of lowering the masonry's strength properties and, as a result, the stability of stone structures.

The idea of the expediency of using carbonate clays instead of lime in masonry mortars in the construction complex of Nagorno-Karabakh arose during the restoration work of facilities affected by hostilities, in connection with the suspension of lime production enterprises.

Conflict Setting

The idea of using cement-sand mortars plasticized with carbonate clays for creating masonry from saw limestone in antiseismic construction has been supported by experimental tests of the materials' physical and mechanical properties.

Utilizing cement-sand mortars plasticized with carbonate clays to construct buildings and other structures made of stone will increase seismic resistance and construction efficiency.

Research Results

For the first time, the compositions and physical and mechanical properties of cement-sand mortars plasticized with carbonate clays have been revealed, which make it possible to carry out earthquake-resistant construction from local building materials of Armenia and Nagorno-Karabakh.

Materials and methods:

1. Determination of the chemical, granulometric and macroscopic composition of local clay raw materials.
2. Experimental studies on choosing the composition and determination of the physical-and-mechanical characteristics of cement-sand mortars plasticized with carbonate clays for masonry from local sawn limestone in earthquake-resistant construction of buildings and structures.
3. Analysis of the reliability of research results
4. Approbation and practical application of research findings.

Experimental studies were carried out at the Armenian Research Institute of Earthquake Engineering and Protection of Constructions JSC with the participation of the author [6]

Armenian Scientific Research Institute of Seismic Construction and Protection of Structures

The following types of building materials were used in the studies: cement of the Ararat Production Association "AraratCement" M300 (Tab. 1).

Table 1

Physical-and-mechanical characteristics of Portland cement Ararat PO

Apparent density, kg/m^3	Setting periods		Normal density of cement	Strength limit of cement, MPa, at			
	onset	end		Bending strength at ages		Compression strength at ages	
				3 days	28 days	3 days	28 days
1050	1h.10m.	4h.20m.	29,0	17,3	33,7	3,6	5,1

air hydrated lime - produced by the Stepanakert plant of building materials (Tab. 2).

Table 2

Chemical analysis of hydrated lime from Stepanakert building materials plant

Content of active oxides CaO+MдO in terms of dry matter, % by weight	Carbon dioxide content CO_2, % by weight	Lime grade
51,2	2,0	1

Clay from the Askeran deposit (Tables 3, 4, 5) [7].

Table 3

Macroscopic description of clay raw materials

Deposit	Air dry color	Texture	Impurity with large inclusions	Impurity
Askeran	yellowish gray	dense	No	effervescence
Khramort	- // -	- // -	No	- // -

Table 4

Granulometric composition of clays of the Nagorno-Karabakh Republic

Deposit	Percentage of particle size, mm					Particle content (%), size		Classification according to the content of fine fractions (groups)
	1-0.06	0.06-0.01	0.01-0.005	0.005-0.001	<0,001	<10mkm	<1mkm	low dispersion
Askeran	3.71	21.81	18.09	25.92	30.47	69.53	30.47	- // -
Khramor	4.17	22.51	19.33	24.87	31.12	69.88	30.12	- // -

Table 5

Chemical composition of clay raw materials of Nagorno-Karabakh Republic deposits

Deposit	Loss on ignition.	Content of oxides, %							Content of free quartz
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	R_2O	
Askeran	3,18	43,57	7,79	10,02	14,46	2,74	0,36	3,00	16,32
Khramor	3,40	47,65	10,21	9,14	10,42	3,12	0,28	3,10	17,85

Fine filler - river quartz sand of the Stepanakert deposit.

Table 6

Grain composition of quartz sand fractions 0-5 mm
Stepanakert masonry mortar quarry

Sieve size, mm / Residue	2,5	1,25	0,63	0,314	0,14	Passage through a sieve 0,14mm
Partial, %	6,5	13,0	34,3	35,5	8,5	2,2
Full, %	6,5	19,5	53,8	86,3	97,8	-

Size modulus M_s =2,67. The results of the sieve analysis of the sand showed that the content of particles larger than 5 mm in the sand is 5.5%.

According to the standard, the presence of grains larger than 5 mm should not exceed 10% by weight.

Wall stone materials of the Armenia and Nagorno-Karabakh limestone deposit.

Table 7

Basic physical-and-mechanical properties of Nagorno-Karabakh stone quarries

№	Name	Indicators		
		from	to	average value
1	Density, g/cm^3	1.87	2,15	2,01
2	True density, g/cm^3	2,0	2,32	2,16
3	Porosity, %	3,0	25,6	14,3
	Ultimate compression strength, MPa: - dry: - in a water-saturated state: - after freezing	 7,9 5,6 3,9	 19,8 16,3 13,5	 13,9 10,9 8,7
4	Softening coefficient	0,71	0,82	0,77
5	Frost resistance coefficient	0,65	0,74	0,70
6	Water absorption, %	0,9	9,3	5,1

Sample testing processes (Fig. 1, 2, 3, 4)

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Experimental results

Strength characteristics of mortars for masonry

The graph of strength change for cement-clay masonry mortars is shown in Fig. 5, from which the effectiveness of the use of cement-clay mortars is seen in comparison with cement-lime mortars. Thus, with a quantitative ratio of 80% ÷ 20% and 60% ÷ 40%, the strength of the solution using a component of carbonate clays increases on average by 1.4 times.

The effectiveness of cement-clay mortars in comparison to cement-lime mortars can be seen from the graph of strength change for cement-clay masonry mortars in Fig. 5. As a result, using the quantitative ratios of 80% ÷ 20% and 60% ÷ 40%, the strength of the solution containing a carbonate clay component increases by 1.4 times on average.

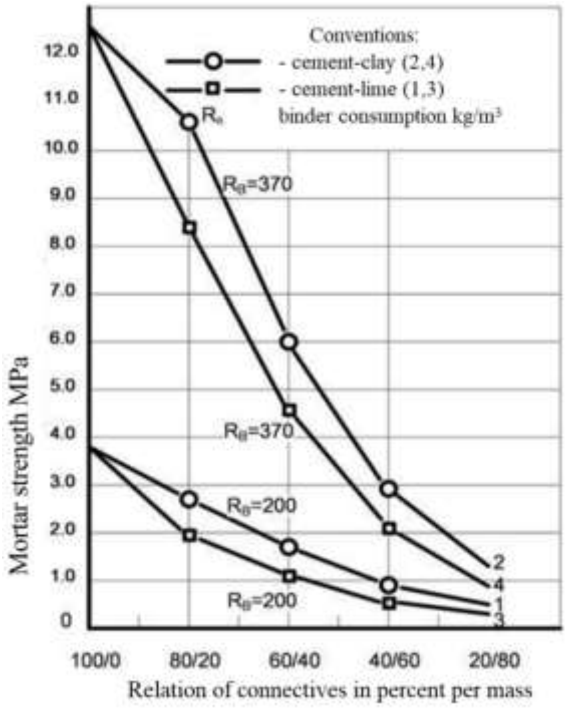

Fig. 5 Mortar strength change for masonry depending on the percentage

Adhesion strength of mortars with sawn limestone

The work of Polyakov S.V., Izmailov Ya.A., Orudzhev F.M. and Polyakov F.M. [8] is a thorough study of properties of masonry from saw limestone of various varieties and the adhesion strength of mortars. According to the research, the following elements have the biggest effects on how well mortar adheres to stone: the mortar's strength, composition, and consistency; the stone's absorption qualities; the condition of the stone's contact surfaces; the masonry's maturation conditions; and the bricklayer's qualifications. All of these elements function simultaneously and are interrelated in the "mortar-stone" system to generate adhesion, and different combinations of them might have different outcomes.

The adhesion strength the masonry was determined by laboratory testing of specimens in pull, R_t (normal bond) or shear, R_{sq} (tangential bond).

Comparison of the results of shear and tear tests showed that, in the general case, the ratio (hereinafter referred to as coefficient K) can vary over a wide range (K = 1, 2 - 4.0). For most limestones, the K value is in the range of 1.5 - 2.5. In many cases, K is practically equal to 2.0 (with minor deviations in one direction or another).

In accordance with the requirements of the current Building Code IV of the Republic of Armenia - 13.01-96 "Stone and reinforced masonry structures" in seismic areas, when constructing load-bearing and self-supporting walls made of natural and artificial stones is carried out to ensure adhesion strength, mortar with stone not lower than the following values:

- for stones of the correct form on mortars of grade 50 and higher (normal adhesion)

$$R_t = 0.17 \text{ MPa;}$$

- for masonry of all types in an unbound section (tangential adhesion)

$$R_{sq} = 0.17 \text{ MPa.}$$

The values of normal adhesion at a coefficient K = 3 are shown in Table 7

Table 7

The values of normal adhesion at a coefficient K = 3

№ compositions according to the Table 5.20.	Plasticizer	Brand of mortar	Ultimate compression strength, MPa	Normal adhesion, MPa
				Sawn limestone
22	-	25	3,0	0,067
23	-	50	5,1	0,120
24	-	75	7,4	0,170
25	-	100	10,3	0,223
26	clay	25	3,6	0,063
27	clay	50	5,0	0,133
28	clay	75	7,6	0,160
29	clay	100	10,5	0,213
38	lime	25	3,2	0,060
39	lime	50	5,6	0,117
40	lime	75	7,5	0,133
41	lime	100	10,6	0,187

- Values of tangential adhesion at coefficient K = 3 are shown in Table 8

Table 8

The values of tangential adhesion at a coefficient K = 3

№ compositions according to the Table 5.20.	Plasticizer	Brand of mortar	Ultimate compression strength, MPa	Tangential adhesion, MPa
				Sawn limestone
22	-	25	3,0	0,20(0,11-038)
23	-	50	5,1	0,36(0,23-0,50)
24	-	75	7,4	0,51(0,40-0,57)
25	-	100	10,3	0,67(0,54-0,71)
26	Clay	25	3,6	0,19(0,13-0,26)
27	Clay	50	5,0	0,40(0,28-0,46)
28	Clay	75	7,6	0,48(0,34-0,52)
29	Clay	100	10,5	0,64(0,53-0,68)
38	Lime	25	3,2	0,18(0,15-0,25)
39	Lime	50	5,6	0,35(0,23-0,42)
40	Lime	75	7,5	0,40(0,32-0,46)
41	Lime	100	10,6	0,56(0,61-0,59)

The measured tangential adhesion values and the manner in which the samples were destroyed attested to the feasibility of giving the investigated mortars made with sawn limestone a suitably high adhesion strength.

The transition from the obtained values of tangential adhesion (R_{sq}) to normal adhesion (R_t) was performed using the coefficient K = 3.

The coefficient K is assigned taking into account the following considerations:

- The samples were made in laboratory conditions, in compliance with all the rules of production work (cleaning, wetting the stone, careful dosage and preparation of the mortar, its consistency, etc.);

The samples were made by the same skilled workers under the supervision of technical staff, etc.

Thus, cement-clay mortars of grades 50 and 75 provide masonry of category II (Building CodeII-7-81 * Table 5), and cement-clay mortars of grade 100 provide masonry of category I, or to ensure seismic resistance of construction from sawn blades limestone, the use of cement-sand mortars, plasticized with carbonate clays, grades 50-75 and 100, which, according to the results of tests for frost resistance, meets the regulatory requirements of earthquake-resistant construction, is justified.

Reliability of results

1. Chemical and granulometric compositions, as well as macroscopic description of clay raw materials were carried out by the State Design and Survey Institute “Gruzgiprovodkhoz”.
2. Experimental work was carried out at the Armenian Research Institute of Seismic Construction and Protection of Structures.
3. The obtained research results are consistent with the research regulations on earthquake-resistant construction.
4. The results of the research have been tested and implemented in the production of restoration work on objects affected by hostilities in the construction complex of Nagorno-Karabakh.

Conclusions

1. An important result of the conducted research is the experimental confirmation of the possibility of using cement-sand mortars plasticized with carbonate clays for laying stone structures made of sawn limestone. At the same time, these mortars' indicators of adhesion to stone not only compare favorably to cement-lime, but also offer stronger adhesion values.
2. The compositions of cement-sand mortars with their plasticization with carbonate clays were developed on the basis of experimental research that revealed the physical and mechanical qualities of the raw materials. It has been demonstrated that using these mortars effectively reduces cement consumption while 1.4 times increasing mortar strength when compared to cement-lime mortars.
3. Studies have shown that up to 40% of the cement in masonry mortars can be replaced with other materials without affecting the mortars' quality indicators (strength, water

resistance, and water absorption). This excludes the costly and in-demand usage of lime in mortars at the moment.

4. It has been established that the strength of tangential and normal adhesion of cement-sand mortars plasticized with carbonate clays exceeds the strength of their adhesion to sawn limestone, in comparison with cement-lime mortars, by almost 1.2 times. The use of cement-sand mortars, plasticized carbonate clays of the M50 and M75 grades, as well as the M100 grade, provides masonry of the first and second categories in terms of seismic resistance.
5. The norms for the consumption of materials for masonry mortars of grades M25, M50, M75, and M100 were developed and approved on the basis of a generalized analysis of the research results. Recommendations to reduce the consumption of cement and lime in masonry mortars for use in organizations of the Artsakhstroy trust (including in restoration work) were also made.

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Շուշիի տեխնոլոգիական համալսարան

Փորձարարական ուսումնասիրություններն ապացուցել են սեյսմակայուն շինարարության մեջ կարբոնատային կավերով պլաստիկացված ցեմենտավազային շաղախների օգտագործման հնարավորությունը: Առաջին անգամ որոշվել են այս շաղախների բաղադրությունը և ֆիզիկամեխանիկական հատկությունները, ինչը հնարավորություն է տվել նվազեցնել ցեմենտի սպառումը մինչև 40%, ինչպես նաև 100%-ով բացառել թանկարժեք կրի օգտագործումը՝ դրա ամրության ցուցանիշները բարձրացնելու դեպքում: Առաջարկություններ են մշակվել կարբոնատային կավով պլաստիկացված ցեմենտավազային շաղախների օգտագործման վերաբերյալ՝ տեղական սղոցված կրաքարերից սեյսմակայուն շինարարություն իրականացնելու համար: Փորձերի արդյունքները փորձարկվել և ներդրվել են Լեռնային Ղարաբաղի շինարարական համալիրում: Հետազոտության արդյունքները համաձայնեցվում են քարակառույցի համար նախատեսված ցեմենտ-կավե շաղախների վերաբերյալ գիտահետազոտական և նորմատիվ փաստաթղթերի հետ:

Բանալի բառեր. քարե շարվածք, սղոցված կրաքարեր, քարե շարվածքների շաղախներ, ցեմենտ, կարբոնատային կավեր, ամրության բնութագրեր, սեյսմակայունություն:

О СВОЙСТВАХ ЦЕМЕНТНО-ПЕСЧАНЫХ РАСТВОРОВ, ПЛАСТИФИЦИРОВАННЫХ КАРБОНАТНЫМИ ГЛИНАМИ

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Экспериментальными исследованиями доказана возможность использования в сейсмостойком строительстве цементно-песчаных растворов, пластифицированных карбонатными глинами. Впервые определены составы и физико-механические свойства этих растворов, позволяющие сократить до 40% расход цемента, а также исключить на 100% использование дорогостоящей извести, при повышении его показателей прочности. Разработаны рекомендации по использованию цементно-песчаных растворов, пластифицированных карбонатными глинами для выполнения сейсмостойкого строительства из местных пильных известняков. Результаты экспериментов были апробированы и внедрены в строительном комплексе Нагорного Карабаха. Результаты исследований согласуются с научно-исследовательскими и нормативными документами по цементно-глиняным растворам для каменных кладок.

Ключевые слова: каменная кладка, пильные известняки, кладочные растворы, цемент, карбонатные глины, прочностные характеристики, сейсмостойкость.

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