OPEN ACCESS
Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) |ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://scholarsmepub.com/sjet/

Original Research Article

# Study of the Durability of Pouzzolanic Concrete in the Aggressive Environments

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**DOI:**10.21276/sjeat.2019.4.6.3 | **Received:** 16.06.2019 | **Accepted:** 25.06.2019 | **Published:** 30.06.2019

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## Abstract

The durability of concrete constructions in aggressive media has been studied. We prepared samples of ordinary concrete with different natural pozzolana content of beni-saf as a substitute for cement. The main objective of this experimental work is to study the valorization of the natural pozzolana of beni-saf on the mechanical properties (compressive strength) and the durability of concrete (corrosion) in the aggressive environment. Through experimental results obtained, we conclude that beni-saf's natural pozzolana has a positive effect on mechanical properties and the effect is somewhat acceptable for concrete durability especially in the long run.

**Keywords**: Durability of concrete, Natural pozzolana, Mass variation, Corrosion.



## INTRODUCTION

Concrete is subject to dimensional variations as soon as it is first used without any external loading. These variations are generally of physicochemical, mechanical, thermal and / or hydrous origin of one of its components which is the cement. Pozzolan is a volcanic material, so natural, which exists in considerable quantity in Algeria. Which stretches along 160 km between the Algerian-Moroccan bordé and the Sahel of Oran.

The evaluation of the effect of the pozzolanic reaction on the durability of pozzolanic concretes requires knowledge of the mechanisms likely to lead to its degradation, and the study of the resistance of the material to these degradations. The qualification of the durability of pozzolanic concretes in more or less aggressive media (medium rich in sulphate, chloride medium) is determined by highly relevant and objective performance criteria, based on accelerated laboratory tests according to the ASTM C standards (ASTM C 267-96, 01) [1]. Thus, this durability is quantified by an accelerated corrosion test of pozzolanic concretes for variable pozzolan substitution rates.

The use of Béni-Saf's pozzolan improves the performance of concrete and leads to the creation of a new economical and ecological construction material.

## USED MATERIALS

The materials used for the manufacture of concrete are:

### *Cement*

The cement used in all the tests is a CPA-CEM I 42.5N cement coming from the Zahana cement plant, delivered in a 50 kg bag, with a technical sheet N ° FR-0026LAB Version2 according to the Algerian standard NA442.

Guaranteed minimum resistances at 02 days 08MPa and at 28 days 40,0MPa. The cement and mineralogical chemical compositions of clinker are given in Tables 1 and 2.

**Table-1: Elemental chemical composition of cement CPA-CEM I 42.5N**

| CaO | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $SO_3$ | $K_2O$ | $Na_2O$ | MgO | CaO libre |
|---|---|---|---|---|---|---|---|---|
| 65 | 20,71 | 4 | 7 | 2,72 | 0,41 | 0,13 | 1 | 1,20 |

**Table-2: Mineralogical composition of clinker**

| $C_3S$ | $C_2S$ | $C_3A$ | $C_4AF$ |
|---|---|---|---|
| 51,15 | 25,69 | 2 ,84 | 14,32 |

Blaine's specific surface area of cement is
SSB = 3308 cm² / g.
The absolute density of the anhydrous cement is
ρ= 3,16 g/cm3.

***The natural pozzolana***

The natural pozzolana used ***is*** of volcanic origin extracted from the Bouhamidi deposit located south of Béni-Saf. The deposit is represented by a conical mountain called El-Kalcoul located at the absolute 236 m. This pozzolana is essentially composed of well stratified slags and pumice stones, ranging in color from red to black [5].

The natural pozzolan used in all the tests is in the form of a powder, resulting from crushing pozzolanic slag, baked for 24 hours at a temperature of 50 ° C in order to eliminate their moisture, then crushed until the powder The resultant can pass through a sieve with 80 µm mesh [6].

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

**Table-3: Basic chemical composition of Beni-Saf natural pozzolana**

| CaO | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $SO_3$ | $K_2O$ | $Na_2O$ | MgO | Cl | $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|
| 12,36 | 42,95 | 16,32 | 9,49 | 0,01 | 1,39 | 3,00 | 4,20 | 0,00 | 10,75 |

The specific surface area of Blaine of natural pozzolana is SSB = 4330 cm² / g
The absolute density of natural pozzolana is ρ = 2,45 g/$cm^3$

***Sand***

It is the sea sand of Terga corrected with 40% Sea Sand, 60% Sand of Quarry. The sand is initially prepared to be classified according to the French standard NF P 15-403. This sand is a granular skeleton that has the greatest impact on the qualities of concrete and mortar [4]. It plays a key role by reducing the volume variations, the heat released and the cost price of concrete. It must be clean, do not contain harmful elements.

**Table-4: Physical characteristics of sand**

| **Absolute density (g / $cm^3$)** | **2,64** |
|---|---|
| Apparent density (g / $cm^3$) | 1,44 |
| Sand equivalent (%) | 98,4 |
| Finesse module | 1,80 |
| Coefficient of curvature | 1,20 |
| Coefficient of uniformity | 2,40 |
| Nature of the sand | Quartzeux |

***Aggregates***

In the composition of the concrete, the particle size of 3/8 limestone gravel and 8/15 (Figure 1) were used according to the standard (NFP 15-403).

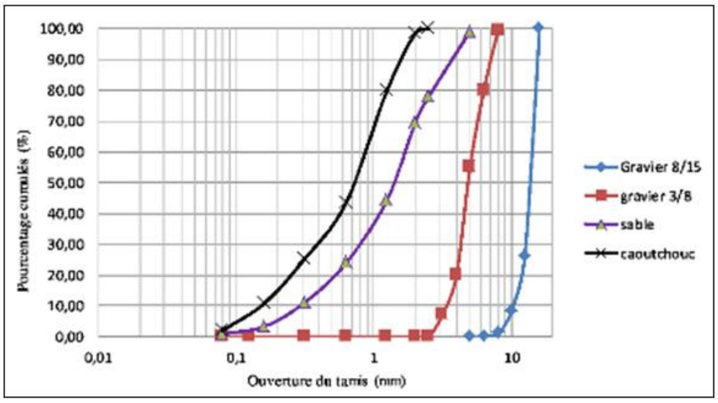


**Fig-1: Grading curves of gravel**

***Mixing water***

The mixing water used for the preparation of mortars is drinking tap water, its chemical composition is illustrated [8] in Table 5.

**Table-5: Chemical analysis of the mixing water**

| Compound | Symbol | Content (mg / l) |
|---|---|---|
| chlorides | Cl | 127 |
| sulfates | $SO_4$ | 190,23 |
| Magnesium | Mg | 54 |
| Calcium | Ca | 86 |
| Carbon dioxide | $CO_2$ | 2,43 |
| bicarbonates | $CO_3H$ | 138 |
| Organic materials | MO | 0,12 |
| Potential hydrogen | pH | 7,50 |

***Steel***

The reinforcements used in the test are 10 mm diameter and 100 mm long high-adhesion steel bars (Figure 2), each bar with two parts; a protected part with a resin the length of 60 mm and the other part exposed to corrosion after putting in the concrete.

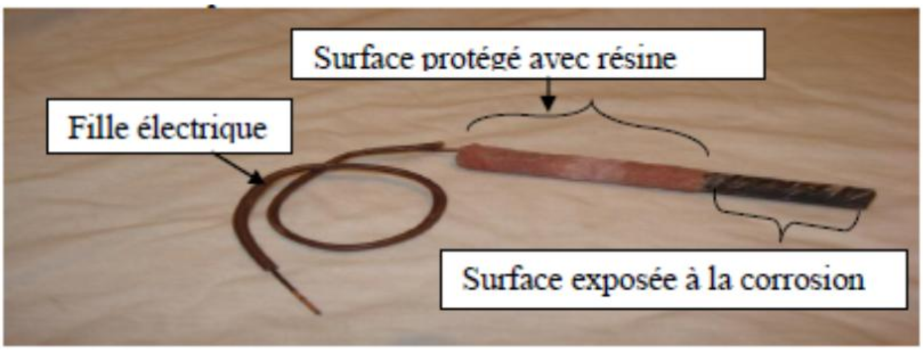


**Fig-2: Steel bar used in concrete**

**Concrete preparation and testing methods**

**Preparation of concretes**

The compositions of the concretes studied are chosen on the basis of economic and environmental criteria. The composition of the control concrete chosen in this study is designed for works in the Oran region in Algeria. Thus four types of concrete were made (Table 6) using the Dreux-Gorisse method. The substitution of 10%, 20% and 30% of the cement with pozzolan leads to the production of three pozzolanic concretes (B10, B20 and B30). For each binder, concrete mixes were made in accordance with ASTM C1012 [05]. Concretes are intended for the manufacture of 70x70x70 mm3 specimens and cylindrical specimens of dimensions; diameter 70mm, length 100mm.

**Table-6: types of concrete made using the Dreux-Gorisse method**

| Component | BT | B10% | B20% | B30% |
|---|---|---|---|---|
| CEM1 42.5 cement | 350 | 315 | 280 | 245 |
| Water | 200 | 200 | 200 | 200 |
| Pozzolan addition | 0 | 35 | 70 | 105 |
| Sea sand | 955 | 964,5 | 963 | 961,5 |
| Limestone gravel 3/8 | 220 | 230 | 228,1 | 227,75 |
| Limestone gravel 8/15 | 636,9 | 613,5 | 613 | 611 |

***Test methods***

To evaluate the durability of concrete and to highlight the influence of the substitution of cement by the natural pozzolan of Béni-Saf. The mass variation monitoring is carried out on the 70x70x70 mm3 cubic specimens for concrete according to ASTM C267 [1], using a 0.001 g precision balance. The variation of the mass is evaluated as follows:

$$\textbf{Mass variation\%} = (M_2\text{-}M_1) / M_1 \times 100$$

$M_1$: the mass of the specimen, before immersion in (g);
$M_2$: the mass of specimen after immersion in (g).

The measurement of the rate of corrosion is a technique most used in the field of non-destructive testing in civil engineering. This method is used to determine the corrosion state of steels in concrete.

Recommendations have been published by ASTM (C876-91) [1] and RILEM TC154-EMC [2].

## RESULTS AND DISCUSSIONS

### *Variation of the mass*

The variation of the mass of cubic specimens of 70x70x70 $mm^3$ concretes preserved in the two distinct environments, namely fresh water and solution of 5% of sodium chlorine and the 5% $Na_2SO_4$ + 5% $MgSO_4$ mixture solution, was carried out according to ASTM C267 standard [1], also followed as the steps of the test specimens of the concretes preserved in previous media.

### *Variation of the mass of concretes preserved in fresh water*

Figure 3 shows the variation of the mass of the specimens of concretes made from different pozzolanic contents as a function of the immersion time in fresh water.

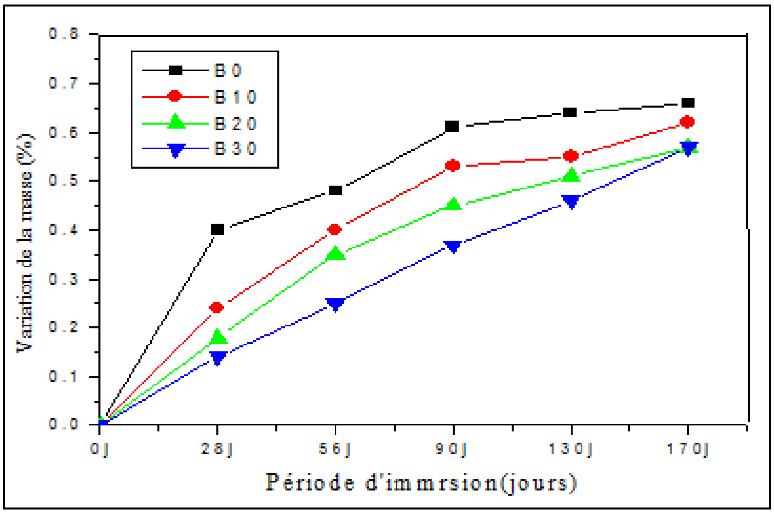


**Fig-3 : Evolution of the variation of submerged mass in freshwater**

There is a permanent increase in the mass of concretes immersed in fresh water. After this period and up to 170 days, it is noted that the increase in the mass of control concrete compared to pozzolanic concrete which becomes lower than that of the control concrete.

Pozzolanic concretes show lower gains than pozzolan-free concrete. This can be attributed to the reduction of the amount of portlandite following the pozzolanic reaction.

### *Variation of the mass of the concretes preserved in the 5% NaCl solution*

The variation of the mass as a function of time of concretes immersed respectively in 5% NaCl (FIG. 4).

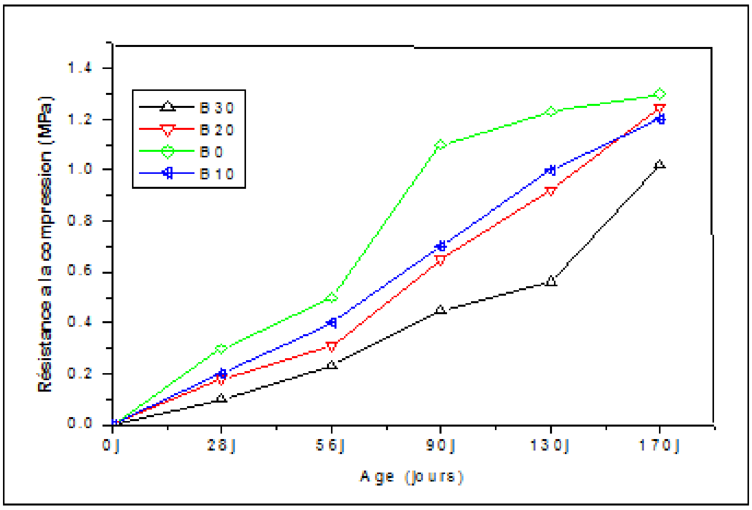


**Fig-4: Evolution of the variation of the immersed mass in the 5% NaCl solution**

We notice a regular increase of the masses of the concretes at the age of 170 days to 28 days of immersion of the specimens in the solution of 5% NaCl the addition of the pozzolane does not have a significant influence on the variation of the masses of the test pieces, from 28 days up to 170 days the increase in the mass of the control concrete compared to natural pozzolana concretes becomes lower than that of the control concretes.

***Variation of the mass of the concretes preserved in the solution 5% Na2SO4 + 5% MgSO4***

A positive change in the mass variation of all the concretes is observed as a function of the immersion time in the 5% Na 2 SO 4 + 5% MgSO 4 solution (FIG. 5). This positive evolution is attributed to the continuity of the formation of hydrates in the various concretes, and to the formation of gypsum and secondary ettringite following the reaction between the hydrates and particularly the portlandite and the sodium sulphates and sulphates. magnesium.

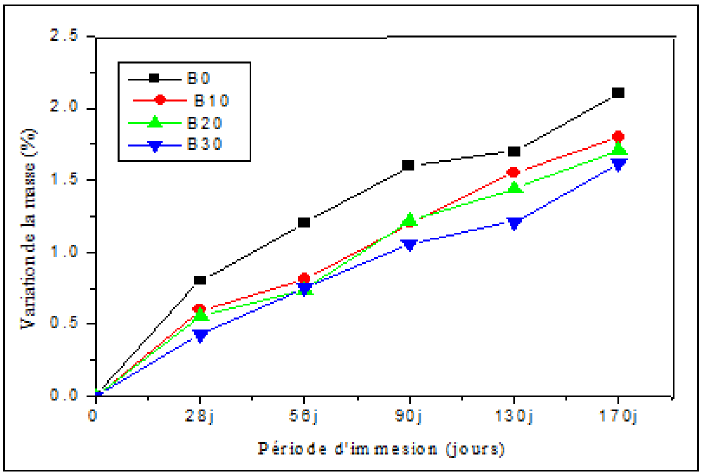


**Fig-5: Evolution of the variation of the immersed mass in the solution 5% Na2SO4 + 5% MgSO4**

We conclude the increase in mass after 170 days of immersion of the various concretes in the three preservation media that the mass gain in the case of immersion in fresh water is lower than the gain measured on the samples immersed in sulphate solutions. Comparing the results of the mass increase of the samples immersed in solution of (5% NaCl) and the solution of the mixture (5% $Na_2SO_4$ + 5% $MgSO_4$), we find that the increase in mass of the solution of the mixture is higher than that of (5% NaCl).

**Corrosion**

Numerous laboratory tests have been carried out of specimens in order to obtain accelerated corrosion. For our work, samples of cylindrical specimens were used. Concretes 70 mm in diameter and 100 mm in length were put directly into the following media:

With fresh water and the 5% $Na_2$ $SO_4$ + 5% $MgSO_4$ solution, was carried out according to RILEM TC-154-EMC standard [2].

The specimens are first partially immersed during cycles (drying-wetting). The cycle equals 20 days of each measurement with the potentiostat device (photo A).

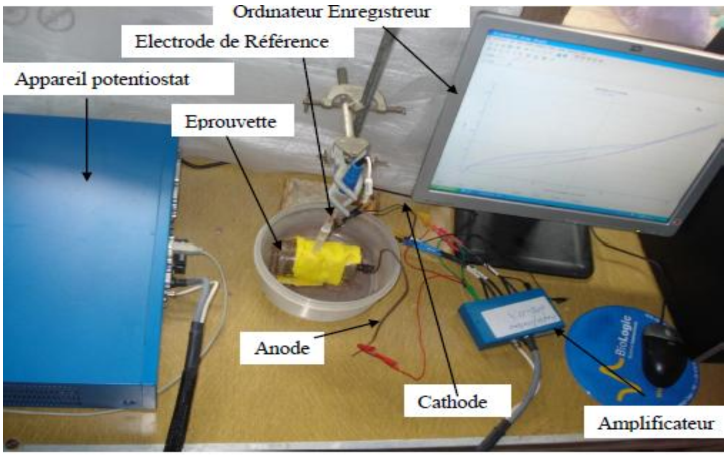


**Photo A. The Potentiostat Device**

**Fig-6 : Illustrates the corrosion rate after 200 days (10 cycles) of immersion of the various concretes in the three preservation media with the potentiostat apparatus:**

- Freshwater
- The solution of (5% NaCL)
- The solution of (5% $Na_2$ $SO_4$ + 5% $MgSO_4$).

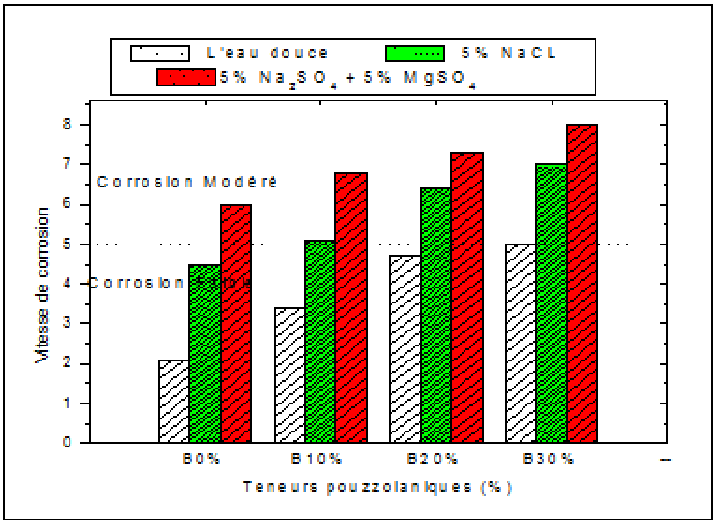


**Fig-6: Corrosion rate of concrete samples to 200 days**

We notice: Fresh water has a weak corrosion of all pozzolanic concretes. In chlorides there is Moderate corrosion. In sulphate solutions there is high corrosion. There is an increase proportional to different pozzolan content in all immersion media, in concretes.

## CONCLUSION

The present work consists in optimizing a composition of a cement by using as an active mineral addition the pozzolan of Beni-Saf (western Algeria).

In order to revalue this local material. We chose to study this natural addition for its pozzolanic responsiveness and for its very low cost. For this, we conducted several experiments focusing on the influence of the amount of addition, as well as its fineness on the mechanical behavior and durability of concrete (mass variation, corrosion rate).

The analysis of the results obtained shows that the addition of pozzolan in optimal quantity (up to 10%) has two essential advantages: a good durability and a better economy. It can be noted that the use of pozzolans in cement works is doubly important, because it allows both energy savings and obtain cements of varied properties.

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