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Physical-chemical characterization and exploitation of an ultra fine local in mortars

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Abstract. The research aims to find a suitable replacement for the current ultrafine material used in concrete and mortar formulation. The study will focus on the physical, chemical, and mechanical properties of the new ultrafine material in the cement matrix. The goal is to improve the performance of mortars through the use of local ultrafine. The study will include physico-chemical characterization of the ultrafine material, which may include clay or dune sand. The research will provide insights into the impact of using local ultrafine on cement-based mortars. The findings will inform the development of better formulations for concrete and mortar. The research will contribute to the use of locally sourced materials in the construction industry.

1. Introduction

Currently, research on new construction materials has shifted towards the use of local materials to produce cost-effective and high-performing mortars and concrete. The utilization of industrial by-products is justified due to their abundance and the lack of recycling and recovery programs.

Our work is part of an experimental study on the physical-chemical characterization and utilization of a local ultra-fine material in mortars. Mortars are widely used and provide benefits such as strength, workability, and porosity.

However, some of these properties are still subject to research and improvement. For example, ultra-fines significantly improve the strength of mortar. [1], [2]

The incorporation of additives (ultra-fines) is now an important technique in improving the properties of mortar such as strength and durability. These additives significantly affect the rheology of fresh cementitious materials, which is directly related to the development of strength and durability of hardened materials.

However, to fully benefit from these advantages and choose the best solution for optimization, it is necessary to understand the characteristics of these additives and their effects on mortar properties.

Can we achieve acceptable performance by using locally obtained ultra-fine additives from dune sand (Taghit erg).

The main objective of this study is to:

- Physico-chemical characterization of local ultra-fines (clays from Tabalbala and El-Outa).
- Utilization of a local ultra-fine material in dune sand-based mortar.
- Development of a new, economical mortar.

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. [3]

2.2.1 sand dune:

Fig. 1, sand dune

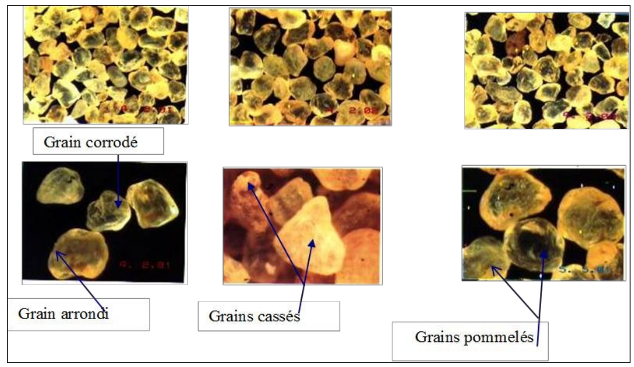

Fig. 2, Observations of sand grains under the optical microscope [Tafraoui, 2009].

The optical microscope (Fig. 2) 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 (Fig. 3) a peak of about 100% silica which reflects the dominance of SiO2 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.

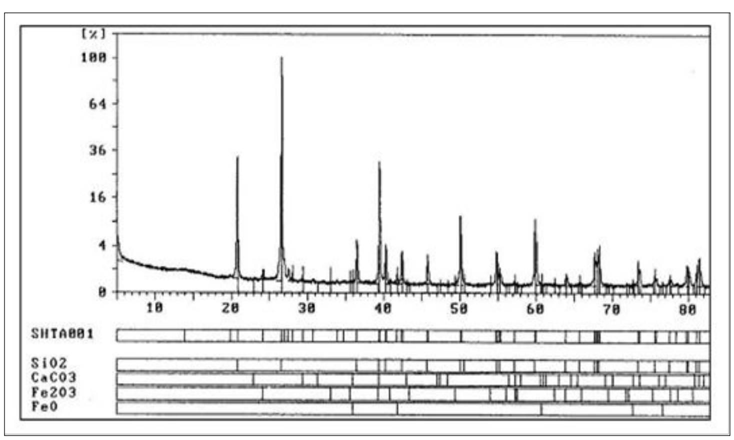

Fig. 3: XRD analysis of a dune sand (Savd of Taghit) [9]

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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 (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	81,61	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 Fire	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**

2.1.1 Particle size analysis by sieving [NFP 18-560].

a- 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.

b- 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.

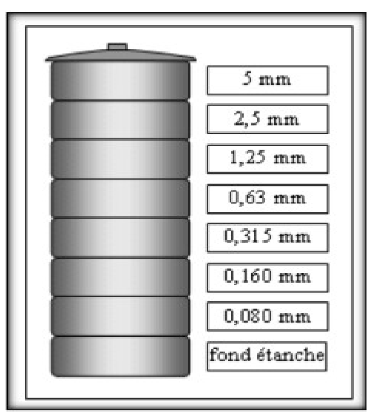

Fig. 4, Sieve column

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

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

Sample mass(g)		Refusal weights	Refusal weights	Cumulative refusal weights	Sieve(%)
1000	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
	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

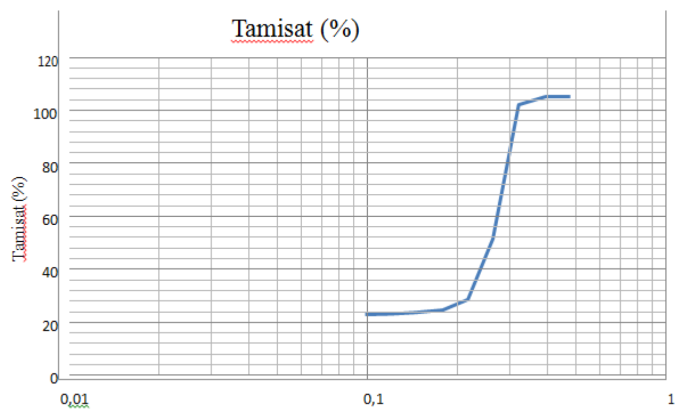

Fig. 5, Grain size curve of a dune sand

2.1.2. 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 a 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.
Eq. 2.1, is

$$Mf = \frac{\sum Rc\%}{100} \quad (2.1)$$

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 a 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

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2.1.3 Equivalent of sand [NF P 18-598]

a- 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.

b- 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 h1: clean sand + fine elements.

Height h2: clean sand only.

The equivalent sand content is then deduced, which, by convention in the Eq. 2.2, is

$$ES = \frac{h2}{h1} * 100\% \qquad (2.2)$$

c - 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. Fig. 6 A. The test tube is then placed horizontally in an automatic vibration machine. Fig. 6 B. The test tube is vibrated 90 times and left for 20 minutes.

Fig. 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 to appreciate its quality for the composition of a concrete.

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 of the nature of the fines by a test with
02	65%≤ES<75%	60%≤ES<70%	Slightly clayey sand of acceptable cleanliness for standard quality concrete when the shrinkage has no significant effect on the quality of the concrete.
03	75%≤ES<85%	70%≤ES<80%	Clean sand with a low proportion of clay fines perfectly suited for high quality concrete.
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

From the interpretation table Table. 4, we concluded that the dune sand is very clean.
The results obtained are established in the following Table. 5,

	Sand equivalent		Value limit	Observation
Dune sand	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.

2.1.4 Density (NF P 18-301)

a- 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.

b- 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.

2.1.4.1 Absolute density

a- 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 (V1=300) of water.

b- 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 V2, Fig. 7,
The absolute density in the Eq. 2.3, is :

$$\rho_s = \frac{M_S}{V_2 - V_1} \tag{2.3}$$

ρ_s : absolute density.
M_s : mass of solid grain.
V_1 : volume of water.
V_2 : total volume (solid grain + water).

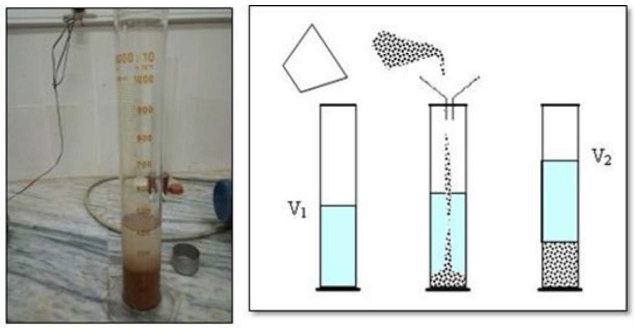


Fig. 7, Absolute density test

2.1.4.2 The apparent density

a- 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.

b- 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 Fig. 8,
The apparent density in the Eq. 2.4, is :

$$\rho_a = \frac{M_t - M_0}{v} \tag{2.4}$$

ρ_a: apparent density
M_0: the mass of the empty measuring vessel
M_t: the mass of the vessel with the sample
V: the volume of the vessel
The results of the tests of the apparent density ρa and the absolute density ρs are recorded in Table. 4, follows:

	Apparent density	Absolute density
Sand dune	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), [6].

2.2.1 Chemical analysis of cements

The results of chemical analysis of cement are interpreted in Table. 5 following :

Table. 5, Chemical analysis of cements (CEM I) [LAFARGE ALGERIE].

Characteristics	**Results (%)**
Loss of iron	0,5 à 3
Sulphate content (SO3)	1,8 à 3
Magnesium oxide content (MgO)	1,2 à 3
Chloride content	0,01 à 0,05
Iron loss	10,0 ± 2
Sulphate content (SO3)	2,5 ± 0,5
Magnesium oxide content (MgO)	1,7 ± 0,5
Chloride content	0,02 – 0,05

2.3 Ultra-fines

The ultrafines 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. (Fig. 8).

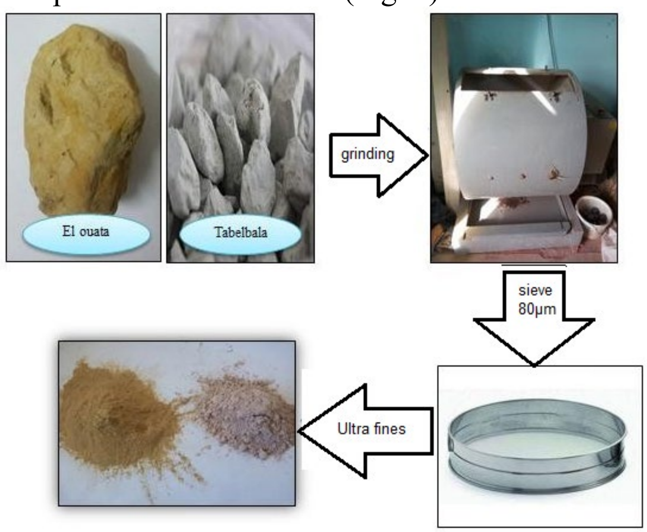


Fig. 8, Preparation steps of the ultras fines

2.3.1 Density

After obtaining the final state of the two materials, the role of passing through physical and chemical analyses will come. The Table. 6, below summarizes the results of the density found

Table. 6, Density results of the ultras fines

The sample	**Density (g/cm^3)**	
	Apparent	Absolute
TAB	0,45	3,38
ELO	0,99	2,82

2.3.2 Chemical analysis of ultra fines

- **Methylene blue test (spot test) [NF P18-592].**

a- Objective

This test measures the capacity of fine elements to adsorb methylene blue.

b- The 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 (Fig. 9).

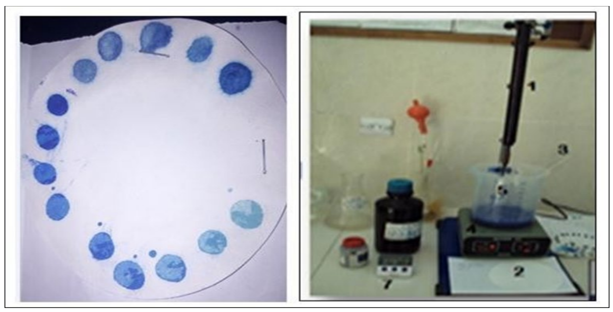


Fig. 9 , Methylene blue apparatus

Expression of the results is given by the following Eq.2.5,

$$V.B.S = \frac{V}{m} \qquad (2.5)$$

V.B.S: Value of blue.
V: Volume of methylene blue.
M: The mass of test sample =30g.
Positive. The test is repeated identically, five times at one minute intervals to confirm it.
Table. 7, following:

Table. 7, 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 are given in the table. 8, *Table. 8, test results*

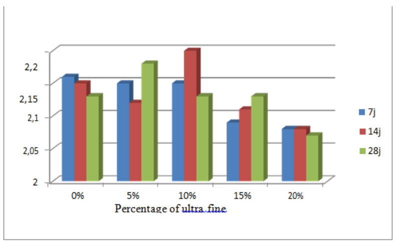
The sample	m (g)	VB (ml)	VBS	Observation
TAB	30	80	2,66	Clayey-silt soil
ELO	30	35	1,16	Silty soil

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).

3.1 Density of the mortar

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



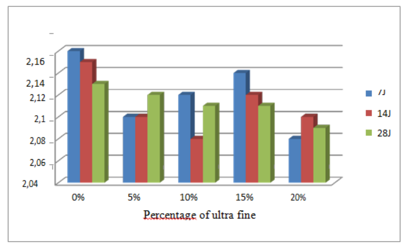
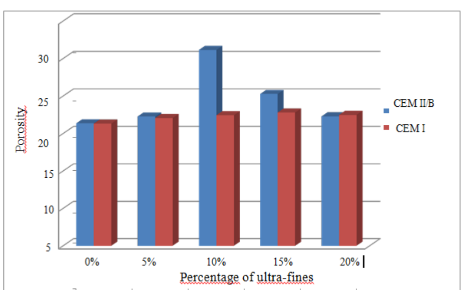


Fig. 10, The evolution of the density in (g/cm3) TAB, Fig. 11, The evolution of the density in (g/cm3) ELO

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.



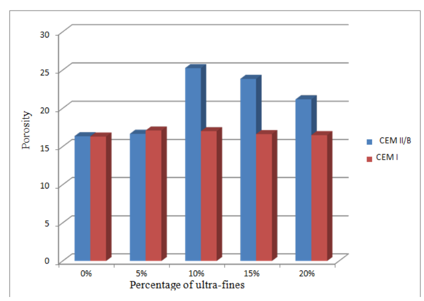


Fig. 12, The evolution of the porosity (TAB) , Fig. 13, The evolution of the porosity (ELO)

According to Fig. 12and Fig. 13 the porosity of the specimens for both cements increases with the increase of the percentage of ultra-fines (TAB; ELO)

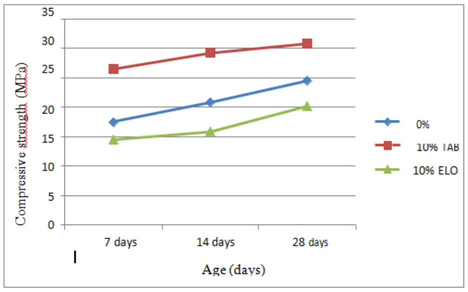
3.3 Tensile strength by flexion

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.

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 Fig. 17 show the increase in tensile strength of a mortar at the average age (14 days). [8]

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.



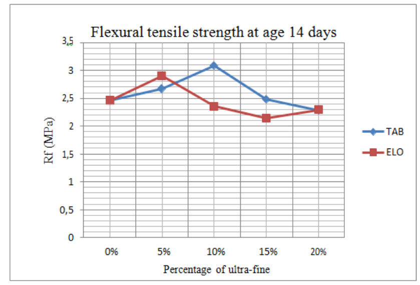


Fig. 14 Variation of compressive strength as a function of age of mortars containing 10% of ultras fines (TAB and ELO)

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

magnifications x150 and x800.

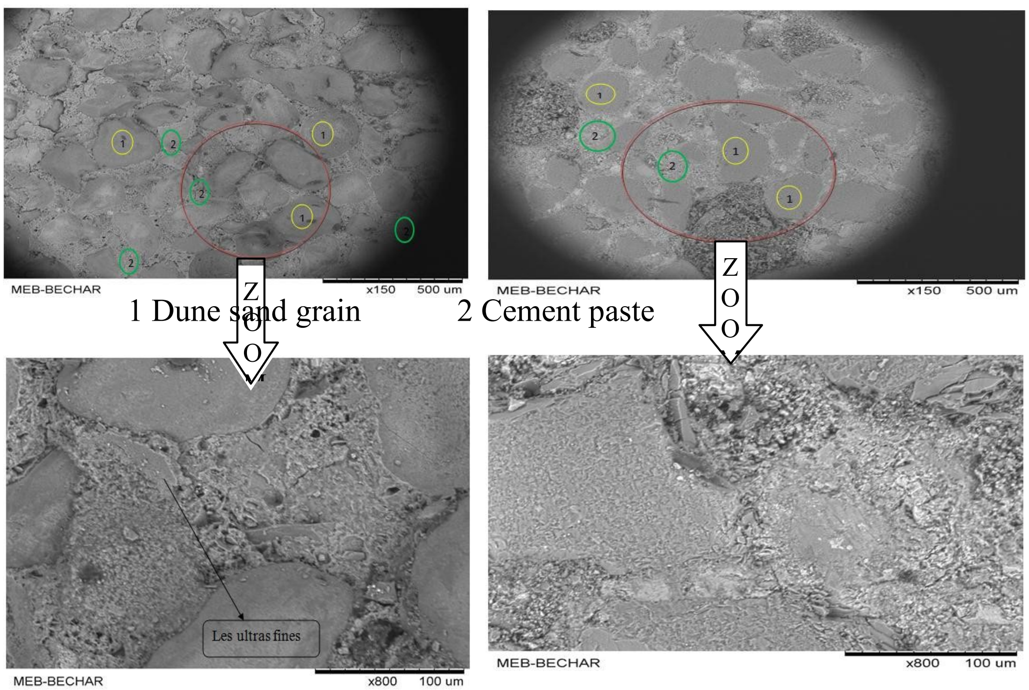


Fig. 15, SEM observation of the polished plain mortar interface at different

Fig. 15, present the interfaces of the polished mortars which shows the dune sand grains in zone 1 and the cementitious 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 cementitious paste due to the presence of the ultra fines.

Conclusion

The present research falls under the framework of exploiting local materials, including additive elements, for the preparation of economical mortars. The new mortars are based on several high-quantity additives, which are known to be expensive and rare as they are industrial products. This drawback prompted us to find an equivalent product that plays a role in the mortar and is available in our region, and is accessible to all.

The second part of the research was carried out in the laboratory, allowing us to identify the sand dune, the cements used, and the ultra-fines from various sources, as well as chemical and physical analysis. 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 is comprised of an experimental study on the fresh mortar, workability and bulk density, as well as a study on the hardened mortar, mechanical testing (flexural and compression strength), porosity, and bulk density.

Through this study, we have achieved the production of mortars using local ultra-fines and sand dune, leading to a very interesting valorization for the sand of the western erg both technically and economically.

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