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STRENGTH OF RIGID PAVEMENT CONCRETES MODIFIED WITH POLYCARBOXYLATE ADMIXTURE ON DIFFERENT TYPES OF CEMENT

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Abstract. Strength of the concrete modified with MasterGlenium SKY 608 polycarboxylate admixture of rigid pavement on different types of cement was investigated. For concrete mixtures preparation, two types of cement were used: ПЦ II/A-Ш-500 (CEM II/A-S 42.5) and pozzolanic cement ПЦЦ IV/A-500 P (CEM IV/A(P) 42.5 R-SR). Amount of modifier ranged from 0.8 to 1.4% by mass of cement. Slump of all concrete mixtures was 6-7 cm. The aim of the research was to select a rational amount of the polycarboxylate admixture, taking into account early and grade compressive strength of concretes for rigid pavement repair.

It was found that the MasterGlenium SKY 608 admixture significantly reduces W/C of mixtures in comparison with unmodified three-component concretes while maintaining the flowability of the mixture. The biggest reduction in the W/C of concrete mixtures is achieved with the addition of the polycarboxylate type admixture in an amount of 1.2% by weight of cement. In this case, the W/C of concrete mixtures based on pozzolanic Portland cement ПЦЦ IV/A-500 P (CEM IV/A(P) 42.5 R-SR) was significantly higher than the W/C of mixtures with similar flowability based on Portland cement ПЦ II/A-Ш-500 (CEM II/A-S 42.5). Accordingly, for mixtures based on ПЦЦ IV/A-500 P (CEM IV/A(P) 42.5 R-SR) W/C varied from 0.542 to 0.371, for mixtures based on ПЦ II/A-Ш-500 (CEM II/A-S 42.5), from 0.502 to 0.292.

The early strength at the age of 3 days, and grade strength of unmodified concrete based on ПЦ II/A-Ш-500 (CEM II/A-S 42.5) (29.3 MPa and 51.3 MPa, respectively) was higher than early and grade strength of similar concrete based on pozzolanic cement ПЦЦ IV/A-500 P (CEM IV/A(P) 42.5 R-SR) (19.9 MPa and 36.3 MPa). This is due to the increased water demand of pozzolanic cement and, accordingly, concrete mixtures based on it. For modified concrete mixtures with MasterGlenium SKY 608 admixture, there is also a tendency towards greater concrete strength based on ПЦ II/A-Ш-500 (CEM II/A-S 42.5).

Polycarboxylate type admixture in an amount of 0.8% by weight of cement increased the compressive strength of concrete on both types of cement by almost 2 grades. With the addition of 1% modifier, strength increased by one more grade, and at 1,2% – by 3 grades for concrete based on Portland cement ПЦЦ IV/A-500 P (CEM IV/A(P) 42.5 R-SR) and by 2 grades for concrete based on Portland cement ПЦ II/A-Ш-500 (CEM II/A-S 42.5). An increase in the amount of admixture to 1.4% does not increase strength, because at the same time, W/C of mixtures increased. Thus, rational for concrete on both types of cement is the amount of admixture 1.2% of the binder mass, that the maximum compressive strength is achieved by minimizing of W/C.

Based on Portland cement ПЦ II/A-Ш-500 (CEM II/A-S 42.5) high-strength concrete for rigid pavement repair was obtained with a compressive strength 85.6 MPa, which corresponds to a grade no less than C 50/60. Based on Portland cement ПЦЦ IV/A-500 P (CEM IV/A(P) 42.5 R-SR) concrete was obtained with a compressive strength 64.1 MPa, which corresponds to a grade no less than C 40/50.

Keywords: rigid pavements, repair, early-strength concrete, pozzolanic cement, polycarboxylate type admixture.

Introduction. Continuous growth of transport and air transportation requires an improvement of pavement quality. The worldwide trend of the construction and transportation industry has shown

that the construction of highways and airfields with a rigid pavement is increasing. The lifetime of many existing traffic interchange and airfield pavements is nearing its end or has long been exhausted [1-3]. Therefore, there is a need of road repair with fast opening of traffic. As a strategy, full-depth repair using high-early strength concrete mixtures is more frequently used [4-6]. Full-depth repair supposes replacing of the pavement layer from 1/3 to its full thickness.

Our investigation focuses on the design of modified concrete mixtures with the optimal type of Portland cement and the required amount of superplasticizer BASF MasterGlenium SKY 608 based on polycarboxylate ether.

Analysis of recent researches and problem statement. Flexible pavements prevail in our country [7]. It should be noted that in recent years Highway Department of Ukraine has changed its development strategy and switched to the implementation of some road network sections using concrete pavement technology [8]. The service life of rigid pavement is 3-6 times longer than flexible asphalt concrete pavement, moreover for asphalt concrete in Ukraine mainly imported bitumen is used. In addition, crude oil reserves for bitumen production are limited in difference to the reserves of raw materials for cement production [2].

According to the 21st World Road Congress [2] and data [1, 3, 7], the length of highways with rigid pavement is as follows: USA – 60%, Austria – 46%, Belgium – 41%, Germany – 31%, France – 20%, Netherlands – 15%, Portugal – 10%, Spain, Italy, Canada, Switzerland, Great Britain <5 %, Ukraine – 1,92%. Most of them were built over 40 years ago and need major repairs or reconstruction.

The main requirements for repair concrete mixtures are their early compressive and tensile strength in bending (1-3 day). Different strength values can be used to open traffic [1, 3, 4, 6], that are specified by national and other specifications. The technology of high-early strength concrete repair mixtures has been widely used [4-6]. According to [9], strength of repair concrete at 28 days age must be no less than design strength of existing concrete pavement, for example, for a road of the 1st category – this is concrete grade class C30/35. However, due to the lack of special regulatory documents for repair concrete mixtures in Ukraine and based on the experience of other countries, the strength characteristics of repair concrete must be adjusted taking into account the necessary conditions for opening a section of the road for traffic and the region where repairs are being carried out.

It is known that the main prerequisites for obtaining early strength concrete are [10-12]: reduction W/C due to the use of additives-superplasticizers affecting on the hydration processes and structure formation; use of rapid-hardening binders and high-quality aggregates. Today, polycarboxylate type superplasticizers are the most effective, that can significantly increase strength and improve other properties of concrete without increasing the amount of cement, also maintains workability of the concrete mixture during 1.5-2 hours [13].

In Ukraine, rigid pavement repair technology is not sufficiently developed and there is practically no standards base. Research in this direction will create technical requirements with recommendations for full-depth repair of rigid pavements using high-early strength concrete, this is a crucial task.

Research objective. Selection of a rational amount of the polycarboxylate additive for the repair concrete mixture using different types of cement, with allowance for the early and grade compressive strength of the obtained concrete for a rigid road pavements repair.

Materials and research methods. Two types of cement were used in the study: ПЦ II/A-Ш-500 (CEM II/A-S 42.5), manufactured by PJSC «Dyckerhoff Cement Ukraine» and pozzolanic cement ПЦЦ IV/A-500 Р (CEM IV/A(P) 42.5 R-SR) manufactured by PJSC «Ivano-Frankivsk Cement». Granite crushed stone of the Gorikhovsky quarry (fraction 5-20 mm) and quartz sand of the Nikitovsky quarry (Voznesensky district) were used as aggregates. Sieve analysis of aggregates is presented in Table 1. Polycarboxylate type modifier MasterGlenium SKY 608 was used in an amount of 0.8-1.4% by weight of cement. Unmodified concrete compositions were also investigated. The concrete mix preparation process and sample testing were carried out in accordance with current requirements.

It should be noted the technological feature of the MasterGlenium SKY 608 modifier. For the effective action of the modifier, aggregates and cement were mixed to a homogeneous condition using 90% mixing water. The modifier was added in the required quantity with the remaining amount of mixing water.

Table 1 – Sieve analysis of fine and coarse aggregates

Sieve size, mm	% Passing by weight	
	Granite breakstone	Sand
20	100	100
10	95.8	100
5	5.0	100
2.5	0,8	98.0
1.25	0	84.5
0.63	0	29.5
0.315	0	35.3
0.16	0	10.5
< 0.16	0	1.5

Research results. Slump of concrete mixtures was (6…7 cm), that corresponds to the most common flowability of concrete mixtures for the rigid pavements repair**.** 10 batches of concrete samples were manufactured. The concrete mixtures and W/C are shown in Table 2.

Table 2 – Concrete mixtures and W/C

№	Cement type	Cement, kg/m^3	Breakstone, kg/m^3	Sand, kg/m^3	Admixture MasterGlenium SKY 608, %	Water, l/m^3	W/C
1	ПЦЦ IV/A-500 P (CEM IV/A(P) 42.5 R-SR)	400	1140	705	–	216.8	0.542
2				735	0.8	188.4	0.471
3				740	1.0	181,6	0.454
4				755	1.2	148.4	0.371
5				750	1.4	160.8	0.402
6	ПЦ II/A-Ш-500 (CEM II/A-S 42.5)	400	1140	720	–	200.8	0.502
7				765	0.8	148.4	0.371
8				785	1.0	125.2	0.313
9				800	1.2	116.8	0.292
10				795	1,4	119.2	0.298

The admixture significantly reduced W/C of the mixtures in comparison with the unmodified three-component concrete mixtures № 1 and 6 and retained their flowability. Effect of the amount of MasterGlenium SKY 608 admixture and the type of cement on W/C mixtures are shown in Fig. 1.

As shown in Fig. 1, the greatest W/C reduction of concrete mixtures is achieved by adding a polycarboxylate type admixture MasterGlenium SKY 608 in an amount of 1.2% by weight of cement. In this case, the W/C of concrete mixtures based on pozzolanic Portland cement ПЦЦ IV/A-500 P (CEM IV/A(P) 42.5 R-SR) was significantly higher than the W/C of similar flowability mixtures based on Portland cement ПЦ II/A-Ш-500 (CEM II/A-S 42.5).

The average density of the investigated concretes ranged from 2430 to 2510 kg/m^3. Strength characteristics of the obtained concretes are shown in Fig 2. Compression strength tests were carried out for each batch at the age 3 and 28 days.

The analysis shown in Fig. 2 graphs allow to note that early and grade strength ($f_{ck.cube.3}$ = 29.3 MPa, $f_{ck.cube.28}$ = 51.3 MPa) of unmodified concrete based on ПЦ II/A-Ш-500 (CEM II/A-S 42.5) are higher than the early and grade strength ($f_{ck.cube.3}$ = 19.9 MPa, $f_{ck.cube28}$ = 36.3 MPa) of similar

concrete based on pozzolanic cement ПЦЦ IV/A-500 P (CEM IV/A(P) 42.5 R-SR). This effect is caused by the increased water demand of pozzolanic cement and, accordingly, concrete mixtures based on it. For modified concrete mixtures with MasterGlenium SKY 608 admixture (№ 2-5 and №7-10) there is also a tendency towards greater strength of concrete based on the cement ПЦ II/A-Ш-500 (CEM II/A-S 42.5).

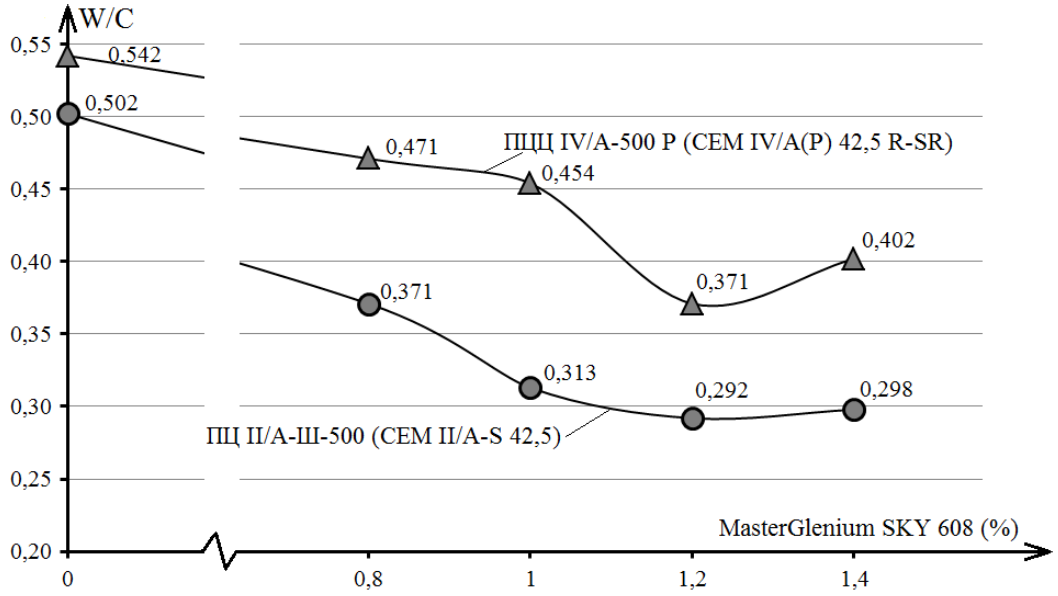

Fig. 1. Effect of the amount of MasterGlenium SKY 608 admixture on W/C of equal flowability mixtures

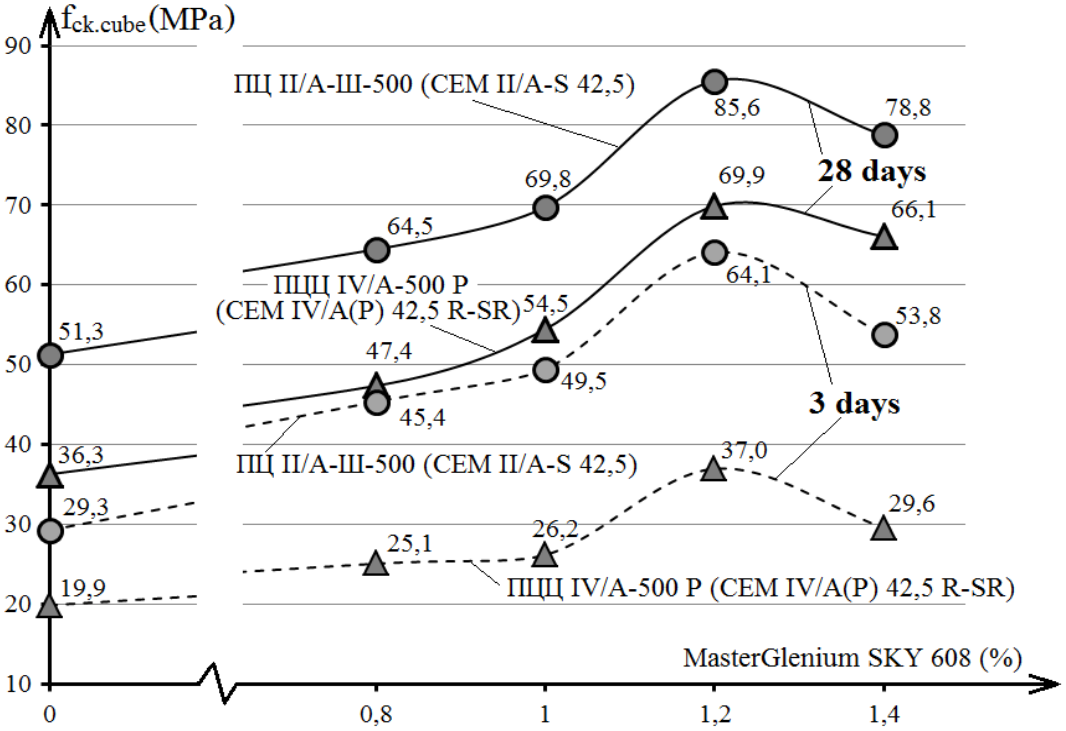

Fig. 2. Strength of the investigated concretes at the age 3, 28 days

The use of MasterGlenium SKY 608 admixture in an amount of 0.8% by weight of cement increased the compressive strength of concretes on both types of cement by almost 2 grades. With the addition of 1% modifier, the strength increased by another 1 grade, and with 1.2% – by 3 grades for concrete based on Portland cement ПЦЦ IV/A-500 P (CEM IV/A(P) 42.5 R-SR) and by 2

grades with Portland cement ПЦ II/А-Ш-500 (CEM II/A-S 42.5). Increasing the amount of admixture to 1.4% is not rational, because at the same time, W/C of the mixtures increases and, accordingly, strength of the investigated concrete of rigid pavements decreases.

Thus, for concrete on both types of cement the rational amount of admixture is 1.2% of the binder mass, that allows to achieve the maximum compressive strength by minimizing the W/C.

High-strength concrete was obtained based on Portland cement ПЦ II/А-Ш-500 (CEM II/A-S 42.5) with compressive strength 85.6 MPa, that corresponds to grade no less than C 50/60. Concrete based on Portland cement ПЦЦ IV/А-500 Р (CEM IV/A(P) 42.5 R-SR) had compressive strength 64.1 MPa, that corresponds to grade no less than C 40/50.

It is important to note that early strength, i.e. strength at age 3 days, of modified concrete on pozzolanic cement ПЦЦ IV/А-500 Р (CEM IV/A(P) 42.5 R-SR) was 45...53% of concrete grade, and concrete based on Portland cement ПЦ II/А-Ш-500 (CEM II/A-S 42,5) – 68…75%, depending on the amount of admixture. That is, due to the use of modified concrete, the strength required for most concrete of rigid pavements is reached at the age of 3 days, which is important for repair materials.

Conclusions and prospects for further researches. Using a rational amount of BASF MasterGlenium SKY 608 admixture based on polycarboxylate ethers allows to obtain high-strength and early- strength concretes. The use of such concretes in the rigid highway and airfield pavements repair contributes to the early start traffic. For concretes based on pozzolanic cement ПЦЦ IV/А-500 Р (CEM IV/A(P) 42.5 R-SR) and Portland cement ПЦ II/А-Ш-500 (CEM II/A-S 42.5) the rational amount of MasterGlenium SKY 608 admixture is 1.2% by weight of the binder.

Further research will be aimed at determining the tensile strength in bending of such concrete and fiber concrete. Also, the indicators of wear resistance and frost resistance of these concretes will be determined, as the main ones in assessing the durability of rigid road pavements. It is planned to pay attention to the structure formation of the tested samples.

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МІЦНІСТЬ МОДИФІКОВАНИХ ПОЛІКАРБОКСИЛАТНОЮ ДОБАВКОЮ БЕТОНІВ ЖОРСТКИХ ДОРОЖНІХ ПОКРИТТІВ НА РІЗНИХ ТИПАХ ЦЕМЕНТУ

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Анотація. Досліджено міцність модифікованих полікарбоксилатною добавкою MasterGlenium SKY 608 бетонів жорстких дорожніх покриттів на різних типах цементу. Для приготування бетонів використовувалися два типів цементу: ПЦ II/А-Ш-500 (CEM II/A-S 42,5) і пуцолановий портландцемент ПЦЦ IV/А-500 Р (CEM IV/A(P) 42,5 R-SR). Кількість модифікатора варіювалося від 0,8 до 1,4% від маси цементу. Рухомість всіх бетонних сумішей складала Р2. Метою досліджень був підбір раціональної кількості полікарбоксилатної добавки з урахуванням ранньої і марочної міцності при стиску отриманих бетонів для ремонту жорстких дорожніх покриттів.

Встановлено, що добавка MasterGlenium SKY 608 істотно знижує В/Ц сумішей в порівнянні з не модифікованими трьох-компонентними бетонами при збереженні рухомості суміші. Найбільше зниження В/Ц бетонних сумішей досягається при введенні добавки полікарбоксилатного типу в кількості 1,2% від маси цементу. При цьому В/Ц бетонних сумішей на основі пуцоланового портландцементу ПЦЦ IV/А-500 Р було значно вище, ніж В/Ц сумішей аналогічної рухомості на основі портландцементу ПЦ II/А-Ш-500. Відповідно для сумішей на основі ПЦЦ IV/А-500 Р В/Ц змінювалося від 0,542 до 0,371, для сумішей на основі ПЦ II/А-Ш-500 – від 0,502 до 0,292.

Рання, тобто у віці 3-х діб, і марочна міцність не модифікованого бетону на основі ПЦ II/А-Ш-500 (29,3 МПа і 51,3 МПа відповідно) була вищою ранньої і марочної міцності аналогічного бетону на основі пуцоланового цементу ПЦЦ IV/А-500 Р (19,9 МПа і 36,3 МПа). Це викликано підвищеною водопотребою пуцоланового цементу і відповідно бетонних сумішей на його основі. Для модифікованих добавкою MasterGlenium SKY 608 складів також простежується тенденція більшої міцності бетонів на основі ПЦ II/А-Ш-500.

Введення добавки полікарбоксилатного типу в кількості 0,8% від маси цементу підвищило міцність при стиску бетонів на обох типах цементу майже на 2 класу. При введенні 1% модифікатору міцність підвищилася ще на 1 клас, а при 1,2% – на 3 класи для бетонів на основі портландцементу ПЦЦ IV/А-500 Р і на 2 класи для бетонів з портландцементом ПЦ II/А-Ш-500. Підвищення кількості добавки до 1,4% вже не призводить до зростання міцності через збільшення В/Ц сумішей. Таким чином, раціональним для бетонів на обох видах цементу є кількість добавки 1,2% від маси в'яжучого, при якому досягнута максимальна міцність при стиску за рахунок мінімізації В/Ц.

На основі портландцементу ПЦ II/А-Ш-500 отримано високоміцний бетон для ремонту жорстких дорожніх покриттів з міцністю 85,6 МПа, що відповідає класу не менше С 50/60. На основі цементу ПЦЦ IV/А-500 Р був отриманий бетон міцністю 64,1 МПа, що відповідає класу не менше С 40/50.

Ключові слова: жорсткі дорожні покриття, ремонт, рання міцність, пуцолановий цемент, добавка полікарбоксилатного типу.

ПРОЧНОСТЬ МОДИФИЦИРОВАННЫХ ПОЛИКАРБОКСИЛАТНОЙ ДОБАВКОЙ БЕТОНОВ ЖЕСТКИХ ДОРОЖНЫХ ПОКРЫТИЙ НА РАЗНЫХ ТИПАХ ЦЕМЕНТА

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Аннотация. Исследована прочность модифицированных поликарбоксилатной добавкой MasterGlenium SKY 608 бетонов жестких дорожных покрытий на разных типах цемента. Для приготовления бетонов использовались два типов цемента: ПЦ II/А-Ш-500 (CEM II/A-S 42,5) и пуццолановый портландцемент ПЦЦ IV/А-500 Р (CEM IV/A(P) 42,5 R-SR). Количество модификатора варьировалось от 0,8 до 1,4% от массы цемента. Подвижность всех бетонных смесей составляла Р2. Целью исследований был подбор рационального количества поликарбоксилатной добавки с учетом ранней и марочной прочности на сжатие полученных бетонов для ремонта жестких дорожных покрытий.

Установлено, что добавка MasterGlenium SKY 608 существенно снижает В/Ц смесей в сравнении с не модифицированными трехкомпонентными бетонами при сохранении подвижности смеси. Наибольшее снижения В/Ц бетонных смесей достигается при введении добавки поликарбоксилатного типа в количестве 1,2% от массы цемента. При этом В/Ц бетонных смесей на основе пуццоланового портландцемента ПЦЦ IV/А-500 Р было значительно выше, чем В/Ц смесей аналогичной подвижности на основе портландцемента ПЦ II/А-Ш-500. Соответственно для смесей на основе ПЦЦ IV/А-500 Р В/Ц изменялось от 0,542 до 0,371, для смесей на основе ПЦ II/А-Ш-500 – от 0,502 до 0,292.

Ранняя, то есть в возрасте 3-х суток, и марочная прочность не модифицированного бетона на основе ПЦ II/А-Ш-500 (29,3 МПа и 51,3 МПа соответственно) была выше ранней и марочной прочности аналогичного бетона на основе пуццоланового цемента ПЦЦ IV/А-500 Р (19,9 МПа и 36,3 МПа). Это вызвано повышенной водопотребностью пуццоланового цемента и соответственно бетонных смесей на его основе. Для модифицированных добавкой MasterGlenium SKY 608 составов также прослеживается тенденция большей прочности бетонов на основе ПЦ II/А-Ш-500.

Введение добавки поликарбоксилатного типа в количестве 0,8 % от массы цемента повысило прочность при сжатии бетонов на обоих типах цемента почти на 2 класса. При введении 1 % модификатора прочность повысилась еще на 1 класс, а при 1,2 % – на 3 класса для бетонов на основе портландцемента ПЦЦ IV/А-500 Р и на 2 класса для бетонов с портландцементом ПЦ II/А-Ш-500. Повышение количества добавки до 1,4% уже не приводит к росту прочности, т.к. при этом увеличивается В/Ц смесей. Таким образом, рациональным для бетонов на обоих видах цемента есть количество добавки 1,2 % от массы вяжущего, при котором достигнута максимальная прочность на сжатие за счет минимизации В/Ц.

На основе портландцемента ПЦ II/А-Ш-500 получен высокопрочный бетон для ремонта жестких дорожных покрытий с прочностью 85,6 МПа, что соответствует классу не менее С 50/60. На основе цемента ПЦЦ IV/А-500 Р был получен бетон прочностью 64,1 МПа, что соответствует классу не менее С 40/50.

Ключевые слова: жесткие дорожные покрытия, ремонт, ранняя прочность, пуццолановый цемент, добавка поликарбоксилатного типа.

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