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STUDY OF THE PARAMETERS OF SPRAED CONCRETE WORKS IN THE RESTORATION AND STRENGTHENING OF INFRASTRUCTURE FACILITIES

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The substantiation of the parameters of shotcrete works in the construction and strengthening of infrastructure facilities for various purposes is presented. A study of the properties of raw materials and shotcrete-concrete mixtures based on cement, mineral fillers and additives was carried out in accordance with the current regulatory documents of Ukraine. A number of studies of multicomponent building compositions in terms of their rheological and physical-mechanical properties of the finished coating have been carried out. The most rational dosage of components that have an impact on the properties of the working mixture and the finished building coating is presented. The main parameters of the technology of shotcrete works using building mixtures based on cement, mineral fillers and additives have been determined.

Keywords: shotcrete, dry building mix, adhesion strength, compressive strength.

Entry. Today, there are a large number of buildings and structures in our country that require repair, strengthening, and, possibly, reconstruction. These are mainly infrastructure facilities for various purposes (bridge structures, infrastructure facilities of factories, mining enterprises, civilian buildings, buildings of public institutions, educational and medical institutions, etc.). This situation is due to the fact that for a long period of time in Ukraine there has been no activity in direction of construction of new infrastructure facilities. What is currently in operation are buildings and structures from Soviet times. Construction during the Soviet Union is distinguished by large areas and was most often aimed not at quality, but at quantity.

In modern Ukraine, there is a completely different trend – the state and business representatives are interested in obtaining high-quality, efficient, durable buildings and structures at the lowest possible cost of any resources, and this is a completely rational approach to the implementation of such projects. As for the infrastructure facilities that already exist, certain works must also be carried out that can improve their quality, comfort and sustainability. As a result of such works, old infrastructure facilities are able to maintain the economy of Ukraine and the well-being of the population at a decent level for a long time.

The main defects of such buildings and structures are damage to concrete and reinforced concrete surfaces, which is the result of the combined action of mechanical and temperature factors in combination with chemical aggression. The most characteristic of them are peeling of the concrete surface, the appearance of cracks of different depths of their opening, and, as a result, corrosion of reinforcement. These damages require appropriate repairs using materials and technologies that ensure the efficiency of repairs, reduction of overhaul periods, saving materials, labor and energy resources. The process of adhesion of new and old concrete depends on many factors, the age of the concrete; the

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nature of the surface treatment of old concrete; the composition of new concrete; method of embedding and conditions for gaining strength of new concrete or other materials [1].

Such defects can be eliminated by using the method of repair and strengthening of infrastructure facilities for various purposes – the shotcrete method, which has been popular since the 50s of the last century. The use of shotcrete is one of the most effective and reliable ways to apply protective coatings to concrete surfaces that are exposed to aggressive environments and low temperatures, to correct defects in concrete, strengthen concrete and reinforced concrete structures, etc. By adjusting the water supply, it is possible to obtain such a degree of mobility of the plastic layer that the aggregate grains with a certain supply of kinetic energy overcome the resistance forces and can penetrate into this layer to a certain depth,sufficient for their strong adhesion and the formation of a dense monolith. As the results of the research show, the optimal value of the relative depth of penetration is in the range of 0.5-1.0 cm. Shotcrete is an effective method of reinforcing reinforced concrete structures, which is ensured by its high density, strength and adhesion to the base. However, for its use in this industry, it is necessary to take into account a number of factors: the selection of the composition and components of the mixture, the use of application techniques and technologies, etc. [2].

In the case of buildings and structures that are intended for permanent or temporary stay of people, a significant deterioration of the situation is associated with significant physical wear of the main structural elements, as a result of which heat consumption through external walls is about 30%, basement and attic floors – 10%, window and door openings – up to 30%, ventilation systems – 30%. According to statistics, the existing housing stock of Ukraine consists of houses of different construction periods: 4.2% are houses built before 1975; 57.7% – 1946-1970; 26.3% – 1971-1990, the heat transfer resistance of the enclosing structures of which is 2... 4 times lower than the indicators regulated by DBN B.2.6-31:2006 "Construction of buildings and structures. Thermal insulation of buildings".

Thermal insulation reduces the risk of damage to the structural elements of the house. By increasing the temperature of the internal surfaces and structural elements of the house, it is possible to minimize the problems caused by the condensation of water vapor and the increase in humidity of structural elements. Energy saving prolongs the life of buildings, and this is an indisputable fact [3].

Statement of the main material. Shotcrete concrete as a method of concreting is a concrete mixture that is supplied to the place of work through closed pipelines that can withstand increased pressure, and applied by spraying. In construction, hoses are mainly used to transport the mixture. To ensure good adhesion of shotcrete to the surfaces on which the mixture is applied, their pre-treatment is required. The process of adhesion of new and old concrete depends on many factors: the age of the concrete; the nature of the surface treatment of old concrete; the composition of new concrete; method of laying and conditions of hardening of new concrete, etc. [4, 5, 6].

In the course of the research, a dry building mixture of the "Bifastening" type was used. This material is very actively used by mining enterprises in the construction of combined fasteners. The peculiarity of this building composition is that the shotcrete-concrete shell has the properties of forming a load-bearing structure as early as 3 days after its construction. In the case of the needs of the mining and metallurgical complex, this is a very important point.When performing a set of studies, including laboratory ones, it was taken into account that all mortars for shotcrete work must meet the requirements of DSTU B.V.2.7-239:2010. Building mortars. Test methods. Table 1 shows the composition of the building mixture of the "Bifastening" type.

Table 1

Approximate composition of shotcrete-concrete mixture based on cement and mineral fillers

Calculation for 1 m^3		Calculationfor 1 t:	
Cement M 500	571.5 kg	Cement M 500	482.3 kg
Hussarovsky sand	254.5 kg	Hussarovsky sand	214.8 kg
Fly ash	358.3 kg	Fly ash	302.4 kg
Liquid Glass	34,3… 40 kg	Liquid Glass	28,9… 33.8 kg
Water	250.8 l	Water	210 l
W/T = 0.21; W/C = 0.44		W/H = 0.21; W/C = 0.44	
Note. Fly ash – 30% by weight of solid matter			

The volumetric weight of the dry mixture of the "Bifastening" type is 2100... 2300 kg/m3. At the same time, the higher the ash content, the lower the value of the bulk density of the dry mixture, i.e. 2100 kg/m3 for the 70/30 mixture and 2300 kg/m3 for the 80/20 mixture. For the mixture Bi-fastening = 100%, the value of the bulk density in the dry state is 2400 kg/m^3. Table 2 shows the physical and mechanical characteristics of samples of shotcrete-concrete mixtures of the "Bifastening" type with the addition of fly ash from Kurakhovskaya TPP in the amount of 30... 70%.

Table 2

Physical and Mechanical Characteristics of Shotcrete-Concrete Mix Samples (Bifastening/Fly Ash)

№ Salary	Component Ratio	Compressive strength, MPa				Wet density at Water/Hard = 0.2, kg/m^3
		7 day	14 day	21 day	28 day	
1	Bi-fastening :Ash = 50 : 50	12,0	13,2	14,5	15,4	1924
2	Bi-fastening :Ash = 60 : 40	13,9	16,4	17,3	18,5	1940
3	Bi-fastening :Ash = 70 : 30	15,8	20,7	21,2	23,0	2140
4	Bi-fastening :Ash = 40 : 60	5,0	8,9	11,8	12,0	1895
5	Bi-fastening :Ash = 30 : 70	–	5,2	6,7	7,7	1840

In this case, the introduction of fly ash from Kurakhivska TPP into the main composition is not effective in terms of improving the qualities of the mixture, which is already actively used. However, this is necessary from the point of view of improving the environmental situation in such regions, so the introduction of fly ash into the existing composition is possible in an amount of no more than 20... 30% by weight of cement. Also, instead of liquid glass, calcium chloride can be added to these two options in the amount of 2... 5% by weight of cement, which in some cases is more appropriate. Based on the data obtained, the composition of shotcrete-concrete mixtures based on cement and mineral fillers for the two options was calculated, which is shown in Table 3.

Table 3

Composition of shotcrete-concrete mixtures based on cement and mineral fillers

Option 1 (BFA+)		
For 20% fly ash: Cement quartz sand Lime-fluff Fly ash W/T = 0.62 according to the patent	 405 kg 428 kg 141 kg 194.8 kg	 34,6% 36,7% 12,0% 16,7%
Liquid Glass Additive 6... 7% by weight of cement 24.3... 28.4 kg		
Option 2 (BFA+)		
For 30% fly ash: Cement quartz sand Lime-fluff Fly ash W/T = 0.62 according to the patent	 405 kg 428 kg 141 kg 292.2 kg	 32,0% 33,8% 11,1% 23,1%
Liquid Glass Additive 6... 7% by weight of cement 24.3... 28.4 kg		

Also, in the course of the research, options for adding waste rock from the mines of the Donetsk region to the basic building mixture will be considered. These were mainly mudstones, siltstones and sandstones (in small quantities). Such rocks are predominantly clayey, not resistant to water, and when in contact with water, they tend to crumble into separate plates and swell. However, in some cases, this ability of rocks has a stabilizing effect on the resulting solution [7].

Figure 1 shows the technological process of applying shotcrete pavement, which vividly illustrates the need for the mortar for shotcrete works to be homogeneous in consistency, resistant to

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delamination, and the introduction of a clay component is expedient and in no case has a negative impact on both the quality of the material itself and the features of the technological process for the installation of such coatings. The compressive strength of cube specimens with the addition of mine rocks is shown in Table 4.

Table 4

Compressive strength of cube specimens with the addition of mine rocks

Component Ratio	Compressive strength, MPa					
	1 day	day 3	day 7	day 14	21 days	day 28
1. Biclination :Rock = 1 : 3	-	0,2	1,1	2,6	3,4	3,7
2. Biclination : Rock = 1 : 2	-	5,0	6,0	6,8	7,4	8,7
3. Bitrimony :Rock = 1 : 1	-	3,9	9,8	10,2	10,5	11,7
4. (BFA+) :Rock = 1 : 1	3,7	8,2	11,9	12,1	13,2	13,7
5. (BFA+) :Rock = 1 : 2	-	4,8	5,1	5,2	5,5	6,3
6. (BFA+) :Rock = 1 : 3	-	0,24	0,26	0,27	2,1	2,3
7. Cement :Sand : Rock = 1 : 1 : 2	11,8	21,4	22,0	23,8	25,1	25,4

(a) (b)

Fig. 1. Technological process of applying shotcrete concrete coating: (a) application of shotcrete-concrete mixture using shotcrete equipment; (b)leveling the coverage using a rule.

At the last stage of laboratory research, a number of experimental works were carried out to determine the possibility of using mine rocks from the Svyato-Varvarynska CPP in combination with a predetermined type mixture (BFA+). The results of the studies are presented in Table 5.

Table 5

Compressive strength of cube samples with the addition of coal beneficiation wastes

Component Ratio	Compressive strength, MPa				
	day 3	day 7	day 14	21 days	day 28
1. Bi-fastening : Rock = 1 : 1.5	4,1	9,9	10,1	10,6	10,8
2. (BFA+) :Rock = 1 : 1.5	3,6	8,8	9,5	10,2	11,2
3. Bi-fastening : Rock = 1 : 1	12,6	12,9	13,0	14,5	14,9
4. (BFA+) :Rock = 1 : 1	11,2	12,3	12,6	12,9	13,2
5. Cement :Sand = 1 : 8 (plugging)	0,14	0,15	0,16	0,23	0,24
6. Bi-fastening : Rock = 1 : 2	5,1	6,0	6,6	6,8	7,0
7. (BFA+) :Rock = 1 : 2	4,8	5,2	5,4	5,6	5,8
8. Cement : Rock = 1 : 8	0,06	0,08	0,09	0,12	0,15

From the table below, it can be seen that the most rational ratio of components is Bi-fastening : Rock (CPF) = 1 : 1 with a strength index of 14.9 MPa. A study of the possibility of using fly ash from thermal power plants, mine rocks and coal enrichment waste rocks was carried out in order to process multi-tonnage waste from Ukrainian industry into a useful and effective product. The given

formulations of shotcrete-concrete mixtures can be used in any combination and with minor differences in raw materials or when clarifying the data. These materials are currently effectively used in the construction of combined fasteners of coal mines, bridges, and surface infrastructure facilities both independently and in combination with various polymeric materials [8].

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Conclusions. The issue of repair, restoration and strengthening of infrastructure facilities is currently very relevant not only in connection with the material depreciation of existing industrial and civilian facilities, but also in connection with military operations on the territory of Ukraine. Of course, there are objects that have been completely destroyed, but also those that can be reconstructed or repaired, and this will be more profitable than the construction of a new one. On the other hand, there is a need for rational use of waste. In particular, the mining industry and the fuel and energy complex, which can be rationally used in construction. There are striking examples when the result of restoring the old one is better than the design and construction of a new object.

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DOSLIDZHENNIA PARAMETRIV VYKONANNIA TORKRET-BETONNYKH ROBIT PRY ZVEDENNI TA UKRIPLENNI INFRASTRUKTURNYKH OBIEKTIV

Подано обгрунтування параметрів проведення торкрет-бетонних робіт при відновленні, ремонті та укріпленні інфраструктурних об’єктів різного призначення. Виконано дослідження властивостей сировини та торкрет-бетонних сумішей на основі цементу, мінеральних наповнювачів та добавок згідно з діючими нормативними документами

України. Проведено ряд досліджень багатокомпонентних будівельних композицій з точки зору їх реологічних та фізико-механічних властивостей готового покриття. Визначено співвідношення сировинних компонентів та добавок-прискорювачів тужавлення. Рекомендовано до використання два види добавок прискорювачів тужавлення. Надані рекомендації щодо кількості кожного з рекомендованих видів прискорювачів тужавлення відносно маси цементу. Досліджено можливість використання золи-виносу Кураховської ТЕС як компонента сухих будівельних сумішей для торкрет-бетонних робіт. Визначено найбільш раціональну кількість золи-виносу Кураховської ТЕС та визначено зміни насипної маси та густини матеріалу у зачиненому стані для всіх варіантів. На основі отриманого співвідношення досліджено можливість введення в торкрет-бетонну суміш слабких шахтних порід та відходів збагачення кам'яного вугілля у якості крупного заповнювача. Подано найбільш раціональне дозування компонентів, які мають вплив на властивості робочої суміші та готового будівельного покриття. Визначено основні показники міцності торкрет-бетонних сумішей з використанням шахтних порід та відходів збагачення кам'яного вугілля. Наведено рекомендації щодо раціонального використання поданого діапазону сировинних компонентів та інформацію щодо можливих відмінностей їх якості. Доведено доцільність раціональної переробки багатотоннажних відходів гірничої та енергетичної галузі промисловості як різноманітної та дешевої сировинної бази для будівництва. Визначено основні параметри технології виконання торкрет-бетонних робіт з використанням будівельних сумішей на основі цементу, мінеральних наповнювачів та добавок, а також можливої їх комбінації з подібними полімерними матеріалами.

Ключові слова: торкрет-бетон, суха будівельна суміш, міцність адгезії, міцність на стиск.

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STUDY OF THE PERFORMANCE PARAMETERS OF SPRAYED CONCRETE WORKS IN THE RESTORATION AND STRENGTHENING OF INFRASTRUCTURE FACILITIES

The substantiation of the parameters of sprayed concrete works during the restoration, repair and strengthening of infrastructure facilities of various purposes is presented. A study of the properties of raw materials and dry building mixtures based on cement, mineral fillers and additives 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 physical and mechanical properties of the finished coating have been conducted. The ratio of raw components and curing accelerator additives was determined. Two types of curing accelerator additives are recommended for use. Recommendations are given for the amount of each of the recommended types of curing accelerators relative to the mass of cement. The possibility of using the fly ash as a component of dry mortars for shotcrete works has been investigated. The most rational amount of fly ash was determined, and changes in the bulk mass and density of the material in the wet state were determined for all options. Based on the obtained ratio, the possibility of introducing weak mine rocks and coal beneficiation waste into the sprayed concrete mixture as large aggregate was investigated. The most rational dosage of components that have an impact on the properties of the working mixture and the finished construction coating is presented. The main indicators of the strength of sprayed concrete mixtures using mine rocks and coal beneficiation waste have been determined. Recommendations for the rational use of the given range of raw materials and information on possible differences in their quality are given. The feasibility of rational processing of multi-tonnage waste from the mining and energy industries as a diverse and cheap raw material base for construction has been proven. The main parameters of the technology for the execution of sprayed concrete works using construction mixtures based on cement, mineral fillers and additives and their possible combination with similar polymer materials have been determined.

Keywords: sprayed concrete, dry building mixture, adhesion strength, compressive strength.

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Гаркуша В.С., Гапєєв С.М., Симонов С.І., Гудзь С.А., Годун Т.М. **Дослідження параметрів виконання торкрет-бетонних робіт при відновленні та укріпленні інфраструктурних об'єктів** // Опір матеріалів і теорія споруд: наук.-тех. збірн.–К.:КНУБА, 2025.– Вип. 115.– С. 271-277.
Подано обґрунтування параметрів проведення торкрет-бетонних робіт при зведенні та укріпленні інфраструктурних об'єктів різного призначення. Виконано дослідження властивостей сировини та сухих будівельних сумішей на основі цементу, мінеральних наповнювачів та добавок згідно з діючими нормативними документами України. Проведено ряд досліджень багатокомпонентних будівельних композицій з точки зору їх реологічних та фізико-механічних властивостей готового покриття. Подано найбільш раціональне дозування компонентів, які мають вплив на властивості робочої суміші та готового будівельного покриття. Визначено основні параметри технології виконання торкрет-бетонних робіт з використанням будівельних сумішей на основі цементу, мінеральних наповнювачів та добавок.
Табл. 5. Іл. 1. Бібліогр. 9 назв.

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Tabl. 5. Fig. 1. Ref. 9.

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