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# ADDING FINELY CRUSHED DUNE SAND TO CEMENT ON THE EVOLUTION OF HYDRATION OF PASTA PORTLAND CEMENT

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## ABSTRACT

Influence of adding finely crushed dune sand Sd to cement, on the physical-mechanical performances results primarily from two effects: a physical-chemical and a chemical effect. On one hand it modifies the hydration process of cement as well as the structuring of hydrated products, on the other hand, it reacts on the cementing medium and develops new hydrated products. These effects act simultaneously and in a complementary way on the final performance of cementing materials.

In order to better understand the gain in strength of the premixed cement OPC of the finely crushed dune sand, the microstructural aspect has been examined. Mixtures of Sd-lime pastes present a hydraulic setting which is due to the formation of a CSH phase. The latter is semi-crystallized. The study of mixtures Sd-lime paste is thus a simplified approach of that of the mixtures Sd-OPC in which the main reaction is the fixation, by the Sd, of lime coming from the hydration of $C_3S$ in the form of CSH.

**Keywords:** Portland cement; pure lime; finely crushed dune sand; filler effect; pouzzolanic effect; hydration

## 1. INTRODUCTION

The search for cheaper cement made of local natural resources has become a major concern to compensate the deficit in the manufacture of cement.

However, to ensure the development of this vital building material, the approach of sustainable development should be incorporated into the production of cement and concrete, which will enable it to reach a balance between the constraints of environmental protection and the economic, technical and social considerations. In this context, the challenge of the cement industry and concrete to produce a concrete durability at a competitive cost and with minimal environmental impact.

Since 1970, a main effort of research was provided on the use of the cementing additions as a partial substitution to Portland cement. These additions come from natural sources or by products of other industries [1].

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The additions present an increasing binding activity with their quantity, their smoothness, their mineralogical composition and the type of cement also influence. Into practical terms, this activity results in a profit of resistance [2].

The level of porosity influences in remarkably the mechanical characteristics of the material. The determining effect of the reduction of porosity on the mechanical resistance of cement was shown in many studies [3-4].

The sand of dune is a material of a great availability in Algeria (nearly 60% of the own territory). This material is practically not exploited, in spite of the possible characteristics which it can present. The compactness of the cement paste can be improved by the formation of calcium silicate hydrates CSH of second generation. The latter are obtained by the introduction of fine siliceous particles equipped with a certain pouzzolanic role and contribute to the increase in the resistance and the durability of the concretes to which they are built-in [5-6].

The analysis by diffractometry with the X rays highlighted the pouzzolanic role of the finely crushed dune sand Sd. Indeed, small quantity of portlandite detected by DRX in the cement pastes with the presence of Sd, represented the pouzzolanics partial reaction of this addition, which contributes in the increase of the mechanical resistance and improves the compactness of the paste. And it also shows that Sd consists of tiny quartz grains $SiO_2$ well crystallized (homogeneous constituted of atoms presenting an organized arrangement which are repeated in a periodic way in three dimensions of space.) type Low-Quartz [7-8].

In the light of what was evoked previously, and with an aim of lengthening the lifespan of the layers of the raw materials and to increase the production of cement, The required objective is to evaluate through experiments the combined contribution of the physical-chemical and possibly chemical effects of adding finely crushed dune sand to cement, on the evolution of hydration of pasta Portland cement.

## 2. CHARACTERISTICS OF MATERIALS USED

Larger is the physical-chemical activity of cement, higher is the total developed surface of the grains. In cement, a particle of diameter > 50 µm is practically inert. It is here about a crushing of the sand of dune and clinker. Crushing is carried out using a conventional ball crusher “Metal horizontal rolls put in rotation and filled to the 1/3 with steel balls which crush the matter while running up and rubbing in a cascade movement”, after that, sifting is carried out, Figures 1 and 2.

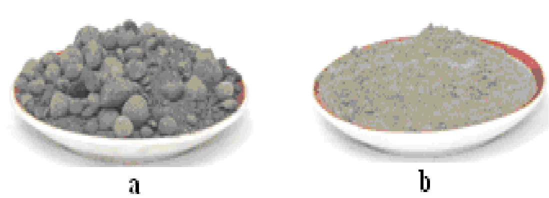


Figure 1. Clinker, a: Before crushing, b: After crushing

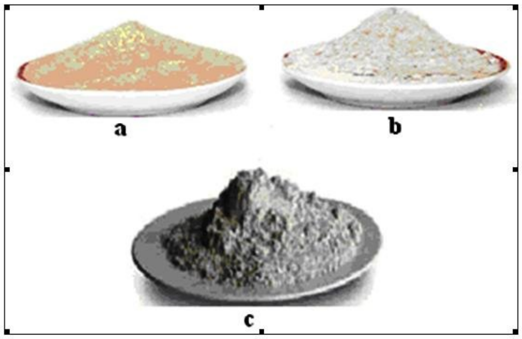


Figure 2. Dune sand, a: No crushed dune sand, (b: $S_{S1}$ = 3000 $cm^2/g$" and c: $S_{S2}$ = 4000 $cm^2/g$): Finely crushed dune sand

*2.1 Finely Crushed Dune Sand*

The choice of an adding report by another is usually after the local availability at acceptable costs, focused on the high silica. We have used finely crushed dune sand from the region of Biskra.

After the silica grains have been reduced to the wanted size, they can be subjected to various processes of valorisation aiming at eliminating the impurities which are generally made up of clay, carbonates and minerals containing ferromanganese.

*Chemical analysis*

Table 1 contains the chemical analyses which were carried out in the laboratory of the cement factory of AIN TOUTA. From a chemical sand dune finely crushed is mainly composed of silica $SiO_2$. (A very important content and majority).

Table 1. Chemical analysis of the finely crushed dune sand

| **Elements** | **$SiO_2$** | **$Al_2O_3$** | **$Fe_2O_3$** | **CaO** | **MgO** | **$SO_3$** | **$K_2O$** | **$Cl^-$** | **PAF** |
|---|---|---|---|---|---|---|---|---|---|
| (%) | 74.61 | 1.35 | 0.86 | 17.3 | 0.29 | 0.04 | 0.47 | 0.005 | 5.04 |

*Analysis ray diffraction X*

The analysis by ray diffraction X using the powder method, finds his main using in identifying minerals. Each body crystalline product indeed a spectrum or diffractogramme X, which reflects its internal structure and nature of minerals. You can treat any diffractogramme X is a kind of (fingerprint) specific, which can distinguish a mineral another.

In order to identify a body, from his diffractogramme X, it has a file or ASTM minerals are classified according to their three main lines, including the intensity of the strongest rais is set at 100. While several species are brought together in mineral powder studied, the chart is the juxtaposition of elementary diagrams.

*To this end, we analyzed by DRX*

Firstly finely crushed dune sand, state anhydrous, to highlight their mineralogical nature.

Thereafter, we followed the kinetic fixing lime depending on the time of pasta mixes have been previously stored in PVC tubes T = 20°C sealed.

*Mineralogical nature*

In order to highlight their mineralogical nature, the ray diffraction X is made on finely crushed dune sand. The test results are shown in Figure 3 schematically different mineralogical components.

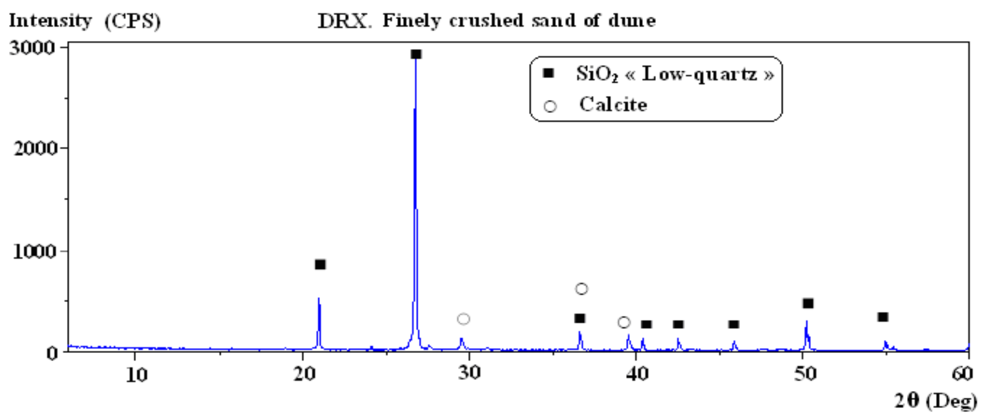


Figure 3. X-ray diagram Sd

**Figure 3; shows that**

The finely crushed dune sand presents a crystalline structure siliceous such as Low-Quartz. The crystalline silica presents a regular three-dimensional structure, the basic reason is a tetrahedron, each summit is occupied by an oxygen atom and the centre by a silicon atom.

Its atomic structure is changed if the temperature reaches over 870 °C. (The passage of quartz to tridymite), [9]. According to [10]; (Nothing is ultrafine inert. Thus quartzs crushed deemed crystal, are amorphised on surface. They can therefore be associated with lime according responsiveness pozzolanic classic). The dune sand, which is finely crushed silica, can have the same benefits (physical and pozzolanic) than other additions, [11].

**Property physical**

Apparent bulk density = 1300 kg/$m^3$

Absolute bulk density = 2770 kg/$m^3$

Specific surface = 3000 and 4000 $cm^2$/g

*2.2 Portland Cement*

The Cement that was used is an ordinary Portland cement OPC; it is composed of clinker 95% and gypsum 5%, for the regularization of the catch. The clinker which we used is that of the cement factory of AIN-TOUTA (Batna).

**Chemical analysis and mineralogical**

The potential mineralogical composition of the clinker is calculated according to the empirical formula of Bogue [12].

The chemical analysis of cement shows that it is in conformity with standard NFP 15-301 with knowing: % [MgO + CaO (free)] < 5%. Chemical and mineralogical compositions of clinker are presented in Tables 2 and 3, respectively.

Table 2. Chemical composition of clinker

| Chemical composition (%) | | | | | | | |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | RI | CaO (free) | PAF |
| 22.0 | 5.30 | 3.38 | 65.16 | 1.77 | 1.40 | 2.32 | 0.48 |

Table 3. Mineralogical composition of clinker

| Mineralogical composition (%) | | | |
|---|---|---|---|
| $C_3S$ | $C_2S$ | $C_3A$ | $C_4AF$ |
| 58.02 | 23.32 | 8.32 | 10.27 |

**Physical property**

Apparent bulk density = 1120 kg/m$^3$

Absolute bulk density = 3050 kg/m$^3$

Specific surface = 3200 cm²/g

## 3. RESULTS AND DISCUSSIONS

*3.1 Mechanical Properties*

In order to study the effect of the various percentages of the finely crushed dune sand and the influence of fine milled (Ss = 3000 and 4000 cm²/g), and the influence of the report (W/(C+Sd) = 0.4 and 0.25) on the mechanical resistance of the paste of cement, we chose 4 percentages (5%, 10%, 15% and 20%) to add them to the cement OPC and obtain a new cement with addition. We used cubic test-tubes of (2×2×2) cm$^3$ in pure paste at a rate of six test-tubes per test. The hardening of the test-tubes was in natural conditions, the test-tubes were subjected to a normal cure in drinking water of 20°C, [13]. The results obtained are clearly exposed on the Figures 4, 5, 6 and 7.

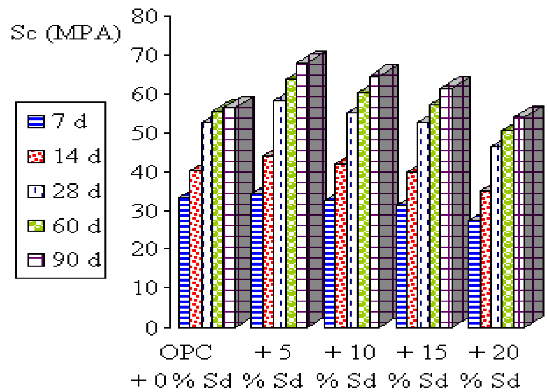


Figure 4. Evolution of the compressive strength of cement according to time and of the percentage of Sd (Ss = 3000 $cm^2/g$, W/L = 0.4)

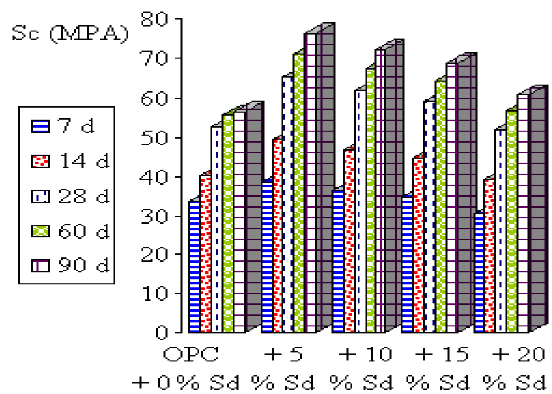


Figure 5. Evolution of the compressive strength of cement according to time and of the percentage of Sd (Ss = 4000 $cm^2/g$, W/L = 0.4)

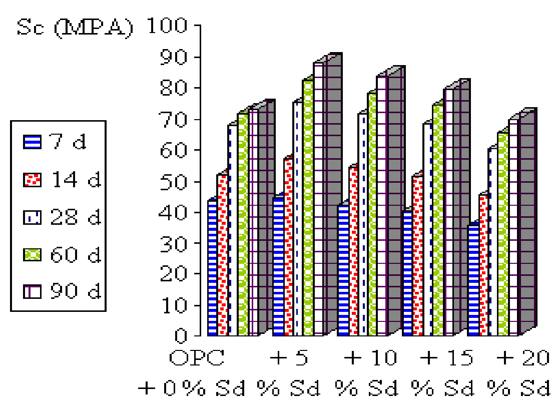


Figure 6. Evolution of the compressive strength of cement according to time and of the percentage of Sd (Ss = 3000 $cm^2/g$, W/L = 0.25)

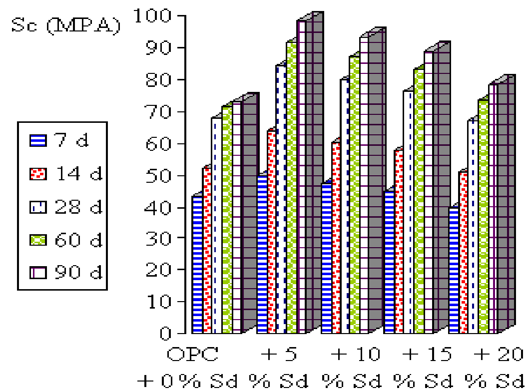


Figure 7. Evolution of the compressive strength of cement according to time and of the percentage of Sd (Ss = 4000 $cm^2/g$, W/L = 0.25)

*Comments*

According to these results one notices that the rate of development of the resistance of the OPC alone of 28 and 90 days, compared to 7 days, is respectively 56% and 68%, resistances of the binders to 5 and 20% of finely crushed dune sand develop a rate equal to 69% for 28 days and 97% to 90 days respectively, that translated the chemical part played by Sd in the long run, therefore confirms the pouzzolanic activity of Sd.

Resistances in compression Sc increase during the substitution of the finely crushed dune sand thus translating the improvement of the compactness of the pastes of cement by double effect: filler and pouzzolanic, Refs. [14-15].

A filler effect: An improvement of the mechanical properties by a thickening of the cementing matrix.

A pouzzolanic effect: Instead of providing lime, like in the case of Portland cement, the pouzzolanic reaction consumes and improves the mechanical performances in the long run of the pastes of cement. The products of hydration fill the capillary pores and increase resistance by refining these capillary pores and transformation of large crystals of CH into a product of hydration slightly crystallized (refining of the grains).

According to the results obtained, one notices that cement of 5% of the finely crushed dune sand had a maximum resistance to compression with a granulometry of Ss = 4000 $cm^2/g$ and the report ratio W/(C+Sd) = 0.25.

(20%) of the finely crushed dune sand is added to the total weight of cement to get a 28 days resistance close to that obtained from cement OPC.

The presence of finely crushed dune sand accelerates the reaction of hydration of Portland cement. This accelerating effect of finely crushed dune sand on the hydration combined with the effect of filling due to their smoothness can lead to better short-term resistances of the cement.

This also makes it possible to reduce the content of cement for a given resistance and a depression. This last characteristic is very interesting from an economic standpoint, since cement is the most expensive ingredient in the composition of the concrete. Another advantage is that it makes it possible for concrete to continue its mechanical performance even after the 28 days period, Refs. [15-16].

The sand dune finely crushed can change the structure of pores, to reduce the number of large pores and increase the small pores. This change is a function of finesse, more particles are fine, their role is more effective. The results showed that by increasing the finesse of 3000 cm²/g in 4000 cm²/g resistance at all ages were improved by 12%, Ref. [14].

Concerning the influence of W/L we see clearly that the resistance of all the hardened cement paste at any age decreases with the increase of W/L. The W/L exerts a great influence on the porosity of the cement paste hydrated (network of pores finer and more discontinuous). That's why pasta with cement W/L low: developing very quickly their resistance to compression by a high concentration in CSH.

*3.2 Study Responsiveness Pozzolanic Finely Crushed Dune Sand*

This work is to analyse the evolution of DRX hydration of pasta Portland cement based finely crushed dune sand. To clarify the effect of this addition pozzolanic pasta in Portland cement, we followed hydration mixtures pasta (50% pure lime + 50% Sd) by DRX.

This study is a simplified approach that pasta cement (80% OPC + 20% Sd) in which the main reaction is the setting of lime from the cement hydration, in the presence of finely crushed dune sand (pozzolanic reaction). To highlight the gain pasta strength based premixed cement finely crushed dune sand. At a given age a portion of the pasta is crushed into a fine powder, whose maximum diameter of grain is less than 40 µm to be tested by DRX.

*For analysing responsiveness finely crushed dune sand we studied*

The evolution of mixtures hydration (50% pure lime + 50% Sd) as a function of time

The evolution of the pozzolanic reaction as a function of time was considered by DRX on pasta containing 50% pure lime + 50% dune sand powder.

*The diffractogramme X Figure 8; shows that:*

The intensity of the rays of lime decreases as a function of time, which explains the fixation of lime by the grains of silica (pozzolanic reaction) to form CSH II semi-crystallized.

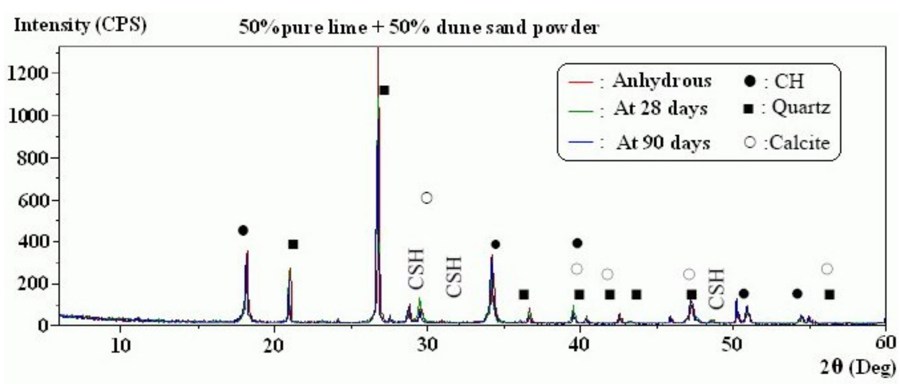


Figure 8. Pasta hydration at different ages (50% pure lime + 50% Sd)

The evolution of mixtures hydration (80% OPC + 20% Sd) as a function of time.

In the same way, we followed by DRX the evolution mixtures hydration pasta 80%

OPC+20% dune sand powder as a function of time. Changes in kinetic hydration of Portland cement, in the presence of finely crushed dune sand are highlighted by the ray diffraction X.

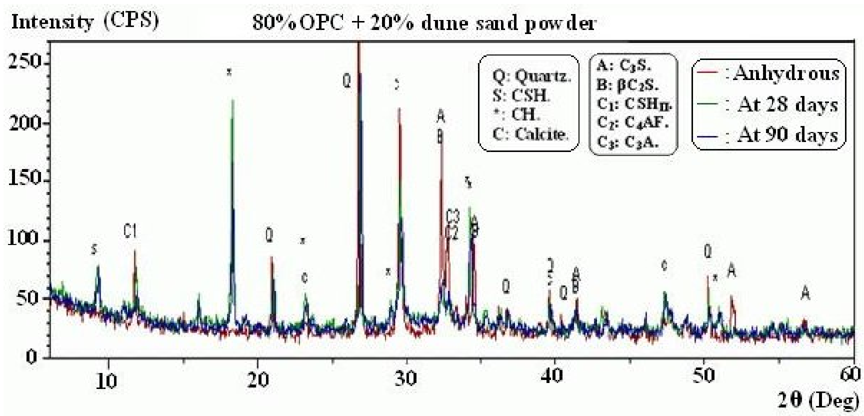


Figure 9. Pasta hydration at different ages (80% OPC + 20% Sd)

*An examination of diffractogrammes X Figure 9; presents the following observations*
At 28 days of hydration, rays of lime and CSH appear, and intensity of the rays of $C_3S$ and $\beta C_2S$ decreases which explains the hydration of calcium silicate. In the presence of finely crushed dune sand and at 28 days of hydration, intensity rays quartz decreased, as compared to that of anhydrous mixture, so the reaction pozzolanic of finely crushed dune sand (which confirmed the results found previously).

At 90 days of hydration, intensities of lines of lime and minerals of cement (even that of quartz) decreasing significantly, which shows the effect pozzolanic.

## 4. CONCLUSION

Resistances to youth develop because of the acceleration of the hydration of the binder, while those in the long run develop thanks to the pouzzolanic reaction which causes the refining of the pores and the replacement of CH by CSH II.

From a chemical sand dune finely crushed is mainly composed of silica $SiO_2$. (A very important content and majority).

The finely crushed dune sand presents a crystalline structure siliceous such as Low-Quartz.

The intensity of the rays of lime decreases as a function of time, which explains the fixation of lime by the grains of silica (pozzolanic reaction) to form CSH II semi-crystallized.

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