INFLUENCE OF MIXING DESIGN PARAMETERS ON PERFORMANCE OF SUPERPLASTICISERS IN CONCRETE MIXTURES

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ABSTRACT

The use of superplasticisers in concrete manufacture was a milestone in the history of concrete, and this played a central role in the development of strength/high performance concrete. Superplasticisers are admixtures, which are added to concrete mixture in very small dosages. Their addition results in significant increase of the workability of the mixture, in reduction of water/cement ratio or even of cement quantity. Their performance depends on the type of the superplasticizer, the composition of the concrete mixture, the time of addition and the temperature conditions during mixing and concreting.

Measurements of workability, slump loss, air content, as well as of strength development have been made to reach a conclusion about superplasticisers performance. Apart from this, it seems that the quantity of fines in a mixture influences the performance of superplasticisers.

1. INTRODUCTION

The use of superplasticisers in concrete began in the 1960s and was a milestone in concrete technology and the field of construction [1]. In this way the production of concrete of high performance and durability was achieved, because adding, superplasticisers high workability remained at a very low ratio of w/c. The superplasticisers are poly-electrolytes of organic origin, which function like the dispersing chemical media in heterogeneous systems.

The most well known superplasticisers are of lignosulfonic origin and are based in lignin (produced by paper factories). It is generally acceptable that lignosulfonic superplasticizers in high dosages result delaying the curing of concrete. Another group of reactive superplasticisers are based in sulfonated products of synthetic polymers (e.g., SNF, naphthalene or SMF, melamine). These materials result in a higher decrease of required water and so higher strengths are achieved. The family of superplasticisers which are based in polycarboxylic products are more recent (1980s). These materials are of higher reactivity, they do not contain the sulfonic group and they are totally ionized in alkaline environment. The superplasticisers of high reactivity, which in high dosages do not have the side-effect of delaying the curing of concrete, made the production of concrete with a big volume of fly ash or slag possible [2].

As it is known the superplasticisers increase the workability of a mixture very much. However, this increase is not retained for than 30-60 min. There are various ways (addition of admixtures during the placement or in doses) in which workability can be retained for more time. The type of the admixture also seems to affect this time.

Although the superplasticisers do not react by a chemical action at hydrated products, they affect the microstructure of cement gel and concrete. The porosity and the bleeding decrease significantly and, on a second level, the drying shrinkage and creep deformations. Thus, beyond the increase of strength, there is also an increase of the durability of concrete with the use of superplasticisers [3].

2. EXPERIMENTAL PART

Three types of modern superplasticisers were checked in mixtures of concrete with local materials. The first type (code S1) is based on water diluted sulfonated polymers of high relative density and alkalinity, and it is recommended for mixtures of low ratio of water / binder. The second type (code S2) is based on synthetic polymers, it is of low relative density and alkalinity (pH 6-8), and it is recommended for cases where retaining workability for a long time is required. The third type (code S3) is based on modified polycarboxylic ether, it is of low relative density and it is recommended for high decrease of required water and retaining workability for a long time. All types comply with the relative specifications ASTM C494 and ASTM C1017. The most important characteristics of the admixtures appear in table 1.

Among the parameters which affect the performance of the admixtures, the following ones were studied:

Dosage of admixture. Three dosages (1%, 1,5%, 2% per weight of cement) were checked for every type of superplasticisers.

Type and gradation of aggregates. Each dosage for the admixtures mentioned above was used in mixtures of concrete with natural river aggregates of two gradations a) 0-8mm and b) 0-31,5mm. In both gradations the choice of the participating fragment of aggregates was made according to the criterion that the final gradation curve be in suitable areas of the limits which are proposed by Greek “Standards of Concrete Technology”. In two gradations, c) 0-8mm and d) 0-31,5mm, crushed aggregates from the quarry of Drimos, Thessaloniki were also used for all dosages. The gradations of the participated fragments of aggregates and their ratio in the final mixtures appear in tables 2,3. It is also noticed that the used aggregates were by order cleared off the fine material < 0,25 mm.

Cement percentage of type I45 was used in two percentages for all dosages. Cement was added with 0-8mm aggregates (river or limestone ones) in the mixture at an amount, of 420 kg/m^3, which corresponds to the category of high-performance concrete.

Cement was added with 0-31,5mm aggregates in the mixtures at an amount of 320 kg/$m^{3,}$ which corresponds to the category of medium strength concrete, which is widely used in common structures.

Volume density, voids percentage and workability (measured by slump test) were checked in the mixtures, in order to clarify the influence of the type of superplasticizer as well as its dosage on loss of workability through time. The compressive strength of concrete in hardened condition was checked in 3,7 and 25 days in cylindrical specimens of 15x30 cm. The characteristics of the checked concrete syntheses and the decrease of required water which was achieved for stable original workability of 15±1 cm is given in table 4. The development of compressive strength at various dosages of superplasticisers are given in diagrams 1 to 6. The loss of workability of these mixtures with 1,5% of superplasticizers S1, S2, S3 and 420 kg/m^3 of cement are indicatively given in diagrams 7,8 and the loss of workability for dosages 1% of S1, S2, S3 and 320 kg/m^3 of cement are given in diagrams 9,10.

3. CONCLUSIONS

From the comparison of the superplasticisers the conclusion drawn in that the type S3 of carboxylic base is of higher performance than types S2, S3. It gives a higher decrease of the w/c ratio which is up to 40% in mixtures with crushed aggregates. The loss of workability through time is normal and at the same level compared with that of the reference mixture without superplasticisers. The performance depends, of course, on the dosage. A compressive strength of 58 MPa (an increase of 50% compared with reference strength) is developed in 28 days in mixtures with 2% of S3 by weight of cement. Higher loss of workability is given by superplasticizers of type S1, which are based on sulfonated polymers. This type in dosage of 2% gives a compressive strength in 28 days of approximately 50 MPa (an increase of 25% compared with reference strength). The type S2 which is based on synthetic polymers behaves in a similar way to type S1 but the loss of workability through time is relatively smaller and more normal. The maximum strength, which is achieved with 2% dosage, is 47 MPa (increase of 18% compared with the reference strength). Comparing the corresponding pairs of mixtures, in which superplasticizers of the same type and in the same dosage were added and which also differ only in the type of aggregates (river/crushed), it can be said that the performance of all superplasticisers with natural river aggregates is lower. Water decreases and the achieved strength is of a lower level. This can be explained by the higher amount of fine materials (0,25 – 1,0) mm which exist in river aggregates (see grading). Regarding percentage of voids of concrete with superplasticisers, it seems that in most cases there is an increase as a result.

As a conclusion, it can be said that there is the possibility of choosing high reactivity superplasticisers, which are based o sulfonated products and give a higher loss of workability. In general terms, concreting with superplasticisers show a decrease of workability from 15 cm slump to 7-8 cm after one hour – although this method of testing workability is not so accurate.

Acknowledgements

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4. REFERENCES

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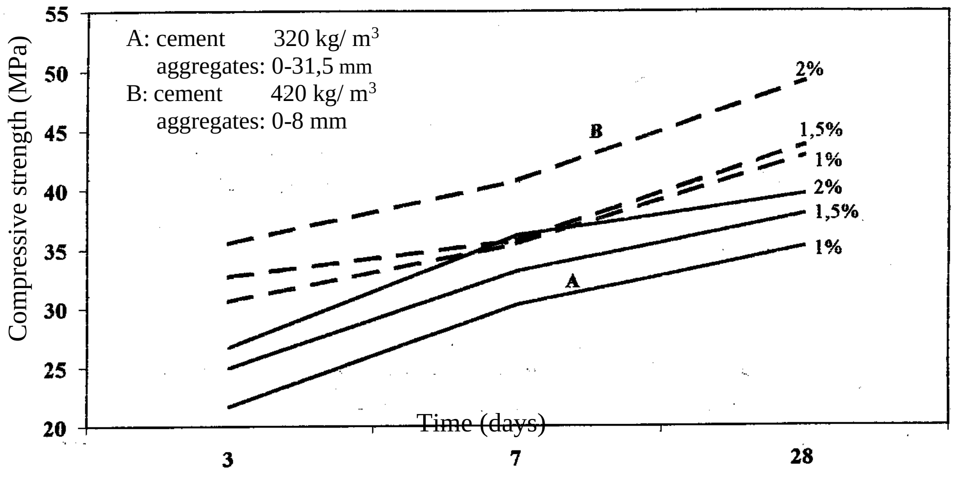

Fig. 1. Increase of compressive strength with S1 and natural (river) aggregates

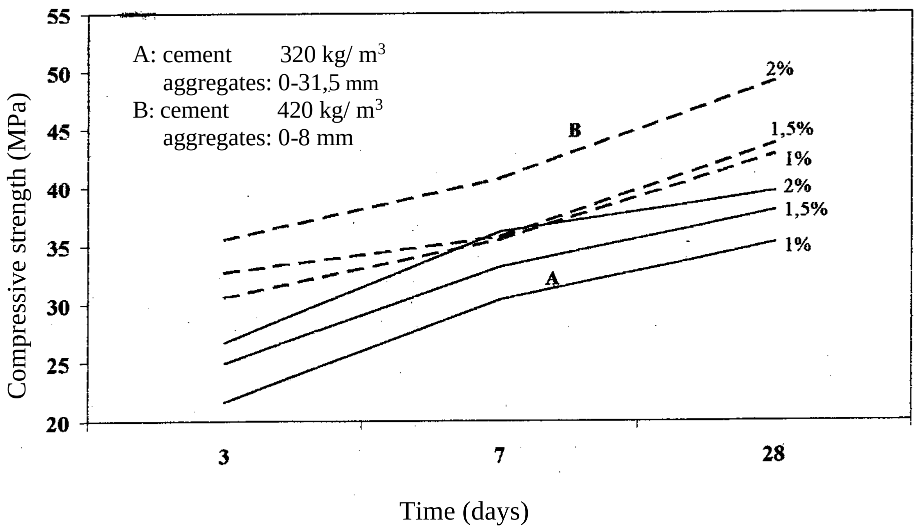

Fig 2. Increase of compressive strength with S1 and crushed limestone aggregates

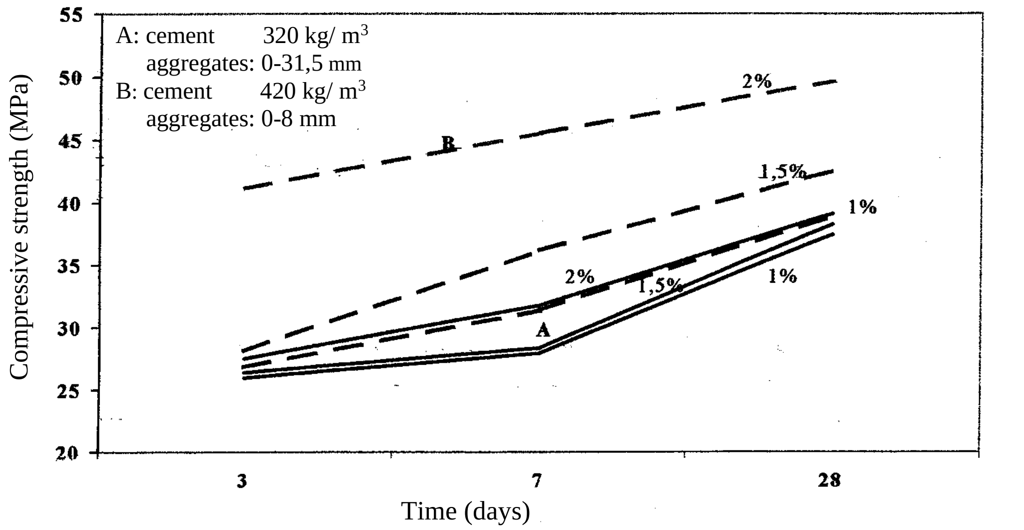

Fig. 3. Increase of compressive strength with S2 and natural (river) aggregates

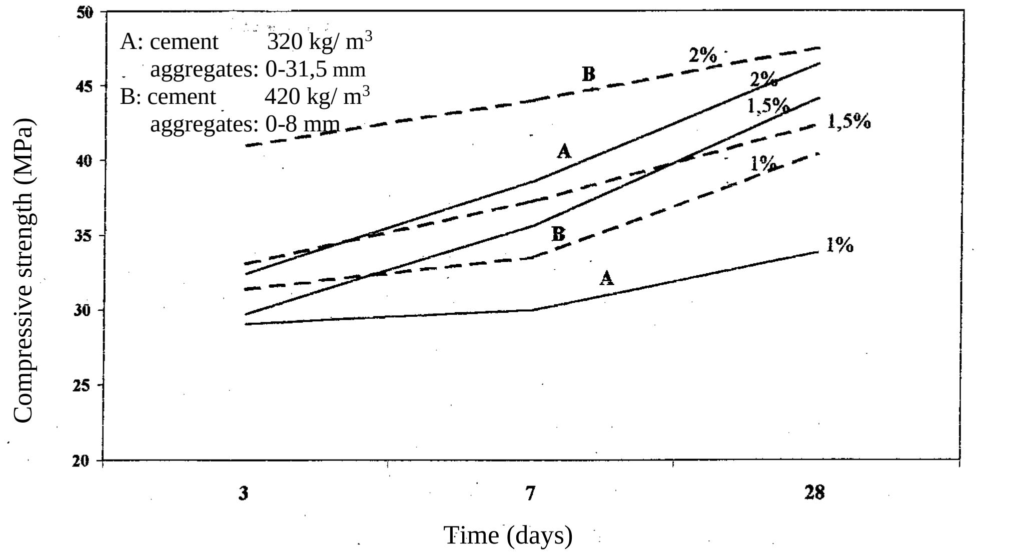

Fig. 4. Increase of compressive strength with S2 and natural (river) aggregates

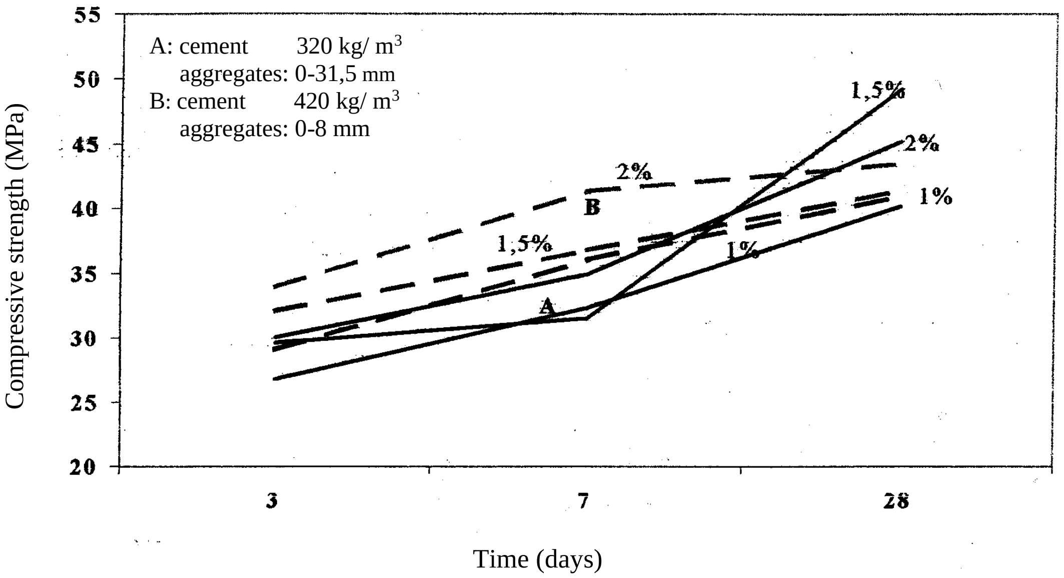

Fig. 5. Increase of compressive strength with S3 and natural (river) aggregates

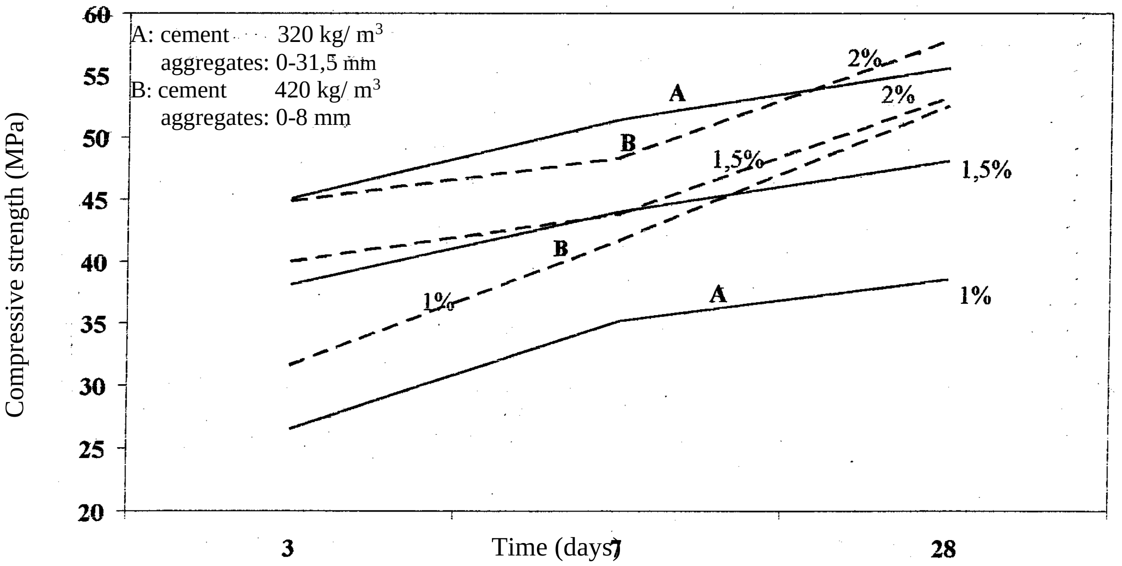

Fig. 6. Increase of compressive strength with S3 and natural (river) aggregates

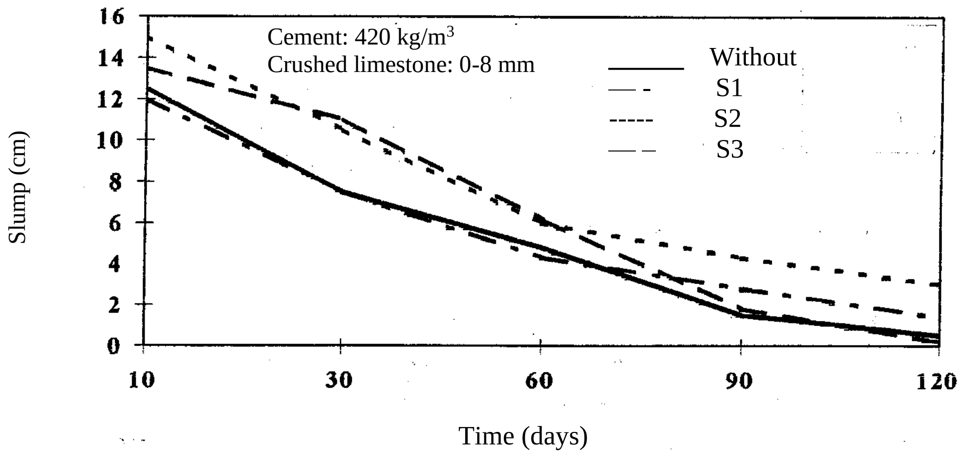

Fig. 7. Loss of slump because of superplasticisers addition (1%)
Aggregates: natural crushed limestone, 0-8 mm

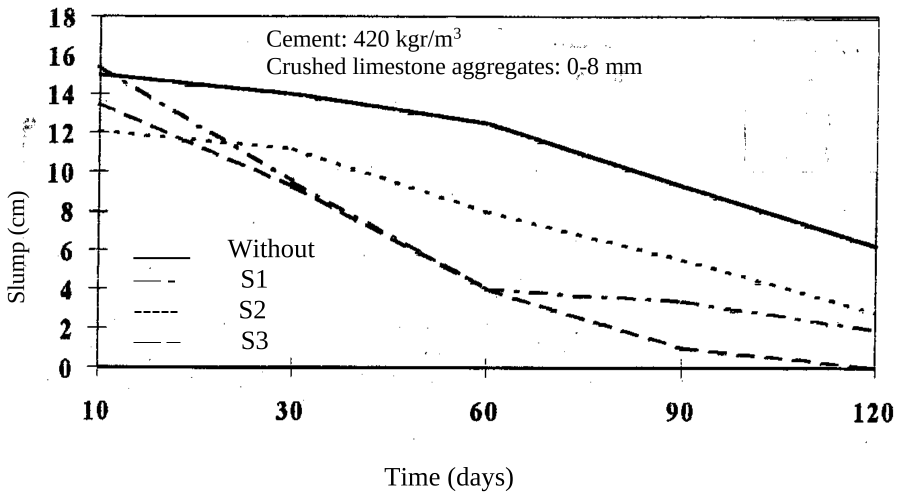

Fig. 8. Loss of slump because of superplasticisers addition (1 %)
Aggregates: natural crushed limestone, 0-8 mm

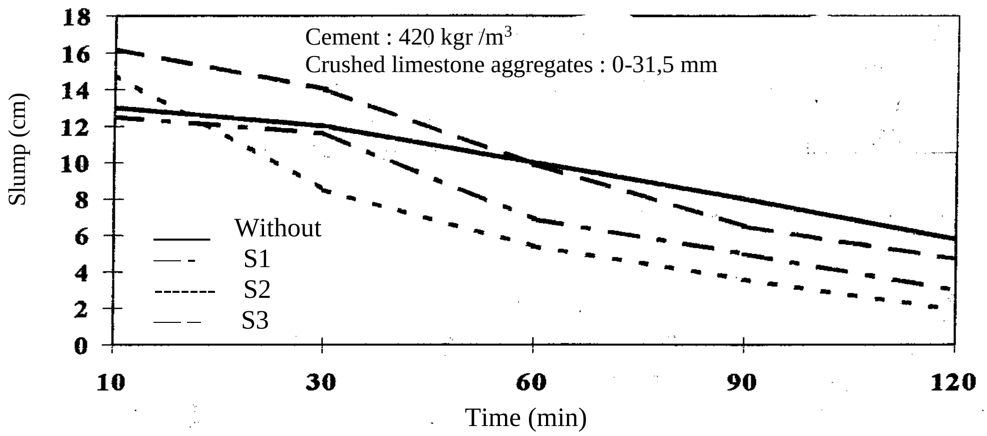

Fig. 9. Loss of slump because of superplasticisers addition (1 %)
Aggregates: natural crushed limestone, 0-31,5 mm

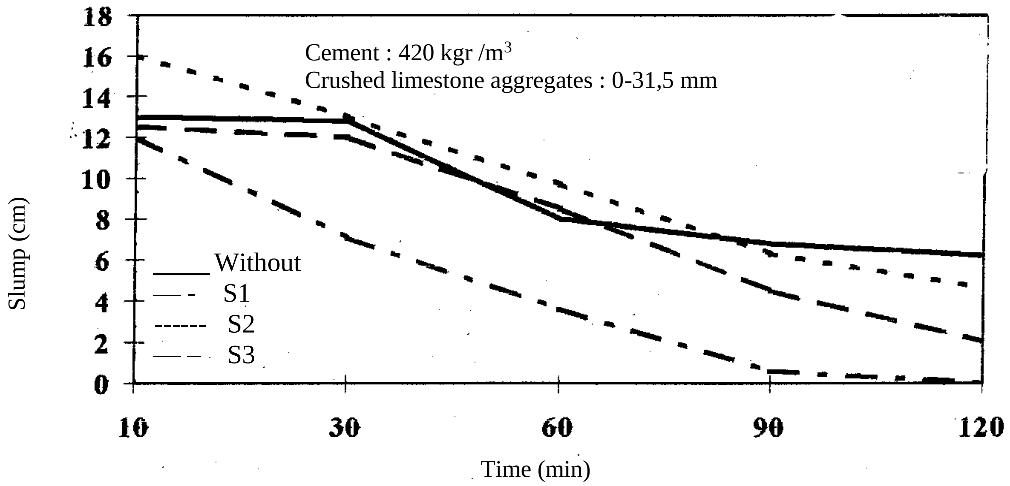

Fig. 10. Loss of slump because of superplasticisers addition (1%) Aggregates: natural crushed limestone, 0-31,5 mm

Code No	Colour	Specific gravity (gr/m^3)	pH	Viscosity (cps)	Clorides (%)
S1	Brown	1,23-1,25	7-9	-	0,0%
S2	Light Brown	1,02-1,08	6-8	100-200	<0,01%
S3	Brown	1,06	7	39±5	0,0%

Table 1. Characteristics of superplasticisers

	% Passing			
Sieve (mm)	0-4 mm	4-8 mm	8-16 mm	16-31,5 mm
31,5	100	100	100	100
16	100	100	100	33,42
8	100	100	67,08	0,27
4	97,38	33,04	0,77	0
2	77,32	1,28	0,12	0
1	55,11	0,75	0	0
0,5	23,11	0,65	0	0
0,25	1,02	0,24	0	0
0	0	0	0	0

Table 2. Granulometric gradation of natural aggregates (Axios river)

	% Passing			
Sieve (mm)	0-4mm	4-8mm	4-16mm	16-31,5mm
31,5	100	100	100	100
16	100	100	100	30,39
8	100	100	24,13	0,19
4	99,92	36,56	0,56	0,18
2	53,62	12,49	0,38	0,17
1	24,42	9,15	0,36	0,15
0,5	9,01	7,4	0,3	0,13
0,25	0	5,97	0,24	0,1
0	0	0	0	0

Table 3. Granulometric gradation of natural crushed limestone aggregates (Drimos quarry)

Mixture	Percentage on cement (%)	W/C	Loss of water (%)	Spacific gravity (gr/cm^3)	Voids percentage (%)
Cement I45, 420kg/m^3 River aggregates 0-8mm Superplasticiser S1	0 1 1,5 2	0,675 0,665 0,576 0,365	 1,48 14,67 45,93	2,369 2,319 2,231 2,219	2,5 4,8 3,5 3,6
Cement I45, 420kg/m^3 River aggregates 0-8mm Superplasticiser S1	0 1 1,5 2	0,693 0,547 0,519 0,468	 21,07 26,12 32,47	2,344 2,456 2,481 2,519	0,6 1,1 1,0 0,28
Cement I45, 420kg/m^3 Crushed limestone aggregates 0-8mm Superplasticiser S1	0 1 1,5 2	0,571 0,570 0,527 0,492	 0,18 7,71 13,84	2,494 2,419 2,394 2,356	3,4 3,2 2,5 2,4
Cement I45, 420kg/m^3 Crushed limestone aggregates 0-31,5mm Superplasticiser S1	0 1 1,5 2	0,842 0,640 0578 0515	 23,99 31,35 38,84	2,444 2,519 2,544 2,544	1,7 2,6 2,2 2,1

Table 4. Characteristics of mixtures with superplasticisers

Mixture	Percentage on cement (%)	W/C	Loss of water (%)	Specific gravity (gr/cm^3)	Voids percentage (%)
Cement I45, 420kg/m^3	0	0,675		2,369	2,5
River aggregates	1	0,500	25,93	2,344	3,7
0-8mm	1,5	0,427	36,74	2,306	3,4
Superplasticizer S3	2	0,409	39,41	2,191	3,2
Cement I45, 420kg/m^3	0	0,693		2,344	0,6
River aggregates	1	0,691	0,29	2,319	1,7
0-8mm	1,5	0,576	16,88	2,344	0,6
Superplasticizer S3	2	0,458	33,91	2,519	0,4
Cement I45, 420kg/m^3	0	0,571		2,494	3,4
Crushed limestone aggregates	1	0,477	16,46	2,494	3,2
0-8mm	1,5	0,471	17,51	2,494	3,0
Superplasticizer S3	2	0,457	19,96	2,506	2,9
Cement I45, 420kg/m^3	0	0,842		2,444	1,7
Crushed limestone aggregates	1	0,609	26,67	2,506	3,1
0-31,5mm	1,5	0,531	36,94	2,594	2,8
Superplasticizer S3	2	0,503	40,26	2,596	2,2

Table 4. Characteristics of mixtures with superplasticisers (cont.)

Mixture	Percentage on cement (%)	W/C	Loss of water (%)	Specific gravity (gr/cm^3)	Voids percentage (%)
Cement I45, 420kg/m^3	0	0,675		2,369	2,5
River aggregates	1	0,516	23,56	2,244	1,7
0-8mm	1,5	0,432	36	2,294	1,0
Superplasticizer S2	2	0,316	53,19	2,231	0,15
Cement I45, 420kg/m^3	0	0,693		2,344	0,6
River aggregates	1	0,571	17,6	2,506	0,9
0-8mm	1,5	0,529	23,67	2,494	0,8
Superplasticizer S2	2	0,523	24,42	3,081	0,5
Cement I45, 420kg/m^3	0	0,571		2,494	3,4
Crushed limestone aggregates	1	0,533	6,65	2,494	3,4
0-8mm	1,5	0,505	11,56	2,394	3,2
Superplasticizer S2	2	0,481	15,76	2,356	3,0
Cement I45, 420kg/m^3	0	0,842		2,444	1,7
Crushed limestone aggregates	1	0,609	27,67	2,506	1,9
0-31,5mm	1,5	0,538	36,1	2,556	1,75
Superplasticizer S2	2	0,515	38,84	2,594	1,65

Table 4. Characteristics of mixtures with superplasticisers (cont.)