View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Journal of Materials and Engineering Structures

Journal of Materials and Engineering Structures

Research Paper

Experimental study on the reuse of a dredging sludge from west of Algeria in brick fabrication

Hafida Marouf [a], ***Abdelaziz Semcha*** [b], ***Noureddine Mahmoudi*** [c,*], ***Nasreddine Bouhamou*** [a], ***Mahfoud Benzerzour*** [d], ***Walid Maherzi*** [d]

[a] *Laboratoire construction transport et protection d'environnment, Université de Mostaganem, Mostaganem, Algeria.*

[b] *Université Ahmed Draya, Adrar, Algeria*

[c] *Laboratoire Génie Industriel et Dévellopement Durable, Centre Universitaire Ahmed Zabana Rélizane, Bourmadia, 48000, Rélizane, Algeria.*

[d] *Ecole des mine de Douai, GCE, 764 BD Lahure, BP 1083,59508 Douai, France*

ARTICLE INFO

Article history :

Received : 8 January 2018

Revised : 21 May 2018

Accepted : 30 May 2018

Keywords:

Valorization

Sludge

Characterization

Brick

ABSTRACT

The siltation as a natural phenomenon threatens the performance of harbors by reducing their docking volume compared to dams in terms of water storage, as well as their life span. An alarming rate of siltation is noted in the various basins requires an urgent cleaning operations. In a context of valorization of the sludge resulted from the dredging operations of the basins of the Oran's port and those of the Bouhanifia's dam which are located in Western Algeria, it is a question of studying possibilities which are offered by the use of these vases in the design of bricks building. The followed methodology is based on a physicochemical and mineralogical characterization of the two vases to reveal the one closest to the standards recommended for the manufacture of the baked brick. After analyzing sediments dredged in the port of Oran, it turned out that there is a dominance of sandy sediments, which are not recoverable in the areas of bricks we have targeted. Sustainability tests were performed on several sludge dam samples at different temperatures and percentages of water. The results gave a satisfaction in mechanical strength and durability for a firing temperature of 850 ° C and a percentage of water of 20%.

1 Introduction

The acceleration of population growth in the world in general and in Algeria in particular has implied a strong demand for building materials for the realization of various infrastructures including housing. The scarcity of deposits and basic

* *Corresponding author. Tel.: +213 561 557 999.*
E-mail address: mahmoudi.noureddine@yahoo.fr

e-ISSN: 2170-127X, (cc) BY-SA

RESEARCH REVIEW of Sciences and Technologies

materials has led researchers in the field of Civil Engineering to find reliable and concrete alternatives to these materials. The valorization of the sediments result from the dredging of the ports and the dams presents a solution to the economic and environmental raised problem. The fields of Civil Engineering offer many possibilities for the reuse of these materials that have long been considered as waste.

The dredging mud is considered as waste and it has been tested and used as secondary raw material in substitution of the cement by a prior treatment [1-2]; Brick autoclaved [3]; Repair Mortar [4]; Self-compacting Concrete [5]; Filling Material [6-8]; and in the fabrication of red brick [9-21]. This study is a part of an approach to the management of the dredged sediments of the Bouhanifia's dam and the Oran's port by proposing a technically and economically viable value chain [4]; this required knowledge of the sediments for the establishment of their identity card [22]. Besides, Prior to the adoption of any recovery process, a work and feasibility methodology is required.

2 Experimental methods

2.1 Materials

This study focuses on the Bouhanifia dam, which is of great economic importance for the Mascara region (West of Algeria). The dam was built in 1937, which has a capacity of 73.1 Mm^3 and year after year its capacity is reduced by decantation of solid materials. The dam has an important activity for Mascara, which is agricultural region. This dam is subject to natural erosion that raises the siltation rate to 53%, this rate reduces its capacity relative to its initial state, so the managers were forced to use dredging operations to preserve the capacity of water storage.

Dredging operations are in progress; this will generate large quantities of solids to take care of (depot, storage, and recovery ...). The envisaged work, enters in a perspective of valorization of the sediments that result from the dredging of the dam in the fields of civil engineering.

Moreover, we have not only been satisfied with the valorization of the mud which results from the devastation of the dams, but also with exploring and using the mud from the dredging of the port of Oran, which is subjected each year to a significant siltation.

Oran is the second important economic town in Algeria, and its prosperity is due to the economic port which is the first port in The South side of Mediterranean Sea from Gibraltar that has big drafts for navigation of big cargos.

Indeed, the port of Oran was built at the mouth of three Wadis (Ras El Ain, Magenta and that of the White Ravine), which carry large quantities of sediments. These sediments are deposited as the currents flow in the harbor. The necessary drafts for navigation are reduced each time and this process requires many operations (dredging, storage, and salvage on the high seas.

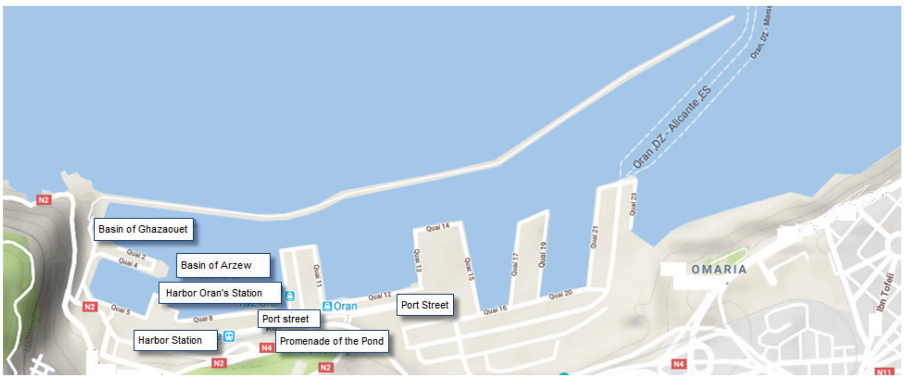

Fig.1-The Situation of the Quays of Oran's Port

The sample of the marine mud is taken from the quays 11 and 12 named before Casa and Safi on the basin of Mostaganem (Oran Port) illustrated in Fig.1. Sludge sample is taken downstream of the dam.

2.2 Study methodology

Prior to the adoption of any recovery process, a work and feasibility methodology is required. The study of methodology is illustrated Fig.2. Furthermore, the analysis is carried out by dry sieving after washing and carrying out in accordance to standard NF P 94-056. This analysis separates the particles with dimensions smaller than 80µm by sieving, then they are analyzed according to the sediment metric method according to standard NF P 94-057.

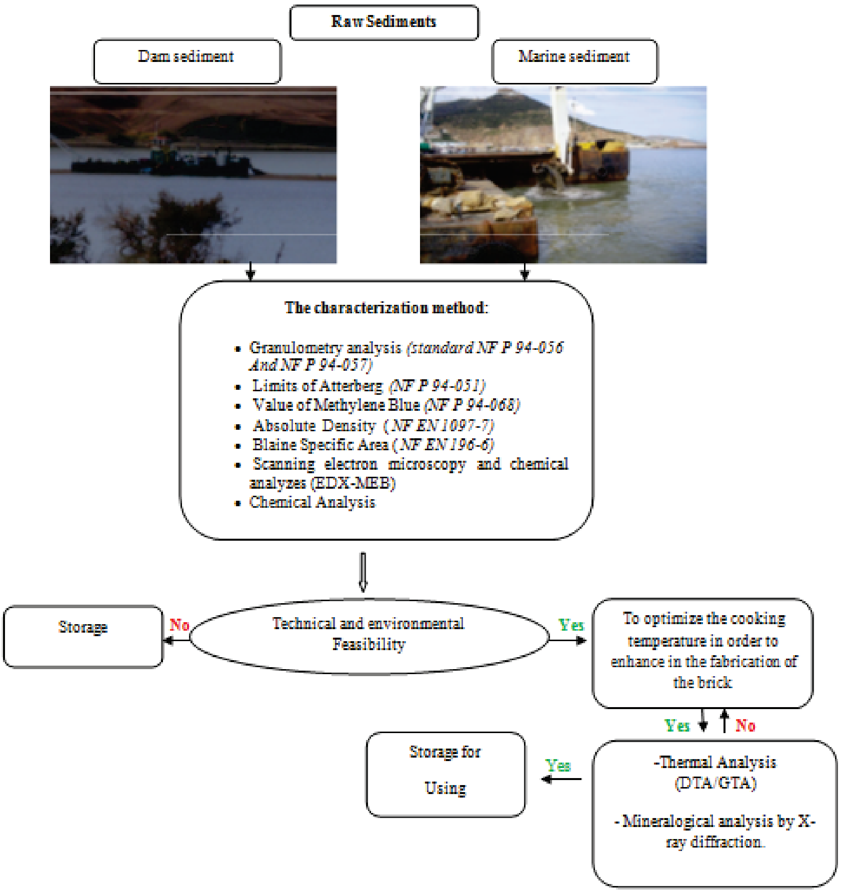

Fig.2 - Study methodology

2.3 Samples preparation

After pounding, and sifting at 80 µm and drying the material at 105°C during 24 hours, preliminary tests permitted us the confection of a brick to be used in building. Samples of mud were mixed with water until having a plastic state, which can be made in a cylindrical box (of the shearing test machine), with 50mm in diameter and 20 mm in high. The samples were passed in their boxes and extracted for the thermic treatment. The cooking temperatures were as follows: 900°C-950°C-1000°C and 1050°C. This treatment was realized in two main schedules. The fire stone, from ambiance temperature to the cooking temperature, which was maintained during three hours. The second one corresponds to the cooling schedule until ambiance temperature (to avoid the thermal impact).

Fig.3-Cooking temperature of Bouhanifia's mud (900°C, 950°C, 1000°C and 1050°C)

3 Results and discussion

3.1 Raw Sludge characterization

The results of the particle size analysis of the marine vase reveal a clay fraction 6%, silty 35%, sandy 52 and a gravel fraction 7%. This composition classifies the sediment in the category of silty sand according to the nomenclature GTR (Technical Road Guide). For sediment of the dam, the particle size analysis gives around 14.5% clay fraction, 70% silt and the rest is sand (decreasing matter).

We refer to standards; we can classify ours as clayey soil. The characterization results are identical to those of Labiod et al [9] and Remini [10].

The physical characteristics for the identification of the mud are summarized in the following table 1.

Table 1 - Summary table of physical analysis results

Physical characteristics	Results	
	Marine Vase	Dam's Vase
Water content (%) w	60%	49,8
Liquidity limit (%) w_l	95	50
Limit of plasticity (%) w_p	50	28
Plasticity index Ip	45	22
Absolute Density (g/cm3) ρ_s	2.3	2.6
The Value of Methylene Blue	1.28	6.76
Blaine Specific Area (cm2/g)	3666	2515
Carbonates $CaCo_3$ (%)	30.9	12.59
Organic materials MO (%)	6	3.01
Chlorides Cl^- (%)	1.46	-

In this table we globally remark that the marine vase is different than the dam's vase, and we can classify the first as sand and the second as clay.

According to the chemical analysis (Table 2), it is remarked that the sludge of the dam of Bouhanifia is closer to the recommended thresholds than the marine mud. The silica content of SiO2 is well within the standards and is sufficient to perform the role of degreaser without the need for additions of inert elements such as sand.

The alumina Al_2O_3 linked to the plasticity, allows using this vase for the manufacture of the brick since it is at the lower allowed limit. The content of Fe_2O_3 is very acceptable and makes it possible to consider this sludge as clay with a medium content of the colouring oxide. For marine mud, iron oxide and alumina levels do not meet the recommended thresholds.

Table2 - Chemical analysis

Oxides	dam Sludge	Marine Sludge	Recommended Threshold (%)[23]	Clay of Brickwork
SiO_2	49.36	70.17	35 à 85	47.91
Al_2O_3	12.26	3.29	9 à 25	14.4
Fe_2O_3	5.13	0.27	3 à 9	5.94
CaO	10.03	12.9	0 à 25	10.4
MgO	2.34	0.32	0 à 5	2.73
SO_3	1.77	-	0 à 3	0.4
K_2O+Na_2O	1.27	-	1 à5	2.79
TiO_2	0.63	-	0.3 à 2	0.78
PAF	15.15	23.4	13	14.44

Difference between KAZI's analyzes [24]: The observed differences are probably due to:

- The sampling area is not the same in both cases, nor in the same period.
- The dredging system used (suction dredge) mixed sediments of the sediment before sucking them to the storage area, which basically depends on the dredged layer in which the sediments differ.
- When collecting samples from storage ponds, where we targeted the clay deposits.

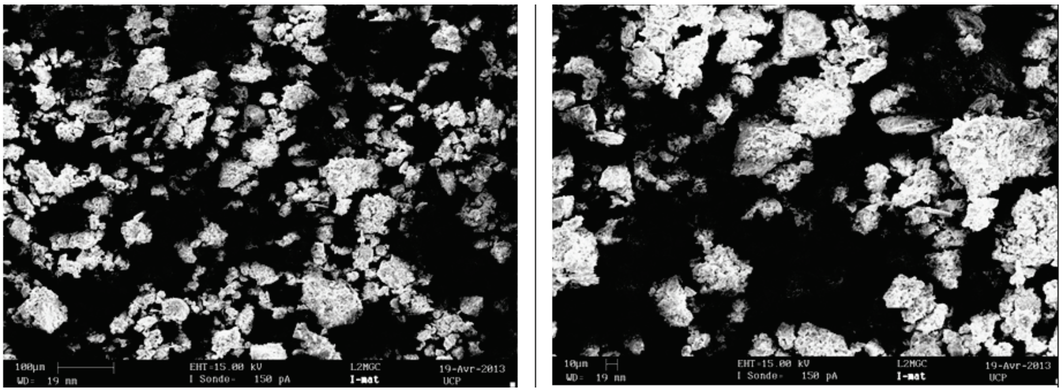

Fig 4- Topographic representation of Marine Sludge

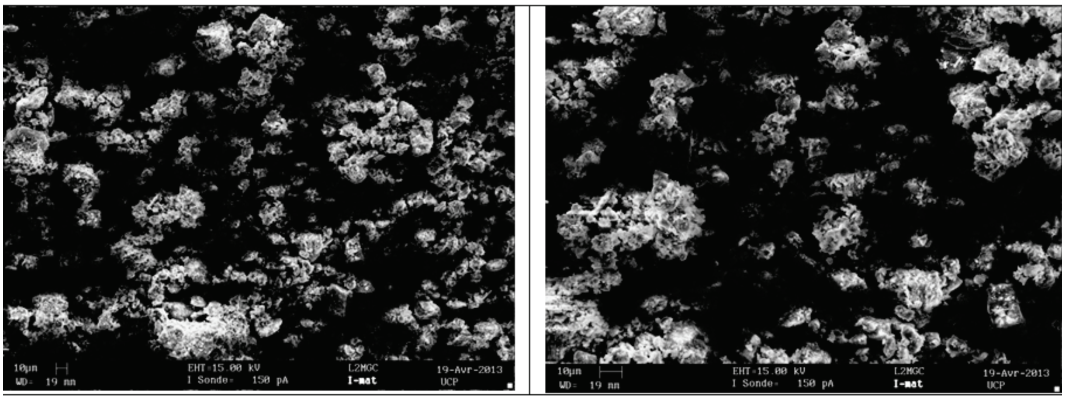

Fig.5- Topographic representation of Dam Sludge

The table 3 Percentage of mass of different elements that composed the marine and dam sludge.

Table 3- ***Semi-quantitative analysis of raw sludge***

	% mass	
Element	**Marine**	**Dam Sludge**
Ca	7,61	0.76
Si	8,22	6.08
Al	3,52	3.4
Mg	1,75	1.65
O	44,67	64.45
C	15,26	18.46
Na	4,58	0.84
Cl	4,12	-
S	1,30	-
K	0,66	0,22
Ni	0,70	0,01
Fe	1,56	-
Total	93,95	95,86

Moreover, a significant amount of oxygen is reported, which means that the environment is healthy and that the water in the dam is good quality.

In the marine sludge, Fe appearance and S elements curious result. Possibility of pollution's of samples.

Ni comes from the metallization of the sample during the analysis, so it should not be taken into account.

Knowing also that the mud of the studied dam is generally rich in oxygen. However, the marine mud is less oxygen-free and porous. The detected pollutants during analysis prevent the material from being compact. According to the results of analyzes carried out at the L2MGC laboratory in Cergy, the vase of the dam of Bouhanifia presented the possibility of valorizing it for the design of the brick building.

According to the study methodology, and by following the choice of the feasibility of the dredging mud; An ATD / ATG thermal characterization and an X - ray mineralogical analysis confirm and update the choice of temperature which aims at the pozzolanic activation of the material.

Calcination of the sludge was optimized at a temperature of 750 ° C at a rate of 5 degrees per minute and duration of 5 hours [3]. A similar study [1], the choice of activation temperature was 850 ° C for a duration of one hour.

With the Thermal Analysis (DTA/GTA) we noticed a first peak located around 800°C justifies the calcination that causes the dihydroxylation reaction of material, which leads to the formation of methacholine.

Through the study of diffraction the X-rays (Fig.7), we noticed the appearance of the other elements with important intensities. At a temperature of 650 ° C no element of considerable intensity appears. At 900°C there is an active presence, which confirms the thermal results of ATD/ATG.

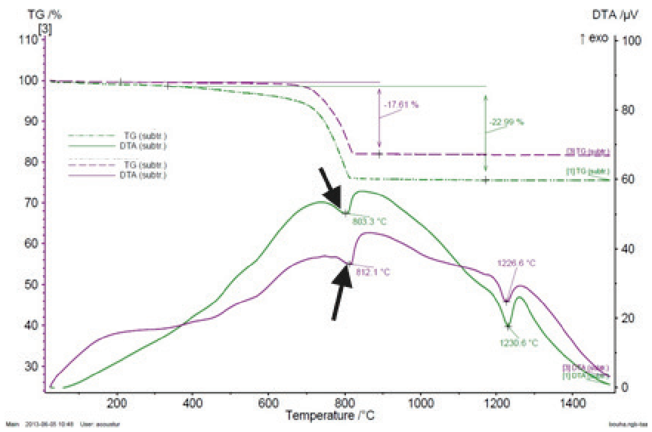

Fig.6- Thermal Analysis DTA / GTA

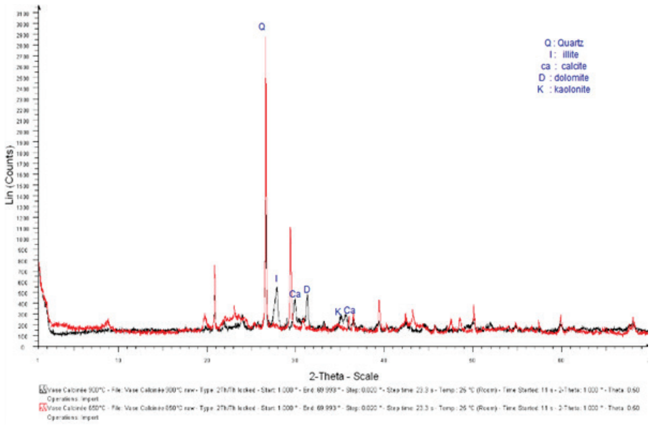

Fig.7 - DRX sludge calcined at 650°C and 900°C

3.2 Study of Brick Samples Properties

3.2.1 Water absorption test

According to EN 771-1 which is determined by dividing the weight of the brick after immersion in water by the initial weight of the brick. After recording the initial weight of baked bricks at temperatures 900°C, 950°C, 1000°C and 1050°C, the samples were immersed in fresh water for 24 hours.

In addition, we noticed that water absorption increases with the increasing baking temperature. Porosity is then directly related to the amount of water absorbed. Besides, we deduced that porosity increases with increasing baking temperature.

Moreover, porosity has an important influence on the mechanical strength and the permeability [14]; we may deduce that mechanical resistance will decrease. For these reasons, we thought that testing at a very low temperature level should be optional 900 °C.

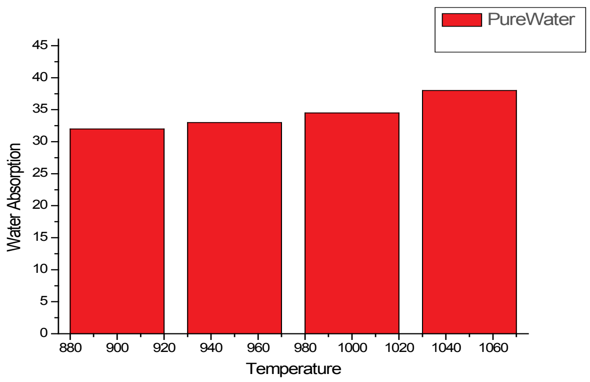

Fig.8-Water absorption (%) after cooking

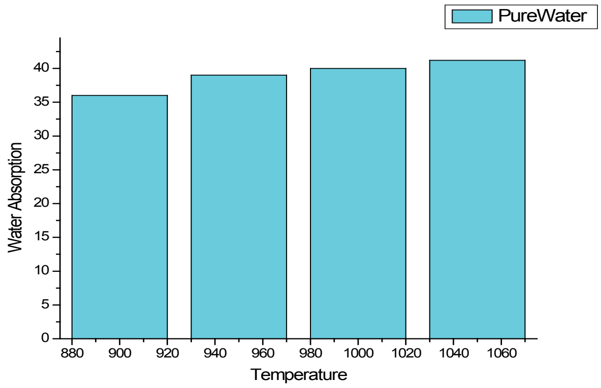

Fig.9-Water absorption (after 25 Freeze-Thaw cycles)

3.2.2 The Freeze-Thaw Test

The test consists of subjecting the products 25 freeze-thaw cycles (-15°C to +15°C).The durability and strength of our samples is checked after being tested freeze-thaw by immersion in water for 24 hours. The freeze –thaw causes a slight increase in the absorption of water, which is explained by the deterioration of the analyzed samples.

Following the manufacture of cylindrical bricks, tests were carried out on prismatic molds (4x4x6) cm^3. Shaken on a shaking table, which is pressed with a hydraulic press and baked at an optimized temperature of 850 °C.

Fig10-Prismatic molds cooked at 850 ° C

3.2.3 Mechanical resistance

The result of the compressive strength is 21Mpa. The obtained values obtained from the resistance to compression are acceptable because they are higher than the limit tolerated by the standards in force which is 100 bars [10].

3.2.4 Design Procedure

For a baked brick-making process based on the dredged sludge at the Bouhanifia dam, a sample preparation with water percentages of 10%, 15% and 20% with a baking temperature of 850°C. Is shown in fig.11.

Fig.11-Samples Brick fired

3.2.5 Water absorption test

According to standard EN 771-1 it is determined by dividing the weight of the brick after immersion in water by the initial weight of the brick (Fig.10). For 10% the calculated water content is 39%, for the kneaded samples with 15% of water and the absorption reaches 34% and at the end the choice of 20% of water gave us 29%.

4 Conclusions

The results obtained in this study led us to the following conclusions:

The characterizations and tests of the various vases resulted from the dredging offer encouraging prospects for their use in the field of Civil Engineering; in particular, the vase resulted from the dredging of Bouhanifia dam, which promises to be used as building material in the red brick. Indeed, the working plotted methodology shows the importance of each characterization; According to the chemical analysis, the level of oxides of the Bouhanifia mud meets the recommended thresholds for clay raw material in the manufacture of baked brick. According to the physico-chemical and mineralogical analyzes made on the mud from the port of Oran, it turned out that it is a silty and fragile sand according to the topographic images of the SEM. The choice of valorization as basic material in the manufacture of cooked brick was for the mud dredged funds of Bouhanifia dam. In addition, Microscopic analysis scanning SEM gives images, which have homogeneous forms (compactness and resistance to the material). The thermal analysis of DTA /TGA confirms the metastable state (amorphous) and the crystalline state from which the baking temperature is quite determined.

Thermal analysis revealed that, at a temperature of 800 ° C., is an amorphous phase that gives pozzolanic activation for this material. Moreover, DRX mineral analysis and thermal analysis confirm this choice of temperature. The scanning microscopic analysis revealed images with homogeneous and compact shapes (presence of surface oxides and silicates in a large rigid mass, which tend to give resistance.

On one hand, knowing also that the mud of the dam studied is generally rich in oxygen. On the other hand, the marine mud is eroded and porous and it is also shown with less oxygen, the detected pollutants during analysis prevent the material from being compacted. In this way, selected cooking temperatures are determined as follows 900°C-950°C-1000°C and 1050°C. Consequently, no cracks appeared on various tested products. The durability tests (the water absorption and freeze testing), gave very encouraging results. Porosity increases with the cooking temperature together with the fragile product. Furthermore, knowing that at 1300°C, our product melts and obtains its melting point (vitrification). Therefore, we conclude that the cooking temperature between 800°C and 900°C samples was satisfactory for the use of silt in Bouhanifia dam and it contributes in the production of a less porous and fragile brick. The tests we have carried out on the product which is cooked at 850°C verify the standards in force. According to standard EN 771-1 determined by dividing the weight of the brick after immersion in water by the initial weight of the brick, the choice of 20% of water gave the good results. Additionally, the use of river silt in Civil Engineering field is a relevant solution that comes from to remedial siltation to problems in Bouhanifia dam and answers the traditional materials shortages.

REFERENCES

[1]- M. Benzerzour, M. Amar, N.E. Abriak, New experimental approach of the reuse of dredged sediments in a cement matrix by physical and heat treatment. Constr. Build. Mat. 140(1) (2017) 432-444. doi:10.1016/j.conbuildmat.2017.02.142

[2]- M. Benkaddour, F. Kazi Aoual, A. Semcha, Durabilité des mortiers à base de pouzzolane naturelle et de pouzzolane artificielle. Rev. Nat. Tecnol. 41(1) (2009) 63–73.

[3]- A. Semcha, Valorisation des Sédiments de Dragage : Applications dans le BTP, cas du Barrage de Fergoug. PhD Thesis, Université de Reims Champagne-Ardenne France, 2006.

[4]- F. Kazi Aoual, M. Hacini, A. Semcha, B. Mekerta, Valorisation des sédiments marins contaminés dans les mortiers dans le cadre de la restauration des darses du port d'Oran et la protection de l'environnement. *XIIèmes Journées Nationales Génie Côtier – Génie Civil Cherbourg* (2012). doi:10.5150/ jngcgc.2012.112-K

[5]- O. Belaribi, Durabilité des bétons autoplaçants à base de vase et de pouzzoloane. PhD Thesis, Université de Cergy-Pontoise, France, 2015.

[6]- B. Mekerta, A. Semcha, A. Benaissa, F. Kazi Aoual-Benslafa, Comportement mécanique des sédiments de dragage pour leur valorisation en technique routière. In : Prooceeding of SBEIDCO – 1st International Conference on Sustainable Built Environment Infrastructures in Developing Countries, ENSET Oran, Algeria, October, 2009, pp 12-14.

[7]- R. Zentar, V. Dubois, N.E. Abriak, Mechanical behaviour and environmental impacts of a test road built with marine dredged sediments, Resour. Conserv. Recy. 52(6) (2008) 947-954. doi:10.1016/j.resconrec.2008.02.002.

[8]- P.Y. Scordia, Caracterisation et valorisation de sédiments fluviaux pollues et traites dans les materiaux routiers. PhD Thesis, Ecole centrale de Lille, 2008.

[9]- Z. Labiod, B. Remini, M. Belaredj, Traitement de la vase du barrage de Bouhanifia en vue de sa valorisation. Larhyss J. 3(2004) 7-12.

[10]- B. Remini, Valorisation de la vase des barrages quelques exemples Algériens. Larhyss J. 5(2006) 75-89.

[11]- Z. Lafhaj, M. Samara, F. Agostini, L. Boucard, F. Skoczylas, G. Depelsenaire, Polluted river sediments from the north region of France: treatment with Novosol® process and valorization in clay bricks. Constr. Build. Mater. 22(5) (2008) 755–762. doi:10.1016/j.conbuildmat.2007.01.023

[12]- C. Martínez-García, D. Eliche-Quesada, L. Pérez-Villarejo, F.J. Iglesias-Godino, F.A. Corpas-Iglesias, Sludge valorization from wastewater treatment plant to its application on the ceramic industry, J. Environ. Manag. 95 (2012) S343-S348, doi:10.1016/j.jenvman.2011.06.016

[13]- A. Mezencevova, N.N. Yeboah, S.E. Burns, L.F. Kahn, K.E. Kurtis, Utilization of savannah harbor river sediment as the primary raw material in production of fired brick. J. Environ. Manag 113(2012) 128-136. doi:10.1016/j.jenvman.2012.08.030

[14]- L. Benallal, M. Ammari, S. Azmani, S. Lamrani, I. Frar, Valorisation des Sédiments de Dragage Portuaire du Nord du Maroc dans des Matériaux de Construction en Terre Cuite. In: Proceedings of Coastal and Maritime Mediterranean Conference, Tanger, Morocco, 2011. doi:10.5150/cmcm.2011.028

[15]- M. Samara, Valorisation des sédiments fluviaux pollués après inertage dans la brique cuite. PhD Thesis, Laboratoire de Mécanique de Lille, 2007.

[16]- V. Cappuyns, V. Deweirt, S. Rousseau, Dredged sediments as a resource for brick production: Possibilities and barriers from a consumers' perspective. Waste Manage. 38 (2015) 372–380. doi:10.1016/ j.wasman.2014.12.025

[17]- C. Grifaa, Ch. Germinarioa, A. De Bonis, M. Mercurio, F. Izzo, F. Pepe, P. Bareschino, C. Cucciniello, V. Monetti, V. Morra, P. Cappelletti, G. Cultrone, A. Langella, Traditional brick productions in madagascar: from raw material processing to firing technology. Appl. Clay Sci. 150(15) (2017) 252–266, doi:10.1016/j.clay.2017.09.033

[18]- K.Y. Chiang, K.L. Chien, S.J. Hwang, Study on the characteristics of building bricks produced from reservoir sediment. J. Hazard. Mater. 159(2-3) (2008) 499–504. doi:10.1016/ j.jhazmat.2008.02.046

[19]- M. Samara, Z. Lafhaj, C. Chapiseau, Valorization of stabilized river sediments in fired clay bricks: Factory scale experiment. J. Hazard. Mater. 163(2-3) (2009) 701–710. doi:10.1016/j.jhazmat.2008.07.153

[20]- F. El Fgaier, Z. Lafhaj, C. Chapiseau, Use of clay bricks incorporating treated river sediments in a demonstrative building: Case study. Constr. Build. Mater. 48(2013) 160–165. doi:10.1016/j.conbuildmat.2013.06.030

[21]- Y.M. Zhang, L.T. Jia, H. Mei, Q. Cui, P.G. Zhang, Z.M. Sun, Fabrication microstructure and properties of bricks

fired from lake sediment, cinder and sewage sludge. Constr. Build. Mater. 121(2016) 154–160. doi:10.1016/j.conbuildmat.2013.05.155

[22]- D. Levacher, M. Sanchez, Z. Duan, Y. Liang, Valorisation en unité pilote de sédiments méditerranéens : étude des caractéristiques géotechniques et de la perméabilité. Revue Paralia, 4(2011) 4.1-4.20. doi:10.5150/revue-paralia.2011.004

[23]- E. Olivier, Technologie de Matériaux de Construction. Ed. Entreprise Moderne, Part II, 1978.

[24]- F. Kazi, M. Ameur, B. Mekerta, A. Semcha, Caractérisation des sédiments de dragage du barrage de Bouhanifia pour une réutilisation. In: Proceedings of XIII Conference: National Days Coastal Engineering - Civil Engineering, Dunkerque, Jully, 2-4, 2014. doi:10.5150/jngcgc.2014.110.