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Effect of mineral additives (natural pozzolana and sand of dunes) by substitution of cement on the performance and durability of mortars

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Abstract. The objective of our work consists of the study of the substitution effects of clinker by mineral additions such as: natural pozzolana (PZ) and the sand of dunes (SD) finely crushed on the mechanical properties and the durability of the mortars worked out according to various combinations containing these additions. The results from this research confirm that the substitution of 20% to 30% of cement APC (Artificial Portland Cement) by additions in binary cement (APC + PZ) or ternary (APC + PZ + SD) contributes positively to the mechanical strength of mortars and resistance to the chemical attacks in various corrosive conditions such as: hydrochloric acid, sulfuric acid and nitric acid.

The mechanical strength of the different variants is comparable to those of the APC. The test results of the weight loss and phenolphthalein shows that the chemical resistance of variants (PZ20) and (PZ20 with SD5) are larger compared to the reference mortar APC and other variants.

This study shows that adding value by substituting a part of clinker. This substitution can save20% to 30% of clinker used for the manufacture of cement; this will have a beneficial effect for cement and economically (less energy spent for the clinker burning).

This study contributes to the protection of the environment as to produce one ton of clinker generates about one ton of$CO_2$is harmful to the atmosphere. Based on our results we will reduce from 20% to30% CO_2gasresponsible for the greenhouse effect.

1. Introduction

The cement is required for the manufacture of concrete [1-2]. In terms of energy needed for its production, cement ranks third all materials, second only to steel and aluminum. According to some studies, the production of one ton of cement generates about one ton of CO2. It is responsible for about 5 % of the emissions of this gas on the planet. This situation should be taken seriously because the concrete is expected to play a role increasingly important in the development and maintenance of human activity. Minimizing the removal of these industrial waste and reduction in resource demand usually has duration of longer than concrete "traditional" life. In addition to providing a very high durability, the ternary cement allows the concrete to be much more impervious to chemical attack [3-4]. Another advantage is that it allows the concrete to continue its mechanical performance even after the normal curing period of 28 days, which is why it is used for construction projects to be particularly durable, such as roads, bridges, tunnels, viaducts, dams and oil platforms [5-6-7-8]. The design of concrete is extremely related to the environment in which it will be exposed during the lifetime of a

structure. Certain ions in an aqueous environment can be detrimental to the hydrated cement and consequently to the integrity of the concrete material [9-10-11].

The first part of this work is devoted to the development of mortars with additions (pozzolana and dune sand finely crushed) by substituting clinker with different percentages. The second part consists in the characterization of different mortars developed. And finally the third part, we are interested to study the durability of these mortars in various aggressive environments [12-13-14-15].

2. Experimental study

In order to demonstrate the influence of mineral additives on the performance and durability of mortars made based Portland cement with mineral additions (pozzolana and dune sand).

2.1. Materials used

Artificial Portland cement (APC); Washed river sand; Sand of dunes and Pozzolana

2.2. Formulation mortars and Confection specimens

We used prismatic specimens 4 x 4 x 16 cm3 according to standard NF EN 196-1 for testing mechanical strength and durability.

- With binary cements: APC + Pouzzolana (PZ) with different percentages (Table1).

Table 1. Different compositions of mortars APC + PZ.

Notation	% of PZ	APC (g)	PZ (g)	River Sand (g)	W/C	Number of test specimens
APC	0%	450	0	1350	0,5	12
PZ10	10%	405	45	1350	0,5	12
PZ20	20%	360	90	1350	0,5	12
PZ30	30%	315	135	1350	0,5	12

- With ternary cement: CPA + Pouzzolane (PZ) + sand dune (SD) with different percentages (Table2).

Table 2. Different compositions of mortars APC + PZ + SD

Notation	% of PZ	%SD	APC (g)	PZ (g)	SD (g)	River Sand (g)	W/C	Number of test specimens
$\mathbf{PZ_{15}SD_5}$	15%	5%	360	67,5	22,5	1350	0,5	06
$\mathbf{PZ_{20}SD_5}$	20%	5%	337,5	90	22,5	1350	0,5	06
$\mathbf{PZ_{20}SD_{10}}$	20%	10%	315	90	45	1350	0,5	06

2.3. Confection procedure

After mixing in the automatic mixer (CONTROLAB), test samples were made according to standard NF EN 196-1 in 4x4x16cm^3 prismatic molds and mechanically compacted using a shock table (CONTROLAB) for 60 shocks applied for 60 seconds. Once leveled, the molds containing the samples are stored in the laboratory environment at a temperature of 20° ± 1°C and a relative humidity of about 55 ± 5%. The demolding is effected after a period of 24hours.

2.4. Durability of mortars

To characterize the chemical resistance, prismatic mortar specimens 4x4x16 cm^3 crafted according to NF EN 196-1; demolded after 24 hours, the samples are stored in the open air laboratory at 20 ± 2° C until to 28 days. After 28 days, we proceeded to test different drying by baking (100-105°C) until constant weight (dry weight) before etching. These specimens were then immersed in different solutions to assess the sustainability of each mortar composition:

Solution of 5% hydrochloric acid (HCl) (PH=2)

- Solution of sulfuric acid (H_2SO_4) diluted to a (PH = 1,45)
- Solution of ammonium nitrate and nitric acid 5 % (PH=2)

The attack due to chemicals specimens immersed in these solutions is evaluated according to ASTM C 267-96.

To assess the degree of degradation by calculating the mass loss of the specimens immersed in various aggressive environments according to time, we adopted the procedure below:

Each 7 days of attack and for a period of 28 days, the samples are cleaned with fresh water to remove the mortar removed altered, dried and stewed until the total elimination of absorbed moisture (the mass becomes constant) at a temperature of 105 °C. The degree of degradation is evaluated by the following formula loss weight:

$$\textbf{Mass loss (\%) = [(M1 -M2) / M1)] x 100}$$

With: **M1**: dry mass of the specimens before immersion
M2: dry mass of the specimens after immersion

3. Results and discussions

3.1. Mechanical properties of mortars

The following table presents the results of mechanical strength of test pieces made up of different combinations.

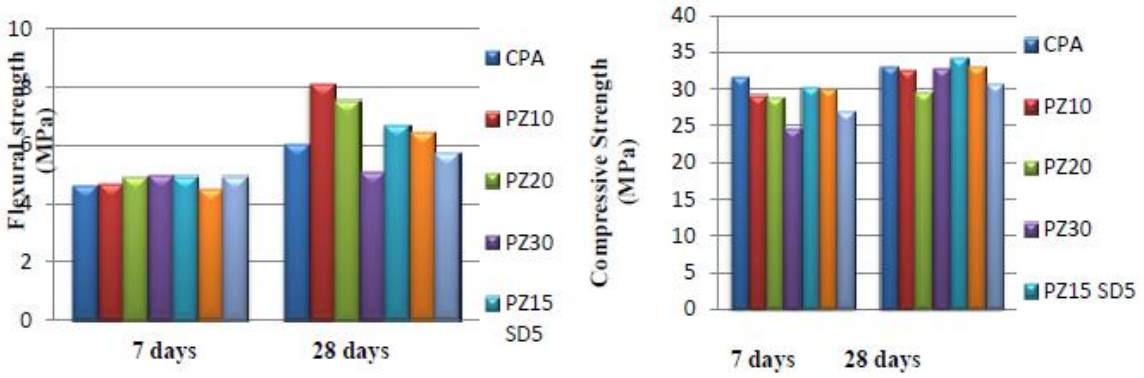

Figure 1. Evaluation of mechanical strengths

The figure shows the effect of substitutions additions rate used on the flexural and compressive strengths of mortars and 7 to 28 days. From this figure we note that the flexural strengths of mortars made with different rates of substitutions pozzolana and sand of dunes are approximate but above resistance control (APC). At 28 days, the resistance has developed except the PZ30. In seven days we observe that the resistances of all mortars of different rates of substitution are approximate resistance mortar control (APC). At 28 days, the resistances are increased especially for mortar (PZ15and SD5).

3.2. Mass loss in different aggressive environments

The following figure shows the histogram comparing weight loss among the three aggressive environments.

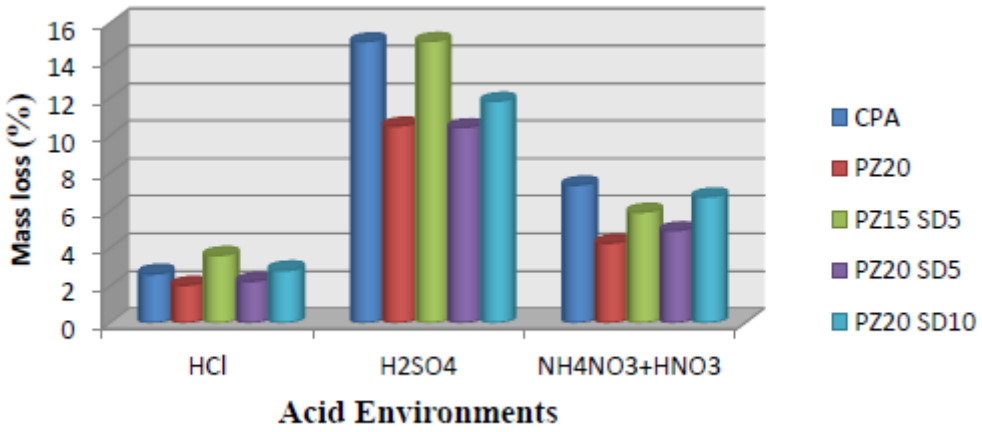

Figure 2. Histogram of mass loss in three different variants aggressive environments

3.3. Determination of the degraded depth

The degraded depths were determined by staining assay with phenolphthalein indicator.

Figure 3. Phenolphthalein indicator staining specimens attacked by HCl, H_2SO_4 and (NH_4NO_3 + HNO_3)

After staining phenolphthalein, one notices the pink color indicates that the basicity of the healthy part (not degraded), so we can determine the depth of degradation by using the measurement of the thickness with a caliper. According to our results, we note that the cement prepared with 20% substitution of pozzolana shows good resistance against the APC and the different variations, this is valid for 3 aggressive environments.

We note that our specimens immersed in various aggressive media for a period of 28 days undergo a much larger degradation in sulfuric acid solution and the depth is greater degradation. As against these specimens are more resistant to the hydrochloric acid solution and the thickness is degraded shallower. It was also noted that the specimens are more resistant (PZ20) and (PZ20 SD5) compared with controls (APC), this is consistent with the results of the resistance mechanically.

4. Conclusion

The study undertaken in this paper indicates that it is possible to exploit deposits of natural resources such as pozzolana and sand dunes to produce the binary and ternary cements in our country. These have compelling interests of technical, economic, environmental and sustainability point of view

towards different chemical attacks. The experimental results conducted through this study allow drawing the following general conclusions:

- The mechanical strengths of the different variants are comparable to APC.
- The test results of the mass loss and phenolphthalein show that the chemical resistance of variants (PZ20) and (PZ20SD5) are larger compared to APC and other variants.
- This study adds value by replacing the addition of a portion of clinker.
- This substitution can save 20% to 30 % of clinker used to manufacture cement; this will have a beneficial effect for cement economic (less energy spent for the clinker burning).
- This study contributes to the protection of the environment as to produce 1 ton of clinker generates about 1 ton of CO2 is harmful to the atmosphere. Based on our findings we will reduce from 20% to 30% CO2 gas responsible for the greenhouse effect.

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