УДК 666.972.16

INVESTIGATION OF THE OPERATING PROPERTIES OF CEMENT-CONCRETE PRODUCTS MODIFIED BY COMPLEX ADDITIVE

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Abstract. The article is devoted to the problem of improving the performance and technical characteristics of the road surface and increasing its durability and durability. Changing the conditions of roads in recent decades has led to the need to improve the durability of the layers of cement-concrete pavements. Expanding construction of rigid pavements will allow to effectively solve the problem of a significant increase operability and durability of roads, and it is necessary to develop a cement concrete with improved technological and operational properties, which include, in particular, with complex cement-concrete additives.

In the course of the experiment, cement concrete was obtained from concrete slurry mixes (cone draft of 2-3 cm) and high mobility (cone sediment 16-18 cm) of different compositions with or without a modifier additive. The issues of development of warehouses of concrete mixes and cement concrete modified by a complex additive of polycarboxylate type and investigation of their technological and operational properties are considered. It is shown that the use of a modified complex additive can reduce up to 20% water for mixing, obtain a mixture of high viability, which reduces the cost of inserting and sealing the concrete mixture. The investigated concrete mixtures are characterized by high sensitivity of rheological properties to changes in water content.

The results of studies of the impact modifier additives on physical and mechanical properties of cement-concrete curing different dates, show that developed modified cement-concrete with high early strength (3 days) and branded strength (28 days). Economical concretes of the class B30-B35 with increased durability were created. The resulting road concrete is characterized by improved technological properties (bundle, density, water absorption) of concrete mix and operating parameters (strength, water resistance, frost resistance, abrasion) of cement concrete.

Keywords: concrete mixture, cement concrete, complex additive, strength, road surface.

Introduction. Changes in road maintenance conditions during the last decades (increased load on the vehicle axle and traffic intensity) necessitated the increase of the durability of the layers of the pavement from cement concrete. As the domestic and world experience shows, the hard road type meets the new requirements of the movement [1]. The actual problem of the development of highways is to improve the operational and technical characteristics of the road surface and improve its strength and durability. Modern technologies of concrete allow to change properties of concrete mixes and the most concrete in wide limits. The actual problem of the development of highways is to improve the operational and technical characteristics of the road surface and increase its strength and durability. Modern technologies of concrete allow to change properties of concrete mixes and the most concrete in wide limits.

At the present time, society of Ukraine understands the feasibility and necessity of building roads

with a hard coating, considering the benefits and best practices. Expansion of the construction of hard road pavement layers will effectively solve the problem of increasing the efficiency and durability of roads, and for this it is necessary to develop cement concretes with improved technological and operational properties, which include, in particular, cement concrete with complex additives.

The analysis of research and publication materials [2-5] indicates that it is possible to significantly improve the durability and quality of concrete for pavements by introducing chemical additives that improve the properties and structure of cement concrete. In the world practice the share of concretes with the content of additives is growing and amounts to about 90% of concrete. Modern concrete, thanks to new chemical additives, is becoming an increasingly complex composite material with improved properties.

Analysis of the construction and operation of road pavement from cement concrete in Ukraine and other countries of the world has shown that the most promising material for road construction is modified cement concrete [6, 7]. Problems in the theory and practice of the use of concrete in construction of roads, modified concrete, concrete study of the structure, the use of mathematical models to analyze the impact of factors on the physical and mechanical performance and engaged in a number of scientists such as Batrakov V.G., Hamelyak I.P., Dvorkin L.Y., Sainitsky M. A., Solodky S.Y., Solonenko I.P., Tolmachov S.M. and many others. Based on the results of their work, the possibilities for improving the quality of the road surface from cement concrete by its modification (the introduction of complex additives based on superplasticizer and micro filler) have been analyzed.

At the present stage of road construction, thanks to the comprehensive use of modifiers of a new generation on a polycarboxylate basis, the evolution of concrete from conventional to highly functional modified has become possible. Such concrete is considered as a composite material with specified parameters, which are necessary for conducting monolithic concreting and providing increased strength and durability of concrete structures. The huge potential of modification of concrete mixes creates rational approaches for the development of monolithic concretes with new characteristics. The use of modifiers ensures the effectiveness of the concrete mix and concrete decking in the shortest possible time, with sufficient quality of the latter, the production of road clothes with increased durability.

The technology of using of concretes with effective modifiers of structure and properties improves their functional characteristics and allows obtaining new compositions of special concretes. Manufacture of concrete at this stage also involves improving their rheological properties due to the use of complex effective modifiers that can provide high strength and durability.

The purpose and objectives. Development of compositions of concrete mixtures and cement concrete modified with a complex addition of polycarboxylate type and investigation of their technological and operational properties.

Materials and methods of research. During the researches, the influence of the modified complex additive polycarboxylate type (superplasticizer MC-PowerFlow3100 and aerant) on the technological properties of the concrete mixture and the operational properties of cement concrete was studied.

Experimental studies of cement concrete were carried out using portland cement PC II / A-Sh 400, fine aggregate (sand with Mkr = 1.48) and coarse aggregate of various fractions (granite crushed stone with a fraction of 5-10 mm and 10-20 mm). Determination of rheological properties (workability, delamination), physical (density, amount of entrained air), physical-mechanical and special (waterproofness, frost resistance, abrasion) of the properties of the concrete mixtures and concrete studied were carried out according to standard methods according to the current standards.

The results of research. The task of this work was to obtain concrete mixtures with high initial mobility indices (not less than P4) and long-term storage of this mobility in time, so that they could be transported over considerable distances and with various temperature fluctuations. In addition, such concrete mixes should have high strength values, both on the first day of hardening, and the vintage strength. The mobility of the concrete mixture (workability), to a large extent, depends on its water-cement ratio, which, in turn, affects the amount of water and additives. This indicator is determined when the concrete mixture is delivered to the site to its investment in the structure (control of the hoisting behavior). The properties of the concrete mixture are formed under the influence of a number

of technological factors: the water content of the mixture, the properties and costs of the binder, the physico-mechanical parameters of the aggregates, the parameters of the composition of the mixture, and the like. The complexity of technological problems associated with the manufacture of a concrete mixture with specified rheological properties is further aggravated by the fact that the solution of these problems is due to the main result – the achievement of the required strength and other physico-mechanical properties of solidified concrete. Therefore, the management of the properties of the concrete mix, the regulation of its parameters are carried out under certain restrictions [8].

When carrying out the experiment, the influence of a complex additive from the superplasticizer MS-PowerFlow3100 in the amount of 0.2-1.0% and air intaking additives – aeration 0.1% of the mass of cement on the rheological properties of the concrete mixture were studied. The results of the experimental studies carried out are presented in Table. 1

Table 1 – Influence of a complex additive MS-PowerFlow3100 and an aeration on the rheological properties of a concrete mixture

№	The composition of the concrete mix, kg/m^3				Water, l	Additive,% mass of cement	W/C	Cone slump, cm, every…, min			
	Cement	Sand	Scree					0	20	40	60
			fr. 5-10 mm	fr. 10-20 mm							
1	400	698	408	743	236	-	0,59	16	13	5	2
2	400	705	412	750	199,5	0,2	0,50	16	16	9	4
3	400	719	420	765	190,5	0,4	0,48	16	13	10	6
4	400	725	425	773	176	0,6	0,44	16	15	12	10
5	400	730	430	780	161	0,8	0,40	16	15	13	12
6	400	730	430	780	159	1,0	0,39	16	16	12	11

The control (reference) concrete mixture was prepared only with water without using an additive (composition No. 1). The corresponding water was mixed with the complex additive and introduced into the mixture. For each batch, the initial mobility was determined. Then the concrete mixture was aged for 20; 40 and 60 minutes in laboratory conditions, and then the grinding of each composition of the concrete mixture was determined in time. Determination of the rheological properties of the concrete mixture was carried out with a portland cement consumption of 400 kg/m^3 of concrete.

The properties of the concrete mix after its preparation are changed in connection with modifying cementitious structure during the hydration process and structure. The concrete mix gradually thickens with time. As can be seen from the data in Table 1, in the control concrete mix, the cone sediment decreases from 16 cm (initial) to 13 cm after 20 minutes and up to 2-5 cm – after 40-60 minutes. endurance. For the concrete mix with the addition of a superplasticizer in an amount of 0.2% (composition No. 2), the initial mobility was 16 cm and did not change after 20 minutes, and after 40 minutes – decreases to 9 cm. The increase in the amount of the additive to 0.4% (composition No. 3) allows to maintain a sufficiently high mobility of the concrete mixture for 20 and 40 minutes (Table 1) and (Figure 1).

With further increase of the amount of additive in the composition of concrete mix (0.6-1.0%) is stored the cone slump. Characteristic of the resulting concrete mix (composition №2-6) mobility is a long-term storage, whereas the reference blend (composition №1) gradually loses it.

Modified complex additive can be attributed to water-reducing (Water-retaining) additives of the first class, which provides water separation of the concrete mix no more than 2%. It should be noted the high workability of the concrete mix in time, after holding for 60 minutes. In this case, the cone slump of concrete mix with a complex additive is from 4 to 12 cm (Fig. 1). Additive used, due to the effect of surface adsorption and spatial separation of particles acts as a very strong plasticizer. Thus, 0.2% of the additive (Table 1) reduces the amount of water by 15.5%, and 0.4% -0.8% of the additive – by 19.3-31.7%. It has been established that the introduction of polycarboxylates to high-mobility modified cement systems ensures optimal formation of the cement stone structure, which

is confirmed by studies of the effect of changes in the water content, phase composition and microstructure of the cement stone [9].

Thus, the use of a complex additive of modifying action based on the superplasticizer MC-PowerFlow3100 and Aerant makes it possible to reduce up to 32% of the mixing water in carrying out these experiments and studies, to obtain mixtures of high viability, which reduces the cost of laying and compacting the concrete mixture. The investigated concrete mix (Fig. 1) are characterized by high sensitivity of rheological properties to changes in water content.

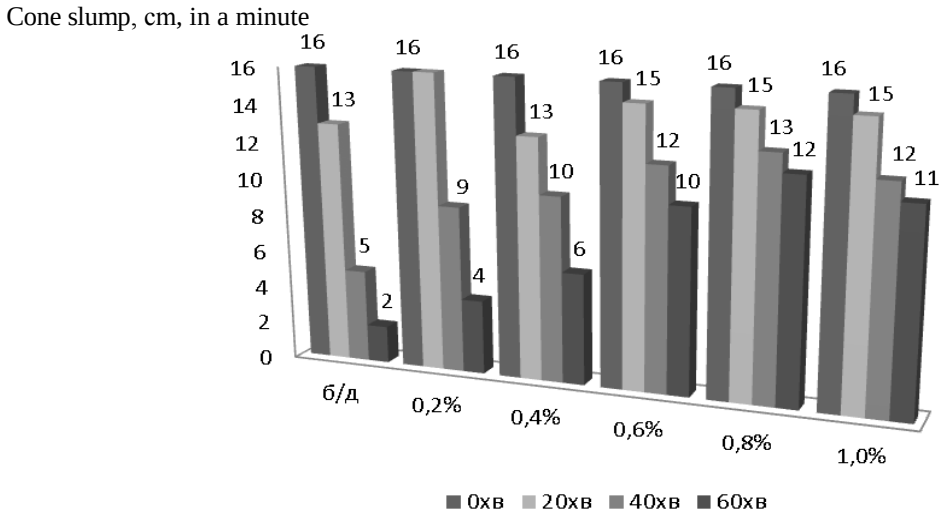

Fig. 1. Influence of the complex additive on the mobility of the concrete mixture

It is not advisable to increase the consumption of superplasticizer to 1.0%, since there is no significant decrease in water and during transportation, the mobility of the concrete mix may be lost and its dehydration may be observed. It should be noted that the concrete mixes with mobility P2-P5 for road concretes can be compacted by means of small-scale mechanization (screed or deep vibrator), and with the lightweight index P1 – by the method of sliding formwork using a concrete paver.

The results of studies of the effect of additive modifier on the physical and mechanical properties of cement concrete at various times of hardening, with the aim of obtaining high-strength concrete for road surfaces, are given in Table. 2.

Table 2 – Durability of cement concrete with a modifying complex additive (consumption of cement – 400 kg/m^3)

№	Complex additive,% of the mass of cement		W/C	Compressive strength, MPa, in days		
	MC-Power Flow3100	Aheranth		3	7	28
Cone slump of concrete mix (CS=2-4 cm)						
1	-	-	0,41	15,1	20,4	42,4
2	0,4	0,1	0,39	19,8	32,8	46,0
3	0,6	0,1	0,38	20,4	33,0	48,2
4	0,8	0,1	0,37	22,0	34,5	49,5
5	1,0	0,1	0,32	22,7	33,9	50,0
Cone slump of concrete mix (CS=16-18 cm)						
6	-	-	0,59	10,3	23,7	30,8
7	0,4	0,1	0,48	16,5	28,9	37,4
8	0,6	0,1	0,44	18,9	31,0	38,6
9	0,8	0,1	0,40	22,7	33,0	45,8
10	1,0	0,1	0,39	17,4	31,3	40,3

With the use of Portland cement PC II / A-W 400 with additives of polycarboxylates, in addition to reducing the water-cement ratio with the same mobility of concrete mix, an increase in the early strength of concrete is also achieved. It has been established that the polyfunctional character of the modifiers adds to obtaining concrete of the class B25-B35. This strength is sufficient for the manufacture of road structures, including for the top layer of the coating. In inactive concrete mixtures, the effectiveness of the superplasticizer decreases, since the amount of water is insufficient to ensure their action. Therefore, concurrently studied and concrete mixtures, which according to the draft of the cone are highly mobile (CS = 16-18cm).

During the experiment, cement concrete was prepared from concrete mixes of various compositions with or without addition of a modifier (Table 2.). The test shows that strength indicators increase both at the initial time of hardening (3 days, and after 7 and 28 days). The amount of water in low-mobility concrete mixes decreases and W/C decreases from 0.54 to 0.38 (by 29.7%), and in high-mobility mixtures it decreases from 0.41 to 0.32 (by 22%). This significantly increases the strength of concrete-grade modified complex additive. At the age of 28 days it reaches 49.5-50.0 MPa (CS = 2-3 cm), which corresponds to the class of concrete B35 and 40.3 to 45.8 MPa with CS = 16-18 cm (concrete class B30).

The quality of road concrete is determined by its composition, methods of concluding and subsequent care, high demands are imposed not only on strength, but also on frost resistance, water resistance, resistance to aggressive action of various media, abrasion, crack resistance and durability. These requirements for concrete can be met through the introduction of additives in cement concrete. The properties of concrete mixtures and the operational parameters of cement concrete, both with a complex additive modifier and without additives at a cement consumption of 400 kg/m^3, are presented in Table. 3.

Table 3 – Technological properties of concrete mixtures and performance indicators of cement concrete with additives (cement consumption – 400 kg/m^3, cone slump – 4 cm)

Indicators	Without additives	Modifying complex additive
Concrete mixture		
Splitting, %	1,0	0
The average density, kg/m^3	2413	2488
Water absorption, in % of weight	2,8	2,2
Amount of intake air, %	2,4	4,8
Cement concrete		
Compressive strength for the 28th day, MPa	42,4 (B30)	49,5 (B35)
Tensile strength in bending, MPa	4,0	5,1
Water resistance, mm	50	38
Frost resistance	F200	F350
Wearing capacity, g/cm^2	0,71	0,33

The delamination may occur during the laying and compacting of the concrete mixture. The tendency to delamination increases with an increase in water flow and water-cement ratio. Tests have shown (Table. 3), which in concrete mixtures containing a superplasticizer in an amount of 0.8% and 0.1% additive povitrezahoplyuyuchu, no bundle of the concrete mix. The density index of a concrete mixture characterizes the frost resistance of cement concrete; its increase leads to an increase in the frost resistance of concrete. The data of Table 3 indicate that the developed composition of a concrete mixture with a complex additive is characterized by a high average density of 2488 kg/m^3 in comparison with the reference composition (average density 2413 kg/m^3).

Introduced air-entraining additive creates and stabilizes during the mixing of concrete a significant number of very small bubbles that play the role of dampers in the development of stress, are in the case of freezing water. The amount of air entrained concrete of the test composition was 4.8%

(Table. 3), which is two times more than concrete without additives. A similar picture is observed in the determination of water absorption. Cement-concrete without additives is characterized by a large water absorption by mass (2.8%) than with a modified complex additive (2.2%).

It was experimentally established that the introduction of a modified additive increases the compressive strength of concrete by 16.7% and the concrete class from B30 to B35. The main indicator of the mechanical properties of road concrete is the tensile strength at bending. A significant effect of increasing the strength of concrete on bending is achieved with the use of polycarboxylate additives. Test results show that this figure for concrete with a complex additive modifier is above concrete without additives and 21.6% is 5.1 MPa.

One of the important operational indicators of road cement concrete is wear resistance, which is affected by the structure and composition of the upper layer of the coating. In this connection, the process of erasing cement concrete samples after the frost resistance test was investigated. It is established (Table 3) that the introduction of a complex additive modifier reduces by 42.8% the abrasion of concrete (from 0.71 g/cm^2 to 0.33 g/cm^2) as a result of a reduction in W/C and the creation of a fine-porous dense structure of cement stone.

The value of the permeability of concrete was evaluated by the depth of penetration of water under pressure (standard EN 12390-8). It depends on the volume and distribution of macropores in the concrete. According to Table 3, the penetration depth of the water in the test cement without additives is 50 mm, and when it is used – 38 mm. Thus, the developed composition of road cement concrete can be considered waterproof.

Conclusions. The use of a complex additive based on a superplasticizer and aeration modifier can reduce up to 32% of the mixing water, while obtaining mixtures of high viability, and also develop compositions of a modified concrete mixture and create economic cement concrete with improved technological and operational properties that provide increased strength and durability of the road surface .Used modifying complex additive has no delayed action on the hardening of concrete mixtures, and road concrete with 0,4-0,8% additive shows a high early strength (3 days) 16,5-22,7 MPa so, and brand strength (28 days) – 37.4-49.5 MPa.

Economic efficiency, achieved from the introduction of a modifying complex additive, can be realized both in the production of road coatings from cement concrete, and in their operation.

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ДОСЛІДЖЕННЯ ЕКСПЛУАТАЦІЙНИХ ВЛАСТИВОСТЕЙ ЦЕМЕНТОБЕТОНІВ, МОДИФІКОВАНИХ КОМПЛЕКСНОЮ ДОБАВКОЮ

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Анотація. Статтю присвячено проблемі поліпшення експлуатаційно-технічних характеристик дорожнього покриття: підвищення його міцності і довговічності. Зміна умов експлуатації доріг протягом останніх десятиліть зумовило необхідність підвищення довговічності шарів дорожнього одягу з цементобетону. Розширення будівництва жорстких дорожніх одягів дозволить ефективно вирішити проблему підвищення працездатності і довговічності автодоріг, а для цього необхідно розробити цементні бетони з поліпшеними технологічними та експлуатаційними властивостями, до яких відносяться, зокрема, і цементобетони з комплексними добавками.

У процесі проведення експерименту цементобетони отримували з малорухомих (осадка конусу 2-3 см) і високорухомих (осадка конусу 16-18 см) бетонних сумішей різних складів як з добавкою модифікатора, так і без неї. Розглянуто питання розробки складів бетонних сумішей і цементобетона модифікованих комплексною добавкою полікарбоксилатного типу і дослідження їх технологічних і експлуатаційних властивостей. Показано, що застосування модифікованої комплексної добавки дозволяє скоротити до 20% води для замішування, отримувати суміші високої довговічності, що знижує витрати на укладання та ущільнення бетонної суміші. Досліджувані бетонні суміші характеризуються високою чутливістю реологічних властивостей до зміни водовмісту.

Результати досліджень впливу добавки модифікатора на фізико-механічні показники цементобетона в різні терміни твердіння, показують, що розроблені модифіковані цементобетони мають високу ранню міцність (3 доби), а також марочну міцність (28 діб). Створені економічні бетони класу В30-В35 з підвищеною міцністю. Отримані дорожні бетони характеризуються поліпшеними технологічними властивостями (розшарування, щільність, водопоглинання) бетонної суміші і експлуатаційними показниками (міцність, водонепроникність, морозостійкість, стирання) цементобетона.

Ключові слова: бетонна суміш, цементобетон, комплексна добавка, міцність, дорожнє покриття.

ИССЛЕДОВАНИЕ ЭКСПЛУАТАЦИОННЫХ СВОЙСТВ ЦЕМЕНТОБЕТОНОВ, МОДИФИЦИРОВАННЫХ КОМПЛЕКСНОЙ ДОБАВКОЙ

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Аннотация. Статья посвящена проблеме улучшения эксплуатационно-технических характеристик дорожного покрытия: повышения его прочности и долговечности. Изменение условий эксплуатации дорог в течение последних десятилетий обусловило необходимость повышения долговечности слоев дорожных одежд из цементобетона. Расширение строительства жестких дорожных одежд позволит эффективно решить проблему повышения работоспособности и долговечности автодорог, а для этого необходимо разработать цементные бетоны с улучшенными технологическими и эксплуатационными свойствами, к которым относятся, в частности, и цементобетоны с комплексными добавками.

В процессе проведения эксперимента цементобетоны получали из малоподвижных (осадка конуса 2-3 см) и высокоподвижных (осадка конуса16-18 см) бетонных смесей различных составов как с добавкой модификатора, так и без нее. Рассмотрены вопросы разработки составов бетонных смесей и цементобетона модифицированных комплексной добавкой поликарбоксилатного типа и исследования их технологических и эксплуатационных свойств. Показано, что применение модифицированной комплексной добавки позволяет сократить до 20% воды затворения, получать смеси высокой долговечности, что снижает расходы на укладку и уплотнение бетонной смеси. Исследуемые бетонные смеси характеризуются высокой чувствительностью реологических свойств к изменению водосодержания.

Результаты исследований влияния добавки модификатора на физико-механические показатели цементобетона в разные сроки твердения, показывают, что разработанные модифицированные цементобетоны имеют высокую раннюю прочность (3 суток), а также марочную прочность (28 суток). Созданы экономические бетоны класса В30-В35 с повышенной прочностью. Полученные дорожные бетоны характеризуются улучшенными технологическими свойствами (расслоение, плотность, водопоглощение) бетонной смеси и эксплуатационными показателями (прочность, водонепроницаемость, морозостойкость, стирание) цементобетона.

Ключевые слова: бетонная смесь, цементобетон, комплексная добавка, прочность, дорожное покрытие.

Стаття надійшла 5.07.2018