Case Studies in Construction Materials 8 (2018) 459–468

Contents lists available at ScienceDirect

Case Studies in Construction Materials

journal homepage: www.elsevier.com/locate/cscm

Effect of thermo-activation on mechanical strengths and chlorides permeability in pozzolanic materials

M. Elbar[a,b,*], Y. Senhadji[b,c], A.S. Benosman[b,d], H. Khelafi[a], M. Mouli[b]

[a] Université des Sciences et de la Technologie d'Oran Mohamed Boudiaf, USTO-MB, BP 1505, El M'naouer, 31000 Oran, Algeria
[b] Département de Génie Civil, Laboratoire des Matériaux LABMAT, ENPO Maurice Audin, 31000 Oran, Algeria
[c] Département de Génie Civil, Université Mustapha Stambouli, Mascara, Algeria
[d] Ecole Supérieure en Sciences Appliquées ESSA de Tlemcen, 13000 Tlemcen, Algeria

ARTICLE INFO

Keywords:
CEMI
Pozzolana
Hydration
Strength
Temperature
Chlorides

ABSTRACT

The present research aimed to study the combined effects of natural pozzolana and curing on the compressive and flexural strengths of mortars; it also investigated the chloride permeability of concrete. To do that, Ordinary Portland cement (CEMI) was used and three concrete preparations were made by incorporating natural pozzolana at a rate of 10, 20 and 30% by weight of CEMI. Moreover, three curing methods were employed. The first one is a standard curing method, at temperature 20 °C, and 2 other thermo-activation methods at the temperatures of 40 °C and 70 °C, for a setting time of 4 h. The thermo-activation methods were used to accelerate the initial hydration, for the purpose of improving the strength of the prepared mortars and concretes at the early age. The results obtained indicate that, substituting natural pozzolana for CEMI with a level below 20% gives strengths comparable to those obtained with CEMI alone. The curing methods at 40 °C and 70 °C allowed increasing mortar and concrete strengths at the early age; however, it was found that the temperature of 70 °C reduces strengths, at later age. Natural pozzolana limits the penetration of chlorides.

1. Introduction

Today, there is a growing need across the world for resistant, durable, environmentally friendly, and cheaper concrete structures. Mineral additions have always been used in cement manufacturing or in concrete industry for their technical and economical benefits. The simplest and most advantageous ecological perspective is to limit the greenhouse gas emissions [1,2] by reducing clinker consumption while using the same quantities of concrete and some mineral additions. Low cost concrete with performances similar to those of CEMI Portland cement could be obtained; they showed high strength and better durability [3]. However, the most obvious drawback to the substitution of CEMI by Natural Pozzolana (PN) is that the early age strength is low [4]. To solve this problem, several techniques can actually be used to improve the strength of pozzolanic cements in the short term. Some of these techniques are the chemical activation method [5,6], the thermal activation of mineral admixtures through calcination at high temperatures [7,8,9] and the mechanical activation by increasing the specific surface area [10,11]. It is also possible to accelerate the hydration of pozzolanic cements either with an adjuvant or by heat curing. Using this last method traces back to Michaelis (1880), who was the first to use autoclaving. Freyssinet (1927) applied a heat treatment cycle at 80 and 100 °C.The first applications of the electric heating methods took place in Sweden (1931) and Russia (1940) [12], where the infrared radiation appeared as an effective means of heating. Today, thermal curing is used for the production for many kinds of concrete, i.e. reinforced concrete, pre-stressed

* Corresponding author.
E-mail addresses: amineaf2002@yahoo.fr, mohamed.elbar@univ-usto.dz (M. Elbar).

https://doi.org/10.1016/j.cscm.2018.04.001
Received 6 December 2017; Received in revised form 2 April 2018; Accepted 5 April 2018
Available online 07 April 2018

concrete and Ultra-High Performance Concrete (UHPC) [13,14,15]. However, using this technique is always accompanied by a change in the physicochemical and mechanical properties of materials. Several studies have indicated that increasing the curing temperature for slag cement mortars results in higher strength at an early age and in lower strength at a later age. At the curing temperature of 20 °C, as the pozzolan content increases, the initial setting time of the mixture of cement and pozzolana also increases. On the other hand, when the cure temperature exceeds 30 °C, the final setting time starts decreasing. This means that the heat treatment of pozzolanic mortar accelerates the hardening process [16]. Cement hydration kinetics increases with temperature [17,18]. High temperatures during curing might have a negative impact on the properties of concrete. Indeed, micro-cracks might appear, and the delayed ettringite formation (DEF) in concrete may start at early age when the curing temperature is high. Moreover, plastic shrinkage and drying shrinkage of silica fume cement concrete increased under hot and dry curing conditions, and more monosulphoaluminate was formed at the temperature of 60 °C than at 20 °C. Also, the C-S-H gel chain length increased with the hydration time. However, mineral admixtures, such as silica fume, and with low W/C ratios are efficient in reducing the negative effects of high temperature curing [19–23].

In this paper, three curing methods were tested, namely the standard curing (T = 20 ± 2 °C) and accelerated curing in an oven at two temperatures, i.e. T1 = (40 ± 2 °C) and T2 = (70 ± 2 °C), during the first 4 h of setting of the mortar mix. An outdoor thermal-activation at 40 and 70 °C was used to enhance the chemical reactions and hydration kinetics which will subsequently be interpreted through the mechanical strengths. On the other hand, it is essential that the building material retain its mechanical properties and durability, continue to fulfill its function throughout its useful lifetime and resist damages it may be exposed to. Therefore, the influence of the curing temperature on the resistance of concrete to chloride ions penetration was studied, according to the standard ASTM C1202 [28], at the age of 28 days.

2. Materials and methods used

2.1. Cements

We used CEM I 42.5 and three composite cements (Natural Pozzolana cement) NPC10, NPC20 and NPC30, obtained from the incorporation Algerian natural Pozzolana (NP) at a rate of 0, 10, 20 and 30% by weight of CEMI. The testing was done according to the standard EN196-3 [24]. Their chemical and physical properties are summarized in Table 1.

2.2. Specimens of mortar

Mortars have been prepared asstandardized mortars, manufactured according to the standard EN 196-1 [25]. Each mixture manufacturing three prismatic specimens simultaneously of 40 × 40 × 160 mm^3 and the flow table test was done in accordance with ASTMC1437 [26]. Notation and flow of fresh mortars are given in Table 2.

2.3. Specimens of concrete

The concretes were prepared in accordance with standard EN 206-1 [27].The water/binder ratio was kept constant. The aggregates were invariable. The concretes composition for 1m^3 is as shown in Table 3. The test-tubes used are cylindrical, with a

Table 1
Properties of NP and cements.

Chemical composition, XRD %			NP	CEMI 42.5	[a]NPC 10	NPC 20	NPC 30
Silicon dioxide	SiO_2		46.95	21.38	23.94	26.49	29.05
Aluminum oxide	Al_2O_3		17.81	4.11	5.48	6.85	8.22
Ferric oxide	Fe_2O_3		9.74	5.16	5.62	6.08	6.53
Calcium oxide	CaO		10.97	63.47	58.22	52.97	47.72
Magnesium oxide	MgO		2.46	1.16	1.29	1.42	1.55
Sodium oxide	Na_2O		3.29	0.17	0.48	0.79	1.11
Potassiumoxide	K_2O		1.57	0.38	0.49	0.61	0.73
Sulphur trioxide	SO_3		0.84	1.97	1.85	1.74	1.63
Bogue composition, %							
C_3S				55.24			
C_2S				19.63			
C_3A				2.16			
C_4AF				15.70			
Physical characteristics							
Blaine specific surface area		cm^2/g	3720	3300	3342	3384	3426
Specific gravity		kg/m^3	2.65	3.15	3.10	3.05	3.00
W/B for normal consistency		%		25	26	26.5	27.3
Initial setting time		min		145	155	175	208
final setting time		min		230	245	255	260

[a] NPC: Natural pozzolana cement.