6th International Symposium on Advances in Science and Technology
SASTech
Malaysia | Kuala Lumpur
24 - 25 March, 2012
Scope of the Symposium
Organised by:
Khavaran Institute of Higher Education
Hosted by:
Geospatial Association of South East Asia

The Influence of Natural Pozzolan Content on Durability of High Performance Concrete

A. Talah[1], F. Kharchi[2], R.Chaid[3], A.Merida[4]

[1] *Built Environment Res. Lab.(LBE), Algiers, Algeria;* [2]*Built Environment Res. Lab.(LBE), Algiers, Algeria,*[3]*University of Boumerdes,Algiers, Algeria* [4]*Built Environment Res. Lab.(LBE), Algiers, Algeria,*

Name of the Presenter: ***Aissa Talah***

Abstract

This paper presents an experimental study of the influence of natural pozzolana on the mechanical properties and durability of high performance concretes. The analysis of the experimental results on concrete at 7.5% content of pozzolana with a fineness modulus of 9600 cm^2/g, in a chloride environment, showed that it contributes positively to the perfection of its mechanical characteristics, its durability with respect to water absorption and migration of chloride ions. On the basis of the experiments performed, it can be concluded that the natural pozzolana is suitable for formulation of high performance concretes and their properties are significantly better compared to the reference concrete.

Key words:: natural pozzolana; water absorption; concrete durability; chloride resistance

1. Introduction

The worldwide demand for high-performance cement-based materials has increased and predictions are that it will be widely used in construction industry during the early 21st century. Economical and environmental considerations had a crucial role in the supplementary cementing material usage as well as better engineering and performance properties [1-2]. This study has been exclusively focused on the hardened properties of the high performance concrete containing an optimum quantity of pozzolana under aggressive and normal curing regimes.

It is now well established that the evaluation of the performance of a concrete mix is not limited to the determination of its mechanical properties since it is of paramount importance to characterize the material in terms of the parameters that rate its durability [3]. **15**

The present study is focused also in the mechanism of chloride penetration in cementitious materials. Chloride ions penetration in cementitious materials is one of the processes widely responsible for the degradation of concrete structures.

This paper deals with the effect of natural pozzolana-Portland cement optimal ratio on the physical, mechanical, and durability properties of concrete. The best combination of this pozzolanic addition, can lead to excellent durability. The amorphous silica present in this additive combines with the calcium hydroxide liberated during the hydration of cement in concrete, to form additional cementitious compound, namely new calcium silicate hydrate.

The objective of this experimental study is to examine the durability performance of pozzolana high-performance concrete (PHPC) conserved in hydrochloric solution.

2. Materials

The materials used in this investigation were Portland cement, natural pozzolana, aggregate, water and super plasticizer.

Portland cement (CPA-CEM-I / A 42.5) conforming to the Algerian standard NA 443 and natural pozzolana were utilized as cementitious materials. Crushed limestone coarse aggregates with a nominal size of 16 mm, and a specific gravity of 2.70, and natural sand with a specific gravity of 2.60 were used for the concrete samples. The size grain, the fineness modulus (FM = 3.2), the sand equivalent value (SEV= 97%) and shock resistance (SR=33%) show that gravel and sand can be used in developing a high performance concrete (HPC)**.** A commercially available sulphonated naphthalene formaldehyde-based super plasticizer was used to give a consistent workability.

2-2. Formulation, mixtures, specimens, and curing procedures

Two formulations of concrete were studied:
- reference concrete (RC);
- pozzolana high-performance concrete (PHPC).

The prepared specimens were stored for one year in an environment containing 5% calcium chloride, (media 1) and drinking water (media 2).

In order to investigate the natural pozzolana on the performance properties of concrete, two different concrete mixes were employed, details of which are given in Table 1**.**The control mix contained only Portland cement as the binder. In the PHPC, Portland cement was partially replaced with, respectively, 7.5% natural pozzolana (by weight). The super plasticizer was added at the time of mixing. All concretes were mixed in accordance with ASTM C192 standard in a power-driven revolving pan mixer. Concrete cubes of 280x70x70 mm in size, and cylinders of dimensions 110Ø x220 mm were cast in steel moulds for the study of the compressive strengths, absorption characteristics, and rapid chloride permeability test, respectively. All specimens were cast and compacted by a vibrating table. After casting, the moulded specimens were covered with a plastic sheet and left in the casting room for 24 hours. They were then demoulded and divided into two equal groups and cured under the following conditions: in the first curing condition, the specimens were immersed in water until the age of testing, while in the second curing condition, those were immersed in aggressive water (5% $CaCl_2$) until the age of testing. To ensure a concentration of chlorides

constant throughout the tests, the solution in the tanks was regularly checked once a week and changed if the difference between the concentration of the solution and the initial concentration exceeded 5%.
The main tests carried out on the fresh concrete are the workability (sag cone Abrams), the percentage of air contents determined by the aerometer and the density.
The results of these tests are given in Table 1. For good implementation of RC, sag of PHPC should reach about 20 cm, which is the case**.**

Table 1**-** Mixture proportions and properties of concrete.

Concrete	W/C Ratio	Cement (Kg/m^3)	Pozzolana (Kg/m^3)	Water (Kg/m^3)	Sand (Kg/m^3)	Gravel 3/8 (Kg/m^3)	Gravel 8/16 (Kg/m^3)	SP[a] (%)	air contents (%)	Sag (cm)	Density (kg/m^3)
RC	0.50	425	0	212.5	788	163	886	0	2.0	7	2480
PHPC	0.27	393	32	100	788	163	886	1.5	1.7	18	2576

[a] SP: Super plasticizer (wt.% of total cementitious content)

3.Research Methodology

3-1 Compressive strength

To evaluate strength characteristics of each mixture, the compression test was carried out on concrete 110x220 mm cylinder by a 2000 KN capacity testing machine according to ASTM C39. The strength measurements of concrete were performed at 28, 90,180 and 365 days of age. The results reported are the average of nine compression tests.

3.2 Rate of water absorption (sorptivity

The sorptivity test was conducted in accordance with ASTM C1585. It was measured on 70 mm concrete cubic specimens which were oven dried at 105 °C for 24 hours.

3.3 Chloride permeability

The resistance of the concrete to the penetration of the chloride ions was measured in terms of charge passed through the concrete in accordance with ASTM C1202 .

4. Results and Analysis

The results regarding the compressive strength, water absorption by capillary rise and chloride permeability of the different concretes are graphically depicted in Fig. 1, 2, and3, respectively.

4-1 Compressive strengths

The data regarding the variation of compressive strength with respect to concrete age and curing condition for different types of concrete in the two mediums are shown in the Fig.1. The strength values for the reference concrete and pozzolana high-performance concrete ranged from 38 to 48 MPa and from 60 to78 MPa respectively, depending mainly on pozzolana content, curing condition, and concrete age.

The result indicates that there was a systematic gain in compressive strength with the pozzolana content [4]. This trend agrees with results reported. It was observed that the ratio of the compressive strength of the specimens subjected to water curing to those cured under aggressive water for the reference concrete deviated up to 20.8%. However, this ratio for concretes containing pozzolana lay within a range of 3.8 %, depending mainly on pozzolana content and testing age. This implies that reference concretes are more sensitive to aggressive medium than pozzolana concretes. Therefore the increase of resistance is remarkable after 28 days, following the pozzolanic property of this addition.

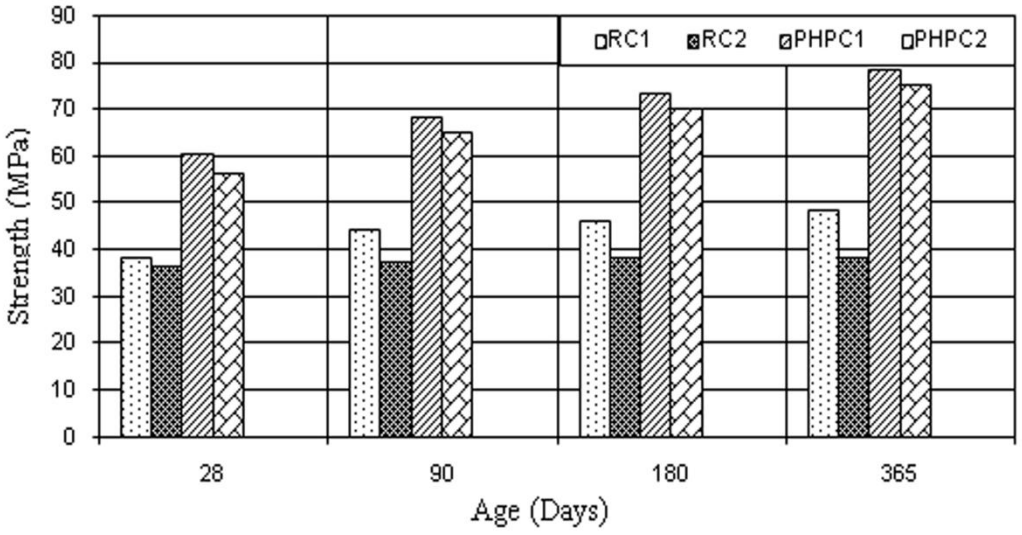

Fig.1 - Evolution of compressive strengths at different ages

4.2 Absorption characteristics

The change in water absorption rate with concrete age and curing condition for RC and PHPC are given in Fig.2. It is clear that the rate of water absorption decreases systematically with an increase in curing period (from 28 to 365 days), and the gradients of the water absorption tends to decrease.

Generally, pozzolana concrete performed better than the reference concrete and marked improvements in terms of lower rate of water penetration through capillary suction were apparent,

particularly under aggressive condition. This reduced water absorption rate reflects a finer pore structure that would, for example, inhibit ingress of aggressive elements into the pore system, especially for pozzolana concrete. Several researchers showed the effectiveness of the mineral additions on the absorption rate of the concretes and mortars [5-6].

This reduction in the water absorption with age indicates better performance of pozzolana blended cement concretes over reference concrete. It is noticed that natural pozzolana reduced the water absorption rate during the advancement of age of concrete**.**

The incorporation of 7.5% pozzolana is very advantageous; it allows a reduction in water absorption rate from 78% to 77% at the age of one year.

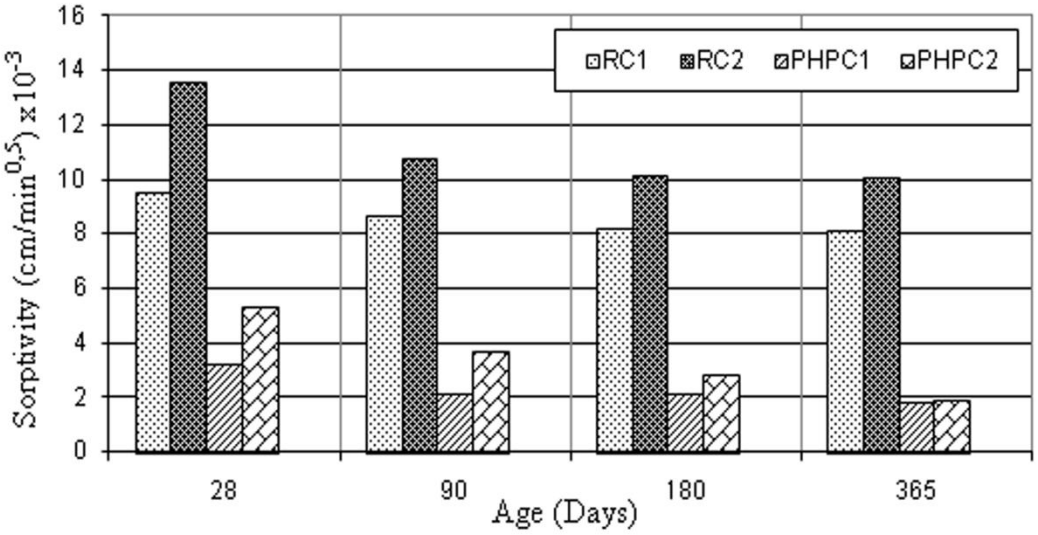

Fig. 2- Rate of water absorption

4.3 Resistance to chloride ion penetration

The effect of curing conditions (up to 28 and 365 days of age) and the partially replacement of cement with pozzolana (from 7.5%) on chloride permeability of the concrete is shown in Fig.3. The test results show that the values of the current and the electric charge for PHPC are too small.

Obviously, this reduction is more precise when the age of concrete at the advanced test is given the pozzolanic reactivity of the addition, which reduces the amount of hydrated lime in the cement matrix.

This decrease is linked to clogged pores of PHPC and with the weak ratio CaO/SiO_2 of CSH in pastes containing natural pozzolana. The large decrease in the permeability with the use of supplementary cementing materials in the concretes is due to the change in the pore structure of the hydrated cementitious system [7].

Arezki and al have used a concrete containing 30% diatomaceous earth with a water / binder = 0.40 at age 28 days, they found a reduction of passed charge from 62% compared to concrete control [8]. While our test revealed a reduction of 88% **.**

This indicated that the pozzolana concretes had remarkably lower permeability than the control concretes. As it is also observed in Fig.3, the extension of the curing period from 28 to 365 days and the curing conditions applied to the test specimens resulted in a reduction of the charge passed through the concretes, with the difference much more marked for the pozzolana high performance concretes than the reference concretes.

This confirms the contribution of the pozzolana against degradation (PHPC) in a hydrochloric media.

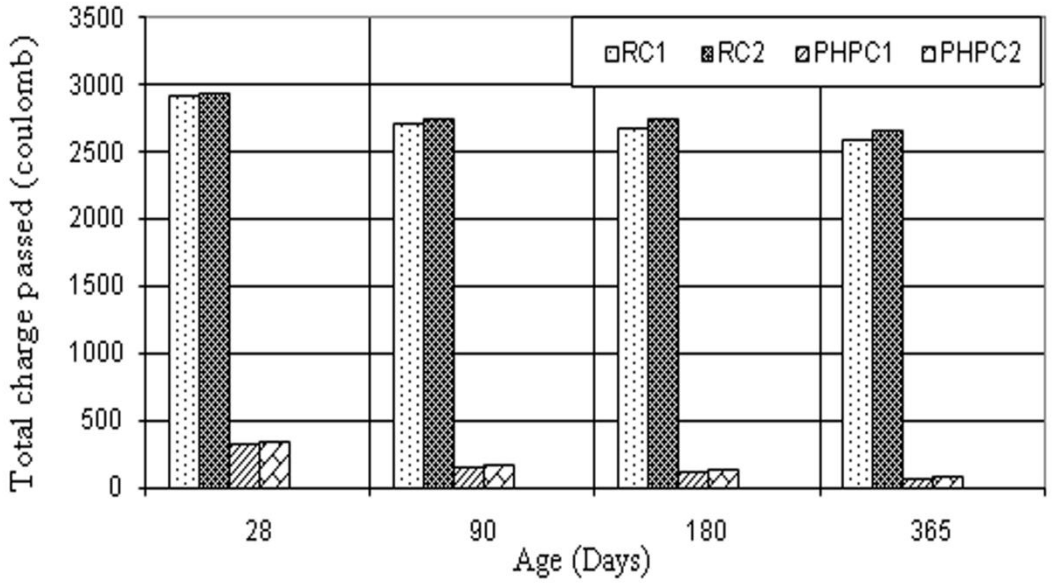

Fig.3- variation of charge passed at different ages

5. Conclusions

The following conclusions are drawn from the test results and analysis presented in this paper:

1. For the mixture with optimal replacement of pozzolana, addition played a critical role in realizing the full potential of concrete in terms of strength and especially durability characteristics. Note that the durability is strongly influenced by the parameters of compositions (different types of concrete), for the duration of treatment and conservation conditions (middle aggressive and non-aggressive).

2. The durability test on the concrete, containing natural pozzolana, consisted of immersion in running water, chloride solution, in all cases, structural changes to the samples were noted, either due to dissolution of portlandite or by formation of calcite or gypsum crystals. In all cases the mineral admixture had improved the physical characteristics of concrete relatively to the reference concrete sample.

3. Based on the results of the chloride permeability test, pozzolana concrete specimens had superior performance and mostly gave longer time to failure at similar curing condition and testing age in comparison to reference specimens. Similar to water absorption and chloride permeability results, the compressive strengths of the specimens increased considerably with pozzolana content. For example, the 365 days aggressive cured specimen containing (7.5% pozzolana) exhibited about 97% higher compressive strengths than the reference sample.

4. Finally, it was noted that the pozzolanic action effectively contributes to the reduction of chloride ion penetration and water absorption rate and increase the durability of concrete. The results show the positive influence of natural pozzolan on the properties of concrete under hydrochloric mediums.

Acknowledgements

This research work was supported by Built Environment Research Laboratory (LBE/ USTHB), Civil Engineering Faculty, (Algiers, Algeria.).We are grateful to many staff members from this laboratory.

References

[1] Badogiannis, E., Papadakis, V.G., Chaniotakis, E., Tsivilis, S., 2004,"*Exploitation of poor Greekkaolins: strength development of metakaolin concrete and evaluation by means of k-value*", Cement and Concrete Research, ,vol.34, pp.1035–1041.

[2] Ramezanianpour, A.A., Malhotra, V.M., 1995,*"Effect of curing on the compressive strength, resistance to chloride ion penetration and porosity of concretes incorporating slag, fly ash, or silica fume*", Cement Concrete Composite., vol.17, pp.125–133.

[3] Basheer, L., Kropp, J., Cleland, D.J., 2001, "*Assessment of the durability of concrete from its permeation properties",* Construction Building Materials **15** (2– 3), pp. 93–103.

[4] Chaid, R. Jauberthie, R. Renell, F., 2004, "*influence, of a natural pozzolana on the properties of high performance mortar*" Indian Concrete Journal; vol.78, pp.22-26.

[5] Tasdemir,C., 2003 "*Combined effe*ct of mineral admixtures and using on the sorptivity coefficient of concrete" Cement and Concrete Research., vol.33,pp.1637-1642.

[6] Dias, W.P.S, Nanayakara, S.Q., Ekeneligoda,T.C, 2003, *"performance of concrete mixes with opc.pfa blends*" magazine of concrete research. Vol. 55 N.02 pp.162-170.

[7] Kunhanandan Nambiar, E.K., Ramamurthy, K., 2007, "*Sorption characteristics of foam concrete*" Cement and Concrete Research, Vol.37, pp.1341-1347.

[8] Taghnit, H., A., Petrov, N., Luke, K., 2003, *"Properties of concrete containing diatomaceous earth*", American Concrete Institute, Mate. J., vol.100, pp.73-79.