International Journal of Concrete Structures and Materials
Vol.3, No.1, pp. 11~14, June 2009

Incorporation of Crushed Sands and Tunisian Desert Sands in the Composition of Self Compacting Concretes Part II: SCC Fresh and Hardened States Characteristics

Abdelhamid Rmili,[1,2] Mongi Ben Ouezdou,[1] Mhamed Added,[3] and Elhem Ghorbel[4]

(Received January 19, 2009, Revised April 30, 2009, Accepted May 4, 2009)

Abstract: This paper is interested in the incorporation of crushed sand and desert sand in the composition the self compacting concretes (SCC). Desert dune sand, which has a fine extra granulometry, and the crushed sand, which contains an important content of fines, can constitute interesting components for SCC. Part II consists in studying the behaviour of SCC containing various sands with different origins. These sands, with different sizes, consist of several combinations of rolled sand (RS), crushed sand (CS) and desert sand (DS). The study examines the influence of the granular combination of sands on the characteristics in the fresh and the hardened state of SCC. The results of the experimental tests showed an improvement of the workability of the fresh SCC by combining sands of varied granulometry. The addition of the DS to CS or to RS allowed the increase of the mixture viscosity but decreased the mechanical strengths. Furthermore, the CS-RS combinations increased the compressive and the tensile strengths of the studied SCC. The optimized formulations of sands gave the highest performances of the SCC.

Keywords: self compacting concrete, deserted sand, crushed sand, rolled sand, sands combinations.

1. Introduction

In north Africa and in most countries of the south, the aggregates for concretes are made up exclusively of rolled sands and crushed gravels. These countries suffer from an important lack of aggregates and mainly of suitable sands. However, the use of crushed sands is quasi-non-existent in constructions.[1] Furthermore, these countries contain inexhaustible quantities of desert sands which were never seriously used in constructions. However, these extra-fine desert sands and crushed sands (a by-product from the aggregate quarries), which contain high percentages of fillers, can constitute interesting components of the self compacting concretes (SCC).[2,3] These SCC require for their composition of a high percentage of sand and added filler.[4,5]

This study consists in the incorporation of rolled sand (RS), crushed sand (CS) and desert sand (DS) in the SCC formulation. Several combinations of these sands constitute the elements of the study related to the influence of the size and origin of the sand on the performances of SCC.

[1]Civil Engineering Laboratory, Tunis National Engineering School, ENIT, BP 37, 1002 Tunis Belvedere, Tunisia. E-mail: mongi.benouezdou@enit.rnu.tn.
[2] Higher School of Sciences and Technology of Tunis, ESSTT, BP 56 Bab Menara, 1008 Montfleury Tunis, Tunisia.
[3]Testing and Construction Techniques Center, CETEC, Av. 15 October 1963, El Ouardia 1009 Tunis, Tunisia.
[4]LM2GC, University Of Cergy Pontoise, 5 Gaiy-Lussac, Neuville sur Oise 95031 Cergy Pontoise Cedex, France.

It is to be recalled that in part I[6], the physicochemical characteristics of the various components of SCC and a study of their formulation were presented. The results obtained showed that the combination based on these sands (RS, CS and DS) improved the compactness of the granular mixture and decreased the intergranular voids volume. In the same manner, the quantities of filler and water, necessary for the composition of the SCC, are reduced compared to SCC based on uncombined sands.[6]

This paper examines the influence of the combination of these three sands on the characteristics of SCC, in the fresh and in the hardened state. Part II presents workability tests of the studied SCC by varying the proportioning of the superplasticizer. The selected formulations, which answer the normative criteria of SCC, were submitted to mechanical testing. An analysis is carried out on the influence of the combinations of the three sands on the compressive and the tensile strengths of these SCC.

2. Workability in a fresh state of the SCC

The formulation of the studied SCC was based on the filling of the intergranular voids by the binder paste in order to have a maximum compactness of the mixture.[7-9] The granular mixture consists of gravel and several combinations of the three sands (RS, RS and DS). These combinations will be compared with the optimal mixtures, which are determined by the compressible model of packing.[9,10]

The materials used for the composition of these SCC are the same as those presented in part I.[6] Their main characteristics are presented as follows:

- a rolled sand (RS) siliceous 0/2.5 and of fines content of 1.80%,

- a crushed sand (CS) calcareous 0/5 and of fines content of 12.44%,
- a desert sand (DS) siliceous 0/0.4 of fine content of 14.4%,
- a crushed gravel (G) calcareous 4/16 (from the same quarrel as the CS),
- a calcareous filler (F) 0/0.112 with 96.6% < 0.080 mm,
- a superplasticizer (SP): a high water reducer of new generation,
- a cement (C) of type CEM I 42.5 conform to Tunisian standard NT 47.01.

2.1 Workability tests in the fresh state

The SCC thus formulated[6] were submitted for workability testing in the fresh state for various proportionings in SP (0.7%, 1%, 1.3% and 1.5%). The results of the flow tests, V-funnel tests and the capacity and rate of filling are presented in Figs. 1, 2, 3 and 4. SCC types are the same as used in part I.[6]

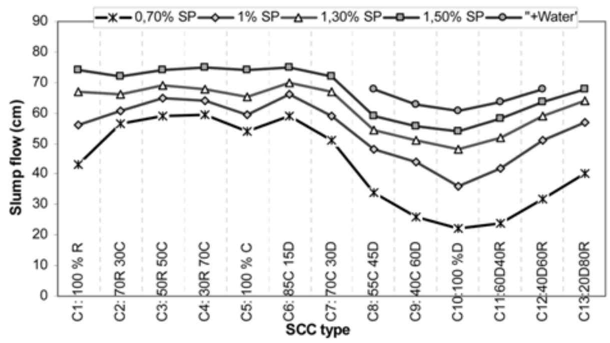

Fig. 1 Slump flow for various sand combinations and various SP percentages.

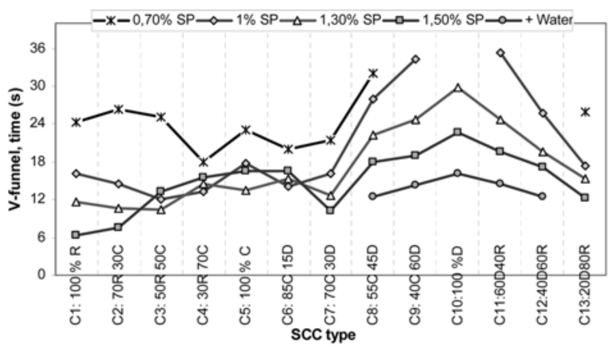

Fig. 2 V-funnel time of flow for various sand combinations and various SP percentages.

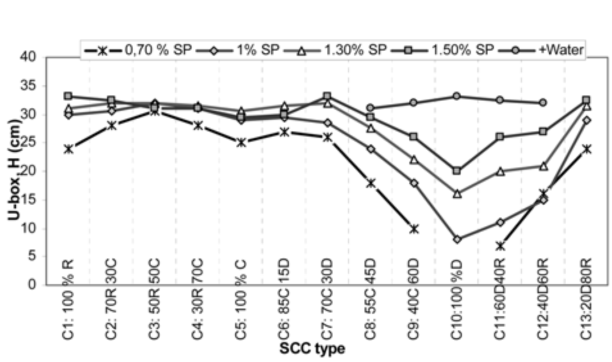

Fig. 3 Filling capacity for various sand combinations and various SP percentages.

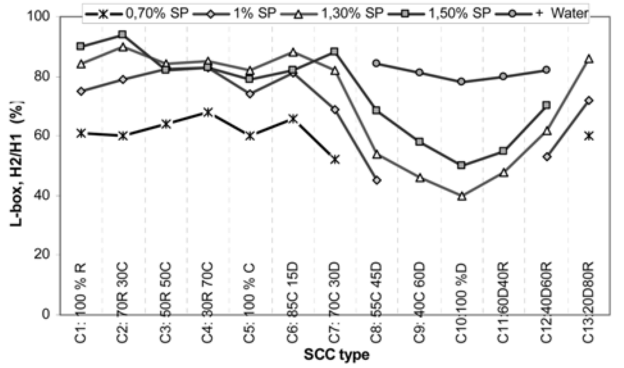

Fig. 4 Rate of filling for various sand combinations and various SP percentages.

Figure 1 shows that low proportionings in SP (0.7%) did not allow obtaining suitable flows for the majority of the SCC. Optimized formulations (C4, C6 and C13) (b) gave the best flows. The SCC with strong proportioning in DS gave low flows even at high contents of SP (1.5%). This state required the addition of water (C8, C9, C10, C11 and C12). The SCC with high proportioning of RS showed a good behavior with contents of rather high SP (C1, C2 and C13).

Figure 2 shows that the SCC with low content of SP (0.7 and 1%) gave slow V-funnel times especially for high proportionings in DS (C9, C10 and C11). However, these times were short for the high percentages of SP (1.5%) especially for the SCC with high proportioning of RS (C1 and C2). Furthermore, these times became again slow with high percentages of SP for the SCC with high proportioning in CS (C3, C4, C5 and C6).

Figure 3 shows that the filling capacities were important for the SCC with high proportioning of RS (C1, C2, C3 and C13). These capacities were lower for the SCC with high proportioning in DS that is why water addition was needed (C8, C9, C10, C11 and C12). The SCC, with high proportioning in CS, gave acceptable filling capacities for all proportioning in SP.

Figure 4 shows that the rates of filling were low for the SCC with high proportioning in CS and especially for the high proportioning in SP (1.5%) (C3, C4, C5 and C6).

2.2 Interpretations

- The results of the workability tests (Figs. 1~ 4) showed that: The SCC with high proportioning in CS required high filler quantity to fill the intergranular voids[6] and to decrease the intergranular frictions of the crushed aggregates. These SCC required also moderate SP proportionings to avoid any segregation and flow blocking through the creation of arches formed by coarse aggregates.[11-13]
- The SCC highly proportioned in DS required at the same time important proportionings in SP and in water. This is due to the large finesses of these sands and to their need for water (absorption coef. = 2.3%)[6] causing an increase in the viscosity.[14] A demand for additional water is then necessary to improve the workability behavior of these SCC.
- The SCC with strong proportioning out of RS allowed workability which increased with an increase in SP content.[15] With an adapted proportioning, the RS gave suitable values in spite of average qualities of these sands according to their

granulometry and their quantity of fines.

- With a given SP proportioning, the workability of the SCC was improved by the addition of the DS to the CS. However, the slump flow decreased starting 15% of the DS and the V-funnel time, the capacity and the rate of filling reached their optimum for a 30% of the DS (compared to the CS).
- As for the combination of the DS and the RS, the workability evolved proportionally according to the addition of the DS. The slump flow is acceptable for the DS < 40% (compared to the RS). The other remaining characteristics reached their best values for the DS < 20% without any water addition. Beyond 20%, the water addition is necessary.
- The combination of the CS and the RS clearly improved the workability of the SCC for all proportionings. The slump flow and the V-funnel time reached their optimum for 70% of the CS (compared to RS). The capacity (resp. the rate) of filling gave the best values for 50% (resp. 30%) of the CS compared to the RS.

3. Mechanical strengths of the SCC selected

The criterion used for the choice of the selected formulations, is such that these SCC have an almost identical slump flow (≈ 650 mm). While referring to part I,[6] the selected SCC had the formulation parameters as presented in Table 1. Figures 5 and 6 present the strengths of these SCC.

Figure 5 shows that the highest compressive strengths are obtained for the SCC containing CS especially for the optimal mixtures C4 and C5 (48.6 and 47.02 MPa respectively). These strengths result from the large size of the crushed sand.[16,17] The SCC with high proportioning in DS gave low compressive strengths due to a high quantity of water (0.57 < W/C < 0.62) and to a large quantity of filler (F/C > 0.5). For the moderated proportionings in DS (≤ 30%) these strengths are satisfactory (Exp: 38 MPa for C7 containing 30% of DS and 70% of CS).

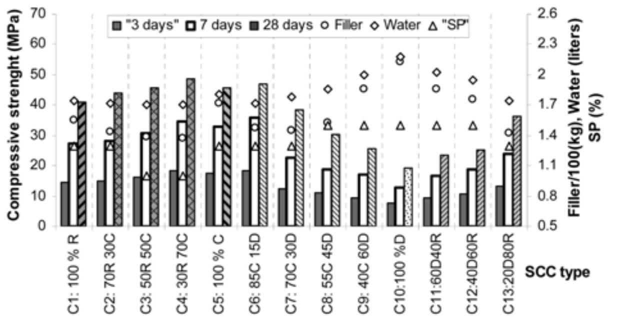

Fig. 5 Compressive strengths of the SCC selected (R = RS, C = CS, D = DS)

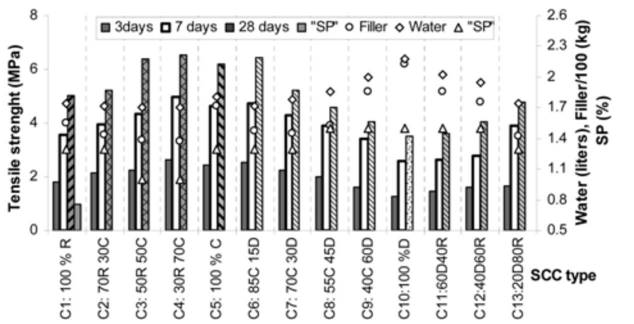

Fig. 6 Tensile strengths of the SCC selected (R = RS, C = CS, D = DS)

Figure 6 shows that the tensile strengths are high for the SCC containing CS (6.55 and 6.43 MPa for C4 and C5 respectively). This is due to the adhesion of the paste to the crushed aggregates and to the identical calcareous nature of the aggregates and the fillers.[18] For the SCC with high proportioning in DS, the corresponding tensile are appealing (exp.: 3.5 MPa for C10 containing 100%

Table 1 Parameters of formulation of the SCC selected.

SCC codes	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
RS (kg)	951.080	680.624	492.650	298.599	-	-	-	-	-	-	350.932	543.036	774.080
CS (kg)	-	291.696	492.650	696.731	932.200	824.466	676.494	522.445	352.112	-	-	-	-
DS (kg)	-	-	-	-	-	145.494	289.926	427.455	528.168	805.940	526.398	362.024	193.520
G (kg)	824.230	824.230	824.230	824.230	824.230	824.230	824.230	824.230	824.230	824.230	824.23	824.23	824.23
G/S	0.87	0.85	0.84	0.83	0.88	0.85	0.85	0.87	0.94	1.02	0.94	0.91	0.85
C (kg)	350	350	350	350	350	350	350	350	350	350	350	350	350
SP/B (%)	1.3	1.3	1	1	1.3	1	1.3	1.5	1.5	1.5	1.5	1.5	1.5
Sp (kg)	6.55	6.41	4.88	4.86	6.78	4.98	6.44	7.53	8.03	8.44	8.03	7.88	7.39
F (kg)	154.388	143.371	138.301	136.485	171.683	147.891	145.156	152.414	185.681	212.545	185.539	175.117	142.601
W_{th}. (kg)	174.455	171.286	170.891	170.459	180.161	176.953	177.953	182.171	194.101	207.609	193.838	187.366	174.172
$W_{ad.}$ (kg)	0	0	0	0	0	0	0	4	6	10	8	7	0
W (kg)	174.455	171.286	170.891	170.459	180.161	176.953	177.953	186.171	200.101	217.609	201.838	194.366	174.172
B (kg)	524.455	521.286	520.891	520.459	530.161	529.953	527.953	536.171	550.101	567.609	551.838	544.366	524.172
W/B	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.37	0.37	0.38	0.37	0.37	0.35
W/C	0.50	0.49	0.49	0.48	0.51	0.49	0.51	0.53	0.57	0.62	0.58	0.55	0.50
F/B	0.30	0.29	0.29	0.28	0.33	0.3	0.29	0.30	0.34	0.38	0.35	0.33	0.29
F/C	0.44	0.41	0.39	0.39	0.49	0.42	0.41	0.43	0.53	0.60	0.53	0.50	0.41

W_{th}.: theoretical water, W_{ad}.: added water, W: total water, B: binder of DS). These strengths are high values due probably to the lack of intergranular voids because of the presence of high quantities of binder paste.

4. Conclusions

This study showed that the combination of sands of varied granulometry contributes to the improvement of the characteristics of the SCC. With a given proportioning in the super plasticizer, the workability in the fresh state was improved by the addition of the DS to the CS. However, the slump flow started to decrease from 15% of the DS, requiring an increase in water, even with high contents of super plasticizers. The tests of V-funnel flow and the capacity of filling showed that viscosity was improved by adding the DS. These characteristics are optimal for a proportion of 30% of DS. However, these characteristics evolved quasi-linearly with the addition of the DS to the RS. Beyond 20% of DS with respect to the RS, an important quantity of water is required to reach the necessary workability of the SCC. In the same way, the combination of CS and RS allowed for an improvement of the SCC characteristics in the fresh state. The slump flow and the V-funnel time reached their optimum for the 30% of the CS with respect to the RS. The capacity of filling gave the best values respectively for 50% of the CS compared to the RS.

The mechanical strengths of the SCC are increased by adding the CS to the RS. The optimum is reached for the 70% of the CS with respect to the RS (48.6 MPa in compression and 6.5 MPa in tension). However, the compressive strengths of the SCC decreased by adding the DS to the CS. These strengths reached their optimum for 15% of the DS (47 MPa) and decreased beyond this percentage. At 30% of the DS, this strength reached 38 MPa. In the same way the strengths decreased when the DS is added to the RS. But at 20% of the DS addition (resp. 40%), these strengths reached only 36 MPa (resp. 25.2 MPa) as compressive strength and 4.7 (resp. 4 MPa) as tensile strength.

Acknowledgments

The authors wish to acknowledge the "Tunisian SIKA" for providing the admixture and the fillers. They thank also Mr. Sami Saaied for his help with the proof reading of the document.

References

1. Achour, T., Lecomte, A., Ben Ouezdou, M., Mensi, R., and Joudi, I., "Contribution of the Fillers Limestones to the Paste-Aggregate Bond: Tunisian Examples," *Materials and Structures*, Vol. 41, No. 5, 2008, pp. 815~830.
2. Ayed, K., Benaissa, A. Pons, G., Vidal, T., and Benhouna, M., "Optimisation de la Formulation des Bétons Autoplacants par les Matériaux Locaux," *Cmedimat*, 2005, Oran Algeria.
3. Zhang, G., Song, J., Yangb, J., and Liu, X., "Performance of Mortar and Concrete Made with a Fine Aggregate of Desert Sand," *Building and Environment*, Vol. 41, 2006, pp. 1478~1481.
4. Okamura, H. and Ouchi, M., "Self-Compacting Concrete-Development, Present, and Future," RILEM, *Proc. 1st International RILEM, Symposium on Self-Compacting Concrete*, 1999, pp. 3~ 14.
5. Zhu, W. and Gibbs, J. C., "Use of Different Limestone and Chalk Powders in Self-Compacting Concrete," *Cement and Concrete Research*, Vol. 35, 2005, pp. 1457~1462.
6. R'mili, A., Ben Ouezdou, M., Added, M., and Ghorbel, E., "Incorporation of Crushed Sands and Tunisian Desert Sands in the Composition of Self Compacting Concretes. Part I: Study of Formulation," Accepted in the *Int. Jour. Conc. Str. Mat.*, 2009.
7. Su, N., Hsu, K. C., and Chai, H. W., "A Simple Mix Design Method for Self-Compacting Concrete," *Cement Concrete Research*, Vol. 31, 2001, pp. 1799~1807.
8. De Larrard F., *Concrete Mixture Proportioning-A Scientific Approach*, London: E&FN Spon 1999, p. 164~169.
9. Brouwers, H. J. H. and Radix, H. J., "Self-Compacting Concrete: Theoretical and Experimental Study," *Cement Concrete Research*, Vol. 29, 2007, pp. 1~12.
10. Sedran, T. and de Larrard F., "René_LCPC : un Logiciel Pour Optimiser la Granularité des Matériaux du Génie Civil," *Note Technique*, *LCPC*, No. 194, 1994, pp. 87~93.
11. Khayat, K. H., "Workability, Testing and Performance of Self-Consolidating Concrete," ACI *Mater. J.*, 1999, Vol. 96, No. 3, pp. 346~353.
12. Ouchi, M. and al., "A Simple Evaluation Method for Interaction between Coarse Aggregate and Mortar's Particles in Self-Compacting Concrete," *Trans. Japan Conc. Inst.,* Vol. 21, 1999, pp. 1~6.
13. Bosiljkov, V. B., "SCC Mixes with Poorly Graded Aggregate and High Volume of Limestone Filler," *Cement Concrete Research*, Vol. 33, 2003, pp. 1279~1286.
14. Yahiaa, A., Tanimura, M., and Shimoyama, Y., "Rheological Properties of Highly Flowable Mortar Containing Limestone Filler-Effect of Powder Content and W/C Ratio," *Cement Concrete Research*, Vol. 35, 2005, pp. 532~539.
15. Okamura, H. and Ouchi, M., "Self-Compacting Concrete," *Jou. Adv. Conc. Tech.,* Vol. 1, No. 12003, pp. 5~15.
16. De Larrard, F. and Belloc, A., "L'Influence du Granulat sur la Résistance à la Compression des Bétons," *Bulletin de Liaison des Laboratoires des Ponts et Chaussées*, No. 219, Janvier-Février, 1999, pp. 41~52.
17. Leconte, A., De Larrard, F., and Mechling, J. M., "Résistance à la Compression de Bétons Hydrauliques au Squelette Granulaire non Optimisé," *Bulletin de Liaison des Laboratoires des Ponts et Chaussées,* No. 234 2001, pp. 89~105.
18. Achour, T., Leconte, A., Ben Quezdou, M., and Mensi, R., "Tensile Strength and Elastic Modulus of Calcareous Concrete: Application to Tunisian's Mixtures," *Materials and Structures*, Vol. 41, 2008, pp. 1427~1439.