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THE EFFECT OF FINENESS OF CEMENTS AT MINERAL ADDITIONS ON THE MECHANICAL RESPONSE OF CONCRETE

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ABSTRACT

This experimental work is a contribution to the improvement of the properties of the concretes by mechanical activation (fineness) of two types of cements (C.E.M II) manufactured in various cement factories (cements with various mineral additions : slag and tuff). The physical properties of cements (C.E.M II) activated mechanically at anhydrous state and the state hydrated (specific weight, consistency of the cement pastes, setting times and shrinkage) thus the characteristics of the concretes made at their bases, such as the mechanical behavior (compressive strength for the concrete) are studied. According to the experimental results obtained, it comes that the increase of the specific surface and the chemical composition of cements to the mineral additions are the principal responsibles to the improvement of the latent reactivity of mineral additions and the increase of the mechanical strengths of the concretes.

Keywords: Fineness, mineral additions, cement, concrete, mechanical response

1. INTRODUCTION

The mineral additions are largely used in the manufacture of cements with mineral additions in the world. From an economic standpoint, they present a very significant factor in the production of made Portland cement with mineral admixture (C.E.M II), since clinker consumption drops according to the content of addition used [1,2].

The Portland cement (C.E.M II) with mineral addition presents a hardening slowed down at its initial period in comparison with an ordinary Portland cement (cement without secondary component : C.E.M I) [3,4]. This latent property of cement with mineral addition (C.E.M II), requires the use of a efficace activation, chemical, mechanical or thermal [5].

The blended cements with mineral additions (C.E.M II) have a latent setting times than ordinary Portlands cements (C.E.M I), especially in the case of concreting in cold time [6]. It is known that setting times can be shortened [7]:

* by high fineness (specific surface) of cement,

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* or by the use of accelerating admixtures (NaOH, KOH,......).

The objective of this study is to evaluate experimentally the influence of the fineness (specific surface) of cements with mineral additions on the mechanical resistance of the concrete. This work is a contribution to the improvement of the properties of the concretes by mechanical activation of two types of cements (C.E.M II) of various cement factories (cements made with various active and inert mineral additions : slag and tuff).

2. CHARACTERISTICS OF USED MATERIALS

2.1 Natural sand (fine aggregates)

The sand's equivalent measured by the NF P18 standard shows that the dune sand used in this experimental study was clean, siliceous and contains very few fine dust or clayey elements. The fineness modulus calculated was M_f = 1,73. The different characteristics are grouped in Table 2. Its chemical composition is shown in Table 1. Its granulometric curve is shown in Figure 1.

Table 1. Chemical composition (%, by weight) of sand dune used

Constituents %	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**CaO_{free}**	**SO_3**	**LOI***	**IR****
Sand of dune	94.00	0.880	0.370	2.960	0.110	-	-	1.500	-

(*Loss on ignition and **Insoluble residue)

2.2 Crushed gravel (coarse aggregates)

Crushed gravel is obtained by crushing of the limestone rock from the quarry of COSIDER situated in El-Euch region (B.B.A). Two fractions 3/8 and 8/15 of coarse aggragates (crushed gravel) have been used in this experimental study. The sieve analysis results are shown in Figure 1. The information on the physical, morphological and mechanical properties of the crushed gravel used is given in Table 2 and in Table 3.

Table 2. Characteristics of dune sand and crushed gravel used in the tests

Materials	**Absolute density (Kg/l)**	**Apparent density (Kg/l)**	**Compactness (%)**	**Porosity (%)**	**Sand equivalent value (sight/test)**
Dune sand (0/3)	2,56	1,64	64,06	35,94	76/77
Crushed gravel (3/8)	2,68	1,28	47,46	52,24	-
Crushed gravel (8/15)	2,68	1,32	49,25	50,75	-

Table 3. Physical, morphological and mechanical properties of crushed gravel used

Coarse aggregates	Superficial tidiness	Flattening Coef	$CaCO_3$ (%)	Los Angelas
Crushed gravel (3/8)	1,50	18	92	20
Crushed gravel (8/15)	1,28	19	92	23

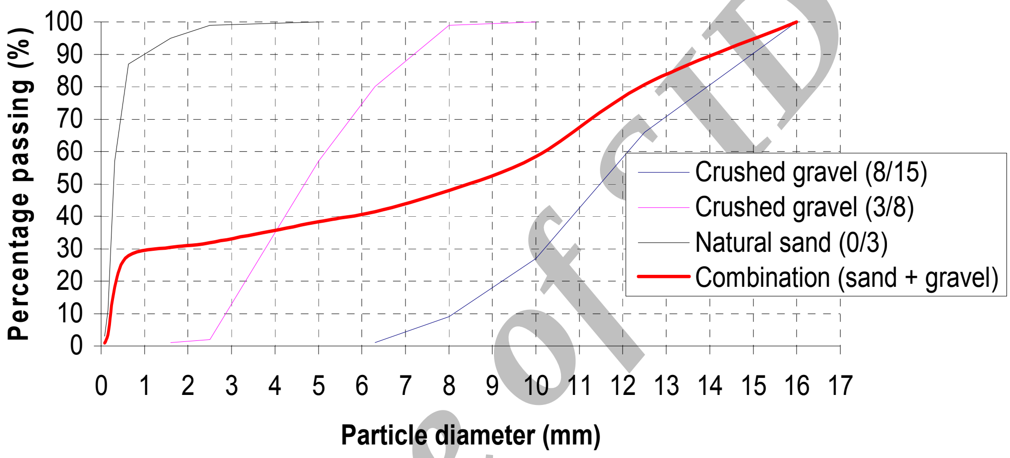

Figure 1. Particle size distribution of tested materials

2.3 Cements

Two types of Portlands cements (CEM II) of various cement factories (cements with various mineral additions : slag and tuff) were used in this experimental study who are :

* CEM II/A of Sour-El-Ghozlane (clinker : 85%, gypsum : 5% and tuff : 10%).

* CEM II/B of Hadjar-Soud (clinker : 65%, gypsum : 5% and tuff : 30%).

These two types of cements studied are CEM II/A and CEM II/B, which presents different chemical compositions (different clinkers and mineral additions).

Each type of used cement was ground in a grinder in order to obtain various fineness (different specific surfaces) while varying the time of grinding from 15 to 30 minutes :

1st fineness (F1) : t = 0 min (initial fineness of the cement factory).

2nd fineness (F2) : t = 15 min (time of grinding is equal to 15 minutes).

3rd fineness (F3) : t = 30 min (time of grinding is equal to 30 minutes).

Tables 4 and 5 present the type and the chemical composition of various mineral additions used for the cements studied.

Table 4. Mineral admixtures of cements studied

Ciments used CEM II	Clinker (%)	Set regulator	Contents (%)	Admixtures	Contents (%)
Sour-El_Ghozlane	85	Gypsum	5%	Tuff	10
Hdjar-Soud	65			Slag	30

Table 5. Chemical composition of mineral additions

Constituents %	CEM II -SG		CEM II-HS	
	Gypsum	**Tuff**	**Gypsum**	**Slag**
SiO_2	10,57	54,92	8,06	36,00
Al_2O_3	3,49	13,94	2,53	7,37
Fe_2O_3	1,60	4,69	1,04	4,44
CaO	28,54	13,96	30,97	42,73
MgO	3,42	1,47	2,58	4,15
SO_3	31,41	0,65	32,64	1,37
K_2O	0,47	4,05	0,38	0,41
Na_2O	0,13	1,75	0,07	0,16
LOI	21,32	4,77	21,86	1,01
H_2O	13,42	-	14,92	-

The chemical composition of the two types of cements used in this research have been determined by the testing method “X-ray Fluorescence Spectrometry (XRF)“.

Table 6 gives the chemical composition of the two cements used in this experimental work.

Table 6. Chemical composition of two cements studied

Types of cements used	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	K_2O (%)	Na_2O (%)	SO_3 (%)
CEM II-SG	23,48	5,63	3,28	60,60	1,38	0,97	0,19	1,18
CEM II-HS	24,77	5,81	3,68	64,03	1,19	0,93	0,19	1,19

We used two types of cements (CEM II) manufactured with different mineral additions (slag and tuff), this in the aim of analyzing the influence of the specific surface of hydraulic cements at various mineral additions on the physical characteristics of hydraulic cements at the state hydrated and also on the mechanical behavior (compressive strength for the concrete). The fineness of hydraulic cement with mineral admixtures studied was determined by Air Permeability Apparatus.

3. MECHANICAL TESTS (COMPRESSIVE STRENGTH)

The concrete mix proportion used in laboratory tests has been determined by "DREUX GORISSE METHOD". The mix quantities of the concrete used are given in Table 7. The mechanical properties of the test specimens studied were compressive strength. The moulds with fresh concrete test specimens were cured for 24 h at relative humidity of 95% RH, and after demoulding in water at ambient temperature of 20°C. The compressive strength of the concretes was determined on 10x10x10 cm^3 cubics specimens at the ages of 2, 7, 28 and 90 days. The specimens were centred on the tray of the press then a continuous load applied on the specimen.

Table 7. Characteristics of the concrete used for the specimens

Composition of the mixture	U. of meas	Quantity
Cement (CEM II)	Kg/m^3	360
Fine aggregate (Sand : 0/3)	Kg/m^3	600
Coarse aggregate (Gravel : 3/8 and 8/15)	Kg/m^3	1160
Water	l/m^3	210
Water/Cement ratio (W/C)	-	0,58
Sand/Gravel ratio	-	0.52

4. RESULTS AND DISCUSSION

4.1 Influence of the fineness on the specific weight of cement

The figure 2 presents the effect of fineness (specific surface) on the specific weight of cement. From the results obtained (Figure 2), the following conclusions may be drawn :

* a significant difference of the specific weight between the various studied cements.

* a reduction of the specific weight with the increasing of the fineness of cement.

The difference observed between the specific weights of studied cements, depends of the nature of the mineral addition incorporated in the cement (difference of the density of the addition mineral). The cement CEM II/A (made with the tuff) present the specific weights definitely higher compared to the cement CPJ-CEM II/B (made with the slag of blast furnace), it is mainly with the quantity of clinker present in each type of cement and with the porosity of the mineral addition used.

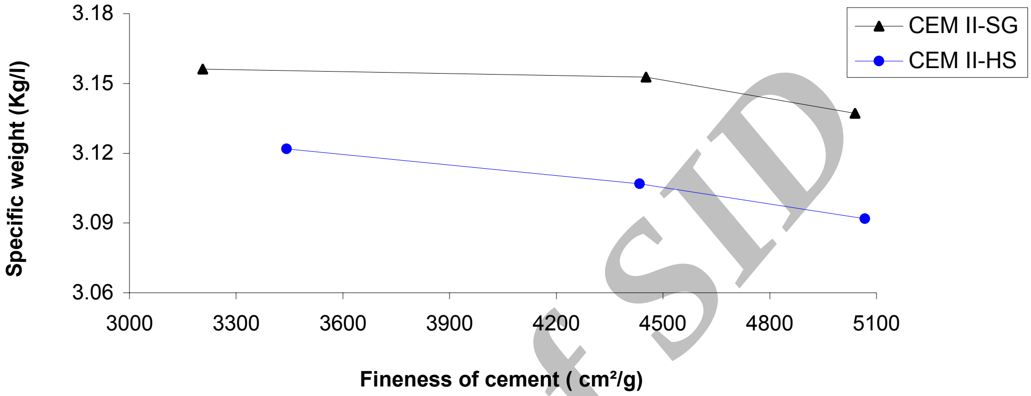

Figure 2. Effect of fineness on the specific weight

4.2 Influence of the fineness on the cement paste studied

The Figure 3 presents the effect of fineness (specific surface) on the normal consistency of cement paste. The cements pastes are prepared with three different finenesses and the water demand is measured using the Vicat needle test (standart Vicat test). The influence of the fineness on the cement paste is expressed by the changes in normal consistency (water demand ratio).

One notices also that the granulometry of cement has a significant influence on the normal consistency of cement paste (water demand ratio), this is translated by increase of the total surface of the particles when the cement is ground more finely.

The initial and final set times of cement paste are shown in figures 4 and 5. When the fineness increased of cement, the initial and final setting times of cement paste are decreased. In general, the set time of cement paste is shortened with the increase of fineness. That is explained by the fact that the pozzolanic reactivity is accelerated in the short-term. The kinetics of hydration of the binder becomes increasingly fast according to the increase of the Blaine fineness (specific surface) of cement.

Indeed, the very fine particles adhere the some to the others and activate the phenomenon of set time of cement paste. Thus the effect of the great Blaine specific surface on the acceleration of the pozzolanic activity reacts with the calcium hydoxide [$Ca(OH)_2$, Portlandite] to form C-S-H gel crystals. The pozzolanic reaction is:

$$[Ca(OH)_2 + SiO_2 + H_2O \rightarrow \text{C-S-H}].$$

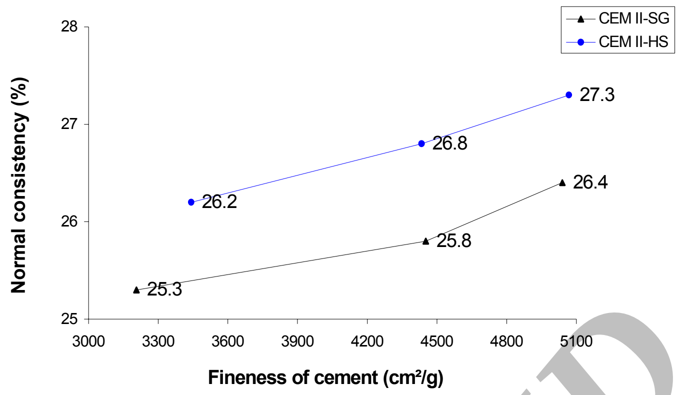

Figure 3. Effect of fineness on the normal consistency of cement

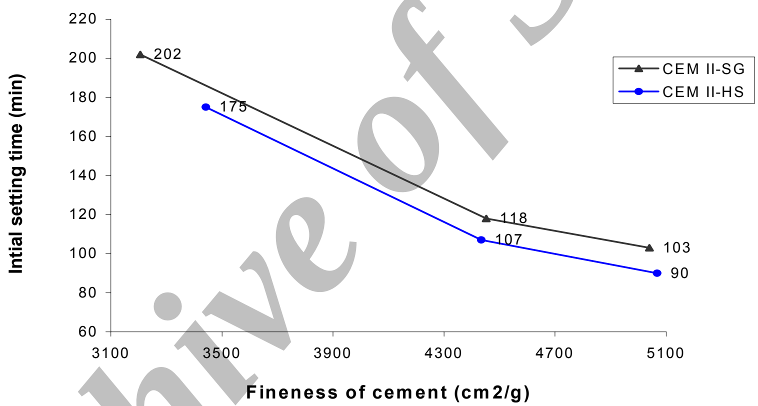

Figure 4. Effect of fineness on the initial setting time

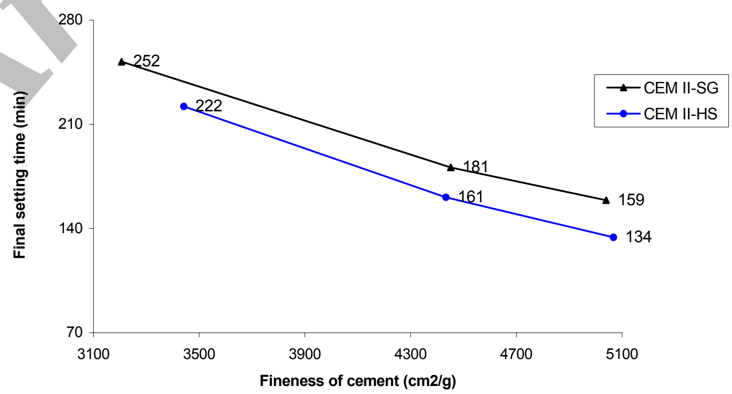

Figure 5. Effect of fineness on the final setting

4.3 Influence of the fineness of cement on the shrinkage

The variation of the shrinkage as a function of Blaine fineness of cement is shown in Figure 6. According to the results obtained, one can affirm that all the studied cements cause a low shrinkage on the specimens of normal mortar that one tested. The principal remarks drawn concerning the shrinkage observed for the two studied cements are :

* Increase of the shrinkage according to the time of hardening (3, 7 and 28 days).
* Increase of the shrinkage according to the variation of the fineness of cement.

The increase of the shrinkage according to the fineness, is essentially due to the presence of an elevated capillary porosity. In this case the kinetics of the hydration reaction becomes very fast inside the paste of the cement hydrated.

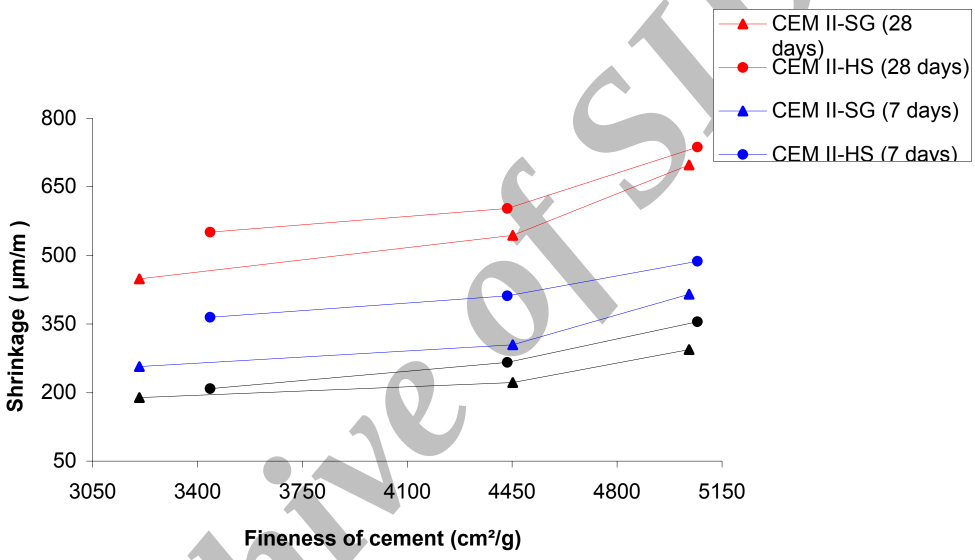

Figure 6. Evolution of shrinkage as a function of fineness of cement

4.4 Influence of the fineness on the compressive strength of concrete

The development of compressive strength of the test specimens is shown in Figure 7. The increase of the Blaine specific surface of cement gives an increase of the mechanical strength. That is explained by the increase of the fast kinetics of hydration of the mineral C_3S (tricalcium silicate) and C_2S (dicalcium silicate). These latter are the two principal minerals which ensure the development of the resistances to short and medium-term.

The increase of the Blaine fineness of the cement clearly improves the mechanical strength of the concrete. This confirms the role of the granulometry (mechanical activation or advanced grinding) in the fast and complete hydration of the cement (pozzolanic activity) by the formation of the $Ca(OH)_2$ released during the hydration of the cement. This pozzolanic reaction gives the second C-S-H supplementary, main responsible for the hardening of the concrete. Therefore the weakness of the strengths to the short-term can be compensated by mechanical activation of cement (increase of the fineness).

The increase of the mechanical responses as a function of the variation of the fineness (mechanical activation) believes a way different of a cement to another cement, this depends of the type and percentage of the mineral addition (reactivity of the admixture) incorporated in the cement.

Thus, one can conclude that the fineness of cement is a significant characteristic : during the hydration of the mixture, more the particles are fine, more the cement surface in contact with water is large and more the hydration is fast and complete (shortening of set times).

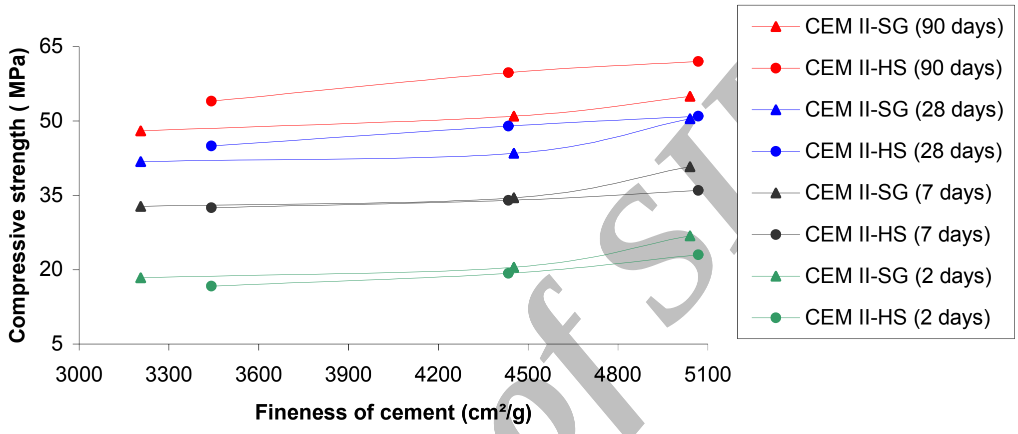

Figure 7. Devlopment of compressive strength of concrete as a function of fineness

5. CONCLUSIONS

The results obtained from this research, allow us to draw the following conclusions :

* the increase of the fineness (specific surface) of cements with mineral additives (composed cements) influence appreciably on the water demand necessary to have a normal consistency of cement paste.

* the setting times (initial and final) decrease proportionally with the increase of the fineness (specific surface) of cements with mineral admixtures.

* the mechanical activation (high fineness) of cements with mineral additives presents two essential advantages : high mechanical strength of the concrete as well as a kinetics of hydration reaction accelerated at the initial hardening (short-term) with dimensional variations (shrinkage) low in accordance with standard NF P 15-433.

Finally, cements with mineral additives must be finely to grind (S_p > 3500 cm^2/g) in order to accelerate the kinetics of hydration of short-term cements (improvement of the reactivity of the cementing mineral additions) and to ensure a high mechanical resistance of material.

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