Effect of Adding Sawdust on Mechanical-Physical Properties of Ceramic Bricks to Obtain Lightweight Building Material

Bachir Chemani, and Halima Chemani

***Abstract*—**This paper studies the application of a variety of sawdust materials in the production of lightweight insulating bricks. First, the mineralogical and chemical composition of clays was determined. Next, ceramic bricks were fabricated with different quantities of materials (3–6 and 9 wt. % for sawdust, 65 wt. % for grey clay, 24–27 and 30 wt. % for yellow clay and 2 wt% of tuff). These bricks were fired at 800 and 950 °C. The effect of adding this sawdust on the technological behaviour of the brick was assessed by drying and firing shrinkage, water absorption, porosity, bulk density and compressive strength. The results have shown that the optimum sintering temperature is 950 °C. Below this temperature, at 950 °C, increased open porosity was observed, which decreased the compressive strength of the bricks. Based on the results obtained, the optimum amounts of waste were 9 wt. % sawdust of eucalyptus, 24 wt. % shaping moisture and 1.6 particle size diameter. These percentages produced bricks whose mechanical properties were suitable for use as secondary raw materials in ceramic brick production.

***Keywords*—**Clay brick, Porosity, Sawdust.

I. INTRODUCTION

NOWADAYS, several research fields on materials recycling environmentally friendly and energy conservation are operated. Many previous researches have obtained valuable results to use the industrial wastes in various forms of construction materials production. Some researches carried out in the past used wood ash wastes as a replacement for cement in concrete mixes [1] - [2].

Another Attempt have been made to incorporate waste in the production of bricks; for instance, the use of rubber [3], limestone dust and wood sawdust [4], processed waste tea [5], fly ash [6] - [7], polystyrene [8] and sludge [9]. Recycling of such wastes by incorporating them into building materials is a practical solution to the pollution problem.

In addition, demand for clay bricks with higher insulating capacity is increasing. One way to increase insulation capacity of brick building is generating porosity in the clay body. For this purpose, the sawdust, polystyrene, paper sludge, coal, and coke are organic materials most frequently used as pore formers. Organic product wastes are extensively used as a pore former in the brick industry [10]. The organic nature of these wastes requires an energy input to release its calorific power during combustion in the ceramic firing process, enabling energy saving in manufacturing and reducing fuel use. Further, such combustion products give the fired clay a more porous microstructure. This both decreases the clay's density and is expected to improve the clay's thermal insulation capacity. In conclusion these materials had properties which resembled those of lightweight concrete materials.

Although these researches are providing encouraging results, the brick mixtures having Eucalyptus, Alep pine and Tuff combination hitherto has not been investigated.

In the present study, Sawdust can be defined as loose particles or wood chippings obtained as by-products from sawing of timber into standard useable sizes. The recycling of chips of wood such as sawdust seems to be the best insulator which offers the properties of required ceramic products.

The main chemical components of sawdust are carbon 60.8%, hydrogen 5.19%, oxygen 33.83%, and nitrogen 0.90% [11]. Dry wood is primarily composed of cellulose, lignin, hemicelluloses, and minor amounts (5–10%) of extraneous materials.

Laboratory tests were carried on specimens made of brick clay with up to 30% volume of sawdust as pore-forming agent. The latter reinforce the structure of the ceramic body during drying. A highly porous ceramic structure is obtained after firing at temperatures of up to 920 °C [12]

The present study aims to investigate the suitability of sawdust in mixture of ceramic material which simultaneously acts as a degreaser and the possibility of obtaining clay brick with alveolar appearance, low density and of higher mechanical strength compared with traditional bricks.

Two types of sawdust were considered, the Alep pine (family of coniferous woods) and eucalyptus (hardwood broad family). Both wood wastes are distinguished by their origin, structure, physical properties, chemical, etc.

The mixtures characteristics of clays - tuff - sawdust in the presence from 3, 6 and 9% wt sawdust having particles diameter 0.5, 1 and 1.6 mm under shaping moisture varying from 22, 24 to 26%wt, have been investigated.

Firing was carried out at temperatures of 850 and 950 °C. The characterization of the ceramic products obtained during drying and of firing made it possible to raise the considerable

Bachir Chemani is with Department of Process Engineering, Faculty of Engineering Sciences, University M'Hamed Bougara, Boumerdes 35000 Algeria (phone:213-24-819153; Fax:213-24-816373 e-mail: chemani_ba@yahoo.fr).

Halima Chemani is with Department of Materials Engineering, Faculty of Engineering Sciences, University M'Hamed Bougara, Boumerdes 35000 Algeria (phone:213-24-911658; Fax:213-24-816373 e-mail: chemani_salimaa@yahoo.fr).

differences regarding to the physical and mechanical properties.

An optimization comparative study between the various products obtained made it possible to fix the choice on the products developed with 22%wt moisture, content 9% wt eucalyptus sawdust and 1.6 mm diameter particles corresponding to 1.48 g/cm^3 of density and 138.60 kgf/cm^2 of mechanical resistance.

The recycling of eucalyptus wood wastes such as sawdust seems to be the best insulator which offers the properties of required ceramic products.

II. Materials and Method

In this study, production of insulating ceramic bricks was accomplished from mixtures of two different clays, tuff, and sawdust. The Yellow clay, Grey Clay and Tuff were used as Al_2O_3 and SiO_2 supplies, while sawdust (Eucalyptus and Pine Alep) was used as pore former to attain insulating properties of bricks.

Sawdust used is generated from the mechanical processing of raw wood in the sawing process. Sawdust is used in its original form and taken from its disposed area near the timber manufactures in the local region. The results of chemical analysis of tuff and clay are given in Table I.

Sawdust and clay used in this study is categorized as Eucalyptus and Pine Alep-Mixed in terms of their particle sizes. Fig.1 shows the raw materials used in the fabrication of bricks samples.

Fig. 1 Raw material

In order to determine the extent of the pore-forming effect of the sawdust (Pine Alep and Eucalyptus), several different amounts of sawdust (3%, 6%, and 9% in oven dry state) were chosen. Brick clay was passe through a drum-type crusher having a 1-mm opening. The mix proportions were prepared based on the dry weights of the ingredients. After weighing the ingredients, the sawdusts were placed in water for 48 h and then mixed with the clay and tuff. In order to obtain comparable results, three different mixtures of samples were prepared for the tests, a separate series for each percent sawdust addition. Mixtures M1, M2 and M3 contain 3%, 6%, and 9% sawdust additions, respectively are shown in Table II.

Solid brick clay samples were produced using pilot laboratory procedures and equipment. The shaped samples were dried in laboratory conditions (21 °C, 60% relative humidity) for 72 h by a ventilated oven at 105°C.

Particle size analysis was determined by wet using a sieves series of different diameter Φ (5 - 2 - 1- 0.63- 0.20 mm) and by pipette "Robinson". The optimization of ceramic bodies is carried on briquettes prepared from mixtures M1, M2 and M3.

The moisture contents of shaping are in the range 22, 24 and 26%. For each moisture contents, we considered three types content sawdust, and in each content, three type particles size were considered. The drying process of the briquettes is carried in the open air then in a dryer chamber for 24 hours. The cooking was carried out in a tunnel furnace at temperatures of 850 and 950 ° C.

Characterization of physical and mechanical properties such as the shrinkage on dry and fired, absorption, porosity, density, specific gravity was determined. The mechanical strength is determined by a flexural device type 401 NEZSCH EN100. Chemical analysis is determined by the sequential ray spectrometer type Siemens SRS 303. Water supply: 3V min. Air supply: 2V min, water pressure: Bars 4-8, Air pressure: 4.5 to 10 bar.

TABLE I
Chemical Composition of the Clays And Tuff (% Wt.)

	Gray Clay	Yellow Clay	Tuff
SiO_2	48.02	51.28	33.66
Al_2O_3	10.63	12.34	15.78
Fe_2O_3	4.68	4.76	4.42
CaO	13.49	11.39	2.27
MgO	1.67	1.48	2.42
SO_3	1.23	0.95	-
K_2O	1.51	1.67	4.34
Na_2O	0.61	0.57	3.40
MnO	-	-	0.08
P_2O_5	-	-	0.08
TiO_2	-	-	0.40
L.O.I.	17.34	14.72	2.92

The main minerals and clays combined with the natures of phases are determined by X-ray diffractometer type Siemens "500D" 20mA - 40k Volt with CRT Cu.

TABLE II
MIXTURES COMPOSITIONS (% WT)

Mixture	Gray Clay	Yellow Clay	Sawdust	Tuff
M1	24	65	3	2
M2	27	65	6	2
M3	30	65	9	2

III. RESULTS AND DISCUSSIONS

According to chemical analyzes, both types of clays have one common characteristic. On the one hand, the rate of Al_2O_3 in both clays is lower at 14% which they classified in the group of acidic clays and secondly, the rate of limestone is between

6 - 20 % which classifies these clays in the group of marly clays where products cooked yellow [13].

Elements K_2O, Na_2O acting as energy flow, have a slightly higher rate for YC (Yellow Clay), giving the best cooking properties.

The main element distinguishes these two clays is SiO_2, higher in the YC. This observation underlines that this type of clay is more sandy and thus acts as a degreaser.

It is also noted the rate of CaO, SO_3 is higher in case to GC (gray clay) which is in exact correlation with great ignition loss.

The mineralogical analysis results (Table III) show that used clays are respectively type illite / montmorillonite and illite / kaolinite / chlorite.

TABLE III
MINERALOGICAL ANALYSIS OF CLAYS (% WT)

Principal minerals	Gray Clay	Yellow Clay
Quartz	32	27.5
Calcite	21	18
Dolomite	3	2
Feldspar: potassic	1	1
Feldspar: sodic, calcic	2.5	2.5
Semi gypsum hydrate	2	2
Ferriguneux minerals	4.5	4.5
Illite	13.5	15
Kaolinite / chlorite	12	13.5
Montmorillonite	8.5	14

The result analysis (Table IV) reveals that gray clay contains much more argillaceous particles than yellow clay; this is in correlation with the data of the Table I.

The grain size analysis of two types of clays is illustrated in Table IV.

TABLE IV
GRANULOMETRIC ANALYSIS OF CLAYS

	Particle size (mm) "By Robinson pipette"				
	1 to 0.063	0.063 to 0.01	0.01 to 0.005	0.005 to 0.001	< 0.001
	Content (%)				
Gray Clay	14.65	30.99	13.20	11.00	30.16
Yellow Clay	12.40	25.28	13.28	22.72	26.32

	Mesh size of screen (mm) "by wet process"				
	5.00	2.00	1.00	0.63	0.20
	Content (%)				
Gray Clay	0.00	0.00	0.03	0.03	0.10
Yellow Clay	0.00	0.00	0.00	0.1	0.03

We observe in Table IV that rejection rate the yellow clay is lower than the gray clay. The yellow clay is composed of many small particles that are likely due to the presence of montmorillonite clay mineral associated. The relationship is made with the results in Table III. From the main mechanical and physical properties studied, it is noticed that the shrinkage on dry product made from Aleppo pine sawdust is superior to those obtained from Eucalyptus. The shrinkage on dry tends to decrease with the increase of particle size and sawdust content. Values are noticeably higher when the moisture shaping of the ceramic is to 22 to 26%. This variation is identical to the case of the addition for two types of sawdust; this is attributed to the original wooden structure. From analysis of shrinkage on firing, the same variations are recognized. The shrinkage on firing varies proportionally with the firing temperature and has values higher than eucalyptus. The high shrinkage is recorded for moisture shaping of 26%. For 3% of sawdust content and a particle diameter (Φ) 0.5 mm, the recorded values are 2.44 to 2.79% for firing temperatures of 850 and 950°C respectively. The high shrinkage values translate into particles rearrangement leading to texture consolidation the relative to the initial state followed by contraction [14]-[15].

The sawdust serves as degreaser in the raw paste and pore forming agent during firing. The specific mass values obtained using the Aleppo pine remains in their turn higher than eucalyptus. The density is inversely proportional to content of sawdust, particle size and the dough moisture, but varies in proportion to the firing temperature.

These values are higher than of eucalyptus sawdust. The increase in temperature leads to swelling and a decrease in volume of the material obtained.

There is a direct correlation between the absorption values and open porosity. At low absorbance values corresponds the low open porosities. These values are proportional to content of sawdust, the particle size but inversely proportional to temperature. During firing the ceramic product, there is development of liquid phase that helping to eliminate of voids and pores for the approximation of particles as a result of formation of contact areas inter granular [16].

The lower density of ceramic product is obtained from mixture sawdust eucalyptus with 22% and 24% shaping humidity, a particle diameter (Φ) 1.6 mm, sawdust content 9% and a firing temperature 950 ° C. The corresponding values for these two types of shaping humidity are respectively 1.52 and 1.43 g/cm^3.

Fig. 2 shows physical-mechanical properties of lightweight bricks made from sawdust eucalyptus fired to 950 ° C.

Considering the results with 26 % shaping moisture shows that the Aleppo pine provides the same strength as that of eucalyptus (see Figs. 2 and 3). For moisture shaping value clay paste of 24% corresponds to density of 1.65%. For eucalyptus, the values of densities and mechanical strengths are lower at 26% moisture shaping. To avoid the problem of sensitivity to drying, it would be necessary to stay within a fairly limited interval by wetting the clay mixture and choose humidity of 24%.

The shrinkage rates from the Aleppo pine are significant with increasing moisture of the clay paste. This makes the slow and delicate drying. It is noticed that the characteristics of the eucalyptus with pulp humidity of 24%, remains the best product recycling timber. This moisture allowed acquiring the desired properties of lightweight bricks and insulating. Fig.2 and Fig. 3 clearly demonstrates considerable difference of two sawdust.

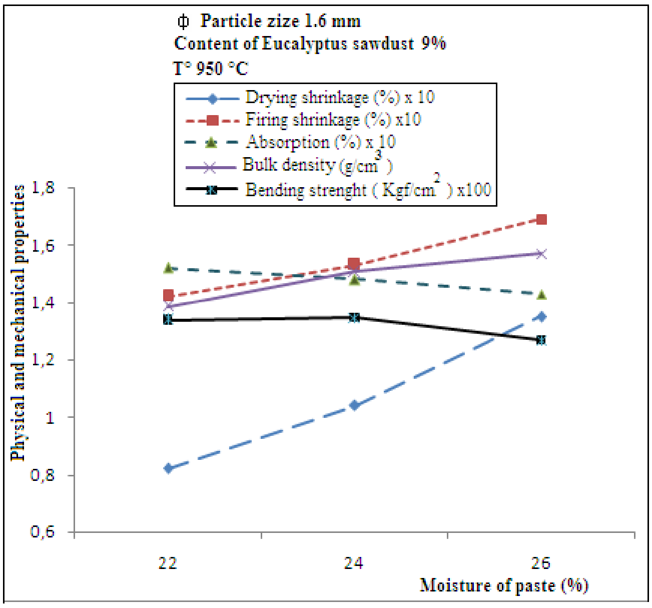

Fig. 2 Physical-mechanical properties in relation with moisture of mixtures according the particle size and Eucalyptus content

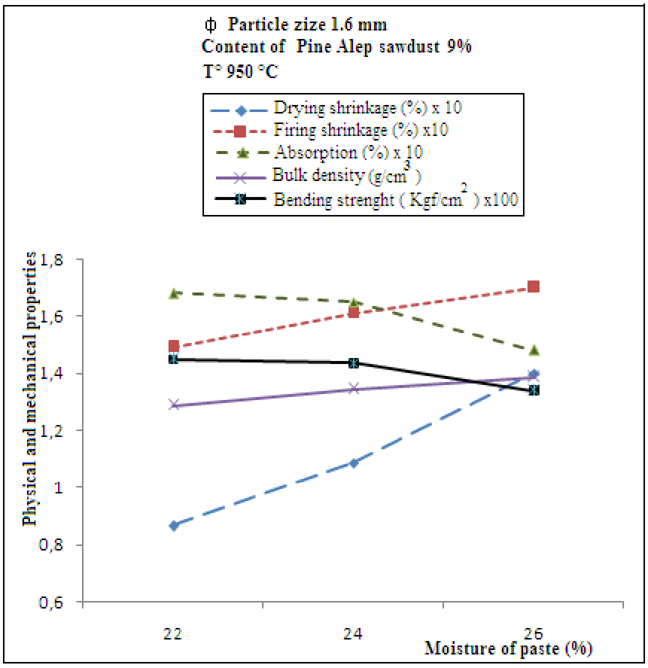

Fig. 3 Physical-mechanical properties in relation with moisture of mixtures according the particle size and Pine Alep content

IV. Conclusion

The feasibility of producing ceramic bricks with adding wood sawdust was showed technically in this study

The present study has shown that it is possible to obtain lightweight ceramic brick production from added sawdust.

The incorporation of sawdust into the mixture has been proven as a key factor in altering quality, affecting technological properties of the final ceramic product.

The results obtained in this work showed that up to 9% Eucalyptus sawdust can be incorporated into material mixture (clays and tuff).

The having sawdust particle size 1.6 mm provided better results.

Results indicate that bulk density varies between 1.48 g/cm^3 and 1.65g/cm^3 when sawdust is incorporated, which corresponded to a decrease of 20% and 10% respectively compared to the bulk density of traditional ceramics brick used in construction, and therefore they can be used in lightweight building material. Water absorption and the bending strength decreased with the shaping moisture increase.

Based on these preliminary results, it can be concluded that Eucalyptus addition sawdust can be used as secondary raw materials for production of lightweight insulating ceramic bricks. Optimal results are obtained by incorporating 9 % (wt) of eucalyptus sawdust addition to clay body.

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