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Influence of the origin of metakaolin on pozzolanic reactivity of mortars

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Abstract

Cement is one of the main sources of environmental impacts of concrete use. It is thus recognized that the most pragmatic solution for minimizing environmental impacts of concrete is the reduction of the cement content. This could be achieved by replacing a part of cement with mineral additions such as fly ash, blast-furnace slag or metakaolin (MK) during concrete mixing. In recent years, the incorporation of MK in building materials is growing. Metakaolin (Al_2Si2O_2) is a material obtained by calcination of kaolinite between 500°C and 800°C.
In this study, Three MK issued from three different regions in Algeria were tested. The regions are, Jijel, Gulema and Béchar. This study aims to investigate the effects of the origin of MK blended at early age. The chemical and minalorgiques analysis (XRD, BET, SSB and SEM) show a difference in their metakaolinite content. One mortar prepared with 15% substitution rates of cement with different MK. The early-age reactivity of metakaolin-blended cement mortar was investigated. Isothermal calorimetry and compressive strength tests were performed. The hydration rate and the evolution of $Ca(OH)_2$ content of mortars were monitored using thermogravimetric analysis (ATG). The early age reactivity of the three MKs is very different.

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Keywords: metakaolin, reactivity, pozzolanic, portlandite, mortar

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1. Introduction

Cement is the most essential building material in the modern world because of its low manufacturing cost and the diversity of its use. The decomposition of limestone CaCO3 CaO and CO2 generates a very important pollution, which is the biggest failure of the cement. Substitution by other cement based materials such as allumino silicate is necessary.
Metakaolin is an adequate solution for this use. The energy generated by calcination of kaolin is derived from dehydroxylation of the kaolin by calcination according to the following formula:

$$Al_2O_3(SiO_2)2(H_2O)_2 \text{ (kaolinite)} \longrightarrow Al_2O_3(SiO_2)_2(H_2O)_x + (2\text{-}x)H_2O \text{ (metakaolinite)} \quad (1)$$

This dehydroxylation generates only water evolution, which is an important asset. In addition, the metakaolin has very interesting pozzolanic properties that can improve the performance of concretes [1].

The pozzolanic activity is the reaction between the silica from the dissolution of MK and calcium hydroxide ($Ca(OH)_2$) produced by cement hydration. This reaction gives rise to CSH and CASH [2].

The objective of this study was to compare the activity of three pozzolan metakaolin produced in our laboratory through the index of pozzolanic activity. The evolution of the compression behavior of mixtures cement/metakaolin was carried out on mortars. The microstructure portion showing and explaining the increase in the mechanical performance of mortars containing metakaolin compared to the normal mortar (standard mortar) was carried out on paste. The balance of these two parts allowed us to see the influence of the properties of metakaolins and their pozolanic activity on the quality of concretes.

2. Materials and experimental techniques

The three metakaolins used in our study have been made in our laboratory. They came from three kaolin whose origin and properties are completely different. After calcination at an optimal temperatures and time, those elements were grinding with the same grinding time and determine their fineness to assess the energy consumption required to manufacture them. Chemical analysis, mineralogical and SEM imaging tests were performed to complete the properties of these metakaolins.

Table 1. Metakaolins properties

Comp. (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO_2	K_20	TiO	MgO	SO_3	MnO	FL (%)	BET (m²/g)	Metakaolinite content	D50 (µm)
MKB	38,63	21,85	3,92	24,62	2,85	1,20	1,98	4,06	-	9		27,4	20,1
MKJ	54,33	34,87	4,65	0,21	5,53	-	-	-	-	1	18	60,42	9,08
MKG	49,42	41,89	0,24	3,66	0,28	-	-	1,32	2,75	5		80,9	27,67

Normal mortar (standard mortar) used for the compression test, is prepared according to standard NF P 15-403. A substitution of 15% of the mass of cement by the MK and a water/cement ratio of 0.4 has been used. To improve the workability of the mixture, a polycarboxylate superplasticizer was used in a proportion of 0.8% of the weight of cement.

The mortar specimens (4x4x16 cm^3) which have been implemented have been cured in water at 20 °C until performing the tests. The results obtained in terms of mechanical strengths are used to obtain the index of pozzolanic activity of different metakaolins.

This index is the weight ratio of the compressive strength of mortars containing metakaolin at the "j" day on the compressive strength of the controlled mortar witness at the same day [3].