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THE HYDROCHLORIC ACID EFFECTS ON MODIFIED CEMENT WITH NEW COMBINATIONS BASED ON CALCINED DAM'S MUD AND NATURAL POZZOLAN

Abdelkadir Belghit[1], Nasr Eddine Bouhamou[1], Miloud Hamadache[2,3] and Belkacem Ziregue[1].

1. *Abd el Hamid Ibn Badis University (UMAB), Faculty of Science and Technology, Laboratory of Materials and Construction Process (LMPC), belhacel street 27000, Mostaganem, Algeria, abdelkadir.belghit.etu@univ-mosta.dz; nbouhamou@yahoo.fr; ziregue.kacem@gmail.com.*
2. *National Polytechnic School, Laboratory of Materials (LABMAT), El M'Naouer, Oran, Algeria, hamadache.miloud@yahoo.fr*
3. *Relizane University Center, Department of Civil Engineering, Relizane, Algeria*

ABSTRACT

Reducing the amount of clinker in the cement industry using Supplementary Cementitious Materials (SCMs) is one of the solutions developed by researchers in our field to respect environmental requirements. In the same context, the present work aims to test the feasibility of new combinations using two Algerian SCMs and evaluate their behavior while exposed to hydrochloric acid. To concretize this objective, we fabricated a control mortar (based on cement CEMI) and nine other mortars containing modified cement by a binary and ternary mixtures of Portland Cement CEMI, Calcined Mud of Chorfa Dam, and Natural Pozzolans. All these mixtures were tested at fresh state for consistency and setting time of pastes and at hardened state for apparent density measure, water absorption, and compressive strength of mortars. After that, the ten of them were immersed in hydrochloric acid (HCl) 5% during fifteen weeks (105 days). Then they were examined for mass loss, volume loss, density decrease (apparent density), and visual appearance. The results obtained in most tests showed that the mixtures containing SCMs, especially the ternary mixtures, are realizable, economical, and more advantageous compared to the control mortar with higher water demand and a better behavior after compression and HCl attacks. In the end, we propose the mortars containing ternary mixtures with rates of 10% and 20% to develop new formulations with high performance.

KEYWORDS

Cement, Mortar, Natural Pozzolan, Calcined dam's mud, Hydrochloric acid

INTRODUCTION

To stop the global warming, we should respect the international strategy to reduce CO2 emission in atmosphere, evaluated to 33 Gt in 2021 [1], Alone the cement industry is responsible for 2.2 Gt of world CO2 emission [2] 50 to 60% of this amount is caused by limestone decomposition, and 30 to 40% is due to fuel combustion in kiln factories [3], reducing the quantity of clinker in the cement industry by using supplementary cementitious materials (SCMs) is one of the solutions adopted by researchers to respect environmental requirements [4-5], several sorts of SCMs were discovered by time as natural pozzolan, fly ash, silica fume, granulated blast furnace, limestone, and metakaolin [6], which have diversified the types of cement produced [7-8] and improved their behavior towards the aggressive environment [6,8], this situation gave builders more freedom to choose the quality of cement to use in their structures to withstand different types of exposure [6,8], Algerian regulations authorize the production of 27 cement products [9-10] but in reality, only four products are available in the market [11], natural pozzolan is a material of unaltered or partially altered volcanic origin located in volcanic regions, existing in several deposits in Algeria [6,12] which is currently used as an SCMs in local cement industry, the Beni Saf deposit in Ain Temouchent city has a reserve exceeding 18 million cubic meters [13], on the other hand, several materials have proven their place in this field, among them the calcined mud of some dams in western Algeria (Bouhnifia, Fergoug, and Chorfa), which exist in nature as hydraulic wastes in millions of cubic meters (estimated at 32 million cubic meters per year in 2010) [14], However, it has never been used in the cement industry before. The dredging of these dams periodically - by the National Agency of Dams and Transfer- to recover their storage capacity is very expensive [14]; this operation results in a considerable quantity of wastes stored next to the dams. After being heated at 750°C for 5 hours [15], the calcined mud of Chorfa dam replaces cement by 30%, according to Semcha. A, 2006 [15]; At fresh state is characterized by a decrease in manoeuvrability which increases the water -or admixtures- consumption [15-18], and better compressive strength than natural pozzolan at an early age and long term [17], chemically its high reactive silica content (Sio2) offers the capacity to react with hydrated phases like calcium hydroxide (CH) that produces a second degree of calcium silicate hydrate (CSH) in a pozzolanic reaction, which was reflected in the increase in long-term of the compressive strength after the age of 120 days [16], Both mortar and concrete based on calcined mud have given a higher compressive strength than Portland cement CEMI for rates of 10% and 20% and a similar behavior with CEMI for 30% replacement rate, these results were considered as better than wastes of the other dams (Bouhnifia and Fergoug) [16-18], physically and because of its high finesse at the nano and micro scale, these particles filled concrete microstructure which is favorable for durability [18], the use of the calcined mud from Chorfa dam decreases the heat of the cement hydration and especially for the 20% replacement rate of CEMI cement by CM compared to other replacement rates that are also beneficial for mortars and concrete’s durability [19], the tests done to evaluate the resistance of these sediments against acid attacks were carried out by Safer. O [16] who tested the resistance of ordinary concrete based on cement containing levels of 10%, 20%, and 30% of CM immersed in sulfuric acid and found a similar behavior to CEMI cement, especially for 10% and 20%, the exposure of CM to hydrochloric acid has not been well evaluated, because -in formulations of self-compacting concrete – only Belaribi. O [17] followed the resistance of his formulation containing one replacement rate (20%) by calcined mud of Chorfa dam. It proved a better resistance than the self-compacting concrete control (based on a CEMI cement). On the other hand, natural pozzolan has also shown resistance to acid attacks; explained by the consumption of calcium hydroxide resulting from hydration during the pozzolanic reaction and the filler behavior due to the high finesse of pozzolanic materials [20-21], all cement containing lime is sensible to acid attacks, especially when the pH is less than 3.5 [6], also Mohit. M [22] explained that the resistance of pozzolanic materials is better than ordinary cement exposed to acid solutions by the CH consumption that reacts with HCl and products soluble chloride of calcium CaCl2, which is harmful to the cement matrix and facilitates the decomposition of CSH and calcium aluminate hydrate (CAH).

In the present experimental work, we will test the feasibility of a new combination using two sorts of Algerian SCMs (natural pozzolan “NP” and calcined mud of Chorfa dam “CM”) and evaluate their behavior while exposed to hydrochloric acid.

MATERIALS AND METHODS

Cement

The cement used in the present work is the Portland Cement CEMI 42.5 produced by GICA-Algeria, conform to the Algerian standard NA-442, 2013 [9] that is similar to the European standard NF EN197-1 [7], the physical characteristics are shown in Table1, the chemical composition in

Table 4 and the mineralogical composition of clinker calculated with Bogue formula [6] presented in Table 2.

Natural pozzolan

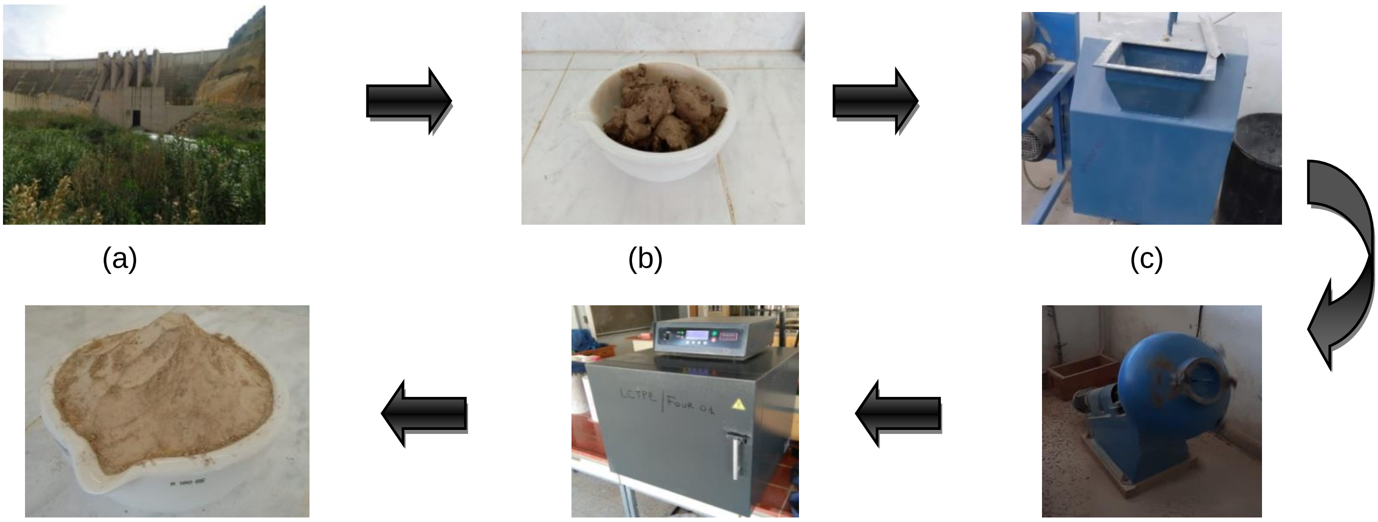
The natural pozzolan used in this work is from the Beni-Saf deposit in Ain Temouchent city in western Algeria (Figure 1-a), recovered from the GICA Oran cement plant, then crushed by a ball mill (Figure 1-b), sieved in 63 µm mesh (Figure1-c) the physical and chemical characteristics are shown in Tables1 and 4.

(a) (b) (c) (d)

Fig. 1 - (a) natural pozzolan, (b) ball mill, (d) sieving of natural pozzolan in 63 µm mesh, (d) natural pozzolan powder ready to use.

Calcined Mud of Chorfa Dam

The mud was extracted from the drain valve of Chorfa Dam (Figure2-a), transported to the laboratory, dried outdoors for a few days (Figure2-b), calibrated in crusher in medium dimensions 15/25 mm (Figure2-c), dried by temperature between (40°-50 C) until water elimination (Figure2-e), crushed by a ball mill (Figure2-f), sieved in 63 µm mesh, then thermally treated in calciner at 750°C during 5 hours, increasing the heating by 5°C/Min- [15] (Figure2-e), the Tables 1 and 4 present physical and chemical characteristics of calcined mud of Chorfa dam.



(a) (b) (c)

(f) (e) (d)

Fig. 2 - Steps of the mud of Chorfa dam calcination (a) Extraction, (b) The mud of Chorfa dam (c) Calibration to 25mm,(d) Grinding, (e) Thermal treatment 750°C,(f) Calcined mud ready to use.

Tab. 1- Technical characteristics of cementitious materials.

properties	Bulk density	Finesse by Blaine method (Cm^2/g)	Pozzolanic activity index« i %»	pH
Cement CEM I	3.14	3285	/	/
Natural pozzolan	2.50	4323	86	8.92
Calcined mud	2.58	7190	92	10.51

Tab. 2 - Mineralogical composition of clinker calculated with Bogue Formula.

Components	C3S (%)	C3A (%)	C2S (%)	C4AF (%)
Cement CEMI	62.22	3.66	12.26	15.15

Aggregates

The present work used two sorts of sand as fine aggregates, natural siliceous sand from Oued El Kheir (Figure 3-a) and crushed limestone sand from Terga (Figure 3-b). Initially, the two sorts were washed in a 63 µm sieve until fine particles were eliminated, with the conservation of fines of crushed sand apart, after the two sorts of sands were dried at a temperature of 105°C during 48 hours until the elimination of water, the results of technical characterization and chemical composition of are shown in Tables 3 and 4, and the particles' size distribution is shown in Figure 4.

(a) (b)

Fig. 3 - (a) Natural sand of Oued El Kheir, (b) Crushed sand of Terga.

As seen in Tables 3, 4, and Figure 4, the crushed sand has a good technical requirement except for the high finesse modulus that equals 3.7. To obtain sand that respects the technical requirements of standardization NF P 18-545 [23], we elaborated a mixture (40% of natural sand and 60% of crushed sand) that modifies the finesse modulus and obtains values of corrected sand equal to 2.8; Figure 4 presents the particles size distribution of the corrected sand, which fits into the acceptance zone described by NF P 545-18.

Tab. 3 - Technical characteristics of Aggregates.

Properties	Bulk density	Finesse modulus	Sand equivalent	prohibited impurities	Absorption Coefficient	Organic matter	pH
Natural sand	2.70	1.48	84.26	None	1.53	0.59	9.53
Crushed sand	2.73	3.70	89.79	None	4.12	0.69	9.95

Tab. 4 - Chemical composition of cementitious materials.

Constituents	SiO_2(%)	Al_2O_3(%)	Fe_2O_3(%)	CaO(%)	Na_2O(%)	K_2O(%)	MgO(%)	So_3(%)	Cl (%)
Cement CEM I	20.72	04.56	4.98	63.24	0.21	0.79	1.82	2.54	0.05
Natural pozzolan	44.33	12.77	11.26	16.48	0.10	0.18	3.62	0.20	0.01
Calcined mud	49.22	12.11	07.23	23.99	0.44	3.22	2.45	0.13	0.00
Natural sand	86.90	0.00	0.39	11.68	0.00	0.00	0.00	0.00	0.0213
Crushed sand	10.89	0.33	0.78	74.77	0.00	0.00	0.00	0.00	0.0284

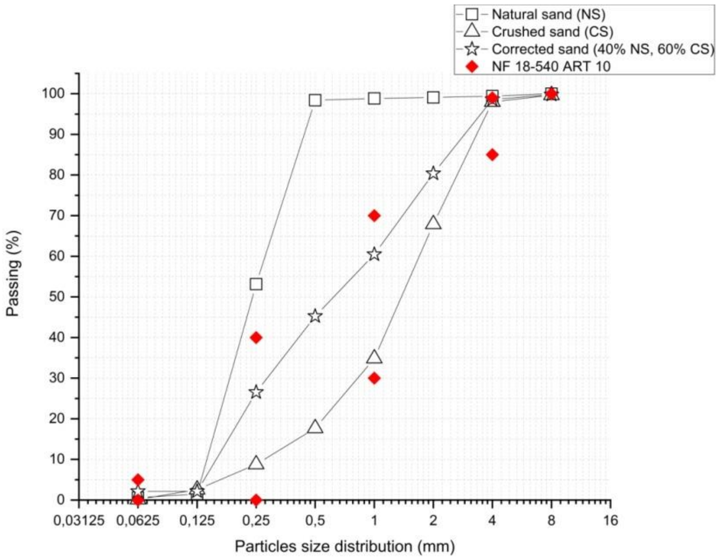


Fig. 4 - Particle size distribution of sands used.

To evaluate the modified cements of our experimental program, ten mortars mixtures were developed according to NF EN 196-1 [25], with three components Sand: Cement : Water by mass proportion 3:1:1/2 respectively for control mortar [24], and for mortars mixtures that contain modified cements, the same mass proportions used previously except the quantity of water that was adjusted using type B workability meter, by similar flow time for all ten mortars in accordance with NF P 18-452 and NF P15-437 [26-27], to insure the exact quantity of water needed for hydration -since we increased the volume by replacing the cement with SCMs grains characterized by a higher surface area-; The mixtures shown in Table 5 were made with normalized mixer "CONTROLAB" with method described in NF 196-1 [24], after the mixtures were casted in prismatic molds 40x40x160 mm and cubic molds 50 mm, compacted in vibrant Table during 30 second for maximum elimination of voids and air bubbles, after the upper surface was smoothed with a trowel, the molds were protected from evaporation by plastic film in the first 24 hours, the samples were demolded and cured in lime saturated water at 20°C temperature, until the day of the test to elaborate.

Tab. 5 - Mortar mixtures.

Types \ composition	Sand (g)	CEMI (g)	CM (g)	NP (g)	Water (g)	E/(C+SCMs)
MC	1350	450	0	0	225	0,5
MM10	1350	405	45	0	229,5	0,51
MM20	1350	360	90	0	240,75	0,535
MM30	1350	315	135	0	247,5	0,55
MP10	1350	405	0	45	227,25	0,505
MP20	1350	360	0	90	236,25	0,525
MP30	1350	315	0	135	243	0,54
MM5P5	1350	405	22,5	22,5	229,5	0,51
MM10P10	1350	360	45	45	238,5	0,53
MM15P15	1350	315	67,5	67,5	245,25	0,545

The prismatic samples 40x40x160 mm were made for compressive strength test [24] and water absorption [32-34], while the cubic samples of 50 mm were fabricated to test the mass loss, volume loss, density decrease [31-32], and visual appearance of the ten mortars exposed to hydrochloric acid HCl 5% [27].

TEST PROCEDURES

The standardized consistency and the setting time tests of pastes were determined by Vicat's needles according to NF EN 196-3 [28], with the initial E/C ratio equal 0.25.

The prismatic specimens of 40x40x160 mm have been cut into two parts of 40x40x80 mm to elaborate the compressive strength test [24]; the mortars were tested by a compressive strength machine "CONTROLAB" that applies a uniaxial force by parallel squares with a surface pressure of 40x40 mm applied on the lateral facets [24].

The apparent density (D) of mortars was calculated by Formula 1 [29-30] with the determination of M and V by a method described below, and (g/cm3); the apparent density measurement schedule is at 3, 7, 14, 28, 56, 90 180 days, the values of M were recorded in gram, V in a cubic centimeter and $\rho water$ in g/cm^3 .

$$D = \frac{M}{V} \times \frac{1}{\rho\ water} \tag{1}$$

The liquid transfer properties of our mortars were tested by the water absorption after immersion, determined on prismatic mortars of 40x40x160 mm at the age of 28 and 180 days, measuring the mass (M) of the samples defined below, then they were subjected to oven 105°C observing the variation in mass every 24 hours until an error of 0.2% between two successive weightings (Md), the values of Md were recorded in gram;

Also, the water absorption (W.A) values after immersion were calculated by Formula 2 [31-32].

$$W.A = \frac{M - Md}{Md} \tag{2}$$

Two cubic specimens of 50 mm of each mortar group were produced and cured in saturated lime water during a maturation period of 90 days, removed from the curing tanks 24 hours before the exposure to acid, and left in open air [16-17]. The cubes were immersed in hydrochloric acid solution HCl 5% (Figure 5), examined for mass loss, volume loss, density decrease, and visual appearance, and were carried out each week; After each weekly examination, the solutions of the acid were renewed [16-17, 21,27].

Fig. 5 - Cubic specimens 50 mm immersed in HCl 5% solution.

On the day of Mass measurement, they were removed from the liquid, wiped by a piece of cloth to remove the excess water, weighed in the open air to obtain the mass of the sample in the saturated state (M). The volume was determined by measuring their masses underwater (Mw) with a mass measurement caliper underwater (Mst) [according to the standardization NF EN 12390-7-[29-30], with the determination of the volume by the following formula (3), with the values of Mst and Mw were recorded in gram and ρ water in g/cm^3;

$$V = \frac{M - [(Mst - Mw) - Mst]}{\rho \ water} \tag{3}$$

The mass and volume loss (X%) of the tested samples were calculated with the (Formula 4);

$$X = \frac{X1 - X2}{X1} \times 100 \tag{4}$$

RESULTS AND DISCUSIONS

Standardized consistency

Figure 6 presents the results of standardized consistency tests of the pastes evaluated. We can see that SCMs used in the present work increase the water demand compared to the control cement, proportionally with the rate of replacement (10%, 20%, and 30%) to reach the standardized consistency, the calcined mud of Chorfa dam consumes more water compared to the natural pozzolan and a similar quantity of water consumption between the NP and the combination CM-NP. This combination of CM-NP decreases the water demand slightly compared to the CM alone.

These results are related to the irregularity form of grains and the finesse of SCMs used compared to cement grains [6,18]. The works carried out by A. Semcha, O. Belarii, O. Safer, K. Belguessmia, and F. Taieb also note that the calcined mud and the natural pozzolan in the replacement of cement reduce the maneuverability of mortars [16-19]. The slight decrease in water consumption by the combination CM-NP is beneficial to develop new economic formulations based on these materials by using admixture to avoid the problem of water demand.

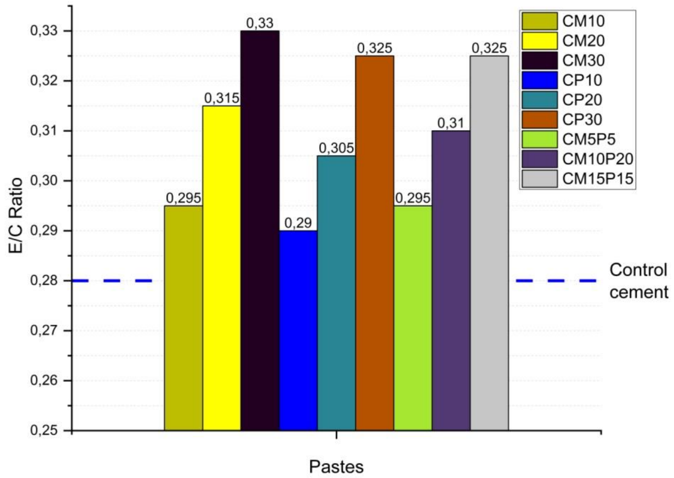


Fig. 6 - E/C Ratio relative to the standardized consistency by the Vicat apparatus.

Setting time tests

The results of the setting time of the ten pastes studied in the present work are shown in Figure 7. The setting times of pastes decrease proportionally with the rate of replacement of cement by SCMs, especially for the calcined mud that records important values. Slightly lower values were saved for the NP's pastes, with the similar behavior between NP and the combinations CM-NP. In general, the use of our SCMs decreases the setting time of pastes slightly, and the results of setting time tests of CM and NP presented in Figure 7 are similar to those cited in literature elaborated by O.Belaribi and O.Safer [16-17]. Also, the new combinations recorded the same behavior (reducing the setting time slightly), which is advantageous for their use in formwork striking times and works in cold weather as natural admixtures.

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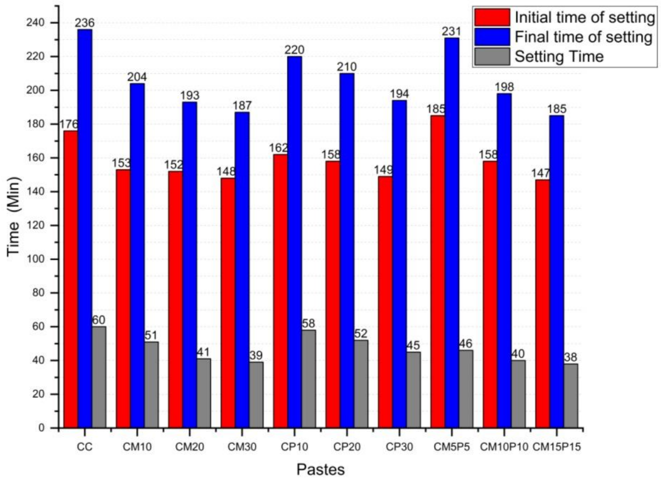


Fig. 7 - Setting time of cement with Vicat's needles.

Compressive strength

The compressive strength (CS) results of the control mortar and the nine mortars that contain modified cement, shown in Figure 8. The results obtained for the order of replacement 10% have very close values of CS compared to the control mortar, especially at long term (In the order of 60 MPA), with an advantage for the combination MM5P5 than the mortars MM10 and MP10; in other hands, at an early age, we note an advantage for MM10 and MM5P5 and a late of CS for MP10.

For the replacement rate with 20% SCMs, we note an advantage for MM20 and MM10P10 at both early age and long term, and the lowest values recorded for MP20, especially at an early age.

The best compressive strength results of mortars containing modified cement with 30% replacement of CEMI with CM and NP are noticed for MM30 (46 MPA), for the combination MM15P15 (42.5 MPA). The lowest results for this rate are saved for MP30 (40 MPA).

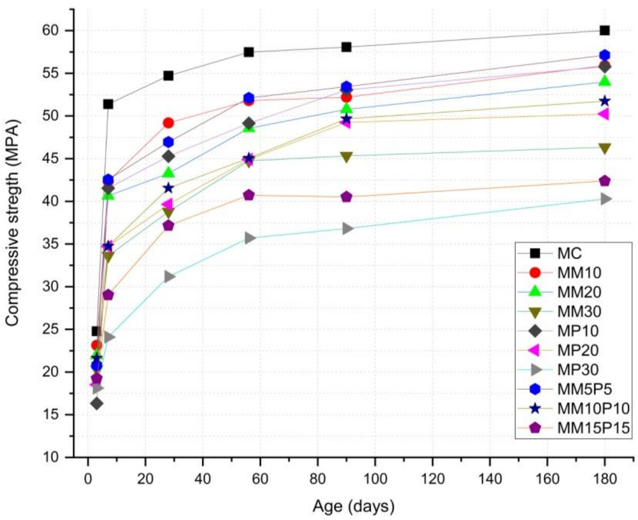


Fig. 8 - The mortar's Compressive strength Results.

These results indicate that CM presents a good pozzolanic reactivity than natural pozzolan, as noted in works cited in the literature [16-19]. However, the strengths of CM did not exceed the results of MC in the long term, as proved in the previous.

These good compressive strength results obtained of mortars containing a combination of CM and NP can be related to the increases the probability of lime and calcium hydroxide reaction by two types of reactive silica with variables degrees of finesse, which explains a higher compressive strength of the combination compared than CM or NP alone, with more reactivity at an early age compared to NP and a similar mechanical behavior at later age.

These results improve the feasibility of the combination between CM and NP, especially for CM5P5 and CM10P10 at an early and later age that is good for the formwork striking times, which encourages us to think about developing new formulations based on these components for the development of high-performance mortars.

The low CS results obtained for mortars contained a rate of replacement of 30%, compared to the results cited previously can be related to the high “E/C” ratio, these formulations can be proposed in masonry and plastering of walls.

These results are not perfectly similar to those of O. Belaribi and O. Safer [16, 17]; for those, the compressive strengths of the mortars containing the calcined mud are better than that of the long-term control mortar. Moreover, this can be explained by the use of superplasticizers, which reduce water consumption, participate in the excellent placement and densification of mortars structures that reduces the porosity of the mortars and increase the compressive strength of the mortars.

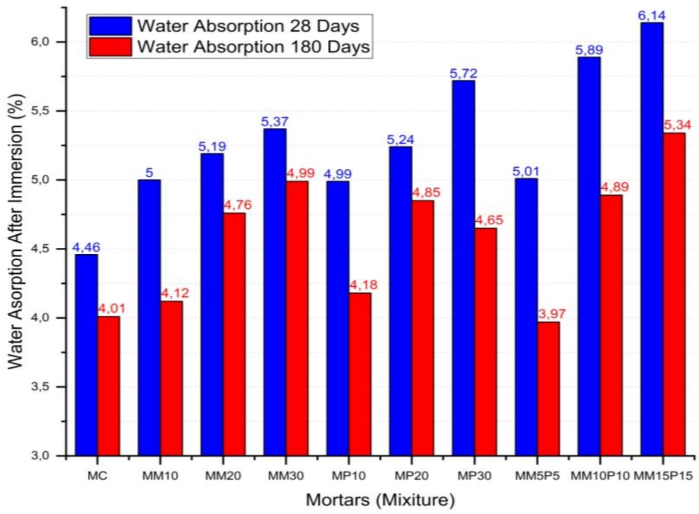


Fig. 9 - Water absorption of mortars after immersion.

Water absorption after immersion

As seen in Figure 9, we noticed that mortars mixtures containing modified cement have a higher water absorption rate than control mortar at an early age due to the high E/C ratio mixtures that increase porosity.

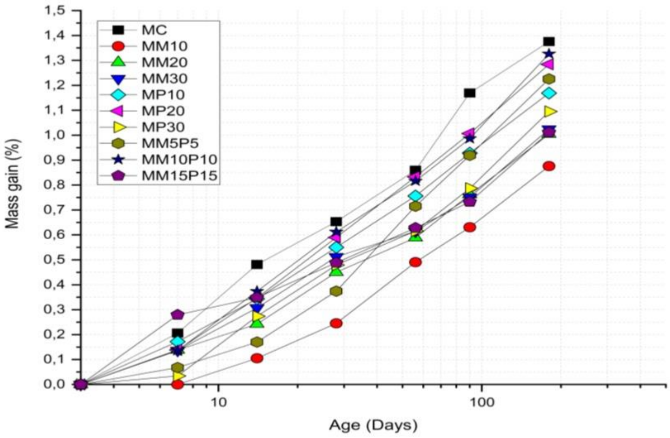
The rates of water absorption decrease in the long term, especially for mortars containing SCMs, which is related to the consumption of lime and calcium hydroxide by reactive silica due to a pozzolanic reaction that fills pores, decrease porosity, higher density and compressive strength, the mortars MM10, MP10, and MM5P5 present similar values to the control mortar with a slight advantage for MM5P5 mortar mixtures.

This test is a simple and good indicator of liquid transfer properties. It confirms the properties mentioned in the bibliography that the particles CM and NP enhance the compacity and decrease the porosity of mortars, which are beneficial for durability and resistance to acid attacks.

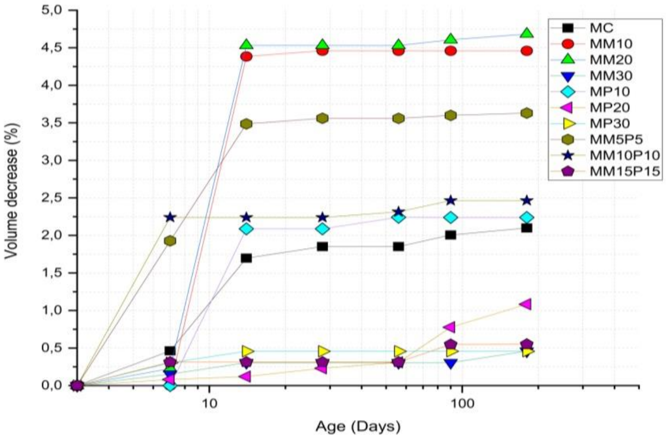
This test has never been developed on these materials and even rare works that have been used on mortars. Compared to the work of R. Aswin Maria Sebal [31], who worked on the water absorption after immersion on the mortars containing the rubber, it obtained higher values than ours, explained by the high mortars' porosity.

Hydrochloric acid attack

In normal curing conditions, the variation mass increases from 0.9% to 1.4% in 180 days and decreases in a volume less than 4.5% that happens in the first ten days, with an increase in apparent density of all mortars between 1% to 5.6% in 180 days (Figure 10).



(a)



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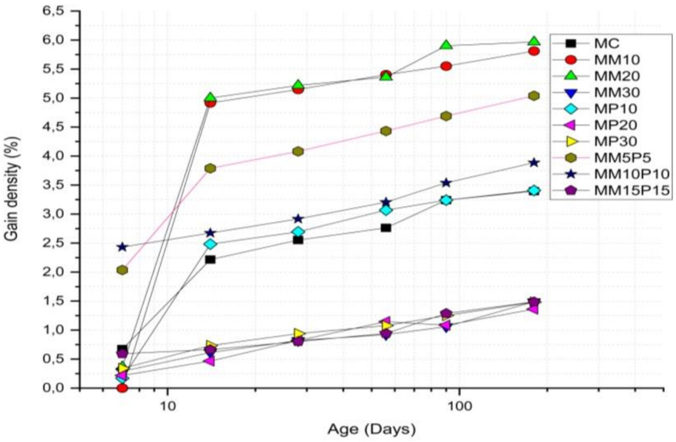

(c)

Fig. 10:- (a) Mass gain in normal curing, (b) Volume loss in normal curing, (c) Density gain of mortars in normal curing.

Figure 11 shows the mass loss of different mortars exposed to acid HCl 5% during 15 weeks; in the first five weeks, MM10, MM20, MP10, MP20, MM5P5 save lower mass loss values than MC, those same mortars continue to resist better than control mortar at the 10th week with MP30, MM10P10, and MP15P15 except MM30 that save a value of mass loss higher than MC. After 15 weeks of exposure to HCl 5%, all mortars containing SCMS resist better than the control mortar, and the best values of mass loss were given by MP20, MP10, MM5P5, MM10, and MM15P15 with values between 33.29% to 40.40 % compared to 58.01% of mass loss of the control mortar (Figure 14).

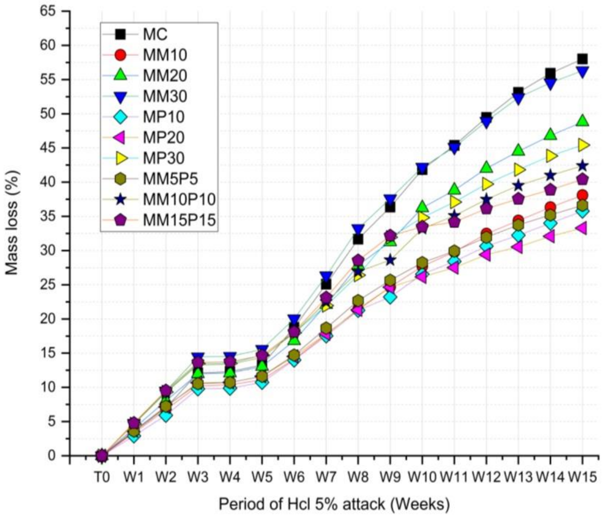

Fig. 11 - Mass loss of mortars exposed to hydrochloric acid 5%.

These results are related to lime and calcium hydroxide consumption, responsible for mass loss after reacting with HCl acid. For mortars with modified cement, especially MP20, MP10, MM5P5, MM10, and MM15P15, lime and CH are better consumed with reactive silica-rich CM and NP, increasing CSH rate and filling pores that delay the HCl attack [6, 22]. This result improves and completes the work of O. Belaribi [17], who used the calcined mud as supplementary cementitious materials to Postpone HCl attack.

The high resistance of natural pozzolana against HCl acid attacks has improved the ability of mortars based on combinations to resist this type of attack. These results agree with other studies conducted by several researchers showing the benefits of natural pozzolan and fly Ash enhancing the resistance to the hydrochloric acid attack [34-35].

We can report that the MM15P15 mortar resists against HCl acid attack despite its low compressive strength (compared to the control mortar), related to its high E/C ratio. To avoid this problem, it suffices to develop this mixture using admixture to reduce the quantity of water and a good particle's placement.

The volume loss of mortars after 15 weeks of exposure with HCl is illustrated in figure 12; we can note that the variation in the volume of mortars is similar to the variation in the mass of the same mortars that improves the results obtained previously.

The reduction in volume is principally due to the reaction between HCl and the CH, which produces a soluble chloride of calcium $CaCl_2$, which is harmful to the cement matrix and facilitates the decomposition of CSH and CAH [22] and secondary to the liquid transfer properties of mortars that facilitates the infiltration of acid into mortars, unlike SCMs-based mortars, this process is slow.

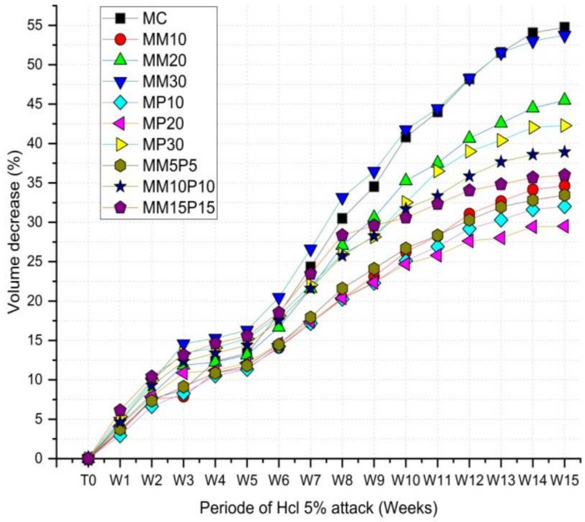

Fig.12 - volume loss of mortars exposed to hydrochloric acid 5%.

Figure 13 presents the results of examination during the exposure to HCl 5% for fifteen weeks. In the first five weeks, the values of density decrease were low, almost stable, after five weeks, we noticed a rise in the rate of density decrease than before, after ten weeks, the rate of density decrease became higher, especially for the control mortar that gave the higher value of density decrease compared to mortars containing modified cement.

These results are principally related to the decomposition of mortar structures that vary from a mortar to another and secondary to the porosity [6]; the mortars MM5P5 present the lowest density decrease value highest values are saved for the mortars MC, MM15P15, and MM20.

The high-density decrease of MM15P15 and MM20 is also due to the high values of water absorption that facilitate the infiltration of acid into mortars and eases the decomposition of CSH and CAH.

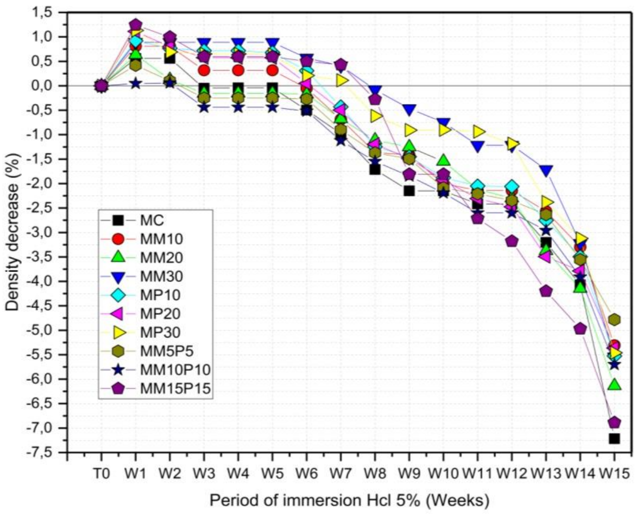

Fig.13 - Density decrease of mortars exposed to hydrochloric acid 5%.

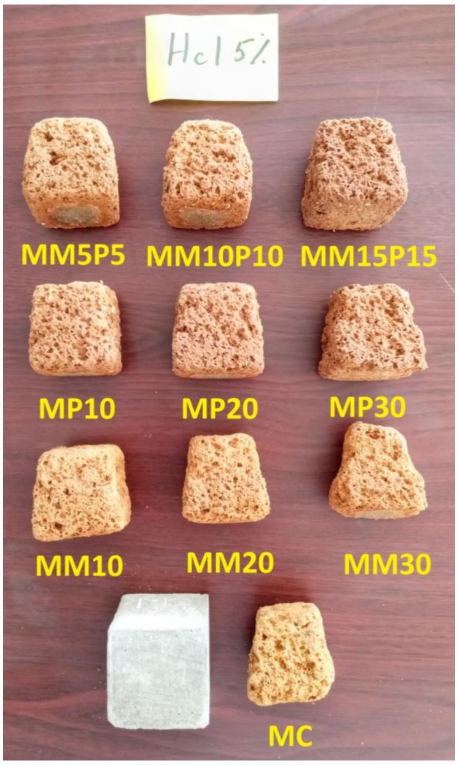

Fig. 14 - The ten mortars after 15 weeks exposed to HCl 5%.

CONCLUSION

At the end of this work, we can summarize it in the following notes:

The calcined mud of the Chorfa dam records a higher water demand than cement grains and is slightly higher than the NP due to the irregularity of CM grains and the higher finesse particles [6, 18], while the combination CM-NP maintains a similar behavior as the NP alone.

The setting time of the pastes containing SCMs used decreases proportionally with the cement replacement rate, especially for CM, which is comparable with the works cited in the literature [16-17], which is beneficial for formwork striking times and concrete works in the cold weather [6]. Also, we note that the combination CM-NP decreases the setting time with similar values compared to NP alone.

The compressive strength results of mortars with SCMs are lower at an early age, especially the NP, and comparable to MC at long term (60 MPA), especially for mortars MM5P5, MW10, MP10, MM10P10, and MW20 (53 to 57 MPA).

At a young age, the combination between calcined mud and natural pozzolan achieves compressive strength values higher than natural pozzolan alone, which is beneficial for fast formwork striking times.

The combination CM-NP is realizable, economic (until 30% of reduction in clinker), and more advantageous, this is due to the variable types of reactive silica of both CM and NP with two finesses degrees, that higher the probability of lime and calcium hydroxide consumption, more than each one of them alone (CM or NP).

Mortar with modified cement has a higher water absorption rate than MC at an early age due to the high E/C ratio that increases porosity. The rates of water absorption decrease in the long term for mortars with SCMs, by filling the voids and compensating the higher porosity noticed at an early age by lime and hydroxide calcium consumption (pozzolanic reaction), higher density, and compressive strength in the long term, that is beneficial for durability [6].

After exposure to HCl 5% until 15 weeks, we notice that the best mortars that showed better mass loss values are MP20, MP10, MM5P5, MM10, and MM15P15, with values between 33.29% to 40.40 % compared to 58.01% of mass loss of MC. This variety is due to the reactive silica's lime and calcium hydroxide consumption rate; for mortars with modified cement, Cao and CH are better consumed with reactive silica-rich CM, increase CSH rate and fill the voids that are beneficial to HCl acid resistance.

The mortars MM5P5 and MM10P10 present comparable compressive strength values than MC and better resistance to HCl attack; we propose that they be developed concrete with high performance.

The MW15P15 is characterized by good resistance to HCl attack. Still, a higher water demand, lower compressive strength, and a higher water absorption rate encourage its development in the future by using admixtures to enhance the compressive strength and decrease porosity.

The variation in the volume of mortars is similar to the mass loss of the same mortars exposed to HCl attacks.

The high results of density decrease of MC, MM15P15, and MM20 are principally related to the decomposition of mortar structures that vary from a mortar to another and are secondary to the high-water absorption [6].

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