Incorporation of calcined clay as cement addition

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Abstract: *This work is dedicated to the promotion of local materials, the main purpose is the evaluation of a red marl clay abundant in M'sila region. Hitherto used in the production of local pottery, it contains clay components, such as kaolinite and illite. After a thermal analysis, a calcination degree was defined and slow calcination was carried out in a fixed laboratory furnace during 5 hours. The calcined clay is mixed with clinker to produce new cement. It has been studied following standard tests - physical, chemical and mechanical properties - and compared with a Portland cement in the same laboratory.*

The conclusion was beneficial, as it was found that 10% addition gives the best results, with a srength of 43MPa and 44MPa for portland cement.

Keywords - *Clay, calcination, cement, standard mortar, strength.*

1. INTRODUCTION

In Algeria we use generally as an addition to cement the blast furnace slag, pozzolan, tuff, etc. The pozzolans are silico-aluminous materials which in the presence of water, react with calcium hydroxide to form compounds "hydrated" having the properties of cements [1,2]. These are natural products of volcanic origin (ash, slag ...) or artificial obtained by different methods [3]. The most commonly used are fly ash from thermal power plants, bauxites and calcined clays. The advantages of partial replacement of cement with pozzolan materials are diverse: Amelioration of chemical attack resistance, improving impermeability and durability of the mortar, reducing alkaline reactions with aggregates [4].

After chemical and mineralogical analysis of red clay, used only in local pottery, it revealed that we can use it like a substitute of clinker to obtain new cement.

2. EXPERIMENTAL PROCEDURE

2.1. Used materials

2.1.1. Red clay

Very abundant in the region of M’sila, but little exploited.

2.1.2. Clinker and gypsum

Made in a local factory, the clinker has a regular chemical composition.

2.1.3. The aggregates

To prepare concrete, sand and gravels fractions from local quarries were used, their physical characteristics are shown in Table 3

The chemical and mineralogical compositions of different materials are respectively given in Table 1 and 2 and the physical characteristic of aggregates in Table 3. The Clay Differential thermal analysis is illustrated in Fig.1.

Table 1. Chemical composition of used materials

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	LOI
Clay	32.96	6.87	3.01	23.24	5.80	1.19	1.96	0.01	24.46
Clinker	22.14	5.23	3.03	65.49	0.07	1.18	0.94	0.13	0.00
Gypsum	7.18	2.25	1.06	31.37	2.42	34.42	0.47	0.00	20.80

Table 2. Clay mineralogical percentage composition

Quartz	Calcite	Dolomite	Feldspath plagio.	Gypsum	ferruginous minerals	Illite/Muscovite	Chlorite
17	30.5	16.5	01	02	03	20	09

Table 3. Physical characteristic of used aggregates

Characteristic	Sand	Gravel 3/8	Gravel 8/15
absolute density	2.54	2.6	2.57
Bulk density	1.63	1.35	1.27
Porosity	35.81	48.18	50.23
compactness	64.18	51.83	49.77
voids Indices	0.557	0.929	1.009
ESV/ESP	80.7/85.2	-----	-----

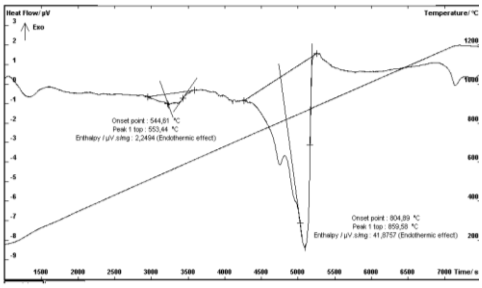

Fig. 1. Clay differential thermal analysis.

2.2. Testing and results

2.2.1. Composition

In order to evaluate the effect of the calcined clay, on cementitious materials (dry, mortar, concrete), we subjected the different specimens of blended cements (the composition is given in Table 4), to typical standard tests.

Table 4. Nomination of cement types

Nomination	Clinker %	Gypsum %	Addition R %
CEMI	95	5	0
R10	85	5	10
R20	75	5	20
R30	65	5	30

2.2.2. Grinding

All materials (clinker, gypsum, calcined clay) endured a separate grinding. The blended cements have almost the same fineness (Table 5).

Table 5. Fineness of the cements

	CEMI	R10	R20	R30
Finenes s cm2/g	3568.41	4310.46	4547.37	4512.32

2.2.3. Chemical analysis of the cements powders

After drying and grinding, the chemical compositions of different cements are summarized in Table 6. All variants meet the requirements, such as the rate of loss of ignition, the sulfate content and the content of MgO . For the hydraulic module (HM) only R30 is below the range which means low initial strength.

All cements have an acceptable hydraulicity index (or Vicat index) and even greater than 0.5, which proves their very good chemical resistance.

Table 6. Chemical composition of studied cements

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	LOI
CEMI	21.93	5.53	2.98	63.31	0.08	0.00	1.09	0.13	1.78
R10	23.77	5.91	3.04	60.36	0.99	1.81	1.37	0.13	2.62
R20	25.61	6.21	3.11	56.96	0.70	1.83	1.57	0.14	3.87
R30	26.30	6.37	3.21	53.58	0.79	1.95	1.83	0.12	5.81

2.2.4. Physical properties of cements

2.2.4.1. Density

It is noted that the density decreases with the percentage of addition, which causes an increase in volume, as shown in Fig. 3.

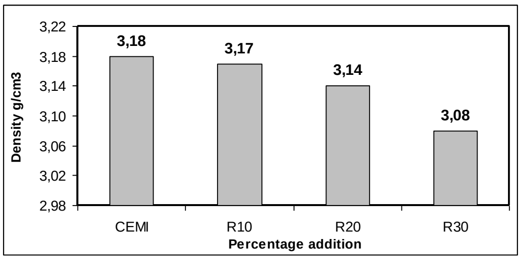

Fig. 3. Specific density of the cements.

2.2.4.2. Normal consistency

From Table 7, we see the growth in the volume of water to wet 500g of cement, which means that the W/C ratio increases with each increase in the percentage of addition Fig. 4.

2.2.4.4 . Setting time

Table 7. Volume of water required for a standard consistency

	CEMI	R10	R20	R30
Volume of water ml	144	148	155.5	168

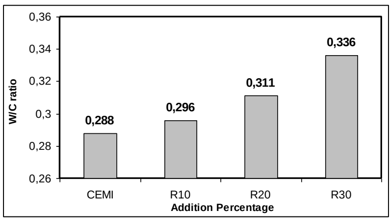

Fig. 4. W/C ration for normal consistency

2.2.4.3. Expansion

It is regular and it is below 2 mm, it is about 1 mm, which means that the amount of free lime is less than

Fig. 5 shows the increase of setting time (beginning and end) of the variants compared to portland cement.

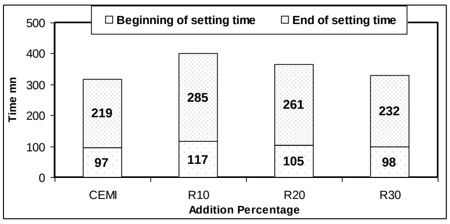

Fig. 5. Setting time (Beginning and end).

2.2.5. Mechanical strengths of mortars

The Specimens of different variants were tested in uniaxial compression respectively at 2 and 28 days. At two days, the mechanical strength of blended cements are superior to Portland cement, this is explained by the significant value of the fineness modulus, except for the R30 case. At 28 days, Portland cement takes the advantage. Different resistance values are summarized in Table 8

Table 8. The mechanical strengths of mortars

	CEMI	**R10**	**R20**	**R30**
Mechanical strength at 2 days MPa	20.3	23.9	20.88	18.82
Mechanical strength at 28 days MPa	44.22	43.5	39.38	36.41

2.2.6. Mechanical strength of concretes

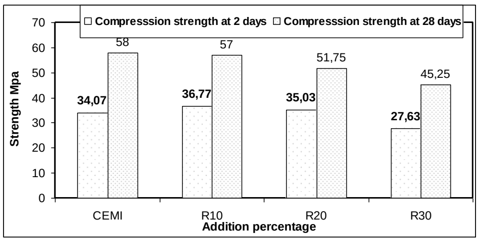

Fig. 6. Compressive strength of different types of cement 2 and 28 days

It is noted that the compression strength of concrete containing 10% addition, are higher than of a Portland cement concrete at 2 days as shown in Fig. 6, because of the fineness of cement. Beyond the seventh days the resistors are falling in, because of the substitution of a part clinker by adding.

5. CONCLUSION

After calcination of clay at 780 °C for 5 hours in a [5] fixed the furnace and its incorporation to the clinker to produce cement, we noted the following points:

- The reduction of density, increase with the proportion of calcined clay.
- The increase of percentage addition involves the increase of consistency. The nearest consistency to Portland cement is obtained with the incorporation of 10% of additions
- The long setting time period has no effect on strength.
- The incorporation of 10% calcined clay provides fairly close mechanical responses of a portland cement, which is of the order of 42-43 MPa, for blended cements, and 44 MPa for portland cement.

With his comments may be said that these cements can be used in structures with moderate wear.

6. REFERENCES

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