

# Mineral Activator and Physical Characteristics of Slag Cement at Anhydrous and Hydrated States

A. Naceri, M. S. Bouglada, and P. Grosseau

**Abstract**—The setting agent  $\text{Ca}(\text{OH})_2$  for activation of slag cement is used in the proportions of 0%, 2%, 4%, 6%, 8% and 10% by various methods (substitution and addition by mass of slag cement). The physical properties of slag cement activated by the calcium hydroxide at anhydrous and hydrated states (fineness, particle size distribution, consistency of the cement pastes and setting times) were studied. The activation method by the mineral activator of slag cement (latent hydraulicity) accelerates the hydration process and reduces the setting times of the cement activated.

**Keywords**—Mineral activator, slag cement, Anhydrous and hydrated states, physical characteristics.

## I. INTRODUCTION

THE Portland cement (C.E.M II) with pozzolanic admixture (slag) is low in  $\text{C}_3\text{S}$  (tricalcium silicate), low in  $\text{C}_3\text{A}$  (tricalcium aluminate) and low heat of hydration and high long term strength [1]. Hydrated lime (calcium hydroxide) or quicklime (calcium oxide) is commonly used in building construction. Lime is obtained from calcium decarbonation above 900 °C. The lime may be quicklime or slaked lime after to have been hydrated air calcium lime is sometimes called fat lime [2]. Lime may come in various forms : rock or powder for quicklime, powder, suspension in water (milk of lime) or lime putty for hydrated lime. The lime is used in industry thanks to its numerous physico-chemical properties (basicity, specific area, etc.). Lime is mainly used in construction (masonry mortar), water treatment (domestic, industrial or waste water treatment), soil treatment, etc., because of its neutralising capacity (chemical base).

The lime saturation factor (LSF) controls the potential  $\text{C}_3\text{S}$  to  $\text{C}_2\text{S}$  ratio in the finished cement.  $\text{C}_3\text{S}$  governs the early age strength development while  $\text{C}_2\text{S}$  governs the later age strength.

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The activation of the slag cement by fine lime (calcium hydroxide) is a simple and economic method especially for cement containing not very reactive slag or low coefficient of activity [3].

Lime plays 2 roles [4]: to hydrate the slag of granulated blast furnace (formation of the hydrated compounds CSH: tobermorite), to maintain cement with a  $\text{pH} > 12$  and the hydration of the clinker (formation of ettringite) accelerates.

The objective of this present experimental work is to evaluate the influence of mineral activator (hydrated lime) on the physical properties of slag cement (latent hydraulicity) at anhydrous and hydrated states.

## II. EXPERIMENTAL

The setting agent  $\text{Ca}(\text{OH})_2$  used for activation slag cement is used in the proportions of 0%, 2%, 4%, 6%, 8% and 10% by various methods (substitution and addition by mass of slag cement). The absolute density and apparent density were 2,32 Kg/l and 0,54 Kg/l, respectively. The specific surface area (fineness) of hydrated lime was 8150  $\text{cm}^2/\text{g}$ . The mineral activator (calcium hydroxide) contained 0,46%  $\text{SiO}_2$ , 68,56%  $\text{CaO}$ , 0,22%  $\text{Al}_2\text{O}_3$ , 0,35%  $\text{Fe}_2\text{O}_3$ , 0,05%  $\text{K}_2\text{O}$ , 0,03%  $\text{Na}_2\text{O}$ , 0,65%  $\text{MgO}$  and 0,24%  $\text{SO}_3$ .

The Portland cement (CEM II) with mineral addition (slag) was used in this experimental study. In this experimental study, the setting agent  $\text{Ca}(\text{OH})_2$  used for activation slag cement is used in the proportions of 0%, 2%, 4%, 6%, 8% and 10% by various methods (substitution and addition by mass of slag cement).

Table I gives the mixes of the eleven cements activated with calcium hydroxide [ $\text{Ca}(\text{OH})_2$ ] by different methods (substitution and addition by mass of slag cement) used in this experimental work.

The particle size distribution of eleven cements is shown in Figs. 1 and 2. The particle size was measured by means of laser diffraction method. The main parameters that characterize the particle size distribution and the BET specific surface area are shown in Table II. The particle size distributions obtained from laser granulometry of cements powders used in this study. The percentage passing of particles of cements tested between 0,08 – 874  $\mu\text{m}$ . No particles < 0,08  $\mu\text{m}$  were detected in any of the samples. The increase of the percentage of the mineral activator (hydrated lime) causes two significant phenomena: (a) a decrease in size

of particles and (b) a variation in total pore volume (pore size distribution).

TABLE I  
MIX COMPOSITION OF ELEVEN CEMENTS ACTIVATED BY THE CALCIUM HYDROXIDE

Mix of cements	Cement "CEM II", %	Lime "Ca(OH) <sub>2</sub> ", %
CEM <sub>00</sub>	100	0
CEM <sub>2</sub>	100	2
CEM <sub>4</sub>	100	4
CEM <sub>6</sub>	100	6
CEM <sub>8</sub>	100	8
CEM <sub>10</sub>	100	10
CEM <sub>2</sub>	98	2
CEM <sub>4</sub>	96	4
CEM <sub>6</sub>	94	6
CEM <sub>8</sub>	92	8
CEM <sub>10</sub>	90	10

TABLE II  
PARTICLE SIZE PARAMETERS AND SPECIFIC SURFACE AREA OF THE ELEVEN CEMENTS STUDIED

Types of cements	D <sub>10</sub> (μm)	Medium size D <sub>50</sub> (μm)	D <sub>90</sub> (μm)	Specific surface area S.S.A (cm <sup>2</sup> /g)	
				Blaine fineness	Laser Diffraction
				CEM <sub>00</sub>	3,10
CEM <sub>2</sub>	2,42	19,23	80,67	3620	13070
CEM <sub>4</sub>	2,37	17,33	79,61	3840	13935
CEM <sub>6</sub>	2,18	16,98	78,89	4020	14430
CEM <sub>8</sub>	1,89	14,59	75,32	4160	16392
CEM <sub>10</sub>	1,25	11,32	73,65	4302	18017
CEM <sub>2</sub>	2,15	18,34	79,68	3458	12424
CEM <sub>4</sub>	2,03	16,46	78,86	3675	13572
CEM <sub>6</sub>	1,81	15,28	77,16	3860	14140
CEM <sub>8</sub>	1,36	14,09	74,68	3960	15277
CEM <sub>10</sub>	1,04	11,02	72,37	4095	16236

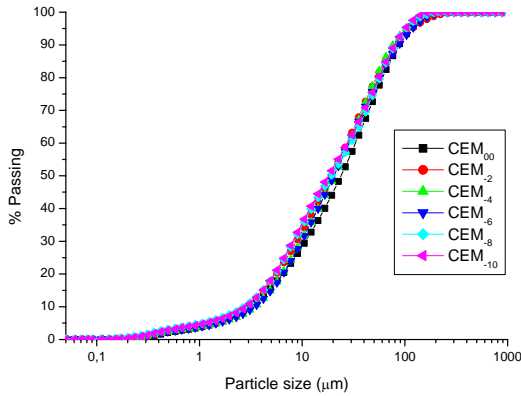


Fig. 1 Particle size distribution of cements activated by substitution method

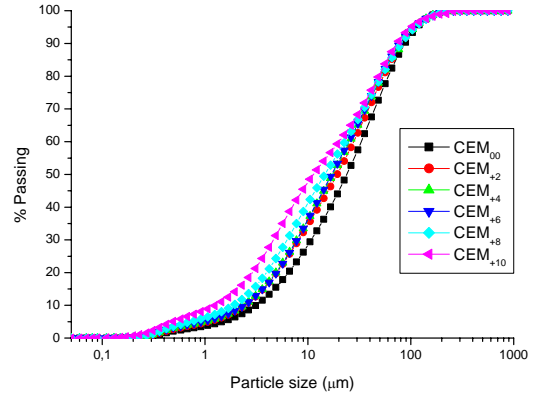


Fig. 2 Particle size distribution of cements activated by addition method

The difference observed between the curves obtained is due to agglomeration of particles. The particle size measurement by dry laser diffraction method gives relatively larger distribution for the cement (activation by addition method) but for the cement (activation by substitution method) the particle size distribution is smaller.

### III. RESULTS AND DISCUSSION

The water demand is measured using the Vicat needle test (standart Vicat test). The influence of the mineral activator on the cement paste is expressed by the changes in normal consistency (water demand ratio). One notices also that the granulometry of cement (specific surface area) has a significant influence on the normal consistency of cement paste (water demand ratio), this is explained by increase of the total surface of the particles when the cement is ground more finely.

The initial and final set times versus normal consistency of cement paste are shown in Figs. 3 and 4. When the content of lime increased of cement activated by the mineral activator (hydrated lime), the initial and final setting times of cement paste are decreased (high fineness of cement activated). In general, the set time of cement paste is shortened with the increase of fineness of cements studied (very high fineness of hydrated lime). 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.

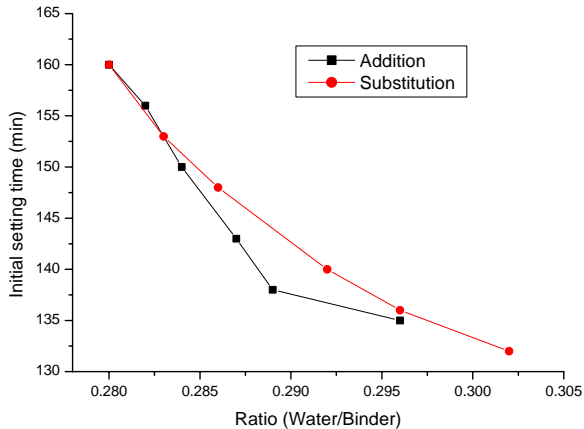


Fig. 3 Variation of the initial setting time versus the ratio (Water/Binder)

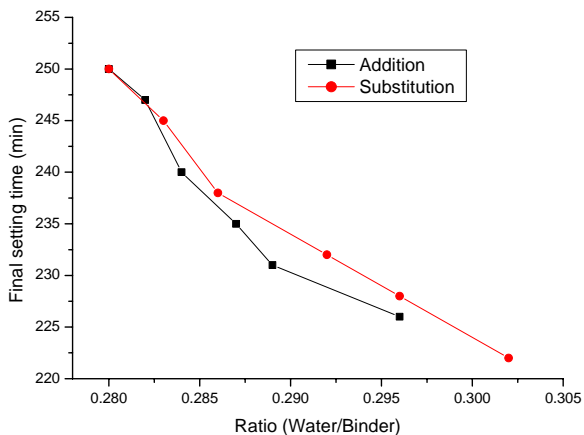


Fig. 4 Variation of the final setting time versus the ratio (Water/Binder)

#### IV. CONCLUSION

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

- \* the activation method by the mineral activator (hydrated lime) of slag cement (latent hydraulicity) influences 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 percentage of lime of cement activated by the mineral activator (hydrated lime),

- \* the mineral activation (very high fineness of hydrated lime) of slag cement (latent hydraulicity) presents a kinetics of hydration reaction accelerated at the initial hardening (short-term).

This is also due to the high fineness of hydrated lime and the percentage of the calcium oxide in cement activated, which accelerate the hydration process, leading to fast setting. Generally, the activation method by the mineral activator of slag cement (latent hydraulicity) accelerates the hydration process and reduces the setting times of the cement activated.

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