



Compressive strength and corrosion evaluation of concretes containing pozzolana and perlite immersed in aggressive environments

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HIGHLIGHTS

- Pozzolan improves the mechanical properties of concrete at 20% of replacement rate of cement.
- Perlite improves the mechanical properties of concrete at 10% of replacement rate of cement.
- 10% PZ and 10%P led to an increase in reduction of the corrosion rate in 5% of NaCl.
- 20% and 30% of PZ and P respectively has a negative effect on corrosion in the aggressive medium.

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ABSTRACT

This study contributes to the development of more sustainable systems to limit and adverse the environmental effects as well as the disintegration of artificial Portland cement (APC) concrete structures. In this context, experimental tests were carried out to develop sustainable binders using natural pozzolan (PZ) and perlite (P) with a relatively high cement substitution rate. A certain level of cement replacement with these pozzolans is very advantageous in terms of cost, energy efficiency, environmental benefits, as well as mechanical properties and durability.

A number of important properties of concrete such as compressive strength, corrosion resistance, chloride penetration, sulphate resistance have been developed and noted here. The results obtained show that 10% and 20% of natural pozzolan improves the mechanical properties, and it is noted that 10% of the replacement of the cement by pozzolan and 10% of the perlite led to a reduction of the speed of NaCl corrosion. A larger replacement of pozzolan and perlite had a negative effect on corrosion. Finally, it should be noted that sulfate ions did not affect the corrosion.

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1. Introduction

“Durability of concrete” means resistance against deterioration; It is a matter of choice that indicates whether a concrete is durable or has no minimum porosity. i.e. it has high resistance to alkali-silica reaction and sulphate, high corrosion protection capacity, reduced heat of hydration, better resistance to chloride attack, and greater resistance against the aggressions of the harmful environment.

The growing need for building materials leads us to a depletion of natural resources. It is now essential to think in a logic of sustainable development [1,2]. Indeed, the use, as often as possible, of alternative materials (including marginal by-products or

recycled materials) can make up for this scarcity of traditional building materials. Some industrial by-products such as natural pozzolans, perlites, fly ash, blast furnace slags or silica fume have been showing a high potential for use in the past few decades, replacing to a certain extent Portland cement [3,4]. Research shows that it is possible to safely introduce them into a concrete, often even improving its mechanical properties and durability. Mechanical properties of concrete containing silica fume were more effective than those of concrete containing fly ash at the early ages. However, these values were almost similar at 90 days [5].

The corrosion of reinforcing bars in concrete is a major durability problem for reinforced concrete. High corrosion resistance of concrete is always a major concern and comes in the second place after the mechanical property of reinforced concrete. Different techniques have been used to protect steel from corrosion of reinforcement in concrete. Indeed, corrosion durability of activated concrete was studied by a number of researchers [6–11].

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Thamas et al. and Wallah et al. [12,13] reported that the use of pozzolanic materials such as natural pozzolan and perlite are extremely beneficial not only to minimize environmental pollution but also to improve the durability of concrete. When added to concrete, they generally modify the existing pores in the concrete and minimize water permeability. Therefore, the addition of pozzolans to concrete improves water penetration resistance and water erosion such as corrosion of reinforcements, frost damage, acid and sulphate attack [14–16]. Many aspects of durability of mortar and concrete produced by the use of pozzolanic materials had been studied.

Indeed, the use of the local pozzolanaremainns still only partial in the manufacture of cements and concretes. In fact, previous research studies showed that the use of local pozzolana (western Algerian region) led to considerable improvements in the mechanical properties of mortars and concretes [17–19]. However, few researches studied the durability of mortars and pozzolanic concretes subjected to aggressive environments [20–24].

According to the researchers [25], two cement systems were investigated to obtain different materials for different application - geocement system for repair materials and protective coatings. Fly ash alkali activated hybrid cement for corrosion resistant common cements and concretes.

It was studied that sulfate resistance of fly ash alkali activated cements after 3 years of storing in aggressive environments like 5 and 10% solutions of sodium sulfate, 2 and 4% solutions of magnesium sulfate and sea salt solution. It was shown that fly ash containing cements were characterized by high corrosion resistance (coefficient of corrosion resistance after 3 years of storing in aggressive environment is in the ranges 0.8, 1.0) compared to clinker cements (0.45, 0.88). Meaning, high sulfate resistance of cements under study in time is caused by graduate structure development and crystallization of new formations with compacting structure of material that effect on service properties of materials.

The results of study of other researchers [26] show that the developed geocements-based ($\text{Na}_2\text{O} \times \text{Al}_2\text{O}_3 \times 6\text{SiO}_2 \cdot 30\text{H}_2\text{O}$) coatings are corrosion resistant ones in a 5% solution of ammonium sulfate. This can be attributed to the synthesized faujasite, chabazite, mordenite zeolites with NH_4^+ ions: ammonium analcime, (NH_4 , Na)-zeolite-E, zeolite a, zeolite ZK-21 and NH_4 -zeolite-W that are known to exhibit high corrosion resistance. The coated concrete surface has a coefficient of resistance $K_r = 1.01$ which is at the age of 30 days by 1.2 times higher than that of the uncoated concrete surface of the same age.

Potentialand current density measurements were made using the corrosimeter and the multimeter with an accuracy of ($\mu\text{m}/\text{cm}^2$). The interpretation of the results by TAFEL data leads to the corrosion rate (thickness loss, polarization resistance) as recommended by RILEM TC154-EMC and ASTM 876-09.

The aim of this study was to examine the use of natural pozzolan and perlite as partial substitute for Portland cement in concrete, and thus to qualify their effects on the mechanical strength and corrosion in aggressive media such as sulphate attacks and chlorides.

For this reason, we have carried out several experiments focusing on the influence of the proportion of mineral addition on the mechanical properties and durability of concrete.

Table 1
Chemical composition of cement CEM I 42.5 N (%).

CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	SO ₃	K ₂ O	Na ₂ O	MgO	Cl	LOI
65.86	21.36	4.98	3.63	0.93	0.77	0.08	2.06	0.02	2.48

LOI: Loss on ignition.

2. Used materials and test methods

2.1. Used materials

2.1.1. Cement

Portland cement CEM I class 42.5 from the Lafarge cement plant in Msila. The chemical compositions of this cement and clinker mineralogy, determined by the Bogue method are given in Tables 1 and 2 respectively.

2.1.2. The natural pozzolana

The used natural pozzolana is of volcanic origin extracted from the Bouhamidi deposit located south of Beni-Saf in Algeria.

The chemical composition of the natural pozzolan after grinding is shown in Table 3.

The Blaine specific surface area of the used natural pozzolana is: SSB = 4330 cm²/g.

Its absolute density is $\rho = 2.45 \text{ g}/\text{cm}^3$.

Natural pozzolan was analyzed by XRD ,The X-ray elemental spectra of natural pozzolan obtained by Scanning Electron Microscopy/Energy Dispersive. X-ray analysis confirm the presence of large amounts of silica (Si), moderate amounts of alumina (Al), minor amounts of alkali metals (Na) , and some traces of iron (Fe) and calcium (Ca). The mineralogical composition of NP was determined by X-ray diffraction (XRD), and it is depicted in Fig. 1. According to the XRD data, natural pozzolan contains crystalline minerals and a glassy phase. Based on the XRD peak intensities, it is easy to deduce that pozzolan consists of:

Prevalence of zeolite (analcime: $\text{NaAlSi}_2\text{O}_6 \cdot \text{H}_2\text{O}$ and cordierite: $2\text{MgO} \cdot 2\text{Al}_2\text{O}_3 \cdot 5\text{SiO}_2$);

Feldspar (plagioclase including albite: $\text{NaAlSi}_3\text{O}_8$ and anorthite: $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{SiO}_2$);

pyroxene (augite: $(\text{Mg}, \text{Fe})_2 \cdot 2\text{SiO}_6$);

Cristobalite: SiO_2 ;

Illite: $(\text{K}, \text{H}_3\text{O})(\text{Al}, \text{Mg}, \text{Fe})_2(\text{Si}, \text{Al})_4\text{O}_{10}[(\text{OH})_2, (\text{H}_2\text{O})]$.

2.1.3. The perlite

The used perlite is a siliceous volcanic rock [27]. The rock is first crushed and calibrated by granulometry. It was extracted from the deposit of Hammem Boughrara located in Tlemcen, Algeria. The industrial expansion of perlite is carried out by EFISOL in special furnaces, fixed or rotary [28]. Under the effect of heat, the grains of perlite expand: a multitude of closed cells are formed inside the grains. The perlite is used in the form of a sifted powder at 80 μm in all tests [29]. The chemical composition of the crushed perlite and the XRD spectrum are shown in Table 4 and Fig. 2, respectively.

The Blaine specific surface area of the used perlite is: SSB = 4060 cm²/g.

Table 2
Mineralogical composition of cement CEM I 42.5 N (%).

C ₃ S	C ₂ S	C ₃ A	C ₄ AF
61.34	14.83	7.04	11.05

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