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Research Article

EVALUATION OF THE SUSTAINABILITY (ASSESSMENT) OF POZZOLANIC CEMENTS EXPOSED TO CHEMICAL ATTACK

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ABSTRACT

The purpose of this work is to evaluate the performance of formulated pozzolanic cement (clinker, gypsum and calcined clay) by studying mechanism of deterioration of the mortar: acid deterioration.
To do this, we used cubic mortars of 5x5x5 cm^3. After storing the specimens at 28 days in water, they are put in acid solutions of the same concentration 5% (HCl, CH_3COOH). The loss of mass and the loss mechanical strength of the test pieces, as well as the monitoring of the pH reading of each attack solution, are the various tests carried out to study the sustainability of the mortars.
The results obtained make it possible to highlight the beneficial effect of the addition of calcined clay TIT_1 on durability.

INTRODUCTION

Durability is an essential feature for building materials and building elements. In addition, a structure must satisfy, with a constant level, the user's needs over time and withstand the various aggressions or demands (physical, mechanical, chemical, etc.) and the loads to which it is subjected, as well as the actions induced by the wind, the rain, the cold, the heat, the environment ... while maintaining its aestheticism. Moreover, to integrate sustainable development into the construction process, it seems obvious that the cement industry must evolve the constituent materials and their implementation. This can be done by changing the nature of the materials or some of their components, the techniques of developing these materials (less energy, less polluting). The durability of the works made of cement (concrete) is a very important feature, as it ensures the increased safety and service life of these works. This durability also guarantees a long-term economy.

Acidic environment that are likely to be aggressive for the cement matrix start in pure waters, extend to fresh water, little or much loaded with carbon dioxide, then acid rain, to end with the mineral and organic acids, in there including the residuary water [1]. In addition, the waters likely to come into contact with the hardened mortar are essentially natural waters and wastewater in which a large number of chemicals can be found in the dissolved state.

Experimental program

The study is based on the assessment and the qualification of the durability of the mortars to basis of the clay charred TIT_1 opposite the aggressive environment.

Used materials

The clinker

The clinker used is that of the cement plant in Togo, whose chemical and mineralogical composition is given in Table 1.

Table 1 Compositions chemical and mineralogical of the clinker [2]

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	CaO_{Libre}	Total
21.17	5.90	3.90	67.08	1.09	0.19	0.12	0.06	1.98	99.51

Composition mineralogical

C_3S	C_2S	C_3A	C_4AF
66.89	10.59	9.00	11.86

Calcined Clay TIT_1

The clay used is a local clay from Burkina Faso, whose characteristics were previously determined; the clay was calcined at 680 °C for 2 hours to fully benefit from its pozzolanic activity. The material resulting from the calcination

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has been referenced TIT_1. The characteristics of TIT_1 are listed in Tables 2 and 3:

Table 2 Composition chemical of TIT_1 [2]

Oxydes	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	PF_{1000}	Total
% massique	56.74	22.71	10.89	0.26	0.78	0.16	0.26	2.57	91.8

PF_{1000}= loss to fire

Table 3 Some physico-chemical parameters of TIT1 [2]

	Density [$g.cm^3$]	Finesse Blaine [$cm^2.g$]	% amorphous	% CaO Fixed Resistance		Activity Index of Resistance (%)
				1 day	28 days	
TIT_1	2,92	5300	70,5	58	90	81

Gypsum

The gypsum was used to react in the solution with the clinker in order to prevent a quick setting of the cement [3]

Mortar Formulation

For the characterization of chemical resistance to acid attack, mortars intended for the manufacture of test specimens measuring 5x5x5 cm^3 were mixed and prepared according to the procedures of standard NF EN 196-1[4]. The mixing procedure is that recommended in standard NF P 15-403 [5]. The composition of the mortars is reported in Table 4. The amount of water was adjusted to have the same consistency that means the normal consistency. No superplasticizer dosage was retained for all mortars.

Table 4 Composition of mortars [3]

Formulated Cement: (450 g)					CEM II 32.5 R(g)	Sand (g)	Water (mL)	W/C
Mix	Code	Clinker (%)	TIT_1 (%)	Gypsum (%)	-	-	-	-
M20	CP20	75	20	5	-	1350	270	0.60
M30	CP30	65	30	5	-	1350	280	0.62
M40	CP40	55	40	5	-	1350	290	0.64
MT	-	-	-	-	450	1350	240	0.53

W=water; C=cement

The test pieces were made and stored for 28 days in water at a temperature of 20 °C ± 2 °C after demolding. After the curing time under water of 28 days, the test pieces are weighed to determine the mass of the mortar samples before putting them in the following different solutions:

- 5% hydrochloric acid (HCl: strong acid and mineral), an equivalent concentration of 1.62 M;
- 5% acetic acid (CH_3COOH: weak acid and organic), equivalent concentration of 0.87 M.

All submerged mortars are all covered with approximately 2 cm of acid solution.

The experimental procedure consists of studying the behavior of cement mortar specimens exposed to acid attack during immersion time (1, 7, 14 and 28 days). The physical, chemical and mechanical modifications of cement mortars are analyzed throughout the immersion in acid solution. A comparison between samples degraded in acid solution and control samples kept safe from carbonation and stored is carried out.

Resistance due to chemical attack of samples immersed in these solutions is evaluated according to ASTM C 267-96 [6]. The specimens are washed 3 times with tap water to remove the weathered mortar and allowed to dry for half an hour (30 minutes). Then we proceed to the weighing of the latter at each test deadline. The scale used is precision 0.01 g. The attack solution is renewed every 7 days. The degree of attack is evaluated by the mass loss (PM) given by the relation:

$$\mathbf{PM}\ (\%) = \frac{M_1 - M_2}{M_1} \mathbf{x\ 100}$$

With $\mathbf{M_1}$, $\mathbf{M_2}$ the masses of the specimens before and after immersion, respectively.

Then at each test deadline, the pH of the immersion solutions was measured using a portable pH meter. Thus, we analyzed the evolution of the pH according to the type of mortars. Finally, for the purpose of a comparative analysis of the mechanical properties of the various specimen mortars with respect to the acid attack, we determined the fall in the compressive strength of the various mortars having stayed in aggressive media after 28 days.

RESULTS AND DISCUSSION

Acid actions

pH monitoring of immersion solutions

Figures 1 and 2 show the evolution of the pH of the immersion solutions (5% HCl, 5% CH_3COOH) mortars M20, M30, M40, MT (control mortar).

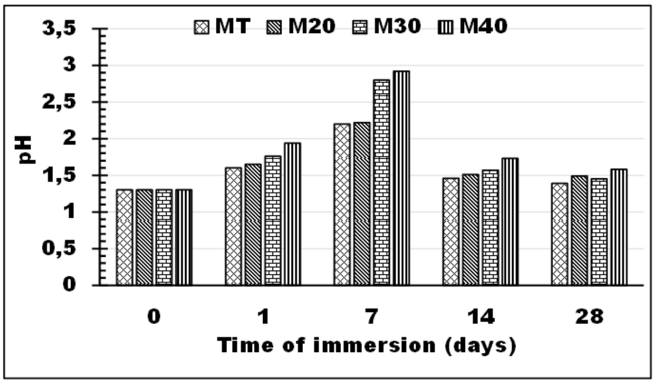

Figure 1 Evolution of the pH of the middle HCl 5% for the mortars of cement

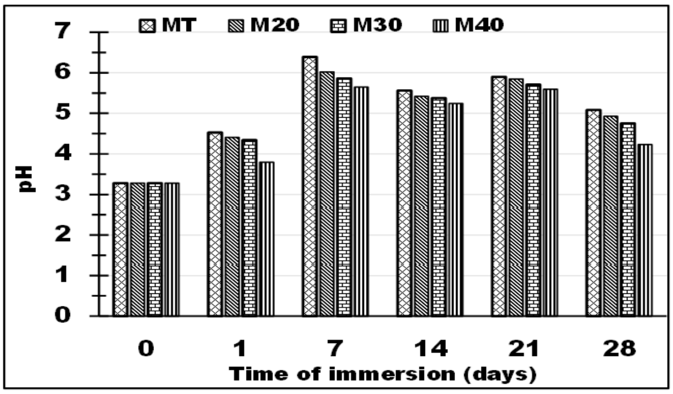

Figure 2 Evolution of the pH of the middle CH_3COOH 5% for the mortars of cement

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With $\mathbf{M_1}$, $\mathbf{M_2}$ the masses of the specimens before and after immersion, respectively.

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RESULTS AND DISCUSSION

Acid actions

pH monitoring of immersion solutions

Figures 1 and 2 show the evolution of the pH of the immersion solutions (5% HCl, 5% CH_3COOH) mortars M20, M30, M40, MT (control mortar).

In general, the attack of acetic acid of all the samples is very weak compared to the attack of hydrochloric acid. Mass losses are generally lower compared to mass losses with HCl. Unlike in the case of HCl, the mass losses of the control are greater than the losses of the formulated cements. This result confirms the previous results on the pH evolution of immersion solutions. Mortars incorporating TIT_1 are more resistant to the CH_3COOH solution than the control.

Mechanical characterization of mortars after acid attack

For the purpose of a comparative analysis of the mechanical properties of the various specimen mortars with respect to the acid attack, we have determined the fall of the compressive strength of the various mortars. Figures 5 and 6 show the compressive strengths of mortars having stayed in aggressive media after 28 days.

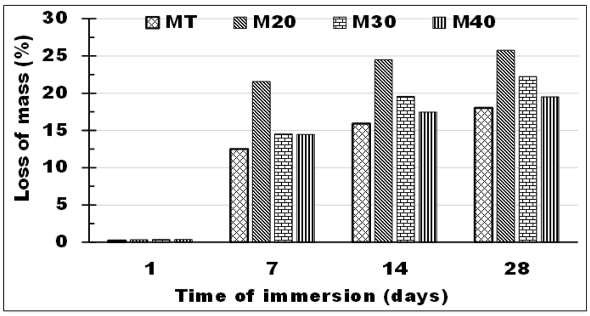

Figure 3 Loss of mass of the mortars having remained in the solution of HCl acid 5%.

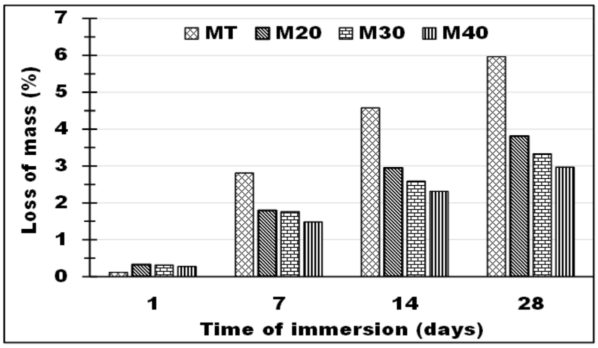

Figure 4 Loss of mass of the mortars having stayed in the solution of CH_3COOH 5%.

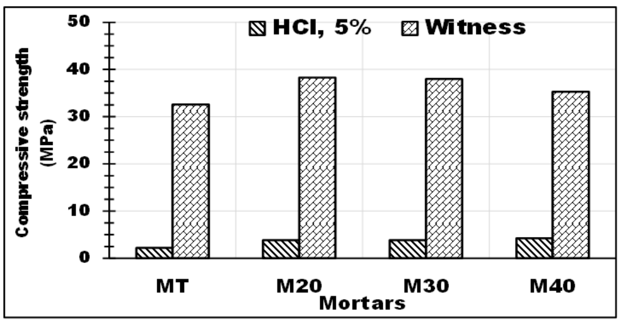

Figure 5 Resistance to compression after 28 days of immersion in 5% HCl solution mortars

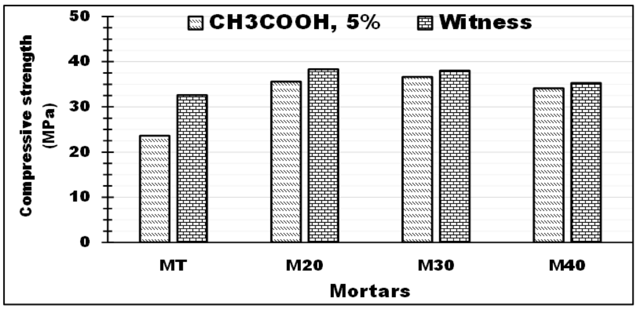

Figure 6 The compressive strength after 28 days of immersion in the CH_3COOH solution 5% of the mortars.

There is a drop in compressive strength for mortar specimens stored in aggressive acid solutions compared to those stored in tap water. The compression strength drops in CH_3COOH medium are significantly lower than those in HCl surrounding. This drop in resistance is certainly due to the deterioration of the mortar caused by leaching and decalcification of the mortars. The drop in resistance and the marked degradation observed on the mortars having stayed in the aggressive surroundings are thus linked to the dissolution, at least partial, of the CSH and of the portlandite (constituting the hydrated phase majority of the cement matrix) which are at the origin of the mechanical strength of the mortar. These results are in conformity with the states of the mortars before and after immersion in the aggressive solutions. Several authors that the phenomenon of leaching, which is of physicochemical origin, leads to a fall in the mechanical properties: resistance to bending and compression [9-11]. The dissolution of portlandite has a considerable influence on the strength and modulus of the hardened cement paste. The leaching of the cementitious matrix is a slow reaction manifested by the dissolution of portlandite and C-S-H leading to mortar damage. In general, the compressive strength drops are of the order: M40 < M30 < M20 < MT.

CONCLUSION

At the end of this campaign to evaluate the durability of the studied cements, we have observed:

- The drop in compressive strength and the clear degradation of the mortars having stayed in aggressive surroundings (acids);
- The degradation of mortars assimilated to a progression of a dissolution front which is accompanied by a variation of pH, and the progression of the degradation which results in the advance of dissolving fronts observable by colored pH indicators;
- The decalcification of the mortar dragging a loss of mass and a general embrittlement of the material;
- The mortars incorporating TIT_1 are more resistant to the CH_3COOH solution than the control (CEM II 32.5 R);

In sum, the contribution of calcined clay (TIT_1) is beneficial to the durability of the formulated cements. Particles of TIT_1 contribute by their presence to maintain resistance to degradation of formulated cement materials.

References

1. Duval R., Hornain H., the durability of the concrete opposite the aggressive waters. THE DURABILITY OF THE CONCRETES. Presses of the national school of the Bridges and Pavement, Paris, 1997.

Under the direction of Jacques BARON and Jean-Pierre OLLIVIER
2. François Ganon, Adama Yameogo, Brahima Sorgho, Lamine Zerbo, Mohamed Seynou, Younoussa Millogo, Raguilnaba Ouedraogo, Preparation of pozzolan with a raw clay material from burkina faso. Scientific Study & Research Chemistry & Chemical Engineering, Biotechnology, Food, 2015; 16 (4): 371 – 383.
3. François GANON, Ouanmini BOBET, Alain Ignassou DJINET, Mianpereum TARKODJIEL, Implementation of pozzolanic cement based on activated natural clay (ecocement): technical challenges and normative aspect, Int. J. Biol. Chem. Sci. 2022; 16 (5): 2372-2383,
4. AFNOR, NF EN 196-1. « Methods of testing cement - Partie 1: Determination of mechanical strength », 2006. sagaweb.
5. AFNOR, NF P 15 – 403. « Normal sand and normal mortar », 2006.
6. ASTM C 267-96. Standard Test Methods for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacings and Polymer Concretes, October 2001.
7. Baron J., Ollivier J.P., The durability of the Concretes, Presses of the national school of the bridges and pavements, Paris, 1992.
8. Mainguy M., Tognazzi C., Torrenti, J.-M., Adenot F. Modelling of leaching in pure cement paste and mortar. Cement and Concrete Research, 2000; 30: 83–90.
9. Carde C., "Characterization and modelling of the change of the mechanical properties due to the lixiviation of the cimentitious materials ". Thesis of the University of Toulouse. (France), 1996.
10. Kamali S., « Modelling of the lixiviation of cimentitious materials, application to different cements in different environments ". Thesis of doctorate, Superior Normal School of Cachan (France), 2003.
11. Le Bellego C. Chemistry-mechanical couplings in the structures made of concrete attacked by water: experimental survey and numeric analysis. Thesis of doctorate, Superior Normal School of Cachan, France, 2001.

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