# SELF-COMPACTING, HIGH-PERFORMANCE AND LIGHT-WEIGHT CONCRETES

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**Abstract**

The “best” self-compacting lightweight concrete was tried to be attained in terms of excellent workability, high compressive strength, crack-freedom, effective durability even in very aggressive exposures, low specific weight as well as low elastic modulus.
Concretes were studied in the fresh state as well as in the hardened one by measuring compressive strength, restrained expansion and dynamic elastic modulus. Due to lower specific weight and elastic modulus, these SCCs should be particularly suitable in meeting the specific requirements of reinforced structures in seismic areas.

**Keywords**

Self-compacting concrete. Light-weight concrete. Drying shrinkage. Superplasticizer. Shrinkage-reducing admixture. Expanded clay. Expansive agent. Elastic modulus.

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## 1. INTRODUCTION

Lightweight self-compacting concretes were manufactured with special performances in terms of low water/cement ratio, low drying shrinkage even in dry environments, low specific weight and elastic modulus. The latter two performances are particularly suitable for concrete to be used in reinforced structures exposed to the risk of seismic actions.

## 2. Materials and experimental

A combination of about 400 kg/m$^3$ of portland cement (CEM I 52.5 R according to the European Standard EN 197-1) and about 95 kg/m$^3$ of ground limestone filler (with a Blaine fineness of 450 m$^2$/kg) were used to manufacture cohesive self-compacting concretes (SCCs) with a slump-flow of at about 720 mm without bleeding and segregation. 0-8 mm of natural sand (900 kg/m$^3$) and 0-16 mm of expanded clay (400 kg/m$^3$) were used to manufacture a concrete mixture with a specific weight lower than 2000 kg/m$^3$.
Four kg/m$^3$ of a shrinkage-reducing admixture (SRA) were used to keep as low as possible the drying shrinkage.
In one of these SCCs part of the filler (30 kg/m$^3$) was replaced by a CaO-based expansive agent to manufacture a shrinkage-compensating concrete (1).
In one of the examined SCCs 4 kg/m$^3$ of 15-mm long and 0.5-mm thick poly-vinyl-alcohol (PVA) synthetic macrofibers were used in order to study whether or not they can reduce the number and/or the thickness of cracks, if any.
Twelve kg/m$^3$ of a poly-carboxylate superplasticizer (PCS) were used as superplasticizer to keep the w/c ratio 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/Ca0 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 % ;
- free shrinkage according the Italian Norm UNI 11307 norm of the unreinforced specimens demolded at 1 day and then kept at a RH of 55%;
- restrained expansion of reinforced specimens demolded at 6 hours, protected by plastic coating for 1 day and then exposed to air with a RH of 50% according to the Italian norm UNI 8148- B method;
- dynamic modulus of elasticity determined at longer ages (180 days) by measuring the velocity of ultrasonic waves;
- visual measurements at 180 days of cracks and their size width opening by optical microscope in field tests on SCCs slabs (8 m-long, 400 mm-wide and 60 mm-thick) exposed to open air and restrained to the ends in order to induce tensile stresses caused by drying shrinkage (Fig. 1).


Figure 1 Field tests on restrained drying shrinkage of concrete slabs (8 m long, 400 mm wide and 60 mm thick)

## RESULTS

The results shown in Table 1 indicate that lightweight SCCs with a specific weight of about 1975 kg/m$^3$ were manufactured with a slump flow of 720 mm in the absence of bleeding water.

Table 1 Composition of the SCC mixtures with w/c of 0.42 and a slump-flow of 720 mm

| SCC Type | CEM I 52.5 R (kg/m$^3$) | $CaCO_3$ Filler (kg/m$^3$) | Expansive Agent (kg/m$^3$) | 0-15 mm Expanded Clay (kg/m$^3$) | 0-4 mm Sand (kg/m$^3$) | Water (kg/m$^3$) | PCS (kg/m$^3$) | SRA (kg/m$^3$) | PVA Fibers (kg/m$^3$) | Specific weight (kg/m$^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Control Mix | 399 | 93 | — | 399 | 907 | 166 | 12 | — | — | 1976 |
| SRA Mix | 399 | 93 | — | 398 | 905 | 166 | 12 | 4 | — | 1976 |
| SRA/CaO Mix | 398 | 64 | 29 | 398 | 905 | 166 | 12 | 4 | — | 1976 |
| SRA/PVA Mix | 395 | 92 | — | 395 | 899 | 164 | 12 | 4 | 4 | 1965 |

Figure 2 shows the compressive strength as a function of the curing time. With respect to the superplasticized *Control Mix*, there is small reduction in the 28-day compressive strength of the *SRA Mix* and *SRA/PVA Mix*, whereas in the presence of both SRA and expansive agent (*SRA/CaO Mix*) there is small strength increase in the compressive strength (about 45 MPa at 28 days). At longer ages, such as 180 days, the compressive strength is about 45-50 MPa in all the lightweight SCCs except in the *SRA Mix* with 40 MPa.

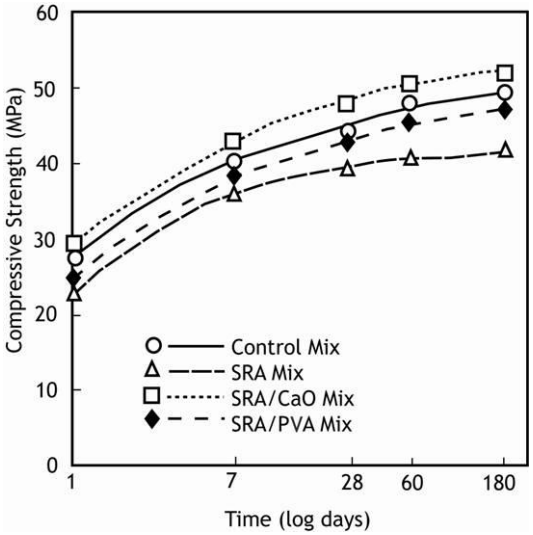


Figure 2 Compressive strength of the lightweight SCCs at different ages

The dynamic elastic modulus is about 25 GPa at 28 days and 30 GPa at 180 days in all the concrete mixtures. These relatively low values combined with the low specific weight of about 1975 kg/m$^3$ (Table 2) are particularly suitable for concrete structures in seismic areas exposed to the risk of earthquake.

Table 2 Number of visible cracks and their width determined by an optical microscope in the restrained slabs shown in Figure 1

| SCC Type | Number of cracks | Width (mm) |
|---|---|---|
| Control Mix | 4 | 1,4 |
| SRA Mix | 2 | 0,2 |
| SRA/CaO Mix | 0 | ---- |
| SRA/PVA mix | 0 | ---- |

Figure 3 shows the free length-change of the unreinforced concrete specimens (except those containing the expansive agent) due to drying shrinkage measured according to the UNI 11307 norm. There is a significantly lower drying shrinkage (about 15-25%) in the two SCCs containing SRA with respect to the *control mix*. The addition of PVA to the *SRA Mix* does not reduces the drying shrinkage.

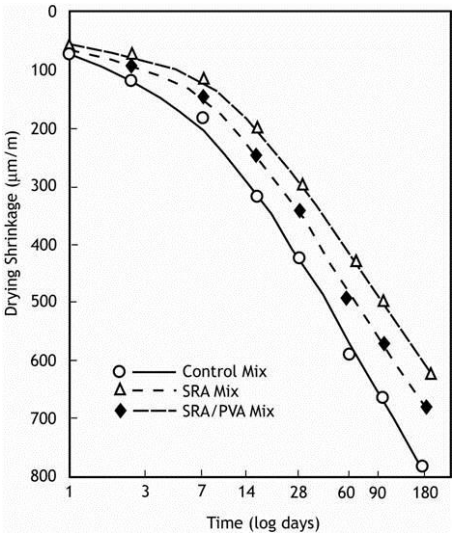


Figure 3 Drying shrinkage of the lightweight SCCs at different ages

Figure 4 shows the length change of the restrained reinforced specimens of the *SRA/CaO Mix*. There is an expansion during the first day, when the specimen was protected from drying by an envelopment made by a thin plastic coating, and then there is a slow expansion-loss up to 2 months of permanent exposure to a dry environment with a RH of 55%.

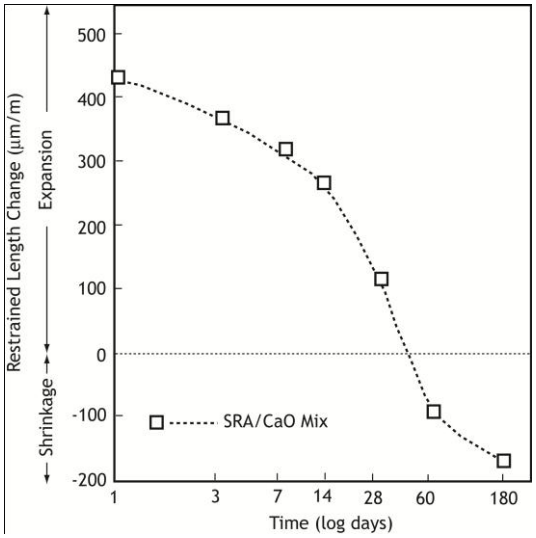


Figure 4 Restrained expansion of the SRA/CaO Mix permanently kept at a RH of 55% after 1 day

Table 2 shows the number and the crack-width opening determined on the restrained concrete slabs exposed to open air shown in Fig.1: no crack occurred in the *SRA/CaO Mix* as well as in the *SRA/PVA Mix* although in the latter mixture the drying shrinkage was a little higher than in the *SRA Mix* (Fig. 2). This behavior indicates the influence of the PVA macro-fibers in removing the crack appearance provided that the drying shrinkage is lower than the *Control Mix* because of the presence of the SRA (Figure 3).

## CONCLUSIONS

Some special lightweight SCCs were studied with a *w/c* ratio of 0.42 and a 28-day compressive strength of 40-45 MPa.
The combined use of a shrinkage-reducing admixture (SRA) with PVA macrofibers (15 mm long and 0.5 mm thick) or with a CaO-based expansive agent in superplasticized SCCs produces crack-free concretes even in the absence of wet curing.
Therefore durable and reliable structures for the low *w/c* ratio and the absence of cracks can be carried out by using this technique in self-compacting concretes. Moreover these SCCs, with respect to ordinary concrete mixtures, are more reliable and less dependent on the quality of the workmanship on the job site for both placing and curing.
Because of a low specific weight (1975 kg/m$^3$) and a relatively small elastic modulus (30 GPa at 180 days) these SCCs are particularly suitable in seismic areas.

## REFERENCES

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