

Studies for understanding effects of additions on the strength of cement concrete

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Abstract. The paper analyzes the effects of different types of additions introduced in concrete mix on the compressive strength. The current studies show that additions contribute to improve some characteristics of concrete and to reduce the cement dosage, so it can obtain concretes which are cheaper and friendlier with environment. In the experimental mixes were introduced: crushed natural aggregates, slag aggregates, silica fume, fly ash, chopped tire, polystyrene granule, glass fibers and metallic fibers. The experimental values of compressive strengths were compared for two concrete grades (C20/25 and C25/30). The study shown that near the well-known possibilities of improving mechanical strengths of cement concrete by increasing cement dosage and strength, by using crushed aggregates and by reducing the water/cement ratio, there are other methods in which less cement is used by replacing it with different wastes or by adding fiber.

1. Introduction

In construction industry one of the most used materials is concrete, which, in the last decades has improved its mechanical and durability properties due to its versatility of combining with different materials. The properties of cement concrete can be improved in different ways, which can contribute to preserving the natural resources and to the consumption of wastes that are polluting the environment. The researchers have replaced parts or totally the cement or even the aggregates with other materials (by-products, polymers, wastes, etc.) [1, 2, 3, 4, 5]. Also in the composition were added powders, fibers, nano-materials, etc., and so new eco-friendly concretes were developed. Some additions such as silica fume, fly ash, fibers, rice husk, etc. had contributed to obtaining high strength and high performance concretes [6, 7, 8, 9, 10, 11].

Concrete properties depend on a lot of factors, such as: components, admixtures, pouring technology, treatment after pouring, etc. [12, 13, 14, 15]. The influence of different components on the properties of cement concrete is studied for new concretes because each material has its own effect in the mix and each depends on a lot of factors. For the application domain of concrete with additions preliminary studies must be done for characterizing and recommending the specific use.

Generally, the constructions realized of concrete do not require all performing characteristics. A concrete with high strength can be realized by using active additions. The influence of additions



wastes on concrete properties was analyzed in the paper for two grades of concrete with cement. It must mention that each result represents the best value obtained from an experimental study made separately for each type of concrete sample [16, 17, 18].

Experimental program

The samples from the experimental study were realized of three types of aggregates (river, crushed and slag), different types of cement and with/ without additions (fly ash, silica fume, chopped tire, polystyrene granule, glass fiber or metallic fibers). All additions are wastes which pollute the environment. An admixture type superplasticizer was used for all mixes.

1.1. Series 1- Concrete grade C20/25.

The samples for the first grade of concrete C20/25 were prepared with different cements type: Pa32.5, (concrete sample A1 and A2, with different dosages), P40, (concrete samples A3 and A4), and CEM-II-32.5 [19] (concrete samples A5, A6, A7, A8), Table 1. The aggregates were type: river (all samples except A5 which was with slag aggregate) and slag, in three sorts: 0-4 mm, 4-8 mm and 8-16 mm, Table 1. The additions types: silica fume (SUF), chopped tires (CT) and polystyrene granule (PG) were added in the compositions (A6 with SUF, A7 with CT and A8 with PG).

Table 1. Components dosage for series 1.

Sample	Dosages								W/C	Addition			f _c N mm ⁻²
	Cement kg m ⁻³	River aggregate kg m ⁻³			Steel slag aggregate kg m ⁻³			Water l m ⁻³		SUF %	CT %	PG %	
		0-4	4-8	8-16	0-4	4-8	8-16						
A1:C20/25 Pa35-L1	343	715	458	659	-	-	-	182	0.53	-	-	-	35.5
A2:C20/25 Pa35-L4	457	517	408	643	-	-	-	242	0.53	-	-	-	39
A3:C20/25 P40-L1	319	783	464	667	-	-	-	182	0.57	-	-	-	33
A4:C20/25 P40-L4	425	683	399	575	-	-	-	242	0.57	-	-	-	33.5
A5:C20/25 CEM II.32.5	350	-	-	-	495	330	1010	185	0.53	-	-	-	36.1
A6:CEM-II-32.5	360	803	384	559	-	-	-	172	0.48	10	-	-	41.2
A7:C20/25 CEM II-32.5	350	495	330	1180	-	-	-	166	0.47	-	25	-	27.67
A8:C20/25 CEM II-32.5	385	671	430	621	-	-	-	130	0.34	-	-	15	27.48

1.2. Series 2- Concrete grade C25/30

The samples for the series 2 grade C25/30 were prepared with two types of aggregates: river (samples B1, and B5 to B12) and with crushed aggregates (samples B2, B3 and B4); three types of cement: Pa35 (samples B5 and B6), P40 (samples B7, B8, but with different dosages of cement) and for all other samples the cement was CEM I-42.5 [19]; different additions were added: B9 with fly ash (FA), B10 with silica fume (SUF), B11 with fly ash and disperse glass fiber (FS), B12 with fly ash and disperse metallic fibers (FM) also with fly ash, Table 2. The glass fibers were of 30 mm length and the metallic fibers were of 50 mm length with deformed ends.

The cubic samples of 150 mm sizes were poured and kept in standard conditions. The tests were effectuated at 28 days according to Eurocode SR EN 12390 - 3:2009 [20].

Table 2. Components dosage for series 2.

Sample	Dosages								Addition					fc N mm ⁻²
	Cement kg m ⁻³	River aggregate kg m ⁻³			Crushed aggregate kg m ⁻³			Water l m ⁻³	W/C	FA %	SUF %	FS %	FM %	
		0-4	4-8	8-16	0-4	4-8	8-16							
1	360	803	384	559	-	-	-	172	0.48	-	-	-	-	36.62
2	360	803	-	559	-	384	-	172	0.8	-	-	-	-	44.73
3	360	803	384	-	-	-	559	172	0.48	-	-	-	-	43.12
4	360	803	-	-	-	384	559	172	0.48	-	-	-	-	47.06
5:C25/30Pa35-L1	444	575	436	232	-	-	-	182	0.41	-	-	-	-	45
6:C25/30Pa35-L4	617	460	348	586	-	-	-	253	0.41	-	-	-	-	48
7:C25/30-P40	387	592	466	735	-	-	-	182	0.47	-	-	-	-	43
8:C25/30-P40	538	488	381	601	-	-	-	253	0.47	-	-	-	-	46
9:10% FA	324	803	384	559	-	-	-	180	0.55	36	-	-	-	44.98
10:10%SUF	324	803	384	559	-	-	-	180	0.55		36	-	-	42.4
11:10%FA+FS	324	803	384	559	-	-	-	180	0.55	36	-	0.25	-	45.95
12:10%FA+FM	324	803	384	559	-	-	-	180	0.55	36	-	-	0.25	45.82

The compressive strength on cubes of 150 mm size was determined for experimental mixes according to European standards at 28 days. The test results experimentally obtained are the medium value of three tests [20].

Results and discussion

1.3. Series 1.

The experimental results which are selected from the studies on each type of concrete in previous researches are presented in Figure 1 [16, 17, 18].

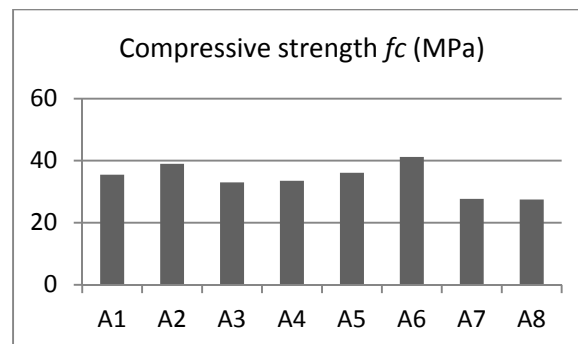


Figure 1. Variation of compressive strength of cement concrete function of components (series 1).

Analyzing the results, it can observe that an improve of compressive strength can be obtained by: increasing the cement dosage, which is not economically, the use of SUF addition in concrete mix (an increase in f_c of about 16% was obtained in comparison with witness A1), and also by the use of slag aggregates (A5), in which case an increase of about 1.7% was obtained in comparison with witness A1. Other additions used in the experiments decreased the compressive strength, but created a more elasticity behavior under load of concrete. The mixes A7 and A8 with chopped tires and respectively

with polystyrene granules had a decrease of f_c of about 22.1% in the case of A7 and of about 22.6% respectively, in comparison with the witness A1.

As conclusion for these types of additions it resulted that for increasing the compressive strength except the classical methods of increasing the cement dosage, using high strength aggregate and reducing W/C ratio, fine addition (SUF) can be used without affecting the compressive strength. Other types of additions such as chopped tires and polystyrene granules can be used in situations in which compressive strength is less important than other characteristics such as elasticity, ductile failure, thermal and acoustical properties, etc.

1.4. Series 2

For the series 2 the experimental results are given in Figure 2.

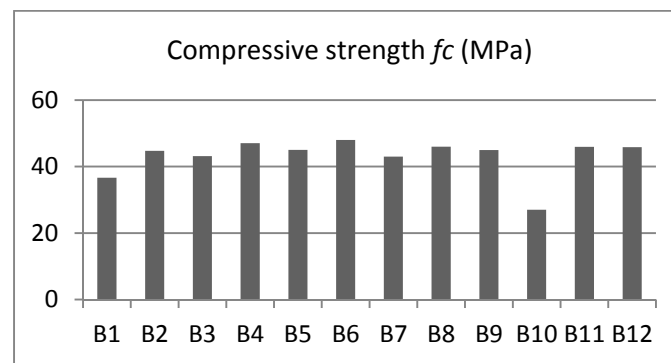


Figure 2. Variation of compressive strength of cement concrete function of components (series 2).

From the graph - Figure 2 - it can observe that in the case of a higher grade of concrete, an improvement of compressive strength can be obtained by using all the additions which were studied. Evidently, the clearest influence had cement dosage and crushed aggregates that are not economical solutions. For improving the compressive strength of concrete, wastes type FA, SUF, fibers can be used as addition or by replacing parts of cement. The crushed aggregates (mix B4) highly influenced the compressive strength, in which case the maximum value of f_c was obtained, that means an increase in compressive strength of about 28.5% in comparison with that of the mix with river aggregate (mix B1), which was considered as witness. The type and dosage of cement also influences the compressive strength, the highest value of f_c being obtained for a dosage of 617 kg m^{-3} for mix B6 (the increase in strength was of about 31.1%). The substitution of 10% cement with fly ash, mix B9, resulted in an increase of compressive strength with 16% in comparison with the compressive strength of witness concrete. An addition of 10% of fly ash as replacement of cement and 1% glass fibers, mix B11, resulted in an increase of compressive strength with 25% of compressive strength in comparison with that of witness concrete.

The conclusion of compared experimental results it is evident that near the well-known possibilities of improving mechanical strengths of cement concrete by increasing dosage and strength of cement, by using crushed aggregates or by reducing the W/C ratio, there are other methods in which less cement is used by replacing it with powder type SUF or FA or by adding disperse fibers type glass or metallic.

Conclusions

The addition of different wastes in cement concrete is a possibility of obtaining new building materials with specific requirements and to consume the wastes. In experimental tests there were studied some types of additions such as silica fume and fly ash, chopped tires, polystyrene granules and disperse

fibers (glass and metallic), the results were compared for a better understanding of properties of new concretes. From the study it can observe that some additions had improved the mechanical strengths and other had changed the physical properties of cement concrete. It resulted that the additions such as: silica fume, fly ash and disperse fibers type glass and metallic improved the compressive strength. Other additions, such as: chopped tire and polystyrene granules had improved the elasticity of concrete and a more ductile failure was observed.

In conclusion, different types of additions can be used for improving properties of concrete and to obtain building materials friendlier with environment. Function the predominant characteristic of the new concrete there are necessary experimental tests for a better understanding of effects of additions and clearer definition of the specific properties of each concrete for recommending the use domain.

Acknowledgements

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