THE INFLUENCE OF FLY ASH ADDITION (OF CET GOVORA ORIGIN) ON SOME PROPERTIES OF CONCRETES

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This present paper provides information regarding the influence of fly ash additions (ranging between 20% and 70%) on the properties of portland cement CEM I 52,5 R concrete.The fly ash provenience was Govora thermal power plant.

The concretes manufacturing with high mechanical strengths and good durability, is possible by controlling the water/binder ratio (lowest possible values).

To achieve a low water/binder ratio, at the preparation of concrete mixtures, it was added a polycarboxylate type superplasticizer.

The influence proportion fly ash, associated with superplasticizer, on the properties of fresh concrete was pointed out by using the slump method, for consistency determinations.

The performances of hardened concretes, containing different proportions of fly ash, associated with polycarboxylic superplasticizer additive, were assessed by the mechanical strengths and the freez - thaw resistance.

Keywords: fly ash, polycarboxylic type superplasticizer, concrete, mechanical strengths, freeze - thaw resistance

1. Introducere

For more than 30 years, there is a worldwide concern regarding the use of secondary resources and the recycling of wastes in order to preserve natural resources, to protect the environment and the population’s health.

Both in Europe and on the other continents, the research programs have been initiated and conducted regarding the possibilities of recycling wastes from different fields of industrial activity.

An important waste, both in terms of quantity as well as reusability, is the fly ash.

Fly ashes are powdery wastes derived at coal burning in thermal power plants. Due to the oxide composition and hydraulic properties, the fly ashes can be capitalized in the binders’ field, with economical, ecological and technical effects. By partially replacing cement in concrete, the fly ash determines the reduction of

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of concrete price, and through its consumption large areas of land occupied by fly ash dumps are free.

Some properties of composite materials of mortar or concrete type, derived from binders containing fly ash, can be improved [1-7]. Associated with portland cement, fly ash, through pozzolanic reaction with the calcium hydroxide produced by the cement hydration-hydrolysis, contributes to the improvement of corrosion resistance of the derived composite materials. But, due to the grains high finesse, the fly ash affects the workability of concretes prepared with a certain water/binder ratio [4]. Through fly ash association with an superplasticizers, the water/binder ratio can be removed. This association is practiced worldwide, in concrete technology, with significant results for performance of such concretes [8-16].

Present paper brings information regarding the evolution of the properties of concretes based on binders in which cement has been progressively substituted with fly ash (20-70%). Also, it was used a polycarboxylic type superplasticizer.

2. Experimental

To study of fly ash's influence on the main properties of concrete, where used portland cement CEM I 52,5 R, F type fly ash, of Govora thermal power plant, characterized by a BET specific surface area of 2642 m2/g and indices of activity: 108.8% - at 28 days and 112.7% - at 90 days. The used aggregate had d_{max} = 16 mm, and is a river aggregate.

The used polycarboxylic type superplasticizer, has been a solution with 21.5 ± 1% concentration and has been dosed in proportion of 0.9% of binder mass. This value was considered optimal based on previous research [17, 18].

For prepared concretes, the cement was replaced progressively with fly ash, the proportion ranging between 20-70%.

As references, concretes free of fly ash and without superplasticizer additive (noted B1) and with 0.9% superplasticizer (noted B2), were prepared.

For each concrete composition containing fly ash (water amount was kept constant), the consistency was determined by the slump method according to EN 12350-2:2009 [19]. These property was determined also for the reference concrete free of fly ash. Thus was emphasized the influence of fly ash, presence on the concrete's consistency.

The influence of fly ash presence on the mechanical strengths of concretes, was evidenced by the compressive strengths determination on cubic specimens with size of 150 mm, cured for hardening for 7, 28 and 90 days, according to EN 12390-3: 2009 [20].

The considered concretes were tested for water permeability (property directly correlated to freeze - thaw resistance) was performed on same cubic specimens, hardened for 28 days. The samples were subjected to water at a pressure of 8 atmospheres for 72 hours, according to EN 12390-8:2009 [21]. Freeze-thaw resistance of concretes was estimated by determinations of mechanical strength on specimens of the same type as the above, hardened for 28 days and subjected to 100 freeze-thaw cycles, according to SR 3518:2009 [22]. The samples were cured in water throughout the entire the entire period of the 100 freeze-thaw cycles [4 hours at (-17 ± 2) ° C and 4 hours at (20 ± 2) ° C].

The compositions of the studied concretes are presented in Table 1.

Table 1

Concrete composition

Concrete code	Binder's component				Aggregates (kg/m^3)	Water volume (l/m^3)	Super-plasticizer (%)	w/b ratio
	Cement		Fly ash					
	%	Kg/m^3	%	Kg/m^3				
B1	100	350	0	0	1850	224	-	0,64
B2	100	350	0	0	1850	166	0,9	0,48
B3	80	280	20	70	1850	166	0,9	0,48
B4	70	245	30	105	1850	166	0,9	0,48
B5	50	175	50	175	1850	166	0,9	0,48
B6	30	105	70	245	1850	166	0,9	0,48

3. Results and discussions

3.1 Fresh concrete properties

For B2 reference concrete, the polycarboxylic type superplasticizer presence, decreases the mixing water with 25.9% as compared to the B1 concrete, (without additive), improving the workability of fresh concrete. The water/binder ratio was decreased from 0.64 to 0.48, at the same workability (slump S3 = 150 mm).

During the preparation of concretes, no segregation phenomenon was observed

This behavior is the consequence of the superplasticizer's action, a higher water reducer, which does not allows the grains agglomeration and determines a better dispersion of binder particles into the liquid phase [23, 24].

This effect of superplasticizer is due to the adsorbtion of polycarboxylic substances on the surface of cement particles. The carboxylate ions give to cement particles, negative charge, so the electrostatic repulsion between cement particles appear, resulting the inhibition of cement paste cohesion tendency (DLVO theory), increasing the cement particles and water contact area [24].

The increase of fly ash proportion in concrete mixtures, to 70 %, thus the decrease of cement proportion, has a negative influence on the workability of concretes, decreasing the slump from 150 mm to 20 mm (Figure 1). For proportions higher than 30% of fly ash, the workability loss is considerable, attaining to 90 ÷ 130 mm. Lower proportions of fly ash (20-30%) cause less significant losses of workability, compared with the reference concrete (10-20%).

This behavior can be explained by the fly ash finesse, much higher than cement finesse, fly ash is acting as filler of the spaces between cement grains, and reduces the concrete workability prepared with a certain water/binder ratio [25].

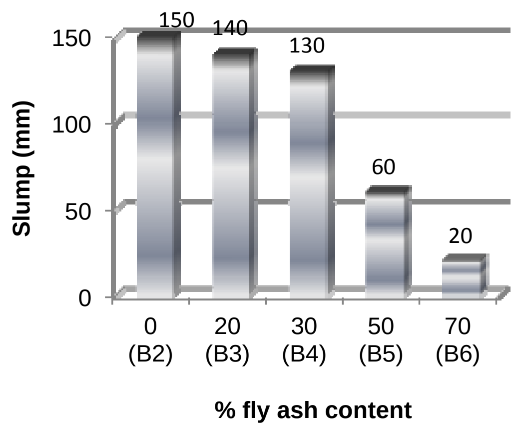

Fig. 1 The influence of fly ash on concrete's workability (slump); the association of the superplasticizer with fly ash additions has contributed to a better cohesion of the fresh concrete components in conjunction with its better workability.

The association of the superplasticizer presencewith fly ash additions induces a better cohesion of the fresh concrete components, thus better workability.

3.2 Hardened concrete properties

The influence of fly ash proportion, the presence of polycarboxylic superplasticizer additive, on the development of concrete's mechanical strengths is presented in Figure 2.

For all concrete compositions, mechanical strengths increases in time due to the binder's hydration processes. Strength values, for 7-90 days hardening period, are higher for concretes from binders with 20-50% fly ash content. These values are higher than those of, concrete without fly ash (B2). To these increases of mechanical strengths at long periods of hardening, also contributes, the pozzolanic reaction of the fly ash. The reaction rate is low, with the formation of calcium silicate hydrates, which contribute to the formation of the strength hardening structure, [26, 27].

These secondary calcium silicate hydrates, together with the primary calcium silicate hydrates (formed by hydration of portland cement), partially fill the capillary pores, thus decrease the overall porosity of the formed hardening structure [28].The used cement have a high hydration reaction heat, thus determines the increase of the concrete's temperature, which favors fly ash reactivity. In this way, the significant increases of strength for the concretes with fly ash content, even at 7-28 days, can be explained.

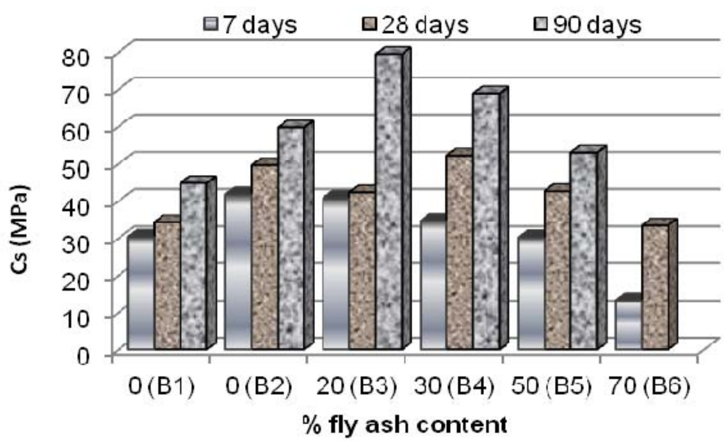

Fig. 2 The influence of the fly ash proportion on the development of mechanical strengths

The two components of the binding system – portland cement and fly ash – are influenced each other in the hydration processes: the very active cement (I 52,5R), by its high hydration heat activates the pozzolanic reaction of fly ash with calcium hydroxide. The $Ca(OH)_2$ consumption, induces the rapid cement's hydration (according to Le Chatelier-Braun principle).

The influence of fly ash addition on mechanical strengths, is correlated with its proportion in concrete. Thus, additions of 20-30% fly ash do not generally affect, the mechanical strengths of concrete, which are even higher for 90 days of hardening in comparison with the reference concrete (due to the filler role of fly ash in concrete). Proportions of fly ash higher than 30%, affect the mechanical strengths of concrete, these being smaller for all considered hardening periods, due to the "dilution" effect of the binder, by the important decrease of the active component - portland cement.

The influence of the superplasticizer additive on the development of mechanical strengths is obviously, by comparing of B2 and B1 concretes. The B2 concrete with superplasticizer additive has a better mechanical behavior, for all hardening periods. To these strength increases contributes also the lower water/binder ratio (0.48) in the concrete with additive, compared with that of the concrete without additive (0.64).

The results of the water permeability determination for the studied concretes are presented in Figure 3. Figure 3 emphasized the role of superplasticizer additive and the fly ash, upon water permeability of concrete. The added superplasticizer in B2 concrete, in amount of 0.9%, induced a significant diminution of permeability with approximately 50% in comparison with the concrete without additive (B1).

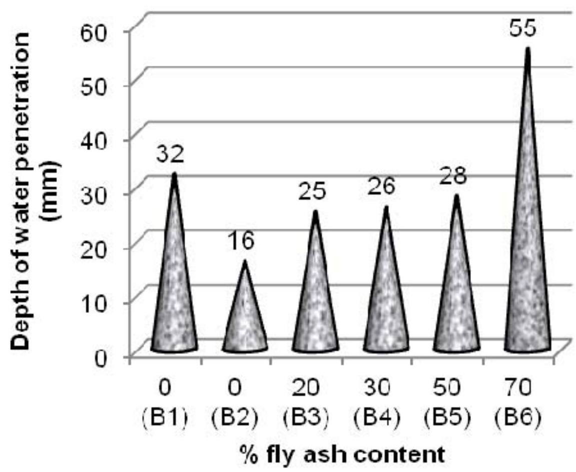

Fig. 3 The influence of fly ash proportion on water permeability of hardened concrete

The concretes with 20-50% fly ash showed similar values of depth of water penetration - 25 ÷ 28mm – this being with about 39% higher than for the reference concrete, with additive - B2 and with about 18% lower than for the concrete without additive - B1. The concrete with 70% fly ash in the binder mass had the highest permeability value. This result is explained by the strong influence of binder"dilution" portland cement representing only 30%.

The freeze-thaw resistance (after 100 cycles) of concretes with 20 and 30% fly ash, which developed the best mechanical strengths at hardening in normal conditions, is presented in Figure 4. As reference, was considered the B2 concrete

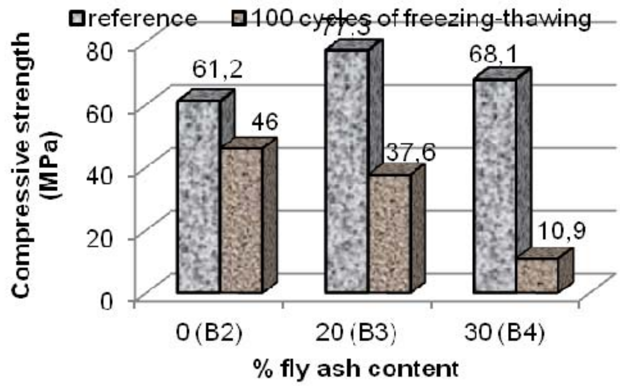

Fig. 4 The influence of the fly ash proportion on the concrete strength after 100 repeated freezing-thawing cycles.

It can be observed that concretes with fly ash showed the higher strength losses after repeated exposure to freeze-thaw, as compared with the reference concrete without fly ash. The greatest strength loss - 84%, was recorded for concrete with 30% fly ash, while the concrete with 20% fly ash the loss was of 51.4% and for the reference concrete it was of only 24.8%.

The higher strength loss by freeze-thaw of the concrete with fly ash content are explained by the stopping of the pozzolanic reaction of fly ash in freezing conditions, the repeated freezing having a cumulative effect [26].

The reference samples, regarding to which the strength losses were calculated, have continued to hydrate, including with the participation of fly ash. The total duration of their hardening has been of 65 days. Comparing the mechanical strengths developed by these samples with those determined for 90 days of normal hardening (Fig. 2), there can be ascertained that the values are very close, for the B3 and B4 concrete compositions. This confirms the fly ash contribution to the development of the strength for these hardening periods.

It can be observe a good correlation between the freeze-thaw resistances of concretes with 20% and 30% fly ash respectively and of the reference concrete B2, with their water permeability: great losses of freeze-thaw resistances correspond to higher values of water permeability.

4. Conclusions

- The polycarboxylic type superplasticizer presence induces a decrease of mixing water with 25.9% (concrete B2) compared to a concrete without additive (B1), for the same workability. Accordingly, the water/binder ratio, decrease from 0.64 to 0.48, without change of the consistency. This is explained by the role of dispersant of the superplasticizer additive, which prevents the flocculation of fine particles of cement.

- The substitution of cement with low proportion of fly ash (20-30%) favored the development of high mechanical strengths. The two components of the binding system – Portland cement and fly ash – are influenced each other in the hydration processes: the very active cement (I 52,5 R), by its high hydration heat activates the pozzolanic reaction of the fly ash with calcium hydroxide. The $Ca(OH)_2$ consumption, induces the rapid cement's hydration (according to Le Chatelier-Braun principle).
- Higher proportions of fly ash (50-70%) negatively affect the mechanical strength of the concrete, for all the considered hardening periods, due to the "dilution" effect of the binder through the significant decrease of the active component – portland cement, thus the hardening strength structure do not longer develop.
- The concretes with 20-50% fly ash content showed similar values of water penetration depth – 25÷28mm, these being with approximately 39% higher than for the reference concrete with additive - B2 and with approximately 18% lower than for the concrete without additive - B1. The effect of binder's "dilution" concretized especially for the concrete with 70% fly ash, by a permeability of about 4 times higher than the reference concrete, in good correlation with the very low mechanical strengths of this concrete.
- The stopping of the pozzolanic reaction by repeated freezing (associated with thawing), explains the great loses of strength for the concretes with 30% fly ash - 84% for B4 and 51.4% for B3 - compared to 24.8% for the reference concrete.

Based on the presented results, it can be ascertained that an addition of 20% fly ash,to a cement CEM I 52.5 associated with a polycarboxylic superplasticizer additive does not affect the main properties of the composite material, of concrete type, even ensuring some improvements of them.

Acknowledgements

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