COMPOSITE BINDER OBTAINED BY USING OF DUST FROM CLINKER KILNS

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The paper deals with the features of obtaining a composite binder containing cement kilns dust, blast furnace slag and Portland cement, in which increased complex activation of blast-furnace granulated slag is achieved, due to the increased content of alkalis in cement dust, as well as the effects of hydroxide and calcium sulphate, contained in the cement. The influence of composition, fineness of grinding and content of chemical additives on the hydration degree and strength of low water demand binders was studied. The optimal relationships between the binder composition and the required fineness of the grinding are established, which ensure the strength characteristics and the hardening speed. The influence of superplasticizers naphthalene formaldehyde and polycarboxylate types, which provide low water demand of binder and high fineness of its grinding, is studied. Using the method of the experiment mathematical planning, equations for the regression of compressive and flexural strengths in different compensations were obtained, which allow predicting strength, taking into account the composition and features of the technology for obtaining the binder.

Keywords: *binder, dust, kiln, grinding, hydration degree, strength*

1. Introduction

About 80% of the total amount of dust produced in cement production consist of dust emissions, when the clinker kilns are operating [1-3]. The dust content of cement kilns varies on average from 5 to 20% of the mixture mass, which is fed to the kilns. Emission of dust depends on the size and type of the kiln, the presence of heat exchangers, the calcination regime, the method for producing cement, and the properties of the raw mixture and fuel [1]

The main way to utilize the dust of clinker rotary kilns is to return it to the production process of clinker. Various methods of returning dust to the kiln have been developed [2-6]. Among them: its mixing to a slurry or raw meal, feed for a kiln chain in a pulverized or granular state, blowing into the kiln from the hot end. Each of these methods has advantages and disadvantages. The return of dust in any way complicates the calcination of cement clinker and usually adversely affects the quality of the cement due to the increase in its alkali content, the increase in the heterogeneity of the chemical composition and the deterioration of the clinker structure. In this regard, the problem of rational utilization of dust from clinker kilns remains relevant.

One of the characteristic features of the dust of clinker kilns is the increased content of alkaline compounds. These compounds are represented by sulfates and carbonates of sodium, potassium and other. According to some of authors [5, 6], alkali content in the dust usually does not exceed 8%. There is also evidence [1] that the total amount of K_2O + Na_2O in the dust trapped by the electrostatic precipitators can vary within wide limits with predominance of potassium oxide. The alkali content increases in the finest fractions. In the dust accumulated in the third field of the electrostatic precipitator, the content of potassium oxide can be 3-4 times greater than in the hoppers of the first and second fields [7].

Increased alkali content reduces the strength of Portland cement and causes its false setting [1]. This leads to a rapid loss of fluidity of concrete and mortar mixes. It causes the need to increase water demand and worsen all the basic properties of concrete. For a high content of alkalis in cement, the danger of alkali corrosion of concrete increases, particularly for the presence of reactive silica in aggregates. Moreover, an excess in alkali content causes efflorescence on concrete [2, 6].

Investigations established [8] that at humid method for obtain of clinker the entire amount of dust trapped by electrostatic precipitators can be fed into the kiln without changing it's quality of the clinker in the case that the content of alkaline oxides in the raw sludge is not more than 0.7 ... 0.8%. Adding of 5 ... 15% dust into the raw sludge can cause it different troubles as: coagulation tendency, fluidity diminish, sticking of the kiln chains, the formation of sludge rings, a decrease in the resistance of the kiln refractory lining [9].

Besides the return of cement kiln dust into the raw mix for the production of clinker, other directions of its application have been developed. Among them, the use of cement kiln dust for

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binders and mortars production is proposed [4, 10, 11-14]. Studies of ways to efficiently use of clinker kiln dust are performed in the work [15].

Dust, formed during the burning of Portland cement clinker and trapped by electrostatic precipitators, has weak binding properties. The presence in the dust of a certain amount of clinker minerals formed as a result of preliminary solid-phase reactions gives it some ability to harden. The interaction of free CaO and dehydrated mineral from clay contained in dust contributes to its hydraulic activity.

Dust could be divided into three classes [16], depending on the indicators of chemical and hydraulic activity. Dust Class I may be used as an independent binder. Dust of the second and third grades can be used as a component of some blended binders containing fly ash and slag, in amount of 15...25 and 20...30% respectively.

The hydraulic dust activity increases significantly with the gypsum addition. According to V.S. Batalin [17] an admixture of 2 ... 3% gypsum increases strength by three or more times compared with pure dust mortar already in the first time of curing. At the same time, the increased content of gypsum negatively affects the final binder strength.

Best results are obtained for compositions of the dust-granulated blast slag and dust-slag-gypsum [15]. In combination with dust, the use of phosphoric and cupric slag is possible. The theoretical precondition for the compatibility of slag and cement dust in the preparation of a composite binder is mainly the presence in it of soluble alkalis. These alkalis have the strongest activating effect on slag vitreous phase [18, 19]. A certain activating effect on granulated slag also has free calcium oxide and calcium sulfate, which are contained in dust [15, 20].

It was established [15] that the highest characteristics have a binder composition consisting of 75% slag and 25% dust.

To increase the activity of dust and stabilize the properties of such binders, it is advisable to introduce a certain amount of Portland cement into their composition. Portland cement is an important activator of blast furnace slag. However, these binders do not always presented good strength [21].

The scientific hypothesis underlying this study, is the possibility of obtaining a composite cement-dust-slag binder in which an increased complex activation of granulated blast furnace slag is achieved, due to the increased content of alkalis in cement dust, as well as the effects of calcium hydroxide and calcium sulfate brought by cement

2. Research aim

The aim of the work was to establish the characteristics of hydration composite binders of low water demand, including Portland cement, dust of clinker kiln and blast furnace slag (CDSB).

To achieve this goal, an experimental program was implemented. It consisted of two stages. At the first stage, the influence of the main factors on the kinetics of hydration and strength

Table 1

Chemical composition of initial materials

Material	*The content of oxides, %*								
	CaO	*SiO_2*	*Al_2O_3*	*Fe_2O_3*	*MgO*	*SO_3*	*R_2O*	*CaO_{free}*	*MnO*
Portland cement	66.35	22.5	5.26	4.06	0.65	0.26	0.36	0.33	-
Slag	47.03	39.53	6.46	0.14	3.13	1.72	-	-	1.17
Clinker kilns dust (sample 1)	42.5	19.6	5.3	4.1	0.6	2.4	2.9	3.1	-
Clinker kilns dust (sample 2)	41.4	18.5	4.4	3.9	0.7	3.3	4.9	4.2	-

Table 2

Chemical compositions and physical properties of cement used in the experiments

Property	CEM I 52.5 N	
Specific surface area (Blaine method), m^2/kg	310	
Setting time: initial	2 h. 00 min.	
final	4 h. 10 min.	
Normal consistency of cement paste, %	25.8	
Ultimate compressive strength at 28days, MPa	53.2	
Mineral Composition of Portland Cement Clinker		
Main Phases Name	CCN	Content, %
Tricalcium silicate	C_3S	59.7
Dicalcium silicate	C_2S	19.6
Tricalcium aluminate	C_3A	6.8
Tetracalcium aluminate ferrite	C_4AF	12.2

was studied. It was necessary to establish a binder pre-composition and its production conditions. At the second stage we investigated the properties of mortars based on low water demand binder, which includes Portland cement, dust and slag.

3. Materials and research methods

The study used Portland cement CEM-I with a compressive strength of 52.5 MPa and two samples of Dickergoff-cement (Ukraine) clinker kilns dust, as well as granulated blast-furnace slag of the Krivoy Rog metallurgical plant (Ukraine). The chemical composition of the materials is given in Table 1, the physical and mechanical properties of cement and its mineralogical composition in Table 2. The samples of cement dust were characterized by a specific surface area of 400...410 m^2 / kg.

The grinding of the binders was carried out in dry state by a laboratory mill, with superplasticizers of naphthalene-formaldehyde (C-3) and polycarboxylate type (Sika VC 225) admixtures.

The hydration degree of binder was apreciated by the method of the chemically bound water amount determination [22]. From pastes of normal consistency cubes specimens were prepared with dimensions of 2 cm. Specimens were stored under normal conditions. After a predetermined period of hardening, the samples were ground (at powder state) until they completely passed through a 008 mm sieve. The samples were treated with ethyl alcohol, dried at 100°C to constant weight, and calcined at 1000°C. The amount of chemically bound water (X_1) was determined by the formula:

$$X_1 = (a-b)/a \,, \tag{1}$$

where a – mass of dry specimen before calcination; b – mass of specimen after calcination.

The hydration degree of binders α was calculated by formula:

$$\alpha = X_1/X_2 \,, \tag{2}$$

where X_2 – the amount of bound water at full hydration.

The value of X_2 was determined after double steaming of samples with intermediate grinding.

The strength and relative cement stone density (d_r) of the cubic specimens (2×2×2 cm) were determined; for relative density, the following formula was used:

$$d_r = \rho_{o.c.s.}/\rho_{c.s.} \,, \tag{3}$$

where $\rho_{o.c.s.}$ – density of cement stone; $\rho_{c.s.}$ – theoretical density of cement stone.

At the second stage, the studies were carried out using the method of mathematical planning of experiments [23]. As a result of making, specimens testing and the data obtained by statistical processing, experimental statistical models of the mortars on a cement-dust-slag binder strength in the regression equations form were obtained.

$$y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ij} x_i x_j + \sum_{i=1}^{k} b_{ii} x_1^2 , \tag{4}$$

where y is output parameter; b_0, b_i, b_{ij}, b_{ii} are regression coefficients; x_i, x_{ij}, x_{ii} are the investigated factors; k is the number of factors.

The experiments were carried out according to the plan B_4 [23] with four factors. The compressive and flexural strength of the mortars was determined on beams measuring 40×40×160 mm after 2, 7 and 28 days. The specimens were prepared using sand with a fineness modulus of 2.1. The binder/sand ratio was1:3 by mass.

4. Results of experimental studies

4.1. Degree of hydration and strength of binders in slag-dust and cement-slag-dust systems

The hardening processes of composite binders in slag-dust and cement-slag-dust systems are based on hydration processes of clinker minerals and vitreous slag in conditions of high content of alkaline oxides and activating influence of $Ca(OH)_2$ and $CaSO_4.2H_2O$.

As is known, the binder's hydration degree is the main factor directly related to the strength of the artificial stone on their basis [18]. For the first time, Powers [24] proposed for the strength of the cement stone the equation:

$$R_{c.s.} = AX^n \,, \tag{5}$$

where A is a constant, characterizing the cement gel strength ($A \approx 240$ MPa); n is a coefficient, depending on cement properties (n = 2.6–3); X – ratio between the gel volume and total volume of the gel and voids.

According to Powers, the parameter X can be found by formula:

$$X = \frac{k_h V_{s.c} \alpha}{V_{s.c} \alpha + W/C} \approx \frac{0.647\alpha}{0.319\alpha + W/C} \tag{6}$$

where k_h=2.09…2.2 is a coefficient of hydration products volume growth; $V_{s.c}$ is the specific volume of cement ($V_{s.c} = 1/\rho_c$ = 0.319 cm^3/g); ρ_c is the cement density; α is the hydration degree (hydrated part of cement).

Other criteria for the cement stone strength were proposed by many researchers

Table 3

Values of the hydration degree for pastes based on composite binders obtained by co-grinding components

№	Type of binder, dust sample (Table 1)	The superplasticizer content, % by weight	Specific surface area m^2/kg	Hydration degree at the age, days		
				3	*7*	*28*
1	slag + dust (sample 1)	-	350	0.20	0.31	0.35
2	slag + dust (sample 1)	1	370	0.17	0.28	0.32
3	slag + dust (sample 1)	-	580	0.24	0.36	0.40
4	slag + dust (sample 1)	1	660	0.21	0.34	0.39
5	slag + dust (sample 2)	-	340	0.22	0.38	0.43
6	slag + dust (sample 2)	1	380	0.20	0.31	0.37
7	slag + dust (sample 2)	-	590	0.25	0.37	0.41
8	slag + dust (sample 2)	1	640	0.21	0.37	0.42
9	cement + slag + dust (sample 1)	-	330	0.30	0.48	0.56
10	cement + slag + dust (sample 1)	1	360	0.27	0.46	0.55
11	cement + slag + dust (sample 1)	-	590	0.38	0.58	0.64
12	cement + slag + dust (sample 1)	1	630	0.34	0.55	0.62
13	cement + slag + dust (sample 2)	-	320	0.31	0.50	0.61
14	cement + slag + dust (sample 2)	1	350	0.29	0.49	0.60
15	cement + slag + dust (sample 2)	-	620	0.40	0.61	0.69
16	cement + slag + dust (sample 2)	1	630	0.36	0.59	0.67

Note: The composition of binder: slag + dust is 1: 1 (by weight), cement + slag + dust - 2: 1: 1 (by weight)

Table 4

The strength and the relative density of the cements stone based on composite binders

Type of binder according to "Table 3"	Normal consistency,%	The superplasticizer content, % by weight	Specific surface area, m^2/kg	Strength, MPa / relative density		
				3 day	7 day	28 day
1	24.2	-	350	8.3/0.659	14.2/0.703	18.4/0.719
2	23.2	1	370	12.5/0.659	17.8/0.704	24.3/0.72
3	31.4	-	580	11.2/0.6	16.3/0.643	21.5/0.657
4	21.8	1	660	17.4/0.692	23.6/0.746	30.3/0.767
5	28.4	-	340	8.8/0.622	15.6/0.682	19.5/0.7
6	22.6	1	380	13.1/0.678	18.4/0.723	24.9/0.748
7	31.5	-	590	12.4/0.603	17.6/0.645	25.2/0.66
8	22.9	1	640	17.8/0.679	25.1/0.744	31.8/0.765
9	27.4	-	330	19.2/0.662	26.8/0.731	35.4/0.761
10	22.3	1	360	24.5/0.711	29.8/0.789	35.5/0.827
11	29.5	-	590	23.4/0.67	28.5/0.743	37.8/0.765
12	22.5	1	630	31.8/0.737	38.4/0.824	53.4/0.852
13	28.1	-	320	21.5/0.659	28.2/0.73	35.8/0.771
14	22.7	1	350	24.8/0.714	30.3/0.796	36.2/0.841
15	31.4	-	620	24.5/0.657	31.6/0.732	38.3/0.76
16	23.1	1	630	33.8/0.737	39.3/0.831	58.4/0.864

[18, 19]. Sheykin [25] related the cement stone strength with the degree of hydration by the value of the relative density:

$$d_r = \rho_{o.c.s.}/\rho_{c.s.} = (1+0{,}23\alpha\rho_c)(1+\rho_c W/C) \qquad (7)$$
$$R_{c.s.} = 310 d_r^{2{,}7}$$

At the same time, as noted in [26], composite low water demand binders (LWDB), including cement, mineral filler and superplasticizer, are characterized by a lower hydration degree both at an early and more age, though such binders are characterized by higher strength. The discrepancy between the hydration degree and strength is explained [27] by the composition and structure of the hydrates, as well as the cement stone structure (lower porosity volume).

Hydration degree values of the paste specimens based on two- and three-component composite binders that contain dust, at the age of 3, 7 and 28 days are given in Table 3. The results of strength and relative density of cement stone determinations are given in Table 4.

Analysis of the data in Table 3 shows that the hydration degree of two-component binders is 1.5...2 times lower than that of the three-component ones. The hydration degree varies nonlinearly over time, the hydration rate decreasing in time from 3 to 7, and to 28 days.

The increase of alkali content in dust causes a slight increase in the hydration degree of composite binders. The reason for this is an additional activation of the slag component. The increase in the specific surface area of binders from 350...380 to 580...660 m^2/kg leads to an increase in the hydration degree by 20...40%. The superplasticizer content in the binder composition reduces the composite binders' hydration degree, especially during the first time of curing. This can probably be explained by their adsorption effect.

Table 4 shows the relationship between strength and relative density of hardened composite binders. These data are consistent with the theoretical ideas proposed by Sheykin for Portland cement stone [25]. A certain contribution to the value of the relative density is brought by both the degree of hydration and W/C, corresponding to normal consistency. The value of normal consistency becomes the determining index for binders containing a plasticizer, regardless of the specific surface area.

4.2. Investigations of the influence of technological parameters for the production of composite cement-dust-slag binders (CDSB) on strength

Algorithmized experiments were implemented using the B_4 plan [28]. The influence of the content of the main components and the grinding fineness on strength was studied. As a result of the experiment, mathematical models standard mortars hardened for 2 and 28 days compressive strength were obtained.

The conditions for planning the experiments are given in Table 5. The experimental results and experimental statistical models of strength are given in Tables 6 and 7.

Analysis of polynomial models (Table 7) makes it possible to trace the clearly expressed nonlinear character of the factors effect on the composite binders' strength and to find their optimum values (Figs. 1 and 2).

The influence of such factors as the proportion of dust (X_2) and its specific surface area (X_3) on strength is extreme (Fig. 1). The influence of the specific surface area in the range of 450-500 m^2/kg (Figs. 1 and 2) is seen especially at the 2-days of hardening. The grinding of the binder using a superplasticizer does not change the character of the specific surface area effect on the strength**.** Specially performed studies (Table 8) showed that in the specified range of specific surface area, with favorable values of other factors and SP C-3 content 1...2%, the binder's normal consistency is 21...22%. When "Sika VC225" is added, the normal consistency decreases to 19...20%. It is

Table 5

The conditions for planning the experiments

Investigated factors		Variation levels			Variation interval
Natural view	Coded view	Lower (-1)	Main (0)	Upper (+1)	
1. Active filler (*F*) content in the binder composition (*F=D+Sl*), %	X_1	10	40	70	30
2. Part of the dust in the active filler composition (D_f) $Df = \frac{D}{D+Sl}$	X_2	0	0,5	1	0,5
3. S, m^2/kg	X_3	300	450	600	150
4. SP, %	X_4	0	1	2	1

Note. D is rotary kiln dust, Sl is blast-furnace slag, S – specific surface area, SP – superplasticizer C-3.

Table 6

The experimental results obtained in the influence study of the CDSB composition on the strength properties

Test No.	X_1	X_2	X_3	X_4	Compressive strength, MPa	
					2 days	28 days
1	1	1	1	1	9.4	30.1
2	1	1	1	-1	3.9	21.6
3	1	1	-1	1	6.7	20.1
4	1	1	-1	-1	2.8	14.8
5	1	-1	1	1	15.4	58.6
6	1	-1	1	-1	10.9	47.8
7	1	-1	-1	1	12.2	44.3
8	1	-1	-1	-1	9.2	36.7
9	-1	1	1	1	22.5	66.9
10	-1	1	1	-1	17.5	58.4
11	-1	1	-1	1	16.8	53.1
12	-1	1	-1	-1	13.4	47.8
13	-1	-1	1	1	24.9	72.1
14	-1	-1	1	-1	21.0	61.3
15	-1	-1	-1	1	18.7	54.1
16	-1	-1	-1	-1	16.3	46.5
17	1	0	0	0	16.9	49.8
18	-1	0	0	0	27.0	73.1
19	0	1	0	0	15.7	36.1
20	0	-1	0	0	20.2	49.7
21	0	0	1	0	19.3	55.1
22	0	0	-1	0	15.6	42.7
23	0	0	0	1	21.7	54.5
24	0	0	0	-1	17.8	46.4

Table 7

Mathematical models of strength CDSB

Strength parameters		Mathematical models	
Compressive strength, MPa	2 days	$f_2 = 21.09 - 5.4X_1 - 2.24X_2 + 1.85X_3 + 1.96X_4 + 0.88X_1^2 - 3.12X_2^2 - 3.62X_3^2 - 1.38X_4^2 - 0.88X_1X_2 - 0.75X_1X_3 + 0.13X_1X_4 - 0.13X_2X_3 + 0.25X_2X_4 + 0.38X_3X_4$	(8)
	28 days	$f_{28} = 52.6 - 11.65X_1 - 6.78X_2 + 6.22X_3 + 4.03X_4 + 8.82X_1^2 - 9.68X_2^2 - 3.68X_3^2 - 2.18X_4^2 - 5.81X_1X_2 - 0.94X_1X_3 - 1.06X_2X_3 - 0.56X_2X_4 + 0.81X_3X_4$	(9)

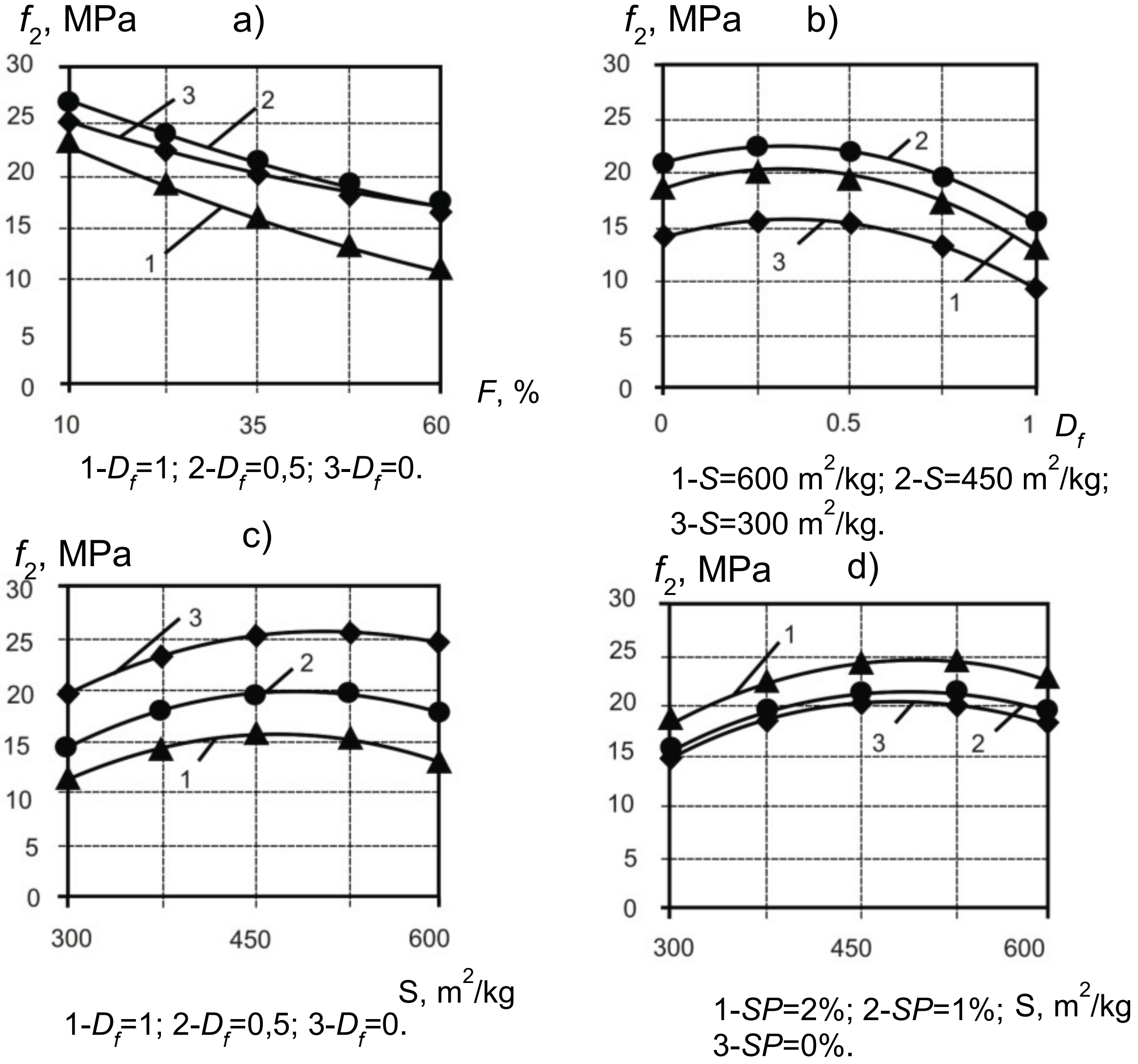

Fig. 1- Influence of varied factors (Table 5) on compressive strength of composite binder at the age of 2 days:
a) Active admixture content in the binder composition (*F, %*)
b) part of the clinker kilns dust in the active admixture composition (D_f)
c), d) binder specific surface area (S, m^2/kg)

Note: other factors are at the main level (Table 5).

characteristic that the normal consistency of binders with C-3 does not increase with specific surface area increase. This conclusion can be explained by the fact that in cement with a higher specific surface area some increase in water demand is compensated by a higher adsorption and, accordingly, water-reducing activity of the superplasticizer additive.

An increase in the dust-and-slag filler content has an ambiguous effect on the binders' strength (Figs. 1 and 2). At an early curing age, an increase of the dust content in the binder composition almost linearly reduces strength. When blast-furnace slag and a slag and dust combination are added, the strength decreases, albeit to a lesser degree. For addition of slag and dust in a ratio of 1:1 by weight and for the addition of slag alone, the strength is reduced equally. At 28-days age, the dust content increase in the binder composition from 10 to 30% reduces the compressive strength by 35%, and to 50% - by almost 2 times. For the cement with dust, strength

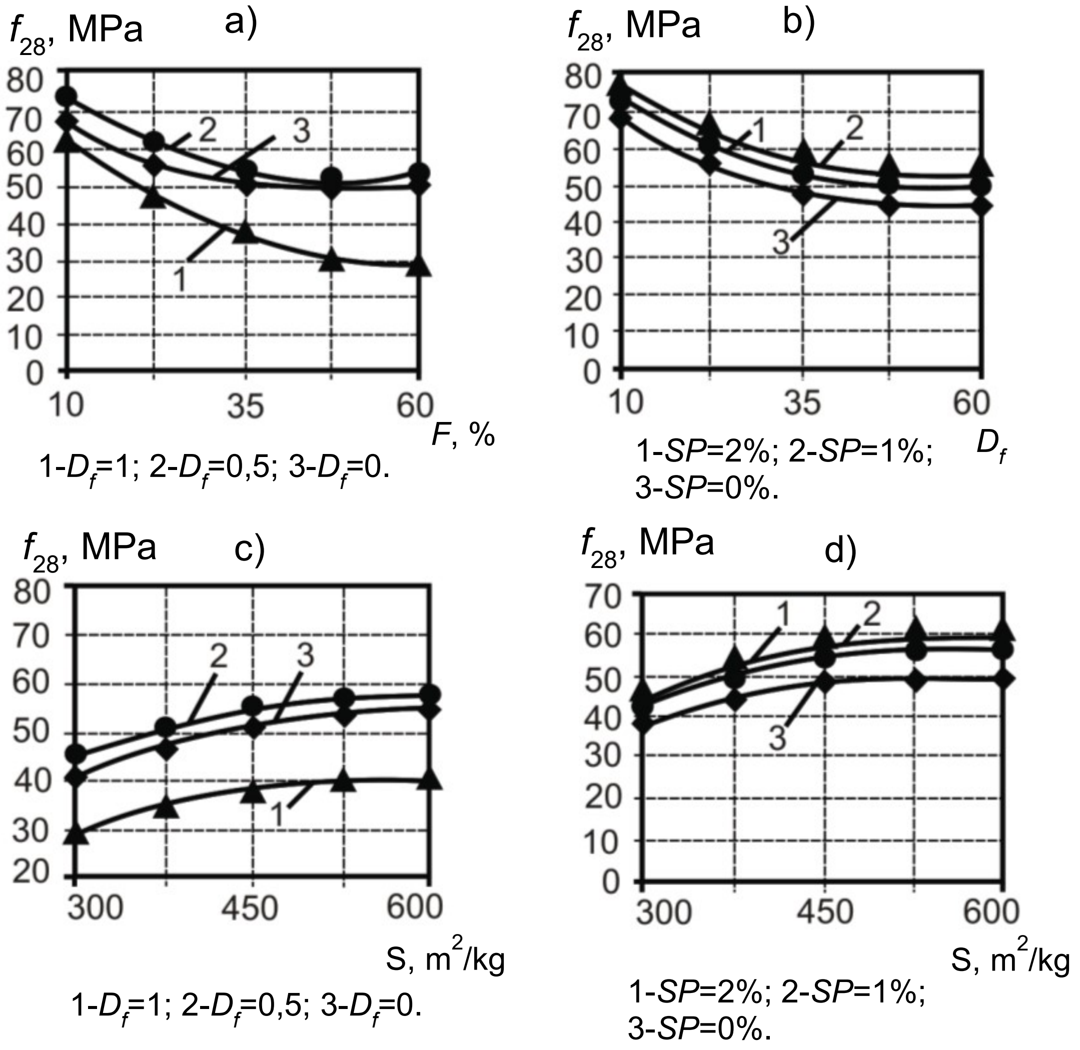

Fig. 2 - Influence of varied factors (Table 5) on compressive strength of composite binders at the age of 28 days:
a) Active admixture content in the binder composition (*F, %*)
b) part of the clinker kilns dust in the active admixture composition (D_f)
c), d) binder specific surface area (S, m^2/kg)

Note: other factors are at the main level (Table 5).

Table 8

Composite binders and mortars water demand

Test No	Binder composition,%				S, m^2/kg	Normal consistency, %	Mortar Water/Binder ratio
	Cement	Slag	Dust	Superplasticizer C-3			
1	65	-	35	-	310	32.3	0.41
2	40	-	60	-	310	36.5	0.43
3	65	-	35	1	320	28.3	0.40
4	65	-	35	2	320	27.8	0.40
5	65	35	-	-	310	27.1	0.40
6	40	60	-	-	310	28.2	0.40
7	40	60	-	1	325	22.2	0.37
8	40	60	-	2	325	21.4	0.36
9	50	25	25	-	320	29.1	0.41
10	50	25	25	1	330	22.7	0.36
11	50	25	25	2	330	21.6	0.35
12	50	25	25	1	460	21.7	0.35
13	50	25	25	1	580	22.1	0.36
14	50	25	25	0.6*	450	19.5	0.33
15	50	25	25	0.6*	590	19.8	0.33

Note. 1. The superplasticizer of polycarboxylate type Sika VC 225 was added to the binder of compositions No. 14 and 15 with milling. 2. Gypsum and superplasticizer added to the cement are taken into account over 100%. 3. The water- binder ratio of the mortar was determined with the standard cone flow 115 mm.

Table 9

Composite binders strength with the addition of superplasticizer Sika VC225

№ п/п	Binder composition, %				S, m^2/kg	Strength, MPa					
						flexural, day			compressive, day		
	Cement	Slag	Dust	SP «Sika»		2	7	28	2	7	28
1	50	25	25	0,3	320	3.8	4.7	5.6	28	36	42
2	50	25	25	0,3	450	4.7	5.8	6.5	31	44	58
3	50	25	25	0,3	580	5.1	6.3	7.1	39	51	64
4	50	25	25	0,6	320	4.8	5.7	6.4	35	43	56
5	50	25	25	0,6	450	5.9	6.8	7.5	49	61	72
6	50	25	25	0,6	580	6.2	7.1	7.9	51	63	75
7	50	25	25	0,7	450	6.0	6.9	7.7	50	62	73

Note. 1. Gypsum and superplasticizer, introduced into cement, are taken into account over 100%. 2. The binder/sand ratio was 1:3 by mass

Table 10

Influence of alkali and free lime in kiln dust on the CDSB strength

Sample of dust (table 1)	Content SP	Specific surface area, m^2/kg	Strength, MPa					
			flexural, days.			compressive, days.		
			2	*7*	*28*	*2*	*7*	*28*
R_2O=2.9, CaO_f =3.1%. (sample 1)	C-3-1%	450	3.4	5.9	6.2	16.9	35.2	49.8
	C-3-2%	450	3.5	6.1	6.5	17.6	36.4	51.6
	Sika-0.6%	450	5.9	6.8	7.5	49.0	61.0	72.0
R_2O=4.9, CaO_f =4.2%. (sample 2)	C-3-1%	450	3.6	6.5	6.9	18.6	39.4	53.3
	C-3-2%	450	3.8	6.7	7.1	19.6	39.7	55.7
	Sika -0.6%	450	6.3	7.2	7.8	51.0	63.0	74.0

sharp decrease is explained by the increase its water demand (Table 8). An increase of the dust-slag admixture content (in the ratio of dust: slag 1:1 by weight) from 10 to 50% causes a reduction in strength by about 30%. Increasing the content of slag admixture in the same range affects the strength also (Figs. 1 and 2). An increase in the dust content from 0 to 50% in the dust-and-slag binder practically does not cause an additional reduction in strength.

The reduction of the water demand by adding a superplasticizer and the increase of binders' specific surface area, lead to the significantly increase of their strength. Cement grinding with a kiln dust admixture of 50-60% and addition of C-3 superplasticizer to a specific surface area of 450-500 m^2/kg makes possible an increase of the compressive strength from 30 to 40 MPa. Under the same conditions (with a content of 50-60% of complex admixture dust - blast-furnace slag in the ratio 1:1 by weight), it is possible to obtain a binder with a compressive strength of 50-60 MPa for 28 days (Table 10, Figs. 1 and 2).

Replacement of the naphthalene formaldehyde superplasticizer with polycarboxylate determines an increase of the binder strength to 70 MPa (Table 9) when the content of the complex dust-slag admixture is 50%. The favorable effect of Sika is clearly visible also, in Table 10.

The resulting composite binders are fast-hardening. The strength of binders at the age of 2 days is more than 50% from the 28 days strength. The ratio of compressive strength to flexural strength for optimal compositions is within the usual limits typical for Portland cement.

As is known, the composition of dust may change the content of alkaline compounds and free CaO. These compounds were determined to have an effect on the CDSB strength. The content of dust and granulated blast-furnace slag in the optimal ratio established earlier. For this additional experiments were carried out. The dust of sample 2 (Table 1) containing an increased amount of alkali oxides R_2O (4.9%) and free CaO (4.2%) was used in the experiments. The binder was composed of cement and 60% dust and slag in a ratio of 1:1. The results of the experiments are given in Table 10.

As results by these data, a slight increase in the content of R_2O and CaO_f in dust causes a slight tendency to increase the strength parameters of composite binder with low water demand. This is due to the additional activation of the slag component, by these oxides.

5.Conclusions

1. Cement-clinker kilns dust can be used as an active component in composite binders, including Portland cement, dust, granulated blast-furnace slag and superplasticizer.

2. The hydration degree of three-component binder (cement-dust-slag) is of 1,5-2 times higher than that of the two-component binder (dust-slag). An increase in the dust of the alkalis content leads to some increase of composite binders' hydration degree due to the additional slag component activation. The increase of the binders specific surface area from 350-380 to 580-660 m^2/kg leads to an increase of hydration degree by 20-40%. The superplasticizer presence

in the binder composition reduces the composite binder's hydration degree, especially in the first days of hardening.

3. The optimum ratio between dust and blast furnace slag in low water demand cement-dust-slag binder (CDSB), obtained by co-grinding of the initial components, has been established. In the binder composition with 50-60% mineral admixture the optimal ratio of dust and blast furnace slag is approximately 1:1 by weight. The optimal value of CDSB specific surface area is 450-500 m^2/kg. The addition of a superplasticizer during grinding does not change the effect character of the composite binders' specific surface area on their strength.

4. When using superplasticizer naphthalene-formaldehyde type, the binder of optimal composition strength is 50-60 MPa, the polycarboxylate type - up to 70 MPa. An increase in dust of alkaline oxides up to 4.5% and free lime up to 4% contributes to the increase of the CDSB strength. Cement-dust-slag binders with low water demand are fast- hardening, their 2-days strength is more than 50% of the 28-days strength.

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