

INFLUENCE DU MÉLANGE DE SABLE DE DUNES ET DE SABLE CONCASSÉ SUR LES PROPRIÉTÉS DU SABLE RÉSULTANT

INFLUENCE OF THE MIXTURE OF DUNE SAND AND CRUSHED SAND ON THE PROPERTIES OF THE RESULTING SAND

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Résumé - Le sable de dunes fait partie des matériaux de construction utilisés dans la fabrication du béton et du mortier, surtout dans les zones arides, en raison de sa disponibilité en grandes quantités et à grande échelle. Le sable des dunes (SD) se caractérise par ses petits grains ($D < 1,25$ mm) et son faible module de finesse ($MF < 1,80$) ; ce qui affecte négativement les propriétés du béton à l'état frais et durci.

Pour cette raison, l'objectif de notre travail était de corriger la distribution granulaire et le module de finesse du sable des dunes en le combinant avec du sable concassé (SC) d'un diamètre de (0/4) mm dans des proportions calculées sur la base de la relation d'Abrams afin d'obtenir un sable préférentiel avec un module de finesse compris entre 2,2 et 2,8.

Dans les résultats des expériences menées sur le sable corrigé obtenu, nous avons constaté une amélioration de la distribution granulaire et une augmentation du module de finesse avec des valeurs acceptables qui répondent aux exigences des normes où nous pouvons combiner le sable concassé jusqu'à 70% avec le sable des dunes pour obtenir une bonne résistance à la compression et à la traction après 28 jours pour le mortier.

Mots - clés : Sable de dunes, Sable concassé, Sable corrigé, Module de finesse, Zone aride.

Abstract-Dune sand is among the building materials used in the manufacture of concrete and mortar, especially in arid zone, due to its availability in large quantities and on a large scale. Dune sand (DS) is characterized by its small grains ($D < 1.25$ mm) and low fineness modulus ($FM < 1.80$), which negatively affect the properties of concrete in its fresh and hardened state.

For this reason, the objective of our work was to correct the granular distribution and fineness modulus of the dune sand by combining it with crushed sand (CS) with a diameter of (0/4) mm in proportions calculated based on the Abrams relation to obtain preferential sand with a fineness modulus between 2.2 and 2.8.

In the results of the experiments carried out on the corrected sand obtained, we have noticed an improvement in the granular distribution and an increase in the fineness modulus with acceptable values that meet the requirements of the standards, where we can combine crushed sand down to 70% with dune sand to obtain good compressive and tensile strength after 28 days for the mortar.

Keywords: Dune sand, Crushed sand, Corrected sand, Fineness modulus, Arid zone.

1-Introduction

Dune sand and crushed sand are frequently used materials in the construction and concrete in manufacturing sector. Dune sand, when finely ground, offering physical characteristics comparable to other additives [1]. On the other hand, crushed sand, can significantly improve the mechanical properties of concrete, especially when used as a coarse aggregate with a high proportion of fine particles ($<80\text{ }\mu\text{m}$), thanks to its angular shape that favors adhesion to cement [2]. In addition, research has shown that the combination of crushed sand and dune sand can affect the fresh, hardened properties of concrete. Dune sand is distinguished by its low fineness ($\text{MF}<1.8$) and higher cleanliness ($\text{ES}>80$) compared to other types of crushed sand [3]. Stabilizing the sand from the dunes with crushed sand improved the cohesion and overall quality of the building materials [4].

The use of dune sand corrected with crushed sand is a common practice in concrete production to improve the properties and performance of the final product. Adding crushed sand to dune sand can significantly improve the mechanical properties of concrete, especially in terms of compressive strength [5].

Studies have shown that the compressive strength of concrete made with dune sand can be improved by adding crushed sand. For example, a study published in the Journal of Building Materials and Structures found that the compressive strength of concrete increased by up to 104.43% when dune sand was used as a partial substitute for river sand, with the addition of crushed sand further enhancing this improvement [6].

The workability of concrete made with dune sand and crushed sand is also an important factor. Studies have shown that adding crushed sand can improve the workability of concrete by reducing viscosity and increasing the fluidity of the mix. For example, a study published in the Journal of Construction and Building Materials found that adding crushed sand to dune sand improved the workability of concrete by increasing slump and reducing viscosity [7].

In recent years, some research has been devoted to the study of alternatives for river and quarry aggregates in concrete. The sand from the dunes, mainly as a partial replacement for the fine aggregates part of the structural concrete, has attracted interest due to its wide

availability [8]. A.S. Al-Harthy et al. [9] in their work on these ordinary structural concretes, where fine sands were subjected to partial replacement (from 10%) to total replacement by dune sand, observed that the workability of these concretes was improved when the sand content of the dunes increased to a certain point as a function of the m/c ratio and the initial subsidence of the control sample. The results of compressive strengths indicated a decrease in performance of up to 24% as the sand content of the dunes increases. The reason, they explained, is the increase in the surface area of the particles, which requires more cementing materials to achieve a suitable coating.

On sand concretes, with consistent proportions of cement, lime powder, water/binder ratio and superplasticizer, T. Bouziani et al. [10] also noted that the addition of sand from round siliceous dunes in proportions of 0.1, 0.2 and 0.3 of the total weight of the sand changed the compressive strength of the mixture. The replacement rate of 0.1 induced a slight improvement in compactness and strength at 28 days, while the rates of 0.2 and 0.3 resulted in a steady and sharp decrease in strength on both parameters. Abu Seif [11] on a large sample of 15 dune sands in the Saudi Arabian desert, evaluated the replacement of crushed sand by dune sand in concrete. Their results showed a strongly correlated smooth decline ($R^2 = 0.9917$) in compressive strength as the proportion of dune sand increases in the mixture. Later, Abu Seif et al. [11] showed that their observations on concretes were also extendable to mortars, since they noted a similar decrease in strength related to the sand of the dunes.

The influence of dune sand on rheological properties, settlement density and porosity has also been demonstrated over the years [12], [13]. And, as far as compactness is concerned, there is a consensus on the enhancing character of dune sand particles in concretes, to a certain extent, which can be explained by the very fine size, smooth surface texture and round shape of these particles. As a result, it is easier for particles to move through the matrix [14], [15]. The same conclusions were drawn on self-consolidating concrete by A. Rmili et al. [16], [17] after studying the gradual replacement of crushed sand by dune sand. Handling parameters, they noted, have been improved with the addition of dune sand by up to 30 percent. Beyond that, the sand from

the dunes improved the viscosity of the concrete but decreased both strength and fluidity. Reports from Abu Seif [11] also showed an improvement in concrete slump values of up to 60% dune sand replacement rate. Higher rates led to an abrupt loss of manoeuvrability, with the largest drop being observed between 60% and 80% with slump dropping from 100 mm to 50 mm. One of the reasons given is the low gradation of these sands, where generally, 25% by weight of the grains are less than 150 μm , while this proportion is generally less than 6% in ordinary sands [18].

2- Experimental program

2.1- Materials

In our study, we used two types of dune sand in addition to crushed sand, the sands used are local materials from the Adrar region. Dune sand from the dunes of the Aoulef region (DSA) and dune sand from the dunes of the Tsabit region (DST) as well as crushed sand from the Koussane quarry (CSK).

Tab.1 shows the different physical properties of the sands studied, in addition to Figure 1 showing the granular analysis curves.

Table 1: Physical properties of the sands.

Tableau 1 : Propriétés physiques des sables.

Type of sand	DSA	DST	CSK
Fineness modulus (FM)	1,69	1,02	3,19
Coeff. of curvature (Cc)	1,22	0,98	1,25
Coeff. of uniformity (Cu)	3,27	2,73	2,81
Water Absorption (WA) (%)	0,23	0,23	2,73
Sand Equivalent (SE)	95,9	79,87	58,23
Apparent Volumetric Mass (g/cm^3)	1,68	1,59	1,65
Absolute Volumetric Mass (g/cm^3)	2,61	2,59	2,57

The results shown in Tab.1 and Fig.1, meaning that:

- The Modulus of Fineness (FM) for the two sands of the dunes (DSA and DST) is less than 1.7 according to the standards, these two sands are classified as fine sand.

- Crushed sand (CSK) is classified as coarse sand when the Fineness Modulus (FM) is approximately 3.20.
- The sand (DSA) is very clean ($ES > 80$), but the sand (CSK) is clayey when their ($ES < 60$).

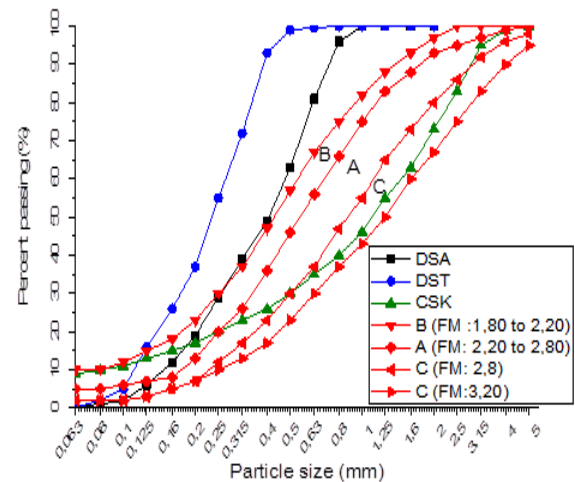


Figure 1: Particle size curves of the sands studied.

Figure 1 : Courbes granulométriques des sables étudiés.

From Fig.1, we can see that:

- The particle size curves of the two sands (DSA and DST) are out of the spindle zones.
- The crushed sand (CSK) particle size curve is in the coarse sand interval.

3- Determination of the proportions of sand (dune sand and crushed sand)

3.1- Fineness modulus

The experimental fineness modulus is defined as the sum of the cumulative percentages, by mass, of the refuse on the following series of sieves, 0.125 - 0.25 - 0.5 - 1 - 2 - 4 (mm), given as a percentage.

Depending on the requirements of the standards (EN12620) [19], the FM is between:

- 1.8 and 2.2: Sand is mostly fine-grained.
- 2.2 and 2.8: Preferential sand.
- 2.8 and 3.3: Sand is a bit coarse.

To obtain a preferential sand with a fineness modulus between 2.2 and 2.8, we use

Abrams' rule [20], to determine the proportions of the two sands (dune sand and crushed sand) :

- Crushed sand = $((FM - FM_2) / (FM_1 - FM_2))$ (1)

Formula (1) is used to calculate the proportion of crushed sand combined with dune sand.

- Dune sand = $((FM_1 - FM) / (FM_1 - FM_2))$ (2)

Formula (2) is used to calculate the proportion of dune sand combined with crushed sand.

- FM: Target fineness modulus.

- FM₁: Fineness modulus of crushed sand.

- FM₂: Fineness modulus of dune sand.

In our case study, three fineness modulus were chosen to obtain a preferential sand:

FM=2.2

FM=2.5

FM=2.8

3.2- Corrected Sand (DSA+CSK)

The tab.2 above shows the deferent proportions for a mixture between the two sands (DSA+CSK).

Table 2: Dune sand (DSA) proportions and crushed sand (CSK)

Tableau 2 : Proportions de sable des dunes (SDA) et de sable concassé (SCK)

	CSK (%)	DSA (%)
FM=2.2	34	66
FM=2.5	54	46
FM=2.8	74	26

The tab.2, shows the proportions of dune sand (DSA) with the incorporation of crushed sand (CSK) we notice that:

- The rate of crushed sand varies between 34% and 74%, this rate decreases with the rate of sand in the dunes which is varied between 66% and 26%.
- When the fineness modulus is increased, the rate of crushed sand is also increased.

3.3- Corrected Sand (DST+SCK)

The substitutions of dune sand (DST) and crushed sand (CSK) for the targeted

fineness modulus are presented in the tab.3 above.

Table 3: Dune sand (DST) proportions and crushed sand (CSK)

Tableau 3 : Proportions de sable des dunes (SDT) et de sable concassé (SCK)

	CSK (%)	DST (%)
FM=2.2	54	46
FM=2.5	68	32
FM=2.8	82	18

Based on these results (tab.3), it can be seen that:

- The minimum dune sand content (DST) for a fineness modulus of 2.2 is 46% because of the fineness modulus of (DST) which is equal to 1.03.
- The proportions of (CSK) are varied in the interval [54%; 82%], meaning that the sand correction (DST) requires a rate of (CSK) greater than 55%.

4- Identification of the physical characteristics of the sands obtained

Once the two types of sand dune sand and crushed sand are mixed, we attempt to identify their distinct physical properties.

4.1- Particle size analysis of corrected sands

After the kneading of the two sands: (DS+CS). We test the particle size analysis to obtain a homogeneous sand.

4.1.1- Corrected sand: Dune sand (DSA) and crushed sand (CSK)

The particle size curves of the corrected sands are illustrated in the following figure (fig.2).

In fig.2, we notice that:

- The two curves of corrected sand with a fineness modulus of 2.2 and 2.5 are in the preferred sand interval.
- The corrected sand particle size curve with a fineness modulus equal 2.8 is outside the preferred sand interval for grains with a diameter varied between 0.5 and 2.0 mm.

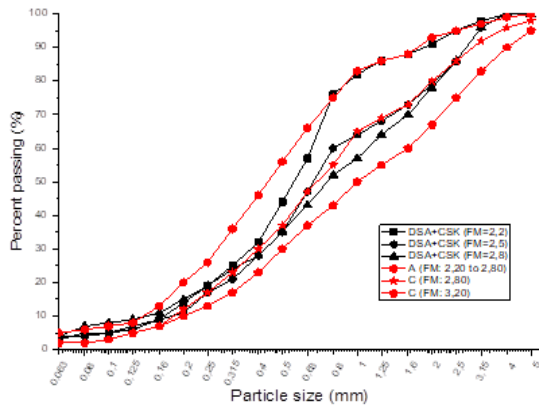


Figure 2: Particle size curves of corrected sands (SDT+SCK)

Figure 2 : Courbes granulométriques des sables corrigés (SDT+SCK)

Tab.4 shows the physical properties of dune sand (DST) after it has been corrected with crushed sand (CSK).

Table 4: Physical properties of the corrected sands.

Tableau 4 : Propriétés physiques des sables corrigés.

Type of corrected sand	DSA+CSK		
Theoretical fineness modulus	2,20	2,50	2,80
Experimental fineness modulus	2,30	2,57	3,01
Coeff. of curvature (Cc)	1,12	0,32	0,09
Coeff. of uniformity (Cu)	3,95	2,00	2,11
Water Absorption (WA) (%)	0,81	1,74	2,11
Sand Equivalent (SE)	80	79	75
Apparent Volumetric Mass (g/cm ³)	1,71	1,69	1,60
Absolute Volumetric Mass (g/cm ³)	2,64	2,65	2,63

Based on the results presented in Tab.4 and, it was concluded that:

- The experimental fineness modulus of the three corrected sands is similar to the theoretical fineness modulus targeted.
- It will be noted that the three corrected sands obtained are clean when the (SE) is greater than 60.

- The rate of (WA) is increased with the increase of (FM).

4.1.2- Corrected sand: Dune sand (DST) and crushed sand (CSK)

The figure (Fig. 3) illustrates the results of particle size distribution curves for the corrected sands (SDT+SCK).

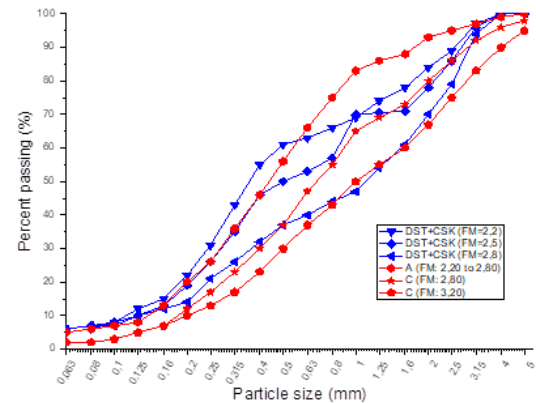


Figure 3: Particle size curves of corrected sands (SDT+SCK)

Figure 3 : Courbes granulométriques des sables corrigés (SDT+SCK)

Fig. 3, shows that:

- The corrected sand particle size curve FM=2.2 contains elements with a diameter of less than 0.5mm more than the preferred sand.
- The sand corrected with a fineness modulus FM=2.5 is well located in the preferred sand interval.
- Corrected sand with a modulus of fineness equal to 2.8 contains aggregates with a diameter 0.5 mm greater than a preferred sand.

The results obtained from the study of the physical properties of dune sand (DST) corrected with crushed sand (CSK) are summarized in Tab.5.

Table 5: Physical properties of the corrected sands.**Tableau 5 :** Propriétés physiques des sables corrigés.

Type of corrected sand	DST+CSK		
Theoretical fineness modulus	2,20	2,50	2,80
Experimental fineness modulus	2,44	2,77	3,14
Coeff. of curvature (Cc)	0,05	0,04	0,04
Coeff. of uniformity (Cu)	3,33	2,67	3,75
Water Absorption (WA) (%)	1,13	1,27	1,74
Sand Equivalent (SE)	78	75	73
Apparent Volumetric Mass (g/cm ³)	1,67	1,68	1,61
Absolute Volumetric Mass (g/cm ³)	2,66	2,65	2,61

Based on the results presented in Tab.4, it was found that:

- The theoretical and experimental fineness modulus values show almost similar results, a difference of (0.20).
- In accordance with the requirements of the standard and according to the fineness modulus obtained from the corrected sands, most sands are classified as preferential sand.
- The three corrected sands obtained are clean sands when the (FM>60).

5- Conclusion

After identifying the physical characteristics of the corrected sands obtained, it was concluded that:

- An improvement on the granular distribution of corrected sands, a well-graded granularity and the sand obtained is preferred.
- The experimental fineness modulus of corrected sands is varied between 2.2 and 2.8 which meets the requirements of the standards.
- The corrected sands obtained are clean with a sand equivalent greater than 70.
- The water absorption coefficient is negligible when it is less than 1.74%.

We can say that the correction of dune sands with crushed sand is essential to obtain a sand with physical characteristics that meets the requirements of the standards.

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