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Pozzolan concrete durability on sulphate attack

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Abstract

Sulfate attack and its effects are important from both scientific and industrial viewpoints. It is perceived that cements containing pozzolan have better performance in sulfate solutions,since the pozzolanic reactions reduce the quantity of calcium hydroxide and increase calcium silicate hydrate. This paper investigates the physical and mechanical properties ofconcretes made by blended cement containing Algerian natural pozzolan of volcanic origin, and Portland cement. inorder to better determine the pozzolanic effect of the pozzolan addition in the concrete, the analysis of the experimental results of the effect of the partial replacement of the cement by the natural pozzolana showed that it contributes positively to the improvement of its mechanical characteristics, its durability with respect to the ultrasonic pulse velocity as well as the sulphate resistance. The present study confirms the pozzolanic reactivity of the natural pozzolans used.

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Keywords: *Compressive strength ; Natural pozzolana ; Durability ; Pozzolanic reactivity ; High performance concrete ;Sulphate.*

1. Introduction

The durability of concrete structures is affected by many environmental factors, the sulphate corrosion being one of the most frequent and detrimental processes. Through the capillary pores of concrete due to the concentration gradient [1, 2] and react with unhydrated components of the hardened cement paste. In consequence, these chemical reactions may lead to expansive reaction products such as ettringite ($C_3A.3CaSO_4.32H_2O$) [3] .In turn; the ettringite may cause the overall expansion of a structural element and its extensive damage progressing from the outer surface towards the specimen inner core [4]. This process may result in a gradual loss of concrete strength [5] accompanied by surface spalling and exfoliation [6].

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Pozzolanic materials improve the microstructure of concrete due to their particle size, and may alter chemical composition and hydration reactions. Pozzolan as an amorphous or glassy silicate material that reacts with calcium hydroxide formed during the hydration of Portland cement in concrete. The substance that contributes to the strength of the concrete called calcium silicate hydrates(C-S-H). Calcium hydroxide will reduce the strength of the concrete. Pozzolan contains silica that react with calcium hydroxide in concrete to form extra calcium silicate hydrates compound and diminish calcium hydroxide [7], further strengthening the concrete due to increase of C-S-H compound and making it stronger, denser, and durable during its service life.
Many researches on the performance of concretes containing pozzolan in sulfate solutions have been performed [8, 9,10].

The aim of this study is to experimentally investigate the effect of replacing 5% of cement by natural volcanic pozzolan in the mixture of high performance concrete (HPC) on the compressive strength, permeability to the chlorine ions, sulphate resistance and ultrasonic pulse velocity of specimens exposed to solutions of 5% sodium sulphate(Na_2SO_4) in comparison with traditional concrete (CC).

The specimens were stored for one year in drinking water (environment 1) and in aggressive solution containing 5% sodium sulphate (environment 2).

2. Experimental programme

2.1 Materials

- *Aggregates*

Natural rolled sand obtained from a local river and crushed limestone with a maximum particle size of 16 mm made fine and coarse aggregates respectively. The size, the finesse modular (FM = 3.2), the sand equivalent value (SEV= 97%).
Sand density = 2, 60 g/ cm^3
Coarse aggregates density = 2, 50 g/ cm^3

- *Cement*

Portland cement (CPA-CEM-I / A 42.5), accordance to the Algerian standard NA 443, EN 197-1.
Specific gravity = 3100 Kg/m^3
Specific surface = 322 m^2/Kg

Table 1. Chemical composition of the cement.

Chemical composition										mineralogy Composition				
CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	Na_2O	SO_3	K_2O	RI	LOI	CaOl	C_3S	βC_2S	C_3A	C_4AF
63.05	21.28	3.85	4.61	1.19	0.18	2.54	0.80	1.11	1.58	0.75	59.83	16.94	6.56	11.64

IR-insoluble residue, LOI-loss on ignition, CaO_l-free lime

- *Natural pozzolan*

Natural volcanic pozzolan,was extracted from the deposit Beni-saf (Algeria).
Specific gravity = 2660Kg/m^3

Specific surface = 960 m^2/Kg
Pozzolanic activity = 110 mg CaO/g

Table 2.Chemical composition of the pozzolan.

Eléments	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	LOI	R.I
%	44,95	16,91	9,47	14,59	3,70	0,20	1,35	1,34	4,30	0,56

- *Reducing superplasticizer*

The reducing superplasticizer used is the 3rd generation derived from polycarboxylates. The study of concrete composition is always to seek simultaneously two essential qualities: strength and workability, but these two qualities are linked to each other but vary in the opposite direction. The idea was to develop a dense concrete from a compact granular skeleton using cement and water and meeting the strength, durability and workability requirements. Its normal use scale is fixed by the manufacturer's recommendation of 0, 5 to 2% of the cement weight.

2.2 Optimisation of natural pozzolan

A series of concrete mixtures with varying percentages of pozzolana was prepared aimed at increasing the compressive strength and optimizing the pozzolana dosage.
The pozzolan content in the mix was fixed at 5% by weight of cement, Figure 1 shows the results.

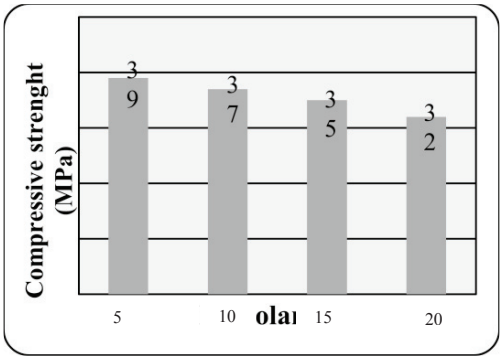

Fig. 1.Compressive strength at 28 days, MPa.

2.3 Optimization of superplasticiser

The study of concrete composition is always to seek simultaneously two essential qualities: strength and workability, but these two qualities are linked to each other but vary in the opposite direction.

The idea was to develop a dense concrete from a compact granular skeleton using cement and water and meeting the strength, durability and workability requirements.

Table 3. Optimization of super plasticizer content in concrete

Super plasticizer SP.30 (%)	Freshly-mixed concrete				Hardened concrete
	N°	W/C	Sag cm	Density Kg /m	Compressive strenght MPa
1	1	0.25	5	2524	27
1.5	2	0.25	8	2536	31
2	3	0.25	14	2542	33
1	4	0.3	15	2539	28
1.5	5	0.3	20	2546	29
2	6	0.3	21	2549	30

The optimized superplasticiser content was 2% at 0.3 W/C ratio giving a slump of about 21cm**.**

2.4 Composition of the concretes

Two different concrete mixes were employed,control mix CC and HPC**.** Mix of HPC, the Portland cement was partially replaced with 5% natural pozzolan (by weight).

Table 4. Mixture proportions and properties of concrete.

Concrete	W/ C ratio	Cement kg/m^3	Pozzolana kg/m^3	Water kg/m^3	Gravel 3/8 kg/m^3	Gravel 8/16 kg/m^3	SPa %	Sag cm	Density kg/m^3
CC	0,5	425	0	212,5	137	837	0	8	2430
CZ	0.3	403.75	21.25	107.66	137	837	2	21	2596

2.5 Test methods

- Compressive strength**:** This test was carried out in accordance with ASTM C39.
- Ultrasonic Pulse Velocity: This test was carried out in accordance with ASTM C597-02.
- Sulphate resistance: This test was carried out in accordance with ASTM C1012.

3. Results

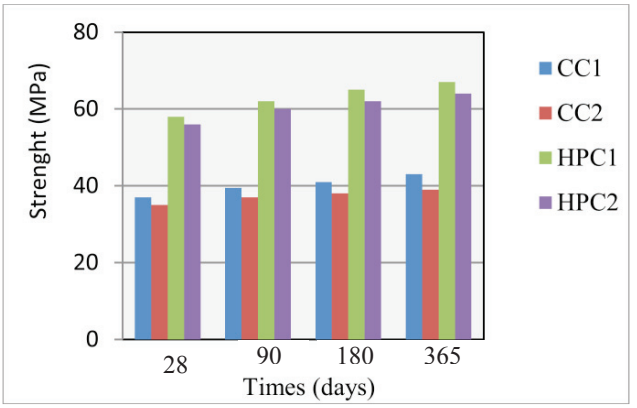

Fig 2.Evolution of compressive strengths.

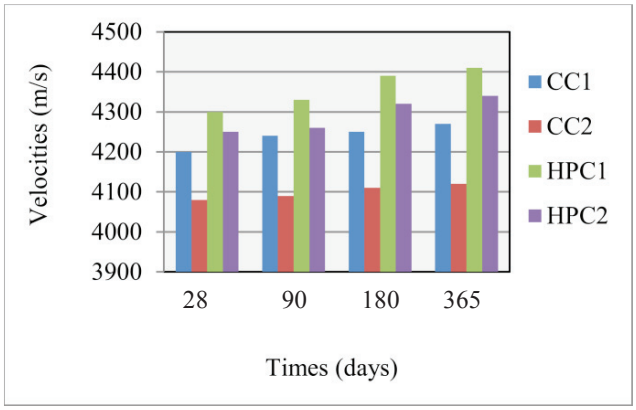

Fig 3.Variation of velocities.

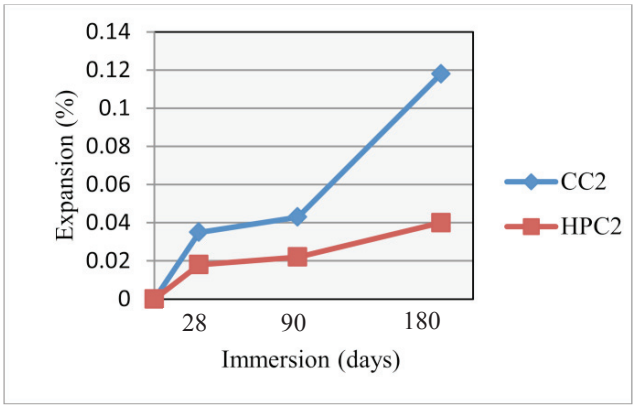

Fig 4. Results of sulphate resistance.

4. Conclusion

The specimens kept in water, the increase in compressive strength continuous as the duration of immersion increases. The specimen concretes curing in water, the strength of control concrete increase from 34 (MPa) to 45 (MPa), whereas the high performance concrete it increase from 56 (MPa) to 73 (MPa). The results indicates that pozzolan addition helps gain compressive strength.

The specimens kept in aggressive solution; the strength of the control concrete is reduced by 17.77(%) whereas the high performance concrete the reduction was by (5.48%) only.

The specimen concretes curing in water, the velocities of the control and pozzolan concretes increase from 4200 to 4260 (m/s) and 4295 to 4410 (m/s) respectively in aggressive solution, its decrease by 3, 4 (%) and 1, 58 (%) respectively.

The expansion rates are low at the beginning of the control and high performance concrete, and increases substantially after three months of curing for the first specimen concrete. The expansion of the control concrete and high performance concrete curing in aggressive solution decrease by 65,21(%).

Based on the obtained data in this study, the use of natural volcanic pozzolan replacing (5%) by weight of cement in the mixture of high performance concrete influences positively the durability specimens concrete cured in sulphate environment. The pozzolan modifies the microstructure of the concrete in terms of its physical and chemical characteristics. It was observed that during the early stages, the filler effect results due to reduction in

porosity. With aging, the pozzolanic action further evidence of densification and low porosity of the concrete due to the natural admixture by the formation of CSH with binding properties similar to those formed in mineral-based cements. I can be concluded that the mineral admixture improved the physical characteristics of concrete relatively to the control concrete sample.

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