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The effect of the kind of sands and additions on the mechanical behaviour of S.C.C

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Abstract

The sand is an inert element essential in the composition of concrete; its use ensures granular continuity between the cement and gravel for better cohesion of concrete. This paper presents the results of a study that investigated the influence of sand quality on the properties of fresh and hardened self-compacting concrete (SCC). The dune sands are very fine materials characterized by a high intergranular porosity, high surface area and low fineness modulus; on the other hand crushed (manufactured) sand has a high rate into thin and irregular shapes which are influencing the workability of concrete. The amount of dune sand varies from (0% 50%, to 100%) by weight of fine aggregates . The effect of additions is also treated (blast furnace slag and lime stone) The results show that the rheological properties favour the use of dune sands; however the mechanical properties support the use of crushed sand.

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1. Introduction

A self-compacting concrete (SCC) is a concrete that flows and sets up in the most complex and scrapped forms under the effect of its own weight. It is important to note that the material should not undergo any form of segregation and should have qualities similar to those of conventional vibrated concrete [1, 2]. Aggregates are very important components of ordinary and self-compacted concretes (figure 1). It's well known that they affect both fresh and hardened concrete properties. Concrete flowability depends on the properties of cement paste, the amount and gradation of aggregates. The lowest the surface area and voids

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are, the best the flowability is [3].

The sand is the key component to insure the granular continuity between the coarse aggregates (the gravel) and powders (cement and fillers). Crushed sands often require more water than round sands (obtained from dunes or rivers) to reach an aimed workability [4]. However, the round sands are characterized by a high intergranular porosity, which affect the aggregates packing and needs more powder to fill the voids and may increase the cost of SCC. The effect of round sand on mechanical properties of SCC is to be investigated.

The effect of crushed and round sands on the SCC is discussed here for both rheological and mechanical properties. The round sand used in this work is dune sand.

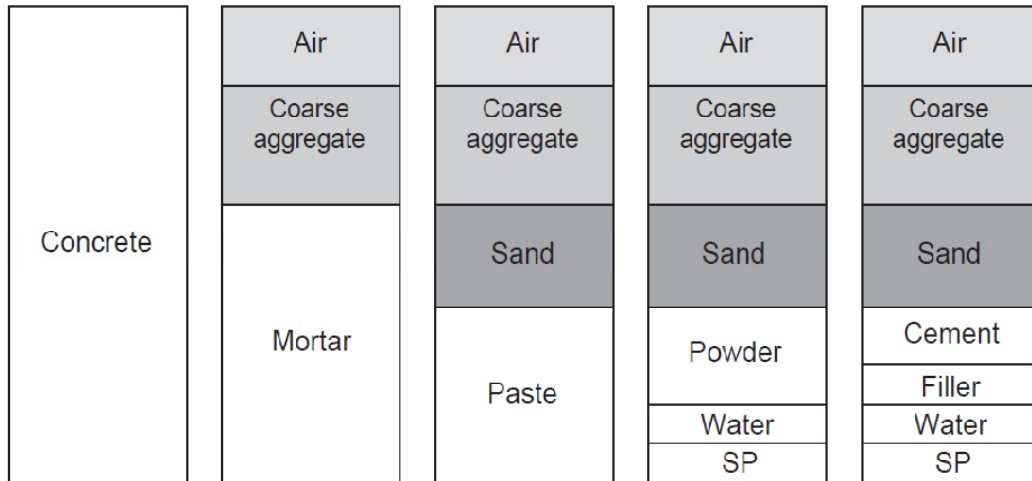


Figure 1 Schematic composition of SCC [5]

2. Materials and methods

The physical properties and the chemical composition of the material used are given in tables 1 and 2 respectively.

Table 1 Physical properties of materials used

Material	Type	ρ [kg/m ³]	Blaine [cm ² /g]
Cement	CEM II/A 42.5		
Filler 1	Limestone powder	3100	4000
Filler 2	Granular slag powder	2660	1600
Dune sand	Boussaada sand 0-3	2940	3200
Crushed sand	COSIDER quarry sand 0-3	2540	/
Crushed Gravel 1	COSIDER quarry gravel 3-8	2530	/
Crushed Gravel 2	COSIDER quarry gravel 8-16	2560	/
Superplasticizer	MEDAFLOW 30	2550	/
(liquid)	(GRANITEX)	1070	/

According to the particles size distribution (figure 2) we can see that the dune sand used in this work is fine (with a fineness modulus $M_f = 1.85 < 2.2$) and not entirely suitable to be used in concrete if we are looking for a good strength. For the crushed sand: $M_f = 2.1$, which may be considered as acceptable sand.

Table 2 Chemical composition of materials used

Materials	SiO ₂	Al ₂ O ₃	CaO	Fe ₂ O ₃	MgO	SO ₃	Na ₂ O	Cl ⁻
Cement	20.70	4.75	62.92	3.75	1.90	1.98	0.09	0.005
Filler 1	10.81	0.31	47.51	0.76	0.21	/	/	/
Filler 2	40.80	5.20	43.01	0.53	6.40	0.80	0.01	0.007
Dune sand	86.95	1.92	6.33	0.09	0.53	0.44	/	/
Crushed sand	40.65	8.87	40.56	3.25	3.65	0.79	0.01	/
Crushed gravel	40.65	8.87	40.56	3.25	3.65	0.79	0.01	/

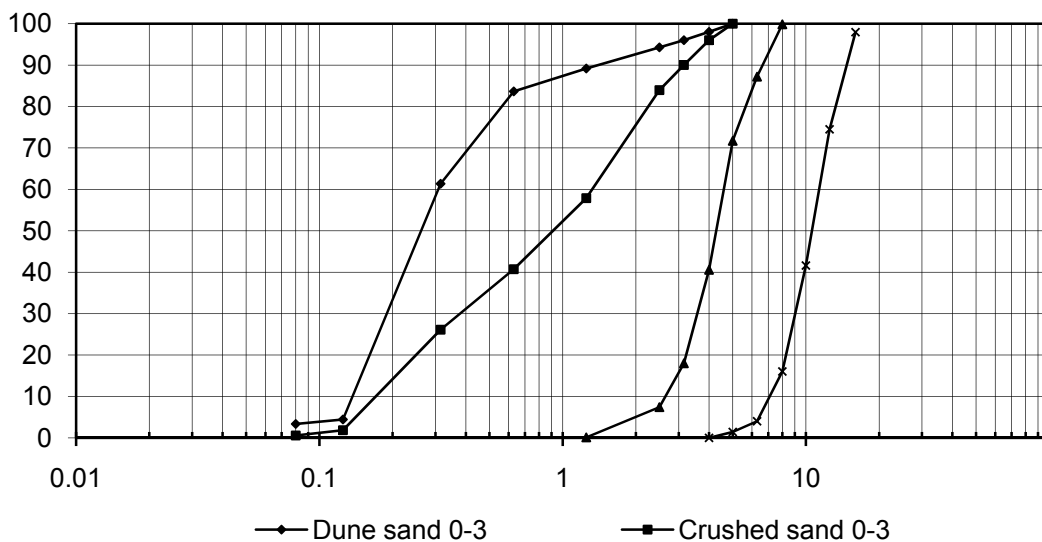


Figure 2 Particles size distribution of used aggregates

According to the recommendations of The European Guidelines for Self Compacting Concrete [6]: five mixtures were prepared as function as the nature and proportion of used sand, as well as the nature of filler used (table 3).

With: Powder/Water = 0.40 and Superplasticizer/Powder = 1.2 %.

The mix composition of mixtures used is given in table 4.

The experiments made on fresh concrete are:

- The passing ability (three bars L-box test);
- The flowability (slump-flow test using Abrams cone);
- The segregation resistance (sieve segregation resistance test).

All the experiments were done according to The European Guidelines for Self Compacting Concrete [6], based on the EN standards.

Table 3 Mix design for the experimental work

Factors	SCC 1	SCC 2	SCC 3	SCC 4	SCC 5
Dune sand	100 %	100 %	50 %	50 %	0 %
Crushed sand	0 %	0 %	50 %	50 %	100 %
Filler 1	0 %	100 %	0 %	100 %	0 %
Filler 2	100 %	0 %	100 %	0 %	100 %

Compressive strength is measured for hardened concrete at 14, 28 and 45 days, using cubic specimens (100 x 100 x 100 mm). While tensile strength is measured at 28 days, by the Brazilian test on cylindrical specimens (\varnothing 160 mm, height 320 mm).

All specimens have been poured and conserved in molds for 24 hours, after that they have been removed from molds and immersed in water basin at a temperature of $20 \pm 2^\circ \text{C}$, until the time of test.

Table 4 Mix composition of mixtures used

Component [kg/m ³]	SCC 1	SCC 2	SCC 3	SCC 4	SCC 5
Cement	400	400	400	400	400
Filler 1	/	100	/	100	/
Filler 2	100	/	100	/	100
Dune sand	850	850	425	425	/
Crushed sand	/	/	425	425	850
Crushed Gravel 1	425	425	425	425	425
Crushed Gravel 2	425	425	425	425	425
Water	200	200	200	200	200
Superplasticizer (liquid)	6	6	6	6	6

3. Experimental results on fresh concrete

Passing Ability

Experiments show that mixtures 1 and 2 (with 100% of dune sand) give a high passing ratio, which means a good flowability of the SCC (figure 3). In the case of mixtures with 50 % dune sand / 50 % crushed sand: SCC3 give higher passing ratio. These results are to be due to the round shape of dune sand particles as well as fineness of the filler used (SCC 1 and 3).

The fine dune sand used ($M_f < 2.2$) gives more flowability to the concrete.

In the case of SCC 5 (with 100 % of crushed sand) the flowing ability is very low, because of both the angular shape of crushed sand and the low fineness of the filler used (limestone powder).

As mentioned above, the use of a 3 bars L-box means that the passing ability class of the three first mixtures is PA2. Which means that they have the ability to flow through structures with a gap of 60 to 80 mm, (e.g. civil engineering structures) [6].

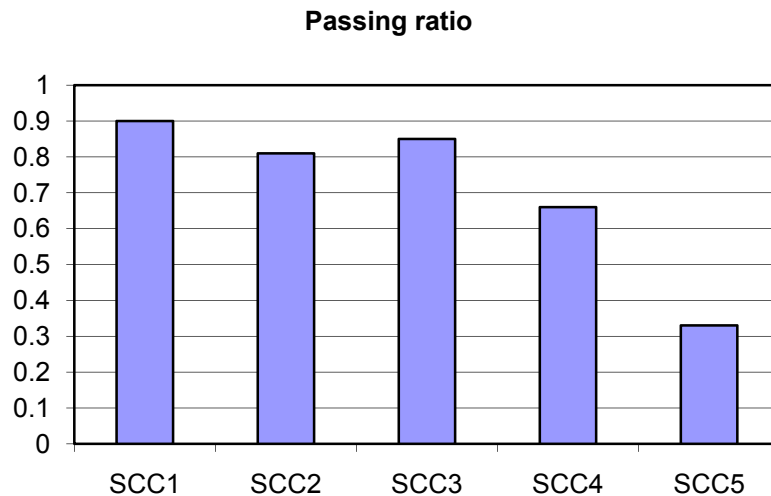


Figure 3 Passing ratio for the different SCC mixtures using 3 bar L-box test

Flowability

According to the results shown in figure 4: only SCC 5 gives a low slump-flow. This maybe to the same reasons mentioned above for which it gives low passing ratio.

We can classify the slump flow of the other mixtures as following [6]:

SF2 (660 – 750 mm) for SCC 2: Suitable for many normal applications.

SF3 (760 – 850 mm) for SCC 1, 3 and 4: Suitable for vertical applications in very congested structures, structures with complex shape, or for filling under formwork.

These good results were obtained with a low amount of superplasticizer (1.2 %), while the ulterior studies showed that a high percentage is required to have a high fluidity [7, 8]. This means that the high fluidity of the studied mixtures is due to the presence of round particles of dune sand.

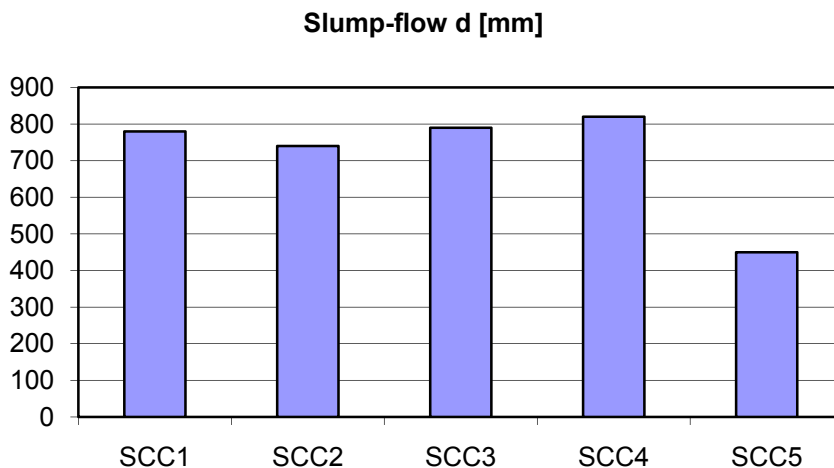


Figure 4 Slump-flow for the different mixtures prepared

Segregation Resistance

All the mixtures prepared in this work show very high segregation resistance (figure 5). The segregation class of the prepared mixtures is $SR_2 < 15\%$ [6]. The SCC 5 shows no segregation risks, for the same reasons of particles shape of crushed sand and the low fineness of the limestone powder used.

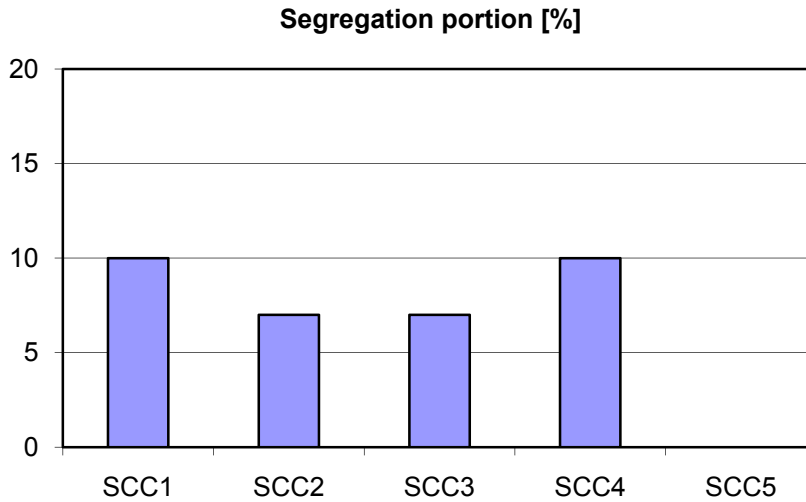


Figure 5 Segregation proportion for the different mixtures prepared

4. Experimental results on hardened concrete

Compressive Strength (f_c)

The compressive strength tests show that mixtures with 100 % of dune sand give less strength than those with a partial substitution with crushed sand (50% - 50%), which give a normal compressive strength (at 28 days) higher than 45 MPa (figure 6). The SCC 5 (100 % of crushed sand) gives a normal compressive strength near to SCC 1 (100 % of dune sand), which has the same filler used (granular slag powder). The mixtures with granular slag powder as filler developed compressive strength quicker despite the nature of the sand used. This is because of the hydraulic nature of granular slag powder and its good fineness, forming additional C-S-H and increasing the concrete’s strength [9].

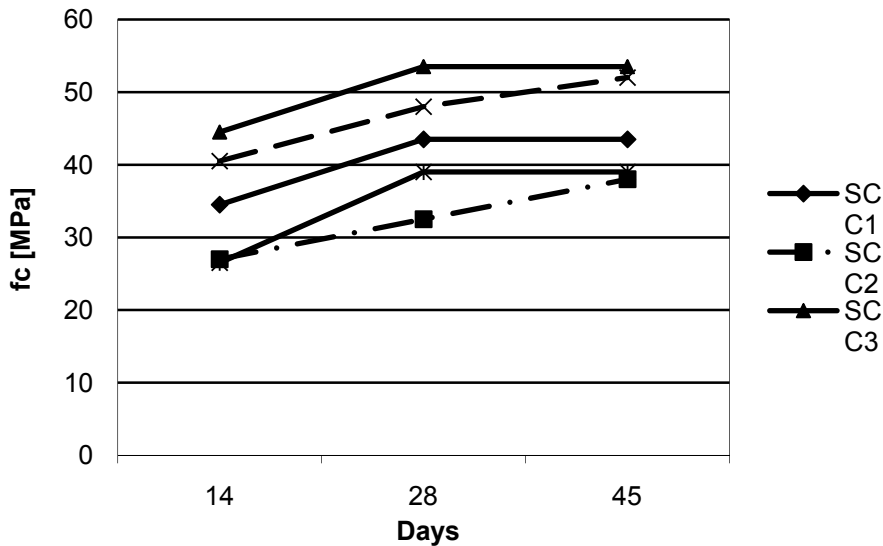


Figure 6. Compressive strength for the different mixtures

The low compressive strength developed by the mixtures with limestone powder at 28 days is due to the low fineness of the latter, which slows down the kinetic of hydration. Also the limestone is a semi-inert addition in comparison with granular slag. At 45 days the compressive strength of the mixtures with limestone powder reaches about 90 % of those with granular slag powder.

Tensile Strength (f_t)

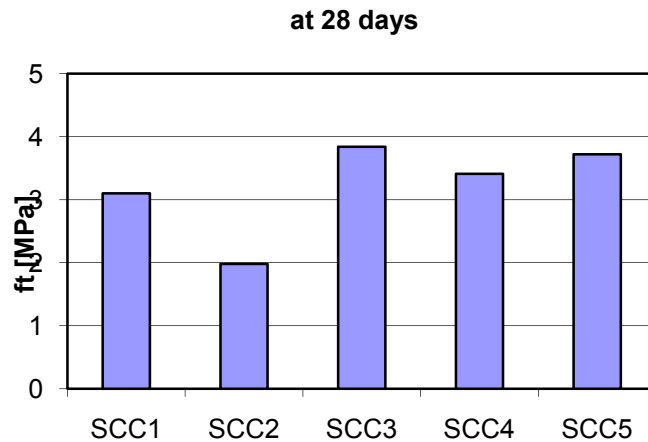


Figure 7 Tensile strength for the different mixtures at 28 days

The tensile strength measured at 28 days for the different mixtures prepared (figure 7) are proportional to the compressive strength at the same age, in exception of the SCC 5, which shows better results than in compressive strength tests.

In fact the three last mixtures with partial or total substitution of dune sand with crushed sand, despite the nature of addition. This means that the angular shape of crushed sand gives better adherence, packing and compatibility with the crushed coarse gravel.

5. Conclusions

This paper has focused on the physical effects of both dune (round) sand and crushed sand on the SCC. Dune sand gives less viscosity and then better flowability to the SCC, due to its round shape which reduces the intergranular friction between sand particles themselves and between sand and gravel. Spheres move easier than angular shape particles [10].

This makes the particles interactions more hydrodynamic. In the other hand, crushed sand gives less flowability to the SCC, due to the high intergranular friction between the different particles > 0.125 mm [11]. Crushed sand needs more water to give the aimed workability; but also the nature of this sand (limestone) makes absorbs some amount of mixing water. This is to be discussed in further works.

Contrary to the rheological properties of fresh SCC, it has been shown that crushed sand has better contribution to the strength development, especially in the case of tensile strength. Dune sand needs more past to cover its fine particles.

In both fresh and hardened SCC properties, the association of dune and crushed sands gives better results than mixtures with only one kind of sand. Dune sand alone gives high slump-flow, but not as high as in case of mixtures with both kinds of sands. This is due to the fine particles of dune sand which reduce the concrete workability [10].

A higher fineness of limestone powder used as filler in this work could give better results for both fresh and hardened SCC and will give more clear answers concerning the effects of both dune and crushed sands.

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