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Physico-Chemical Characteristics of Cement Manufactured with Artificial Pozzolan (Waste Brick)

A. Naceri, M. Chikouche Hamina, and P. Grosseau

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***Abstract*—**The effect of artificial pozzolan (waste brick) on the physico-chemical properties of cement manufactured was investigated. The waste brick is generated by the manufacture of bricks. It was used in the proportions of 0%, 5%, 10%, 15% and 20% by mass of cement to study its effect on the physico-chemical properties of cement incorporating artificial pozzolan. The physico-chemical properties of cement at anhydrous state and the hydrated state (chemical composition, specific weight, fineness, consistency of the cement paste and setting times) were studied. The experimental results obtained show that the quantity of pozzolanic admixture (waste brick) of cement manufactured is the principal parameter who influences on the variation of the physico-chemical properties of the cement tested.

***Keywords*—**Artificial pozzolan, waste brick, cement, physico-chemical characteristics.

I. Introduction

THE research of the economic binder by using the industrial by products (blast furnace slag, silica fume, fly-ashes) and the natural resources (natural pozzolan, limestone) is a major concern to reduce the deficit recorded during the manufacture of Portland cement [1]. These last years, a large effort of research was provided on the use of the supplementary cementitious materials as a partial replacement to Portland cement [2].

A partial replacement of cement by mineral admixture such as, fly ash, silica fume or blast furnace slag in cementing materials mixes would help to overcome these problems and lead to improvement in the workability, strength and durability of cementing materials [3]. This would also lead additional benefits in terms of reduction on cost, energy savings, promoting ecological balance and conservation of natural resources etc. The continuing search for partial cement replacement materials has led the authors to investigate the utlisation of waste fired clay bricks as a pozzolan for mortar and concrete.

Clay is a widespread natural material on all the continents and in particular in the countries of North Africa (Algeria). It consists of a variety of phyllosilicate minerals rich in silicon and aluminium oxides and hydroxides, which include variable amounts of structural water. Clay is distinguished by its small size, layered shape, affinity for water and tendency toward high plasticity [4]. The Algerian clay industry (bricks, tiles, ceramics, etc.) has particular problems (mineral wastes) with its very high level of mineral waste who remains without being to exploit until now. Calcined clay (waste bricks) is an artificial pozzolana and it can hydrated in the presence of $Ca(OH)_2$.

The formation of cementitious material by the reaction of free lime (CaO) with the pozzolan admixture (AlO_3, SiO_2, Fe_2O_3) in the presence of water is known as hydration. The hydrated calcium silicate gel or calcium aluminate gel (cementitious material) can bind inert material together. Since the lime content of calcined clay is relatively low, addition of lime is necessary for hydration reaction with the pozzolan of the calcined clay [5]. The increase of rate of above reaction with temperature may be due to increase of dissolution of $Ca(OH)_2$ in solution giving more Ca^{++} and OH^- ions [6]. Hydration of tricalcium aluminate in the calcined clay provides one of the primary cementitious products in many clays. The hydration chemistry of calcined clay is very complex [7].

This paper presents an investigation of various blended cements produced by replacing 0%, 5%, 10%, 15% and 20% of these cements with a waste brick (artificial pozzolan). This experimental work presents a study on the blended cements produced in laboratory by intergrinding crushed brick, clinker and gypsum. Characteristics examined include chemico-physical characteristics of cement manufactured.

II. Experimental

In this experimental work, we varied the percentage of the artificial pouzzolan (waste brick) in cement by the substitution method (partial replacement of the clinker by the waste brick). The chemical compositions (Oxide compositions) of gypsum and waste brick are shown in Table I. The Table II presents the chemical analysis of the clinker and the Bogue composition.

A. Naceri is with the Civil Engineering Department, M'sila University, P.O.Box 166, Ichbilia, 28000 M'sila, Algeria (corresponding author to provide phone: 00-213-771994801; fax: 00-213-35540338; e-mail: abdelghani_naceri@yahoo.fr).

M. Chikouche Hamina is with the Civil Engineering Department, M'sila University, P.O.Box 166, Ichbilia, 28000 M'sila, Algeria (e-mail: mchikhamina@yahoo.fr).

P. Grosseau is with the ENSMSE-SPIN, LPM, CNRS UMR 5148, 158 cours Fauriel, 42023 Saint-Etienne Cedex 2, France (e-mail: grosseau@emse.fr).

TABLE I
CHEMICAL COMPOSITION (%, BY WEIGHT) OF GYPSUM AND WASTE BRICK

Oxides, %	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3
Gypsum	07.70	03.20	01.44	26.82	01.40	-	-	27.83
Waste brick	66,52	14,20	05,45	06,06	02,35	02,09	00,67	00,75

TABLE II
CHEMICAL ANALYSIS OF THE CLINKER

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	CaO_{free}	SO_3
22.10	04.57	03.95	66.34	01.60	00.02	00.54

The investigation was performed using the mixes composition for the preparation of the five types of cements containing clinker, gypsum and waste brick (mineral admixture). Table III presents the mixes composition used in this experimental work as well as their finenesses. The chemical composition of the five cements used in this research have been determined by the testing method "X-ray Fluorescence Spectrometry (XRF)". The results of the chemical composition of the five cements prepared are presented in Table IV. The incorporation of the pozzolanic additions (industrial mineral wastes) in cement at different percentages (0%, 5%, 10%, 15% and 20%) increases the oxides (SiO_2, Al_2O_3 and Fe_2O_3) but decreases the oxide (CaO). The experiments of grinding for the five types of cements (CEM I, CEM II-1, CEM II-2, CEM II-3 and CEM II-4) were performed in vibratory mills. The fineness (specific surface area) of the different cements grinded was determined by the Blaine method (Blaine Air Permeability Apparatus).

TABLE III
MIXES COMPOSITION AND FINENESSES OF THE FIVE CEMENTS PREPARED

Cements	Clinker (%)	Calcined clay (%)	Gypsum (%)	Finenesses or S.S.A (cm^2/g)
CEM I	95	0	5	3310
CEM II-1	80	5	5	3328
CEM II-2	75	10	5	3346
CEM II-3	70	15	5	3332
CEM II-4	65	20	5	3368

TABLE IV
CHEMICAL COMPOSITION OF THE FIVE CEMENTS STUDIED

Cements	Specific gravity (Kg/dm^3)	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)
CEM I	3.17	21,34	5,00	3,38	60,94	1,91
CEM II-1	3.14	26,31	5,95	3,90	56,03	1,95
CEM II-2	3.07	27,89	6,25	3,98	54,49	1,98
CEM II-3	3.03	29,20	6,49	4,19	52,91	2,03
CEM II-4	3.01	31,18	6,91	4,51	50,96	2,07

In this experimental work, we varied, the percentage of the waste brick in cement prepared (chemical effect) by the method of substitution (partial replacement of the clinker by the waste brick). We used five types of cements manufactured with artificial pozzolan (waste brick), this in the aim of analyzing the influence of a partial replacement of the clinker by the waste brick (0%, 5%, 10%, 15% and 20%) prepared on the physical and chemical characteristics of hydraulic cements prepared at the anhydrous state and the state hydrated.

III. RESULTS AND DISCUSSION

Influence of the Pozzolanic Admixture (Calcined Clay) on the Specific Weight of Cement Powder

The Fig. 1 presents the effect of artificial pozzolan (waste brick) on the specific weight of cement. The results demonstrate the tendency of the specific gravity to decrease below the reference by 0.9%, 3.1%, 4.4% and 5% for cement powders of 5%, 10%, 15% and 20% waste brick, respectively. From the results obtained, the following conclusions may be drawn : (a) a significant difference of the specific weight with the variation of the percentage of waste brick added in the cement studied and (b) a reduction of the specific weight with the increasing of the quantity of waste brick substitited in the cement. According to the results obtained, one notices that the increase in the quantity or percentage of the artificial pozzolan incorporated in the cement has a significant effect on the specific weight of cement. That can be due to the porosity of the replacement level of waste brick clay (quantity of replacement material added).

Effect of the Quantity of Waste Brick Substituted on the Cement Paste Studied

The experimental results obtained (Figs. 2 and 3) presents the effect of the content of artificial pozzolan (waste brick) on the normal consistency of cement paste and setting times. Table V presents the ratios of the normal consistency and setting times of these mixes. The water demand of cements pastes prepared with different percentage of waste brick (replacement level : 0%, 5%, 10%, 15% and 20%) is measured using the Vicat needle test (standart Vicat test). The influence of the quantity of pozzolanic admixture added on the cement paste is expressed by the changes in normal consistency (water demand ratio).

According to the results obtained, one notices that the increase of the quantity or percentage of the waste brick incorporated in the cement has a double effect: increase of the quantity of water required to have a normal consistency of the cement paste and decrease of the setting times. One also notices that the progressive addition of the pozzolanic addition influences appreciably the water demand, this results in an increase in the quantity of water as a function of the percentage of mineral addition used. That can be due to the porosity of the added waste brick. In the same way, it is noticed that setting times (initial and final set times) decrease proportionally with the increase the quantity of waste brick. That is explained by the fact why the chemical reaction is accelerated in the short term. What wants to also say that the kinetics of hydration of the binder becomes increasingly rapid according to the increase in the quantity of the pozzolanic admixture added. Consequently the crystals of C-S-H (element responsible for the phenomenon of hardening of the paste) exist in great quantity at the initial period of hardening.

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The increase of the quantity or percentage of the replacement material (waste brick) of cement studied (with or without mineral addition) decreases setting times (shortening of the setting times). Thus the effect of the pozzolanic admixture (waste brick) on the acceleration of the pozzolanic activity reacts with the calcium hydroxide [$Ca(OH)_2$, Portlandite] to form C-S-H gel crystals.

TABLE V
WATER-TO-CEMENT RATIO FOR NORMAL CONSISTENCY AND SETTING TIMES

	% waste brick replacement cement				
	0	5	10	15	20
Water-to-cement ratio (W/C) %	27.4	28.2	28.4	28.8	29.2
Increasing (+) %	0	+2.92	+3.65	+5.11	+6.57
Initial setting time (min)	162	156	135	129	124
Decreasing (-) %	0	-3.71	-16.67	-20.37	-23.46
Final setting time (min)	274	254	250	248	243
Decreasing (-) %	0	-7.30	-8.76	-9.49	-11.32

IV. CONCLUSION

The aim of this experimental work was to investigate the influence of pozzolanic admixture (waste bricks) on the physico-chemical properties of cement manufactured with artificial pozzolan (waste brick). The main conclusions of this study are summarized as follows:

* The increase of the quantity or percentage of the artificial pozzolan (waste brick) incorporated in the cement has a double effect: increase of the quantity of water required to have a normal consistency of the cement paste and decrease of the setting times.

* The increase of the quantity or percentage of the artificial pozzolan incorporated in the cement has a significant effect on the specific weight of cement.

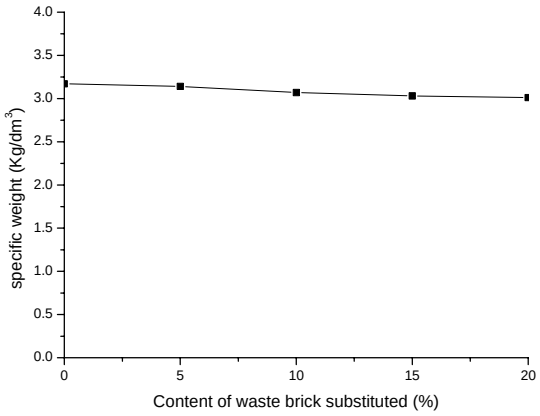


Fig. 1 Variation of the specific weight of cement as a function of the content of waste brick

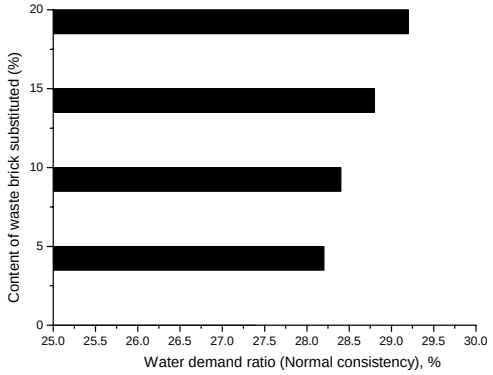


Fig. 2 Variation of the normal consistency cement paste as a function of the content of waste brick

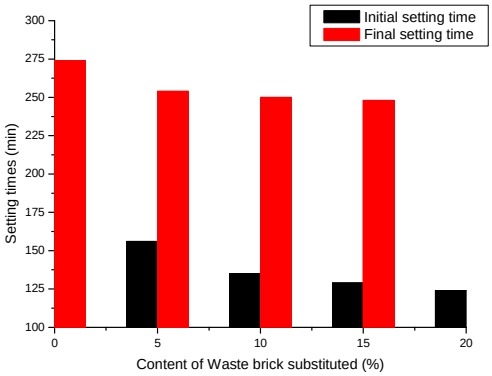


Fig. 3 Variation of the setting times as a function of the content of waste brick

REFERENCES

[1] R. Kaminskas, J. Mituzas, and A. Kaminskas, "The effect of pozzolona on the properties of the finest fraction of separated Portland cement," Ceramics., vol. 50, pp. 15-21, 2006.
[2] P. Tikalsky and R.L. Freeman, The effect of pouzzolan and slag on the resistance of concrete, Univ. Texas, 1998.
[3] A.K. Schindler and K.G. Folliard, "Influence of supplementary cementing materials on the heat of hydration of concrete," Avanced in Cement and Concrete IX Conference, pp. 10-14, 2003.
[4] G. Baronio and L. Binda, "Study of the pozzolanicity of some bricks and clays," Construction and Building Materials., vol. 11, pp. 70-78, 1997.
[5] A. Wild Gallius, H. Hansen, L. Pederson, and J. Szwabowski, "Pozzolanic properties of a variety of European clay bricks," Building Research Information., vol. 25, pp. 170-175, 1997.
[6] S. Caijun, "An over view on the activation of reactivity of natural pozzolans," Canadian Journal of Civil Engineering., vol. 28, pp. 778-786, 2001.
[7] C. He, E. Makovicky, and B. Osaeck, "Thermal stability and pozzolanic activity of calcined kaolin," Applied Clay Sciences., vol. 9, pp. 165-174, 1994.

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