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ScienceDirect

Energy Procedia 139 (2017) 224–229

Energy Procedia

www.elsevier.com/locate/procedia

International Conference On Materials And Energy 2015, ICOME 15, 19-22 May 2015, Tetouan, Morocco, and the International Conference On Materials And Energy 2016, ICOME 16, 17-20 May 2016, La Rochelle, France

Influence of the pozzolanic reactivity of the Blast Furnace Slag (BFS) and metakaolin on mortars

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Abstract

The objectives of this study is to evaluate the pozzolanic reactivity of mortars with two mineral admixtures (Metakaolin and BFS) in substitution of cement. The rate of substitution is fixed after optimization of the mechanical results. Metakaolin and the BFS from blast furnaces have been used with 10% and 40% respectively to the replacement of the cement. At long time, the use of two admixtures provides better results to those of the mortar of reference at early age, The mortar containing metakaolin provides results better than the mortar of reference, while mortar containing BFS gives inferior results up to 70% of the referential mortar. Metakaolin by its important specific surface area and its reactivity improves the mechanical behavior at early ages. However, the BFS reacts very late. In order to improve the mechanical results at early and long time, a new mortar were casted with 10% of MK and 40% of BFS in substitution of the cement. Isothermal calorimetry and compressive strength tests were performed. Hydration phenomena were also analyzed.

Peer-review under responsibility of the scientific committee of ICOME 2015 and ICOME 2016.

Keywords: Metakaolin, BFS, Mortar, Reactivity, pozzolanic

1. Introduction

The most interesting way to reduce pollution caused by the cement industry is the substitution of part of the clinker with less polluting materials and proven pozzolanic hydraulic properties. Among the most used alternative materials,

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1876-6102
Peer-review under responsibility of the scientific committee of ICOME 2015 and ICOME 2016
10.1016/j.egypro.2017.11.200

there is the blast furnace BFS, a byproduct of the industry of the steel industry, the latent hydraulic properties, and metakaolin, derived from dehydroxylation of kaolin, and from very interesting the pozzolanic properties.
The granulated blast furnace BFS is obtained by rapid cooling and by quenching, of the smelting rests of smelting at 1450 ° C, which allows obtaining a vitrified and granulated material [1].
The physicochemical properties of blast furnace BFS confer interesting hydraulic properties to be used as an addition in partial substitution of cement. In addition to its environmental qualities, the blast furnace BFS has other qualities such as resistance to sulphate attack, low permeability, resistance to aggressive environments and resistance to freeze-thaw, low heat of hydration, which leads to an excellent durability [2].
The metakaolin is obtained by dehydroxylation of the kaolin by calcination according to the following formula :

$$Al_2O3(SiO_2)2(H_2O)_2 \text{ (kaolinite)} \longrightarrow Al_2O3(SiO_2)_2(H_2O)_x + (2\text{-}x)H_2O \text{ (metakaolinite)} \quad (1)$$

These physicochemical properties confer pozzolanic qualities more important than any other mineral additives. Its reactivity with portlandite, after cement hydration, enables the manufacture of an additional CHS to the cement one, associated to its high finesse which allows it to fill voids and reduce the porosity, and thus make it more resistant to aggressive agents, thereby increasing the durability of concrete.
The objective of this study is to compare the activity of the BFS and pozzolanic metakaolin, used alone or combined. The evolution of the compression behavior of mixtures cement/metakaolin was carried out on mortar. The microstructure portion showing and explaining the performance increase in the compression of the mortars compared with the control mortar was carried out on the paste. The balance of these two parts has allowed us to see the influence of the physicochemical properties of the two materials on pozzolanic activity on the quality of mortars.

2. Materials and experimental techniques

Metakaolin used in this study was manufactured in our laboratory whose original kaolin comes from a city of Jijel (east part of Algeria). After calcination at the optimum temperature and time, it has been summered and finely ground to achieve a fineness of 18m²/g.
The blast furnace slag was recovered from the steel plant in El Hadjar (Annaba, Algeria). The cement used is CEM1- 42.5. Their properties, chemical analysis, BET and D50 are shown in Table 1.

Normal mortar called also standard mortar (1/3 liant – 2/3 sand) used for the compression tests part, is prepared according to the standard NF P 15-403. Substitution of 5, 10, 15, 20 and 25% of the mass of cement by MK only and 20, 40, 60 and 80% of slag and a combination of the best results in the compression of both materials, the 10% occurrence for MK and 40% for slag have been studied. A water/binder ratio of 0.4 and a superplasticizer has been used.
The mortar prismatic specimens of 4x4x16 cm^3 have been cured in water at 20°C until performing the tests.

Les pâtes utilisés pour la partie microstructure ont étés réalisés dans les mêmes conditions que les mortiers puis stockées dans une salle climatisée (20°C, 50% HR) jusqu'à la réalisation des essais.

Pastes used for the microstructure have been done in the same conditions as mortars and cured in an air conditioned room (20°C, 50% of RH) until performing the tests.

Two methods of investigation on the microstructure have been implemented. These tests have been performed on powder issued from the crushed hardened cement pastes and sieved to 80µm. The diffraction X-ray analysis (XRD) is used to visualize the crystallized phases (anhydrous or hydrated) present in the cement matrix. It also keeps track of developments in the pozzolanic reaction by consuming the portlandite following the heights of the characteristic lines of the latter.

Thermogravimetric analysis (TGA) is used to quantify certain hydrated phases through the mass loss caused by the loss of water from hydrates at increased temperature. Positioning ATG curves between them, gave information about the reactivity of the mixtures studied.