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# Characterization of Cement Mortar Based on Fine Quartz

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***Abstract*—**The introduction of siliceous mineral additions in cement production allows, in addition to the ecological and economic gain, improvement of concrete performance. This improvement is mainly due to the fixing of Portlandite, released during the hydration of cement, by fine siliceous, forming denser calcium silicate hydrates and therefore a more compact cementitious matrix. This research is part of the valuation of the Dune Sand (DS) in the cement industry in Algeria. The high silica content of DS motivated us to study its effect, at ground state, on the properties of mortars in fresh and hardened state. For this purpose, cement pastes and mortars based on ground dune sand (fine quartz) has been analyzed with a replacement to cement of 15%, 20% and 25%. This substitution has reduced the amount of heat of hydration and avoids any risk of initial cracking. In addition, the grinding of the dune sand provides amorphous thin populations adsorbed at the surface of the crystal particles of quartz. Which gives to ground quartz pozzolanic character. This character results an improvement of mechanical strength of mortar (66 MPa in the presence of 25% of ground quartz).

***Keywords*—**Mineralogical structure, Pozzolanic reactivity, quartz, mechanical strength.

## I. Introduction

CEMENT production is one of the most environmentally aggressive products. Approximately 0.9 tons of $CO_2$ gas is released per ton of cement produced, 60% of this emission is due to the cement clinkering process. Current researches aimed to reduce this emission by replacement a part of cement by mineral additions. These materials named supplementary cementitious additions (SCMs) can be natural or industrial waste. Pozzolanic cement addition is, by definition, all siliceous materials with the ability to combine with Portlandite (hydroxide calcium –$Ca(OH)_2$) released during cement hydration to form calcium silicate hydrates (CSH). As explain by the following reaction:

$$\text{Cement + water} \longrightarrow \text{hydrated paste} + Ca(OH)_2$$

$$\text{Mineral admixture + Ca(OH)2 + H2O} \longrightarrow \text{CSH through secondary hydration}$$

CSH is a principal strength-giving compound in the hardened concrete. The formation of additional cementitious compounds during secondary hydration leads to a reduction in temperature rise and refinement of pore structure in the hardened concrete. Calcium hydroxide (Portlandite) is considered as a weak link in the concrete structure. Its consumption to form strength-giving phases, principally C-S-H, during hydration leads to improved durability of the structure in terms of its resistance to deterioration through carbonation, corrosion, sulfate attack, alkali–silica reaction, and so on. Besides the chemical (pozzolanic or cementitious) reaction, the mineral admixtures also act physically. The finely divided particles act as fillers [1], [3].

The morphology of siliceous particles is an important factor influencing the pozzolanic activity of additions. Consequently, crystal structure of ground quartz prevents his activity and makes it chemically inert [4]-[7]. However, latest researches have shown that the presence of amorphous fine particles adsorbed on the crystalline particles, after grinding, allows to quartz a "partial" pozzolanic power [8]-[13].Which contribute to the improvement of the quality of concrete.

The purpose of this contribution is the development of dune sand (very abundant in southern Algeria) in the cement production by analyzing the behavior of standard mortars; by substitution of 15% cement, 20% and 25% of ground quartz.

## II. Experimental Procedure

The materials used in this study are of local origin.

- A CEM I 42.5 Portland Cement type, with a density of 3.15 and a finesse of 3653 $cm^2$ / g.
- A ground DS (quartz) from the south of Algeria with a density of 2.4 and a fineness of 5800 $cm^2$ / g.
- A superplasticizer –High range water reducer with 40% solids.
- A standardd Sand complies with EN 196-1, ISO 679 and ISO 9002 standard.

The chemical and mineralogical compositions of the powders used are summarized in Tables I and II. The mineralogical analysis by XRD of ground DS presented in Fig. 1 shows that it presents a crystalline structure of the low-quartz type.

TABLE I
CHEMICAL COMPOSITIONS OF CEMENT AND DUNE SAND

| Element | Cement | DS |
|---|---|---|
| $SiO_2$ | 20,31 | 73,05 |
| $Al_2O_3$ | 3,81 | 3,97 |
| $Fe_2O_3$ | 4,79 | 0,43 |
| CaO | 62,81 | 0,66 |
| MgO | 2,29 | 0,08 |
| $SO_3$ | 2 ,28 | 0,06 |
| $Na_2O$ | 0,14 | 0,88 |
| Free CaO | 0,608 | -- |
| $K_2O$ | 0,41 | 2,15 |
| Ins | 1,60 | -- |
| $Cl^-$ | 0,0149 | -- |
| LOI | 2,910 | 0,64 |

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TABLE II
MINERALOGICAL COMPOSITION OF CEMENT

| Element | $C_4AF$ | $C_3A$ | $C_3S$ | $\beta C_2S$ |
|---|---|---|---|---|
| % | 15 | 2 | 60 | 13 |

The sand grains are in forms of two populations: The first contains fine amorphous particles adsorbed on large crystallized particles (second population). As illustrated in Fig. 2.

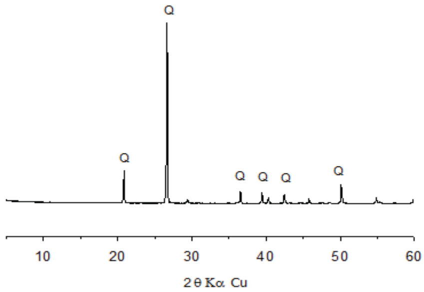


Fig. 1 X-ray diffraction pattern of ground quartz (DS)

## A. Tests on Cement Pastes

Four variants Cement pastes were analyzed: A control cement paste and three-quartz based on cement pastes (containing successively 15%, 20% and 25% of DS by replacement of cement). Setting time was determined on different pastes with a normal consistency. Water requirement of different binder to have a normal consistency was determined according to EN 196-3 standard. Water requirement for normal consistency of different pastes and their setting time are presented in Figs. 3 and 4.

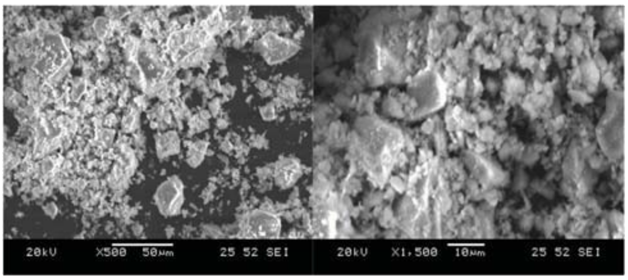

Fig. 2 SEM views of ground quartz (DS)

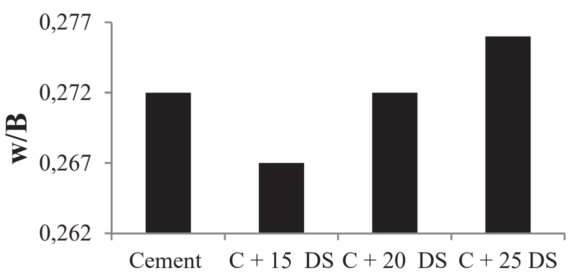


Fig. 3 Water requirement for normal consistency of different pastes

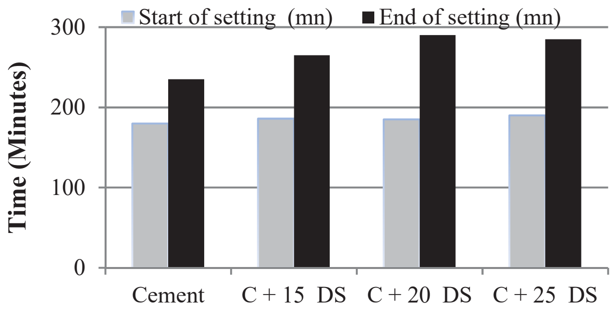


Fig. 4 Initial and End time of setting

## B. Test Mortars

According to EN 196-1, all mortars tested are with a Sand/Binder ration of 3. These mortars are mixed with a water/Binder ratio of 0.35 and 2% of superplasticizer.

1. Workability Test

The flow time of different mortars (determined by testing the workability LCPC) is summarized in Fig. 5:

2. Heat of Hydration (Calorimeter Langavant)

The determination of the heat of different mortars during the first hours was establishes with the calorimeter Langavant (EN 196-9 standard) as shown in Figs. 6-8.

3. Mechanical Tests

Mechanical strength tests Compressive were performed on prismatic specimens (4x4x16) $cm^3$.

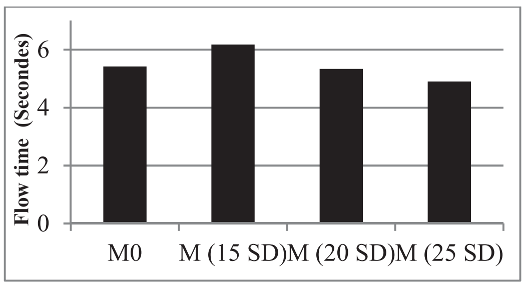


Fig. 5 Flow times of different mortars

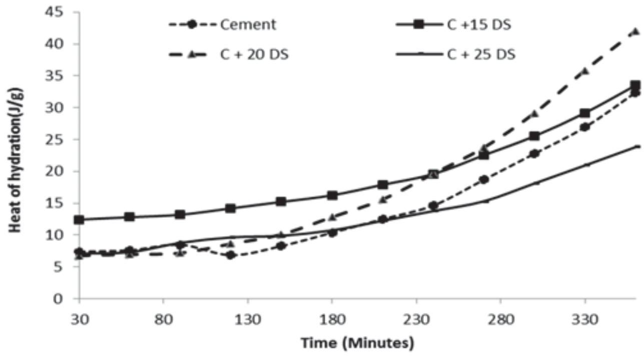


Fig. 6 Heat of hydration of different mortars at the 6 first hours of hydration

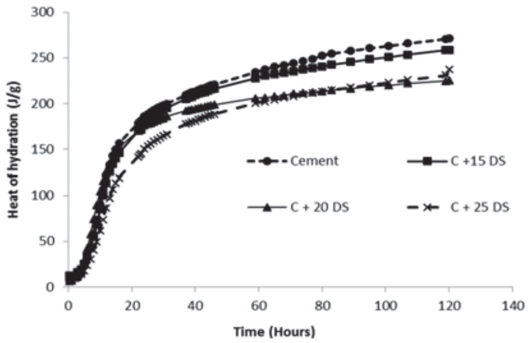


Fig. 7 Heat of hydration of different mortars at the 5 days of hydration

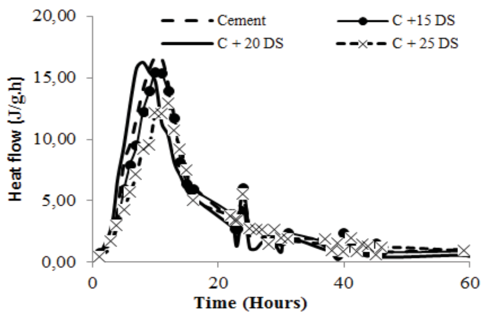


Fig. 8 Heat flow of different mortars

The evolution of pozzolanic activity can be analyzed by calculating the pozzolanic activity index (AI). It is the ratio between the compressive strength of the addition based mortar (σm) and that of the control mortar (σc):

$$AI = 100\ x\ \frac{\sigma_m}{\sigma_c}$$

### C. Water Requirement and Rheology of Mortars

With the exception of pastes based on 15% SD the presence of fine quartz requires an additional amount of water to a constant consistency. The irregular shape of quartz particles causes a change in the intensity of friction between the solid particles [14], [15]. This adverse effect is granular corrected by the introduction of the superplasticizer. This is reflected in the increase of the flow time of the mortar in the presence of quartz and consequently an improvement in workability of mortar.

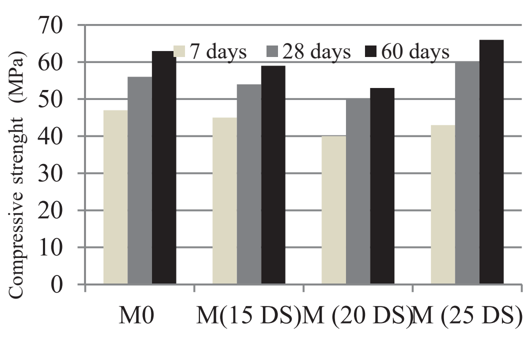


Fig. 9 Compressive strength of mortars

## III. Discussion

### A. Setting and Hydration

The presence of fine quartz did not affect, in a significant way, the time of initial setting. Unlike the time of end of setting which is delayed. During the first hours of hydration, the mortars with 15% and 20% quartz emit more heat than the control which results an acceleration of hydration kinetic. The presence of 25% of quartz reduces the active part and consequently reduces the heat flow corresponding to the second peak associated with the hydration of the $C_3S$. After five days of hydration, a decreased of heat of hydration is observed in the presence. This avoids the appearance of initial cracks. Therefore, protect the mortar against external chemical attack.

### B. Mechanical Behavior

At young ages, the quartz based mortars have lower strength than the control and due to the reduction of the active part. The replacement of 25% of cement by fine quartz provides a greater strength than the mortar for 20% of quartz (although it is smaller than the control at early ages).

In the long term, based on 25% quartz mortars develop greater strengths than those of control (66 MPa at 60 days). This increase is due, to the physical effect of the particles of ground quartz (which presents a high fineness comparatively to cement grains). And to the pozzolanic effect of the first population of fines. This population has an amorphous structure adsorbed on crystalline particles contributes to the formation of CSH by fixing Portlandite released during cement hydration [8]. This is reflected by improvement of the index of pozzolanic activity (107% at 28 days). At 60 days of hydration, the index of activity of pozzolan mortars 25% quartz decreases, reaches a value of 105%. Fine quartz adsorbed at the surface of the crystal particles was consumed. The second population of the crystallized particles is inert. It is involved in the formation of the granular skeleton and contributes to the compactness of the cement matrix [10], [11].

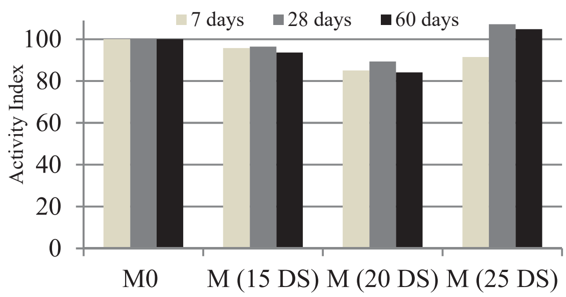


Fig. 10 Activity index of mortars

## IV. Conclusion

This study allowed us to the following conclusions:

- View their irregular shape, the fine quartz has an adverse effect granular (largest water requirement) which can be corrected by introduction of the superplasticizer that improves the workability of the mortar.
- Grinding the DS provides amorphous thin populations adsorbed at the surface of the crystal particles of quartz

which gives to quartz the pozzolanic character. The crystalline structure of quartz is not an obstacle to the pozzolanic reactivity.

- The replacement of cement by Quartz generates low heat of hydration. Reduce all risk of initial cracks and protect concrete against all external aggression.
- The replacement of 25% quartz cement mortars provides Eco-concrete: Economic, ecological, and sustainable concrete. Achieving sustainable development in construction field.

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