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Mechanical Study on the Marine Sediments of Bethioua Port to Valorizing them in the Manufacture of Bricks

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Abstract. The work focuses on the practical use of sediments of Bethioua port in the manufacture of bricks. The sediments were introduced into the reference mixture with a substitution rate of 20% as a replacement for the clay used for making the bricks. The mix used in the Brickyard (reference brick) consists of 75% clay and 25% sand. The manufacture of reference brick test pieces and cylindrical-shaped marine sediment bricks was prepared from mixtures of clay, sand and a sediment substitution rate of up to 20% without any change in manufacturing process. The brick test pieces were fired at temperatures between 600 and 900 ° C with a cooking time of 6 hours and 24 hours. The brick test pieces produced were then subjected to compressive strength tests. The results obtained showed that the mechanical properties of the sediment-based brick with a substitution of 5 and 10% give a better resistance than the reference brick. The sediment substitution with this concentration by sediment increases the compressive strength with low temperature and low cooking time. The results of this study demonstrate that the production of bricks fired with the marine sediments of the Bethioua port improves significantly and gives a better resistance than the resistance of the reference brick for an addition of 5 and 10%. The rate of 15% gives a resistance comparable to that of the resistance of the slip of brick.

Keywords. Marine sediments, Dredging, Valorization, Brick, Characterization.

INTRODUCTION

Dredging operations have always been essential to maintain, deepen or develop these sites and ensure the proper functioning of trade by sea and river (Benyerou, 2017). In recent decades, the manufacture of bricks using marine and fluvial sediments has been evaluated worldwide (Lafhadj et al., 2008; Samara et al., 2009; Yang et al., 2014; Romero et al., 2008; Sépouv et al., 2010). Dredging practices are an issue for the development and maintenance of port activities

(Benamar et al., 2012; Levachie et al., 2011). New and better sediment-based building materials have been developed. Nevertheless, different regions of the world have used traditional clay bricks that have made local resources available in the world (Manoharan et al., 2011). Mechanical characterization is mainly concerned with the effect of the addition of marine sediments according to the increase of the temperature on the resistance. The aim of the valorization is to examine two lines of applied research to reduce the tonnage of dredged materials and to valorize them in the manufacture of bricks.

MATERIAL AND METHODS

The samples of the sediments studied were taken directly from the basin on 20/05/2013 at 14:10 with a temperature of 23°C at the Bethioua Port (Fig. 1). The raw materials used for the manufacture of bricks are made of clay and sand. The sediments studied were taken using a mechanical drag which is basically a mechanical shovel mounted on a pontoon in the "Bethioua". The samples were taken at a depth of 6.50 m (relative to the surface of the water) and a distance of 6.55m from the wharf, the weather was cloudy to very cloudy with rain, the visibility was average with a wind from east to west 10-20 NDS, the sediment activity induced by the sea currents little stirred and the swell was north to north east around 1m. The dredged material was kept in clean watertight bags and transferred the same day to the laboratories. The study includes a set of physical properties (parameters of state and nature, water content, granular distribution), chemical properties (pH, conductivity, organic matter content and hydrocarbons) and mechanical properties (resistance to compression).

Fig. 1. Sediment sampling site (Port of Bethioua).

Physical properties

The water content was determined according to standard NF P94-050 and the absolute density according to standard NF P94-054. The results obtained are shown in Table 1. The particle size analysis was carried out by laser granulometry (Fig. 2). The grain size curves of marine sediments and brick slip are almost confused. These curves show the presence of a clay fraction of the order of 2%, a silty fraction of the order of 20% and a sandy fraction of the order of 78%. The diameters of the d_{10} and d_{95} particles are respectively 3 µm and 270 µm for marine sediments and brick slip. The limits of Atterberg were carried out according to standard NF P94-051, the results give a limit of liquidity W_L = 30.2% and a limit of plasticity Wp = 19.6% for marine sediments. On the other hand, for the clay used in the manufacture of bricks, these limits are respectively 50.1% and 25.2%.

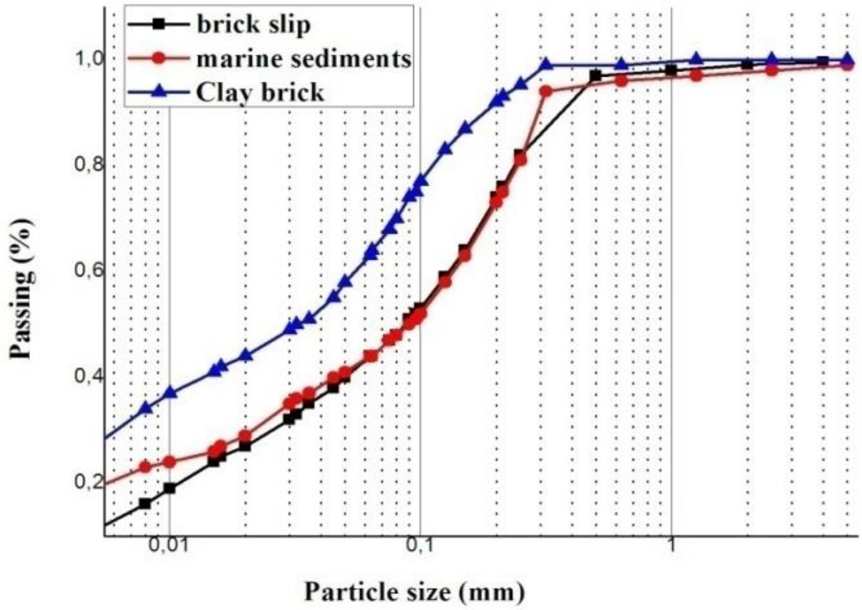

Fig.2. Granulometric curves of marine sediments, brick clay and brick slip.

Chemical properties

Table 1 gathers the chemical properties such as pH, conductivity and organic matter. The pH was determined according to the NF X31-103 standard, the electrical conductivity was measured with a conductimetric cell calibrated according to the NF ISO 11625 standard. The measurement of the organic material was carried out using the XP standard P94-047. The trace elements were determined by atomic absorption spectrometry. The results obtained are collated in (Table 2). They show that there is a low presence of hydrocarbons in marine sediments. In the case where the results found are between the recommendation levels 1 and 2 (see Table 2), an additional investigation is necessary depending on the project in question. Tests are performed to evaluate the overall toxicity of the sediments. To have a more precise idea on the chemical composition of the studied materials, one proceeded by the fluorescence of X-rays. The results are grouped in the (Table 3) and expressed in percentage mass. This detailed analysis of the results is based on the comparison of the contents for different oxides. These results show that alumina (Al_2O_3) is related to plasticity. It is noted that the contents of this oxide are higher in this clay than those of marine sediments. To conserve plasticity it is necessary to mix marine sediments with clay. The silica (S_iO_2) content values in these marine sediments meet the brick manufacturing standards. This oxide corresponds to the presence of quartz with a sufficient content to be used as a degreaser without adding an inert element such as sand. Iron oxide (Fe_2O_3) is the main dye in clays and is responsible for the red color after cooking. The lime content (CaO) is high for marine sediments.

Table 1. Physico-chemical parameters of the materials studied.

Settings	Marine sediment	Clay brick
Density (g/cm^3)	2.2	2.6
Fraction < 6.3 µm (%)	58	88
Fraction > 6.3 µm (%)	42	12
Wp (%)	30	49.8
WL (%)	18.9	25.7
VBS (%)	1.56	5.3
O.M (%)	1.88	3.66
pH	8.7	8.1

Conductivity	361 mS	169 µS

Table 2. Levels Relating to Trace Elements (in mg / kg of dry studied materials analyzed on fraction less than 2 mm), GEODE (METL and MATE, 2000).

Metal	Units	Marine sediment	Brick clay	Level 1	Level 2
Lead (Pb)	Mg.kg	<0.01	<0.01	100	200
Mercury (Hg)	Mg.kg	<0.01	<0.01	0.4	0.8
Chrome (Cr)	Mg.kg	<0.005	<0.005	90	180
Cadium (Cd)	Mg.kg	<0.01	<0.01	1.2	2.4
Arsenir (As)	Mg.kg	<0.05	<0.05	25	50
Tin	Mg.kg	<0.01	<0.01	/	/
Nitrite	Mg.kg	0.00	0.00	37	74
Phenol	Mg.kg	0.017	0.017	/	/
Total	Mg.kg	1.010	0.441	/	/

Table 3. Chemical composition in major elements in the materials used.

Parameters in (%)	**Marine sediments**	**Brick clay**	**Brick slip**
S_iO_2	27.9	48.4	61.0
Al_2O_3	6.1	12.2	12.1
Fe_2O_3	4.01	7.72	5.48
CaO	29.4	10.7	9.09
MgO	2.71	2.50	1.76
SO_3	0.85	0.70	0.04
K_2O	0.70	2.03	1.13
Na_2O	0.34	0.55	0.46
Cl	0.02	0.05	0.13
P_2O_5	0.11	0.21	0.11
TiO_2	0.18	0.56	0.72
LOI	28.9	16.1	7.80

RESULTS AND DISCUSSION

Compaction method and test specimen design

The brick test pieces were prepared by means of triaxial. This last was used to have compacted brick specimens with a definite pressure force (Fig. 3). The slip samples were mixed with a specified amount of water in a kneader for 15 minutes. Finally, the wet material is introduced into a hollow cylindrical mold of dimension 2 cm in diameter and 4 cm in height. Then the compaction is done by applying a pressure force of 100 bars. The material is compacted vertically at the top and at the bottom by means of two cylindrical pistons. After compaction, all the test pieces are placed in a drying chamber (40 ° C).

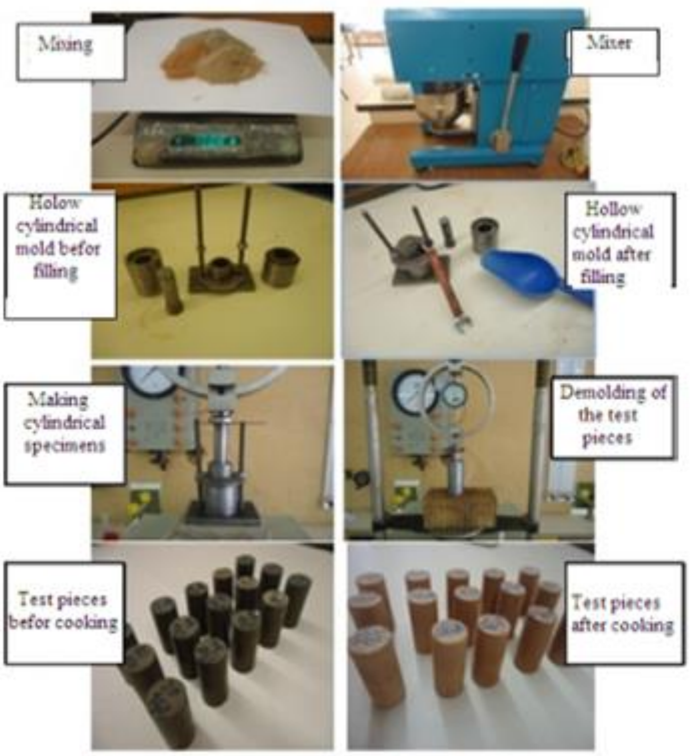

Fig.3. Preparation in laboratory test pieces of the brick.

Thermal and mechanical study

A method of compaction and design of specimens has been carried out or several formulations with different rates of clay substitution by sediments are compared and evaluated on an industrial scale (Benyerou et al., 2017). The prepared mixtures and their compositions are given in table 4 along with their identification codes. The brick test pieces were fired at temperatures between 600 and 900 ° C with a pitch of 100 ° C. These specimens were baked in an oven with a cooking time of 6 hours and 24 hours. The mechanical resistance of the reference bricks is increased with the increase of the temperature. However, the mechanical resistance of bricks based on marine sediments is increased with a lower temperature (Fig. 4, Fig. 5). Sediment substitution at a concentration of 5% and 10% increases the compressive strength with a low temperature (600 ° C instead of 900 ° C) compared to the brick slip. The maximum load reached is noted 38 MPa for a cooking time of 6 hours (Table 6) and the maximum load reached is noted 29 MPa for a cooking time of 24 hours (Table 5). According to (Benyerou et al., 2016), the increase in resistance for a 5% sediment addition is explained chemically. According to the chemical characterization of different formulations, it is noted that for the first formulation (F1) there is a maximum saturation of the monolayer which may be due to a distribution of active adsorption sites on the surface of the solid material. The adsorption capacity corresponding to a maximum saturation of the monolayer of brick clay in major elements in the mixtures. This adsorption capacity is greater for a 5% marine sediment addition than for the other formulations. The compressive strength for (Formulation 3) is comparable to the reference formulation for a cooking time of 600 ° C and then the resistance drops for (Formulation 4). The purpose of increasing the proportion of sediment is to improve the mechanical strength of the bricks to a proportion ranging from 5 to 15% and decreasing for a proportion of 20% of sediments at a temperature of 600 ° C. Given the physical, chemical and mechanical properties, the proportions of 5 and 10% substitution seem to be the most effective.

Table 4. Formulations with addition of marine sediments from 0 to 20%.

	Marine sediments %	Brick clay %	Sand %
Brick slip	0	75	25
Formulation 1(F1)	5	70	25
Formulation 2 (F2)	10	65	25
Formulation 3 (F3)	15	60	25
Formulation 4 (F4)	20	55	25

Table 5. Temperature-dependent compressive strength for brick slips with and without marine sediments for a cooking time of 24 hours.

Resistance in compression (MPa)						
Time (24h)	T(C°)	Brick slip	F1	F2	F3	F4
	600	19.5	28.7	25.8	20	18
	700	24	26.2	22	18.4	15.9
	800	26.1	20.4	18.9	15.6	14.3
	900	28	16.9	15.4	12.4	11.8

Table 6. Temperature-dependent compressive strength for brick slips with and without marine sediments for a cooking time of 6 hours.

Resistance in compression (MPa)						
Time (6h)	T(C°)	Brick slip	F1	F2	F3	F4
	600	26.4	38.5	31.2	25.7	20.9
	700	20.8	35.5	24.6	22.3	17.3
	800	16.4	22.6	20	17.1	12.1
	900	14.1	18.6	17.3	14.6	7.66

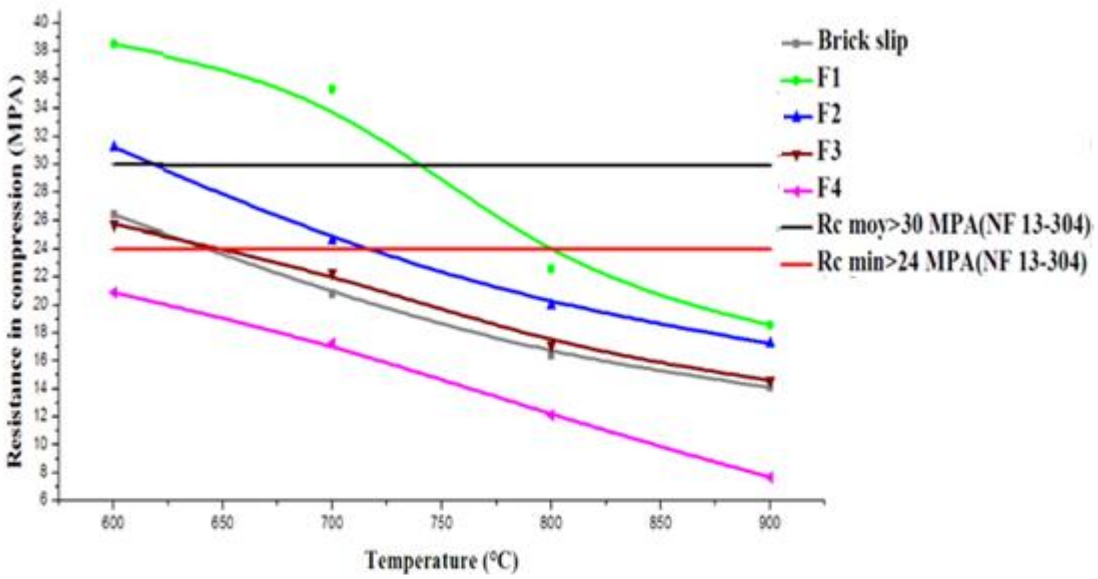

Fig. 5. Resistance to compression as a function of temperature for reference bricks and bricks based on marine sediments with a cooking time of 6 hours.

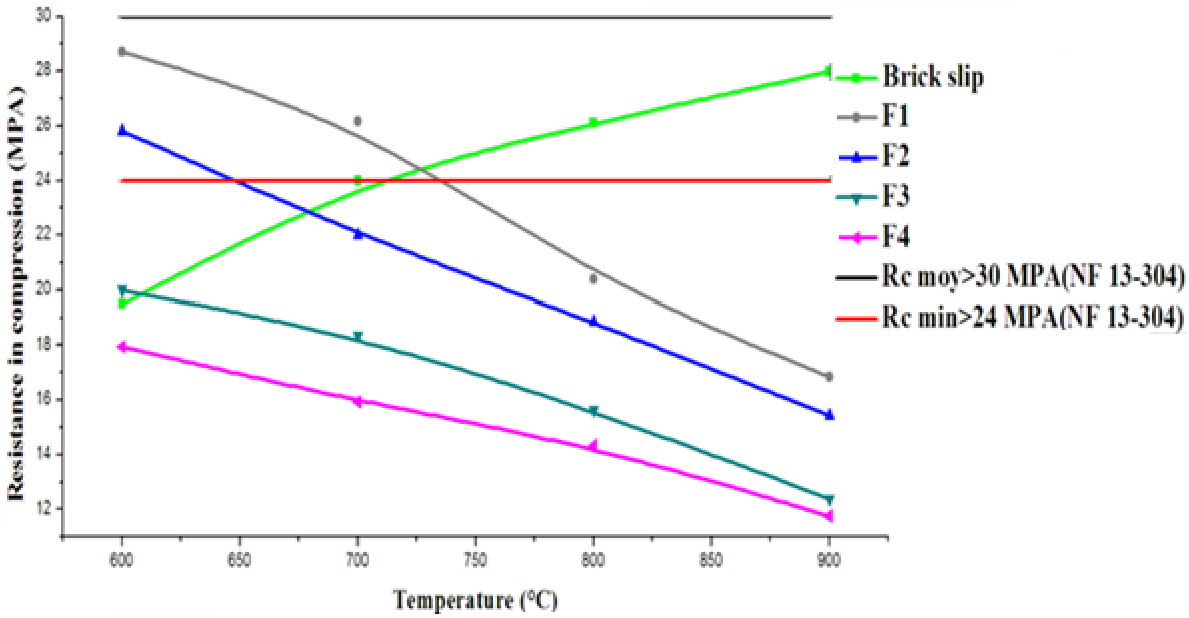

Fig. 5. Resistance to compression as a function of temperature for reference bricks and bricks based on marine sediments with a cooking time of 24 hours.

Economic study

The economic study was carried out using 5% of marine sediments as the first formulation (F1). We calculated the gain of the plant using marine sediments. Table 7 shows the cost calculation of materials used for the manufacture of bricks. The brickyard consumes annually a quantity of materials of about 64 800 tonne. The annual production of bricks is of the order of 10 million 800 pieces of brick with a turnover which reached 12 million DA per year knowing that the quantity of the materials used in the brickworks is of the order of 48 600 tonne of clay and 16 200 tonne of sand.

Table 7. Calculation of cost of materials used for the manufacture of bricks.

Material	Composition (%)		Annual requirement (Tonne / year)		Unit price	Annual cost (DA)	
	Factory	F1	Factory	F1	DA/Tonne	Factory	F1
Clay	75	70	48 600	45 360	42	2 041 200	1 905 120
Sand	25	25	16 200	16 200	855	13 851 000	13 365 000
Marine sediments	-	5	-	3 240	1.5	-	4 860

Total	15 892 200	15 270 120

CONCLUSION

The physical characterization of the marine sediments of the Bethioua port shows that the grain size curves of these sediments and brick slip are almost identical. The chemical characterization of the sediments allowed to evaluate their valorization potential with the necessity to mix these marine sediments with the brick clay to keep the plasticity. These dredging sediments from the port of Bethioua have low hydrocarbon content and an absence of metallic pollution. The study of mechanical performance has shown that compressive strength is influenced by the amount of sediment. Given the mechanical properties of the bricks produced with the addition of sediments, it is noted that the 5 and 10% substitution rates are the most effective and give a better resistance than the reference brick (increase of the order of 30%). Sediment substitution with these 5 and 10% concentrations increases compressive strength with low temperature and low firing time (energy gain in addition to resistance). The rate of 15% gives a resistance comparable to that of the brick slip and a decrease in resistance for the 20% sediment rate. Finally, we can conclude that the bricks produced with the additions of marine sediments of the Bethioua port have very satisfactory physical, chemical and mechanical properties to be valorized.

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