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# CESTOVNE CEMENTNO BETONSKE MODIFICIRANE STRUKTURE

# THE ROAD CEMENT CONCRETE MODIFIED STRUCTURE

***Gnip O.P., P.G. Raevskaya K.A., Shevchuk G.Y., Topilko N.I.***

Prethodno priopćenje

***Sažetak:*** *U ovom radu opisana su eksperimentalna ispitivanja raznih smjesa za izradu cestovnih premaza. Kao aditivi korišteni su moderni aditivi; Sika Mix Plus i Sika Visco Crete 20HE. Prikazani su rezultati istraživanja utjecaja troškova cementa i aditiva na čvrstoću cement-betona ovisno i o vremenu skrućivanja. Svojstva betonskih mješavina i cement-betona u konačnici su karakterizirana trajnošću razvijene smjese (pripravka).*

***Ključne riječi:*** *cement-beton, poroznost, aditivi, čvrstoća, vodopropusnost*

Preliminary notes

***Abstract:*** *This paper describes the experimental investigations of various mixtures for preparation of road coatings. Modern additives are as additives used - Sika Mix Plus and Sika Visco Crete 20NE. The results of research show the cost influence of cement and additives on the strength of cement-concrete especially depending on the time of solidification. The properties of concrete mixtures and cement concrete in the final result are characterized by durability developed compositions pavements.*

***Key words:*** *cement concrete, porosity, additives, strength, waterproof*

## 1. INTRODUCTION

The cement concrete and reinforced concrete coatings are used for the construction of modern roads, motorways with the more heavy traffic, airfields and streets. If we compare the cement concrete with the bituminous concrete, the advantage is on the side of the first. The road cement concrete is much stronger, it is resistant to elevated temperature (summer heat), it is highly resistant to friction. Another important advantage of the cement concrete is that it is quite light, and this significantly increases safety on the road at night. Improving the efficiency of investment in road and airfield construction associated with longevity (service) of the road and airfields coatings, reducing the cost of its construction, rational and cost, and at the same time, evidence-based use of composite materials. The cement concrete answers such criteria exactly [8,6].

At present, high-quality concrete is the modified concrete; its properties (density, strength, frost, etc.) can be changed during manufacture and material with desired characteristics is obtained [1]. Chemical additives are widely used in the technology works in the construction of concrete slabs and foundations, which are aimed to influence the processes of structure of cement stone and concrete, modify the structure of the concrete mixture and concrete to improve the performance properties.

Previously, various chemical products were used as additives in the production of concrete and industrial waste. At the moment, the additives that are released specifically for concrete production are increasingly used. The use of complex additives, which provide the optimal composition of concrete with the essential requirements, is a trend of modern construction. The complex additive is a chosen mixture of several components which reduce side effects of each other and together increase the overall efficiency. If the conventional additives are classified according to the mechanism of action, then the complex are classified to their applications. The complex additives, which are based on super plasticizers, are the most effective and promising modifier properties of concrete and cement concrete. Today they occupy a leading position among chemical additives that are used in concrete technology [4].

**The purpose of this paper**. To develop the road cement concrete pavement for the modified structure with improved performance characteristics using the complex additives super plasticizer of new generation.

## 2. THE EXPERIMENTAL STUDIES

Many scientists showed in their works [2,3] that modified cement concrete can be obtained by the use of cement of high brand and the additives of superplasticizers modifying action. The high-strength Portland cement PC-II / A-SH 500 BAT "Podolsky cement" is an astringent for the preparation of cement. This astringent refers to the first type of the Portland

cement, according to the standard EN 197-1.2002; it is without the extension and consists of cement clinker, gypsum and granulated blast furnace slag (20%). The quartz sand is a fine aggregate for concrete, it meets the requirements of DSTU B V.2.7-32-95, and the granite rubble of various fractions is a coarse aggregate (fr.5-10 mm and 10-20 mm).

The composition of materials on the basis of modern polymers was a complex modifier for concrete mixing, namely Sika Visco Crete 20HE. It is a new generation super plasticizer based on polycarboxylates, which meets the requirements of EN 934-2/2001. It is a multi-purpose additive, recommended in the manufacture of the close and waterproof concrete and concrete pavements. We know that [7,8] the frost is a very important indicator for road concrete, which depends on the amount and type of air pores, so the air entraining agents Sika Mix Plus are used in order to obtain optimum performance.

The hard concrete mixtures are prepared for the experiment (P1) a slump 2-4 cm that meets the road cement concrete pavement. Complex additive was introduced to the concrete with the mixing water during the preparation of concrete. The strength tests of samples cubes (10x10x10 cm) when compressed and the samples prisms (10x10x40cm) stretching at a bend in the destruction were carried out by a hydraulic press. The concretes were tested at the age of 2, 3, 7 and 28 days. The composition of the mixture is the determining factor in the design of cement concrete road and requires the following indicators: Portland cement consumption -350-390 kg/m$^3$ concrete; sand - 32%; rubble fr. 5-10 mm - 28%; fr. 20-40 mm - 40%; mobility of the concrete mix - 2-4 cm; water-cement ratio (w/c) - 0.4; concrete strength when compressed at the age of 28 days - 42.5 MPa; frost - F150; watertight - W8; erasure - T5,5. The road cement concrete mixtures were prepared from different composition during the experiment (Table 1), as with the additives of modifiers and without. Complex admixture Sika Visco Crete was administered at 0.5; 0.7 and 1.0% by weight of cement and air-entraining additive Sika Mix Plus - in the amount of 0.10% by weight of cement in all formulations of concrete. The concrete without additives was adopted as the standard for research. Amount of cement in all formulations was 350; 370 and 390 kg/m$^3$, and the water was adjusted in accordance with the shrinkage of the cone (OK=2,5-3cm) in the preparation of concrete mixes.

**Table 1** The compositions of cement concrete road

| № concrete composition | Cost of materials per 1 m$^3$ of concrete | | | | Additives,% by weight of cement | |
|---|---|---|---|---|---|---|
| | cement, kg | Sand, kg | breakstone, kg | | Sika Mix Plus | Sika Visco Crete 20HE |
| | | | фр. 5-10 | фр.10-20 | | |
| 1; 5; 9 | 350; 370; 390 | 698 | 408 | 698 | 0,10 | - |
| 2; 6; 10 | 350; 370; 390 | 705 | 412 | 705 | 0,10 | 0,5 |
| 3; 7; 11 | 350; 370; 390 | 719 | 425 | 719 | 0,10 | 0,7 |
| 4; 8; 12 | 350; 370; 390 | 733 | 430 | 733 | 0,10 | 1,0 |

The results of the research of the effect of the cost of cement and the modifiers additives to the strength of the cement concrete at different times solidification are given in Table 2. The tests have shown (Table 2), that the strength of the reference composition concrete of the age of 2-3 days is 6.0-9.5 MPa at an expense of cement 350 kg/m$^3$, and before the 28 days to grow to 20.6 MPa. The introduction of the complex additive from 0.5 to 1.0% (composition № 2-4) leads to an increase the early strength (two days) before 8.6-9.8 MPa. The strength of concrete is 24,0-30,3 MPa after months of hardening, that 4.0-9.7 MPa higher than the strength of concrete without additives. The subsequent growth of the strength to 8.8-14.0 MPa is observed with increasing costs of cement to 370 kg/m$^3$ (composition number 5); there is a subsequent increase in strength up to 8.8-14.0 MPa in the initial period of hardening. Addition of modifiers leads to increased strength of cement concrete in all terms of hardening. The compositions № 6-8 with the addition have become strong 10,.-13.1 MPa after 2 days; 18.2-21.2 MPa after 3 days and 24.4-28.0 MPa after 7 days, and the age of 28 days (Table 2). The use of complex additive allows to obtain concrete with strength 42.8 and 40.1 MPa (composition №7 and №8), which is the B30 class of concrete.

**Table 2** The strength of cement concrete road with complex additive

| № concrete compo-sition | Cost of cement, kg/m$^3$ | The amount of additive % by weight of cement | w/c | Tensile strength at bending, MPa after 28 days | Compressive strength, MPa - through the day | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 2 | 3 | 7 | 28 |
| 1. | 350 | - | 0,42 | 3,80 | 6,0 | 9,5 | 12,4 | 20,6 |
| 2. | 350 | 0,5 | 0,39 | 4,21 | 8,6 | 10,3 | 13,2 | 24,0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3. | 350 | 0,7 | 0,36 | - | 9,5 | 10,7 | 15,0 | 28,5 |
| 4. | 350 | 1,0 | 0,34 | 5,72 | 9,8 | 11,0 | 16,8 | 30,3 |
| 5. | 370 | - | 0,43 | 4,34 | 8,8 | 14,0 | 23,3 | 30,1 |
| № concrete compo-sition | Cost of cement, kg/m$^3$ | The amount of additive % by weight of cement | w/c | Tensile strength at bending, MPa after 28 days | Compressive strength, MPa - through the day | | | |
| | | | | | 2 | 3 | 7 | 28 |
| 6. | 370 | 0,5 | 0,40 | 5,22 | 10,2 | 18,2 | 24,4 | 37,0 |
| 7. | 370 | 0,7 | 0,38 | - | 12,8 | 19,6 | 25,6 | 42,8 |
| 8. | 370 | 1,0 | 0,35 | 6,10 | 13,1 | 21,2 | 28,0 | 40,1 |
| 9. | 390 | - | 0,41 | 5,10 | 10,9 | 15,2 | 26,2 | 32,8 |
| 10. | 390 | 0,5 | 0,38 | 6,28 | 12,5 | 19,8 | 27,1 | 41,2 |
| 11. | 390 | 0,7 | 0,36 | - | 15,3 | 20,3 | 28,9 | 43,8 |
| 12. | 390 | 1,0 | 0,34 | 6,93 | 15,0 | 21,2 | 28,2 | 42,6 |

The rising costs of cement to 390 kg/m$^3$ (composition №9) does not lead to a significant increase in the strength of concrete without additives in all terms of hardening. Introduction of integrated additives (composition №10-12) allows to increase the strength of cement concrete up to 2 times in all terms of hardening. The concrete grade M400 (B30) was achieved with such expenditure cement already at 0.5% of complex additives (Table 2).The modifying additive has a positive effect on the water demand of the concrete regardless of the cost of Portland. The water-cement ratio reduces the cost of the binder 350 kg/m$^3$ from 0.42 to 0.34, and at 370 kg/m$^3$ is reduced from 0.43 to 0.35.

The cement concrete road which modified complex additive shows 14-17% higher strength of concrete at early age (2 days) and 25-30% after 28 days of hardening. By reducing the surface tension of the water further in the cement additive achieved deflocculation grain, which gives the opportunity to increase the mobility of the concrete. The use of complex additives of modifying action gives an opportunity to improve the processes of mixing and laying concrete in form of formwork, and to design the optimal concrete with a certain ratio of components improves its quality, water-resistant and frost.

The properties of concrete mixtures and cement concrete in the final result are characterized by durability developed compositions pavements, so the research identified the following indicators: the density of concrete, air entrainment of concrete, open porosity of concrete and its water resistance. To investigate these construction and technical properties of selected concrete roads with an optimum amount of cement, which is 370 kg/m$^3$, and a comprehensive supplement contains from 0.5 to 1.0% Sika Visco Crete and 0.10% Sika Mix Plus. Properties of concrete mixtures were determined during the manufacturing process, and cement concrete - after 28 days of hardening. The test results are shown in Table 3.

**Table 3** Defining the properties of concrete mixtures and cement road

| The composition of the concrete | | The density of the concrete mixture, ρ, kg / m3 | Air entrainment,% | Open porosity % | The density of the concrete, ρ, kg/m$^3$ | Waterproof, mm | $R_{cr}$ 28 days, MPa |
|---|---|---|---|---|---|---|---|
| Portland Cement, kg/m$^3$ | The amount of additive % By weight of cement | | | | | | |
| 370 | - | 2280 | 2,0 | 0,40 | 2320 | 50 | 30,1 |
| 370 | 0,5 | 2292 | 2,4 | 0,32 | 2356 | 44 | 37,0 |
| 370 | 0,7 | 2319 | 2,8 | 0,28 | 2419 | 40 | 42,8 |
| 370 | 1,0 | 2334 | 3,4 | 0,24 | 2435 | 38 | 40,1 |

As seen from the above results (Table 3), the density of the concrete mixture without additives is 2280 kg/m$^3$, and with the introduction of the complex supplements it increases. Increasing the density of the concrete mix takes place by reducing the amount of mixing water of 159 l / m3 to 148,0-129,5 l/m$^3$ of voids and reduction. When equal amounts of cement in these studies are compared (370 kg/m$^3$ in all of concrete) the concrete with low density has lower strength. The composition of cement concrete without additives has brand strength of 30.1 MPa at a density of concrete 2320 kg/m$^3$. Introduction of the complex additive of 0.5-0.7% is to increase the compression strength at 28 days before 37.0-42.8 MPa and the density of the concrete increases to 2356-2419 kg/m$^3$.The obtained results have confirmed the definition of the open porosity of the concrete (Table 3). Therefore, the open porosity of cement concrete without additives is 0.40%, it is reduced to 1.3-1.7 times and within 0.24-0.32% with the addition. The contents of air pores and voids are an important indicator to improve hardiness and to alternate the freezing and the thawing.

## 3. CONCLUSION

The test results have shown (Table 3) that the air-entraining additive Sika Mix Plus (0,10%), which is used and the complex additive Sika Visco Crete (1,0%) can increase by 1.7 times the rate of air entrainment (3, 4) compared with concrete without the additive (2.0%). A water does not fill the pores in the conventional water saturation and it does not constitute a threat to road concrete at low temperatures. The introduced air-entraining additive stabilizes and generates a significant amount of very fine air bubbles during mixing of the concrete, which acts as a buffer during the development of stresses which occur in case of freezing. The water resistance is an important performance characteristic of cement concrete to the road surface which is dependent on its porosity, the pore structure properties of the binder and the aggregates. The permeability of the concrete can be assessed by the permeability coefficient of depth of penetration of water under pressure (Standard EN 12390-8). According to Table 3, the penetration depth of the water is 50 mm in the test cement without additives, and when it is used it is reduced to that of 38-44mm. The compositions of the concrete road can be considered watertight. The complex additive modifying action provides a dense fine pore structure of cement stone - you insert it into the concrete mix and colloidal compounds are thus formed, bridging the porous concrete structure and provide increasing its water resistance.

The application of complex additives and new generation super plasticizer allow the development of modern approaches to the modification of the concrete mix and create concrete with specified operating parameters that will ensure the longevity of pavement. The resulting concrete may be used for the production of building structures used in road construction.

## 4. LITERATURE

[1] Batrakov, V.G.: Modification of concrete - Модифицированые бетоны. – М.: Изд-во АВС, 2003. - 500с.

[2] Pozniak, O.O.; Sanicki, U.D.; Maruschak, U.D.; Olinik, T.V.: The effectiveness of the use of complex modifiers in road concrete - Эффективность использования комплексних модификаторов в дорожных бетонах //Асфальт. – 2009. - №2. – с. 22-34.

[3] Runova, R.F.; Nosovskiy, J.L.: Technology of modified mortars. - Технологія модифікованих будівельних розчинів. – Київ, 2007. – Видавництво КНУБіА. - 256с.

[4] Sanicki, M.A.; Maruschak, U.D.; Mazurak, O.T.; Chemeris, M.M.: The concept of applying modifiers to improve the quality and durability of concrete- Концепція застосування модифікаторів для підвищення якості та довговічності залізобетону //Будівельні конструкції. Збірник наукових праць. –К.: НДУБК, 2003.-с.448-455.

[5] Sanicki, U.D.; Pozniak, O.O.: Modifiers of new generation for concrete - Модифікатори нової генерації для бетонів // //Будівельні матеріали та вироби.-2006. -№1. - с.5-7.

[6] Sheinin, A.M.: Cement for road and airfield pavements. - Цементобетон для дорожных и аеродромных покрытий. –М., 1991. -150 с.

[7] Sinakin, A.G.: Sika additives to modify the ordinary and special concrete - Добавки Sika для модификации рядовых и специальных бетонов., Макеевка, 2008.

[8] Tolimachev, S.N.: Construction of roads with cement concrete pavement in Ukraine - Строительство дорог с цементобетонным покрытием в Украине –реальность сегоднешнего дня / Журнал «Автошляховик України». – №4. -2013.- с.36-40.

Author contact:

**Professor Gnip O.P.**
Odessa State Academy of Civil Engineering and Architecture
65029 Odessa, Didrihsona 4, Ukraine
isi@ogasa.org.ua