Physical-Chemical Characterization and Exploitation of an Ultra Fine Local in Mortars

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Abstract

The present study aims to explore a suitable alternative to the current ultrafine material used in the formulation of concrete and mortar. The objective is to focus on the physical, chemical, and mechanical properties of the new local ultrafine material within the cement matrix. The idea is to enhance the performance of mortars by utilizing an ultrafine material sourced locally, such as clay or dune sand, while promoting sustainable practices in the construction industry.

The obtained results will provide insights into the impact of incorporating local ultrafine material on the properties of cement-based mortars, particularly concerning their strength, durability, and overall performance. These findings will pave the way for the development of more efficient and sustainable formulations for concrete and mortar.

Furthermore, this study will encourage the use of locally sourced materials, thereby contributing to reducing environmental impact and increasing sustainability in the construction sector. By promoting the utilization of abundant local resources, this research can foster a more environmentally friendly and economically viable approach to construction materials in the industry.

In summary, this research aims to explore the potential benefits of using local ultrafine material in cement-based mortars, with the goal of improving the durability and performance of construction materials while promoting more sustainable practices in the construction field. By adopting this approach, the industry can move closer to its sustainable development objectives by reducing its environmental footprint and advocating for responsible use of local resources.

Keywords: Physico-chemical characterization. Formulation. Ultrafine. Clay. Dunesand. Mortar.

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1. Introduction

Currently, there is a growing focus in research on new construction materials towards the utilization of local resources to produce cost-effective and high-performing mortars and concrete.

This shift is primarily driven by the abundance of industrial by-products and the lack of recycling and recovery programs for these materials.

Our work contributes to this ongoing experimental study, which aims to investigate the physical-chemical characterization and utilization of a local ultra-fine material in mortars. Mortars are widely used in construction and offer various advantages such as strength, workability, and porosity. Nevertheless, certain properties of mortars still require further research and improvement.

One area of focus is the incorporation of additives, particularly ultra-fines, which have shown significant potential in enhancing the strength of mortar [1, 2 ,3]. By incorporating these additives, it is possible to improve the rheological properties of fresh cementations materials, which directly impacts the development of strength and durability in hardened materials.

To fully exploit the benefits of these additives and determine the optimal solution for optimization, it is crucial to understand their characteristics and their effects on mortar properties. Therefore, our study aims to achieve acceptable performance by utilizing locally obtained ultra-fine additives sourced from dune sand (Taghit erg).

The primary objectives of this study include:

Physico-chemical characterization of local ultra-fines, specifically clays from Tabalbala and El-Outa.

Utilization of the local ultra-fine material in dune sand-based mortar.

Development of a new, economical mortar that combines the advantages of locally available ultra-fine additives with the desirable properties of dune sand.

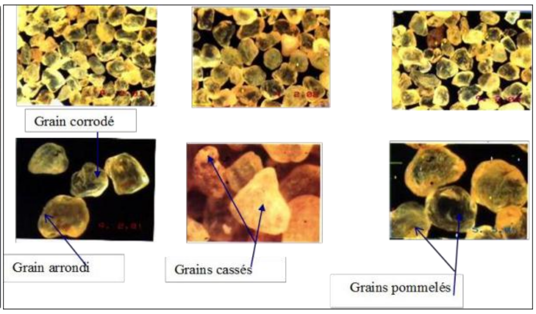
By addressing these objectives, we aim to contribute to the advancement of sustainable construction practices by harnessing the potential of locally sourced materials. This research has the potential to provide valuable insights into the performance and applicability of ultra-fine additives derived from dune sand in the production of cost-effective and high-performing mortars.

2- Materials and Methods

2.1. Materials

The characterization of the materials used in the composition of a mortar plays a very important role on its properties and subsequent performance; the essential properties of the mortar are largely influenced by the characteristics of its constituents. As a result, the standardization of testing methods and identification of mortar components is necessary. The different materials to be used in the preparation of the mortar to be studied, as well as the tests to be performed according to French standards and current operating procedures, are presented [4, 5, 6, 7].

Figure 1 - Sand dune. **Figure 2 - Observations of sand grains under the optical microscope [8].**



Sand dune:The optical microscope Figure2 identifies and qualifies the following minerals:

Quartz: it appears in a white color or under a yellow tint if the slide is a little thick (> 0.03 mm). The grains are mostly rounded but can also be dull or broken.

Iron oxides: they are either in the form of independent grains or they coat the quartz grains. or they are in the form of inclusions in the quartz. They are opaque and appear under a black to reddish color. It was observed other minerals such as calcite, the anhydrite or the dolomite

(But in evidence elsewhere), but this is due to their very low proportions in this sand.

The results of elemental analysis by XRD on the Taghit sand show Figure 3, a peak of about 100% silica which reflects the dominance of SiO_2 in the analyzed sand. The other elements revealed are $CaCO_3$ and Fe_2O_3 present at low percentages, to detect the fraction of the sands richest in silica.

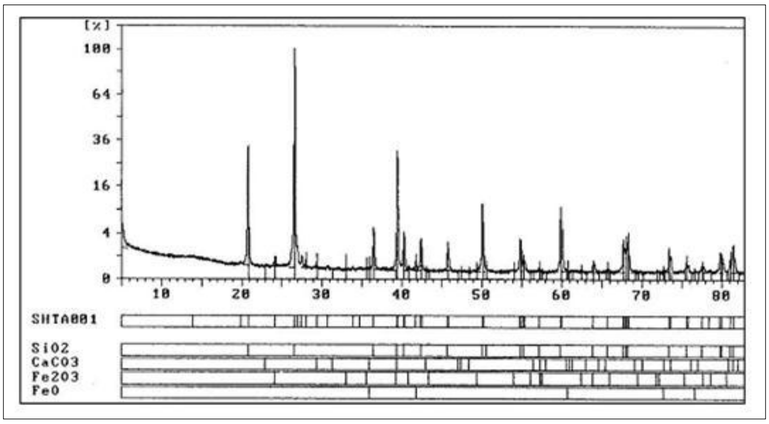


Figure 3 - XRD analysis of dune sand (Taghit) [8].

The results are presented as oxides in the following Table 1,

Table 1 - Results of the elemental chemical analyses DRX (in %) (Sand of Taghit).

Fraction	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 /%	81.61	92.42	95.18	96.33	97.33	97.15
Al_2O_3/%	3.78	2.05	1.41	1.00	0.83	0.79
Fe_2O_3/%	2.24	0.99	0.59	0.30	0.24	0.21
CaO/%	3.92	0.87	0.27	0.33	0.07	0.11
MgO/%	0.63	0.17	0.02	0.47	0.41	0.05
SO_3/%	0.18	0.19	0.16	0.18	0.18	0.14
K_2O/%	1.08	0.59	0.33	0.10	0.04	0.02
Na_2O/%	0.48	0.20	0.09	0.09	0.09	0.18
P_2O_5/%	0.10	0.02	0.01	0.01	0.01	0.00
TiO_2/%	0.96	0.56	0.25	0.07	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
Loss on	4.58	1.61	1.09	0.75	0.65	0.58
TOT/%	99.6	99.7	99.4	99.6	99.9	99.3

Particle size analysis by sieving [NFP 18-560]: Objective, the grain size analysis determines the size and weight percentages of the different grain families in the sample. It applies to all aggregates with a nominal dimension of 63mm or less, excluding fillers. It's important to avoid confusion between grain size, which is concerned with determining the grain dimension, and granularity, which deals with the dimensional distribution of the grains in an aggregate.

Principle, the test involves sorting the grains in the sample using a series of sieves stacked on top of each other with decreasing opening sizes. The material is placed on the upper sieve and the sorting is achieved by vibrating the sieve column [9, 10].

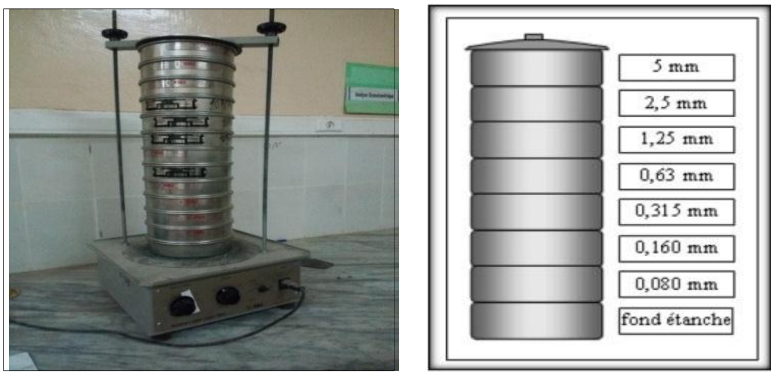


Figure 4 - Sieve column.

The results of the granulometric analysis are assembled in the following Table 2.

Table 2 - Results of particle size analysis of dune sand.

Sample mass/g	Sieve/mm	Refusalweights	Refusalweights	Cumulative weights /%	refusalSieve /%
	0.5	0	0	0	100
	0.4	0	0	0	100
	0.315	36.80	36.80	3.68	96.32
	0.25	614.10	650.90	65.09	34.91
	0.2	276.10	927.00	92.70	7.30
	0,16	47.30	974.30	97.43	2.57
	0.125	11.50	985.80	98.58	1.42
1000	0,1	6,70	992,50	99,25	0,75
	0.08	3.00	995.50	99.55	0.45
	Fond	4.5	1000	100	0

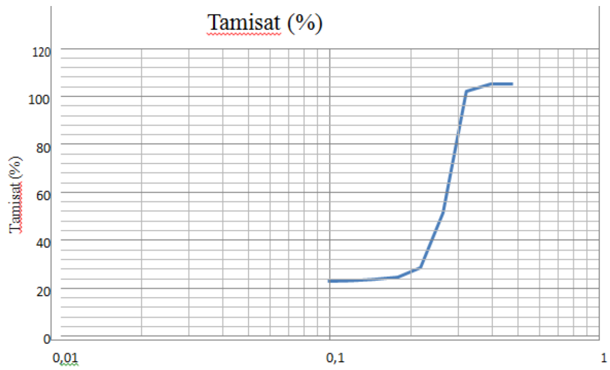


Figure 5 - Grain size curve of dune sand.

Fineness module: The sands must have a granulometry such as the fine elements are neither in excess, nor in too weak proportion, the character more or less fine of sand can be quantified by the calculation of the modulus of fineness (Mf).

The modulus of fineness is all the smaller that the aggregate is rich in fine elements.

Equation 1, is

$$Mf = \frac{\sum Rc\%}{100} \qquad (1)$$

RC: Refuse cumulus in (%) under the sieves of module 0.16 to 5

When Mf is between:

1.8 And 2.2: the sand is mostly fine

2.2 And 2.8: we are in presence of preferential sand

2.8 And 3.3: the sand is a little coarse, it will give concrete resistant but less workable.

The results of modulus of fineness are given in the following Table 3.

Table 3 - The results of modulus of fineness.

Material	Module of finesse
dune sand	1.01

Equivalent of sand [NF P18-598]: Objective, The sand cleanliness test is commonly used to assess the quality of sand in concrete. It separates fine particles from coarse sand to quantify the cleanliness using a standardized sand equivalent coefficient [11, 12]

Principle, The test is performed on sand. The sample is washed according to a standardized process and allowed to rest. After 20 minutes, the following elements are measured:

Height h_1: clean sand + fine elements.

Height h_2: clean sand only.

The equivalent sand content is then deduced, which, by convention in the Equation. 2, is

$$ES = \frac{h_2}{h_1} \times 100\% \qquad (2)$$

Method of operation, Fill each of the three test tubes with water to a level 100 ml lower than the marking. Then weigh a sand sample of 120g and pour one into each cylinder and let it settle for 10 minutes. After this time, fill the test tubes with a little water and shake them, repeating this until the upper marking is reached. Finally, let these mixtures settle for 20 minutes. Figure 6 A, the test tube is then placed horizontally in an automatic vibration machine. Figure 6 B. The test tube is vibrated 90 times and left for 20 minutes.

Figure 6 - Sand equivalent test

The sand equivalent values in Table 4, indicate the nature and quality of the sand according to the measuring means and allow appreciating its quality for the composition of a concrete [13, 14].

Table 4 -The values of sand equivalent indicate the nature and quality of the sand.

N°	S.E. to visual	S.E. at the piston	Nature of the sand quality
01	ES< 65%	ES<60%	Clayey sand : risk of shrinkage or swelling. Sand to be rejected for quality concretes or more precise verification
02	65%≤ES<75%	60%≤ES<70%	Slightly clayey sand of acceptable cleanliness
03	75%≤ES<85%	70%≤ES<80%	Clean sand with a low proportion of clay fines
04	ES≥85%	70≤ES<80%	Very clean sand. The almost total absence of fine clay clayey fines may lead to a plasticity defect of the concrete that will have to be compensated by an increase of the

From the interpretation Table 4, we concluded that the dune sand is very clean.

The results obtained are established in the following Table 5.

Table 5 -The sand equivalent and value limit.

Dune sand	Sand equivalent	Value limit	Observation
	E.S.V%100	E.S.V≥85%	Very clean sand

According to the NF P18 598 standard, this sand is very clean and acceptable for the composition of mortar and concrete.

Density [NF P 18-30]): Objective, the aim of this essay is to determine the mass of a granular fraction when developing a concrete composition. This parameter is used to determine the mass or volume of different granular classes mixed to obtain concrete with specified characteristics.

Principe, the principle involves measuring the weight of a sample in a given volume. It is an indirect measurement used in construction sites as a quantity control argument. Two types of bulk density are generally distinguished.

Absolute density: Definition, the absolute density ρs is the mass per unit volume of the material that constitutes the aggregate, without taking into account the voids that may exist in or between grains. Fill a graduated cylinder with a volume (V_1=300) of water.

Method of operation, Weigh a dry sample M of aggregates (about 300 g) and introduce it into the test tube, taking care to eliminate all air bubbles. The liquid rises in the test tube. Read the new volume V_2, Figure 7,

The absolute density in the Equation 3, is:

$$\rho_S = \frac{M_S}{V_2 - V_1} \qquad (3)$$

Or:

ρ_s: absolute density.(kg/m^3)

M_s: mass of solid grain. (kg)

V_1: volume of water. (m^3)

V_2: total volume (solid grain + water).(m^3)

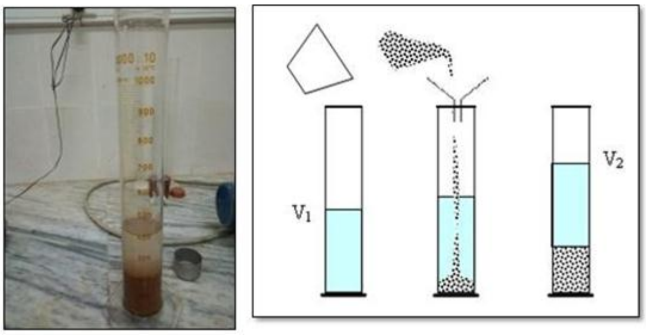


Figure 7 - Absolute density test.

The apparent density: Definition, this is also indicated in the name (bulk density) and is a mass of dry constituents per unit volume constituents per unit volume where the voids between the grains are included.

Procedure, take the sand (for example) in the 2 hands forming a funnel. Place these 2 hands at about 10 cm above a one liter measure and let fall this stable, neither too fast, nor too slow.

Pour the body in this way, always in the center of the measure, until it overflows all the center of the measure.

Pass to the rule. Weigh the contents Figure 8,

The apparent density in the equation 4, is:

$$\rho_a = \frac{M_t - M_0}{v} \qquad (4)$$

With:

ρ_a: apparent density.(kg/m^3)

M_0: the mass of the empty measuring vessel (kg)

M_t: the mass of the vessel with the sample (kg)

V: the volume of the vessel (m^3)

Figure 8 - Apparent density test.

The results of the tests of the apparent density ρa and the absolute density ρs are recorded in Table 6, follows:\

Table 6 -The Apparent and Absolute density.

Sand dune	Apparent density/g/cm^3	Absolutedensity/g/cm^3
	1.48	2.53

2.2. The cement

Two different types of cement have been chosen in this study (CPA CEM I and CPJ CEMII/B), Figure 9. (Cimbéton Technical collection T47)

Chemical analysis of cements: The results of chemical analysis of cement are interpreted in Table7 following:

Table7 - Chemical analysis of cements (CEM I) [LAFARGE ALGERIE].

Characteristics	Results /%
Loss of iron	0.5 à 3
Sulphate content (SO_3)	1.8 à 3
Magnesiumoxide content (MgO)	1.2 à 3
Chloride content	0.01 à 0.05
Iron loss	10.0 ± 2
Sulphate content (SO_3)	2.5 ± 0.5

Magnesiumoxide content (MgO)	1.7 ± 0.5
Chloride content	0.02 – 0.05

2.3 Ultra-fines

The ultra-fines used are local materials found in the Tabelbala and El-ouata regions of southwestern Algeria. They are found in a raw state and must be ground and screened with a 80 µm sieve before being added to the other components of the mortar (Figure 9).

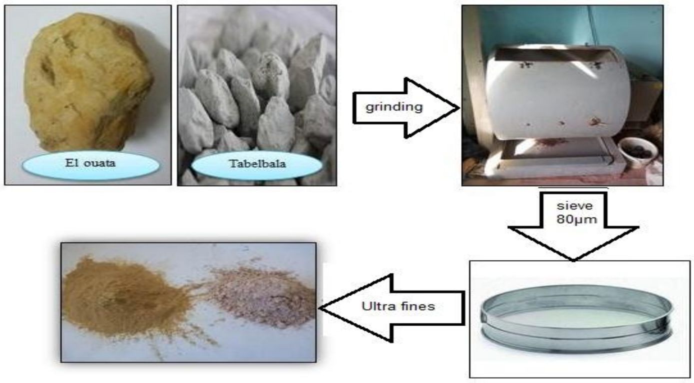


Figure9 - Preparation steps of the ultras fines.

<u>Density</u>: After obtaining the final state of the two materials, the role of passing through physical and chemical analyses will come. The Table 8, below summarizes the results of the density found.

Table8 - Density results of the ultras fines.

Density (g/cm^3)		
The sample	Apparent	Absolute
TAB	0.45	3.38
ELO	0.99	2.82

<u>Chemical analysis of ultra-fines</u>: Methylene blue test (spot test) [NF P18-592].

Objective, this test measures the capacity of fine elements to adsorb methylene blue.

Principle, it consists in introducing in an aqueous bath containing the test sample, increasing quantities of methylene blue by successive doses, and to control after each addition the adsorption of the blue by means of the test "of the spot", until the clayey particles of the material are saturated with blue.

Method of operation:

- Take a sample of 30 g
- Put it into a beaker filled with distilled water to 200 ml.
- Stir the sample using a magnetic stirrer.
- Add 5 ml of blue dye to the suspension and stir for 5 minutes.
- Use a glass stirring rod to take drops of the suspension and place them on a filter paper.
- Gradually add increasing amounts of methylene blue, in 5 ml increments.
- Stop when a light blue halo is observed around the suspension stain. If this occurs, the test is positive (Figure 10).

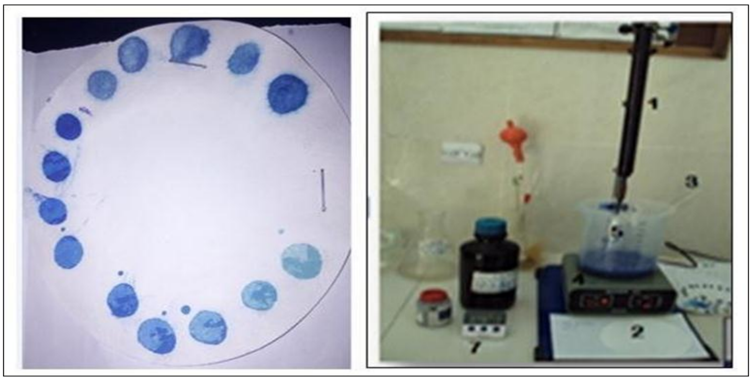


Figure 10 - Methylene blue apparatus.

Expression of the results is given by the following Equation.5,

$$V.B.S = \frac{V}{m} \qquad (5)$$

V.B.S: Value of blue.(m^3)

V: Volume of methylene blue. (m^3)

M: The mass of test sample = 30g.

Positive: The test is repeated identically, five times at one minute intervals to confirm it.

Table 9, following:

Table9 - Methylene blue test results.

Methylene blue value /VBS	Soil category
VBS ≤ 0.2	Sandy soils
0,2 ≤ VBS < 2.5	Silty soil

2,5 ≤ VBS < 6	Clayey-silt soil
6 ≤ VBS < 8	clayey soil
VBS > 8	Very clayey soil

Classification of the ultra-fines is given on the table10,

Table10 -Test results.

The sample	m /g	VB /ml	VBS	Observation
TAB	30	80	2.66	Clayey-silt soil
ELO	30	35	1.16	Silty soil

3. Results and discussion

We present the various results of tests conducted on mortars made according to the two types of ultras fines Tebelbala and El-ouata, such as the density, porosity, tensile strength by bending and compressive strength (7, 14 and 28 days). [15]

3.1 Density of the mortar

The histograms represent the variation of density as a function of percentage of ultras fines.

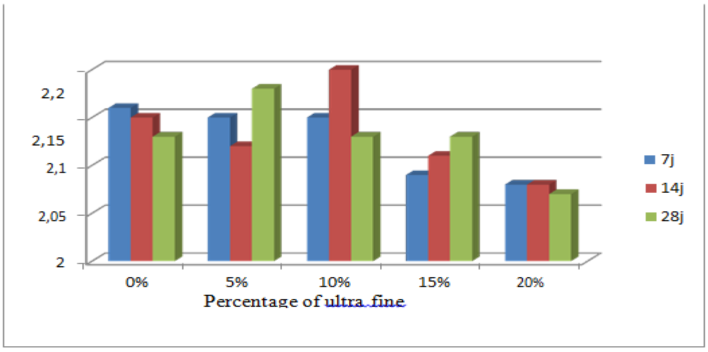


Figure 11 - The evolution of the density in (g/cm^3) TAB.

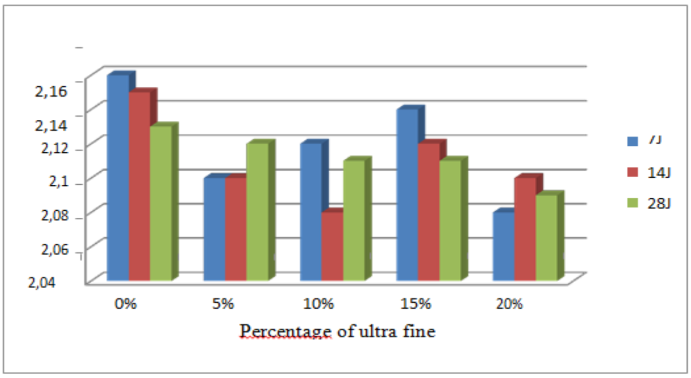


Figure 12 - The evolution of the density in (g/cm^3) ELO.

According to the results presented, despite the different percentages of ultra-fines, the density has a small variation compared to the control mortar, even if the type of cement is changed.

3.2. Porosity

We present the two histograms which give the variation of the porosity according to the percentage of the ultras fines used in the mortars.

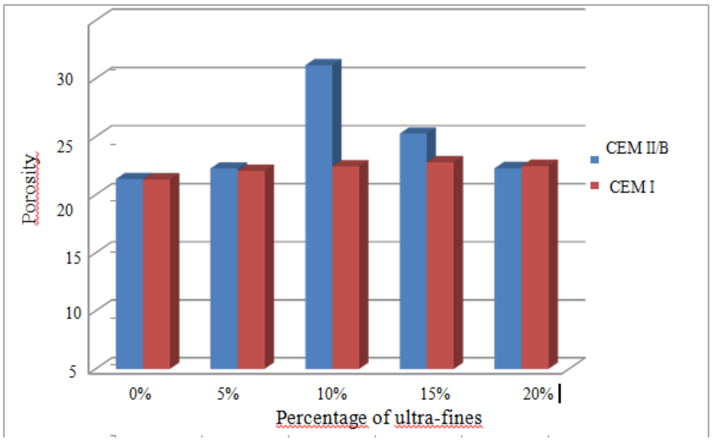


Figure 13 - The evolution of the porosity (TAB).

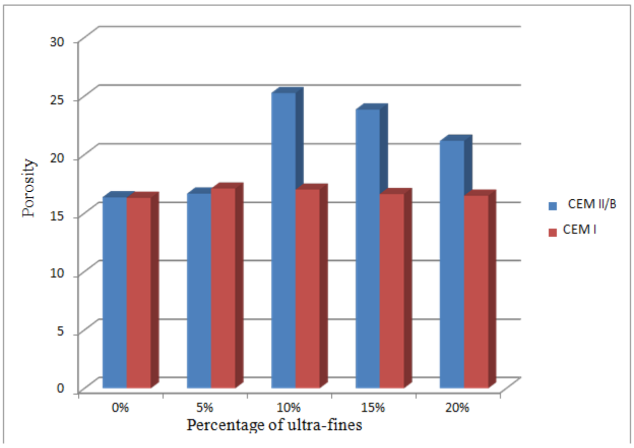


Figure 14 - The evolution of the porosity (ELO).

According to Figure 13 and Figure 14 the porosity of the specimens for both cements increases with the increase of the percentage of ultra-fines (TAB; ELO)

3.3 Tensile strength by flexion

The flexural tensile test is performed on 4x4x16 prismatic specimens using a 3-point bending device. Three specimens are tested for each sample of age (7, 14 and 28) days.

Figure 15 - The bending tensile strength test.

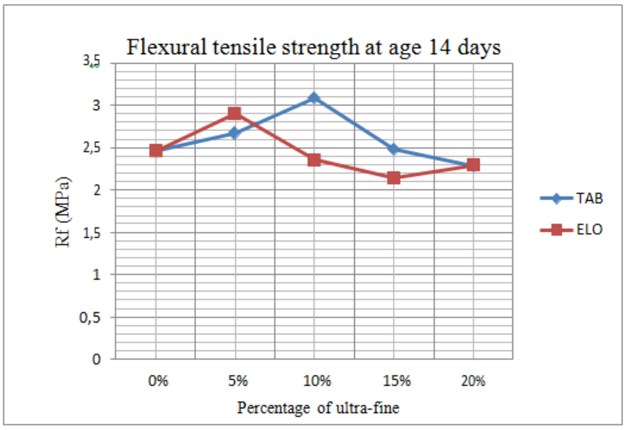


Figure 16 -Variation of the tensile strength by flexion (TAB and ELO) at 14 days of age.

The use of the different types of ultras fines as a partial replacement of cement (CEM II/B)

induced an increase in flexural tensile strength. The results presented in Figure 16 show the increase in tensile strength of a mortar at the average age (14 days). [16].

3.4 Compressive strength

The influence of the addition of the ultras fines on the compressive strength of the mortars at different ages (7; 14 and 28) days is represented on which.

Figure 17 - Compression test device.

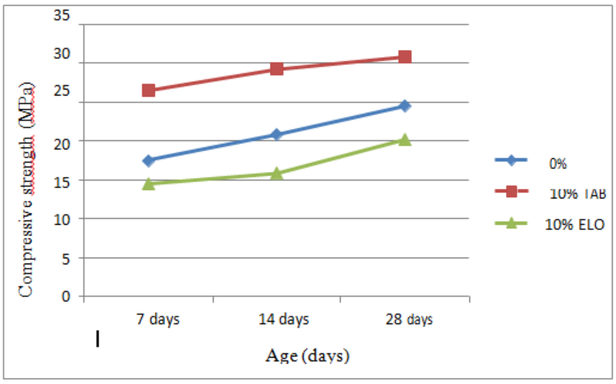
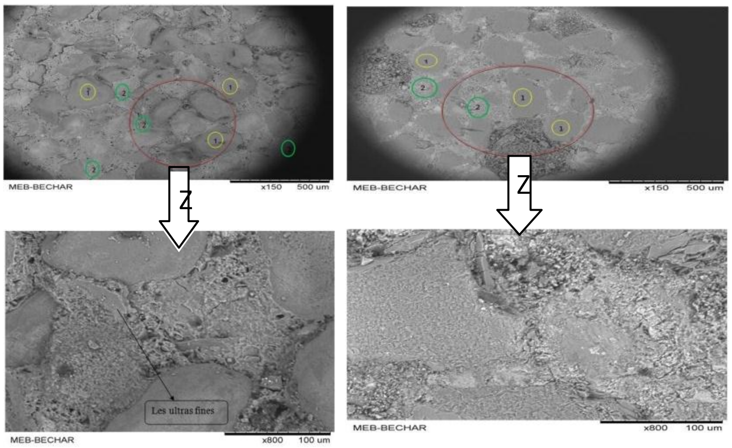


Figure 18 - Variation of compressive strength as a function of age of mortars containing 10% of ultras fines (TAB and ELO).

According to the results obtained, the compressive strength increases with time. These results confirm that the formulation of the mortar which contains 10% of the ultras fines of TABALBALA is better than that of EL-OUATA.

3.5. Scanning electron microscope (SEM) observation



1. Dune sand grain 2. Cement paste

Figure19 - SEM observation of the polished plain mortar interface at different magnifications x150 and x800.

Figure19, present the interfaces of the polished mortars which shows the dune sand grains in zone 1 and the cementations paste and the ultra-fines in zone 2.

It can be seen from the above figures that there is an adhesion between the dune sand grains and the cementations paste due to the presence of the ultra-fines.

4. Conclusion

In conclusion, our research falls within the framework of exploiting local materials, including additive elements, for the preparation of economical mortars. We have successfully developed new mortars based on high-quantity additives, which are known to be expensive and rare as they are industrial products. This drawback led us to search for an equivalent product that can play a role in the mortar and is available in our region, accessible to everyone.

The second part of the research was conducted in the laboratory, allowing us to identify the sand dune, the cements used, and the ultra-fines from various sources, as well as performing chemical and physical analyses. The available testing devices enabled us to highlight the mechanical properties of the mortars made with ultra-fines.

The exploitation of local ultra-fines in sand dune-based mortars comprised an experimental study on the fresh mortar, including workability and bulk density, as well as a study on the hardened mortar, encompassing mechanical testing (flexural and compressive strength), porosity, and bulk density.

Through this study, we have achieved the production of mortars using local ultra-fines and sand dune, resulting in a highly interesting valorization of the sand from the western erg, both technically and economically.

In conclusion, our research has demonstrated the feasibility and benefits of using local ultra-fines in mortars, paving the way for a more sustainable and cost-effective utilization of local materials in the construction industry. These findings hold great potential to encourage regional development and reduce dependence on expensive industrial products. There are still opportunities for future research aimed at further optimizing the formulations and manufacturing processes of ultra-fine-based mortars to enhance their performance and durability.

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