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Study of the pore solution and the microstructure of mineral additions blended cement pastes

R. Cherif*; A.A. Hamami; A. Aït-Mokhtar; J-F Meusnier

University of La Rochelle-CNRS, LaSIE UMR 7356, Avenue Michel Crépeau 17042 La Rochelle Cedex 1, France

Abstract

In this paper, the influence of mineral additions on the microstructure and the chemical composition of the pore solution of cementitious materials is investigated. For this purpose, hardened cement pastes based on Portland cement CEM I are used. In order to study the influence of the cementitious materials composition on their microstructure and pore solution, a part of the cement is substituted by different mineral additions (limestone filler, fly ash, blast furnace slag and silica fumes). Experimental tests covered measurement of chloride diffusion coefficient by migration test and water and mercury porosimetry. Furthermore, pore solutions are extracted by pressing from cement pastes and analyzed by ionic chromatography. Results show that the substitution of cement by mineral addition modifies the total porosity and the pore sizes distribution of the blended cement pastes tested. Chemical analyses showed that all the tested pore solutions are mainly composed by sodium and potassium. A significant concentration of divalent ions, such as sulfates and calcium, is also noticed. The substitution of cement by mineral addition also significantly modifies the pore solution of cement pastes. In fact, a substitution of cement by 10% of silica fume decreases the alkalis concentrations and increases the sulfates and calcium ones. Thus, the divalent species (Ca^{2+} and SO_4^{2-}) should be taken into account for the chloride diffusion modelling unlike the current models of the literature. Results of this chemical investigation could be used as initial and boundary conditions in the modeling of aggressive species transport through porous construction materials.

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Keywords: cement pastes, microstructure, pore solution, extraction, chemical analyses.

* Corresponding author. Tel.: +33-546-458-362; fax: +33-546-458-241.
E-mail address: rachid.cherif@univ-lr.fr

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1. Introduction

The durability of the reinforced concrete structures is conditioned by the mechanical behaviour of materials used as well as their physico-chemical one against aggressive species attacks. This latter concerns especially the transfer of these aggressive species in the material porosity such as the diffusion of marine salt, the carbonation, the external sulfates attack, etc... It is thus necessary to understand all the mechanisms which occur during the transfer of these species.

These transfer mechanisms depend on the physical and chemical interactions of aggressive species with the cementitious matrix and the other species in the pore solution. In order to well understand these transfer phenomena, a prior chemical investigation of the pore solution composition is necessary.

Among the important parameters describing the pore solution, one can distinguish the ionic strength, the pH, the concentration of each component and the redox potential to determine the oxidation state of the multivalent elements.

A study of the chemical composition of the pore solution, made by Andersson et al. [1], showed that the pore solution of the cementitious materials is influenced by the type of cement and the mineral addition used. For this purpose, they analyzed pore solutions extracted from seven different cement pastes with a W/B (Water/Binder) of 0.5. The extraction method firstly described by Longuet et al. [2] was used. The authors distinguished that the pore solution is composed mainly by sodium, potassium, calcium and sulfates. A significant difference is noticed between the pore solution extracted from paste 1 (containing Portland cement produced in Sweden), paste 2 (Portland cement produced in France) and paste 3 (Cement resistant to sulfates). The paste manufactured by cement rich in silica contains the weakest concentration of Na^+ and K^+ while the pastes manufactured by cement rich in aluminium and fly ash are very low in calcium. In fact, other researchers studied the influence of fly ash on the pore solution of cementitious material [3-6]. Results showed that the alkalinity of pore solution decreases as the silica content of fly ash increases, on the other hand, it increases as the calcium and the alkali content of fly ash increases.

Nevertheless, the studies on the chemical composition of the pore solution of cementitious materials are still relatively rare. In this context, the experimental work presented in this paper has two objectives. The first one is to study the effect of mineral addition on the microstructure of cement paste and the second one is to analyze the chemical composition of the pore solution of cement pastes

2. Experimental protocol

2.1. Materials

Ordinary Portland cement (CEM I 52.5 N in respect with European standard NF EN 197-1) is used. The fractions mass of the principal clinker phases provided by the manufacturer (Calcia, Bussac-France) are 65% C_3S, 13% C_2S, 7% C_3A, 13% C_4AF and 4.9% gypsum. The chemical composition of this cement is given in Table 1. Furthermore, Different mineral additions were chosen. They were used as substituent of the cement as follows: 30% of fly ash (FA30), 75% of blast furnace slag (S75), 25% limestone filler (LF25) and 10% silica fume (SF10). A reference cement paste with 100% Portland cement is also manufactured and is called (PC).

Table 1. Chemical composition of materials used.

Composition	CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	K_2O	Na_2O	Chlorides	Density	Blaine fineness (m²/kg)
CEM I(wt.%)	64.20	20.50	5.00	3.90	2.50	0.29	0.05	1.40	3.80	405
LF (wt.%)	98.80	0.30	-	-	0.01	0.01		0.001	2.70	498
FA (wt.%)	5.10		85.53		0.59	2.00	1.95	0.013	2.21	405
Slag (wt.%)	41.50	33.30	12.50	0.40	0.50	-	-	-	2.89	450
SF (wt.%)	1.00	89.00	-	-	2.00	-	1.00	0.10	2.24	-

The objectives of the choice of these additions are:
75% of the slag bring major modifications to the pore solution of cementitious materials, particularly the physical