SUPERPLASTICIZED SILICA FUME HIGH-STRENGTH CONCRETES

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Abstract
The effect of combined additions of silica fume and superplasticizer on concrete compressive strength has been studied by taking into account the following parameters: a) type and dosage rate of superplasticizer; b) type and content of Portland cement; c) way of silica fume utilization (as additional component or as cement replacement). In the presence of silica fume, for both type I and type III Portland cement the Melamine Sulphonated Polymer superplasticizer performs better than the Naphtalene Sulphonated Polymer one, particularly when a high dosage such as 4% is used. A change from 2 to 4% superplasticizer dosage rate in general does not modify or reduce compressive strength in the absence of silica fume, whereas significantly increases compressive strength in the presence of silica fume.
Key words: Silica fume, Superplasticizer, Naphtalene sulphonated polymer, Melamine sulphonated polymer.

1 Introduction

The combined addition of silica fume and superplasticizer is generally used to produce high-strength concretes (1-3). The purpose of the present work is to examine the effect of the following parameters on the concrete compressive strength:
- type of superplasticizer: Sulphonated Naphtalene Polymer (SNP) or Sulphonated Melamine Polymer (SMP);
- dosage of superplasticizer in form of a 40% polymer aqueous solution: 2 or 4% by weight of cement;
- type of Portland cement: type I or III according to ASTM;
- cement content: 300 or 400 kg/m^3 in the reference mixes without silica fume;
- way of silica fume utilization: as additional component (15% by weight of cement) without any cement reduction or as cement replacement (15%).

2 Experimental

Table 1 shows the concrete composition of plain mixes (in the absence of silica fume) with or without SNP or SMP superplasticizers (2 or 4%) by using type I or type III Portland cement.

Table 2 indicates the composition of the same concrete mixes as those shown in Table 1, the only difference being a replacement of 15% by weight of cement by silica fume.

Table 3 shows the composition of the same mixes as those shown in Table 1, the only difference being the addition of silica fume (15% by weight of cement) without any reduction in the cement factor.

All the concrete mixes have been manufactured at a given slump (220 +/- 10 mm) and cured at 20°C.

Compressive strength measurements on cubic specimens (100 mm) have been carried out at 1, 7 and 28 days and their values are shown in Fig. 1-4.

3 Effect of silica fume and superplasticizer on strength of concretes containing type I Portland cement

Figures 1 and 2 show the effect of superplasticizer addition, with or without silica fume, on the compressive strength of concretes containing 300 and 400 kg/m^3 respectively of type I Portland cement. Figures 1A and 2A indicate the behaviour of plain or superplasticized concretes both in the absence of silica fume. Silica fume has been used to replace 15% by weight of cement (Fig. 1B and 2B) or as additional component without any reduction in the cement factor (Fig. 1C and 2C).

In the absence of silica fume, early and later compressive strength are reduced when the superplasticizer dosage rate is increased from 2 to 4%. Such a reduction is in general negligible and becomes more significant for the 1 day strength when 4% of SNP superplasticizer is used (Fig. 1A and 2A). Moreover, compressive strengths of SMP superplasticized concretes appear to be higher than those of SNP treated concretes particularly at 4% superplasticizer dosage rate (Fig. 1A and 2A).

In the presence of silica fume, the change from 2 to 4% of SNP or SMP superplasticizer dosage rate increases remarkably the compressive strength, and this appears to be more effective for the SMP superplasticizer than for the SNP one (Fig. 1B & C and 2B & C).

Table 1. Composition of concretes without silica fume at a given slump (220 +/- 10 mm)

Cement type	Cement factor (kg/m^3)	Superplasticizer type	Superplasticizer dosage (% w.c.)	W/C ratio	Air volume (%)
I	300	-	0	0.73	1.0
I	400	-	0	0.55	1.4
I	300	SNP	2	0.57	6.9
I	400	SNP	2	0.37	7.3
I	300	SNP	4	0.49	9.2
I	400	SNP	4	0.32	5.7
I	300	SMP	2	0.57	1.9
I	400	SMP	2	0.39	2.5
I	300	SMP	4	0.49	1.8
I	400	SMP	4	0.34	1.9
III	300	-	0	0.69	1.4
III	400	-	0	0.57	1.0
III	300	SNP	2	0.46	6.7
III	400	SNP	2	0.35	4.8
III	300	SNP	4	0.43	5.5
III	400	SNP	4	0.32	4.0
III	300	SMP	2	0.46	2.6
III	400	SMP	2	0.35	2.6
III	300	SMP	4	0.43	2.6
III	400	SMP	4	0.32	2.4

Table 2. Composition of concretes with silica fume replacing the cement content (15% by weight) at a given slump (220 +/- mm).

Cement type	Cement factor (kg/m^3)	Silica fume (kg/m^3)	Superplasticizer type	Superplasticizer dosage (% w.c.)	W/C ratio	Air volume (%)
I	255	45	-	0	0.88	1.0
I	340	60	-	0	0.62	1.1
I	255	45	SNP	2	0.76	1.8
I	340	60	SNP	2	0.50	2.9
I	255	45	SNP	4	0.51	6.0
I	340	60	SNP	4	0.35	5.1
I	255	45	SMP	2	0.79	1.1
I	340	60	SMP	2	0.51	1.5
I	255	45	SMP	4	0.51	1.8
I	340	60	SMP	4	0.35	2.2
III	255	45	-	0	0.84	1.1
III	340	60	-	0	0.61	1.3
III	255	45	SNP	2	0.67	2.6
III	340	60	SNP	2	0.50	4.0
III	255	45	SNP	4	0.44	5.4
III	340	60	SNP	4	0.34	4.0
III	255	45	SMP	2	0.73	1.3
III	340	60	SMP	2	0.56	1.4
III	255	45	SMP	4	0.45	2.3
III	340	60	SMP	4	0.36	2.4

Table 3. Composition of concretes with silica fume as additional component (15% by weight of cement) at a given slump (220 +/- 10 mm).

Cement type	Cement factor (kg/m^3)	Silica fume (kg/m^3)	Superplasticizer type	Superplasticizer dosage (% w.c.)	W/C ratio	Air volume (%)
I	300	45	-	0	0.76	1.1
I	400	60	-	0	0.49	1.2
I	300	45	SNP	2	0.61	2.2
I	400	60	SNP	2	0.38	3.3
I	300	45	SNP	4	0.43	4.5
I	400	60	SNP	4	0.29	4.2
I	300	45	SMP	2	0.66	2.0
I	400	60	SMP	2	0.39	2.2
I	300	45	SMP	4	0.43	2.4
I	400	60	SMP	4	0.29	2.3
III	300	45	-	0	0.69	1.1
III	400	60	-	0	0.53	1.3
III	300	45	SNP	2	0.55	2.4
III	400	60	SNP	2	0.43	3.4
III	300	45	SNP	4	0.39	4.0
III	400	60	SNP	4	0.32	4.3
III	300	45	SMP	2	0.59	2.0
III	400	60	SMP	2	0.44	1.9
III	300	45	SMP	4	0.39	2.2
III	400	60	SMP	4	0.32	2.4

Silica fume in superplasticized concretes when used as an additional component (Fig. 1B and 2B) is of course more effective than when used as cement replacement (Fig. 1C and 2C).

The combined addition of silica fume (45 kg/m^3) and superplasticizer (4% SMP) is so effective that even with a significantly low cement factor, such as 255 kg/m^3, the 28 day compressive strength is much higher than that of a richer mix (cement factor 400 kg/m^3) containing or silica fume either superplasticizer. For instance the 28 day compressive strength is about 65 MPa in the leaner cement mix with the combined addition of silica fume and 4% SMP superplasticizer (Fig. 1B), and less than 60 MPa in the richer cement mix containing only 4% SMP (Fig. 2A); even lower (less than 40 MPa) is the compressive strength of the richer cement mix containing only silica fume (Fig. 2C).

On the other hand, silica fume as additional component or cement replacement does not cause any strength increase in the absence of superplasticizer (Fig. 1 and 2). Really in plain mixes silica fume reduces strength particularly at earlier ages (1 day). This is due to the fact that the required mixing water at a given slump increases when silica fume is used without superplasticizer (Tables 1-3). At later ages (7-28 days) the strength reduction caused by the presence of silica fume in plain concrete mixes, becomes gradually lower because of the slow pozzolanic

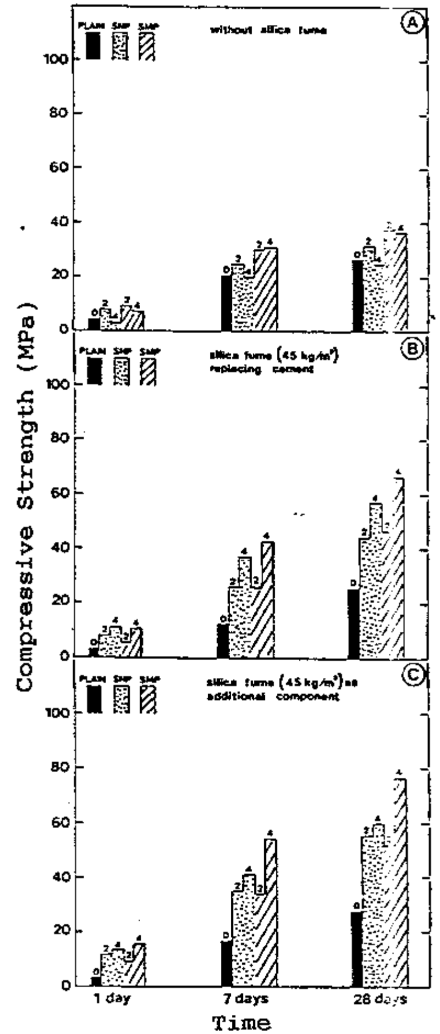

Figure 1

Compressive strength of concretes with 300 kg/m^3 of type I Portland cement without silica fume (A), with silica fume to replace 15% by weight of cement (B), or as 15% additional component (C).

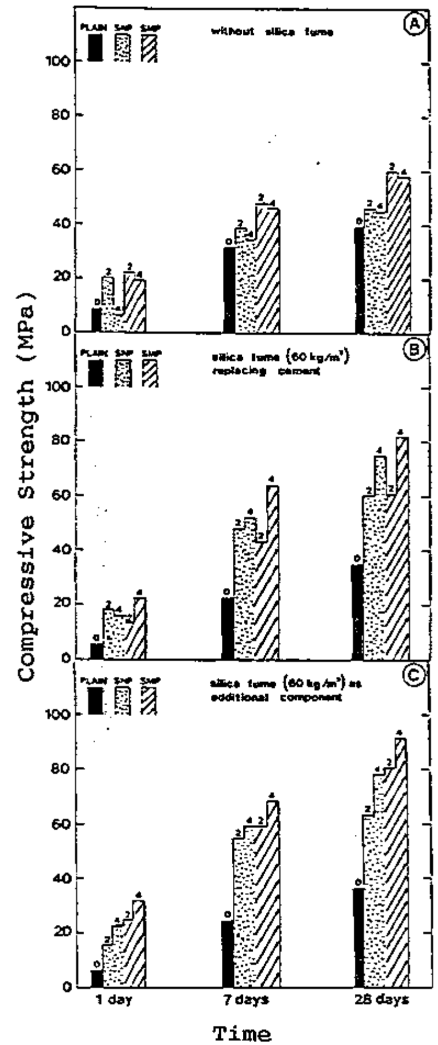

Figure 2

Compressive strength of concretes with 400 kg/m^3 of type I Portland cement without silica fume (A), with silica fume to replace 15% by weight of cement (B), or as 15% additional component (C).

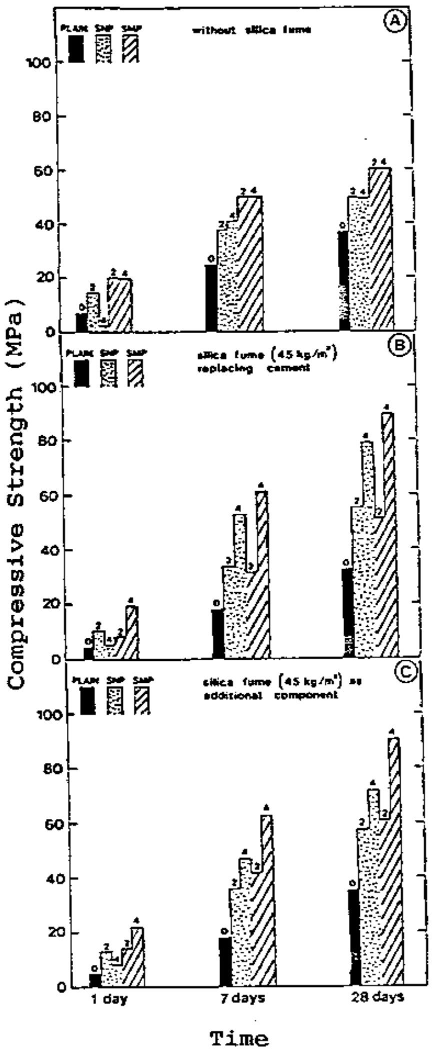

Figure 3

Compressive strength of concretes with 300 kg/m^3 of type III Portland cement without silica fume (A), with silica fume to replace 15% by weight of cement (B), or as 15% additional component (C).

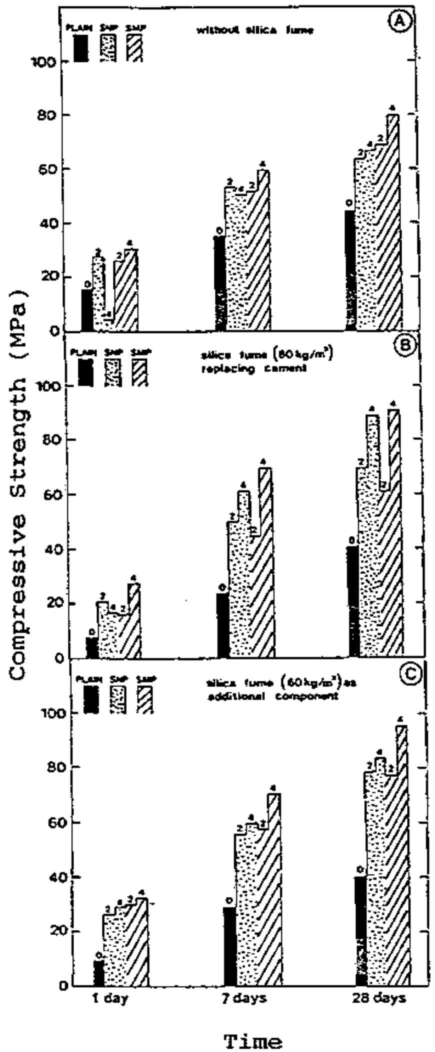

Figure 4

Compressive strength of concretes with 400 kg/m^3 of type III Portland cement without silica fume (A), with silica fume to replace 15% by weight of cement (B), or as 15% additional component (C).

reaction between silica fume and $Ca(OH)_2$ (produced by the cement hydration) which partly compensates the higher w/c ratio caused by the presence of silica fume.

4 Effect of silica fume and superplasticizer on strength of concrete containing type III Portland cement

Figures 3 and 4 show the effect of superplasticizer on compressive strength of concretes containing 300 and 400 kg/m^3 respectively of type III Portland cement with or without silica fume.

No substantial difference has been found in the strength change caused by superplasticizer and/or silica fume additions between concretes containing type I Portland cement (Fig. 1 and 2) on one hand, and those produced by using type III Portland cement (Fig. 3 and 4) on the other hand.

Of course type III Portland cement concrete mixes appear to be stronger than the corresponding concretes containing type I Portland cement. For instance, at the cement factor of 255 kg/m^3, the 28 day compressive strength of the concrete containing 45 kg/m^3 of silica fume and 4% of SMP superplasticizer is 65 or 90 MPa when type I or type III respectively Portland cement is used (Fig. 1B and Fig. 3B).

5 Conclusions

Independently of the type of Portland cement used (I or III), in the absence of silica fume the compressive strength of SMP superplasticized concrete appears to be higher than that of SNP treated concretes; in the presence of silica fume the SMP superplasticizer performs significantly better than the SNP one only at 4% dosage, whereas no substantial difference has been found in general between the performances of SMP and SNP at the 2% superplasticizer dosage.

The change in the superplasticizer dosage from 2 to 4% causes a remarkable increase in the compressive strength of both type I and type III Portland cement concretes only in the presence of silica fume; the effect of this change is more remarkable for the SMP superplasticizer than for the SNP one.

6 References

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