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Effect of Quartz sand Grains Diameter on the Mechanical Properties of Mortars

Azhar Badaoui[1], **Abdeslam Benamara**[2], **Mohamed Amine Benaimeche**[2]
[1]Professor, [2]Master
Ecole Nationale Supérieure des Travaux Publics-Francis Jeanson- ENSTP-FJ
Sidi Garidi Kouba, Algiers, Algeria

ABSTRACT
The aim of this study is to evaluate experimentally the influence of quartz (dune sand) incorporation in the cement matrix by mass substitution at different percentages and diameters, on the mechanical properties of the mortars.

Properties of the mortars were determined by flexural traction and compressive strength; the results obtained highlight the effect of the sand dune grain diameter on the mechanical properties of the mortars tested.

The use of quartz (dune sand) with a diameter of less than 0.16mm improved the mechanical strength of mortars.

Keywords: *quartz; sand grain; diameter; mortars component.*

I. INTRODUCTION
Construction in civil engineering is generally carried out by prefabricated or cast-in-place elements which require a mortar without bleeding to ensure the connection.

A mortar is the hardened mixture of a binder (cement), a fine aggregate (sand) and water, according to its composition a mortar is none other than a fine-grained concrete; it is therefore subject to the same laws as concrete. The largest granulates dimension D determines the name: mortar for D≤ 4mm, concrete for D≥4 [1].

The incorporation of mineral additions such as quartz improved the mortar properties; these additions significantly affect the rheology of cementitious materials in the fresh state, which is directly related to the development of the strength and cured materials durability.

Quartz is a mineral species of the group of silicates; in the form of large colorless, colored or smoked crystals, or microscopic crystals of translucent appearance.

The quartz sand (dune sand) used in the mortar preparation, is fine golden sand with rolled grains (D_{max}≤ 0.63 mm), smooth surfaces, and a very small fineness.

Several researchers have studied the quartz effect addition on the properties of the cementitious material in the fresh and hardened state:

Granular effect, also called filler effect; relates to all modifications induced by the mineral additions presents in the cementitious material at the fresh state. These modifications may result from the stacking capacity of the fine or ultra-fine particles with the other solid components of the mixture and / or the intensity of the friction between the various particles of the mixture [2].

Physicochemical and micro structural effects are the modifications caused by the multiple interactions between the mineral addition particles on the cement hydration process and the structuring of the hydrated products [3].

Chemical effect or pozzolanic is the capacity of the additions to react with the water and the anhydrous or hydrated cement constituents to form new mineral phases which can contribute to the mechanical resistances evolution. Even for quartz (considered as inert in a cementitious medium), very fine crystallized quartz particles with a diameter of less than 5 µm can also react with portlandite[4].

Adding of fine quartz particles improved the mechanical properties and durability of the concrete and a reduced the heat of hydration released from concrete, which decreases thermal cracking [3].

Cement production is a major consumer of energy, replacing it with mineral additions reduces the price of concrete and decrease the CO_2 emission by the cement industry [1].

Mortars are present in all construction sectors and public works. Over the past 40 years, mortars have become increasingly complex; today, they combine hydraulic binders and multiple additives. Plaster mortars, tiling adhesives and repair mortars represent in terms of sales and quantities produced, the most important applications of all the mortars used. Their durability and strength is intimately related to the properties of its components.

This paper reports on the study the influence of the quartz grain diameter on the cement paste.

II. Experimental procedures

A. Materials

The Portland cement used in this study consisted of 95%of clinker and 5% of gypsum by weight. Table 1 summarises the chemical composition of clinker, gypsum and mineral admixtures.

TABLE I. Chemical composition of cement

Element									
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	CaO	K_2O	Cl^-
20,31	3,81	4,79	62,8	1.7	2 ,5	0,14	0,608	0,41	0,02

The aggregates used were:

- Career sand with angular grains, a fineness modulus of 2.9, apparent density of 1.59 g/cm^3, absolute density of 2.55g / cm^3, spread granularity and maximum grain size of 5 mm.
- Quartz " dune sand " with rolled grains, a rounded shape and smooth surfaces , it has a fineness modulus of 0.8, an apparent density of 1.46 g/cm^3, an absolute density of 2.50 g / cm^3, an tight granularity and maximum grain size of 0.63 mm. Table 2 summarises the chemical composition of Quartz sand.

TABLE2. Chemical composition of quartz “dune sand”

Element									
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	CaO	K_2O	Cl^-
73,05	3,97	0,43	0,66	0,08	0,06	0,88	---	2,15	---

For all mortar mixtures, the Sand to cement ratio and Water to cement ratio was kept constant at2, 0·5 by weight. The mix proportions of mortars are listed in Tables 3, and 4.

TABLE 3.Mortars formulations

0 mm ≤Dds≤0.315mm				
Sand mixture%	**Cement**	**Dune sand DS**	**Career sand CS**	**Water**
100% DS	600g	1200 g	/	300g
100% CS	600g	/	1200 g	300g
70%DS +30%CS	600g	840g	360g	300g
70%CS +30%DS	600g	360g	840g	300g
50%DS+ 50%CS	600g	600g	600g	300g
100% DS	600	1200 g	/	300g

TABLE 4. Mortars formulations

0.16mm≤Dds<0.315mm and Dds<0.16mm				
Sand mixture%	**Cement**	**Dune sand DS**	**Career sand CS**	**Water**
100% CS	600g	/	1200 g	300g
70%DS+30%CS	600g	840g	360g	300g
70%CS +30%DS	600g	360g	840g	300g
50%DS+ 50%CS	600g	600g	600g	300g

Granulometric analysis was carried out on the sand mixtures used in the formulation of the mortars, as well as the determination of their fineness modulus.

The mixtures were cast into prismatic molds (4 x 4 x 16) cm^3,the moulds were stored in a moist reaction chamber(temperature of 20±2°C); then, 24 h later, the moulds were removed and the specimens were stored in water until 24 hours before the rupture test.

B. Mechanical properties

A flexural traction strength tests were carried out on (4 x 4 x 16) cm^3 prismatic specimens and a compressive strength tests were performed on pieces of prisms.

III. Results and discussion

Fig. 1 shows the granulometric curves of sand mixtures (70% DS + 30% CS, 50% DS + 50% CS, 30% DS + 70% CS) used in the mortar formulations; the granularity is well spread and continuous, with a fineness modulus of 1.6, 2, 2.4 respectively.

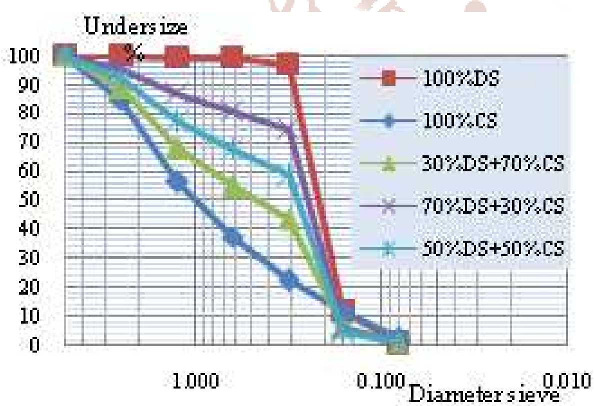


Fig. 1 Granulometric curves

C. Compressive strength

The relative compressive strengths of different specimens are plotted in Fig. 2, 3 and 4

➢ For 0 mm ≤Dds≤0.315mm;

As seen in Fig. 2, for a mortar blended with (30% DS + 70% CS), (50% DS + 50% CS), and (70% DS + 30% CS), the compressive strengths at 3 days were 23MPa, 23.3MPa and 21MPa, respectively; they were 31.8 and 30.5MPa at 7 days.

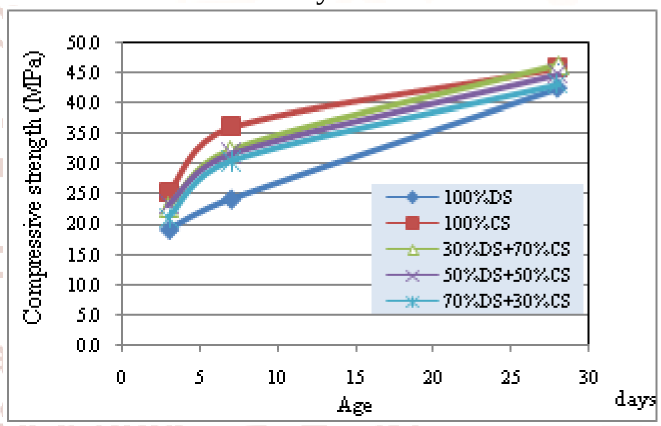


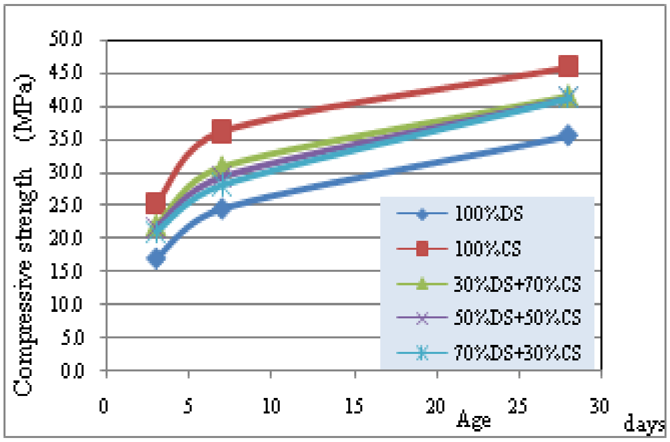
Fig. 2.Compressive strength for 0 mm ≤Dds≤0.315mm

The compressive strengths of these specimens were greater than those blended with « 100% DS » and were lower than that of « 100% CS » which has been confirmed by the previous studies [1].

At 28 days; mortars strengths increased by 9%, 5%, 2% respectively. This was attributed to the densification of the microstructure caused by the spread granularity of sand mixtures and the fine quartz filler effect. In the literature, similar observations were also made by other researchers [7].

➢ For 0.16mm≤D_{ds}<0.315mm;

All mortars developed the same compressive strengths for the same age (Fig. 3), it is due to the setting and similar hardening of these mortars, similar observations were also made by other researchers [7]; the curves of compressive strength highlight the influence of the total substitution of career sand by dune sand on the mechanical properties of the various mortars.



Fig; 3.Compressive strength for 0.16 mm ≤Dds ≤0.315mm

- For Dds<0.16mm;

The compressive strength of the mortars blended with (30% SD + 70% SC), (50% SD + 50% SC), and (70% SD + 30% SC) increased on the order of 27%, 19%, and 13%, respectively compared to mortar (100% SD) at 3 days, and 44%, 39%, and 30% respectively at 7 days (Fig.4).

At 28 days; Compressive strength increased by 12%, 10% and 2%, respectively, and mortar blended with (30% SD + 70% SC) had a better strength than the other mortars, The crystallized particles of dune sand are involved in the formation of the granular skeleton and contribute to the compactness of the cement matrix, which has been confirmed by the previous studies [5, 6].

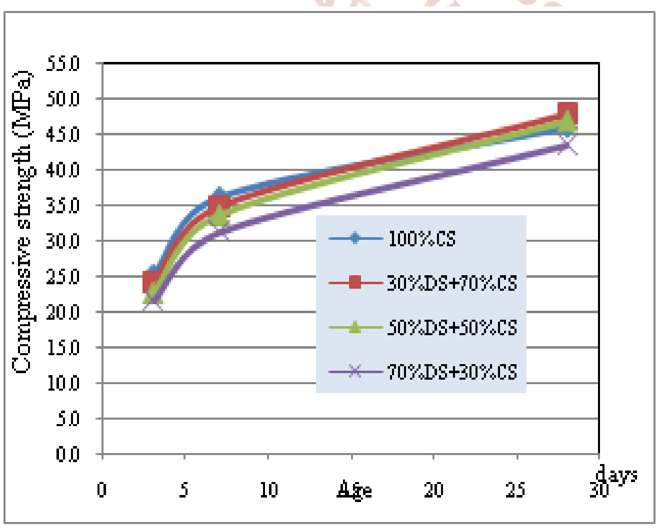


Fig.4. Compressive strength for Dds<0.16mm

D. Flexural traction strength

The relative flexural traction strength of different specimens is plotted in Figures 5, 6 and 7.

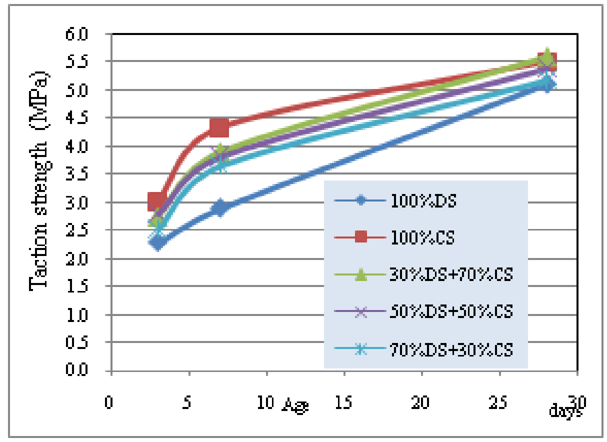


Fig.5. Traction strength for 0 mm ≤ Dds ≤0.315mm

At the early stage (3 and 7 days), the flexural traction strengths of all specimens were almost similar and it substantially followed the compressive strength (Figure5).

At mature ages (28 days), the flexural traction strength of the mortars blended with the entire dune sand granular fraction (0 mm <Dds≤0.315mm) and the mortars blended with a fraction of sand dune (0.16mm <Dds<0.315mm) were much lower than those blended with only Career sand. (Fig. 6 and 7).

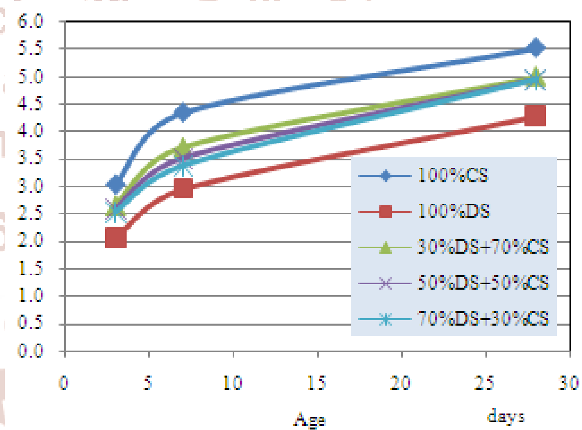


Fig.6. Traction strength for 0,16mm ≤Dds<0.315mm

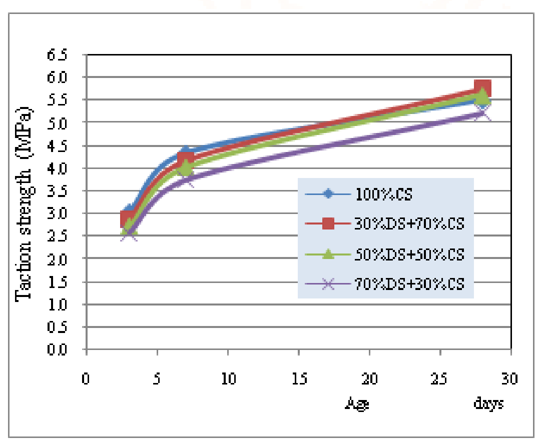


Fig.7. Traction strength for Dds<0,16mm

Moreover, the flexural traction strength of the mortars blended with (30% DS + 70% CS) for **Dds**<0.16 mm, were greater than those blended with only Career sand.

So mortars (30% SD + 70% SC) containing a fraction of sand dune "D <0.160 mm", had the best mechanical characteristics for all ages including tensile strength.

IV. Conclusion

The use of dune sand "quartz" in the preparation of mortars affect the mortars properties, the compressive strengths of all specimens blended with (0 mm <Dds ≤0.315mm)were greater than those blended with « 100% DS » and were lower than that of « 100% CS ».

The study showed that the incorporation of dune sand with a diameter of less than 0.16mm improved the mechanical strength of hardened mortars, Compressive strength increased by 12%, 10% and 2% respectively, and mortar blended with 30% SD + 70% SC had a better strength than the other mortars, The crystallized particles of dune sand were involved in the formation of the granular skeleton and contributed to the compactness of the cement matrix, which has been confirmed by the previous studies

The results obtained highlight the influence of the sand dune grain diameter on the mechanical properties of the mortars tested.

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