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Concretes based on composite cements with the addition of granulated blast furnace slag and cement dust

ABSTRACT

A set of experimental-statistical models has been obtained that makes it possible to predict the workability and strength of concrete on a composite binder, including the addition of dust from cement clinker kilns and granulated blast-furnace slag, as well as polycarboxylate superplasticizer Sika VC 225.

The values of the critical water-cement ratio are determined, which determine the area of constant water demand and take into account the binder normal consistency, as well as the adsorption coefficients of fine and coarse aggregates.

Experimental-statistical models of the coefficients that determine the yield of concrete strength per 1 kg of composite cement and Portland cement Cem I contained in it are obtained.

Keywords: *cement kiln, dust, granulated blast-furnace slag, composite cement, concrete, experimental-statistical model.*

1. INTRODUCTION

During the burning of Portland cement clinker, a highly dispersed, large-tonnage waste is formed – the dust taken away from clinker firing furnaces (cement kiln dust (CKD)), which is mainly caught in dust chambers and electrostatic precipitators [1-3]. The dust specific surface area depends significantly on the material mixture composition and the technological process parameters [1].

Mineralogical studies have shown that the dust contains up to 20% of clinker minerals: dicalcium silicate of β- and γ-modifications – 8...10, dicalcium ferrite and four-calcium aluminoferrite – 10...12, calcium oxide free – 2...14, alkalis – 1...8%. The bulk of the dust consists of a burnt clay and limestone mixture that has not decomposed. The composition of dust significantly depends on the type of furnaces, the type and properties of the raw materials used, as well as the method of capture [3].

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The main method of CKD disposal in the cement industry is its re-introduction into the raw material mixture [1, 4, 5]. This method cannot be considered efficient enough, because when dust is returned, its heat and activity is not used. The quality of clinker decreases if there is a large amount of alkali in the CKD. When burning clinker in a wet way, dust contributes to the formation of sludge rings on the lining of rotary kilns [1].

The increased content of alkaline compounds in the CKD is explained by their accumulation in the gas environment of rotary kilns during the firing of raw mixtures as a result of the release of feldspar minerals and other compounds that are included in the clay component of the raw mixture [2, 4]. The increased content of sulfates in the dust is mainly due to binding of sulfur dioxide, which is formed during fuel combustion [6].

Also of interest are other methods of CKD recycling and, above all, the use in the composite binders as a mineral additive. A number of works have been carried out in this direction [5-11], but in recent years, in connection with the use of superplasticizers and the improvement of grinding technology, new opportunities have opened up in this direction. At the same time, the presence of high alkali content in the CKD opens up the possibility of using it as an activating component of blast furnace slag. In our work [12], we show the features of obtaining a composite binder based on CKD, blast furnace slag, and portland cement, in which complex activation of blast furnace granulated slag is achieved due to the increased content of alkaline compounds in cement dust. It is also relevant to study the specifics of using such a binder to obtain normal weight concrete. This makes it possible to obtain both economic and environmental effects as a result of reducing of the clinker component content in concrete.

2. MATERIALS AND RESEARCH METHODS

The purpose of this research is to study of the influence of the composition and features of the technology of obtaining a composite binder containing Portland cement, cement kiln dust and ground blast furnace slag on the properties of concrete, obtaining mathematical dependencies for predicting its properties and designing compositions.

The research was carried out using Portland cement CEMI 42.5 and dust from the clinker kilns of Dyckerhoff "Volyn Cement" (Ukraine). The enterprise manufactures cement clinker by the wet method from sludge based on carbonate, clay and iron components in furnaces 4.5x170m. Slag from the Kryvorizka Metallurgical Plant (Ukraine) was also used.

The average chemical composition of Portland cement, clinker kiln dust and blast furnace slag are given in Table 1.

Table 1. Chemical composition of dust, blast furnace slag and Portland cement

Tabela 1. Hemijski sastav prašine, šljake visoke peći i portland cementa

Material	The content of oxides, %										
	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	MnO	CaO_{free}
Clinker kilns dust	24,07	12,22	3,41	2,05	49,01	0,84	5,29	2,78	0,55	-	3,10
Blast furnace slag	-	39,53	6,46	0,14	47,03	3,13	1,72	-	-	1,17	-
Portland cement	-	22,5	5,26	4,06	66,35	0,65	0,26	0,12	0,24	-	0,33

Polycarboxylate superplasticizer was used in the research – Sika VC 225.

The research was carried out using the experiment mathematical planning methods [13, 14].

The possibility of using the developed composite cement-slag binders of low water consumption to obtain concretes of a wide range of construction and technical properties was studied. Experiments were carried out in accordance with the typical plan of Ha_5 [15]. The conditions for planning experiments are given in Table 2.

Table 2. Conditions for planning experiments in the study of concrete mixtures slump and strength of concrete on composite cement

Tabela 2. Uslovi za planiranje eksperimenata u proučavanju sleganja betonskih mešavina i čvrstoće betona na kompozitnom cementu

Factors		Levels of variation			Variation interval
Natural view	Coded view	+1	0	-1	
The total content of additives in the composition of binders, %	X_1	60	50	40	10
Sika VC 225 superplasticizer content, (SP, kg/m^3)	X_2	2	1,5	1	0,5
Water-cement ratio (W/C)	X_3	0,6	0,45	0,3	0,15
The water content of the concrete mixture (W, l/m^3)	X_4	160	145	130	15
The volume of sand in the aggregate (r_s)	X_5	0,5	0,45	0,4	0,05

The composite cement was produced at a ratio of blast furnace slag and cement dust of 1:1 (by mass) with a specific surface area of 450 m^2/kg and introduction of the admixture Sika VC 225 during grinding. In addition, during milling, a grinding intensifier was introduced - propylene glycol in the amount of 0.03% of the mass of the binder. Quartz sand with fineness modulus 2.1, as well as granite crushed stone of fraction 5-20 mm were used for the production of concrete mixture.

The composition of the concrete mixture at each point of the experiments matrix was calculated by the absolute volumes method, having previously determined, knowing the required water content and water-cement ratio, the cement consumption. The consumption of sand and crushed stone were calculated according to the formulas:

$$S = \left[r_s \left(1000 - W - \frac{C}{\rho_c} \right) \right] \rho_s , \quad (1)$$

$$CS = \left[1000 - W - \frac{C}{\rho_c} - \frac{S}{\rho_s} \right] \rho_{CS} \quad (2)$$

were

W and C – consumption of water and binder;

ρ_c, ρ_s, ρ_{cs} – densities of binder, sand and crushed stone respectively;

r_s – proportion of sand in the aggregates mixture.

3. RESULTS AND DISCUSSION

The experimental data are shown in table 3, and the experimental statistical models obtained on their basis are shown in table 4.

Table 3. The matrix and results of experiments in the study of the concrete mixtures workability and the strength of concrete on the composite cement

Tabela 3. Matrica i rezultati eksperimenata u proučavanju obradivosti betonskih mešavina i čvrstoće betona na kompozitnom cementu

No	Factors					Slump of concrete mixture, cm	Compressive strength of concrete, MPa		
	X1	X2	X3	X4	X5		1 day	7 days	28 days
1	+1	+1	+1	+1	+1	22	13.6	15.8	25.7
2	-1	-1	+1	+1	+1	17	15	27	32
3	-1	+1	-1	-1	-1	19	31.4	49.6	65.7
4	+1	-1	-1	-1	-1	9	28.5	43.3	61.8
5	-1	+1	-1	+1	+1	23	35.6	54.7	66.6
6	+1	-1	-1	+1	+1	18	25.3	43.5	59.6
7	+1	+1	+1	-1	-1	19	12.8	17.7	26.4
8	-1	-1	+1	-1	-1	13	14.6	24.8	31.7
9	-1	+1	+1	+1	-1	24	16.8	26.4	35.4
10	+1	-1	+1	+1	-1	17	11.5	16.8	24.3
11	+1	+1	-1	-1	+1	18	23.6	44.6	57.8
12	-1	-1	-1	-1	+1	11	22.5	45.8	68.5
13	-1	+1	+1	-1	+1	22	12,6	16,7	25,6
14	+1	-1	+1	-1	+1	8	13.6	19.6	28.7
15	+1	+1	-1	+1	-1	24	25.6	46.7	58.8
16	-1	-1	-1	+1	-1	18	30.7	51.8	64.5
17	+1	0	0	0	0	16	21.5	40.7	51.4
18	-1	0	0	0	0	20	25.5	52.6	62.6
19	0	+1	0	0	0	23	27.6	42.7	51.7
20	0	-1	0	0	0	12	26.5	44.6	54.4
21	0	0	+1	0	0	19	15.6	22.7	34.8
22	0	0	-1	0	0	17	29.5	47.4	62.6
23	0	0	0	+1	0	23	24.5	40.8	52.2
24	0	0	0	-1	0	12	28.6	45.7	56.6
25	0	0	0	0	+1	15	25.6	44.5	51.6
26	0	0	0	0	-1	21	27,8	45.4	56.5
27	0	0	0	0	0	18	25.6	41.8	53.5

Table 4. Experimental-statistical models of concrete mixture slump and concrete strength based on the composite binders

Tabela 4. Eksperimentalno-statistički modeli opadanja betonske mešavine i čvrstoće betona na bazi kompozitnih veziva

Output parameter	Polynomial model	
Slump, cm	$Sl = 17.9 - 0.89X_1 + 3.95X_2 + 0.22X_3 + 3.1X_4 - 0.56X_5 + 0.17X_1^2 - 0.33X_2^2 + 0.17X_3^2 - 0.33X_4^2 + 0.17X_5^2 + 0.12X_1X_2 - 0.5X_1X_3 + 0.6X_1X_4 - 0,12X_1X_5 + 0,25X_2X_3 - 0,9X_2X_4 + 0,12X_2X_5 - 0,5X_3X_4 - 0,25X_3X_5 - 0,12X_4X_5$	(3)
Concrete strength, MPa at the 1 day	$f_c^1 = 26.2 - 1.6X_1 + 0.63X_2 - 7.04X_3 + 0.6X_4 - 0.68X_5 - 2.8X_1^2 + 0.7X_2^2 - 3.8X_3^2 + 0.2X_4^2 + 0.37X_5^2 - 1.1X_1X_2 + 0.6X_1X_3 - 1.2X_1X_4 + 0.34X_1X_5 - 0.5X_2X_3 + 0.5X_2X_4 + 0.48X_2X_5 - 0,49X_3X_4 + 0,52X_3X_5 + 1,2X_4X_5$	(4)
7 days	$f_c^7 = 44.4 - 3.4X_1 - 0.13X_2 - 13.3X_3 + 0.87X_4 - 0.57X_5 + 1.9X_1^2 - 1.1X_2^2 - 9.7X_3^2 - 1.5X_4^2 + 0.2X_5^2 + 0.23X_1X_2 - 0.1X_1X_3 - 1.6X_1X_4 + 0.46X_1X_5 - 1.4X_2X_3 + 0.6X_2X_4 - 0.49X_2X_5 - 0.4X_3X_4 - 0.24X_3X_5 + 0.5X_4X_5$	(5)
28 days	$f_c^{28} = 55 - 3.2X_1 - 0.7X_2 - 16.8X_3 - 0.2X_4 + 1.8X_1^2 - 2.2X_2^2 - 6.5X_3^2 - 0.8X_4^2 - 1.2X_5^2 - 0.14X_1X_2 + 0.48X_1X_3 - 0.83X_1X_4 + 0.32X_1X_5 + 0.12X_2X_3 + 1.3X_2X_4 - 1.1X_2X_5 + 0.6X_3X_4 - 0.47X_3X_5 + 0.37X_4X_5$	(6)

The use of a finely ground binder containing blast furnace slag and kiln dust in combination with the addition of a polycarboxylate superplasticizer made it possible to obtain concrete mixtures in a wide slump range – from 8 up to 24 cm, that is, class S2-S5.

The influence of the main technological factors on the slump of the studied mixtures is shown in fig. 1 and 2. At the same time, the influence of other unaccounted factors that varied was at the basic (zero) level (Table 2).

The main factors determining the slump, as follows from the analysis of the model, are the water content and the superplasticizer content. In all compositions containing the admixture Sika at the upper variation level, even with a water consumption of 130 kg/m^3, the concrete mixture slump does not fall below 18 cm, and with a water consumption of 145-160 kg/m^3, it reaches 23 cm and more, which allows to obtain self-compacting mixtures.

In accordance with the well-known [16, 17] rule of constant water demand, the water consumption practically does not change with the change in W/C until critical $(W/C)_{cr}$ value. In the work [17] on the basis of a theoretical analysis of the change in the rheological properties of cement paste and concrete mixture from W/C, proposed the formula for calculating $(W/C)_{cr}$:

$$(W/C)_{cr} = (1,35...1,65)K_{n.c.} + \frac{K_{w.s.}S + K_{w.cs.}CS}{C} \quad (7)$$

were $K_{n.c}$ – cement normal consistence; $K_{w.s.}$ and $K_{w.cs}$ – wetting coefficients of sand and coarse aggregates; S and CS – content sand and crushed stone in the concrete mixture.

Assuming for quartz sand $K_{w.s}$ = 0.015…0.025, granite rubble $K_{w.cs}$ = 0.005…0.01, [17] it is possible to calculate that for concretes with Portland cement consumption C = 300-500 kg/m^3 $(W/C)_{cr}$ varies from 0.37 to 0.45 (figure 1).

When reducing of normal consistence in the investigated composite binders with the admixture Sika ($K_{n.c}$) to 0.19…0.20 $(W/C)_{cr}$ decreases to 0.3…0.33, which is confirmed by the analysis of the obtained experimental-statistical model of the concrete mixture slump.

Due to the reduced water content, the investigated mixtures are characterized by a relatively low the cement paste volume and their slump drops significantly with an increase in the sand content and, accordingly, r_s, as evidenced by the analysis of the slump model (Fig. 1, 2). At the same time, taken into account the relatively low viscosity of the cement paste in concrete mixtures on composite binders. The possibility of the concrete mixture mortar separation must be taken into account when choosing r_s (with the superplasticizer addition). At the same time, the proportion of sand in the aggregate of the recommended concrete compositions (r_s) reaches 0.45…0.5 [18].

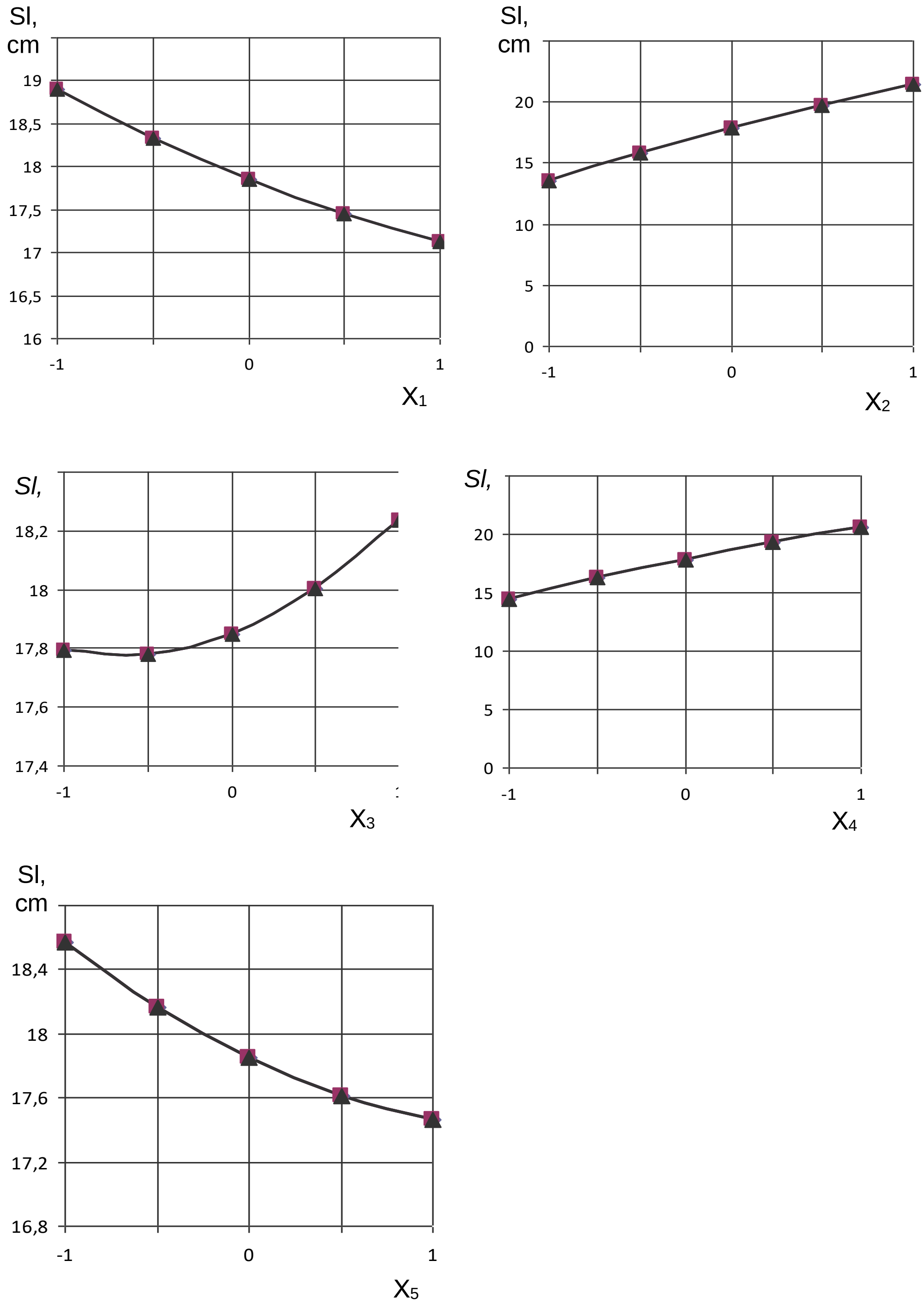

Figure 1. Dependence of the concrete mixture slump (Sl, cm) on various factors (Table 2).

Slika 1. Zavisnost pada betonske mešavine (Sl, cm) od različitih faktora (Tabela 2).

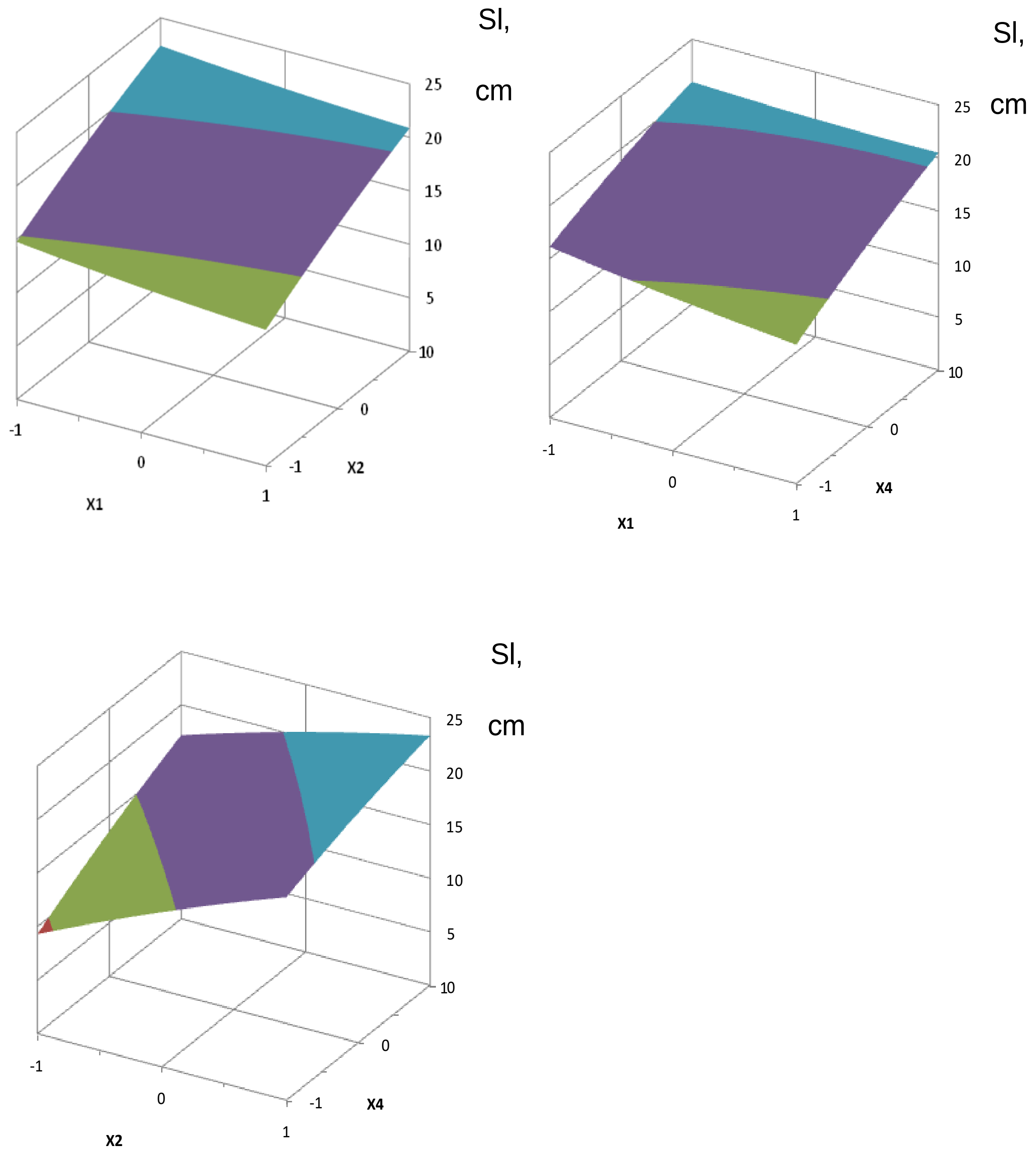

Figure 2. Two-factor dependencies of the concrete mixture slump (Sl, cm)

Slika 2. Dvofaktorske zavisnosti opadanja betonske mešavine (Sl, cm)

The content of the composite mineral admixture containing cement dust and blast furnace slag in the ratio of 1:1 by mass varied in the investigated concrete mixture compositions. This ratio, as shown by studies of the influence of the binders composition on their strength, is close to optimal. With such a ratio and the presence of a superplasticizer in the concrete mixture, the increasing in the binder of cement dust content, leads to a certain tendency of the decrease slump at a constant water content. This tendency cannot be considered strong enough.

The analysis of the obtained strength models (Table 4) shows that in the accepted range of factors (Table 2) the 28-day compressive strength of concrete ranges from 24 to 66 MPa.

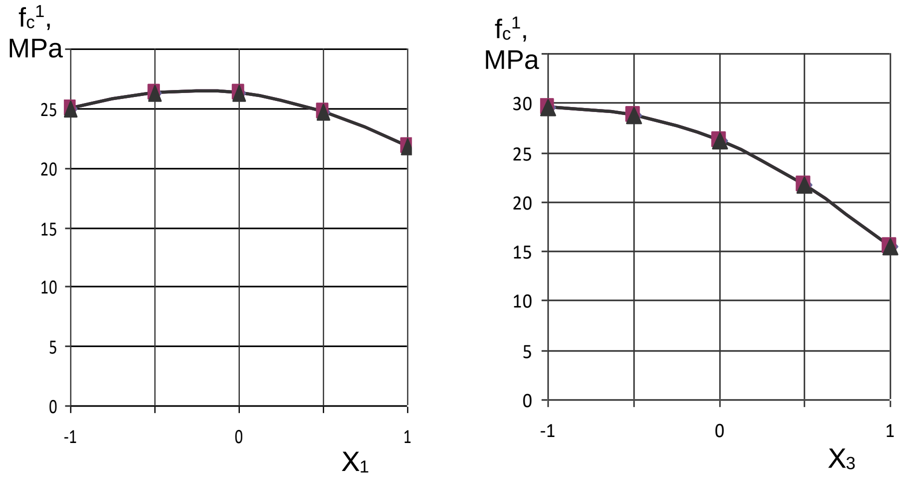

Figure 3. Dependence of concrete strength at the age of 1 day (f_c^1, MPa) on various factors (Table 2)
Slika 3. Zavisnost čvrstoće betona u dobi od 1 dana (f_c^1, MPa) od različitih faktora (Tabela 2)

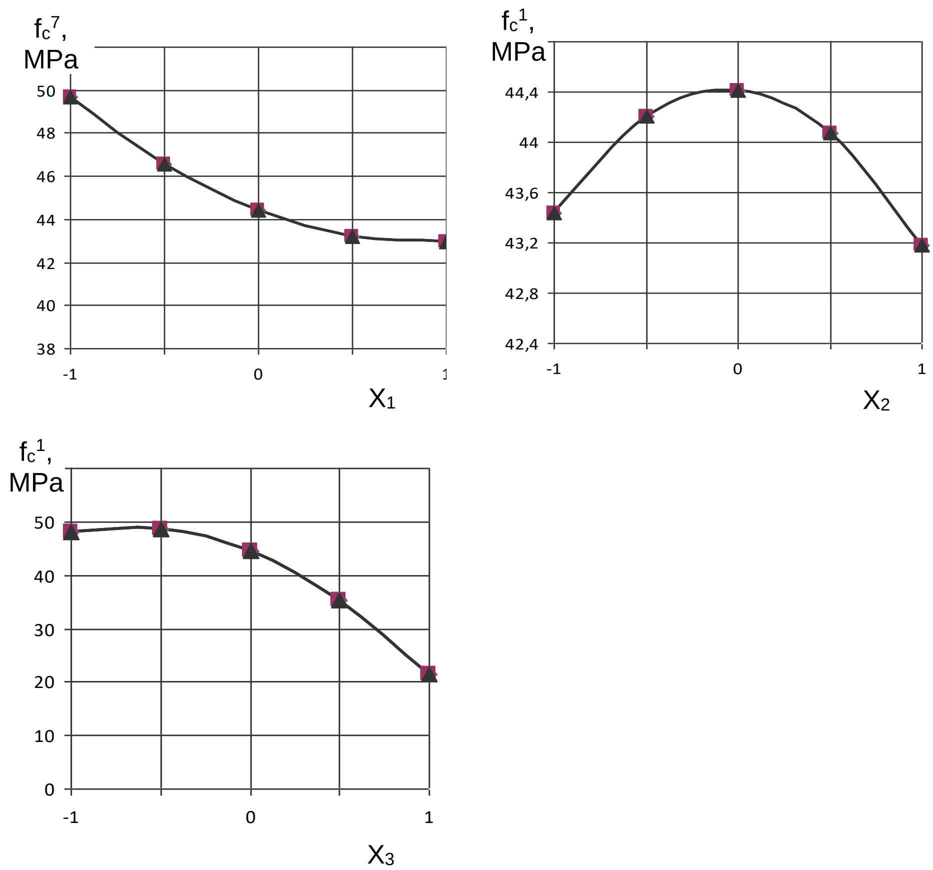

Figure 4. Dependence of concrete strength at the age of 7 days (f_c^7, MPa) on various factors (Table 2).
Slika 4. Zavisnost čvrstoće betona starosti od 7 dana (f_c^7, MPa) od različitih faktora (Tabela 2).

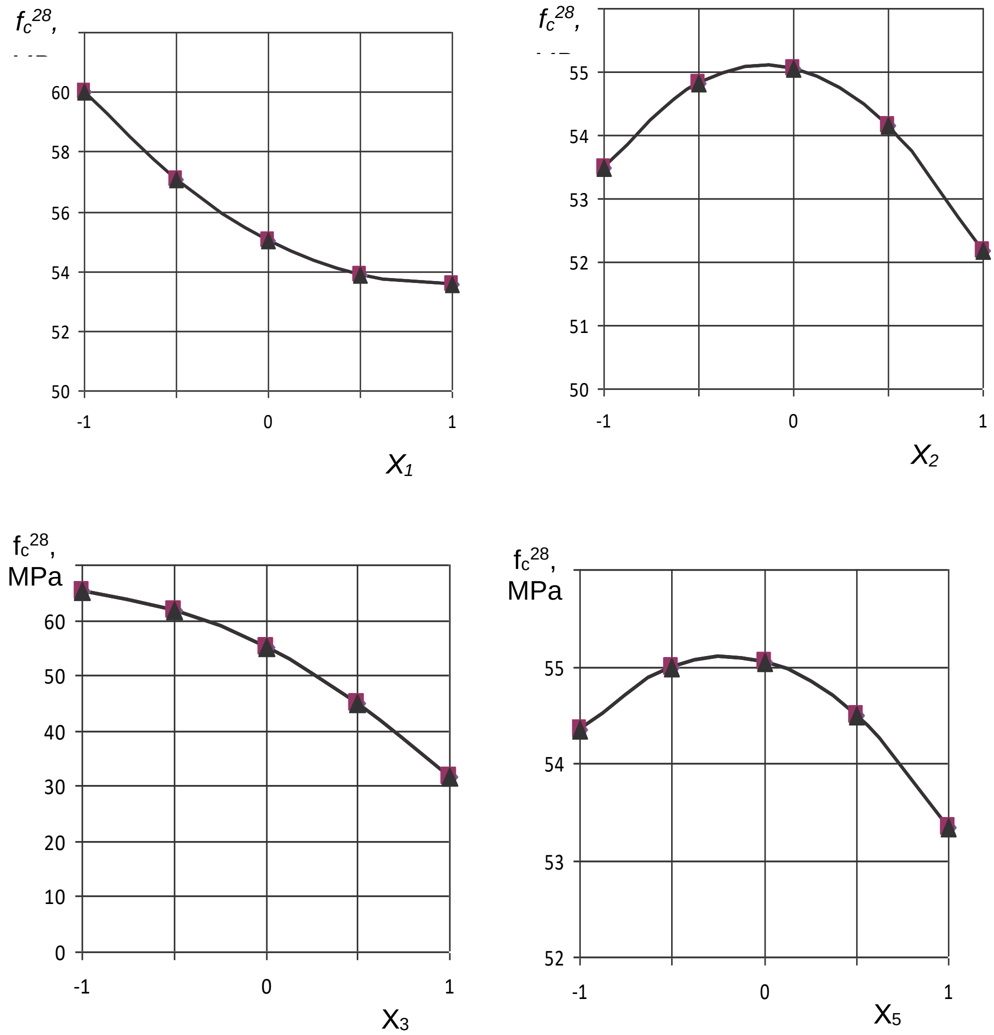

Figure 5. Dependence of concrete strength at the age of 28 days (R_{28}, MPa) on various factors (Table 2).

Slika 5. Zavisnost čvrstoće betona starosti 28 dana (R_{28}, MPa) od različitih faktora (Tabela 2).

The most significant factor affecting the strength of concrete both in the early and subsequent periods of curing is the water-binding ratio. The nature and degree of influence of this factor on the compressive strength of concrete on composite finely ground binders containing the kiln dust and granulated blast furnace slag are approximately the same as in ordinary Portland cement concrete (Fig. 3-5). After processing the relevant experimental data (Table 3), it is possible to obtain the average dependence of concrete strength on cement-water ratio (C/W), which is consistent with general formula $f_c = f(C/W)$ [17]:

$$f_c = K(C/W - b) \quad (8)$$

were

K – coefficient that takes into account the quality of raw materials;

C/W – binder-water ratio (K=15,5; b=0,8).

A more accurate approximation of the calculated data obtained by formula (8) to the experimental data is possible if the coefficient K in the formula (8) is represented as AR_c, where R_c is the composite cement strength. When the strength of the binder varies depending on the content of the composite additive and superplasticizer in the range of 40…60 MPa, the coefficient A will be equal to approximately 0.31 in relation to the aggregates used.

The use of a superplasticizer additive when using finely ground composite binders makes it possible to obtain concretes with W/C ≤ 0.4 based on self compacting concrete mixtures with Sl>20 cm. As is known [18], such concretes with a compressive strength of 28 days not less than 60 MPa and 7 days at least 25…30 MPa are included in the group of High Performance Concrete.

At a constant W/C, there is also a weak tendency to increase the strength as the water content decreases, which is consistent with known ideas [17] and is associated with a decrease of the volume of capillary pores.

Analysis of the obtained experimental data and statistical models (Fig. 3-5, Table 4) shows that the use of finely ground composite binders in concrete mixtures with the addition of a superplasticizer allows one-day strength to reach 50%, and seven-day strength to 80% of the 28-day strength. The main factor determining the kinetics of concrete strength growth, as well as its absolute value, is the water-cement ratio. Reducing the mineral additives total content in the binder composition and reducing the concrete mixtures water content also contribute to the strength gain acceleration (figure 6).

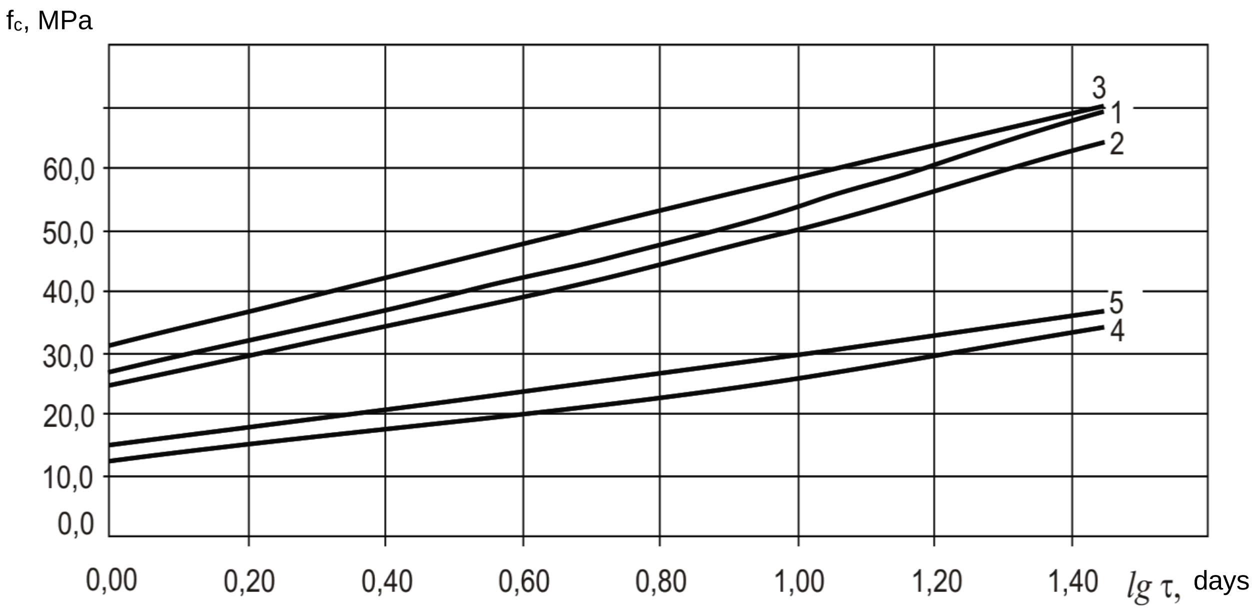

Figure 6. Change in strength of concrete with age: 1 – W/C=0,3 W=130 A=40%; 2 – W/C=0,3 W=130 A=60%; 3 – W/C=0,3 W=160 A=40%; 4 – W/C=0,6 W=130 A=40%; 5 – W/C=0,6 W=160 A=40%. A - additive to cement (clinker kiln dust and blast granulated furnace slag 1:1 (by mass))

Slika 6. Promena čvrstoće betona sa godinama: 1 – W/C=0,3 W=130 A=40%; 2 – W/C=0,3 W=130 A=60%; 3 – W/C=0,3 W=160 A=40%; 4 – W/C=0,6 W=130 A=40%; 5 – W/C=0,6 W=160 A=40%. A - dodatak cementu (prašina iz peći klinkera i šljaka visoke peći 1:1 (po masi))

One of the using binders efficiency indicators in concrete is the so-called efficiency criterion, which characterizes the "strength yield" in MPa per 1 kg of binder. In the studied concretes, the consumption of binder varies in a wide range – from 216 kg/m^3 to 530 kg/m^3, while the 28-day strength varied from 25 to 67 MPa. The efficiency of the different concrete compositions at a certain age can be calculated using the equation $K_{e_C} = f_c^{\tau} / C_b$ (where C_b is the consumption of binder, f_c^{τ}– the concrete strength at the age of T, days). The equation K_{ec} can be calculated based on the data in Table 3 by determining the binder consumption at each point of the matrix and knowing the water content and water-binding ratio of the concrete mixture. Regression equations K_{ec} for one- and 28-day-old concrete are given in Table 5.

Correct comparison K_{ec} for different concrete compositions is possible with the same slump of concrete mixtures. Prediction of the slump and its corresponding adjustment is possible using equation (3).

Table 5. Experimental-statistical models of efficiency coefficients K_{e_C} *and* $K_{e_{cem}}$

Tabela 5. Eksperimentalno-statistički modeli koeficijenata efikasnosti K_{e_C} *i* $K_{e_{cem}}$

Parameter	Model	
Efficiency coefficients of the use of composite cement in concrete $K_{e_C} = f_c / C_b$	$K_{e_C(1)} = 0.082 - 0.004X_1 - 0.004X_4 - 0.002X_5 - 0.008X_1^2 + 0.002X_2^2 - 0.023X_3^2 + 0.002X_4^2 + 0.002X_5^2 - 0.002X_1X_2 - 0.003X_1X_4 + 0.002X_2X_4 - 0.002X_3X_4 + 0.002X_3X_5 + 0,004X_4X_5$	(9)
	$K_{e_C(28)} = 0.173 - 0.009X_1 - 0.003X_2 - 0.004X_3 - 0.014X_4 - 0.002X_5 - 0.009X_2^2 - 0.039X_3^2 - 0.004X_5^2 + 0.003X_1X_5 + 0.005X_2X_4 - 0.004X_2X_5 + 0.003X_3X_4$	(10)

Table 6. Efficiency coefficients for the use of Portland cement in concrete on composite binders

Tabela 6. Koeficijenti efikasnosti za upotrebu portland cementa u betonu na kompozitnim vezivima

Portland cement consumption in the binder, kg/m^3	Composite binder consumption, kg/m^3	Water-cement ratio	Sika VC 225 consumption, kg/m^3	Sl, cm	$K_{ec(1)}/K_{epc(1)}$	$K_{ec(28)}/K_{epc(28)}$
107	267	0,6	3	22	0.4	0.4
160	267	0,6	1	17	0.6	0.6
260	433	0,3	3	19	0.6	0.6
173	433	0,3	1	9	0.4	0.4
320	533	0,3	3	23	0.6	0.6
213	533	0,3	1	18	0.4	0.4
87	217	0,6	3	19	0.4	0.4
130	217	0,6	1	13	0.6	0.6
160	267	0,6	3	24	0.6	0.6
107	267	0,6	1	17	0.4	0.4
173	433	0,3	3	18	0,4	0,4
260	433	0,3	1	11	0.6	0.6
130	217	0,6	3	22	0.6	0.6
87	217	0,6	1	8	0.4	0.4
213	533	0,3	3	24	0.4	0.4
320	533	0,3	1	18	0.6	0.6
129	322	0,45	2	16	0.4	0.4
193	322	0,45	2	20	0.6	0.6
161	322	0,45	3	23	0.5	0.5
161	322	0,45	1	12	0.5	0.5
121	242	0,6	2	19	0.5	0.5
242	483	0,3	2	17	0.5	0.5
178	356	0,45	2	23	0.5	0.5
144	289	0,45	2	12	0.5	0.5
161	322	0,45	2	15	0.5	0.5
161	322	0,45	2	21	0.5	0.5
161	322	0,45	2	18	0.5	0.5

The experimental data presented in Table 3 also allow, knowing the content of mineral additives and, accordingly, Portland cement in the binder (factor X_1), to calculate the regression equation that characterizes the effectiveness coefficient of the Portland cement (PC) use $K_{epc} = f_c/PC$ in MPa/kg when ensuring the concrete strength at a certain age (Table 6).

It follows from the Table 5 that the value of the efficiency coefficients of the investigated composite binders in both one- and 28-day-old concrete is not lower, and the value of the Portland cement use coefficients in the binders composition is significantly higher than when using Portland cement without additives.

For example, according to known data [19], the effectiveness coefficient for CEM I 32.5 in concrete with W/C=0.5 (Sl=3 cm) and strength after 18 hours was 0.055, 28 days – 0.083 MPa/kg. At the same time, the concrete strength was 21.2 MPa and 32.5 MPa, respectively, and the cement consumption was 390 kg/m^3.

4. CONCLUSIONS

1. A set of experimental statistical models has been obtained that makes it possible to predict the workability and strength of concrete on a composite binder, including the cement clinker kiln dust and granulated blast furnace slag, as well as Sika VC 225 polycarboxylate superplasticizer.
2. The value of the critical water-cement ratio are calculated, which determine the area of water demand constancy and take into account the binder normal consistency, as well as the wetting coefficients of fine and coarse concrete aggregates with water.
3. The analysis of the obtained experimental-statistical models made it possible to establish the influence of individual factors and the effects of their interaction on the strength of concrete at different ages, as well as to obtain a calculated dependence for strength. They makes it possible to find the required value of the cement-water ratio depending on the quality indicators of the materials used.
4. Experimental-statistical models of the coefficients determining the yield of concrete strength per 1 kg of composite cement and Portland cement CEM I contained in it have been obtained.
5. The obtained results show that for concretes with W/C<0.4 based on the obtained composite cement (specific surface area 450 m^2/kg, composite mineral additive content 50%, superplasticizer Sika VC 225) concrete strength is about 20...30 MPa can be reached after 1 day of normal curing and reach more 60 MPa in 28 days.

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IZVOD

BETONI NA BAZI KOMPOZITNIH CEMENTA SA DODATKOM GRANULISANE VISOKOPEĆNE ŠLJAKE I CEMENTNE PRAŠINE

Dobijen je set eksperimentalno-statističkih modela koji omogućavaju predviđanje obradivosti i čvrstoće betona na kompozitnom vezivu, uključujući dodavanje prašine iz peći cementnog klinkera i granulisane šljake visoke peći, kao i polikarboksilatnog superplastifikatora Sika VC. 225.

Određene su vrednosti kritičnog vodocementnog odnosa koje određuju oblast konstantne potražnje za vodom i uzimaju u obzir normalnu konzistenciju veziva, kao i koeficijente adsorpcije finih i krupnih agregata.

Dobijeni su eksperimentalno-statistički modeli koeficijenata koji određuju prinos čvrstoće betona po 1 kg kompozitnog cementa i portland cementa Cem I koji se u njemu nalazi.

Ključne reči: *cementna peć, prašina, granulisana visokopećna šljaka, kompozitni cement, beton, eksperimentalno-statistički model*

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