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Effect of Dune Sand on The Properties of Self-Compacting Concretes

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Abstract: *Dune sand is considered an abundant resource in nature. It is available on almost 60% of Algerian territory, its quantity amounts to one billion cubic meters. Dune sand can be considered as a perfect solution to the depletion of natural resources.*

In the present study, three self-compacting concretes were made. The first is a control self compacting concrete "SCC", the second was prepared by substituting crushed sand with dune sand "SCC-DS". The third was made by substituting limestone fillers with finely ground dune sand "SCC-GDS".

Tests have been carried out to study the properties of concretes in the fresh and hardened state as well as the durability of SCCs to sulfuric acid attacks.

The results obtained show a rapid increase in resistance from young age to 28 days. The compressive and tensile strength differs from one concrete to another, it was noticed that it decreases from SCC to SCC-DS to SCC-GDS.

Regarding the durability to sulfuric attacks, a loss of resistance was observed for SCC while the SCC-DS suffered a slight decrease. This may be due to the dune sand nature which has not been affected by the acid.

Keywords: *Self compacting concrete, dune sand, finely ground dune sand, compressive strength.*

1. Introduction

The cost of sand extraction increases every year while the extraction of sand dunes is almost nil. This makes dune sand more economical. The use of dune sand can relieve the habitat area and contribute to the development of southern Algeria regions.

Studies have been carried out in recent years on the possibility of incorporating dune sands into concrete. G. Zhang et al [1] studied the effect of fine aggregate total substitution by dune sand on concrete. M. Tayebi et al [2] studied concrete mixes of 100% dune sand under severe climatic conditions including cracking. The results showed that the cracks are still present and an improvement in the concrete mix is essential. S. Guettala et al [3] studied the possibility of replacing cement with finely ground dune sand, they found that the use of finely ground dune sand improves the porous structure of concrete and also contributes to the densification of the aggregate-matrix interface zone.

Dune sands still remain unknown despite the studies already carried out in this area. For this and to encourage and guide construction actors for the use of this sand, a series of studies and tests were launched to enhance the use of dune sand in concrete and particularly self-compacting concrete.

The objective of this paper is to study the effect of dune sand, finely ground or not, on the properties of self compacting concrete and the durability to sulfiric acid attack.

2. Materials

Cement: The cement used is CEM II/A-P 42.5 N from GICA cement plant in Constantine eastern Algeria.

TABLE I : Chemical composition of the clinker.

Element	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CaO libre	Insoluble residues	LOI
Content %	27.83	6.21	3.12	57.22	0.94	2.02	0.88	2.28	2.41

Aggregates: The aggregates used are natural crushed limestone aggregates from the ENG quarry - Constantine, with granular classes of 0/3 for sand, 3/8 and 8/15 for gravel.

TABLE II : Physical characteristics of the aggregates used.

	Properties measured	Designation		
		0/3	3/8	8/15
Physical properties	Absolute density (kg/m^3)	2750	2560	2620
	Bulk density (kg/m^3)	1460	1330	1370
	Value in blue methylene	0.38	/	/
	Absorption coefficient (%)	1.1	2.28	1.77
	Sand equivalent (%)	69	/	/
Mechanical properties	Los Angeles test (%)	/	28	23
	Micro Deval test (%)	/	25	17

Superplasticizer: A superior 12 WG Superplasticizer was used from TEKNACHEM laboratories.

Limestone powder: The used limestone powder (LP) was manufactured by the ENG quarry in eastern Algeria. Its specific surface and the specific weight were 3500 cm^2/g and 2.7 g/cm^3, respectively.

TABLE III : Chemical properties of limestone powder.

Element	$CaCO_3$	CaO	SiO_2	Na_2O	Al_2O_3	MgO	Fe_2O_3	K_2O	P_2O5	TiO_2	SO_3	LOI	Ph
Content %	99.61	55.94	0.04	0.05	0.03	0.20	0.02	0.01	0.01	0.01	0.02	43.67	9

Dune sand: the dune sand used was from El Mosrane region (40 km north of Djelfa). It was ground until a powder of less than 80 µm was obtained. The absolute density, Bulk density and specific surface were of 2.70 kg/m^3,1.20 kg/m^3 and 3950 cm^2/g respectively.

TABLE IV : Chemical analysis of grounded dune sand

Element	CaO	SiO2	Na2O	Al2O3	MgO	Fe2O3	K2O	SO3	CI
Content %	0.77	92.77	0.00	0.00	0.20	0.38	0.226	0.62	0.027

3. Mix design

The method used for the preparation of self-compacting concrete is the method proposed by Shen et al [4]. Three self compacting concretes were prepared. The first was a control self compacting concrete (SCC). The second (DS-SCC) was prepared by replacing 20% of crushed sand with dune sand. The third (GSD-SCC) was prepared by totally replacing the limestone powder with finely ground dune sand. Table 5 presents the composition in 1m^3 and labeling of the SCC mixture.

TABLE V : Composition of self compacting concretes in 1m^3.

	CEMII	S (0/3)	G (3/8)	G (8/15)	DS	GDS	SP	Water	LP	W/B
SCC	432	833	356	492	0	0	5	211	108	0.49
DS-SCC	432	666	356	492	167	0	5	211	108	0.49
GDS-SCC	432	833	356	492	0	108	5	211	0	0.49

The specimens were cast immediately after concrete production and moved to a room at 20°C and 90% RH. After 24 h they were demoulded. The specimens used to determine the mechanical properties are cubes 15x15x15 cm^3 for compressive strength and prisms 7×7×28 cm^3 for flexural strength. Three specimens were measured per property and age.

As for the durability to sulfuric acid attack, the specimens were kept in a room at 20°C and 90% RH for 21 days before being subjected to sulfuric acid attack test according to ASTM C267 [5].

Six cubes were used for each SCC. Three cubes remain in conservation room (as a reference medium) and the other three were immersed into 2.5% sulfuric acid solution. Drying-wetting cycles were performed to accelerate aggression the acid attack mechanism (2 days at 50° temperature and 2 days in sulfuric acid solutions) for 2 weeks. The solution was renewed every cycle.

4. Results and discussions

4.1. Workability

In order to qualify the prepared SCCs, the following tests were carried out: slump-flow test, V-funnel, L-box and sieve stability test. Also, the real density was measured. The characterization results of each composition are shown in Table 6.

TABLE VI : The characteristics of SCC mixtures.

	SCC	DS-SCC	GDS-SCC
Slump-flow (cm)	70	71	69
L-Box	1	1	0.8
Sieve stability (%)	9.5	8.1	6.9
V-Funnel (s)	18.26	15.25	18.43
Density (kg/m^3)	2385	2360	2326

The table 6 indicates that SCC mixtures properly meet the required specifications [6] for such concrete. All mixtures were stable and did not show any signs of segregation.

The slump flow of the all SCC mixtures can be classified as follows [9]: SF2 (660–750 mm) for SCC 2: Suitable for many normal applications;

All the mixtures of SCC prepared, show very high segregation resistance .The segregation class of the prepared mixtures is SR2 < 15% [9]. The finely ground dune sand give to the SCC, a higher segregation resistance.

4.2. Compressive Strength

The compressive strength test results are presented in figure 2.

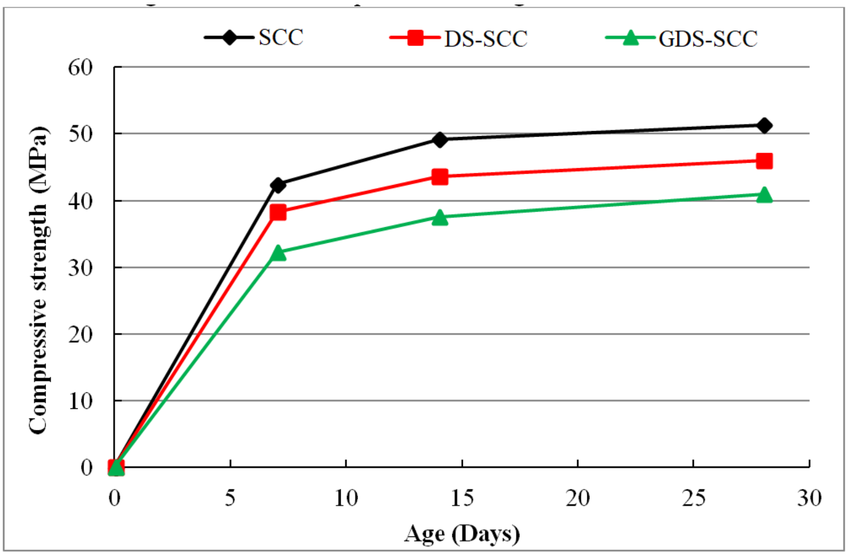

Fig. 1 : Compressive strength of SCCs

According to the figure 2, a gradual increase in compressive strength can be seen due to the development of cement hydration phenomenon as a function of time in the presence of sufficient humidity. The compressive strength of SCC with dune sand does not exceed the control SCC. These results are in agreement with Mechti et al [7]. SCC SDB has the lowest strength compared to the control self compacting concrete, which confirms the results of S. Guettala et al [3] for SCC with 20% SDB.

4.3. Flexural strength

The Flexural strength test results are presented in figure 3.

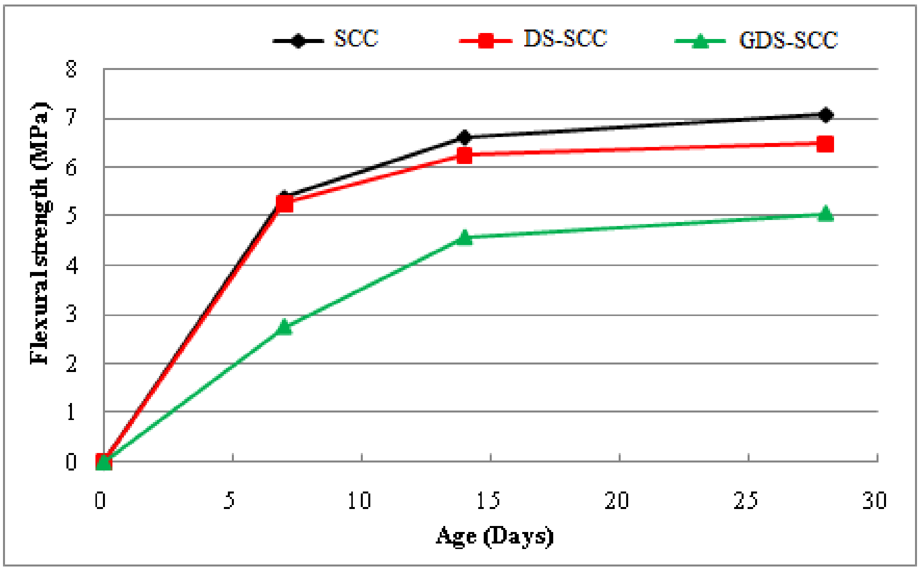

Fig. 2 : Flexural strength of SCCs

According to figure 3, the SCCs show the same evolution as the compressive strength. Dune sand has no justifying influence on the flexural strength.

4.4. Durability to sulfuric acid attack

Fig 3 illustrates the Compressive strength test results of SCC sampls immersed in water and in a 3% sulphuric acid solution. The average compressive strength of the degraded samples was evaluated at the end of drying and wetting with sulphuric acid solutions cycles and compared with the compressive strength of samples cured in water that have the same age.

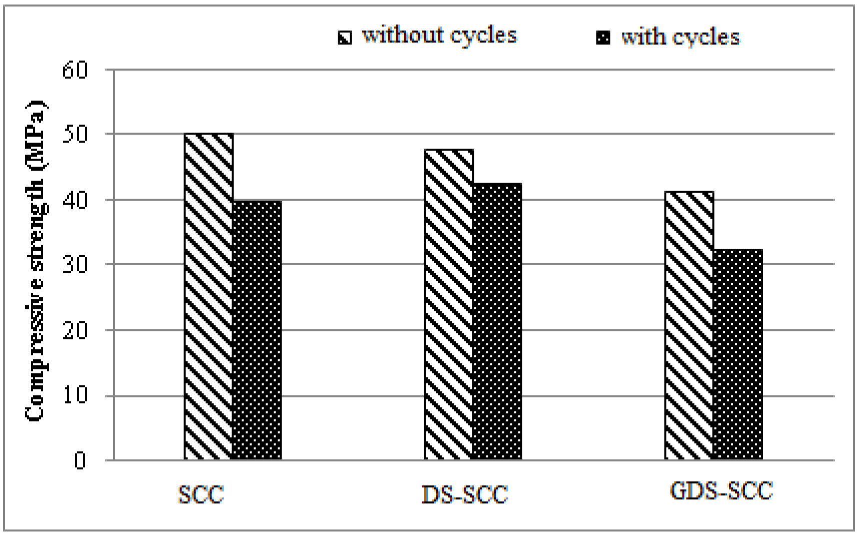

Fig. 3 : Compressive strength of SCC samples immersed in water and in a 3% sulphuric acid solution.

From the figure 4 it can be seen that the mechanical performance of all the SCCs subjected to acid attack has decreased. The strength loss of SCC and GDS-SCC is almost similar with values of 20.46 and 21.91% respectively. While DS-SCC exhibits strength loss of 10.4% this can be explained by the ability of dune sand to enhance concrete resistance against chemical attack. The strength loss is due to the chemical reaction between the portlandite and sulfuric acid that involves the formation of gypsum and ettringite which may contribute to the process of expansive deterioration mechanisms [8].

5. Conclusion

The following conclusions can be drawn:

- The use of dune sand, ground or not ground, decrease the mechanical performance of self compacting concrete but still gaves satisfactory results and can be used in the construction field.
- Dune sand self-compacting concrete is the most resistant to sulfuric acid attack.

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