VALORIZATION OF THE SAWDUST FOR THE IMPROVEMENT OF THE MECHANICAL-PHYSICAL PROPERTIES AND OBTAINING A LIGHT CERAMIC PRODUCT

***H. Chemani*[*], *B. Chemani*[**]**

*Laboratoire des Matériaux Minéraux et composites. Université M'Hamed Bougara Boumerdes 35000 Algérie
E-mail: chemani_salima@yahoo.fr
**Laboratoire de Fiabilité des Equipements Pétroliers et Matériaux.Université M'Hamed Bougara Boumerdes 35000 Algérie
E-mail: chemani_ba@yahoo.fr

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Nowadays terra cotta industry is interested in the manufacture of a new reduced produced whose design deviates from the traditional models. The recycling of chips of wood such as the sawdust seems to be the best insulator which offers the properties of required ceramic products. Two types sawdusts were considered in this study, pertaining to two wood (pine of Alep) family of coniferous timber and the other (the eucalyptus) family of timber broad leaved and which differ by their origin, structure, their physical properties, chemical etc. These sawdusts were introduced into various argillaceous mixtures made up of yellow clay, of grey clay more of the tuff. The work was concerned moistures of shaping varying from 22, 24 and 26 % with contents of sawdust of 3, 6 and 9 % and diameter dimensions of particles of 0.5; 1 and 1.6. Cooking was carried out at temperatures of 850 and 950 °C. The characterization of the ceramic products obtained during drying and of cooking made it possible to raise the considerable differences with regard to the physical and mechanical properties. A comparative study and of optimization enters the various products obtained made it possible to fix the choice on the products having been worked with a moisture of 22 %, a content of sawdust resulting from wood eucalyptus of 9 %, with a diameter of particles ϕ =1.6 mm corresponding to a density of 1.48 g/cm^3 and a mechanical resistance of 138.60 kgf/cm^2.

Keywords: valorization, sawdusts pine of Alep, eucalyptus, development of alveolar bricks, light, insulating

Halima Chemani

Organization: Enquiring teacher, Doctor in sciences, Vice President of the Algerian clays Group, Member of the technical committee of standardization of ceramics products.
Education: M'Hamed Bougara University of Boumerdes, Faculty of Science of Engineer, Department Genius of materials (1980-2007).
Experience: Scientific research projects: National Development of University Research Agency (ANDRU). Member of the laboratory of mineral materials and composite.
Main range of scientific interests: powders, mineral materials, nanomaterials, materials environmental.
Publications: Scientific journal of the Belgian Ceramic Society. Silicates Industrials Vol. 71, 11-12. P. 197-203 (2006); Ceramic Industry and glass, No. 988 June 2003; No. 990 September-October 2003; No. 995 July-August; No. 1005 March-April 2006.

Bachir Chemani

Organization: Enquiring teacher, Doctor of state PHD, Vice dean in charge of the pedagogy.
Education: M'Hamed Bougara University of Boumerdes, Faculty of Science of Engineer, Department of maintenance (1979-2007).
Experience: University Scientific research projects. Member of Laboratory of reliability of the oil equipments and materials.
Main range of scientific interests: materials sciences, nanomaterials, reliability.
Publications: Ceramic Industry and glass, No. 990 September-October 2003.

Introduction

The increasing obligation to manage and develop the industrial and domestic waste leads to the development of new recycled products [1]. To develop waste is a choice which meets at the same time the economic and environmental requirements [2]. Each material must contribute to the total objectives of recycling while fitting in a range of 55 to 80 % and to await a minimum of 60 % of valorization. The principal innovation consists of the fixing of targets differentiated by materials (Glass: Sciences, Technology, Industry, Produced, Art, History) [3]. Wood is a material which seems to be very appreciated for these mechanical properties, its calorific value and other. It has many uses in the building and industry as a fuel [4]. Constituted mainly of organic matter (1.0-1.5 %) of biogenic salts, it also contains a variable share of moisture: Cellulose (40 to 50 %), lignin (20 to 30 %), hemicellulose (15 to 25 %) and other organic substances (polysaccharides, resins, waxes etc) [5, 6]. Nowadays, it is extremely interesting to fix its vision towards new insulating materials because the insulation plays the part of barrier for the thermal transfer by means of this type of material having the capacity to transmit the lowest possible heat. In the Seventies the need for heat insulation to save energy became an obsession. The industrialists then rushed on very powerful and not very expensive insulators often resulting from polystyrenes and polyurethans. Alas these materials are not safe for health and require a great quantity of energy of manufacture. Thirty years later an increased sensitivity appeared coming from the countries of Europe and spreading little by little towards the south concerning the elaborate ecological insulating products starting from vegetable and animal fibres, of mineral insulators as well as other renewable materials such as cellulose, cork, sawdust etc [7]. To achieve these goals our principal efforts in this study were dedicated on the use of the sawdust in a ceramic mixture of mass which at the same time plays the part of grease-remover and amongst other things gives the possibility of obtaining terra cotta bricks having an alveolar aspect, of low density and higher mechanical resistance in comparison with traditional bricks.

Experimentation

The analyses were carried out on raw materials local grey clay, the yellow clay of the tuff and sawdust coming from two types of wood "pine of Alep and eucalyptus". The results of analyses are based on the preparation of sawdusts to various granulometry obtained in sieves (0.5 – 1 – 1.6 mm). The drying of the sawdust is carried out in a drying oven of laboratory at the temperature 105 °C of the type Memmert UL50. Maximum temperature 220 °C with ventilation the granulometric analysis was determined by wet process by using a series of sieve of various diameters (5 –2 – 1 – 0.63 and 0.20 mm), and by "pipette of Robinson". The optimization of ceramic pastes is related to: preparation of briquettes starting from 03 types of mixtures made up of clays grey, yellow, tuff and sawdust. These mixtures are named M_1, M_2, M_3, M_4 of which the proportions are respectively: (65 – 30 – 2 – 3 %), (65 – 27 – 2 – 6 %), (65 – 24 – 2 – 9 %). The water contents of shaping are 22, 24 and 26 %. The contents of sawdusts are 3, 6 and 9 %. For some moisture we considered the 3 types of contents of sawdusts and for each content one considered the 3 types of granulometry. The drying of briquettes proceeded in two stages: with the free air during 24 hours then in a drier with room lasting 24 hours. Cooking was carried out in a tunnel kiln with temperatures of 850 and 950 °C. The characterization of the physical and mechanical properties was related to the drying and firing shrinkage, absorption, porosity, the bulk density and the specific mass. The mechanical resistance is given in an apparatus of inflection of the type 401 NEZSCH EN100. The chemical analysis was determined by the sequential spectrometer of X-ray of the type SRS 303 Siemens. Water supply: 3V min. Supply air: 2V min.; Pressure water: 4 to 8 Bars; Pressure air: 4.5 to 10 Bars. The principal minerals combined with clays and natures of phases are determined by diffractometer X-ray de type Siemens "500D" 20 my – 40 kV with X-ray Cu tube.

Results and discussions

The results of chemical analysis are carried in Tables 1, 2.

Table1

Chemical analysis of two clays

Principal elements	Contents (%)	
	Grey clay	Yellow clay
SiO_2	48.02	51.28
Al_2O_3	10.63	12.34
Fe_2O_3	4.68	4.76
CaO	13.49	11.39
MgO	1.67	1.48
SO_3	1.23	0.95
K_2O	1.51	1.67
Na_2O	0.61	0.57
Loss in ignition PF	17.34	14.72

Table 2

Chemical analysis of the tuff

Tuff	
Element	(%)
SiO_2	33.66
Al_2O_3	15.78
Fe_2O_3	4.42
CaO	2.27
MgO	2.42
P_2O_5	0.08
K_2O	4.34
Na_2O	3.40
TiO_2	0.40
MnO	0.08
PF	2.92

According to Table 1 one notes that the two types of clays have one propriety in common on the one hand: the rate of Al_2O_3 which in both cases is < 14 % which makes it possible to classify them in the group of acid clays [8], in addition the limestone rate ranging between 6-20 % makes it possible to classify them in the group of marly clays. The products cooks yellow [9].
The elements playing the part of energy fluxes (K_2O, Na_2O) have a rate slightly more raised concerning yellow clay, which confers better properties of cooking to him. The principal elements which make distinguish these two clays are first of all the rate of SiO_2 which is higher in yellow clay this makes it possible to say that this type of clay is sandier and plays consequently the part of grease-remover. It is also noticed that the rate of CaO, SO_3 and Loss in ignition PF is higher in the case of grey clay what exact correlation is with the rate raised in loss on the ignition.
One notes according to Table 2 that the prevalent elements in the tuff are silica the iron alumina and oxide. This last element colours the tuff in red. The tuff presents an aspect of perfectly consolidated ash what makes it possible to classify it in the group of pumice tuff [10, 11, 12]. In addition it is noticed that the rate of the alkaline elements is considerably important and makes it possible to conclude that the tuff plays the part of flux in the ceramic mass.
According to the results of the mineralogical analysis (Table 3), yellow clay is of type illite/ montmorillonite and grey clay is of type Illite/ Kaolinite/chlorite.

Table 3

Mineralogical analysis of clays

Principal minerals	Contents (%)	
	Grey 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

According to Table 4 one notes that grey clay contains much more argillaceous particles than yellow clay this is in correlation with the data of the Table 1.
The grain size analysis of the two types of clays are illustrated in Tables 4 and 5.

Table 4

Granulometric analysis of clays "Pipette of Robinson"

Type of clay contents (%)	Dimensions of the particles (mm)				
	1 to 0.063	0.063 to 0.01	0.01 to 0.005	0.005 to 0.001	< 0.001
Grey clay	14.65	30.99	13.20	11.00	30.16
Yellow clay	12.40	25.28	13.28	22.72	26.32

Table 5

Granulometric analysis of clays "Wet process"

Type of clay Contents (%)	Mesh sizes of sieve (mm)				
	5.00	2.00	1.00	0.63	0.20
Grey clay	0.00	0.00	0.03	0.03	0.10
Yellow clay	0.00	0.00	0.00	0.1	0.03

According to Table 4 one observes that the rate of refusal of yellow clay is weaker than that of grey clay. In addition yellow clay is made up much more small particles probably with the mineral montmorillonite which is associated clay and which is in correlation with the results of Table 3.
Among the principal studied physical mechanical properties, one notices that the drying shrinkage the products manufactured containing sawdust of the pine of Alep is higher than that of those manufactured containing eucalyptus. This last A tendency to decrease according to the increase in granulometry and the content of sawdust but the values become definitely high when the moisture of shaping of the ceramic paste passes from 22 to 26 %. This variation remains identical in the case of adding the two types of sawdusts. This is with the structure of the wood of origin [5]. The sawdust of the pine of Alep belongs to the family of coniferous timber tender with structure made up of large channels which have the capacity to absorb much water and to give a great shrinkage compared to the family of leafy trees "eucalyptus" which them consist of vessels [13]. The absorption of water is done by the hydrogen bonds of the hydroxyls groups accessible from hemicelluloses, lignin and cellulose. Water, occupying a space in polymers, inflates the cellular walls and wood dilates as water is absorbed until the cellular walls are saturated. Wood east defines as a hygroscopic material which inflates by absorbing moisture and contracts by losing moisture below the point of saturation of the fibres [14]. For firing shrinkage, one notes the same case of variations of values. On the other hand clay containing sawdust of the pine of Alep varies proportionally with the temperature of cooking, and preserves values always higher than those of the eucalyptus. The highest shrinkage is recorded for moisture of shaping of 26 %, a content of sawdust 3 % with a diameter (Φ) of particles 0.5 mm. The values of the firing shrinkage temperatures of cooking of 850 and

950 °C are respectively 2.44 and 2.79 %. The high values shrinkage of result in a rearrangement of the particles which leads to a texture consolidation compared to the initial state followed by contraction [15, 16]. The sawdust plays the part of grease-remover of paste in a believed state and porogene agent. During cooking the specific values of mass obtained with the pine of Alep remain in their turn higher than those of the eucalyptus. The specific mass is inversely proportional to the content of sawdust to size of the particles and moisture the paste, but varies proportionally with the temperature cooking. The values of bulk density as for them are inversely proportional to the content of sawdust, with the size of the particles, the moisture of the paste and the temperature cooking. These values remain always higher than those of the sawdust of the eucalyptus. The rise in the temperature leads to a swelling and a reduction in volume of material obtained. There is a direct correlation between the values of absorption and apparent porosity. To low values of absorption corresponding to low apparent porosities and on the contrary. These values are proportional to the content of sawdust, with its size but are inversely proportional to the temperature. Because during the cooking of the ceramic product there is appearance of liquid phase which takes part in the elimination of the vacuums and the pores allowing the bringing together of the particles following a formation of zones of contact inter granular [17]. The products leading to the bulk density lowest are those obtained with the sawdust mixture of the eucalyptus with the moisture of shaping of 22 and 24 %, diameter (Φ) of particles 1.6 mm, of content of sawdust of 9 %, temperature of cooking 950 °C. The values corresponding to these two types of moistures of shapings are respectively 1.52 and 1.43 g/cm^3. Table 6 gathers the values the physical and mechanical properties of the cooked eucalyptus with 950 °C.

Table 6

Physical and mechanical properties of light bricks containing sawdust eucalyptus
(Temperatures 950 °C)

H_f (%)	Φ (mm)	Content of sawdust (%)	Drying shrinkage (%)	Firing shrinkage (%)	Abs (%)	Apparent porosity (%)	Sealed porosity (%)	M_v g/cm^3	M_s g/cm^3	R_{Flex} kf/cm^2	R_{Comp} kf/cm^2
22	3	0.5	13.93	1.83	2.37	4.42	23.83	1.84	2.61	165.20	660.80
		1	12.65	1.75	3.30	4.70	24.03	1.82	2.56	158.00	632.00
		1.6	10.89	1.68	5.28	5.69	24.18	1.75	2.51	150.80	603.20
	6	0.5	13.51	1.67	5.19	4.46	24.49	1.82	2.59	162.80	651.20
		1	11.98	1.64	8.35	4.91	24.62	1.80	2.54	154.40	617.60
		1.6	9.28	1.59	10.66	5.74	25.26	1.71	2.45	147.20	588.80
	9	0.5	12.99	1.60	7.36	5.46	24.78	1.79	2.53	154.42	617.68
		1	11.66	1.56	11.18	6.31	24.81	1.72	2.49	148.40	593.60
		1.6	8.66	1.49	12.86	6.39	26.15	1.68	2.43	144.80	579.20
24	3	0.5	15.91	2.35	4.07	4.68	24.34	1.81	2.55	162.80	651.20
		1	14.58	2.04	5.27	5.44	24.37	1.76	2.51	153.21	612.80
		1.6	12.67	1.85	6.80	6.74	24.98	1.70	2.49	148.41	593.64
	6	0.5	14.94	1.98	5.46	4.77	24.67	1.78	2.53	158.02	632.08
		1	12.98	1.81	8.99	5.56	24.77	1.74	2.48	149.60	598.40
		1.6	11.42	1.73	10.97	6.87	25.40	1.67	2.43	146.00	584.00
	9	0.5	14.23	1.82	8.06	5.67	25.15	1.75	2.51	152.02	608.08
		1	12.53	1.67	11.63	6.71	25.30	1.69	2.46	147.22	588.88
		1.6	10.86	1.61	13.45	7.05	26.89	1.65	2.41	143.60	574.40

Legend: ***H_f*** *– Moisture,* ***Abs*** *– Absorption,* ***M_s*** *– Specific mass,* ***R_{Flex}*** *– Bending strength,* ***Φ*** *– Diameter,* ***M_v*** *– Bulk density,* ***R_{Comp}*** *– Compressive strength.*

By considering the results carried in Table 7 one notes that the pine of Alep provides the same mechanical resistance as that of the eucalyptus mentioned in table 6 for a value of moisture of shaping of argillaceous paste of 24 %, to which corresponds a bulk density of 1.65 %. As for that of the eucalyptus the values of bulk densities and mechanical resistances are lower to 26 % of moisture of shaping. To avoid the problem of sensitivity

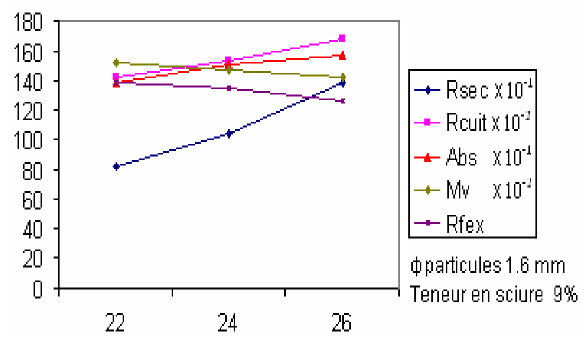
of drying it would be thus necessary to remain in an interval limited enough by humidifying the argillaceous mixtures and to fix our assumption on moisture 24 %.
The rates of shrinkage of the pine of Alep are considerable as the moisture of the argillaceous paste increases which could make drying rather slow and delicate It is advisable to consider that the characteristics of the sawdust of the eucalyptus for a water content of paste of 24 % as it was underlined in fat in Table 5 remains the best recycling wood product.
The latter enabled us to acquire the required properties of light brick.

Table 7

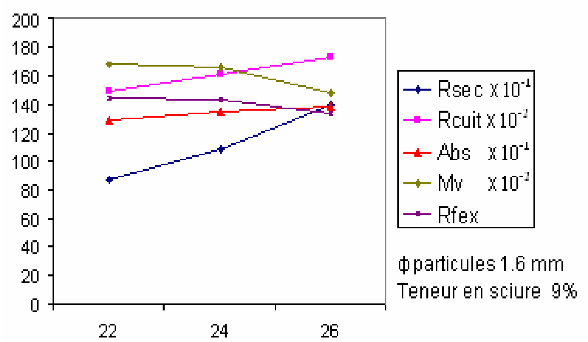
Physical and mechanical properties of light bricks containing sawdust of pine of Alep – sawdust of eucalyptus with 26 % of moisture of argillaceous paste

Parameters of manufacture		Physical and mechanical characteristics	Sawdust of pine of Alep	Sawdust eucalyptus
Sawdust Φ	1.6 mm	M_v (Bulk density)	1.48 %	1.43 %
Content	9 %	Abs (Absorption)	13.85 %	15.70 %
Moisture of the paste	26 %	$R_{flexion}$ (Bending strength)	134.00 kf/cm^2	126.80 kf/cm^2

Fig. 1 shows well a considerable difference between the two sawdusts in comparison with the values obtained in a former study and where addition was of the organic type such "coal".



a



b

***Fig. 1.** Physical mechanical characteristics of the sawdust of the eucalyptus (a) and that of the pine of Alep (b) for a content of 9 % and one diameter of particles of 1.6 mm*

Conclusion

Before developing a waste it would be advisable to know its origin, to analyze it, characterize its current state, its behavior like addition in the mass or mixes to analyze and evaluate its traitability.
Thus the global solution of waste will make it possible to define some its to become with knowing which type of valorization choose.

The sawdust as a matter of recycling introduced into various mixtures of clays plays at the same time the part of grease-remover in the raw paste and porogene agent (insulators) during cooking.
The sawdusts considered and pertaining to two wood different pines of Alep and eucalyptus give products which show definitely different characteristics.
This difference comes owing to the fact that the cells constituting the structure of wood form an assembly according to a true architecture whose plan differs from one wood turpentine to other what confers no identical properties to us.
The sawdust addition resulting from the pine of Alep in the argillaceous mass gives values of definitely high shrinkage becoming increasingly large with the rise in the moisture of the paste. This remains related to the structure of the pine of Alep which is porous compared to that of the eucalyptus. The properties which characterize the quality of required insulating materials are obtained starting from the mixtures made up of 24 % of moisture of shaping, sawdust 9 % of eucalyptus and having a diameter of particles of 1.6 mm.
The value of recorded bulk density is of the order about 1.48 g/cm^3 corresponding to a mechanical resistance of about 134.60 kf/cm^2. The latter is definitely high in comparison with that of a traditional terra cotta brick which is of the order about 100 kf/cm^2.

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