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Self-Compacting High-Performance Concretes

by Mario Collepardi, Roberto Troli, and Stefano Maringoni

Synopsis: Self-compacting high-performance concretes have been manufactured by mixing natural aggregates, portland cement and ground limestone filler in the presence of a poly-carboxylate superplasticizer.

In some concrete mixtures a shrinkage-reducing admixture (SRA) was used to decrease the drying shrinkage by 30% with respect to the control mix without SRA when the specimens were kept at room temperature with a relative humidity (RH) permanently kept as low as 55%.

A special SCC was manufactured combining a CaO-based expansive agent with SRA and the restrained expansion was measured in the absence of any wet curing in very dry environment (RH = 50%). After 2-3 months the restrained expansion was lost but no crack was recorded although the RH was very low.

Similar results were obtained by using a combination of PVA macrofibres with SRA: no reduction in drying shrinkage was recorded in the PVA-SRA concrete with respect to the SRA concrete. However, in the presence of PVA both the number and the thickness of the cracks were significantly reduced. The combined uses of SRA with the expansive agent or the macrofibres make more reliable concretes from the durability point of view because of the absence of cracks.

Keywords: Crack-freedom. Drying shrinkage. Expansive agent. Self-compacting concrete. Shrinkage-reducing admixture. Superplasticizer.

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INTRODUCTION

Self compacting concretes were manufactured with special requirements in terms of high compressive strength, low water/cementitious material ratio and low drying shrinkage, even in dry environments.

MATERIALS AND EXPERIMENTAL

A combination of about 400 kg/m^3 (676 lb/yd^3) of portland cement – type CEM I 52.5 R according to the European norm EN 197[1]- and about 95 kg/m^3 (160 lb/yd^3) of ground limestone filler with a Blaine fineness of 450 m^2/kg (245.5 lb/yd^2) were used to manufacture cohesive self-compacting concretes (SCCs) with a slump-flow of at least 700 mm (27 in) without bleeding and segregation.

A shrinkage-reducing admixture (SRA) was used at a dosage of 1% by cement weight to keep as low as possible the drying shrinkage.

In one of these SCCs, 30 kg/m^3 (50 lb/yd^3) of the filler was replaced by a CaO-based expansive agent to manufacture a shrinkage-compensating concrete.[2]

In one of the SCCs, 15-mm (0.6-in) long and 0.5-mm (0.02-in) thick synthetic macrofibres PVA (poly-vinyl-alcohol) were used in order to study whether or not they can reduce the number and/or the thickness of cracks, if any.

A poly-carboxylate superplasticizer (PCS) at a dosage of 12 kg/m^3 (20 lb/yd^3) was used to keep the water-cementitious material ratio (*w/cm*) as low as 0.42 in all the concrete mixtures.

Table 1 shows the composition of the *control mix* (SCC without SRA, CaO, and fibers) and that of the other three SCCs containing SRA with or without the CaO-based expansive agent or the PVA fibers which will be respectively called: *SRA mix*; *SRA/CaO mix*; *SRA/PVA mix*.

The following measurements were carried out to characterize the SCCs:

- slump flow, bleeding and specific weight of fresh mixes after 5 min of mixing;
- compressive strength (1-180 days) at room temperature (20°C) and RH of 95% ;

Table 1–Composition of the SCC mixtures with a w/ cm of 0.42 and a slump-flow of 720 mm (28.1 in)

SCC Type	CEM I 52.5 R kg/m³ (lb/yd³)	Filler kg/m³ (lb/yd³)	Expansive Agent kg/m³ (lb/yd³)	Aggregate* kg/m³ (lb/yd³)	Water kg/m³ (lb/yd³)	PCS kg/m³ (lb/yd³)	SRA kg/m³ (lb/yd³)	PVA Fibers kg/m³ (lb/yd³)
Control Mix	396 (669.24)	94 (158.56)	—	1740 (2940.6)	166 (208.54)	12 (20.28)	—	—
SRA Mix	398 (672.62)	95 (160.55)	—	1741 (2942.29)	167 (282.23)	12 (20.28)	4 (6.76)	—
SRA/CaO Mix	398 (672.62)	65 (109.85)	30 (50.7)	1741 (2942.29)	167 (282.23)	12 (20.28)	4 (6.76)	—
SRA/PVA Mix	396 (669.24)	94 (158.56)	—	1740 (2940.6)	166 (208.54)	12 (20.28)	4 (6.76)	4 (6.76)

*Sand 0–4 mm (0-0.16 in) = 60%; gravel 4-16 mm (0.16– 0.62 in) = 40%

- free shrinkage according the Italian norm UNI 11307[3] of the unreinforced specimens demolded at 1 day and then kept at a RH of 55%;
- restrained expansion of reinforced specimens demoulded at 6 hours, protected by a plastic coating for 2 days and then exposed to air with a RH of 55%, according to the Italian norm UNI 8148- B method.[4]
- modulus of elasticity at longer ages (180 days);
- visual measurements at 180 days of cracks and their size opening by using a hand-held equipment with magnifying lens in field tests to monitor 8 m-long, 400 mm-wide and 60 mm-thick (8.75-yd long, 16-in wide and 2.3-in thick) concrete slabs exposed to open air and restrained to the end in order to induce tensile stresses caused by drying shrinkage (Fig. 1); one slab per concrete mixture was used to determine cracks and their size opening.

RESULTS

Figure 2 shows the compressive strength as a function of the curing time. Because of the presence of SRA there is a strength reduction in all the SCCs with respect to the control mix. The effect is smaller in the *SRA/CaO Mix* -where the strength loss is about 5-10%- than in the *SRA Mix* or in the *SRA/PVA Mix*. These results agree with those of the modulus of elasticity at 180 days: 45 GPa for the *Control Mix*, 44 GPa for the *SRA/CaO Mix* and 43 GPa for the other two mixtures containing SRA.

Figure 3 shows the free length change of the unreinforced concrete specimens (except those containing the expansive agent) caused by drying shrinkage. There is a significantly lower drying shrinkage (about 25-30%) in all the SCCs containing SRA with respect the *Control Mix*. The addition of PVA to the *SRA Mix* does not reduce the drying shrinkage.

Figure 4 shows the length change of the restrained reinforced specimens of the *SRA/CaO Mix*. There is an expansion during the first 5 days, when the specimen was protected from drying by an envelopment made by a thin plastic coating, and then there is a slow decrease up to 6 months of permanent exposure to a dry environment with a RH of 55%.

Table 2 shows the number of the cracks and the crack-width determined on the restrained concrete slabs exposed to open air: no cracking occurred in the *SRA/CaO Mix* as well as in

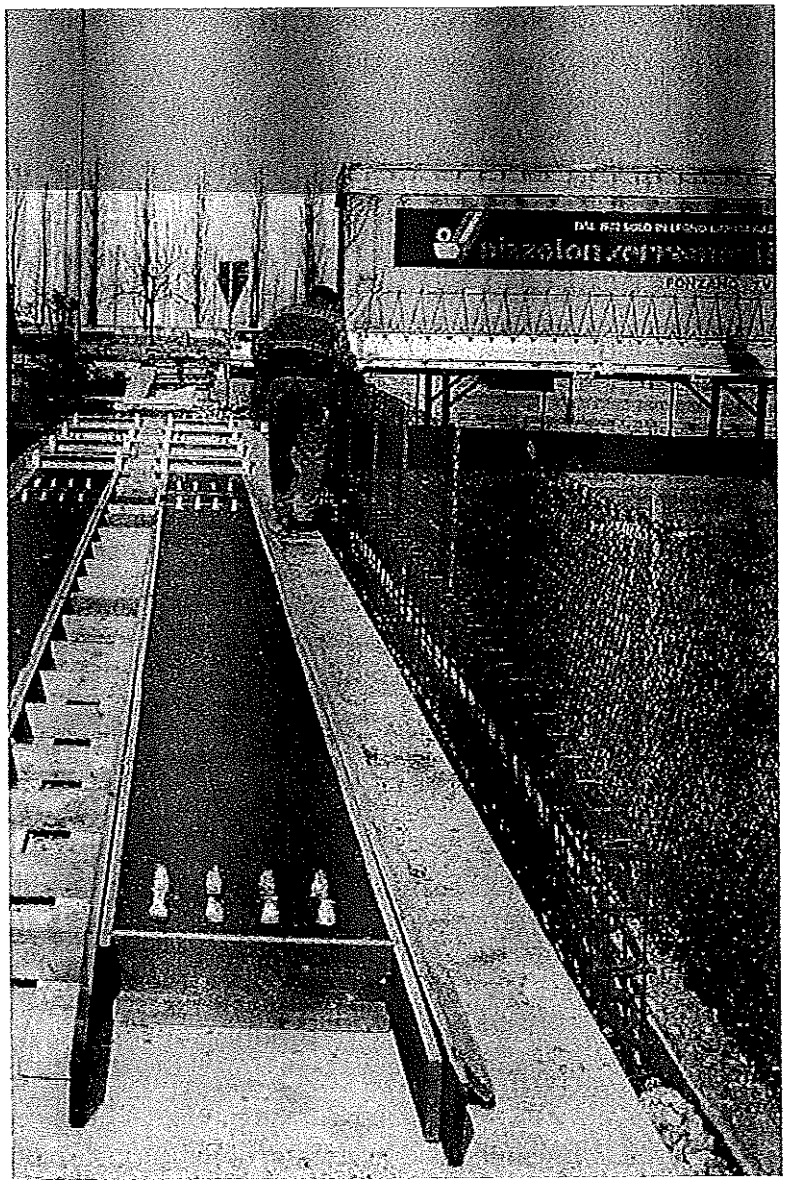

Fig.1 – Field tests on restrained drying shrinkage of concrete slabs 8 m long, 400 mm wide and 60 mm thick (8.75-yd long, 16-in wide and 2.3-in thick).

the *SRA/PVA Mix* although in the latter mixture the drying shrinkage was the same as that of the *SRA Mix* (Fig. 2). This behavior indicates the influence of the PVA macrofibers in removing the crack appearance provided that the drying shrinkage is lower than the *Control Mix* because of the presence of the SRA (Fig. 3).

CONCLUSIONS

Some special self-compacting high-performance concretes were studied. The combined use of a shrinkage-reducing admixture (SRA) with PVA macrofibers or a CaO-based expansive agent in superplasticized SCCs produced crack-free concrete slabs even in the

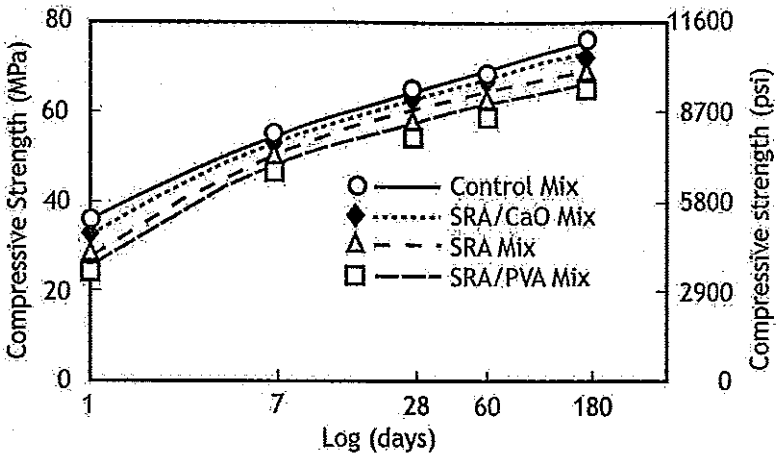

Fig. 2 – Compressive strength at different ages for the SCCs.

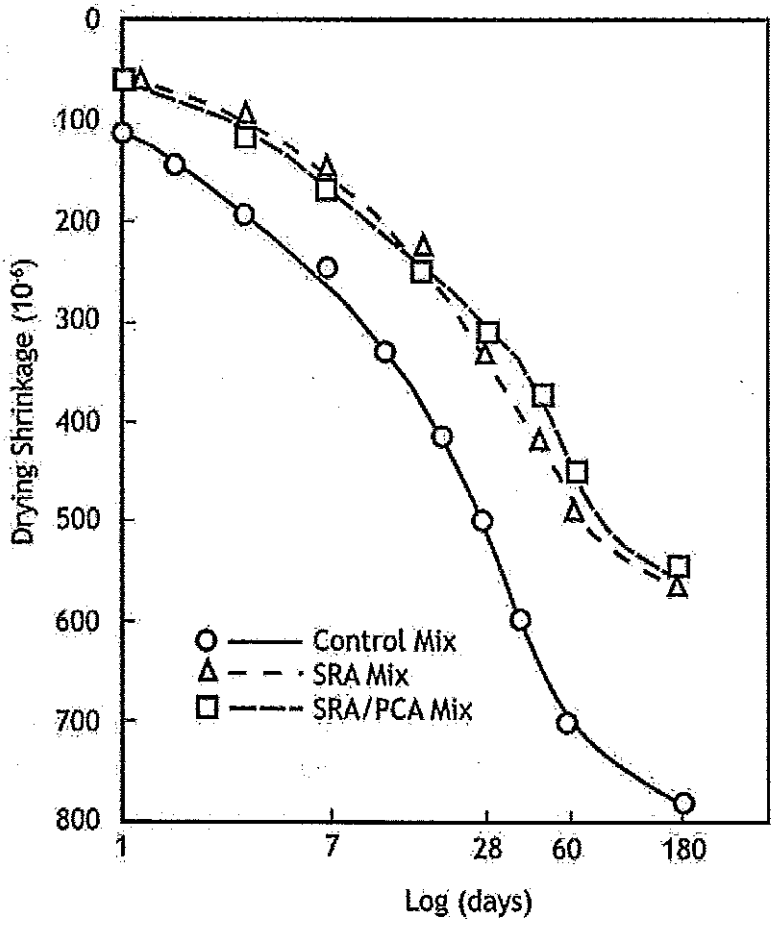

Fig. 3 – Drying shrinkage at different ages of the concretes after demoulded at 1 day.

absence of wet curing. Consequently, more durable and reliable structures without cracks can be made by using this technique in self-compacting concretes.

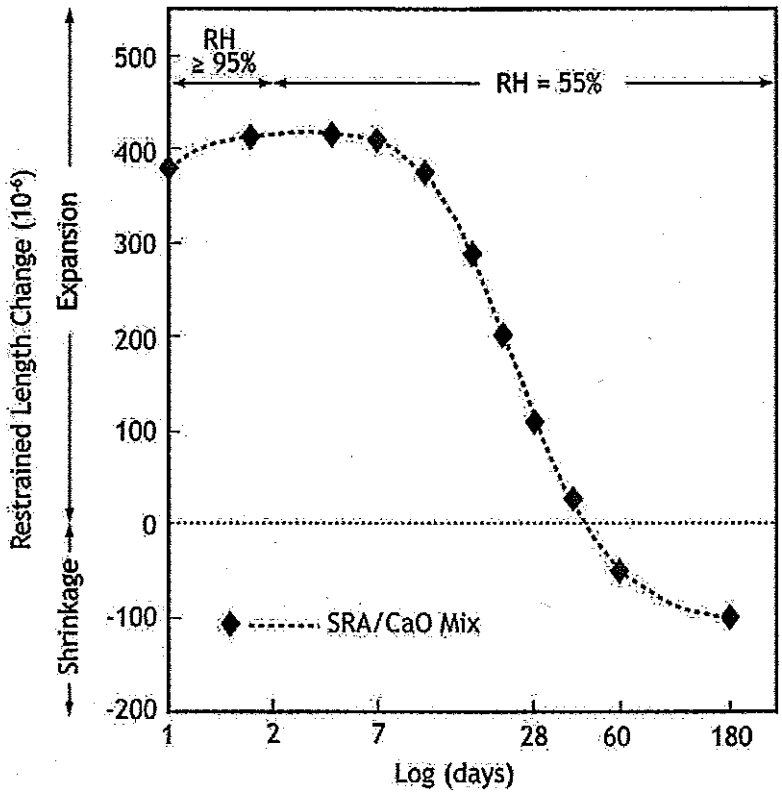

Fig. 4 – Restrained length change in the SRA/CaO Mix at different ages of the concrete demolded at 6 hours.

Table 2– Number of visible cracks and their width

SCC Type	Number of cracks	Width
Control Mix	5	1.1 mm (0.04 in)
SRA Mix	2	0.3 mm (0.01 in)
SRA/CaO Mix	0	—
SRA/PVA mix	0	—

Therefore these SCCs are more reliable and less dependent on the quality of the workmanship on the job site for both placing and curing with respect to the ordinary concrete mixtures.

REFERENCES

1. European Standard, EN 197-1, "*Cement-Part 1: Composition, specifications and conformity criteria for common cements*", pg. 14, 2000.

2. Collepardi, M.; Borsoi, A.; Collepardi, S.; Ogoumah Olagot, J. J.; and Troli, R., "Effects of shrinkage-reducing admixture in shrinkage-compensating concrete under non-wet curing conditions," *Cement and Concrete Composites*, V. 6, 2005, pp. 704-708.

3. Italian Standard UNI 11307, "*Testing for hardened concrete–Shrinkage determination*", 2008.

4. Italian Standard UNI 8148,"*Not metallic expansive agents for cement mixtures–Determination of restrained expansion of concrete*", 2008.