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INFLUENŢA ADAOSURILOR MINERALE LOCALE ŞI A VOLUMULUI PASTEI ASUPRA CONTRACŢIEI BETONULUI AUTOCOMPACTANT
INFLUENCE OF LOCAL MINERAL ADDITIONS AND VOLUME OF PASTE ON THE SHRINKAGE OF SELF COMPACTING CONCRETE

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The study carried out herein aims at investigating the instantaneous and deferred mechanical behaviours of self compacting concrete (SCC). The survey was carried out in three steps. In the first step, local industrial waste fines, such as limestone (L), siliceous (S) and natural pozzolanic (PZ) fillers, were used in the preparation of the self compacting concrete; in the second, a study was performed to optimize the SCC formulation by varying the volume of paste; and finally, the effect of varying the volume of paste on the mechanical strength and shrinkage of the SCC was examined in the third part. Results showed that the addition of local fillers, according to international recommendations, in the preparation of SCC mixes gives better compressive strength and shrinkage behaviour than that of vibrated concretes.

Keywords: *Self compacting concrete; Limestone fillers; Siliceous fillers; Natural pozzolana; Shrinkage; Compressive strength*

1. Introduction

The increasing diversity of concretes, and particularly self-compacting concretes (SCCs), is associated with the variety of mix components available for use. Considering its advantageous features and comparing its technical and economical impacts with those of vibrated concrete (VC), the self compacting concrete (SCC) represents a major development in the building industry, all over the world. Indeed, the SCC is increasingly used in Japan [1], Europe [2], Canada [3] and several African countries, especially in Algeria where numerous new projects, supported by the building industry and a great number of research laboratories, are carried out.

The SCC is very fluid, deformable, and homogeneous; it can easily settle down by gravitation. It has many advantages in terms of technology and can be used to solve special casting problems [4]. For instance, it has a great capacity of filling slender shapes and congested reinforcement, in complex structures without segregation [3]. In order to ensure the compatibility of these two contradictory properties (fluidity and segregation) of the SCC in the fresh state, it is necessary to have a G/S ratio equal to about unity. The cement paste is greatly influenced by the fines added to it, because they occupy a large proportion in the mixture [5].

The volume of paste is generally defined as the sum of all volumes of cement, water, mineral additions and chemical admixtures. The fillers account for 20% of the total volume of paste. Various mineral fillers, such as limestone, siliceous and pozzolanic fillers, silica fume and fly ash, are usually used in SCC mixes.

Builders in our country are not familiar with the practice of using mineral additives, as cement substitutes, in cast-in-place and in ready-mix concretes. It thus seemed important to study and evaluate the impact of these additives on the properties of set concrete. The mineral additives usually used in Algeria are pozzolanic fillers, which come from natural pozzolana found in large quantities in western Algeria (Beni-Saf), and siliceous fillers which come from the quarry waste situated near the town of Sig (east of Oran in western Algeria).

In Algeria, out of the 68 million tons of limestone aggregates that are produced annually, at least 20% are considered unsuitable for use by contractors because the proportion of fine particles (D < 80 μm) is higher than 12%, which is the upper limit set by the regulations [6].

Thus, the storage of these aggregates has become a serious environmental problem [7]. Siliceous fillers (S) are obtained after a lengthy washing of silica sand particles (glass raw

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material).To find a solution for recycling the quarry wastes, the possibility of using these fillers exclusively in the preparation of concrete is investigated in the present study.

Fillers can have three purposes in the preparation of SCC mixes. They can be used as addition contents (i) to ensure the optimisation of compactness by filling the intra-granular pores, (ii) to improve the performance of the freshly mixed concrete and (iii) to increase the mechanical performance of the concrete in the hardened state [8].

It is widely acknowledged, according to the literature review, that no practical formulation methodology seems to be available to ensure the optimisation of the formulation of SCC mixes [4, 9]. Many researchers have developed various types of tests on the SCC in the fresh state. However, the results were obtained either by trial and error methods or gained from experience [8]. Recently, the French Association of Civil Engineering has limited the number of investigations to three specific tests, in order to make sure that the formulated mixes are in fact SCCs. These are the slump flow, L-box and segregation tests. One can also mention other tests recommended by the new European standard EFNARC [10].

There is a large consensus in the literature that to date only scarce and somewhat contradictory results exist about SCC shrinkage [11, 12]. In this context, some authors, like Ogawa et al. [13], found that the drying shrinkage of SCC is larger than that of vibrated concrete (VC). In their studies, they found that shrinkage is related to the amount of fillers used; however, no real difference was reported by authors such as Kuroiwa et al. [14]. For them the significant variations in the shrinkage of SCC are due to the curing process [14]. Moreover, Proust et al. noticed that vibrated concrete (VC) and self compacting concrete (SCC) did not show any difference in shrinkage; however, they have close mechanical strengths [15]. They proposed a model for time-dependent deformations. Turcry joined Pons and Proust in their idea and explained that the small difference in the variation of shrinkage, which can be observed between vibrated concrete (VC) and self compacting concrete (SCC) is due to the preparation parameters of the mixture [16]. Ayed et al. indicated that the nature of additions in the mixture has an influence on the mechanical behavior of the SCC [17]. It should be kept in mind that the composition of SCC is not very different from that of VC, for the same quantity of water, while the G/S ratio is kept nearly equal to unity.

To keep in line with these recent developments, it seemed relevant to compile the results of the experimental investigations carried out in this study to better understand the effect of fillers, from the western region of Algeria, on the behaviour of SCC in the fresh state. The use of local fines could be very useful for the optimization of SCC mixes and thus may solve the ecological, economic and technological problems, as stated above.

The aim of this study is to use these local fines in the development of new concrete technologies and to optimize the SCC mixes. The experimental investigation data were compiled and the tests were performed to assess the effects of mineral and organic addition contents on the mechanical properties of SCC, in both the fresh and hardened states. Moreover, the study was performed to particularly understand the relationship that exists between shrinkage and the volume of paste. The tests, conducted in accordance with the European standards, were limited to slump flow, L-box and screen stability [10, 18].

2. Materials and experimental program

2.1 Materials

All the mixes tested in this study used cement of type CPJ- CEM II 42.5. Its Blaine specific surface area (SSB) is 3600 cm² /g; its composition and its chemical properties are given in Table 1.

Three types of fillers were selected to be used; they are described next.

Limestone fillers (L), provided by the quarry of Kristel (a region situated east of Oran, in western Algeria). These particles were first ground and then controlled, using well-graded wire-mesh sieves. The obtained aggregates presented an absolute density of 2.65 g/cm^3.

Siliceous fillers (S) were obtained after a lengthy washing of the siliceous sand particles (glass raw material), extracted from the quarry of Sig, in western Algeria. The resulting content of particles (< 0.5mm) and the absolute density were 78% and 2.66 g/cm3, respectively. Their chemical properties are reported in Table 2.

Pozzolana fillers (PZ) were extracted from a deposit in the region of Bouhamidi (situated near Beni-Saf, in western Algeria). The particles of the material were ground to a minimum size of 80µm. The results of the chemical analysis of Pozzolana fillers are provided in Table 3.

- The SSB of Pozzolana fillers (PF) was found equal to 5200 cm^2/g; its absolute density was 2.75g/cm^3 and its apparent bulk density 0.81 g/cm^3.
- The mixes were prepared with tap water, in conformity with the French standard (NF P18 404). The chemical analysis of that water showed that the chlorine (Cl) content was about 408.25 mg/l, salt (NaCl) about 672.75 mg/l, and the constituent materials in suspension (CMS) 78 mg/l; its pH was 6.07.
- Two types of admixtures were used in this study; a high-range water reducer (superplasticizer, SP) and a viscosity enhancing agent (VEA). These two types of agents were used in the SCC mixes, according to the technical notes and in accordance with the French standard (NF EN 934.2).

Table 1

Chemical and mineralogical composition of the clinker (%).

Elements	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Loss on ignition	total	CaO free	Insoluble
(%)	20.39	4.91	3.14	62.00	1.13	2.57	1.84	95.98	0.50	1.63

Table 2

Chemical properties of siliceous fillers

Elements	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	MgO
%	95.82	0.08	0.45	0.39	1.86	0.03	0.15	0.02

Table 3

Chemical analysis of pozzolana

	SiO_2	CaO	MgO	Al_2O_3	Fe_2O_3	Loss on Ignition
%	56.25	9.83	1.81	16.98	8.57	6.54

Table 4

Physical characteristics of aggregates

	Sea sand (0/2)	Quarry sand (0/3)	Gravel (3/8)	Gravel (8/15)
Nature	quartz	limestone	limestone	limestone
Fineness modulus	2.40	2.70	-	-
Sand equivalent	79.45	79.75	-	-
Specific gravity (g/cm^3)	2.66	2.65	2.65	2.65
Apparent density (g/cm^3)	1.52	1.46	1.42	1.42
Absorption (%)			1.28	0.93

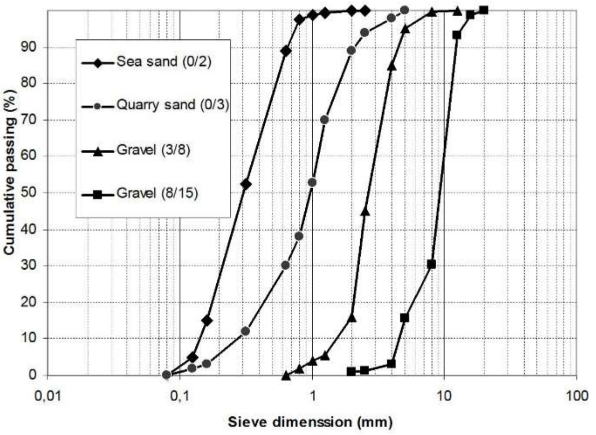

Fig.1 - Granulometric curves of aggregates.

The sea sand used came from Terga, a region situated in western Algeria, and the quarry sand was brought from the quarry of Kristel, a region situated in western Algeria. For sea sand, the average absolute and apparent densities were respectively equal to 2.66 g/cm^3 and 1.52 g/cm^3, whereas the average value of the fineness modulus and that of the sand equivalence (ES) values were respectively equal to 2.40 and 79.45%. Similarly, for the quarry sand, these values were 2.65 g/cm^3, 1.46 g/cm^3, 2.70 and 79.75 %, respectively. The rolled gravels used in the SCC mixes also originated from the quarry of Kristel; they were of class 3/8 and 8/15mm.

The granulometric curves of the aggregates are shown in Figure 1. The physical characteristics of the aggregates are reported in Table 4.

2.2 Experimental procedures

Three concrete mixes were analysed in this study. The proportion of cement in the first mix was taken equal to 350 kg/m^3. The quantities of cement in the other two mixes were taken equal to 420 and 455 kg/m3, respectively. This allowed increasing the volume of paste (VP) by 13 and 19%, respectively, as compared to the VP of the first mix. Moreover, the type of fillers was changed for each mix (limestone, siliceous, pozzolana), and the total number of mixes obtained was equal to nine. The filler contents were adjusted in situ, in order to ensure that the SCC in the fresh state had the characteristics recommended by the French Association of Civil Engineering (AFGC). The compositions of the different SCC mixes are reported in Table 5.

At the end of the preparation of each mix, slump flow, L-box, sieve, T50 and V-funnel tests were conducted (see Table 5) in order to characterize the behaviour of the obtained concretes in the fresh state. For each mix, six 11x22 cm cylindrical specimens were cast to measure their mechanical properties. Shrinkage measurements were performed on six 7x7x28 cm

Table 5

Compositions and properties of mixtures

	SCC1			SCC2			SCC3		
	L	PZ	S	L	PZ	S	L	PZ	S
Cement (CPJ 42,5) (kg/m^3)	350	350	350	420	420	420	455	455	455
Fine limestone (kg/m^3)	130	-	-	169	-	-	150	-	-
Fine Pozzolana (kg/m^3)	-	130	-	-	169	-	-	150	-
Siliceous Fine (kg/m^3)	-	-	130	-	-	169	-	-	150
quartzose sand (kg/m^3)	400	400	400	400	400	400	400	400	400
Sand crushed (kg/m^3)	486	486	486	430	430	430	390	390	390
Gravel 3/8 (kg/m^3)	389	389	389	370	370	370	350	350	350
Gravel 8/15 (kg/m^3)	400	400	400	370	370	370	360	360	360
SP (kg/m^3)	3.5	3.5	3.5	4.2	4.2	4.2	4.55	4.55	4.55
VEA (kg/m^3)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Water total (l/m^3)	200	200	200	210	210	210	228	228	228
Efficient water (Weff) (l/m^3)	172.4	172.4	172.4	184.7	184.7	184.7	204.2	204.2	204.2
A/(A+C) ratio	0.27	0.27	0.27	0.29	0.29	0.29	0.25	0.25	0.25
W eff/Equivalent binder	0.451	0.451	0.451	0.400	0.400	0.400	0.415	0.415	0.415
Volume of paste (l/m^3)	369(VP)	369	369	418(VP+13%)	418	418	440(VP+19%)	440	440
G/S ratio (by mass)	0.891	0.891	0.891	0.892	0.892	0.892	0.899	0.899	0.899
(Water/Cement) ratio	0.493	0.493	0.493	0.440	0.440	0.440	0.449	0.449	0.449

prismatic specimens. Three specimens were used to measure the endogenous shrinkage and the other three to measure the total shrinkage. Before testing, the specimens were stored in a room, at the constant temperature of 20°C, with a relative humidity (RH) of 95%.

Once the shrunk samples were taken off the moulds, they were immediately covered in order to begin shrinkage measurements, 24 hours later, exactly. The compressive strength was evaluated using compression tests, at 28 and 60 days, to observe the long-term pozzolanic reaction. The shrinkage of the specimens was measured in a constant room temperature at 20 ± 1 °C and 55 ± 5% RH. The methods used in this study, to characterize the freshly mixed SCC, are described below.

Slump flow test: This test, based on the traditional slump test, is used to determine the flowability and the flow rate of SCC (Fig. 2a). The equipment used consists of one slump cone and a flow table. The slump cone was filled with concrete and then lifted, vertically. Two characteristic values were measured to determine the flowability of concrete in an unconfined space; first the flow time which is the period that concrete takes to reach the diameter of 50 cm (T50), and then the mean diameter of concrete, at the end of spreading (according to the French Association of Civil Engineering AFGC that diameter should be from 60 to 80 cm). The T50 parameter gives qualitative information about the viscosity of concrete.

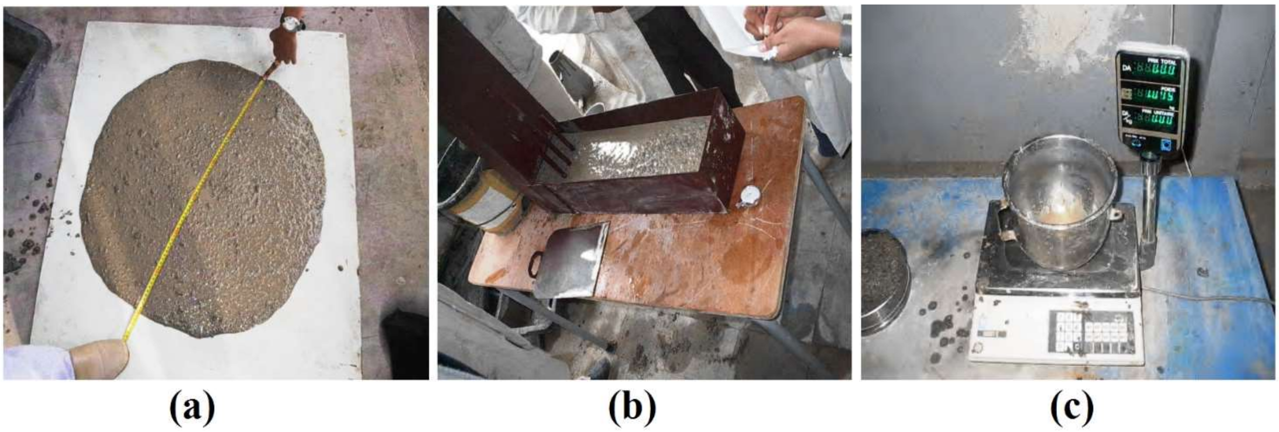

Fig. 2 - Tests conducted in the experimental program.

L-box test: This test is used to determine the flowability and passing ability of the SCC in confined spaces. The test equipment consists only of an L-shaped box (Fig. 2b). The vertical part of the L-box is filled with concrete and then the sliding gate is lifted after 1 min. The concrete flows through the steel bars into the horizontal part. The dimensions H1 and H2 are measured when the pouring of concrete is stopped. The value of the passing ability (H2/H1) is calculated and then compared with that given by the AFGC recommendation (H2/H1 > 0.8).

Sieve test: The resistance of SCC to segregation is determined in this test. After mixing, 10 l of concrete were poured into a pail, and kept for 15 min. Then, 4.8 kg of that concrete were placed into a 5 mm mesh sieve. After a period of 2 mn, the segregated part was calculated as the proportion of concrete passing through the sieve. A highly segregated part is an indicator of low resistance to segregation (AFGC recommendation: < 15%), (Fig. 2c).

V-funnel test: This test is used to determine the filling ability and viscosity of the SCC. The equipment consists of a V-shaped funnel. It was first filled with concrete, and then the time for concrete to flow out of the funnel was measured after opening the gate. A value ranging between 8 and 14 is recommended for the SCC.

3. Results and discussion

The compositions of the different fresh SCC mixes are given in Table 5. The experimental results are reported in Table 6. The tests concerned the two series of samples. One has to keep in mind that the results obtained from the slump flow, L-box, sieve tests, etc. were performed according to the French standards (AFCG) [18]. All the tests generated a slump flow of 60 cm in diameter; the flowability of the designed mixes can be assumed to be satisfactory for confined environments (L-box test). It can be concluded that the types of SCC mixes prepared in the present work can be used to make horizontal surfaces, such as horizontal slabs. It is clearly noted that the pozzolanic fillers are compatible with the associated admixtures, because they give good results of slump flow and filling ability, with reasonable sieve stability test results. Hence, these types of pozzolanic fillers may offer great opportunities, and extend even wider their use in ordinary concretes in general and SCC, in particular. The pozzolanic fillers coupled with admixtures also revealed satisfactory results, according to the French recommendations.

When the tests were carried out according to the French standards and recommendations above, the results of the experimental investigation showed that siliceous fillers could also be used to produce interesting SCC mixes. This can be explained by the fact that the rounded forms of fillers enhance the displacement of particles, and therefore give low shear resistance. This trend has already been noticed by Kayat et al. [3].

3.1. Mechanical properties

In Figure 3, the evolution of slump flow is plotted as a function of the volume of paste (VP). The increase in the volume of paste improved the results. The slump flow values increased with the increase in the volume of paste.

These findings are the same for the three types of fillers, and in all the mixes prepared [3, 19]. In particular, the flow rate was highly improved for the three types of fillers, when H2/H1 > 0.8, and for the same volume of paste (VP = 440 l/m^3).

In Figure 4, the evolution of the compressive strength, at 28 and 60 days, is plotted against the volume of paste. It can be seen that when the volume of paste increased by 19%, the compressive strength increased by approximately 13%. As stated by [8, 9, and 20], the increase in the volume of paste could have a positive effect on the quality of concrete mixes in the hardened state. The increase in the compressive strength with the increase in the volume of paste has already been reported by Persson [21], and Rozière et al. [8]. As shown in Figure 4, the compressive strength also depends on the nature of fillers used. For instance, the pozzolana fillers give higher values of compressive strength, when compared to the stregnth obtained with siliceous or limestone fillers, for the same volume of paste. Furthermore, one can

Table 6

Experimental results

	SCC1			SCC2			SCC3		
	L	PZ	S	L	PZ	S	L	PZ	S
Slum flow (mm)	620	700	620	630	720	650	650	760	700
L. BOX (%)	0.8	0.9	0.8	0.8	0.95	0.95	0.9	0.94	0.9
Sieve test (%)	5	8	9	8	9	8	12	9	10
T50 (s)	6	5	5	5	4	4	3	3	3
V- funnel (s)	15	12	12	15	11	11	11	10	11
fc 28d (MPa)	38	41	40	40	46	44	43	48	45
fc 60d (MPa)	40	44	42	43	48	45	45	51	45
Endogenous shrinkage (300d) (µm/m)	383	331	320	380	339	335	400	373	390
Total shrinkage (300d) (µm/m)	793	777	780	774	745	745	734	678	720

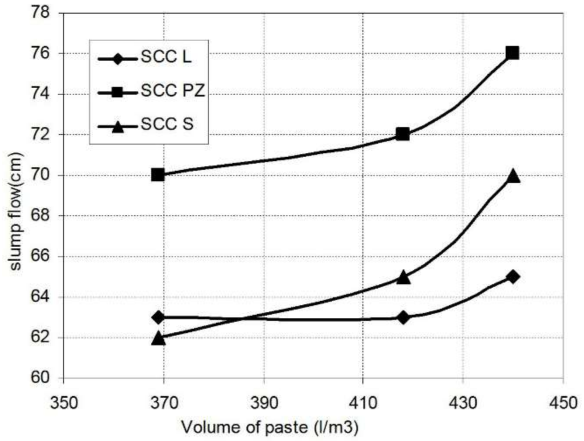

Fig. 3 - Slump flow vs. volume of paste

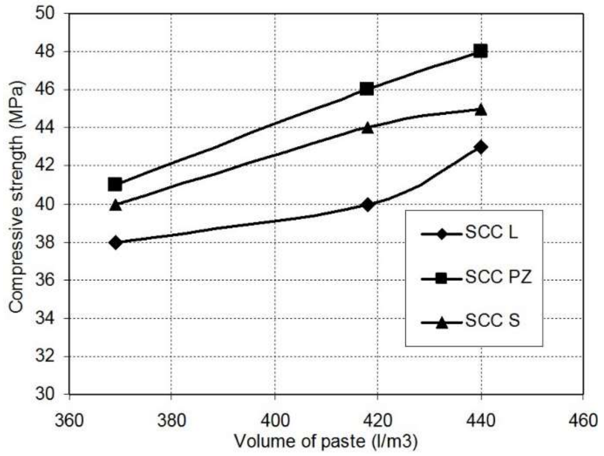

Fig. 4 - Compressive strength vs. slump flow.

notice that the slump flow depends on the compressive strength. This aspect can be highlighted by superimposing any value of the slump flow and the corresponding value of the compressive strength, to show the effect of the volume of paste on the fresh and hardened mixes.

3.2. Shrinkage

In Figures 5 and 6, the total shrinkage and the endogenous shrinkage of the different SCC mixtures are plotted against time. From the measurements, it can be deduced that while the volume of paste increased by 19%, the endogenous shrinkage decreased and the desiccation shrinkage increased. This is mainly due to the water content lost during drying. One can also deduce that the endogenous shrinkage in specimens containing pozzolanic and siliceous fillers is less significant than that of the specimen with limestone fillers. A decrease in the endogenous shrinkage was noted, in the range extending from 9 to 14%, when the volume of paste increased by 19%, with pozzolanic and siliceous fillers. The total shrinkage decreased by 23% for the pozzolanic fillers and 20% for the siliceous fillers.

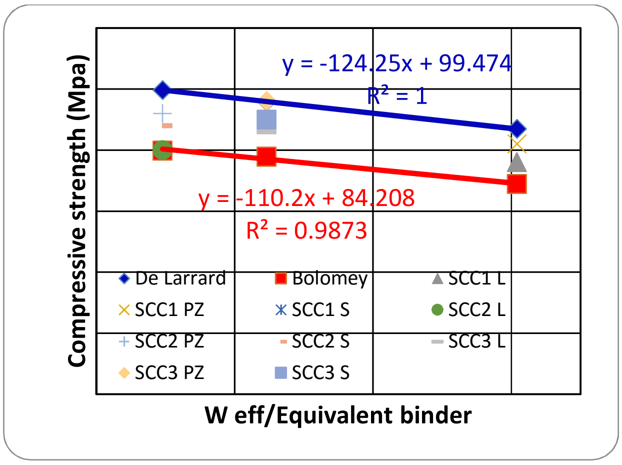

Fig. 5 - Compressive strength vs. Weff/Equivalent binder ratio.

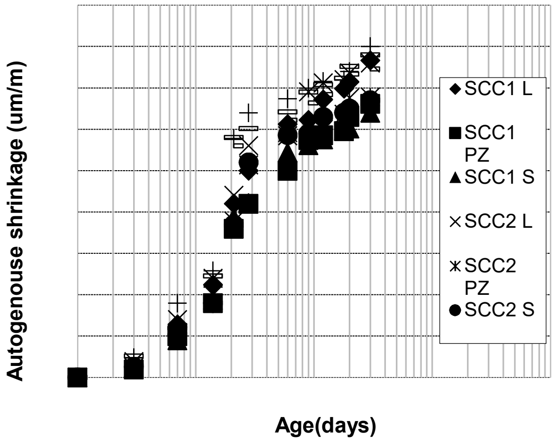

Fig. 6 - Endogenous shrinkage (μm/m).

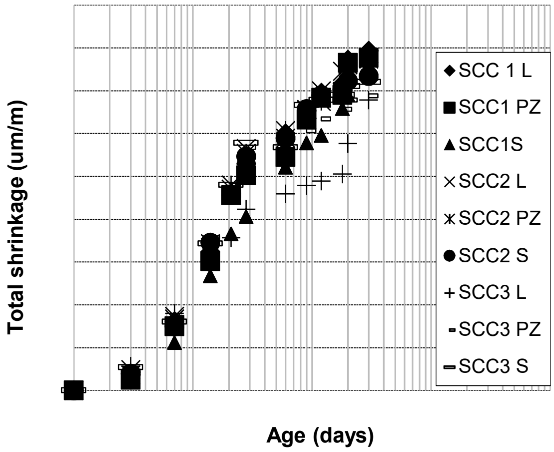

Fig. 7- Total shrinkage (μm/m)

Fig. 7 shows the loss of mass for the various mixtures prepared in the experimental program. The loss of water increased as the volume of paste rose; it is clearly seen that the water loss is related to the volume of paste and the nature of fillers [21]. It can also be noticed that the loss of water with pozzolana fillers is smaller than that obtained with the two other types of fillers. This phenomenon can be highlighted by the fact that the nature of fillers could turn a homogeneous matrix into a porous matrix [22 - 24].

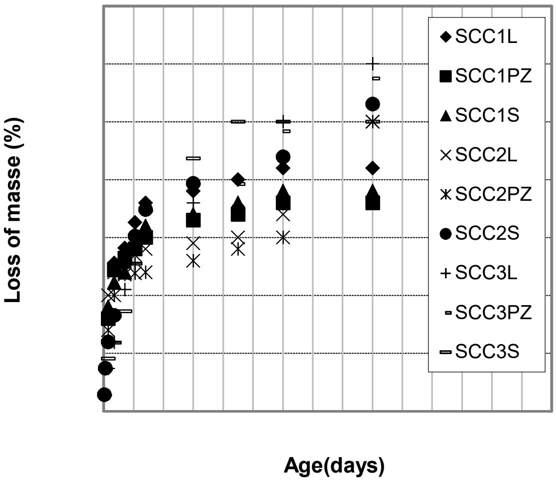

Fig. 8 - Loss of mass in the mixtures.

Figure 8 shows the evolution of the endogenous shrinkage as a function of time and volume of paste. At 7 days, the endogenous shrinkage values of SCC (S) and SCC (PZ) are smaller than that of SCC (L), for a volume of paste (VP) less than 418 l/m^3. On the other hand, one can easily notice that the endogenous shrinkage of all concretes increases appreciably with the increase in the VP, which confirms the findings of Rozière et al. [8].

It is worth noting that the VP at 7 days has no effect on the total shrinkage, which is mostly influenced by the diffusion of water in the pores, as has been stated by Wittman and Acker [24, 25].

At 28 days, SCC (L) is seen to present a significant endogenous shrinkage compared to that of the other concretes. On the other hand, the development of the endogenous shrinkage of SCC (PZ) remains very weak.

After one year, SCC (L) presents significant deformations, because its kinetics is slightly faster than those of the two other self compacting concretes. It is well known that limestone fillers have two effects on the hydration of concrete, as previously stated by Rols et al. and Bonavetti et al. [26, 27]. Although the W/C ratio is identical for the three SCC formulations, it is clear that the endogenous shrinkage increases with the paste volume in the SCC. Therefore, the weak effect of the W/C ratio on SCC (L) seems to be compensated by the presence of the filler because limestone fillers provide cementitious matrices with finer porosities. In the long term, these fillers react with portlandite to form second generation high strength concrete (HSC). Tragardh and Mehta [28, 27] indicated that fine limestone could make concrete denser, by filling the matrix and the paste-aggregate interface (interfacial transition zone or ITZ), which is a zone of low mechanical resistance due to its strong local porosity. Therefore, these fillers improve the mechanical behavior.

Figure 9 shows the evolution of the total shrinkage with respect to time and paste volume. Regarding the total shrinkage, for a volume of paste VP = 369 l/m^3, SCC (L) displays significant shrinkage compared to other SCCs, whereas SCC (S) presents weaker shrinkage. For VP = 418 l/m^3, all three SCCs exhibit shrinkages of the same order of magnitude. For VP = 440 l/m^3, SCC (L) shows weaker shrinkage compared to the other SCCs.

Between 60 and 300 days, the endogenous shrinkage increases with the volume of paste. It can be noticed that SCC (PZ) and SCC (S) present a very weak endogenous shrinkage compared to that of SCC (L). Concerning the total shrinkage, one notices that in the case of SCC (L), the total shrinkage decreases when the VP rises. On the other hand, SCC (PZ) and SCC (S) both show a peak for a paste volume of approximately VP = 418 l/m^3. At 300 days, one notes that as VP increases, the total shrinkage decreases. The evaporation of water, due to the hydraulic gradient between the center of the sample and the surrounding, takes

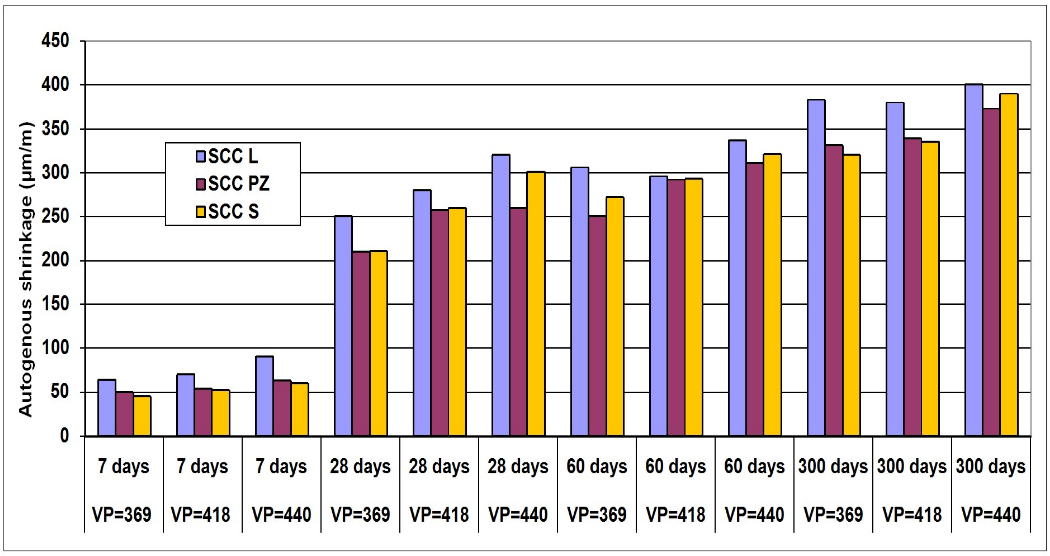

Fig. 9 - Endogenous shrinkage vs. paste volume

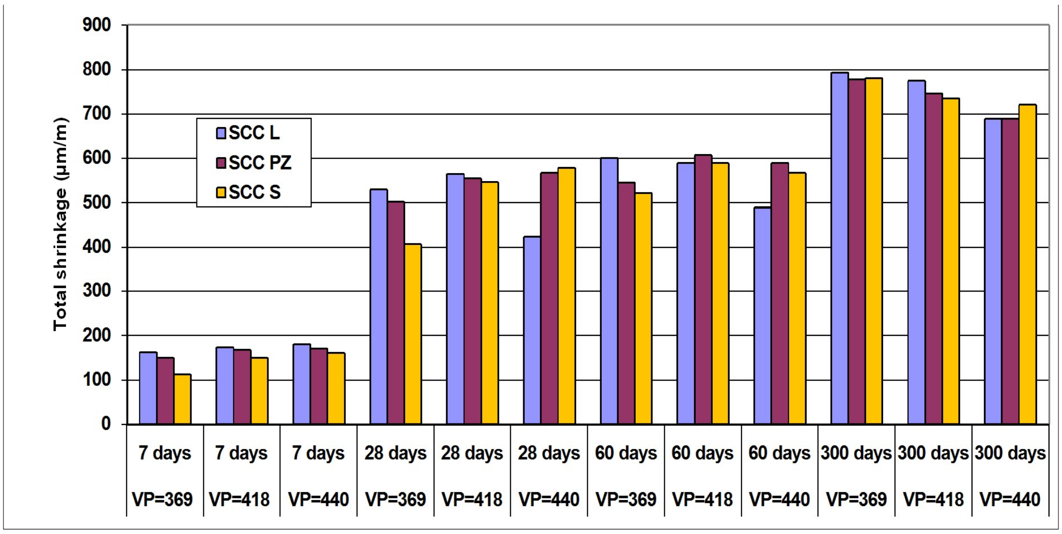

Fig. 10 - Total shrinkage vs. paste volume.

place via the open porosity and the microfissuring of the surface. The porosities accessible to water of the self compacting concretes under study are relatively equivalent, in terms of amplitude. The differences in the evolutions of drying and shrinkage can be imputed to the microstructure and the pore network of concrete. These results appear to be in line with the assumption of a more pronounced capillary porosity in the presence of limestone fillers with a higher drying kinetics, particularly at an early age.

However, it is essential to note that this effect is not solely correlated with the porous volume accessible to water but probably more with the tortuous form of the porous network, such as the distribution of the sizes of pores. This distribution can be very different, depending on the type of built-in mineral additions.

The consumption of water for hydration, principal factor of shrinkage, depends on the size of pores and the degree of interconnection of the porous network. It is therefore believed that in the case of SCC containing more fines (25% to 40%), there is a large number of pores and these concretes have a more significant solid volume. This will give better contact between particles, and thus induces less shrinkage. The development of endogenous shrinkage is much more gradual for SCC with large volume of paste. The pore size certainly influences the diffusion of moisture. The capillary pressure actually depends on the pore radius. In the end, one of the effects of the F/C ratio is undoubtedly the change in the curve of development of the hydrous pressure as a function of the degree of saturation [8]. Diffusivity decreases with the water content of concrete. The loss of mass is higher at the young age in SCC containing more fines. Regarding drying, it is possible that diffusivity decreases more quickly when the volume of paste increases.

Endogenous shrinkage increases with the increase in the volume of paste; the reverse phenomenon is observed for the total shrinkage (Fig. 9 and 10). It is clearly seen (Fig. 11) that when the (WEff /L binder equivalent) ratio is between 0.40 and 0.415, both the endogenous shrinkage and the total shrinkage increase. When this ratio is between 0.415 and 0.45, the two previous shrinkages decrease. So there is an optimum paste volume around 440 l/m^3.

So, considering these results with the nature of fines and the volume of paste, it is easy to notice that concretes made with pozzolan and silica fillers give lower endogenous and total shrinkages compared to those obtained with limestone fillers. The variation in shrinkage as a function of the (Weff /L binder equivalent) ratio was studied by Neville [30-31] who showed that a low (Weff /L equivalent binder) ratio along with a large quantity of paste lead to a decrease in drying shrinkage. The author in [12] found that the evolution of hydration reactions is related to the endogenous shrinkage, which in turn depends on the amount of water present in concrete; water promotes reaction between the different reactants. Therefore, he concluded that the amplitude of the endogenous shrinkage depends on the (Weff / L equivalent binder) ratio. The drying shrinkage diminishes with the (Weff /L equivalent binder) ratio, knowing that the drying shrinkage is the difference between the total shrinkage and the endogenous shrinkage. The addition of finer particles in cement causes an increase in the number of hydrate nucleation sites in the cementitious matrix [30]. Pozzolan fines continue to react with water and cement in the long term, to create more second generation C-S-H, as evidenced by [32-34]. This contributes to increase the mechanical strength and shrinkage.

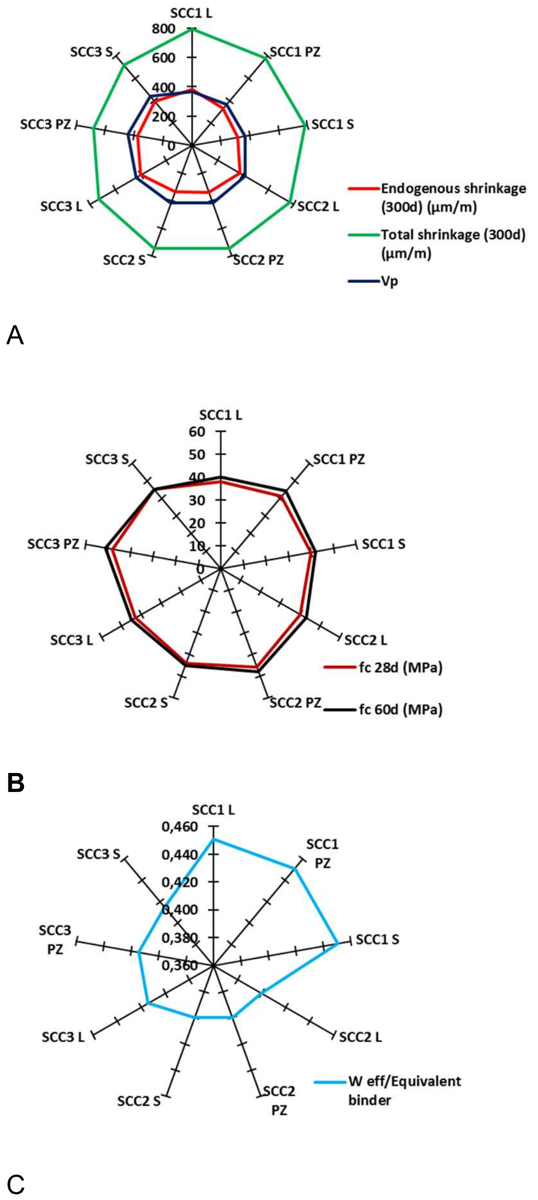

Fig. 11 - (A) Shrinkage. (B) compressive strength and (C) Weff/Equivalent binder ratio.

4. Conclusions

This work aims at promoting the use of local fillers, i.e. pozzolanic, siliceous and limestone fillers, in the composition of SCC mixes. The experimental results reported and discussed in this study relate to these three types of fillers, obtained from a region in western Algeria. The following conclusions can be drawn from this investigation:

- Although all three types of fillers were used, pozzolanic and siliceous fillers turned out to be interesting components in the formulation of SCCs.
- Slump flow, L-box and sieve tests, performed on concrete with pozzolanic and siliceous fillers, all gave good results, according to the French recommendations. They all resulted in good instantaneous and deferred responses, as far as rheological and mechanical properties are concerned.
- Self compacting concrete (SCC) can be better optimised with good instantaneous and deferred behavior, using pozzolanic and siliceous fillers rather than limestone fillers.
- For a ratio (Weff/L equivalent binder) equal to 0.415, an optimum paste volume is obtained; it is around 440 l/m^3.

Pozzolanic fillers have a shrinkage reducing effect. This aspect was not observed with the other two types of fillers.

This study was carried out to gain insight into the use of local fillers in the composition of SCC mixes. The effectiveness of pozzolanic fillers was readily shown in the composition of the CEMII CPJ cement. The intrinsic results, collected during the investigation program, were all obtained with testing procedures, according to the French recommendations. Ongoing study on this issue is to give complementary results on SCCs, using mineral admixtures.

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