Effect of the perlite and natural pozzolan on the corrosion of armed mortars

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Abstract

This paper discusses the use of natural perlite and pozzolana located in the western Algerian region as a substitute for cement to make mortars with different percentages of pozzolanic addition. In general, their use reduces the consumption of clinker by contributing in a simple and economic way to solve the problems related to the environment.

The study consists of studying the effect of pozzolanic additions on the corrosion of mortars in aggressive media, the implementation of protective processes, the characteristics of the anodes used and the measurement models.

The experimental parameters chosen to highlight the efficiency of various contents of additions of the perlite of Hammem Boghrara and the natural pozolana of Beni saf.

We explain the results of the various tests carried out on mortars made according to the different levels of additions of perlite and pozzolana.

These mortars, developed after a period of saturation in a saturated lime solution, are stored for 300 days in different media : **freshwater and 5% NaCl.**

Potential measurements, current density, polarization resistance and corrosion rate are determined according to the recommendations of ASTM C876-09 and RILEM TC 154-EMC-05. Mortars with reinforcements were followed by drying-wetting cycles in an aggressive medium for various perlite (P: 10%, 20% and 30%) and pozzolan (PZ: 10%, 20% and 30%) and different maturities. The control mortar without perlite and pozzolana will serve as a reference in this study.

The results obtained allow to highlight the effect of the perlite and the pozzolana as substituting for the cement.

Keywords : Perlite, Natural Pozzolan, Mortar, Potential, Current density, Polarization resistance, Corrosion speed

1. Introduction

The additions are at present a part of the most recent developments in the production of the cement, because their uses drive an improvement mechanics properties and their effect on the durability of cimentaires materials (mortar and concrete). On the other hand, contributing in a simple and economic way to solve the problems related to the environment.

Chloride ingress is one of the major causes of reinforced concrete (RC) deterioration. Free chloride induces the corrosion of rebars, reducing the material strength, and therefore, the structural behavior. The importance of measuring chloride content and summarizes the state of non-destructive and in situ techniques for measuring chloride content in concrete structures. These techniques have been developed over the past twenty years, and they have been shown as good alternatives in durability field. They are based on three methods: electrical resistivity (ER), ion selective electrode (ISE) and optical fiber sensors (OFS). [1],

Currently, several research groups are working on developing non-destructive techniques (NDT) to survey or measure chloride ingress in concrete Non-destructive techniques imply methods that do not change the environment and the futures usefulness of the material where the measurement is taken, for example techniques that works with external or embedded equipments [2,3].

Electrochemical measurements of open circuit potential, linear polarization and electrochemical impedance spectroscopy (EIS) were utilized to investigate the corrosion behavior and chloride threshold value (CTV) of reinforcing steels submitted to chloride and sulphate attack in simulated concrete pore solution in this study [4].

Determination of corrosion initiation was made by combining half-cell potential (Ecorr) with corrosion current density (Icorr) as well as EIS curves. Results showed that electrochemical measurements were effective in detecting corrosion behavior of steels [5-6].

This experimental work studies the advantages and the possibility of partial substitution of the cement by pozzolanic addition (perlite, nature pozzolan) in the mortar. This experimental study consists in preparing a mortar by replacing a percentage of cement by adding substituted pozzolanic to various (10%, 20%, 30%). In this study, we want to vary the percentage of the pozzolanic addition in the mortar by the substitution method (partial replacement of the cement by pozzolanic) in order to study its effect on the durability devoted mainly to the corrosion of reinforcements coated by the Mortar in the aggressive medium 5% NaCL, and other samples immersed in fresh water as a control test.

2. Characterizations and Identifications of the used Materials

This section presents the description of the materials used, their identification and characterization to see the sustainable development on test specimens made with additions of substitution of perlite and natural pozzolana and also to observe their influence of immersion in the aggressive circles..

2.1- Cement

We used a cement of type CPA-CEM I 42,5N resulting from the cement works of Lafarge to Msila of Algeria. This cement delivered in 50 kg bag with a data sheet N°FR-0026LAB version 2 according to the Algerian Standard NA442 [7], the minimal resistance guaranteed in 02 days of 08 MPa and in 28 days from 43,0 MPa.

The chemical compositions of the cement and mineralogical of the clinker are given in paintings 1et 2.

Table 1. Elementary chemical composition of the cement CPA-CEM I 42,5N (in %)

CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	K_2O	Na_2O	MgO	CaO freed
64,8	21	4	7	2,71	0,41	0,13	0,9	1,20

The mineralogical composition of the cement is determined by the Bogue method and summarized in Table 2.

2.1.1-Bug Formulas

$$C_3S = 4{,}071(CaO) - 7{,}6(SiO_2) - 6{,}718(Al_2O_3) - 1{,}43(Fe_2O_3) - 2{,}852(SO_3)$$

$$C_2S = 2{,}867S - 0{,}7544C_3S$$

$$C_3A = 2{,}65(Al_2O_3) - 1{,}692(Fe_2O_3)$$

$$C_4AF = 3{,}043(Fe_2O_3)$$

Table 2 Mineralogical composition of clinker

C_3S	C_2S	C_3A	C_4AF
51,30	25,70	2 ,80	14,30

The physical characteristics of cement is the specific surface of Blaine (SSB) the cement is SSB = 3710 cms ²/g, according to the standard NA 231 [8] and the density absolved from some cement anhydre is:: ρ = 3.20 g / cm³ .

2.2- Perlite

This work is currently the subject of a scientific research project on perlite under the code N °: J0405520130018 of the Laboratory of Materials (LABMAT) of the National Polytechnic School, ENPO, Maurice Audin in Oran, Algeria.

Perlite is a siliceous volcanic rock [9], Figure 1. The rock is first crushed and calibrated by granulometry. In appearance, extracted from the Hammam Boughrara deposit located in Tlemcen, Algeria. The industrial expansion of perlite is carried out in special furnaces, fixed or rotary [10]. Under the effect of heat, the grains of the perlite are expanded: a multitude of closed cells are formed inside the grains. Perlite is used as a screened powder at 80 µm in all tests, Figure 2 [11].

Figure 1. Slag perlite Hammam Boughrara

Figure 2. Powder of perlite of Hammam Boughrara grind at 80 µm

The chemical composition of the crushed perlite is shown in Table 3.

Table 3. Basic chemical composition of Hammam Boughrara perlite [12]

CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	K_2O	Na_2O	MgO	Cl	$CaCO_3$
3,16	76,40	13,43	2,92	0,01	4,33	0,82	0,37	0,008	8,75

The Blaine specific surface area of the perlite is: **BSS = 4060 cm^2/g**

The absolute density of perlite is : ρ = **2,80 g/cm^3**

2.3- Natural pozzolana

The natural pozzolana used is of volcanic origin extracted from the Bouhamidi deposit located in Béni-Saf in western Algeria. This pozzolana consists essentially of slag and well-stratified pumice stones, varying in color from red to black [11].

The natural pozzolana used in all the tests is in the form of a powder (FIG. 4), resulting from crushing of the pozzolanic slag (FIG. 3); The pozzolan is steamed for 24 hours at a temperature of 50 ° C to remove moisture and then ground until the resulting powder can pass through a 80 µm mesh screen.

Figure 3. Slag natural pozzolana of Beni-Saf

Figure 4. Powder of natural pozzolana of Beni-Saf grind at 80 µm

The chemical composition of the natural pozzolan after grinding is shown in Table 4.

Table 4. 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 Blaine specific surface area of the natural pozzolana is: **BSS = 4330 cm^2/g**

The absolute density of natural pozzolana is : ρ = **2,45 g/cm^3**

2.4- Spectral analyzes of pozzolanic additions

X-ray diffraction (DRX) mineral analysis of the natural pozzolana of Beni Saf and the Hammam Boughrara deposit perlite are shown in Figure 5.

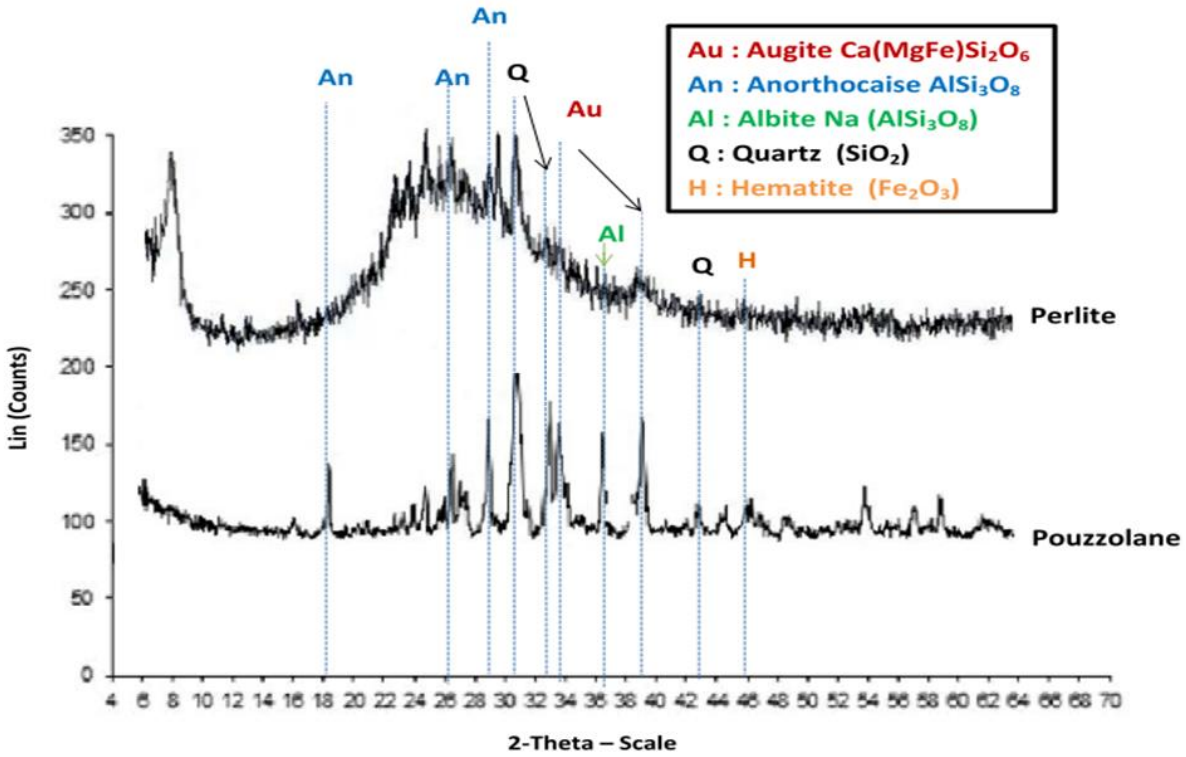


Figure 5. Superposition of the DRX spectra of natural pozzolana and perlite

Figure 5 shows that the results of the X-ray mineral analysis (DRX) of pozzolan and perlite reveal the strong presence of quartz, followed by alumina, then iron oxide and calcite, and some traces of magnesium.

2.5- Frattini test

The preliminary test of evaluation the pozzolanic activity of cement substitute materials is more necessary before making mortars or concretes. The degree of pozzolanic activity of cementitious additions such as perlite and natural pozzolana is obtained using the frattini test ; Which involves chemical titration to determine the concentrations of Ca^{2+} and OH dissolved in solution containing CEM-I and pozzolan or test perlite.

2.5.1- Modus operandi

The procedure specified in EN 196-5 **[13]** was used. Twenty grams of test sample were prepared consisting of 80% CEM-I and 20% of the test pozzolan and mixed with 100 ml of distilled water. After preparation, the samples were left for 8 days in a sealed plastic bottle in an oven at 40 ° C. After 8 days, samples were vacuum filtered through 2.7 µm pore size of the nominal filter paper (Whatman No. 542) and allowed to cool to room temperature in sealed Buchner funnels.

The filtrate [OH] was analyzed by titration of the diluted HCl with a methyl orange color indicator and $[Ca^{2+}]$ by adjusting the pH to 12.5, followed by titration with 0.03 mole per liter, using Patton's EDTA solution and the Reeders indicator **[10]**.

To plot the solubility curve of the lime, the formula given in standard EN 196-5 is used

$$Max[CaO] = 350/([OH]-15) \qquad (1)$$

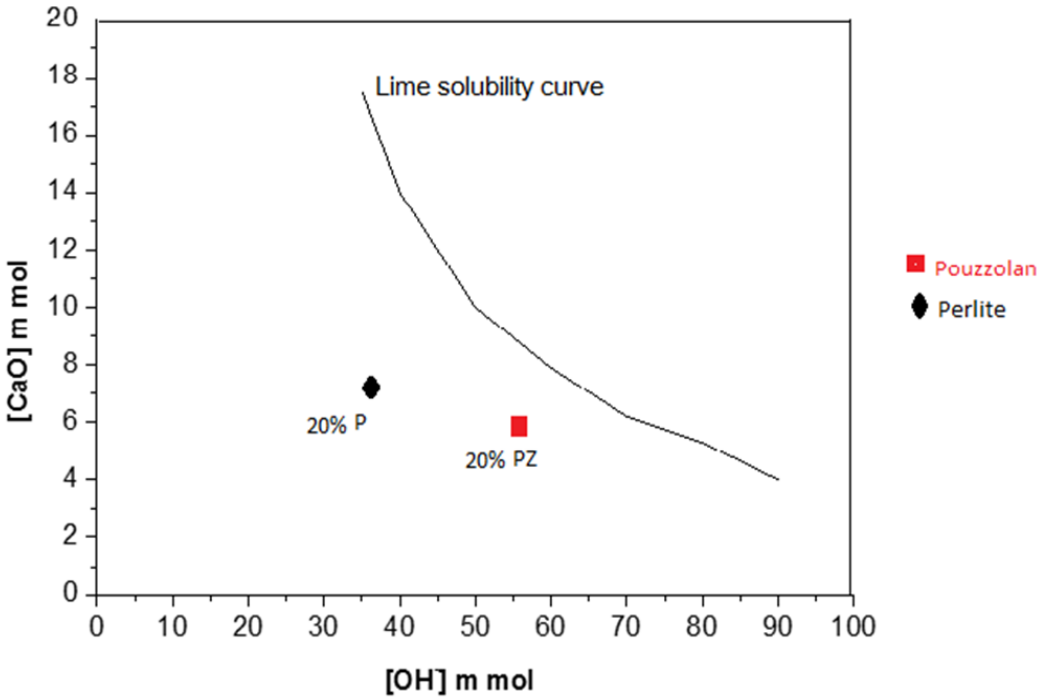


Figure 6. Localization of pozzolanic additions by frattini graph.

The results are presented in graphical form in Figure6: $[Ca^{2+}]$, expressed in CaO_2 equivalents, in 1 mmol / l on the y-axis and as a function of [OH] in 1 mmol / l on the x-axis.

The solubility curve of $Ca(OH)_2$ is plotted for the 100% sample control CEM-I is careful compared to what this result is on the saturation curve itself.
The results of the tests below this line indicate the suppression of Ca^{2+} from the solution which is attributed to the pozzolanic activity. The results on the line provided as a guideline of zero pozzolanic activity and the other results above the line correspond to no pozzolanic activity. It should be noted that this procedure does not assume any other source of soluble calcium that is present in the system.

2.6- The sand

This is the sea sand of Terga corrected with sand quarry. The sand is initially prepared to be classified according to French standards NF P 15-403, its granulometric curve satisfies the reference spindle indicated in Figure 7.
This sand is a granular structure that has the greatest impact on the qualities of concrete and mortar [14]. It plays a vital role in reducing the volume variations, the heat released and the cost of concrete. It must be clean and must contain no harmful elements. The physical characteristics of this sand are given in Table 5.

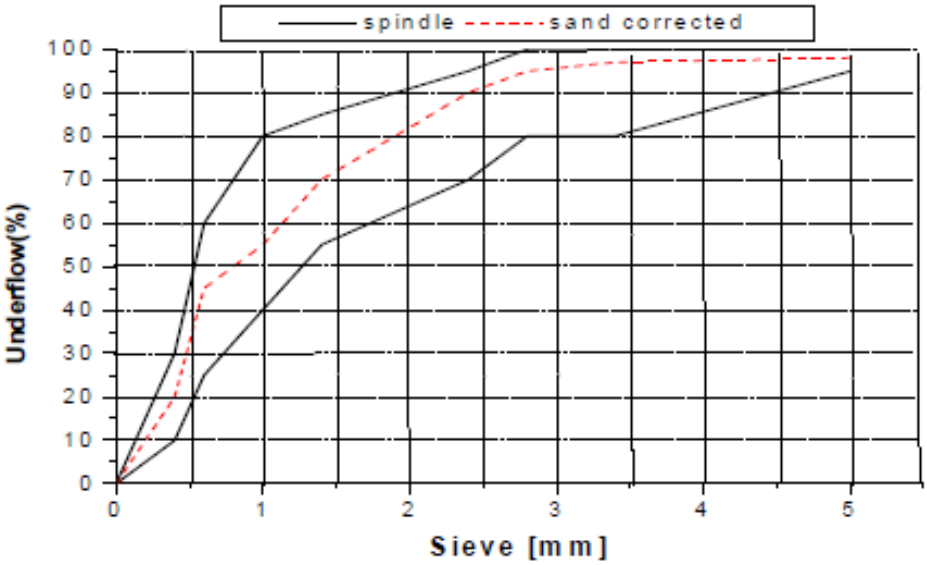


Figure7. Granular sands curve corrected [15]

Table 5. Physical properties of sand used

Characteristics	Sand corrected
Absolute Gravity (g/cm³)	2,69
Apparent Density (g/cm³)	1,42
Equivalent sand (%)	82.36
Fineness modulus (Fm)	2.32
Coefficient of curvature (Cc)	1.03
Coefficient of uniformity (Cu)	9.10
Nature of the sand	Quartz

Was used corrected sand in the formulation to prepare mortars.

2.7-Steel used in mortar

The hardened steel bars (High Adhesion) were used with a diameter of 10mm and 100 mm long, each bar was divided into two parts : One part protected with an epoxy resin to a length of 50 mm and the other part exposed to the corrosion. The bars are integrated into the mortar.

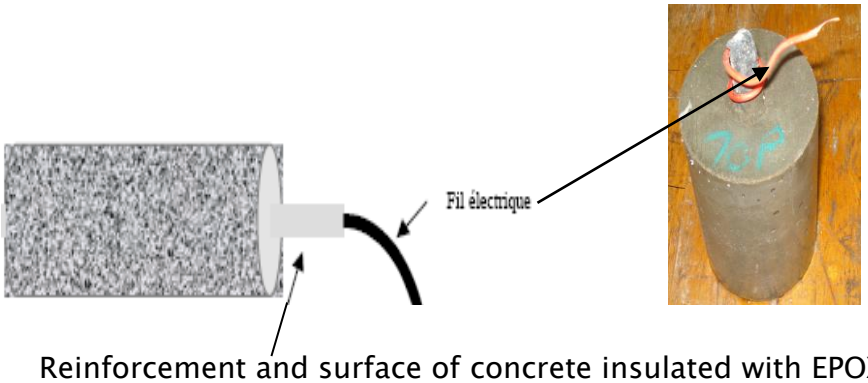


Figure 8. Mortar specimen with rebar

2.8- The mixing water

Drinking water is always usable to spoil the mortar. Chlorides in small proportions may slightly modify the setting and hardening of the cement. On the other hand, the high proportion can react with the cement and compromise the durability of the mortar, their effects are detrimental to the reinforcements whose corrosion causes the mortar to burst.

The norm NF EN 206-1 (NF P 18-325) [16] to fix the maximum quantity of chloride ions.

The mixing water used for the preparation of the mortars is tap water, its chemical composition is illustrated in Table 6.

Table 6. 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
Sodium, Potassium and Nitrates	Na, K, NO_3	0
Carbon dioxide	CO_2	2,43
Bicarbonates	CO_3H	138
Organic matter		0,12
pH=7,50		

Since the values found correspond to those required by the current standard (NF P 18-303) [17], the mixing water is therefore not harmful to its use for the preparation of mortars.

2.9 - Formulation of armed mortars

Mortar mixtures were made from Portland cement CEM I 42,5N and three combinations of binders obtained due to the partial replacement by weight of cement by different pozzolanic additions.

For each binder, mixtures of the mortar were made according to ASTM C1012 **[18]**. The mortars are intended for the manufacture of cylindrical specimens of dimensions ; diameter 50mm and the length of 100mm.

The composition of the mixtures of materials for making the test pieces of the mortars is given in Table 7 with E / L equal to 0.5

Table 7. Composition of mortars in 1m³.

Mortar designation		Natural Pozzolan (Kg)	Perlite (Kg)	Cement (Kg)	Sand (Kg)	Water (L)	Report E /L
M_0	Natural mortar	0	0	450	1350	225	0,50
$M_{10}pz$	Mortar with binary cement	45	0	405	1350	225	0,50
$M_{20}pz$		90	0	360	1350	225	0,50
$M_{30}pz$		135	0	315	1350	225	0,50
$M_{10}p$	Mortar with binary cement	0	45	405	1350	225	0,50
$M_{20}p$		0	90	360	1350	225	0,50
$M_{30}p$		0	135	315	1350	225	0,50
M_5pz_{+5p}	Mortar with ternary cement	22,5	22,5	405	1350	225	0,50
$M_{10}pz_{+10p}$		45	45	360	1350	225	0,50
$M_{15}pz_{+15p}$		67,5	67,5	315	1350	225	0,50

3- Results and discussions

The test methodology of this experimental study is formed from the type of tests in the cured state.
The objective of the various tests conducted for this study is to determine an accelerated corrosion test whose current density is close to the natural corrosion "potentiality" and the emission to be detected of the activity in the mortar due to corrosion.
The corrosion of the cylindrical specimens of the mortars of 60 mm diameter and 100 mm length with a bar of 10 mm diameter immersed in the middle of the mortar and kept in the distinct medium, namely fresh water and 5% NaCl solution, was performed according to ASTM C876-09 [19] and RILEM TC 154-EMC 2005 **[20].**

3.1- Measurement of corrosion potential

The measurement of the corrosion potential can only be carried out on structure with continuous reinforcement and without any surface coating capable of acting as an insulator.

The principle of the test is to expose an armature and then connect it to a terminal of a millivoltmeter with high impedance. A reference electrode is placed on the face itself being connected to another terminal of the millivoltmeter. It is referred to as a reference because it has a constant potential due to an electrochemical equilibrium. The results obtained make it possible to determine the probability of corrosion of the reinforcements.

The simplest way to assess the degree of corrosion of steel is to measure its corrosion potential.

This technique is well known and has been the subject of a process in the American National Standards under the reference ANSI / ASTM C876.

The potential difference between an ordinary portable half-cell, normally constituted by a reference electrode placed on the surface of the mortar on the area exposed to corrosion, is measured and the steel reinforcement underneath is compared results in Table 8 according to ASTM C876-09.

Table 8. Corrosion Probability **[19]**

Corrosion potential mV vs ECS	Corrosion potential mV vs Cu-$CuSO_4$	Probability of corrosion
> - 126	> - 200	Low (<10%)
-126 à - 276	-200 à - 350	uncertain (50%)
< -276	< -350	High (90%)

3.1.1-Immersion in fresh water

Figure9 shows the potential of the specimens of the mortars made based on different pozzolanic contents as a function of the time of immersion in the fresh water.

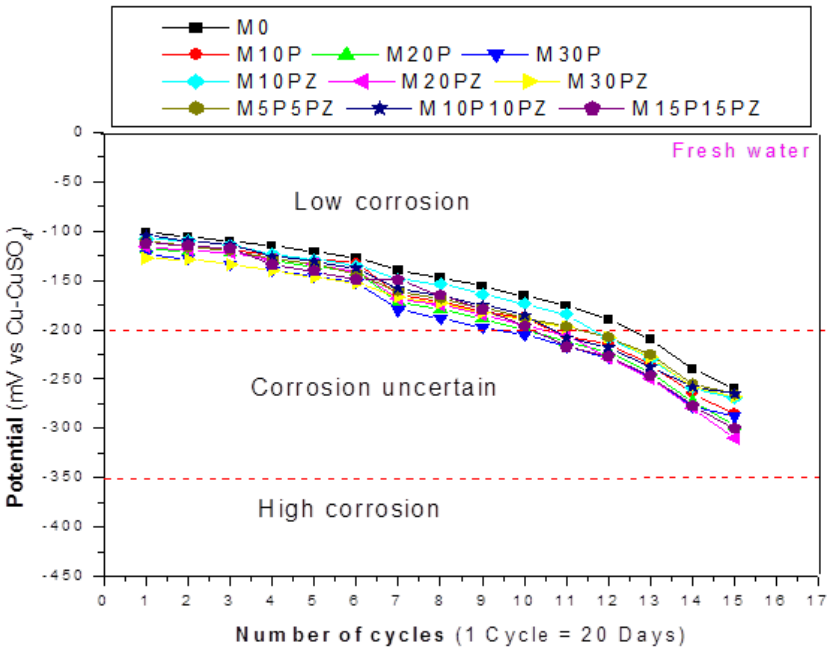


Figure 9. Variation of potential as a function of number of cycles of armed mortars immersed in fresh water

By comparing our values with the values of Table 8, for all mortars : It is found that, starting from the tenth cycle, uncertain corrosion for M20PZ, M30P, M30PZ and M (15P + 15PZ). In fresh water there is no high corrosion for all mortars up to the fifteenth cycle

3.1.2-Immersion in the solution (5 % NaCl)

Figure 10 illustrates the variation in potential as a function of the number of cycles of the mortar with various pozzolanic contents immersed in the 5% sodium chloride solution.

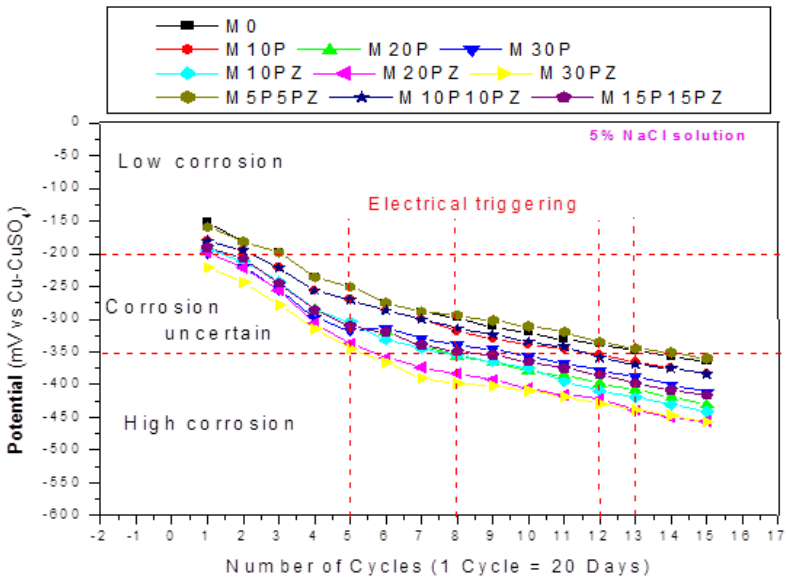


Figure 10. Potential variation as a function of number of cycles of armed mortars immersed in 5% NaCl solution

It can be seen that, as from the fifth cycle, an electrical trigger (high corrosion) for mortar M30PZ; from the eighth cycle for M10PZ, M (15P + 15PZ) and M30P; from Twelfth cycle for M10P and M (10P + 10PZ) and from thirteenth cycle for mortar M0 and M (5P + 5PZ).

3.1.3-Variation of the potential of various pozzolanic mortars at 300 days

Figure 11 illustrates the potential after 300 days of immersion of the various mortars in the two conservation media :

- Fresh water
- Solution of (5% NaCl)

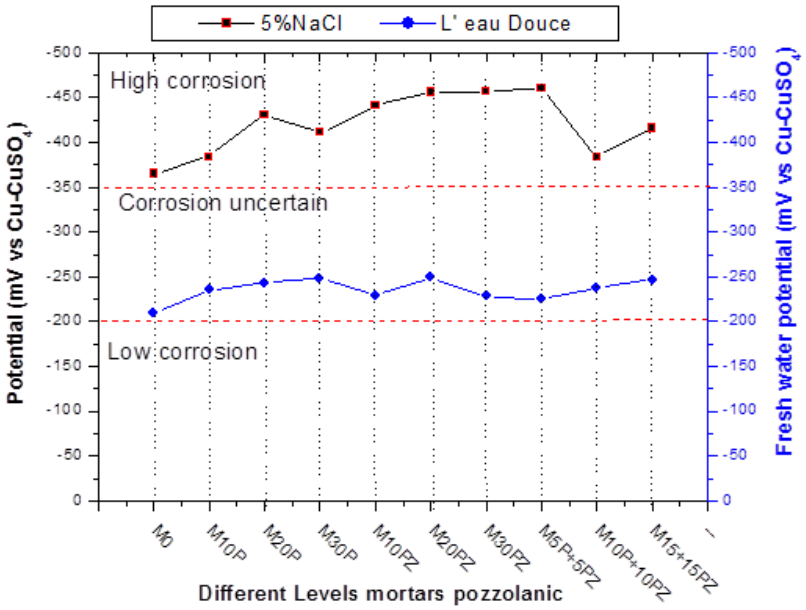


Figure 11. The Potential of the samples of mortars in 300 days.

It is noted that the potential increases when the pozzolan content increases for all the immersion media, but in fresh water there is a low potential relative to the medium of 5% NaCl.

It has been found that:

- In the freshwater environment, uncertain corrosion for all pozzolanic mortars,

- For the medium of 5% NaCl there is a high corrosion.

3.2-Current measurement in (mA)

Firstly, the specimens are partially immersed during the wetting drying cycle.

This cycle is equal to 20 days for each measurement with the apparatus called Multimeter with high accuracy.

Measuring the difference between electrode and against the metal (steel bar) called the current (I) (mA). It is this quantity (I) which is determined by dividing by the area (Cm^2) a current density (i) into ($mA.Cm^{-2}$).

In the case of iron, a current (dissolution) density of 1 $\mu A.Cm^{-2}$ corresponds to a loss of thickness of approximately 10 $\mu m.an^{-1}$ according to the recommendations of the RILEM TC 154-EMC 2005 [20].

3.2.1- Measurement of current in fresh water

Figure 12 shows the variation in the current of the specimens of the mortars made based on different pozzolanic contents as a function of the time of immersion in the fresh water.

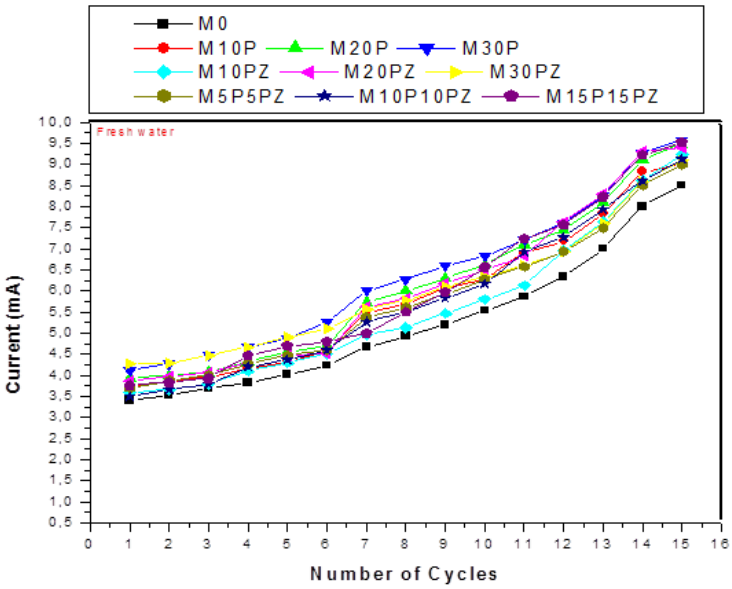


Figure 12. Current variation as a function of number of mortar cycles immersed in fresh water.

Figure 12 shows that there is a steady increase in currents for all pozzolanic mortars and even for the mortar its pozzolanic (control) addition. A low current for the control mortar (M0) compared with the other mortars with the addition of pozzolanic.

3.2.2- Measurement of the current in the solution 5% NaCl

Figure 13 shows the variation of the current as a function of the number of cycles of the pozzolanic mortars immersed in the solution 5% NaCl .

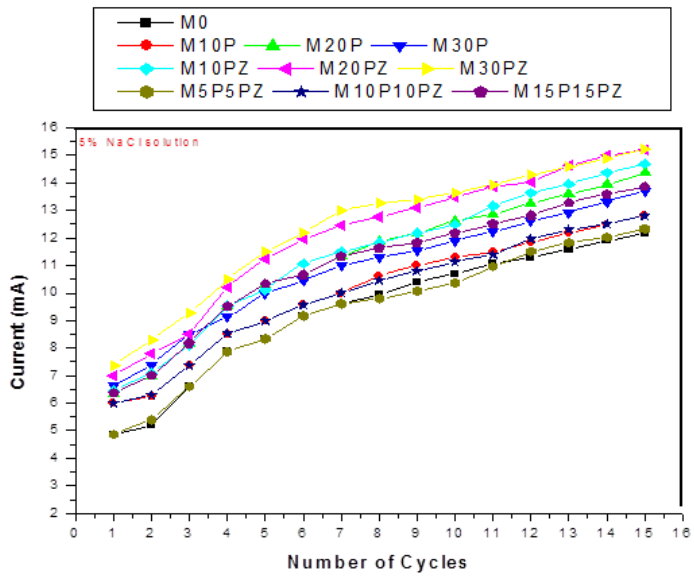


Figure 13. Variation of the current as a function of number of mortar cycles immersed in the solution 5% NaCl.

It is found that the measurements of the mortar currents in the solution of 5% NaCl are higher compared to the other solution. These currents show high corrosion.

- Therefore, the more the current increases the more the potential increases the corrosion is high.

3.2.3- variation of current in the various pozzolanic mortars at 300 days

Figure 14 illustrates the current after 300 days of immersion of the various mortars in the two conservation solution : Fresh water and the solution of (5% NaCl).

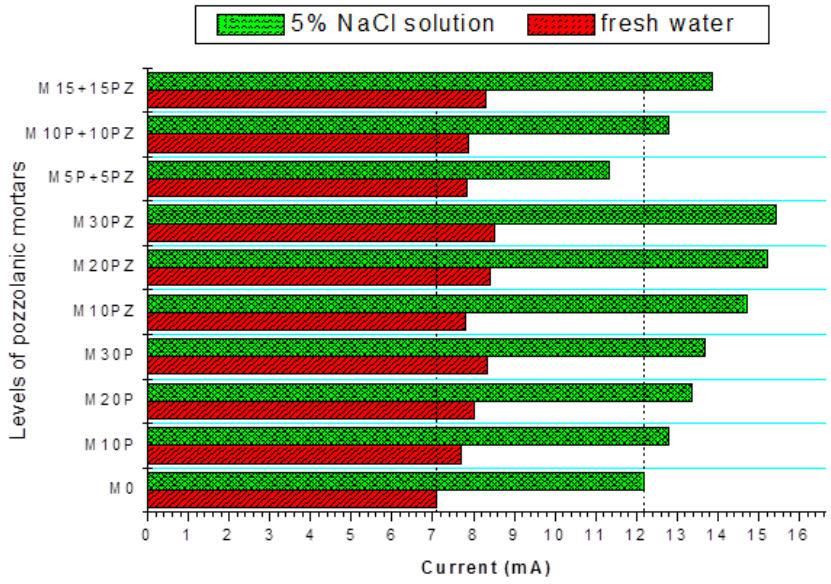


Figure 14. Histogram of currents of mortar samples at 300 days.

It is noted that there is an increase in the current in fresh water for all the mortars containing pozzolana and perlite compared to the control mortar M0. This change in increase varies between 7.10 mA and 8.50 mA. However, in the solution of 5% NaCl a higher current increase is observed by comparing with fresh water, this variation is between 12.17mA and 15.43mA.

3.3-Corrosion speed (Icorr) and the polarization resistance (Rp)

There are 3 main ways to express corrosion rate :

Δe: loss of thickness: $mm.y^{-1}$ (thickness / time)

Δm: mass loss: $mg.cm^{-2}.y^{-1}$ (mass / surface.time)

According to the Faraday law : $\Delta e = (M.i.t)/(n.F)$

i: current density: $\mu A.cm^{-2}$ (current / surface)

To measure the rate of corrosion as a function of the current density, we have the following formula [21]: $V_{corr}\,(mm/y) = 0.0116.i_{corr}\,(\mu A/cm^2)$

The polarization resistance Rp of the armature makes it possible to plot the curve giving the variation ΔE of the potential as a function of the current density i [22]. This is the slope:

$$\left(\frac{d\Delta E}{di}\right)_{i=0}=R_p$$

Depends on the TAFEL formula : $R_p = B/i_{corr}$ or B is a TAFEL constant, B = 26 mV.

The formula for the current density is: : i = I/S

Or S: It is the surface exposed to corrosion, in the making of the specimens the bar immersed in each mortar with an exposed surface: S = 16.48 Cm^2.

According to FIG. 11, a high corrosion is observed for all the mortars in the aggressive medium of 5% NaCl.

For this purpose, the TAFEL diagrams are drawn.

III.5.2.3.2- TAFEL DATA diagrams for the 5% NaCl solution

It is the principle of the Evans diagrams for the determination of a corrosion current density according to the method of TAFEL.

There are ten figures for M0, M10P, M20P, M30P, M10PZ, M20PZ, M30PZ, M5P + 5PZ, M10P + 10PZ, M15P + 15PZ mortars

Figures 15 to 24 represent the potential E as a function of current density Log (i) in the 5% NaCl solution of the 15th Cycle.

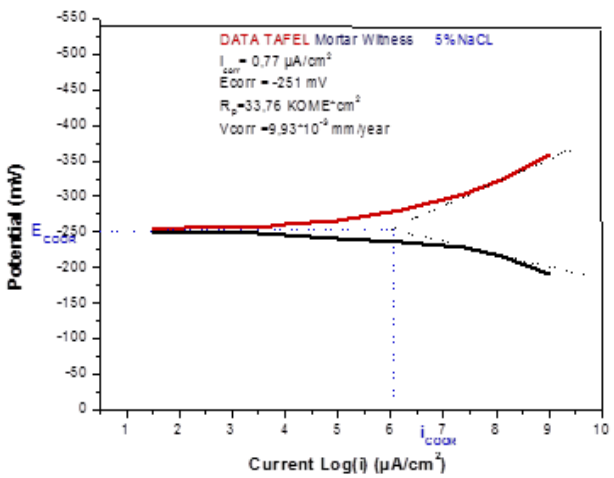


Figure 15. Potential as a function of the density of the reinforced mortar stream M0 in the 5% NaCl solution of the 15th Cycle.

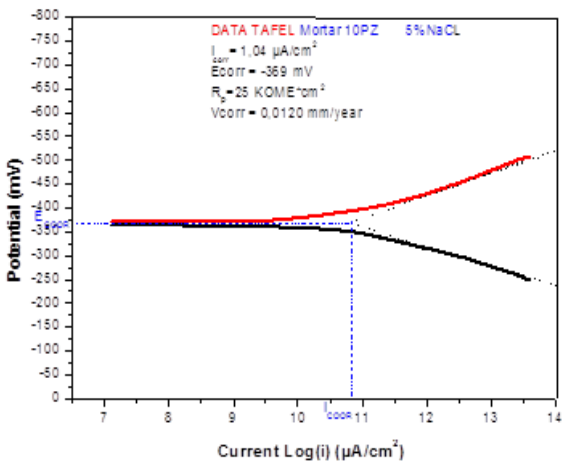


Figure 16. Potential as a function of the density of the reinforced mortar M10PZ in the 5% NaCl solution of the 15th Cycle.

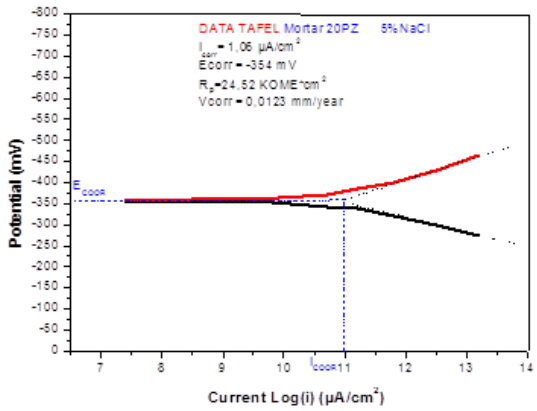


Figure 17. Potential as a function of the density of the reinforced mortar M20PZ in the 5% NaCl solution of the 15th Cycle.

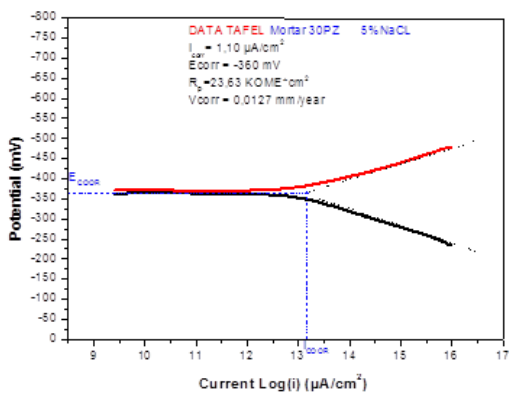


Figure 18. Potential as a function of the density of the reinforced mortar M30PZ in the 5% NaCl solution of the 15th Cycle.

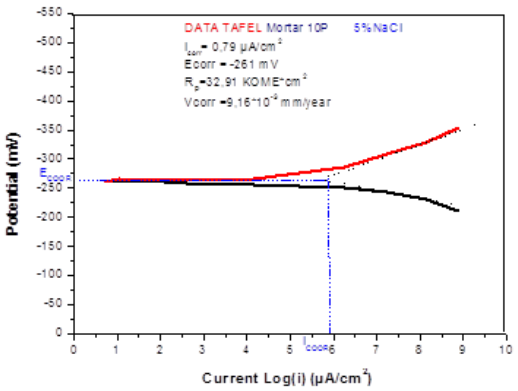


Figure 19. Potential as a function of the density of the reinforced mortar M10P in the 5% NaCl solution of the 15th Cycle.

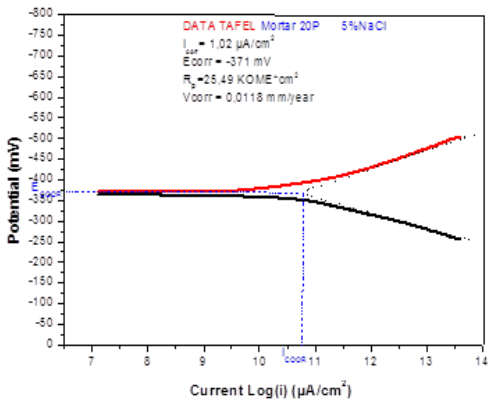


Figure 20. Potential as a function of the density of the reinforced mortar M20P in the 5% NaCl solution of the 15th Cycle.

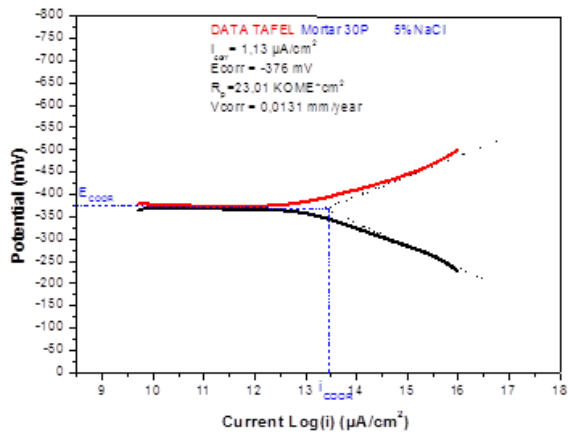


Figure 21. Potential as a function of the density of the reinforced mortar M30P in the 5% NaCl solution of the 15th Cycle.

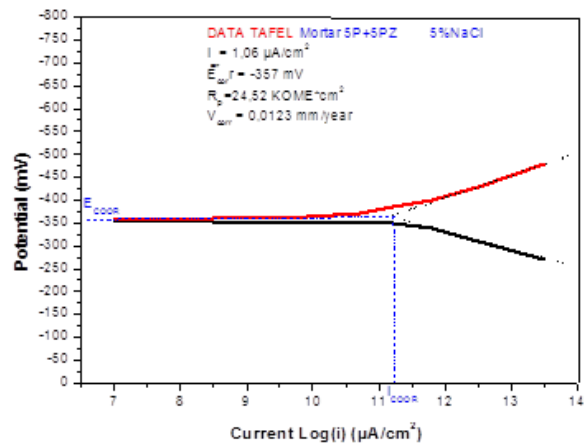


Figure 22. Potential as a function of the density of the reinforced mortar M(5P+5PZ) in the 5% NaCl solution of the 15th Cycle.

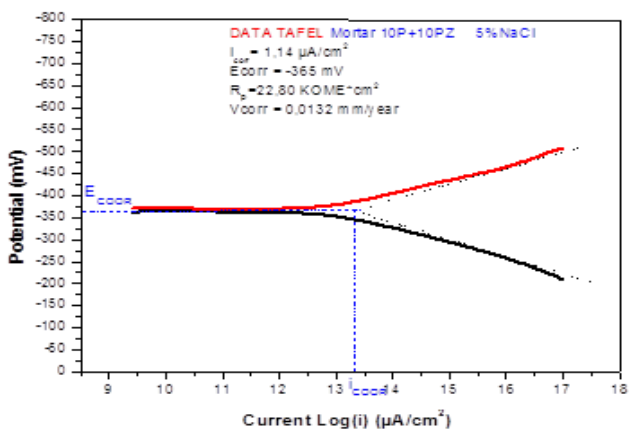


Figure 23. Potential as a function of the density of the reinforced mortar M(10P+10PZ) in the 5% NaCl solution of the 15th Cycle.

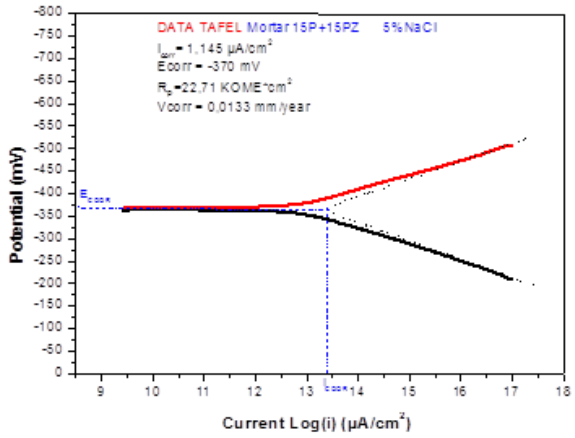


Figure 24. Potential as a function of the density of the reinforced mortar M(15P+15PZ) in the 5% NaCl solution of the 15th Cycle.

The results of the TAFEL DATA Diagrams for the mortars in the 5% NaCl solution of the 15th Cycle are summarized in Table 9 [21].

It has been found that :

- Moderate corrosion for mortars: M0, M10P.

- High corrosion for mortars: M10PZ, M20PZ, M30PZ, M20P, M30P, M (5P + 5PZ) M (10P + 10PZ), M (15P + 15PZ).

If one compares between the most aggressive formulations, one finds a very high corrosion for the pouzolanic mortars. Except for two mortars M0 and M10P where there is moderate corrosion in the solution of 5% NaCl.

Table 9. TAFEL Diagram Results, 5% NaCl Solution

Mortar designation	Current Density icorr (µA/Cm²)	Corrosion potential E_{corr} (mV)	Polarization resistance R_p (KΩ*Cm²)	Corrosion rate (mm/an)	Corrosion level
M_0	0,77	-251	33,76	0,0099	Moderate
$M_{10}pz$	1,04	-369	25,00	0,0120	High
$M_{20}pz$	1,06	-354	24,52	0,0123	High
$M_{30}pz$	1,10	-360	23,63	0,0127	High
$M_{10}p$	0,79	-261	32,91	0,0091	Moderate
$M_{20}p$	1,02	-371	25,49	0,0118	High
$M_{30}p$	1,13	-376	23,01	0,0131	High
M_5pz_{+5p}	1,06	-357	24,52	0,0123	High
$M_{10}pz_{+10p}$	1,14	-365	22,80	0,0132	High
$M_{15}pz_{+15p}$	1,145	-370	22,71	0,0133	High

3.4 - Splitting of the specimens in the medium 5% NaCl

Macroscopic observations were made on the various test pieces and on the steels at the end of the treatment. The most significant photos are shown in Figure 25.

(a) M0 Control mortar in solution 5% NaCl (Uncertain Corrosion)

(b) M10PZ Mortar in solution 5%NaCl (High corrosion)

(c) M20PZ Mortar in solution 5%NaCl (High Corrosion)

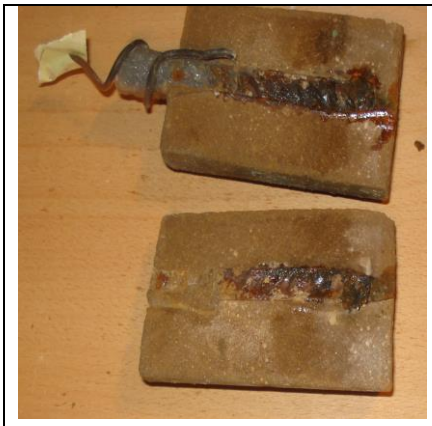
<table>
<tr>
<td> 
(d) M30PZ Mortar in solution 5%NaCl
(High Corrosion)</td>
<td> 
(e) M10P Mortar in solution 5%NaCl
(Uncertain Corrosion)</td>
<td> 
(f) M20P Mortar in solution 5%NaCl
(High Corrosion)</td>
</tr>
<tr>
<td> 
(g) M30P Mortar in solution 5%NaCl
(High Corrosion)</td>
<td> 
(h) M(5P+5PZ) Mortier in solution 5%NaCl
(High Corrosion)</td>
<td> 
(i) M(10P+10PZ) Mortier in solution 5%NaCl
(High Corrosion)</td>
</tr>
<tr>
<td> 
(j) M(15P+15PZ) Mortar in solution 5%NaCl
(High Corrosion)</td>
<td colspan="2">According to the visual appearance of all the ten splits of the mortars, which is shown in FIG. 25 (a), (b) ... up to (j) immersed in the medium 5% NaCl are compatible with the results which found in DATA TAFEL in Table 9

Figure 25. Splitting of mortar details in solution 5% NaCl</td>
</tr>
</table>

By analyzing the above photos, more localized corrosion is observed on the anode armature facing the cathode when these are connected (FIGS. 25 (a) to 25 (j)).

These figures show that, in the case of a higher galvanic current density, more corrosion occurs.
In the case of corrosion without galvanic current, the latter is more uniform and well distributed over the entire periphery of the armature, there are only a few rust points on the anode (mortar), traces of which are visible on the mortar while this corrosion is much greater on the cathode.

Conclusion

In the light of the tests carried out in the framework of this study, we have extracted some numbers of points.
-The major interest that has been at the origin of this study is the possibility of partially substituting an industrial material, cement, for a natural material which is pozzolana and perlite. Both do not have the same cost price. Indeed, natural pozzolana and perlite are natural products and therefore do not pass through industrial processes of expensive energy. They are much cheaper than cement, which goes through very expensive processes.

But, mortars obtained by substitution of cement by materials such as perlite and pozzolan can only be retained if they have physical and chemical performance significantly better than those obtained with the cement alone.
The evaluation of the corrosion processes of reinforcements in the different types of mortars based on pozzolanic additions (natural pozzolana, perlite) in aggressive media show that the potential measurements and the current density were measured by the corrosimeter and the multimeter with an accuracy of (µm / cm^2), the interpretation of the results by DATA TAFEL shows the corrosion rate (loss of thickness, polarization resistance, etc.) to high corrosion of mortars which are immersed in 5% NaCl media .
The indications given by the electrochemical measurements are generally in agreement with the visual examinations.

Symbols

E: Electric potential [mV]
Δe: loss of thickness [$mm.an^{-1}$]
Δm: mass loss [$mg.cm^{-2}.an^{-1}$]
i: current density [$\mu A.cm^{-2}$]
B: Tafel constant [mV]
S: surface exposed to corrosion [Cm^2]
Rp: Polarization resistance [$K\Omega*Cm^2$]
E_{corr}: Corrosion or mixed potential [mV]
I_{corr}: Current corrosion current density [$\mu A.cm^{-2}$]
V_{corr}: Corrosion rate [mm / y] or [µA / cm^2]

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