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EFFECT OF THE "POZZOLIT" ACTIVE MINERAL ADMIXTURE ON THE PROPERTIES OF CEMENT MORTARS AND CONCRETES PART 1: PHYSICAL AND MECHANICAL PROPERTIES

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ABSTRACT

The results from investigations on the physical and mechanical properties of cement mortars and concretes containing the active mineral Pozzolit admixture are presented in this paper. The basic components of this admixture are silica fume (SF) and low calcium content fly ash (FA). The compressive and flexural strength and modulus of elasticity of cement mortars and concretes containing Pozzolit have been determined as well as the water- and gas permeability. The results have been compared with corresponding parameters of cement mortars and concretes without mineral admixture or with only one component - either silica fume or fly ash. It has been established that the Pozzolit active mineral admixture contributes not only to overcome the technological difficulties encountered in the process of silica fume delivery in cement mortars and concretes but also to improve cement stone strength and resistance.

Introduction

The active mineral admixtures (fly ash from thermal power generation plants, silica fume, granulated blast furnace slag, a.o.) are extensively used as components of blended cements for various mortars and concretes. Silica fume (SF), a by-product from the ferro-silicon production, is one of the most effective admixtures and is used on a worldwide scale in high-strength and corrosion-resistant concretes (1,2).

The utilization of silica fume however, is accompanied by serious difficulties, which restrict its wider application in building construction in Bulgaria. The low bulk density (250-350 kg/m^3) and fineness of SF are a source of problems in its delivery, storage, transport and dosage in cement mortars and concretes. The enumerated obstacles and the relatively high cost of SF were the reasons to develop the Pozzolit active mineral admixture (Pz), which preserves the valuable qualities of SF, avoiding to a considerable degree its disadvantages. The basic components of the admixture are silica fume (SF) and processed pulverized fuel ash (FA). The admixture has twice as high bulk density (500-600 kg/m^3) compared to SF and can be easily transported, stored and delivered similarly to cement in mortars and concretes without the need of any additional technological operations (suspensioning and pelletizing) or special equipment as is the case with SF.

TABLE 1
Chemical Analysis of Cement and Mineral Admixtures

Contents, %	Portland Cement PC35A20	Silica Fume	Fly Ash
Silicon dioxide SiO_2, %	26.10	93.12	56.28
Aluminium oxide Al_2O_3, %	4.20	1.09	22.29
Ferric oxide Fe_2O_3, %	3.19	1.79	8.32
Calcium oxide CaO, %	60.70	0.62	3.00
Magnesium oxide MgO, %	0.50	0.54	1.86
Sulphur trioxide SO_3, %	2.10	0.85	0.31
Sodium oxide Na_2O, %	0.78	0.05	1.00
Potassium oxide K_2O, %	0.59	0.43	2.43
Loss of ignition, %	2.14	1.65	2.85

A number of works treating the problem of the use of silica fume, fly ash and superplasticizers in concrete has been published recently. The investigations of Mehta (4), Ronne (5), Austin (6) and especially the report of D.Roy (7) on the hydration of cement containing silica fume or fly ash, prove that the application of these materials considerably improves the properties of blended cements and concretes. The purpose of this work is not to consider separately the properties and behaviour of silica fume and fly ash in concrete but to apply another approach, regarding a complex additive with properties and effect of its own, different from these of its ingredients - namely the Pozzolit admixture.

Materials and Methods

Ordinary Portland cement PC 35 (15% of granulated blast furnace slag), silica fume (a by-product from the ferro-silicon steel production in the "Kremikovtsi" Metallurgical Plant (Bulgaria) and classified fly ash (class F) from the "Bobov Dol" Thermal Power Generation Plant (Bulgaria) were used in the present investigation.

The chemical composition of materials is presented in Table 1 and Table 2 shows the data from sedimentation analysis and specific surface measurements of SF and FA.

The coarse aggregate used in concrete was crushed stone with maximum grain size of 20 mm and the filler was sieved river sand. The aggregates were used in an air dry condition.

A liquid melamine based superplasticizer BP-1 containing 30% of dry substance was used to improve the workability of the mixes.

TABLE 2
Sedimentation Analysis and Specific Surface of the Mineral Admixtures

Fractions in mm	Silica Fume, %	Fly Ash, %
over 0.1	0.6	1.90
0.1 - 0.05	3.2	14.00
0.05 - 0.02	3.2	15.00
0.02 - 0.01	4.0	2.90
0.01 - 0.001	32.0	66.20
under 0.001	57.0	-
Specific surface according to BET, m^2/g	19.2	2.83

Compositions, Samples and Methods of Investigation.

A. Cements. The studied cement mortars had equal consistency (determined according to the flow table test) and the quantity of the chemical admixture BP-1 was 0.5% dry substance of the mass of cement. The active mineral admixtures (SF, FA and Pozzolit) replaced 5 to 25% of the mass of cement respectively.

The cement strength characteristics were determined on 100 × 100 × 400 mm mortar prisms cured under water at a temperature of 20 ± 2°C till the day of testing. The structure of pore space was determined on pieces from mortar prisms after the compressive strength tests. Porosimetric investigations were performed at the 28th day of hydration on a MIP "Carlo Erba" 1500.

The gas permeability was measured according to the CO_2 gas steady filtration, each measurement being carried out for three different levels of pressure under a linear regime of filtration, taking under consideration the effect of Klinkerberg, typical for gas filtration in capillary media. The tests were conducted by means of an equipment, similar to GK-5 (Russia). The samples for the gas permeability tests were cylinders with a diameter and height of 30 mm, three samples being used in each series. They were remoulded at the 24th hour and cured under water at a temperature of 20 ± 2°C till the age of testing. The samples were preliminary dried to constant mass at a temperature of 60°C before testing.

B. Concretes. The compositions of the investigated concretes are presented in Table 3. All concrete mixes contained equal quantities of cement and had a slump (S) of 12 cm. The BP-1 superplasticizer was added in the amount of 1% dry substance of the mass of cement.

The compressive strength was determined by testing of 100 mm cubes and the flexural strength and modulus of elasticity - by testing 100 × 100 × 400 mm prisms. The water permeability and the tensile strength were determined by splitting 150 × 150 mm cylinders.

The test specimens were cured for 24 h under air dry conditions at a temperature of 20 ± 2°C and after remoulding - for 7 days in water (20 ± 2°C). The test specimens were then cured under air conditions at a temperature of 20 ± 2°C and a relative humidity of 65 ± 5%, except for the water permeability samples which were taken out of the water 2 days before testing, kept under air conditions for 1 day, inserted in metal cylinders and sealed by molten bitumen. Concrete cubic specimens (100 mm) were thermally cured under the following conditions: 2 h of normal curing, 4 h of temperature rise up to 80°C, 2 h of curing at 80°C and 10 h of cooling. These specimens were tested at the 1st and 28th day of strength development.

Water permeability of concretes was determined by measuring water penetration under the initial pressure of 0.1 MPa, the pressure being raised to 0.8 MPa subsequently. The depth of penetration was determined after splitting the test samples.

TABLE 3
Composition of Concretes

Materials, kg/m^3	Reference concrete sample	Concrete with BP-1 super-plasticizer	Concrete with SF	Concrete with Pozzolit
Cement,	410	410	410	410
SF	-	-	41	-
Pozzolit	-	-	-	41
Sand	685	705	610	615
Crushed stone,	1060	1065	1095	1105
BP-1	-	13.5	13.5	13.5
Water	220	191	166	167

TABLE 4
Normal Consistency and Setting of Cements

No	Composition	Normal consistency, %	Beginning of setting, h - min	End of setting, h - min
1	PC35-A20	25.6	2 - 30	3 - 30
2	PC + 5% SF	25.6	2 - 20	3 - 20
3	PC + 10% SF	26.2	1 - 50	3 -45
4	PC + 5% FA	25.6	3 - 00	4 - 35
5	PC + 10% FA	25.3	3 - 15	4 - 40
6	PC + 5% Pz	25.6	2 - 45	5 - 10
7	PC + 10% Pz	26.2	2 - 30	5 - 00

The investigations were carried out in the Building Research Institute and in the University of Mining and Geology - Sofia, Bulgaria, in the period 1991-1994.

Results and Discussion

A. Cements. The results from the normal consistency tests and setting times of the investigated cements are presented in Table 4.

TABLE 5
Strength Characteristics of Cement Mortars

Admixture	%	Compressive strength, MPa for days					Flexural strength, MPa for days				
		1	3	7	28	60	1	3	7	28	60
100 % PC 35A20	-	7.0 100	19.4 100	33.3 100	44.1 100	48.7 100	1.8 100	4.9 100	7.0 100	8.2 100	9.0 100
SF	5	11.2 160	24.6 127	38.2 115	48.5 110	54.2 111	3.2 178	5.6 114	7.7 110	8.8 107	9.5 106
Pz	5	10.3 147	28.3 146	41.2 124	53.8 122	59.1 121	3.0 167	6.2 127	7.8 111	9.7 118	10.3 114
SF	10	7.8 111	22.8 118	34.5 104	51.5 117	55.2 113	2.2 122	5.3 108	7.0 100	9.9 121	10.1 112
Pz	10	10.4 149	27.6 142	40.9 123	52.5 119	59.9 123	3.0 167	6.1 124	7.4 106	10.0 122	10.5 117
SF	15	7.7 110	19.3 99	39.5 119	54.6 124	56.9 117	2.2 122	4.6 94	5.3 76	9.8 120	10.6 118
Pz	15	11.9 170	26.1 135	39.4 118	56.2 127	62.5 128	3.1 172	5.5 112	6.9 99	9.4 115	11.2 124
SF	25	10.6 151	25.3 130	36.9 111	57.7 131	64.1 132	2.7 150	5.4 110	7.2 103	10.3 126	10.8 120
Pz	25	8.1 116	19.3 99	34.5 104	49.3 112	56.3 116	2.3 128	4.8 98	7.0 100	10.0 122	10.2 113

The mineral admixtures do not exert substantial effect on the normal consistency of the mixed cements. Cements containing 10% of silica fume exhibit earlier beginning and retarded end of setting, which is explained by the high pozzolanic activity of this admixture. As expected, cements containing fly ash show retarded beginning and end of setting. Cements containing Pozzolit do not change the beginning but display considerably retarded end of setting.

The strengths of the investigated mortars are presented in Table 5. The comparison of the strength parameters shows that the strength values of cement mortars containing SF and Pozzolit admixture exceed the corresponding ones for plain mortars and this is especially well expressed at early ages. The application of the Pozzolit active mineral admixture leads to 28th day strengths by 20-30% higher than these of the reference samples. The comparison between the compositions containing SF and Pz shows that cement mortars containing up to 15% of Pozzolit have higher strengths than silica fume containing mortars at all ages of hydration. Mortars with silica fume quantity greater than 25% possess higher strengths than Pozzolite containing mortars.

The alteration of gas permeability of cement mortars without and with Pozzolit admixture is presented in Fig. 1. The gas permeability of mixed cement mortars is lower than that of the reference sample, the reduction being more considerable at the early ages. Gas permeability values of mortars containing 10 and 25% of Pozzolit do not differ substantially.

Pore size distribution of cement mortars is shown in Table 6. Totally, the specific pore volume of Pozzolit containing mortars is higher than the reference one, but the compositions with admixture exhibit a shift in pore size distribution towards the pores of smaller diameters. A similar effect on pore structure is observed in the case of silica fume addition (3).

B. Concretes. The workability of concrete mixes is considerably improved by the combined action of chemical and mineral admixtures. The combination of a superplasticizer and a mineral

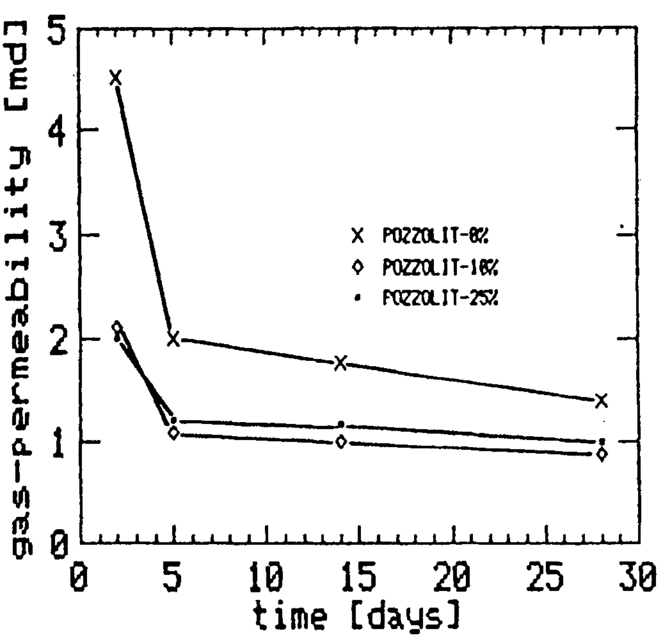

FIG. 1.
Alteration of gas permeability of cement mortars without and with Pozzolit.

TABLE 6
Pore Size Distribution of Cement Mortars without and with Pozzolit

Composition No	Pore content (%) in the radius range, μm				Specific pore volume, cm^3/g
	r < 0.01	0.01 < r < 0.1	0.1 < r < 1	r > 1	
1. no admixture	29.70	55.20	11.80	3.30	0.234
2. 10 %	28.40	56.20	12.70	2.70	0.248
3. 15 %	32.00	54.10	11.20	2.70	0.287
4. 25 %	32.20	53.16	10.70	4.00	0.293

admixture is desirable, since mineral admixtures (silica fume in particular) in the amount exceeding 5% from the mass of cement considerably increase the fine fraction volume and hence the water requirement of the binder.

The strengths of the concrete mixes are presented in Table 7. The data show that the compressive strengths of silica fume and Pozzolit containing concretes at the age of 28 and 180 days are practically the same and are higher than the corresponding strengths of the reference plain concrete (without chemical and mineral admixture) by 50 and 40% respectively. At the age of 7 days the strength of the Pozzolit containing concrete exceeds already the strength of all other compositions.

The 28th day flexural strengths of concretes with mineral admixtures are merely the same and are by about 30% higher than the corresponding strengths of concretes without chemical and mineral admixtures.

TABLE 7
Properties of Concrete

Property	Reference	Concrete with BP-1	Concrete with silica fume	Concrete with Pozzolit
Compressive strength, MPa/%				
normal curing,				
7 days	25.6/100	34.6/135	36.4/142	47.6/186
28 days	38.7/100	46.9/121	58.8/152	59.3/153
180 days	53.0/100	59.0/111	74.0/140	75.0/142
thermal curing,				
1 day	20.4/100	30/147	36.3/178	36.9/181
28 days	35.7/100	41.9/117	45.6/128	47.8/134
Flexural strength, MPa/% 28 days	5.4/100	5.9/109	6.7/124	7.0/130
Split tensile strength, MPa/% 28 days	2.5/100	2.8/112	3.3/132	3.3/132
Water permeability, cm	10.0	3.5	1.5	1.5
Modulus of elasticity, MPa 28 days	26900	27500	28200	28500

It should be noted that the effect of SF and Pz addition is greater in concretes than in mortars, which is possibly due to the formation of a more homogeneous and dense contact zone between the aggregate grains and the binding substance in concrete.

The values of the modulus of elasticity of mineral admixture containing concretes are almost equal. Water permeability exhibits also similar values. This is explained by the higher strengths and more dense structure of concretes with active mineral admixtures.

Conclusions

1. The technical characteristics of the investigated materials containing Pozzolit are analogous to those with SF, but the Pozzolit admixture possesses a number of technological advantages, its behaviour being similar to that of micropeletized SF.
2. Cements with Pozzolit admixture exhibit strengths by 20-30% higher than these of the reference samples as well as lower gas permeabilty and increased content of pores of smaller radius.
3. The application of Pozzolit in concretes in combination with superplasticizers improves the workability of concrete mixes, increases strength by up to 50% (compared to the reference composition), increase the modulus of elasticity and water impermeability.

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