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

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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. 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). These SCC require for their composition of a high percentage of sand and added filler.

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.

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. The granular mixture consists of gravel and several combinations of the three sands (RS, CS and DS). These combinations will be compared with the optimal mixtures, which are determined by the compressible model of packing.

The materials used for the composition of these SCC are the same as those presented in part I. 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 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.

- 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 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.
  - 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%) causing an increase in the viscosity.
  - The SCC with strong proportioning out of RS allowed workability which increased with an increase in SP content. With an adapted proportioning, the RS gave suitable values in spite of average qualities of these sands according to their

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.
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, 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. 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).

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. For the SCC with high proportioning in DS, the corresponding tensile are appealing (exp.: 3.5 MPa for C10 containing 100% of DS).

### Table 1 Parameters of formulation of the SCC selected.

| SCC codes | RS (kg) | CS (kg) | DS (kg) | G (kg) | G/S | C (kg) | SP/B (%) | Sp (kg) | F (kg) | Wth. (kg) | Wad. (kg) | W/B | W/C | F/B | F/C |
|-----------|---------|---------|---------|-------|-----|--------|----------|--------|-------|-----------|----------|-----|-----|-----|-----|
| C1        | 951.080 | -       | -       | 824.230| 0.87| 350    | 1.3      | 6.55   | 154.388| 174.455  | 174.455  | 0.35| 0.50| 0.30| 0.44|
| C2        | 680.624 | 291.696 | 145.494 | 824.230| 0.85| 350    | 1.3      | 6.41   | 143.371| 143.371  | 0.35    | 0.5  | 0.49| 0.41|
| C3        | 492.650 | 492.650 | 289.926 | 824.230| 0.84| 350    | 1.1      | 4.88   | 138.301| 138.301  | 0.35    | 0.5  | 0.49| 0.41|
| C4        | 298.599 | 696.731 | 427.455 | 824.230| 0.83| 350    | 1.1      | 4.86   | 136.485| 136.485  | 0.35    | 0.5  | 0.49| 0.41|
| C5        | -       | 932.200 | 528.168 | 824.230| 0.88| 350    | 1.1      | 4.98   | 147.891| 147.891  | 0.35    | 0.5  | 0.49| 0.41|
| C6        | -       | 824.466 | 805.940 | 824.230| 0.85| 350    | 1.1      | 6.44   | 145.156| 145.156  | 0.35    | 0.5  | 0.49| 0.41|
| C7        | -       | 676.494 | 526.398 | 824.230| 0.94| 350    | 1.1      | 7.53   | 132.414| 132.414  | 0.35    | 0.5  | 0.49| 0.41|
| C8        | -       | 522.445 | 362.024 | 824.230| 0.94| 350    | 1.1      | 8.03   | 135.171| 135.171  | 0.35    | 0.5  | 0.49| 0.41|
| C9        | -       | 352.445 | 262.109 | 824.230| 1.02| 350    | 1.1      | 8.44   | 121.545| 121.545  | 0.35    | 0.5  | 0.49| 0.41|
| C10       | -       | -       | 526.398 | 824.230| 0.94| 350    | 1.1      | 8.03   | 135.171| 135.171  | 0.35    | 0.5  | 0.49| 0.41|
| C11       | 350.932 | -       | -       | 824.230| 0.94| 350    | 1.1      | 8.44   | 121.545| 121.545  | 0.35    | 0.5  | 0.49| 0.41|
| C12       | 543.036 | -       | -       | 824.230| 0.94| 350    | 1.1      | 8.03   | 135.171| 135.171  | 0.35    | 0.5  | 0.49| 0.41|
| C13       | 774.080 | -       | -       | 824.230| 0.94| 350    | 1.1      | 8.44   | 121.545| 121.545  | 0.35    | 0.5  | 0.49| 0.41|

Wth.: theoretical water, Wad.: 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.

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