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Aeolian Sands in Self-Consolidating Mortar Formulations: Study of the Mechanical Impacts

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Abstract: The study presented herein explores the altering potential of using fine dune sand (DS) in self-consolidating mortar (SCM), originally formulated with river sand. The research aims to assess how the inclusion of this fine aggregate-seen as an improper source material for cementitious applications—affects the mortar's rheological, acoustic, and mechanical characteristics. By integrating a very fine *Touggourt*-sourced DS, we seek to alleviate the pressure on river sand (RS), a resource that currently faces significant depletion. With that intention in mind, mortar mixtures were developed with varying DS content (0%, 25%, 50%, 75%, and 100% by volume of RS) and were tested for flow behavior, ultrasonic pulse velocity (UPV), and both compressive and flexural strength. Results indicate that incorporating DS enhances some key properties of the SCM, highlighting its potential even at high substitution rates. Consequently, this research suggests that DS could serve as a sustainable alternative to RS, aiding in the responsible management of river sand resources.

Keywords: Sustainable mortar, Dune sand, River sand, Cementitious materials, UPV

Introduction

Over 60% of Algeria's land area is considered as desert or semi-desert, predominantly located in the arid central and southern regions of the country. These areas are largely covered by extensive sand dune systems. The sand grains constitutive of these dunes exhibit distinct compositional, morphological, and textural characteristics. These properties are strongly influenced by aeolian processes, including long-distance wind transport but also physico-chemical mechanisms affecting their parent rock. As a result, these grains are finer than common sand grains, sub-spherical in shape, and possess smooth surface textures, indicative of prolonged abrasion and selective sorting during transport.

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Over the past decades, the construction industry has witnessed the development of breakthrough cementitious formulations aimed at improving workability and implementation on site. Among these, self-compacting concrete (SCC) and its derivative, self-compacting mortar (SCM), have emerged as engineered materials designed to flow, consolidate, and fill formworks under their own weight, without the need for mechanical vibration or troublesome human intervention, and at the same time minimizing the risks of segregation and bleeding (Lozano-Lunar et al., 2020). The significanlty higher flowability of these materials is achieved through an increased powder content (Hammat et al., 2021), which contributes to a denser particle packing, a finer microstructure, and consequently and enhanced durability. Owing to their fine particle size distribution, dune sands are able to significantly influence the rheological behavior of fresh concretes and mortars (Khelil et al., 2024; Khelil et al., 2025). Their effect is mainly attributed to the capacity of the said fine particles to act as lubricating agents (Khelil et al., 2023) thereby reducing interparticle friction and facilitating the movement of coarser grains during consolidation.

The objective of this study is to investigate the incorporation of very fine dune sand, in combination with alluvial (river) sand, within self-compacting mortar (SCM) formulations. Specifically, two primary research directions were pursued: firstly, assessing the influence of dune sand addition on the rheological characteristics of SCMs, and secondly evaluating the potential for mitigating the environmental impacts associated with the extraction and processing of conventional river sand. The results of this experimental research are meant to contribute to the development of more sustainable mix-design strategies for high-performance, self-compacting cementitious materials.

Materials and Procedures

Materials

In this research, was employed a CEM II/A-L 42.5R cement, which has a specific gravity of 3.1 and is supplied by SPA Biskria, conforming to the EN 197-1 standard (British Standards Institution, 2011). Two morphologically different sands were used for the SCM mixtures. The first one is a natural river sand (RS) originating from the Asif N Sebaw river in the Tizi-Ouzou region of Algeria, whereas the second one is a dune sand (DS) from the saharan region of Touggourt. The particle size distribution curves of RS and DS, revealing a significant difference in their fineness are presented in Figure 1. The fineness modulus value calculated for DS is $M_{f,DS}$=1.94, corroborates its high fineness compared to that of river sand whose fineness modulus is $M_{f,RS}$= 2.98. As for their densities, the bulk densities mesured were 1.715t/m^3 and 1.650t/m^3 for RS and DS, wereas the absolute densities were 2440t/m^3 and 26664t/m^3 for RS and DS respetively. Tap water along with a superplasticizer (Medaplast SP 40) were used to achieved flowability of the SCM.

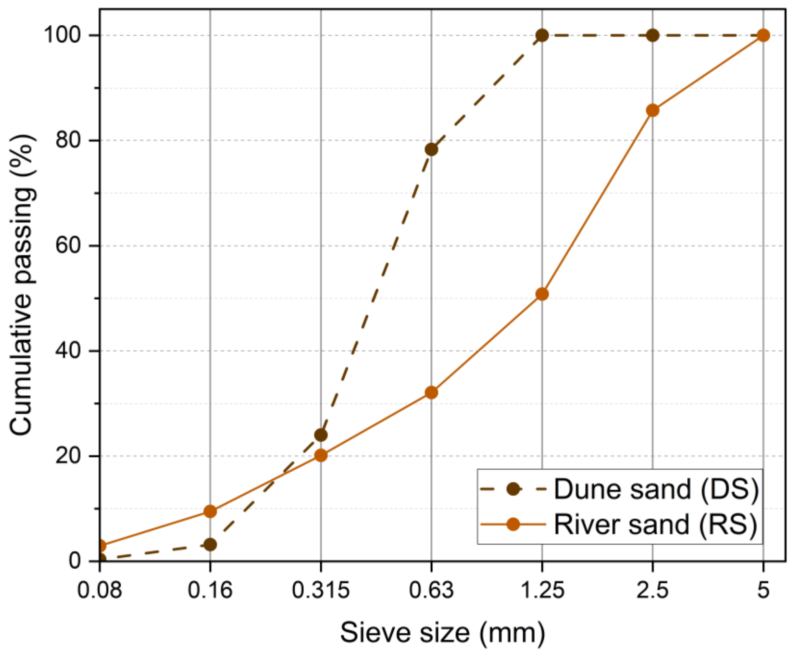

Figure 1. Particle size distribution (PSD) of the fine dune and river sands

Mortars Mix Proportions

Five self-compacting mortar (SCM) mixtures were prepared for this study. In order to achieve the rheological requirements of the SCM, dune sand was used as a flowability-enhacing material owing to its high fineness and sphere-like shape. The specific compositions of the RS-DS sand blends used in the mortars are detailed in Table 1. The mixing process followed the guidelines outlined in EN 196-1 (British Standards Institution, 2016) for standard mortar preparation. It involved a total mixing time of 240 seconds, structured as follows: Initially, water and cement were placed in the mixing bowl, then the planetary mixer was turned on at a low speed for 30 seconds. Next, the sand blend was added at the same speed over the course of 30 seconds, after which the mixer was switched to a higher speed for an additional 30 seconds. The mixer was then paused for 90 seconds to scrape any material that may have adhered to the bowl's bottom or sides. Finally, mixing resumed at high speed for 60 seconds before stopping.

Once mixing was complete, the fresh SCM mixtures were evaluated for flowability using a mini-slump cone. The mixtures were then poured into 40 x 40 x 160 mm³ prismatic molds and left to set for 24 hours at approximately 25°C. After demolding, the specimens were submerged in a water tank at the same temperature until 28 days. For each SCM mixture three prismatic specimens were cast, and at 28 days they are retrieved from water curing and submitted to Ultrasonic Pulse Velocity (UPV) testing, flexural tensile strength testing, and finally compressive strength testing. The results presented below represent the average values obtained from these three specimens.

Table 1. SCM mix proportions

Mortar ID (%CS-%DS)	CS (g)	DS (g)	Cement (g)	Water (g)	Superplasticizer (%)	W/C
M0 (100CS-0DS)	1191.6	0	685.6	205.68	0.5	0.3
M1 (75CS-25DS)	893.7	325.24	685.6	205.68		
M2 (50CS-50DS)	595.8	650.98	685.6	205.68		
M3 (25CS-75DS)	297.9	976.74	685.6	205.68		
M4 (0CS-100DS)	0	1301.96	685.6	205.68		

Fresh-State Workability Testing

The workability of fresh mortar mixtures - low-volume materials with fine particles – is evaluated throught a testing reffered to mini-slump testing. It is particularly suited for self-compacting mortars (SCMs) flowability testing. This test is an adaptation from the conventional slump test performed on concrete, and is designed to give an indication on the mobility of mortar in an unconfined setting, under the effect of gravity. The procedure *per se* involves placing the SCM into the truncated mini-cone mold (reduced-scale concrete slump cone) with dimensions: 100 mm at the base, 70 mm at the top, and 60 mm in height. The cone is filled in two layers, each compacted with 25 strokes using a tamping rod to ensure uniform consolidation. Once filled, the cone is carefully lifted, allowing the mortar to spread freely into a pancake shape. Measurements are then taken on the still SCM mixture, along two perpendicular diameters. According to EFNARC (European Federation of Specialist Construction Chemicals and Concrete Systems, 2005), the typical spread diameter for the fresh mortar spread to qualify as a self-compacting mortars (SCM) should range from 240 mm to 260 mm.

Hardened-State Acoustic Testing

At the hardened state, the mortar specimens were submitted to Ultrasonic Pulse Velocity (UPV) testing - a widely used non-destructive testing (NDT) technique – generally meant for evaluating the internal condition and overall quality of cementitious materials such as mortar and concrete. The aim here was evaluating the mortars' compactness. The principle of the test is measuring the travel time of high-frequency ultrasonic waves as they pass through the material. The pulse velocity is directly influenced by the material's density, elasticity, and the presence of defects such as cracks, voids, or unhomogeneities. A higher velocity generally indicates a more compact and homogeneous structure. During experiments, the UPV methodology followed the precepts given in

European and American standards BS EN 12504-4:2004 and ASTM C597-16 respectively, performed using the Pundit apparatus, equipped with two transducers - one acting as the emitter and the other as the receiver - set to a frequency of 150 kHz. Each prismatic mortar specimen was positioned between the said transducers and used petroleum jelly as a contact agent, to ensure optimal acoustic coupling before initiating the measurement. Three specimens were tested for each mortar formulation, with three repeated measurements taken on each specimen, hence ensuring reliability and reproducibility. The UPV values reported in this study represent consequently the average of nine readings per mix.

Hard-State Mechanical Strength Testing

Consecutively to performing NDT tests, the mortar specimens were subjected to destructive mechanical tests by means of a computer-controlled hydraulic press, as given by European standard EN 196-1 (British Standards Institution, 2016). Each SCM specimen first underwent a three-point bending test, at a constant loading rate of 50 ± 10 N/s, to obtain its flexural tensile strength, then, following the flexural test, the resulting half-prisms were subjected to compressive strength testing at a loading rate of 2400 ± 200 N/s, also in accordance with EN 196-1. Both flexural and compressive strength tests aimed to characterize the mechanical performance of the SCM formulations.

Results and Discussion

Fresh-State Workability Results

Figure 2. shows the results of the mini-slump cone workability testing for the different SCM formulations.

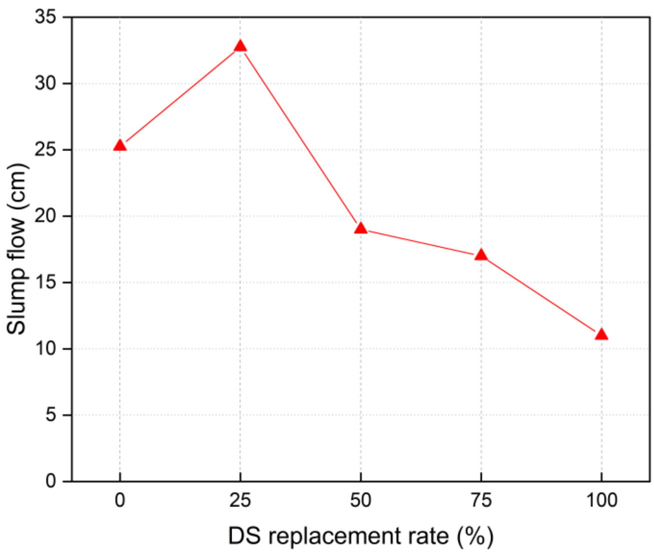

Figure 2. Slump values of the SCM mortars

The experimental results indicate a clear enhancement in slump flow values with the progressive incorporation of dune sand (DS) into the mortar mixtures up to 25%. Specifically, the slump increased from 25.25 cm for the control specimen (M0 or 0% DS) to 32.75 cm, for mixtures M1 (25% DS). Mixtures M2 (50% DS), M3 (75% DS), and M4 (100% DS), exhibited lower values compared to M0, valued at 19, 17 and 11 respectively. These findings underscore the beneficial effect of DS addition on the workability of fresh mortars at low substitution rates (25%). Higher DS substitution rates translated into poorer workability properties of the SCMs.

This improvement in the flowability of the SCM is likely attributable to the morphological characteristics of DS particles, which are predominantly near-spherical in shape. Such geometry reduces inter-particle friction and facilitates the movement of constituent materials under gravity. The texture of such sand particles also play a key role. Indeed, their smooth surface are useful in reducing resistance to the overall motion of the mortar at the fresh state. When combined with the dispersing action of the high-range water reducer (HRWR), DS contributes to the improved particle dispersion and the denser, more homogeneous packing of the cementitious matrix. Beyond 25% DS substitution rate, an opposite observation can be made, where the mortar constituents seem to move in a more impeded way, probably attributable to the high content of fine particles in the river sand and the higher water demand. As a result, it is suggested the need of a better balancing of the HRWR agent amount. Higher contents should be used, to improve SCM ease of motion and achieve a greater pancake diameter.

Ultrasonic Pulse Velocity testing

The ultrasonic pulse velocity test results are shown in (Figure 3).

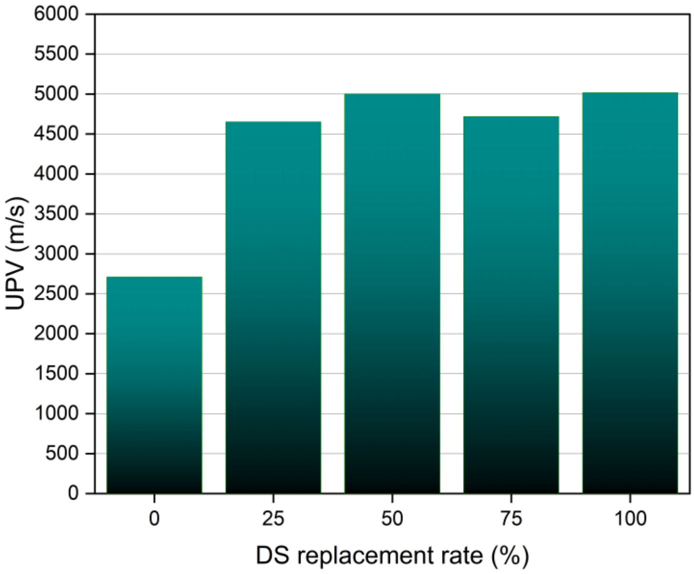

Figure 3. UPV test results of the SCM specimens at 28d

The data of the UPV testing show that DS addition to the SCM indeed modifies its behavior. The recorded velocities are valued at 4651.66 m/s, 5001.33 m/s, 4717.33 m/s and 5017 m/s for 25% DS, 50% DS, 75% DS and 100% DS respectively, representing an improvement of 71.59%, 84.49%, 74.02% and 85.07% from the control M0 (2710.78 m/s). These results seem to indicate a better granular state of the SCM, in other words, the SCMs could possess a denser, and more compact matrix, which goes hand in hand with mechanical resistance. Moreover, these results show that DS content seems not to play a role in the achieved velocity, as no significant change between the different tested dosages translates into significant change in acoustic properties.

Flexural Tensile Strength Results

The flexural tensile strength of the SCM formulations are displayed hereafter (Figure 4).

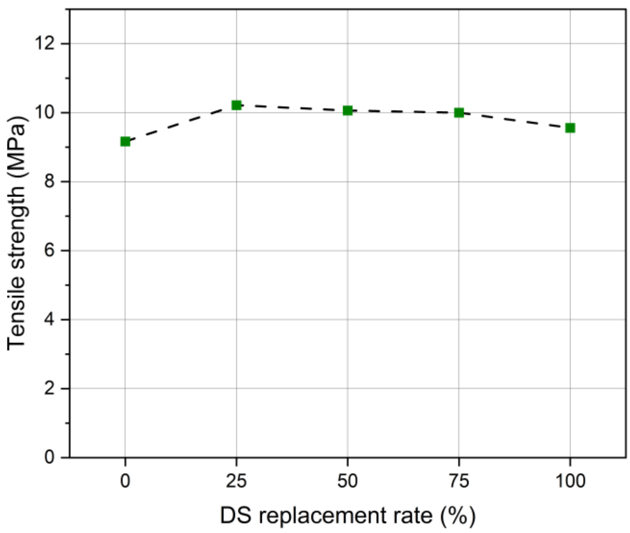

Figure 4. Flexural tensile strength of the SCMs at 28d.

From Figure 4, on can observe an improvement of the flexural strength as the dune sand content increases in the SCMs. Compared to the control formulation devoid of dune sand, the resistance betterment is valued at 11.57%, 9.82%, 9.17% and 4.18% for DS replacement rates of 25% (M1) and beyond, up to 100% respectively. From the recorded values, Mixture M1, containing 25% DS, showed the best results, suggesting that at this rate, the granular skeleton is the most compact. Overall, the formulation with the best behavior strength-wise, would be those ranging from 25% to 75%, as they show a plateau-like profile revolving around 10MPa. These results underline the positive impact of DS particles bring to the mortar mixture, in terms of bearing capacity under third-point loading. These results are in accord with what is often reported in the literature, concerning the fine DS particles which are considered to play a key role in the improvement of mortar/concrete workability properties (Khelil et al., 2023; Khelil et al., 2024; Khelil et al., 2025). Those authors also reported better overall mechanical properties most often related to the capacity of the DS smooth sphere looking particles to act as lubricant for the surrounding mortar granular components, arranging them in a compact stable state in the cement matrix.

Compressive Strength Test Results

The compressive strength test results of the tested mortars are presented in Figure 5.

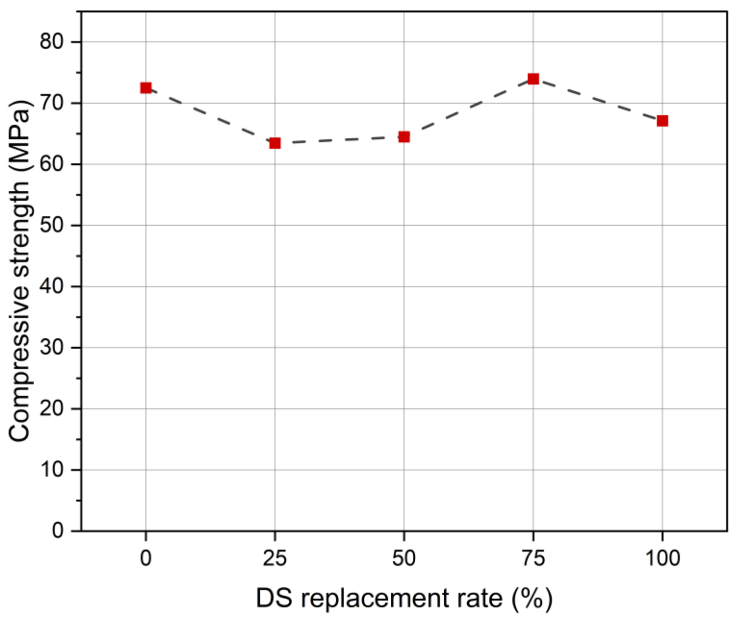

Figure 5. Compressive strength of the SCMs at 28d.

From the figure reporting the results of the compressive strengths, a somewhat antagonistic behavior is observed, with the results of the tensile strength, in the sense that no clear pattern can be defined. Indeed, for the four mixtures that include DS particles, three of them have shown poorer compressive strengths compared to the control, valued at 63.47 MPa, 64.50 MPa and 67.13 MPa, representing a decrease of 12.45%, 11.03% and 7.41% for 25% DS, 50% DS and 100% DS. Concerning mixture containing 75% DS, a modest improvement is reached at 73.96 MPa or 2.01% improvement. Overall, although most mixtures exhibited lessened strengths, their values remain significant. Moreover, these results also show the nature of the substituted sand and more importantly, its particle size distribution on the mortars properties. A closer look at those, brings to light the finer nature of the river sand, which contains a higher content of very fine particles. Those latter could cause, in the cement matrix a higher water demand, capturing more water, aimed originally at hydrating the cement. Lesser water available, means lesser cementing material, and hence, hampered resistance development.

Conclusion

According to the outcomes of the present experimental work, these conclusions can be drawn:

- The use of dune sand in self-compacting mortars is beneficial to a certain extent (25%), while beyond that, a deleterious effect is observable.

- A significant improvement of the acoustic properties of the SCMs is observed with the addition of DS. This illustrates a denser matrix and hence an enhanced durability.
- Third-point tensile strength is slightly improved by DS addition, reaching 11.57% improvement for M1 (25% DS).
- As for compressive strength, the addition of DS does not result in an improvement. It could be attributable to the presence of excessive amounts of fine particles in the substituted river sand.

The outcomes of the experimental study presented herein endorse the idea that dune sand can serve as an efficient substitute for conventional river sand in self-compacting mortars, thereby contributing to the development of more sustainable processes and materials aimed at reducing the environmental impact of the construction industry.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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References

ASTM International. (2016). *Standard test method for pulse velocity through concrete* (ASTM C597-16).

British Standards Institution. (2004). *Testing concrete - Part 4: Determination of ultrasonic pulse velocity* (BS EN 12504-4:2004).

British Standards Institution. (2011). *Cement – Part 1: Composition, specifications and conformity criteria for common cements* (BS EN 197-1:2011).

British Standards Institution. (2016). *Methods of testing cement: Determination of strength* (BS EN 196-1:2016).

European Federation of Specialist Construction Chemicals and Concrete Systems. (2005). *The European guidelines for self-compacting concrete: Specification, production and use*.

Hammat, S., Menadi, B., Kenai, S., Thomas, C., Kirgiz, M. S., & Sousa Galdino, A. G. (2021). The effect of content and fineness of natural pozzolana on the rheological, mechanical, and durability properties of self-compacting mortar. *Journal of Building Engineering, 44*, 103276.

Khelil, N., & Bekri, Y. (2025). Assessment of Touggourt dune sand inclusion in fiber reinforced concrete (FRC). In P. Gallo, M. A. Khalifa, Z. E. Zayed, & A. Ragheb (Eds.), *Urban and transit planning* (pp. 163–172). Springer.

Khelil, N., Boukais, S., Makkeb, R., & Akkouche, K. (2024). Performance evaluation of a self-compacting mortar altered with dune sand. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics, 32*, 329–335.

Khelil, N., Ould Ouali, M., & Meziane, L. (2023). On the use of fine dune sand in reactive powder concrete: Effect on resistance, water absorption and UPV properties. *Construction and Building Materials, 388*, 131684.

Lozano-Lunar, A., Dubchenko, I., Bashynskyi, S., Rodero, A., Fernández, J. M., & Jiménez, J. R. (2020). Performance of self-compacting mortars with granite sludge as aggregate. *Construction and Building Materials, 251*, 118998.

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