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Optimization of Physical and Mechanical Properties of Local Baked Clay Brick of Ain Nouissy Deposit (North-West of Algeria)

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Abstract: In this research, we studied the properties of a brick locally manufactured to basis of kaolinite of Aïn Nouissy (Northwest of Algeria) in order to improve its qualitative properties in the physical and mechanical plans. Two actions on the natural material, the grinding and the ageing, us one permitted to improve strongly, the physical properties of the paste clayey and mechanical of the finished brick. Indeed, the grinding while acting on the granulometry of the natural material, increase the colloidal fraction while dispersing the present aggregations. It follows that the paste clayey becomes more disposed to undergo the effects of the ageing that improve strongly, the shrinkage of the material. The compactness of the material was improven and the resistance to traction and to the compression of the brick finished is doubled in relation to the witness who was not subject to the treatments of grinding and ageing. One of the important results of this survey is that it is practically sufficient to inject in the production line an ageing of 3 weeks of the paste of the kaolin accompanied by a preceding grinding of the material during 60 min to double the performances of the brick of Aïn Nouissy.

Key words: Brick, kaolinite, baking, grinding of material, ageing of paste

INTRODUCTION

The study of research in the ceramics domain, show that the heterogeneity of the raw materials and their very variable original properties affect the quality of the finished product. In this case, it is important to take not only in account in the survey of the ceramic production processes the qualitative aspect of the finished product but also the quantitative aspect. The qualitative aspect to assure to the finished product of the physical and mechanical features answering the needs and requirements of the market in accordance with the conventional norms and the quantitative aspect to answer the demand constantly increasing in products in the sector of the construction that in Algeria, absorb an important part of the manpower.

It perfectly explains the socio-economic importance that requires all research of optimization of the ceramic product properties, in particular, the brick of terracotta that constitutes the part important of the construction products in Algeria.

This survey projects to improve the physical and mechanical properties of a local brick manufactured in Mostaganem (Northwest of Algeria) from the only deposit named Aïn Nouissy available in the region and situated to 8 km in the Southwest of the city. This brick is not enough studied and records insufficient qualitative properties, linked essentially, to the processes of production and to the heterogeneity of the raw material linked, herself to the heterogeneity of the deposit. It is why, it is important to study the characteristics of the paste resulting from the raw material that it uses to manufacture this brick while acting on the parameters of its preparation and its conduct in order to optimize the quality of the finished product. If tentative of treatment of this paste by addition of sand or clay fragment didn't result to improving the quality of this brick, they confirmed nevertheless that the water content currently used remained optimal (Benea and Gorea, 2004; Baran *et al*., 2001). It proves, therefore that, the most determining parameters, in the process of preparation and maintenance of the paste of manufacture that would have a pertinent effect on the quality of the brick are the degree of sharpness and the length of ageing (Traoré *et al*., 2007). Present contribution is therefore in search of the good combination between these two parameters that would optimize the physical and mechanical properties of this brick.

In this study, we considered six degrees of sharpness and five lengths of ageing of the paste to value their effects on the physical properties (absolute density, bulk

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density and porosity) and the mechanical properties (resistance to traction and to the compression) of the finished brick.

MATERIALS AND METHODS

The physical-chemical and mechanical properties of a clay paste depend on its water content and its degree of sharpness. These two determining parameters on the behavior of the paste to the phenomena of swelling and shrinkage (Sigg, 1994; Sridharan and Gorea, 2004) have an important consequence on its rheological characteristics, them even, linked to the Bingham law: $\tau = \eta(v)G+\tau_B$, where, τ represent the constraint of shearing (Pa), η the viscoplasticity (Pa. s), v the speed of deformation (m sec^{-1}), G the speed of shearing or gradient of speed (m sec^{-1}) and τ_B the constraint limits out-flow of shearing (Pa) (Chaari *et al*., 2003; Roussel *et al*., 2002).

Experimental procedure: This survey has been done in 2003 at the laboratory of the materials and processes of construction connected to the Department of Civil Engineering of the University of Mostaganem. The kaolinite at natural state is submitted in first to a grinding during a length of 0 (witness), 15, 30, 45, 60 and 75 min, then it is submitted to a treatment of optimization of its plasticity as indicated below. This operation consists to determinate the optimal consistence of the paste of clay and to deduce the minimal water content for a better workability. We gets a paste that we submit it to an ageing during a variable time of 0 (witness), 1, 2, 3 and 4 weeks. The following treatment, the paste baking, constitutes a constant parameter for all experimental samples. In this case, the sample is maintained at 100°C during the first 2 h, 300°C during the next 4 h then 1000°C during the 6 next h. The cooking process was performed symmetrically (Jouenne, 1990).

Studied material: The used clay in this survey comes from a deposit situated in Aïn Nouissy in the region of Mostaganem (Northwest of Algeria). The results of the chemical and mineralogical analysis (Table 1) show that it is a kaolinite of the family of the aluminosilicates.

These results indicate that the raw material records a report of $(SiO_2)/(Al_2O_3) = 4.13$ and of $(CaO)/(Fe_2O_3) = 0.28$ with a weak part of alkaline-earthy. The fire losses that represent the organic and plant remnants are of 15.5%.

Although the baking constitutes a constant factor in present experimentation, we did a chemical analysis of the material following this operation in order to show its effects on the material. Indeed, this last records an increase of its content in silica (55%), in alumina (13.9%) and in quick lime (11.0%). The reports $(SiO_2)/(Al_2O_3)$ and $(CaO)/(Fe_2O_3)$ pass respectively to 3.96 and 1.89. These results show that the cohesion of the brick is strongly improven after the baking.

Determination of optimal plasticity

The procedure is summarized as follows: A metal disc with weight p = 11.69 N is in free fall from a height H = 186 mm on a cylindrical test-tube of clay paste diameter d = 35 mm and height h = 40 mm and the height h' after deformation is measured. The coefficient of deformation γ = h/h' can then be determined.

Different water contents are determined for different samples and the minimal water content is then deduced versus a coefficient of deformation γ, based on the principle of optimal plasticity. The value of the water of an optimal workability is Wfo = 21.5% for γ = 2.5. This value will be set as a reference for the remaining test experiments (Estellé *et al*., 2003; Lanos, 2000; Lanos *et al*., 2000).

Methods of measures: The physical characteristics studied are: the bulk density, the absolute density and the porosity. The bulk and absolute densities are determined per the rapport between the dry weight of clayey sample-gotten by drying in a standard oven, at 110°C during 24 h and respectively, the bulk volume of the sample and its real volume obtained by weighed in hydrostatic balance after complete imbibitions of sample under immersion during 48 h.

The mechanical characteristics studied are the brick resistance to the traction and compression. The mechanical tests have been achieved on test-tubes prepared with the clay paste after the baking and with

Table 1: Chemical and mineralogical composition of Aïn Nouissy clay

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3T	K_2O	Na_2O	TiO_2	MnO	P_2O_5	Cr_2O_3	Fire loss
Chemical analyze in % for dry weight													
Raw	49.60	12.00	5.30	1.50	2.50	0.10	2.00	0.60	0.62	0.04	0.20	0.03	15.50
Cooks	55.00	13.90	5.80	11.00	3.00	0.20	2.30	0.60	0.70	0.05	0.20	0.03	7.22

Composing	Kaolinite	Illite	Quartz	Feldspath	Calcite	Dolomite
Mineralogical analyze of raw material						
Content (%)	17.00	5.00	31.50	4.00	12.50	11.50

normalized measurements of (4×4×16) cm for the compression test and of (5×5×5) cm for the traction one.

RESULTS

Particle size: The clay was introduced into a balls grinder on porcelain with 1.5 L of capacity and provide of a timer. After 15, 30, 45, 60 and 75 min for grinding, each sample has passed through a series of sieves in order to obtain the necessary values to make the granulometric (particle size between 0.05 to 2 mm) curves (Fig. 1). Thereafter we have applied to the samples the sedimentmetric analyze to obtain the necessary values to the establishment of the sedimentmetric curves (particle size between 1.1 to 50 μm).

The two curves types will permit to cover the complete range of particles size composing the sample. The grinding permits to reduce the module of sharpness for the studied material (Guizol, 1989). In the granulometric and sedimentmetric curves, the ordinates axis considers the accumulated percentage of the quantity of clay whose particles are of sizes inferior to the value chosen in the abscissa axis.

It is important to notice that the clay that we study contains, in the natural state, close to 20% of elements of sizes superior to 50 μm. The grinding during 75 min brought back this range of particles to only 10%. It shows that a good part of the natural material is initially under an aggregation form being composed of several colloidal particles. It is why, the grinding constitutes an interesting means to improve the degree of sharpness of the material while dispersing these aggregations. Thus, we notice that the only clayey part of the material (particle size <1, 8 μm) passed of 28% before grinding to close to 47% after a grinding of 75 min. Especially that we know that it is the

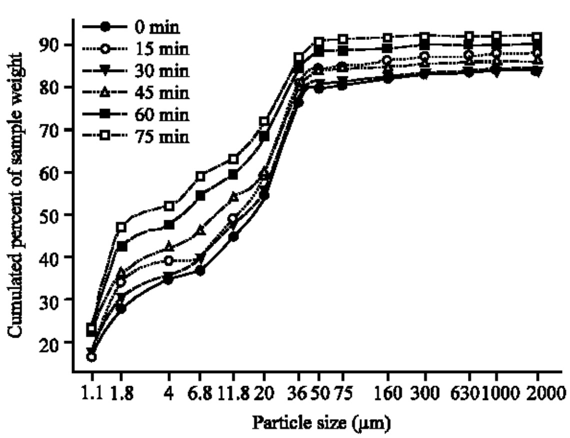

Fig. 1: Granulometric and sedimentmetric curves of the studied clay

range of the sizes inferior to 2 μm (Sridharan and Gurtug, 2004), who is responsible for most properties governing the response of a material to processes of humectation-desiccation (water content and ageing of the paste). Otherwise, the d_{60} -that represents the size that 60% of particles of the material (in weight) are lower to him-passed respectively, from 24.45 to 7.90 μm for the natural material (without grinding) and the one having undergone 75 min of grinding.

In the continuation of this study, we are going to approach the different parameters of qualities of the finished brick under the respective effects of the length of grinding of the raw material and of the period of ageing of its paste.

To study the behavior of different studied parameters, we are going to use the notion of the absolute variation: $x = x_i - x_t$ where x_i represents the experimental values and xt the value corresponding witness to the material not having undergone of treatments of grinding and ageing. In this case, any absolute variation is expressed in relation to the state of the initial brick that we project to improve.

Density: The absolute density (Table 2), records an optimal absolute increase for an ageing of 3 weeks and a period of grinding of 45 min. For the bulk density, the optimal state is gotten for 3 weeks of ageing and 60 min of grinding length. These results show that it is useless to go beyond an ageing of 4 weeks and a grinding of 75 min. But to see the proportions in which evolve the absolute variations of these two parameters, those of the bulk density are on average nine more important times than those of the absolute density. It permits to affirm that the variations of the absolute density due to the grinding and to the ageing are negligible since they are the order of 0.04 in relation to the average of this parameter that is of 2.73. To the inverse, the variations of the bulk density are the order of 0.45 in relation to its average that is of 1.86. It confirms the importance of this last, because it is known that it is the bulk density that expresses best the properties of swelling and shrinkage of a material submitted to the constraints of humectation-desiccation (Sridharan and Gurtug, 2004). It takes out that it is the couple (3 weeks of ageing, 60 min of grinding) that will permit an optimal improvement of the qualitative properties of the brick.

Table 2: Variation of absolute density of brick and bulk density of paste according to time of grinding and the ageing

	Grinding time (min)					Ageing (weeks)			
Variation of	15	30	45	60	75	1	2	3	4
Absolute density	0.03	0.04	0.05	0.05	0.05	0.04	0.05	0.06	0.03
Bulk density	0.25	0.30	0.44	0.61	0.61	0.25	0.44	0.56	0.56

Table 3: Absolute diminution of brick porosity according to time of grinding and the ageing

	Grinding time (min)					Ageing (weeks)			
	15	30	45	60	75	1	2	3	4
Diminution of porosity	6	11	13	15	15	6	10	13	13

Table 4: Absolute augmentation of traction and compression resistance of brick according to the time of grinding and the ageing

	Grinding time (min)					Ageing (weeks)			
Variation of	15	30	45	60	75	1	2	3	4
Traction	1.50	2.40	3.50	4.00	4.00	1.43	2.93	3.93	3.93
Compression	4.00	8.00	11.00	13.00	13.00	6.00	9.00	11.50	11.50

Porosity: In relation to the value of the witness sample, the absolute variation of the porosity appears like a reduction under the respective effects of the lasted of grinding and the time of ageing (Table 3). This reduction marks a landing starting at the third week, for the ageing and at 60 min for the grinding. It is therefore the couple (3 weeks of ageing, 60 min of grinding) that records the optimal reduction of the porosity. The reduction of this parameter expresses a densification of the brick favorable to a good resistance to the mechanical constraints.

Traction and compression: As in the case of the porosity, the variation of the resistances, respectively to traction and to the compression (Table 4), marks a landing starting at the third week for the treatment of ageing and at 60 min for the grinding. The set of the resistances to traction and to the compression undergo an optimal increase for the couple (3 weeks of ageing, 60 min of grinding). As the variations of the resistance to the compression are in averages double of those of the resistance to traction, they shows that the effects of the ageing time and the grinding length are more important to the compression behavior of the brick that to its traction behavior. This result is important because it is the constraint of compression that is the main constraint of application or fatigue of the materials of construction carriers (Kornmann, 2005).

DISCUSSION

In order to debate the results of this study, it is important to recall that the grinding is applied on the natural material (kaolinite of deposit) before its mixture to water to get the paste that goes, thereafter, to undergo the operation of ageing. This last is followed by the phase of baking that succeeds to the finished product. It is on the paste clayey that we determined the measure of the absolute and bulk densities. On the finished brick, we determined the measures of the porosity and resistances to traction and to the compression.

In the paste clayey, the water of shaping distributes itself in fixed water and free water that infiltrates in the material according to the time and move between the solid particles. Indeed, the adsorbant capacity of the kaolinite, loaded negatively, neutralizes the charge of the H^+ ions with the progression of the time of ageing. So, the fixed water moves around the layers of the kaolinite and makes more intimate the link between its particles (Delhaye *et al*., 2000), while the free water evaporates during the drying, dragging so, a partial densification of the material. It is during baking that the continuous densification (Fischer *et al*., 1995; Thevenot, 1992), it can be finished incompletely if the couple (time of ageing, degree of sharpness) is not optimized (entire phenomenon of sintering). Therefore there is an equilibrium, between the adsorbed water content of the paste, that is responsible of the inter-particles links and the one that disappears progressively, during the ageing and then by shrinkage during baking. The optimization of this equilibrium that plays in favor of the quality of the product depends exactly, of the length of ageing and the grinding.

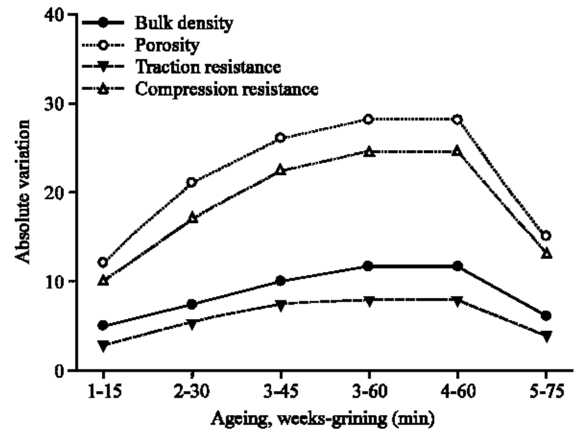

Fig. 2: Relationship between absolute variation of experimental parameters and ageing and grinding treatments

In this study (Fig. 2), it appears that the state of optimization of characteristics of the brick is confirmed for the couple (3 weeks of ageing, 60 min of grinding), but also for the couple (4 weeks of ageing, 60 min of grinding) since the curve makes a landing between these two couples. This is valid for all studied parameters, at the exception of the absolute density for which, we recall the weakness of the variations linked to the treatments of ageing and grinding. It is well obvious that it is the couple (3 weeks of ageing, 60 min of grinding) that will be optimal, it constitutes a precious gain in time (one week). The ageing and the grinding affect the structure of the paste by amplification of the dispersion phenomenon of clay. It is the Na^+ cation that is the principal agent of deflocculation of the paste by the orientation of the H^+ ions of the colloidal layers with the progression of a longer ageing (Baudet, 1981; Sridharan, 2002). It is therefore, this dispersion phenomenon after baking that confers to the brick a double quality of lightness and toughness that we could note through the analyzed parameters. It is important to recall that the operations of ageing and grinding are not cumbersome on the investment level and can be incorporated easily, in the production chain of the Aïn Nouissy brickworks. It is necessary to add, the environmental advantages that present the brick of terracotta. Indeed, the scraps of terracotta bricks remain inert in the alive soil and even after stabilization, come back quickly to the natural state by biodegradation. It is a material to very negligible environmental cost to the point where the resource is abundant and constantly produced, by the rocks alteration (Kornmann, 2005).

CONCLUSION

This study shows that it is not necessary to intervene on the chemical and mineralogical composition of the dough to improve the physical and mechanical qualities of the brick of Nouissy Aïn. It is sufficient to acting, on two important parameters that are the time of ageing and the length of grinding. This study has, indeed, put in evidence that the couple (3 weeks of ageing, 60 min of grinding) succeeds to an optimization of the physical and mechanical properties of the studied brick.

The practical setting of the results of this study can be easily envisaged, since that would be sufficient, to incorporate the operations of grinding and ageing in the production chain of the brickworks of Nouissy Aïn. The pertaining loads to this modification of the production line don't seem costly to us in comparison with the strong improvement that will be brought to the finished product. This economic aspect requires nevertheless, an approach to confirm it.

As for the aspects technical and economic, the environmental aspect takes a dimension all important in the manufacture of the terracotta brick. Indeed, the industry of the brick drags no shape of environmental loss.

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