Influence of Fine Dune Sand on Modulus of Elasticity of Eco-Self-Compacting-Concrete

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Abstract

The aim of this research was to study the effect of fine dune sand on the mechanical performance of Eco-Self-Compacting Concrete (SCC). For that, the fine dune sand of the Western erg (Taghit – Algeria) was being like mineral addition to formulate the SCC, and a comparison was carried out on their effect on the properties of SCC. Our study also showed that the substitution of fine dune sand (DS) by cement in the composition of the SCC, contributes to a slight variation of workability in the fresh state parameters still remaining in the field of SCC required by the AFGC recommendations. The experimental results show that the compressive strengths and modulus of elasticity of SCC improved by substituting of 20% cement by DS.

Keywords: Eco-Self-Compacting concrete; Fine Dune sand; Formulation; Mechanical performance

1. Introduction

The Self-Compacting Concretes (SCC) are very fluid concretes whose implementation without vibration has several advantages at divers levels which interest more and more industries (Neville, 2004: Bethmont et al., 2009). The stability and perfect homogeneity of SCC are ensured by the use of the superplasticizer and the incorporation of the mineral additions in their compositions (Benmerioul et al., 2017, Ayed et al., 2020). In the eighties and nineties, the studies relating to the high performance concretes showed the harmful role of the excess water in concretes. The reduction of this quantity of water, by the use of deflocculants and by the correction of granular stacking via ultrafine, has led to the strength and durability gains that are now known (Okamura & Ouchi, 1999, Bouhamou et al., 2008).

As part of the development, dune sand is now incorporated in the new concrete (Tafraoui, 2012). The negative impact of dune sand on the performance of concrete was due to poor grading and fineness (Ali et al., 2021; Ahmad et al., 2022). Fine aggregate (amount and type) is a primary component of concrete; it significantly affects fluidity, strength and dry shrinkage of concrete.

Increases in dune sand concentration lowered workability (slump) of concrete to 30% (Dawood & Jaber, 2022), The concrete made with a fine dune sand with ratio of 10% showed the highest mechanical performance (Rennani et al., 2020; Lee et al., 2022).

The present work aims to understand the influence of fine dune sand on the mechanical performance of the SCC based on local mineral addition.

2. Materials Used

2.1 Cement and Mineral Additions

The cement used is a Portland cement [NF EN 1971]. Fine dune sand is a crushed dune sand to 80 µm from Taghit, Bechar - Algeria (Figure 1). The granularity, uniformity, chemical purity and nature of the dune sand make it a unique resource.

Fig. 1: Location of dune sand of Tgahit (Bechar -Algeria)

Table 1 presents the physical and mechanical characteristics of Portland cement and dune sand.

Table 1: Physical and mechanical properties of Portland cement and fine dune sand

Properties	Unity	Portland Cement	Fine Dune Sand
Absolute density	kg/m^3	3050	2800
Finesse	cm^2/g	3200	3000
Weight of Unit	kg/m^3	1120	1300
Mechanical strength at 2 days	MPa	24	-
Mechanical strength at 28 days	MPa	50	-

The results of chemical analysis in Table 2 show that the quartz (SiO_2) level in the six fraction of dune sands was found to be greater than 80 %, which means that these sands are of a siliceous nature.

Table 2: Chemical properties of dune sand (Tafraoui, 2012)

Fraction (mm)	0-0.04	0.04-0.10	0.10-0.12	0.12-0.16	0.16-0.20	0.20-0.25
%SiO_2	81.60	92.40	95.20	96.30	97.30	97.20
%Al_2O_3	3.80	2.10	1.40	1.00	0.83	0.80
%Fe_2O_3	2.20	1.00	0.60	0.30	0.24	0.20
%CaO	3.90	0.90	0.30	0.30	0.10	0.10
%MgO	0.60	0.20	0.02	0.50	0.40	0.05
%SO_3	0.20	0.20	0.20	0.20	0.20	0.10
%K_2O	1.10	0.60	0.33	0.10	0.04	0.02

Fraction (mm)	0-0.04	0.04-0.10	0.10-0.12	0.12-0.16	0.16-0.20	0.20-0.25
%Na_2O	0.50	0.20	0.10	0.10	0.10	0.20
%P_2O_5	0.10	0.02	0.01	0.01	0.01	0.00
%TiO_2	0.90	0.60	0.30	0.10	0.05	0.05
%MnO	0.04	0.03	0.02	0.01	0.02	0.01
%Cr_2O_3	0.01	0.01	0.01	0.01	0.01	0.01

The shape of dune sand particle is round form according to Figure 2.

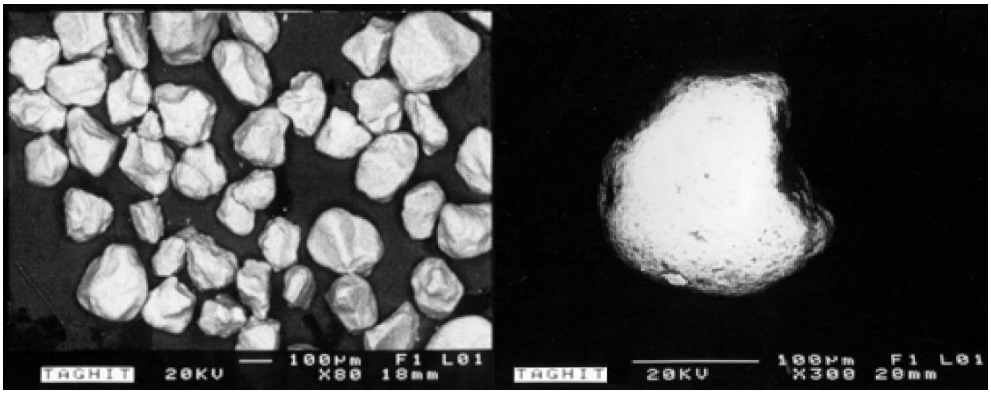

Fig. 2: SEM photographs of dune sand (Tafraoui, 2012)

2.2 Aggregates

The influence of aggregates is very strong on mechanical performance of concrete. All classes used (0/3), (3/8), (8/15) come from the quarry (Bechar).

The distribution curves of all aggregates are presented in Figure 3.

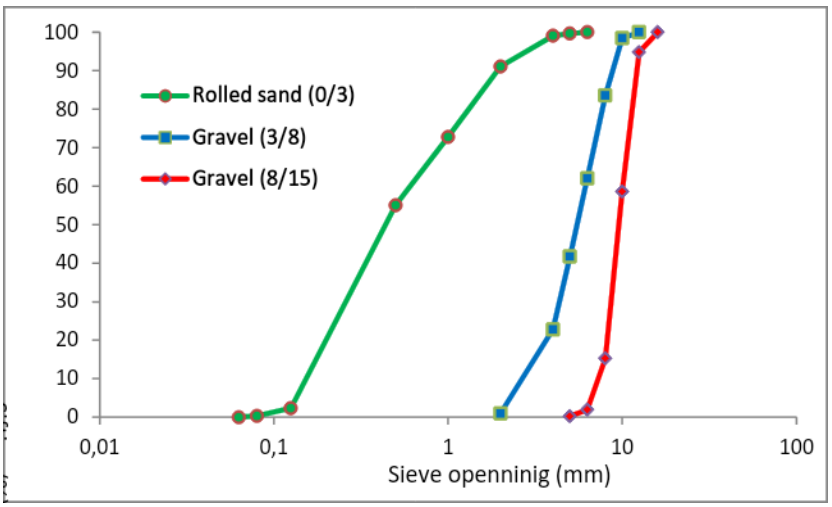

Fig. 3: Sifting of the materials used

The physical characteristics of aggregates used are presented in Table 3.

Table 3: Physical properties of aggregates

Parameters	Unity	Rolled sand	Gravel	Gravel
d/D	-	**0/3**	**3/8**	**8/15**
Equivalent of Sand	%	74	—	—
Modulus of fineness	-	2.1	—	—
Volumetric mass-Absolute	kg/m^3	2604	2630	2666
Volumetric mass-Apparent	kg/m^3	1761	1606	1444

2.3 Mixing Water and Superplasticizer

Mixing water was used from the tap of the laboratory at Bechar University. This water is treated for drinking Standard [NF EN 1008].

The admixture used is superplasticizer SIKAPLAST 5045 according to [NF EN 934 -2].

2.4 Composition of SCC

The final composition of the SCC is given in Table 4. Five concretes are thus obtained with varying percentage of fine dune sand, SCC%DS (0, 5, 10, 15 and 20%).

Table 4: Formulations of Self-Compacting-Concrete (kg/m^3)

	SCC%DS				
Addition	**0%**	**5%**	**10%**	**15%**	**20%**
Cement	520	494	468	442	416
W/C	0.5				
Aggregate 0/3	903				
Aggregate 3/8	151				
Aggregate 8/15	578				
Admixture	6.8				

3. Experimental Methods

3.1 Fresh properties test

The principal properties of SCC in the fresh state (fluidity, static and dynamic stability) are presented in Table 5.

Table 5: Values of principal properties of SCC in the fresh State according to AFGC norm

	Slump Flow test	**L – box test**	**Test of Stability in sieve (%)**
Limit values	600 - 750 mm	≥ 0.8	≤ 15 %
			

2.2 Mechanical Performance Test

The compressive strength was measured by hydraulic press (Figure 4-a) with a loading rate of 0.5 MPa/s. The European standard NF EN 12390-5 has been complied.

The elasticity modulus of concrete is a necessary parameter in structural design for the determination of the strain distributions and deformations, especially when the design of the structure is based on elasticity of materials. This property is conventionally measured using

standardized tests based on specimens of concrete subjected to uniaxial compressive loading. The elasticity modulus test was performed according to recommendations RILEM CPC8 1972 (Figure 4-b). The modulus of elasticity is measured with an extensometric system with two induction sensors.

(a) Compressive strength test **(b)** Elasticity Modulus test

Fig. 4: Mechanical performance test

4. Experimental Results and Interpretations

4.1 Fresh properties of SCC

According to the results presented in Table 6, it was found that all self-compacting concretes comply with the self-acceleration criteria recommended for recommendations AFGC (2008).

Table 6: Fresh state of concrete

	SCC 0%DS	**SCC 5%DS**	**SCC 10%DS**	**SCC 15%DS**	**SCC 20%DS**
T50 (s)	2.00	2.65	3.00	3.24	3.24
Slump flow (mm)	720	660	650	700	670
L-box test	0.89	0.83	0.88	0.89	0.88
Stability in sieve (%)	10.4	6.8	6.1	11.6	14.1

From the experimental results, all concretes have an acceptable fluidity according to AFGC norm (Slump-flow 650-720 mm). T50 time of the respective mixes recorded to reach 500 mm spread circle was observed to increase gradually from 2.00 sec (SCC 0%DS) to 2.24 sec (SCC20% DS). All the concretes have a good mobility of fresh SCC (L-box 0.83-0.89). These concretes present a good stability (Stability in sieve 6.1-14.1%: do not present segregation).

4.2 Compressive Strength and Modulus of Elasticity

The mechanical strength and modulus of elasticity are essential characteristics for the material concrete and the fundamentals parameters of our study. The mechanical performance (the evolution of compressive strength and modulus of elasticity) for the various compositions of concrete are presented graphically in Figure 5.

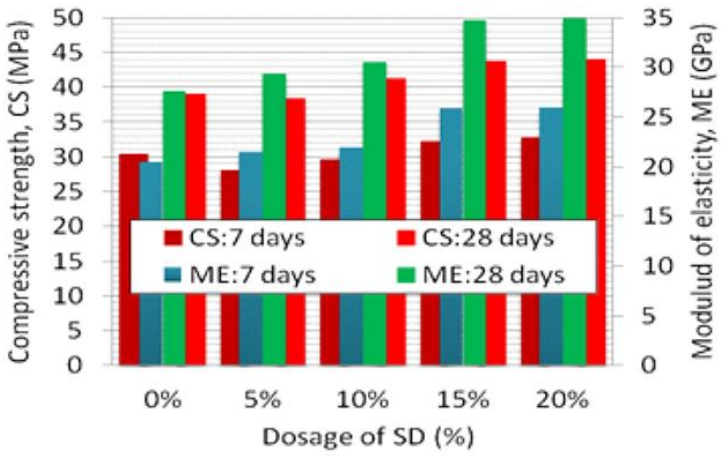

Fig. 5: Compressive strength and modulus of elasticity of SCC

It can be noted from Figure 5 that the increase in the dosage of SD has resulted in an increase in compressive strength and modulus of elasticity for 7 and 28 days. This confirms the positive influence of the fine dune sand on the mechanical performance of concrete. This is due to the physical properties of better bonding, as addition of dune sand approved the compressive strength due to the denser cementitious matrix and better bonding in transition zone (Rennani et al., 2020).

5. Conclusion

Our study focused on the use of fine dune sand as partial replacement of cement in the composition of Eco-self-compacting concrete (SCC). The fresh properties, compressive strength and modulus elasticity of SCC were presented. In general, the following conclusions were made:

- Through this research, we have demonstrated that it is possible to manufacture SCC of different composition parameters, having good rheological and mechanical characteristics.
- The use of fine dune sand in the composition of SCC by varying the dosage (0, 5, 10, 15 and 20%) of fine dune sand contributes to a slight variation of the fresh workability parameters while still remaining in the SCC range required by the AFGC recommendations for these concretes.
- The mechanical behavior of the SCC (compressive strength and modulus of elasticity) is proportional with the dosage of fine dune sand.
- The experimental results show that dune sand has the attitude to be used in SCC. The best substitute dosage for experimental study has been found to be between 15 and 20 %.
- Detailed investigations on durability performance should be explored.

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