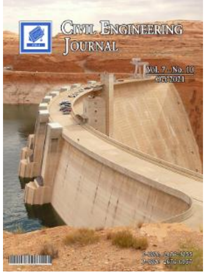
Available online at www.CivileJournal.org

Civil Engineering Journal

(E-ISSN: 2476-3055; ISSN: 2676-6957)

Vol. 7, No. 10, October, 2021



Mechanical Behavior of the Extraction Mud Dam for Use in the Manufacture of CEB

Benaicha Amar Cherif [1*], Fourar Ali [1], Mansouri Tarek [2], Fawaz Massouh [3]

[1] *LARHA, Research Laboratory in Hydraulic Applied, Dept. of Hydraulics, Faculty of Technology, University of Batna 2, Batna 5000, Algeria.*

[2] *LGC-ROI, Civil Engineering Laboratory-Risks and Structures in Interactions, Department of Civil Engineering, Faculty of Technology, University of Batna 2, Batna 5000, Algeria.*

[3] *National School of Arts and Crafts, Paris (ENSAM), France.*

Received 17 June 2021; Revised 08 September 2021; Accepted 21 September 2021; Published 01 October 2021

Abstract

The aim of this work is to study the mechanical behavior of the sediments extracted from the Koudiet Meddaouar, Timgad dam (Algeria), for a possible valorization in the field for building works in order to minimize this phenomenon which is currently a concern for the operators and the persons in charge of the mobilization of the water resources. This siltation therefore severely limits its storage capacity and consequently it's operating life. The extraction of the sediments accumulated in the dam's reservoir is therefore imperative, on the pain of seeing it perish in the medium term. These sediments are, however, of great geotechnical and mechanical value. The results of the tests conducted in the laboratory have enabled us to identify the different sediments from a physical and geotechnical point of view In front of the difficulties noted in the control of the silting up of the dams in Algeria, a very important quantity of silt being deposited annually in the dams. In order to achieve our objective, different mixtures of silt with or without lime treatment, cement glass fibers and powdered fibers were studied for the possible manufacture of Compressed Earth Bricks (CEB). The results obtained show that some of the mixtures present very interesting results in the different tests (compression and bending), verifying the conditions of the standards in force and thus allowing their use in the field of the manufacture of building materials.

Keywords: Dam; Sediments; Valorization; Silt; Mechanical Behavior.

1. Introduction

The silting up of dam reservoirs is a natural phenomenon that reduces the storage capacity and operating life of dams. This loss of capacity through sedimentation depends mainly on the erosion rate of the catchment areas, vegetation covered, relief and climate. The useful capacity of the hydraulic infrastructure in the Arab Maghreb countries decrease in capacity of 0.65% per year Remini et al. (2018, 2009) [1, 2]. In which the silting up of reservoirs is the most important factors in the loss of capacity. The reduction of the storage reserve of hydraulic works has been growing steadily over the last few years for reasons of natural origin, favored by the aggressiveness of the climate, the alternation of dry and wet periods, the fragility of the geological formations and the absence of sufficient plant cover. The alluvialization of dams is one of the most dramatic consequences of water erosion; about 180 million tons are annually torn away from the catchment basins by runoff in northern Algeria Demmak [3].

* Corresponding author: a.benaicha@univ-batna2.dz

http://dx.doi.org/10.28991/cej-2021-03091759

In Algeria, for example, the specific erosion in 30 watershed studied, varies between 30 and 3350 t/Km^2 per year, according to Remini et al. (2018) [1]. The reduction in the hydraulic storage capacity in Algeria, as a result of silting, is estimated annually about 65 million cubic meter Remini et al. (2018) [1]. Dredged sediments have been widely used in various parts of the world for applications related to various infrastructure development activities, such as land reclamation, building construction, Rakshith & Singh (2017) [4]. There are several economic and environmental advantages to the recovery of sediments after dredging. First of all, it improves the management of dredged sediment waste. Secondly, it provides an innovative solution to the problem of scarce resources in construction materials Loudini et al. (2020) and Wang et al. (2012) [5, 6]. They studied the basic characterization of the dredged marine sediments, the effect of cement and lime on the Atterberg boundaries, as well as the mechanical properties of these treated sediments, in order to assess their feasibility in pavements. Anger et al. (2014) [7] they dealt with the feasibility of using dam sediments as an additive in concrete. They concluded that the fine dam sediments studied do not allow performances equivalent to those of standardized limestone or siliceous additions. Nevertheless, their incorporation in concrete is possible, by adding admixtures to limit water input.

Federico et al. (2015) [8] unveil preliminary results of an experimental research on the effects of artificial stabilization with cement and/or lime that will be dredged from the port of Taranto (Italy) in order to evaluate the physical properties and compressive behavior of the dredged natural clayey sediments, through a combined experimental and theoretical approach. Piattoni et al. (2011) [9]. Describes the mechanical behavior of bricks produced from mud processed by manual compaction with different volume fractions of soil, coarse sand and short straw fibers. Through the approach of using sediment as an earthwork material [10, 11]. Evaluated the potential use of dredged soil as earthwork they found that the dredged soil has sufficient stability as new earthwork material. Wu et al. (2014) [12] aim to randomly determine the mechanical behavior of sisal fiber-reinforced loamy clay from Qingdao district (China). They indicate that a 20% improvement in strength is achieved, and a reduction in the risk of soil deformation due to the addition of this fiber.

Enrico and Lenci (2010) [13] Attempted to characterize the mechanical properties such as workability, compression and Young's modulus of this type of adobe brick. Ten different mixtures of adobe that were used to make ancient mud bricks with a straw reinforcement and with coarse sand as a stabilizer, as the romans did, using clay soil. Maherzi et al. (2017) [14] and by means of durability tests (measurement of volume swelling and tensile strength, microstructural observations by electron microscopy) were carried out to identify the essential parameters in order to enhance a road underlay material. The results obtained show a potential for the use of treated mixtures containing dredged marine sediments and sand as a substitute material. Physico-mechanical properties of the sediments have been improved by Boutouil and Saussaye (2011) [15] using corrective additions with a treatment based on cement CEMII/B-M (S-LL) 32.5 R and sands according to different formulations to uncontaminated fine sediment dredged from the port of Ouistreham (Calvados, France). The results show that a cement dosage of 10% combined with a decrease in organic matter content and clays, disturbing elements in the cement-based solidification treatment, improve the geotechnical and mechanical properties of the treated dredged sediment. In order to counterbalance the disturbing fractions Amar et al. (2016) [16] have carried out the appropriate treatment of dredged sediments with a view to their use in cement matrices with substitution rates of the order of 10 to 20%. The procedure envisaged consisted in the direct calcination of the raw materials in a 750°C. This made it possible to improve certain Physico-chemical properties in order to eliminate the organic matter. They found that mortars based on dredged calcined sediment showed a remarkable mechanical and environmental improvement compared to the control mortar.

Bouhamou et al. (2008) [17] have been showed that it is possible to make concrete with different dosages in vase with self-compacting properties compared to traditionally vibrated concrete. Four samples were formulated with variations in the percentage (0, 10, 20, and 30%) of calcined silt from the Chorfa dam (Algeria). Serbah et al. (2017) [18] studied the influence of the addition of hydraulic and air binders (cement, lime) on the mechanical characteristics of these dredged sediments for the realization of pavement layers, three binders have been tested and making it possible to envisage the use of the treated sediment to form a pavement layer. The treatment gives excellent compressive strength and satisfactory results with regard to swelling. Hamouche and Zentar (2017) [19] Exploring in the context of proposing a method for characterizing organic matter simple, suitable for sediments with the aim of recovering dredged sediments in the road works sector.

Couvidat et al. (2016) and Benabid et al. (2021) [20, 21] aim to assess the environmental behavior of mortars formulated with dredged sediments. In order to achieve their objectives; a natural sand was used as reference aggregate, which was entirely replaced by raw and altered contaminated dredged sediments. They concluded that their formulation is reusable in non-structural applications, such as pavement base and wall coating. Loudini et al. (2020) [22] examined dredged marine sediments taken from the Moroccan port treated with a hydraulic binder (Portland cement). A formulation of the mixture was well defined in order to carry out mechanical behavior tests on their samples. They reveal that the experiments show that dredged sediments treated with Portland cement can be used as a road base layer. Research work by Rekik and Boutouil (2006) [23] has been carried out to valorize dredged sediments in the realization of earthworks, in order to evaluate the compacting and compressibility behavior of the sediment sample treated with cement. Geotechnical property tests as well as analyses of the microstructure of the material were carried out. The results show that the sediment treated with hydraulic binder has a potential for use as a backfill material due to its improved bearing capacity and water content. The same applies in order to reduce compressibility in a context of valorization of sludge from dredging operations in the basins of the port of Oran, and those of the Bouhanifia dam, which are located in western Algeria [24]. In addition of the study on the use of silt in the building industry, the authors have studied the possibilities of using vases in the building industry. Durability tests were carried out on several samples of mud from the dams at different temperatures and percentages of water. It turned out that there is a predominance of sandy sediments, which are not recoverable, which they targeted. Also a satisfaction in terms of mechanical resistance and durability for a firing temperature of 850°C and a water percentage of 20%. Larouci et al. (2020) [25] identified trends and correlations between the geotechnical properties of one face and dealt with the capacity of the binders and thus enhance the value of the sediments on another face, in order to Analysis the mechanical behavior. The tests include measurements of unconfined compressive strength. The results obtained show that the sediments of the Fergoug dam (Algeria) do not reach the mechanical performances required by the geotechnical and safety works.

El-Attar et al. (2017) [26] concluded by the results showed that up to 50% of cement kiln dust (CKD), could be used to make economical and environmentally friendly bricks with acceptable properties. However, it is preferable to use CKD with sulphate resistant cement instead of ordinary Portland cement. This approach will reduce the environmental risks associated with the disposal of kiln dust, as well as contributing to sustainable development by using kiln dust in the manufacture of bricks. Zhou (2018) [27] study the eco-friendly high-performance permeable bricks using three kinds of common debris (dredged mud, waste glass, discarded porcelain) as raw materials. The structure of permeable brick is composed of a large void connecting small pores, which achieves an optimal balance between water permeability and compressive strength. The large void is formed by the accumulation of discarded porcelain, and the small pores are produced by the combustion of organic matter in the dredged mud. The effects of aggregate gradation, aggregate content, weight ratios of dredged mud to waste glass, forming pressure a sintering temperature on porosity, permeability and compressive strength of the prepared permeable bricks.

Bernardi et al. (2014) [28] found that bio-bricks can have better mechanical properties and that these bio-bricks are comparable to those treated with additives such as cement and hydraulic lime. In order to improve the quality of certain building materials, Messina et al. (2017) [29] studied two wastes of clay sediments and sludge from water treatment stations with the aim of their valorization in prefabricated construction elements. Tang (2018) [30] observed that bricks processed by glass powder from waste thin-film transition liquid crystal (TFT-LCD) with dredged sediments conformed to normalized construction bricks.

Safhi et al. (2020) [31], study three different mixes were prepared with 0, 10, and 20% cement replaced by treated silt, and the tests showed that the mixes had acceptable self-consolidation characteristics. A study was carried out by Bounouara et al. (2020) [32], on the mud extracted from the Bouhanifia dam (Western Algeria). These materials were treated with various percentages of bentonite (2, 4, 6, 8 and 10%). In order to study the effect of bentonite concentration on the geotechnical and hydraulic characteristics of the sediments, they found sediments prepared with bentonite can be used as a clay barrier for a hazardous waste landfill. The characteristics of cementitious construction materials based on dredged sediments from the Chorfa dam (Algeria), fresh and cured sediments and the carbon footprint of mortars to understand the potential behavior of carbonized sediments on the properties of cementitious mixtures were also studied by Sadok et al. (2021) [33]. Twenty samples of sediments dredged in the port of Sfax were analyzed by X-ray diffraction and showed percentages of sulphate and sodium chloride in the raw sediments. The desalted sediments were added to sand and activated with blast furnace slag and lime. Mixtures of 58% sand and 30% raw sediments, activated with 9% blast furnace slag and 3% lime, gave the required value for use of the mixture in the sub-base.

The purpose of this study, is to evaluate the mechanical behavior of the sediments extracted from the Koudiet Meddaouar - Timgad dam (Algeria, See Figure 1), for a possible valorization in compressed earth bricks (CEB), with mixtures of additions (cement, lime, glass fiber, glass powder) with different percentages, cement (2, 4, 6%), lime (2, 4, 6%), glass fiber (0.15, 0.25, 0.35%), glass powder (1.5, 3, 4.5%).

2. Research Methodology

The flowchart of the research and characterisation methodology is presented in Figure 2.

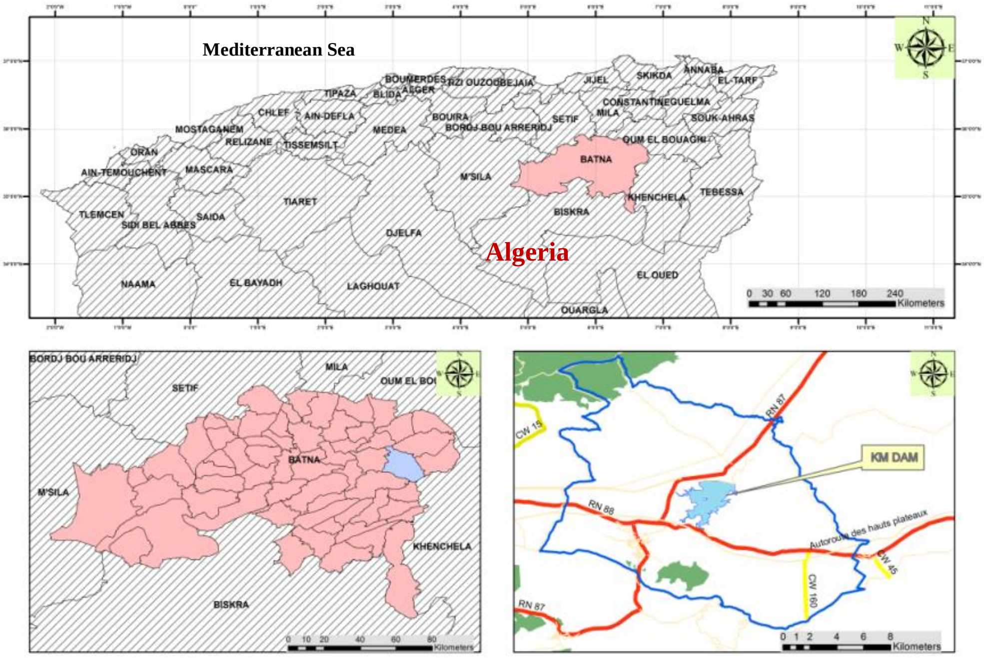


Figure 1. Location map of the study area

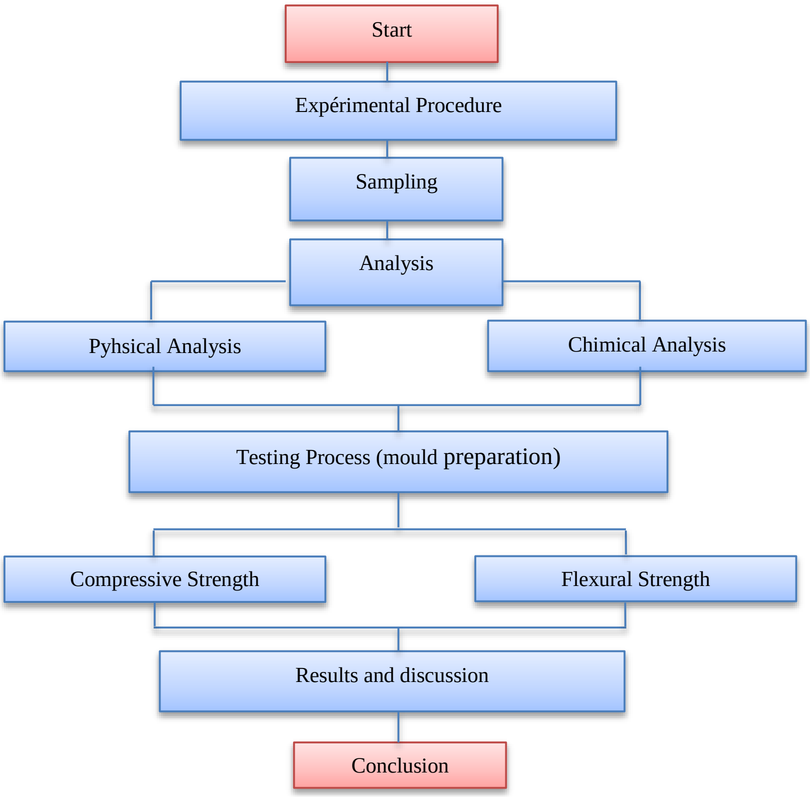


Figure 2. Flowchart of the research work

3. Experimental Procedure

3.1. Materials

The Samples of dredged sediments were taken from 04 points (P_1, P_2, P_3 and P_4). Extracted from the basin and at the outlet of the discharge from the bottom see (Figures 3 and 4). The samples were homogenized after they had been stored in a dark place. These sediments are muddy and characterized by a fine grain size, with 99.95 % passing to 80 µm of which 74% are silt. The methylene blue value reaches 4.75 g per 100 g. The initial organic matter content, not modified during the study is 0.072 % and the water content of the sediment at extraction was 85%.

Figure 3. Sampling instrument

Figure 4. Mud sampling points

In order to improve the characteristics of our sample, to create a material for the manufacture of reliable compressed earth blocks, the addition of cement and lime was the subject of our study. The cement used in this formulation is of the ordinary Portland type CEM I 42.4N (PC) conforming to the NA 442 edition 2013 SCIMAT standard, as well as the lime is a hydraulic lime (L) from Lafarge Holcim Algeria, classified according to standard NF EN 998-1. (Table 1) present chemical composition of lime and cement. The filling of pores, the non-absorption of water and the solidity of transparent glass bottle waste, converting into powder, has beneficial and ecological characteristics. This is why we have chosen a glass powder (GP). Glass fiber (GF) A T-23 fabric in the form of fabric reinforcement with a thickness of 0.01 mm, is designed by TU 6-48-53-90. Cut to lengths of 25 mm, easy to apply, the anti-cracking, tensile and alkali resistance of the cement led us to use this addition.

Figure 5. Mixture components

3.2. Physical and Chemical Analysis

The sediment extracted from the Koudiet Medaouar dam was collected in June 2020, using a boat and a mud sampler in four locations of the dam P_1, P_2, P_3 and P_4 (Figure 4). Tables 1 summarize physical analysis of the tested sediments; and (Figure 6) illustrate the particles' size analysis by sedimentometry test.

Table 1. Physical properties of the tested silt.

Settings	W (%)	W_L (%)	W_P (%)	I_P (%)	γ_S (g/cm3)	γ_d (g/cm^3)	V_b	MO (%)
-	85	64.38	36.37	28.01	26.5	25.5	4.75	0.072

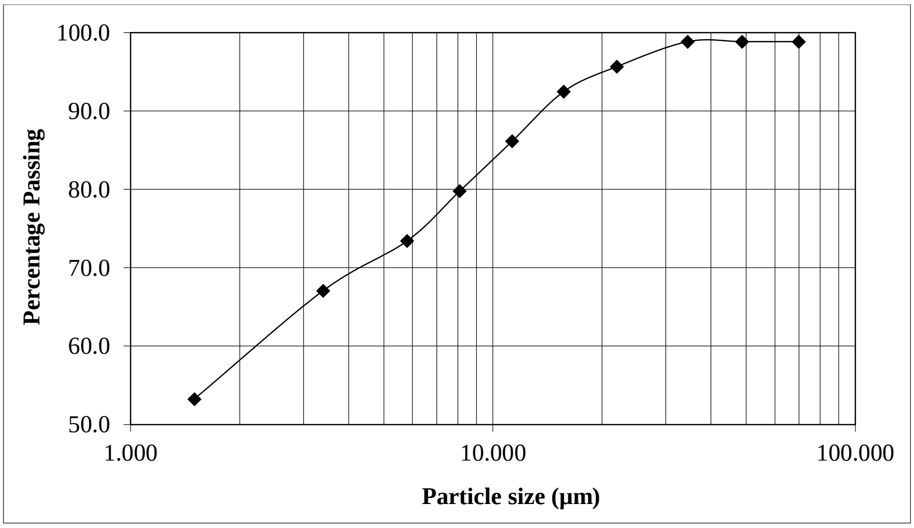


Figure 6. Particles' size analysis by sedimentometry

X-ray fluorescence spectrometry (XRF) identifies chemical analysis of the dredged silt of the Koudiet Medaouar dam, to see the main minerals that make up this silt (Table 2).

Table 2. X-ray fluorescence spectrometry silt results

Elements	Content (%)		
	Dredged Silt	**Cement**	**Lime**
SiO_2	38.13	21.45	0.16
CaO	18.32	61.43	97.92
Mg O	1.74	1.24	0.20
Al_2O_3	13.79	4.31	0.06
Fe_2O_3	4.92	4.56	0.03
SO_4	0.82	2.28	-
CL	0.13	0.018	-
Na_2O	0.18	0.39	-
SO_3	0.12	2.28	-
K_2O	1.32	0.61	-
$P.F_2$	17.43	2.19	-
$CaCO_3$	43	-	18.47
H_2O	37.20	25.82	-

The X-ray fluorescence spectrometry (XRF) analyses made on the samples of the mud from the Koudiet Medaouar dam illustrate the main crystalline minerals with lines characterizing, quartz (SiO_2), and ($CaCO_3$) carbonates calcite, as well as a quantity of alumina (AL_2O_3) in the form of Kaolinite (AL_2O_3 $2SiO_2$ $2H_2O$).

4. Testing Process

4.1. Method

This work is an attempt to valorize the dredged sediments and to find a sustainable disposal method for the glass bottle waste. The work started with sampling of the dredged silt from the basin of the Koudiet Medaouar dam. The cement used in this formulation is of the ordinary Portland type CEM I 42.4N from the SCIMAT production unit, as well as the lime is a hydraulic lime from Lafarge Holcim Algeria, in order to make compressed earth bricks BTC with different mixes. Soda glass bottles, collected for this project, are crushed by a hammer and then the broken glass is crushed by a machine to obtain glass powder. The glass powder is white color and have a maximum size of 3.5 mm. Potable water is generally considered suitable for compressed earth brick manufacture. Water should be free of acids, oils, alkalis, vegetable matter or other organic impurities. Water also produces weaker bricks. Water has two functions in the mixing of the dough, it serves as a vehicle or lubricant in the mixing of fine aggregates. In this project we used normal drinking water, it was collected in the municipality of Batna, and it has a PH of 6.9. A twenty-nine different mixes that were prepared and cast, the blocks of (100×200×60) mm samples were conditioned in ambient conditions and were tested after 28 days, to determine the compressive and flexural strength. The combinations and percentages are presented in (Table 3).

Figure 7. Mould preparation

Table 3. Mix proportion and materials

Specimen	Mix Composition	Clay %	Portland Cement (%)	Glass powder (%)	Glass Fiber (%)	Lime (%)
S00	Untreated clay	100	-	-	-	-
S01	C+2%L	98	-	-	-	2
S02	C+4%L	96	-	-	-	4
S03	C+6%L	94		-		6
S04	C+2%PC	98	2	-	-	-
S05	C+4%PC	96	4	-	-	-
S06	C+6%PC	94	6	-	-	-
S07	C+1.5%GP	98.50	-	1.5	-	-
S08	C+3%GP	97	-	3	-	-
S09	C+4.5%GP	95.50	-	4.5	-	-
S10	C+0.15%GF	99.85	-	-	0.15	-
S11	C+0.25%GF	99.75	-	-	0.25	-
S12	C+0.35%GF	99.65	-	-	0.35	-
S13	C+2%CP+6%L	92	2	-	-	6
S14	C+4%CP+4%L	92	4	-	-	4
S15	C+6%CP+2%L	92	6	-	-	2
S16	C+2%CP+4.5%GP	93.50	2	4.5	-	-
S17	C+4%CP+3%GP	93	4	3	-	-
S18	C+6%CP+1.5%GP	92.50	6	1.5	-	-
S19	C+2%CP+0.35%GF	97.65	2	-	0.35	-
S20	C+4%CP+0.25%GF	95.75	4	-	0.25	-
S21	C+6%CP+0.15%GF	93.85	6	-	0.15	-
S22	C +2%L+0.35%GF	97.65	-	-	0.35	2
S23	C +4%L+0.25%GF	95.75	-	-	0.25	4
S24	C +6%L+0.15%GF	93.85	-	-	0.15	6
S26	C +2%L+4.5%GP	93.50	-	4.5	-	2
S27	C +4%L+3%GP	93	-	3	-	4
S28	C +6%L+1.5%GP	92.50	-	1.5	-	6

4.2. Casting of the Samples

The materials required for moulding such as clay, glass powder, cement, lime and glass fiber were mixed manually in dry state, then water was added gradually with a constant quantity as required to obtain the required consistency during the mixing phase. The inner surfaces of the mould were properly oiled, then filled into the mould to the edge in layers by tamping properly and the top surface was finished with a trowel to obtain a uniform surface finish.

4.3. Drying of the Compressed Clay Brick Samples

Firstly, the bricks were kept for drying in the shade to avoid plastic shrinkage cracks formed by the evaporation of water from the brick surface. Finally, the samples were then taken for testing properties, such as compressive strength and flexural strength.

5. Results and Discussion

Twenty-eight samples were prepared with different addition components of different proportions including an untreated reference sample, in order to estimate their flexural and compressive strengths, (Figures 8 and 9) shows the evolution of the tensile strength and unconfined compressive strength, respectively; of the cured samples. The figures below show the results of the different samples.

5.1. Effect of Compressive Strength With Different Mixtures

The compressive strength of the specimen was determined using a universal testing machine (CM0157), with a maximum capacity of 250 kN. The test procedure was guided by (ASTM C109). The half-samples that were recuperated from the bending experiments were tested in compression with a load increment that was applied until the specimen failed, of which the stress-strain values obtained from the testing machine were also registered.

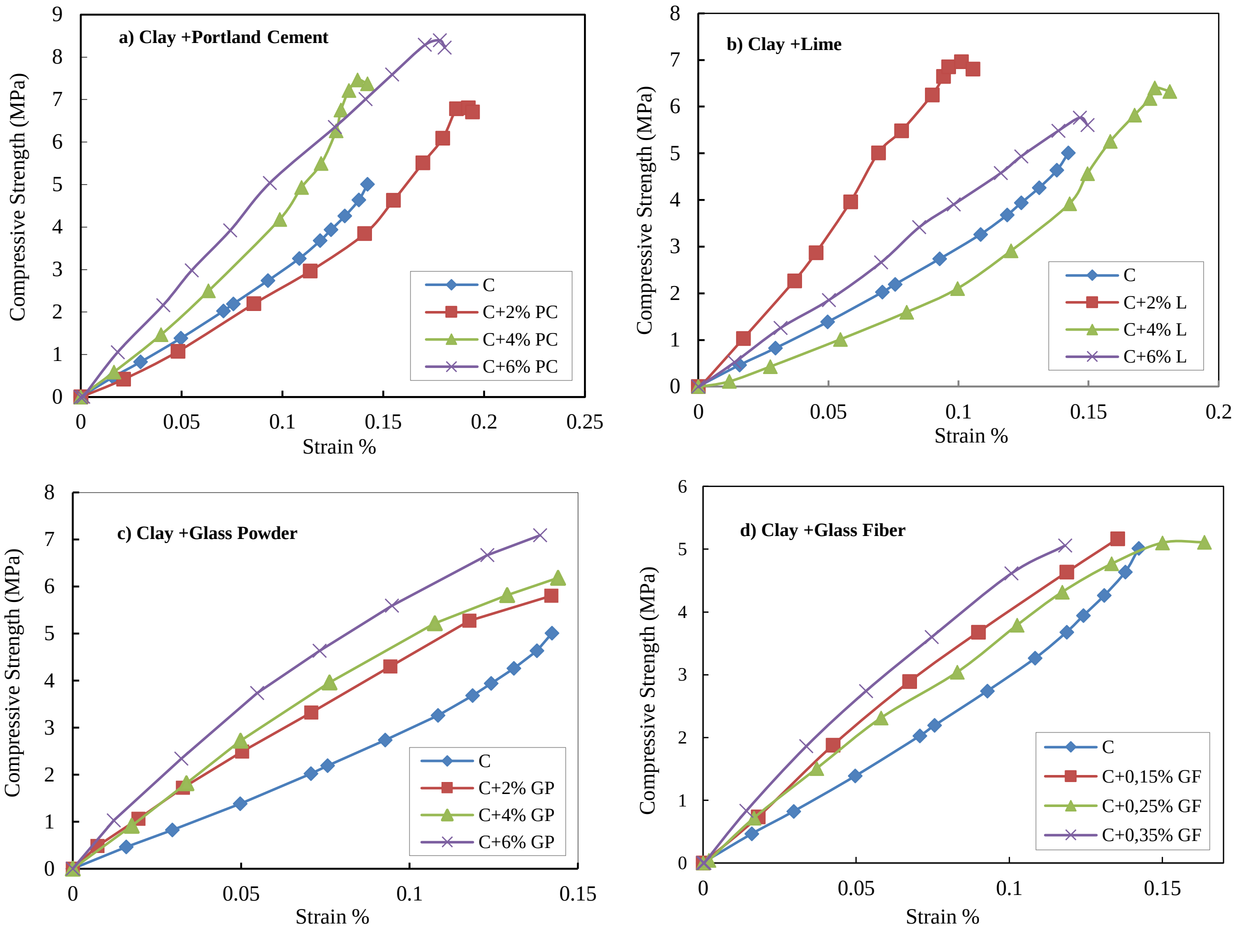


Figure 8. Compressive strength of proportion

(Figure 8) shows that all mixes show a considerable increase in compressive strength compared to the untreated clay. (Figure 8a) shows that the compressive strength of the mixture (clay-cement) shows a considerable increase. The proportional values of 6.80, 7.46 and 8.39 MPa were observed by the addition of 2.4.6% cement (Figure 9).The addition of 2% lime shows a significant increase of 6.96 MPa in compressive strength, therefore the addition of 4 and 6% results in values of 6.40 and 5.76 MPa which shows a decrease in strength (Figure 9).

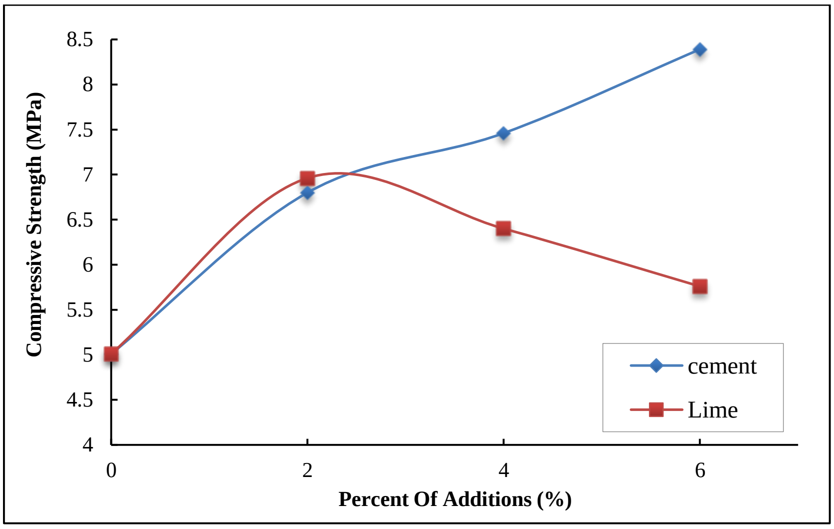


Figure 9. Compressive strength of cement and lime

The experimental results reveal that the mixture (clay-glass powder) gives a higher compressive strength than the untreated clay with values of 5.80, 6.18 and 7.09 MPa for 1.5, 3 and 4.5 % addition. A similar trend is found for the clay-glass fiber mixture, where the results are almost identical to those of the untreated clay.

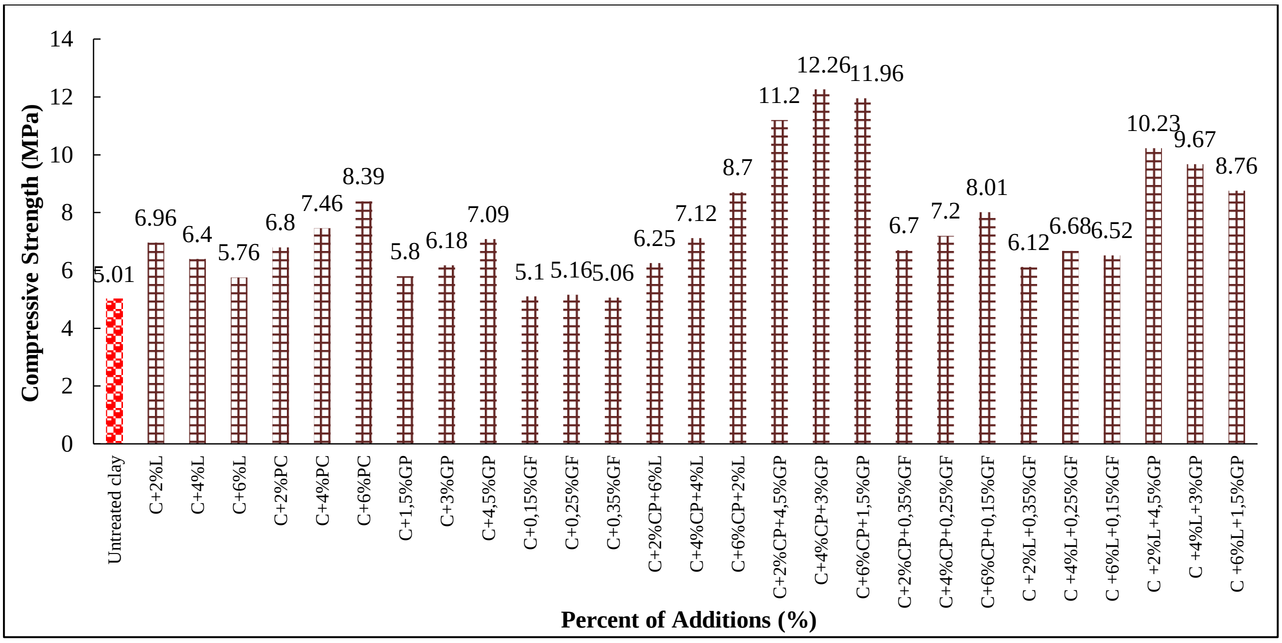
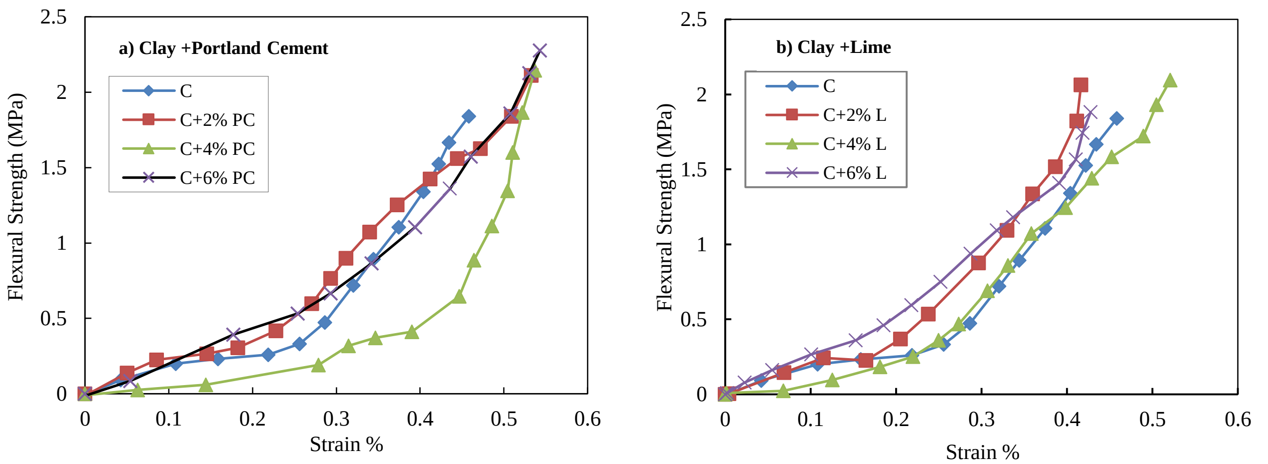


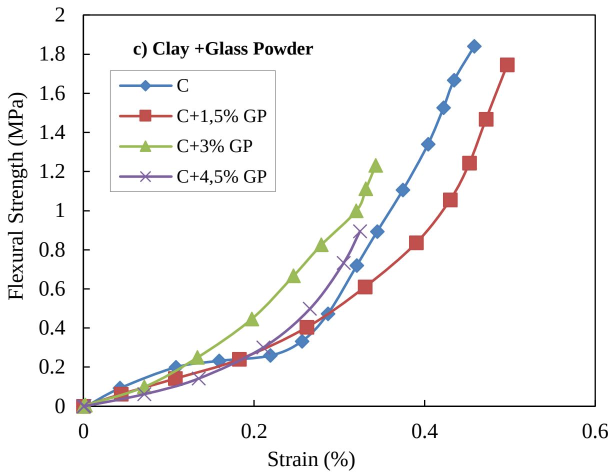
Figure 10. Compressive strength comparison between several specimens

The graph shows that the addition of the different additions at different percentages in our reference sample (dam clay) increases the compressive strength with irregular values. The addition of cement provides optimum compressive strength with rates between 35% (S04) and 150% (S17) compared to the reference sample. This is due to the increase in inter-granular bonding, however the addition of lime also increases the compressive strength by 15% (S03) to 105% (S26) with the exception of a surprising decrease beyond 4% which was observed, this is because the grains of lime needs more water for hydration than those of cement. A significant increase in compressive strength was observed with the addition of glass powder compared to the reference sample (S00) in the range of 16% (S07) to 145% (S17), see (Figure 10), due to the pozzolanic characteristics of this material, a siliceous material that reacts in water and calcium hydroxide, which offers advantages such as increased durability and mechanical strength, as well as a reduction in the amount of cement needed, which reduces the environmental burden. A very slight increase in compressive strength was observed with the addition of glass fiber in all mixes, the results of which remained practically unchangeable. This is due to the overlapping of the glass fibers, which results in poor cohesion

5.2. Effect of Flexural Strength with Different Mixtures

Three-point bending tests were guided, based on ASTM C78 to achieve bending failure of our test brick. The brick was placed on two supports and a perpendicular force was applied without eccentricity of the specimen by applying an incremental loading until failure. Stress/strain results were acquired and recorded by the machine.





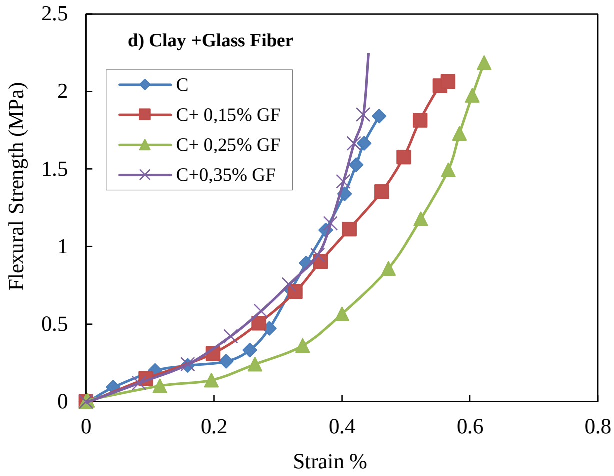


Figure 11. Flexural strength of proportion

When examining (Figure 11), the specimens containing the glass powder show lower flexural strength results than the untreated clay. A significant increase in the flexural strength of the mixture (clay-cement) was observed. Hence a progressive variation of 2.11, 2.14 and 2.27 MPa was marked when varying the addition of 2.4 and 6% cement (Figure 11a). The addition of 2 and 4% lime shows a significant increase of 2.06 and 2.09 MPa of flexural strength, furthermore the addition of 6% lime decreases the flexural strength value to 1.88 MPa (Figure 11b).

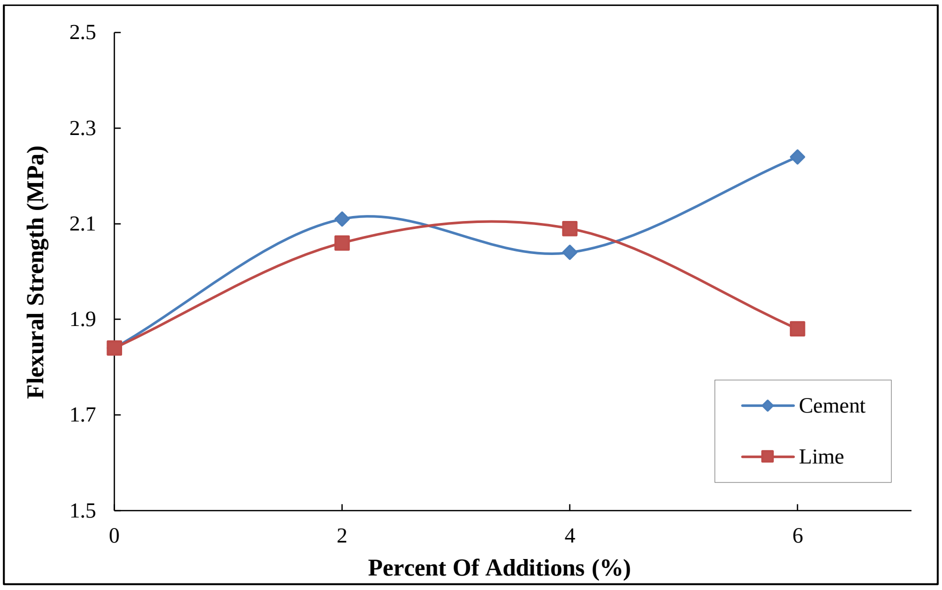


Figure 12. Flexural strength of cement and lime

The experimentation shows in (Figures 11c and 11d) that the addition of glass powder decreases the flexural strength in comparison to the mixtures (clay-cement) and (clay-lime). The influence of the addition of glass fiber on the flexural strength has a beneficial effect on the mix, as can be seen in (Figure 11d) which results in an increase of 2.06, 2.18 and 2.31 MPa with the percentages of 0.15, 0.25 and 0.35 % respectively.

5.3. Mixture Flexural Strength Comparison

The pattern reveals that the addition of the different additions in our reference sample (dam clay), improved the flexural strength with the exception of the glass powder addition with irregular values. During the tests, all the unreinforced blocks failed suddenly, whereas none of the fiber-reinforced blocks did; this is due to the behavior of the fibers which are known to oppose and prevent the formation of micro-cracks which have a tendency to spread. As a result the glass fiber reinforced blocks gave a better flexural strength than any of the mixes, as the fibers start to take over and the load starts to increase again. In order to achieve a significant strength of the order of 112% (S10) to 180% (S20) with reference to the control. Similar trends in compressive strength are observed for mixes treated with 2, 4 and 6% cement and subjected to flexural tests, these tests result in values ranging from 115% (S04) to 169% (S20). (Figure 13) reveals that a progressive increase in flexural strength due to the addition of lime with rates ranging from 112% (S01) to 114% (S02) and 119% (S22) to 137% (S23) with the exception of an astonishing decrease in the order of 2% (S03) and 14% (S24) by the addition of 6% of lime.

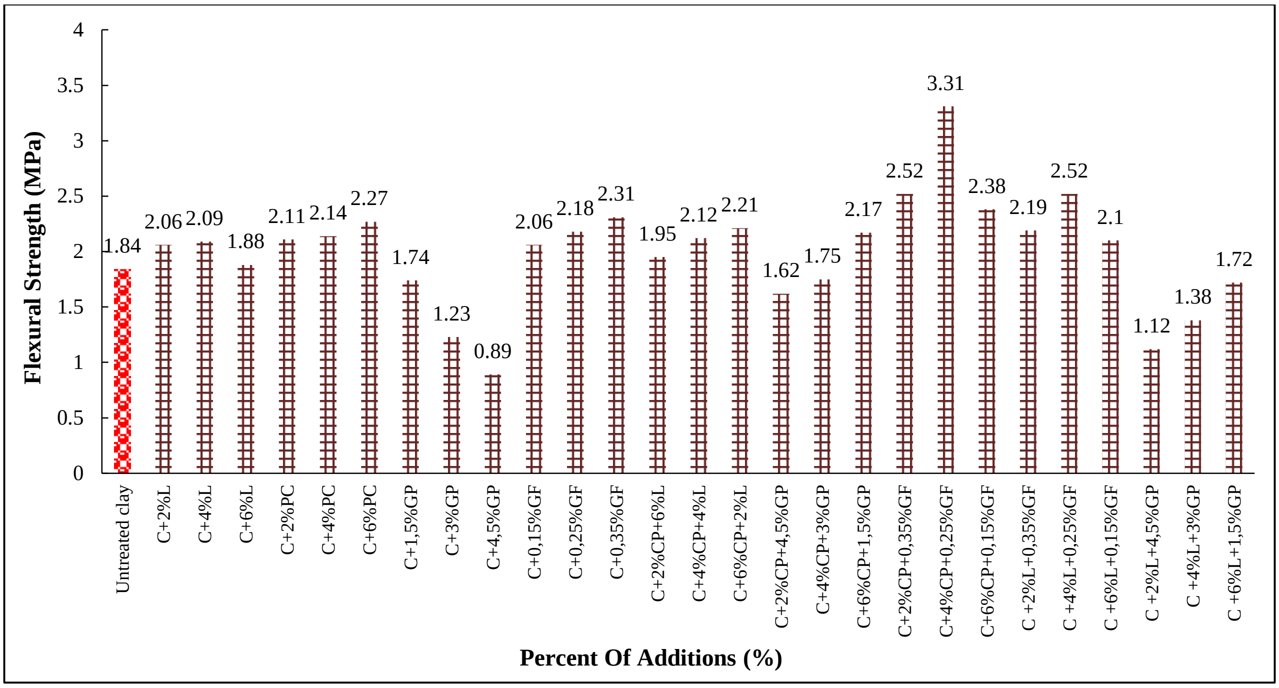


Figure 13. Flexural strength between several specimens

6. Conclusions

In this study, various laboratory tests were conducted to determine the mechanical behavior of compressed earth bricks (CEB) for possible use in the industrial field. From the results obtained, the following findings and conclusions were made:

- Increasing and similar trends found in compressive and flexural strengths in the order of 35-150% and 112 - 180% respectively due to the addition of 2, 4 and 6% cement. The addition of lime increases the compressive strength by 15-105%. With the exception of 6% lime a surprising decrease was observed. On the other hand, a progressive increase in flexural strength of the order of 112-137% compared to the control was observed, with the exception of a decrease of the order of 2-14% by the addition of 6% lime, a fact which can be clarified by the insufficient hydration of the lime powder grains.
- A beneficial effect of the glass powder is that it increases the compressive strength by 16-145% due to the pozzolanic characteristics of this addition. Therefore the addition of glass powder has a negative effect on the flexural strength.
- Overlapping of the glass fibers resulting in poor grain cohesion, which results in compressive strengths similar to those of the control. On the other hand, a considerable flexural strength of 112-180% was observed compared to all mixtures, due to the tensile strength characteristics of this material.

7. Declarations

7.1. Author Contributions

Conceptualization, T.M.; methodology, A.C.B.; validation, T.M.; investigation, A.C.B.; data curation, A.C.B. and F.A.; writing—original draft preparation, A.C.B.; writing—review and editing, F.A. and F.M.; supervision, T.M. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available in article.

7.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7.4. Conflicts of Interest

The authors declare no conflict of interest.

8. References

[1] Remini, B., D. Bensafia, and A. Mekhatri. "Sidi M'hamed Ben Aouda's Dam (Algeria): Acceleration to the Silting." LARHYSS Journal 33 (2018): 221-252.

[2] Remini, Boualem, Christian Leduc, and Wassila Hallouche. "Évolution Des Grands Barrages En Régions Arides : Quelques Exemples Algériens." Sécheresse 20, no. 1 (January 2009): 096–103. doi:10.1684/sec.2009.0172.

[3] Remini, B. "Algeria: The Mud At The Bottom Of The Dams, What To Do?." LARHYSS Journal P-Issn 1112-3680/E-Issn 2521-9782 40 (2019): 213-247.

[4] Rakshith, Shetty, and D. N. Singh. "Utilization of Dredged Sediments: Contemporary Issues." Journal of Waterway, Port, Coastal, and Ocean Engineering 143, no. 3 (May 2017): 04016025. doi:10.1061/(asce)ww.1943-5460.0000376.

[5] Loudini, Ahmed, Mounsif Ibnoussina, Omar Witam, Ali Limam, and Oksana Turchanina. "Valorisation of Dredged Marine Sediments for Use as Road Material." Case Studies in Construction Materials 13 (December 2020): e00455. doi:10.1016/j.cscm.2020.e00455.

[6] Wang, Dong Xing, Nor Edine Abriak, Rachid Zentar, and WeiYa Xu. "Solidification/stabilization of Dredged Marine Sediments for Road Construction." Environmental Technology 33, no. 1 (January 2012): 95–101. doi:10.1080/09593330.2011.551840.

[7] Anger, Baptiste, Isabelle Moulin, Emmanuel Perin, François Thery, and Daniel Levacher. "Utilisation de Sédiments Fins de Barrage Dans La Fabrication de Mortiers." XIIIèmes JNGCGC, Dunkerque (2014). doi:10.5150/jngcgc.2014.105.

[8] Federico, Antonio, Claudia Vitone, and Agnese Murianni. "On the Mechanical Behaviour of Dredged Submarine Clayey Sediments Stabilized with Lime or Cement." Canadian Geotechnical Journal 52, no. 12 (December 2015): 2030–2040. doi:10.1139/cgj-2015-0086.

[9] Piattoni, Quintilio, Enrico Quagliarini, and Stefano Lenci. "Experimental Analysis and Modelling of the Mechanical Behaviour of Earthen Bricks." Construction and Building Materials 25, no. 4 (April 2011): 2067–2075. doi:10.1016/j.conbuildmat.2010.11.039.

[10] Park, Jaesung, Younghwan Son, Sookack Noh, and Taeho Bong. "The Suitability Evaluation of Dredged Soil from Reservoirs as Embankment Material." Journal of Environmental Management 183 (December 2016): 443–452. doi:10.1016/j.jenvman.2016.08.063.

[11] Belabed, Lazhar, Hacene Benyaghla, and Jarir Yahiaoui. "Internal Stability Analysis of Reinforced Earth Retaining Walls." Geotechnical and Geological Engineering 29, no. 4 (January 13, 2011): 443–452. doi:10.1007/s10706-011-9390-4.

[12] Wu, Y. K., Y. B. Li, and B. Niu. "Investigation of Mechanical Properties of Randomly Distributed Sisal Fibre Reinforced Soil." Materials Research Innovations 18, no. sup2 (May 2014): S2–953–S2–959. doi:10.1179/1432891714z.000000000511.

[13] Quagliarini, Enrico, and Stefano Lenci. "The Influence of Natural Stabilizers and Natural Fibres on the Mechanical Properties of Ancient Roman Adobe Bricks." Journal of Cultural Heritage 11, no. 3 (July 2010): 309–314. doi:10.1016/j.culher.2009.11.012.

[14] Maherzi, Walid, Mahfoud Benzerzour, Yannick Mamindy-Pajany, Eleanor van Veen, Mohamed Boutouil, and Nor Edine Abriak. "Beneficial Reuse of Brest-Harbor (France)-Dredged Sediment as Alternative Material in Road Building: Laboratory Investigations." Environmental Technology 39, no. 5 (April 9, 2017): 566–580. doi:10.1080/09593330.2017.1308440.

[15] Boutouil, Mohamed, and Lucile Saussaye. "Influence de L'ajout D'un Correcteur Granulométrique Sur Les Propriétés Des Sédiments Traités Aux Liants Hydrauliques." Revue Paralia 4 (2011): 8.1–8.11. doi:10.5150/revue-paralia.2011.008.

[16] Amar, Mouhamadou, Mahfoud Benzerzour, Nor-Edine Abriak, and Walid Maherzi. "Étude de valorisation des sédiments de dragage." Academic Journal of Civil Engineering 34, no. 1 (2016): 882-889. doi:10.26168/ajce.34.1.107.

[17] Bouhamou, N., N. Belas, H. Mesbah, A. Mebrouki, and Y. Ammar. "Étude Du Comportement à L'état Frais Des Bétons Autoplaçants à Base de Matériaux Locaux." Canadian Journal of Civil Engineering 35, no. 7 (July 2008): 653–662. doi:10.1139/l07-134.

[18] Serbah, B., M. A. Bourabah, S. Bouchemella, N. Abou-Bekr, and S. Taibi. "Etude du comportement mécanique d'un sédiment de barrage en technique routière." Academic Journal of Civil Engineering 35, no. 1 (2017): 291-294. doi: 10.26168/ajce.35.1.71.

[19] Hamouche, Fawzi, and Rachid Zentar. "Caractérisation des Matières Organiques dans les sédiments de dragage par méthodes thermiques et chimiques en vue d'une valorisation dans le domaine des travaux routiers." Academic Journal of Civil Engineering 35, no. 1 (2017): 218-221. doi: 10.26168/ajce.35.1.53.

[20] Couvidat, Julien, Mostafa Benzaazoua, Vincent Chatain, and Hassan Bouzahzah. "Environmental Evaluation of Dredged Sediment Submitted to a Solidification Stabilization Process Using Hydraulic Binders." Environmental Science and Pollution Research 23, no. 17 (May 24, 2016): 17142–17157. doi:10.1007/s11356-016-6869-9.

[21] Benabid Abderrahmane, Benmbarek Naima, Mansouri Tarek, and Merdas Abdelghani. "Influence of Highway Traffic on Contamination of Roadside Soil with Heavy Metals." Civil Engineering Journal 7, no. 8 (August 1, 2021): 1459–1471. doi:10.28991/cej-2021-03091736.

[22] Loudini, Ahmed, Mounsif Ibnoussina, Omar Witam, Ali Limam, and Oksana Turchanina. "Valorisation of Dredged Marine Sediments for Use as Road Material." Case Studies in Construction Materials 13 (December 2020): e00455. doi:10.1016/j.cscm.2020.e00455.

[23] Rekik, Boubaker, and Mohamed Boutouil. "Etude de La Compressibilité et de La Microstructure D'un Sédiment de Dragage Traité Au Liant Hydraulique." IXèmes Journées, Brest (2006). doi:10.5150/jngcgc.2006.061-r.

[24] Maarouf, Hafida, Abdelaziz Semcha, Noureddine Mahmoudi, Nasreddine Bouhamou, Mahfoud Benzerzour, and Walid Maherzi. "Experimental study on the reuse of a dredging sludge from west of Algeria in brick fabrication." Journal of Materials and Engineering Structures, JMES, 5, no. 2 (2018): 163-172.

[25] Larouci, A., Y. Senhadji, L. Laoufi, and A. Benazzouk. "Valorisation of Natural Waste: Dam Sludge for Road Construction." Nature Environment and Pollution Technology 19, no. 3 (September 1, 2020): 1075–1083. doi:10.46488/nept.2020.v19i03.018.

[26] El-Attar, Mohamed M., Dina M. Sadek, and Amir M. Salah. "Recycling of High Volumes of Cement Kiln Dust in Bricks Industry." Journal of Cleaner Production 143 (February 2017): 506–515. doi:10.1016/j.jclepro.2016.12.082.

[27] Zhou, Chaoqun. "Production of Eco-Friendly Permeable Brick from Debris." Construction and Building Materials 188 (November 2018): 850–859. doi:10.1016/j.conbuildmat.2018.08.049.

[28] Bernardi, D., J.T. DeJong, B.M. Montoya, and B.C. Martinez. "Bio-Bricks: Biologically Cemented Sandstone Bricks." Construction and Building Materials 55 (March 2014): 462–469. doi:10.1016/j.conbuildmat.2014.01.019.

[29] Messina, F., C. Ferone, A. Molino, G. Roviello, F. Colangelo, B. Molino, and R. Cioffi. "Synergistic Recycling of Calcined Clayey Sediments and Water Potabilization Sludge as Geopolymer Precursors: Upscaling from Binders to Precast Paving Cement-Free Bricks." Construction and Building Materials 133 (February 2017): 14–26. doi:10.1016/j.conbuildmat.2016.12.039.

[30] Tang, Chao-Wei. "Properties of Fired Bricks Incorporating TFT-LCD Waste Glass Powder with Reservoir Sediments." Sustainability 10, no. 7 (July 17, 2018): 2503. doi:10.3390/su10072503.

[31] Safhi, Amine el Mahdi, Patrice Rivard, Ammar Yahia, Mahfoud Benzerzour, and Kamal Henri Khayat. "Valorization of Dredged Sediments in Self-Consolidating Concrete: Fresh, Hardened, and Microstructural Properties." Journal of Cleaner Production 263 (August 2020): 121472. doi:10.1016/j.jclepro.2020.121472.

[32] Bounouara, Zohra, Souad Malab, Belkacem Mekerta, Abdelatif Benaissa, and Souad Amal Bourokba. "Treatment of Dredged Sediments of Bouhanifia Dam for Their Valorization in Passive Barrier of Landfill." Geotechnical and Geological Engineering 38, no. 4 (March 18, 2020): 3997–4011. doi:10.1007/s10706-020-01273-x.

[33] Hadj Sadok, Rachid, Nadia Belas, Mahfoud Tahlaiti, and Ridha Mazouzi. "Reusing Calcined Sediments from Chorfa II Dam as Partial Replacement of Cement for Sustainable Mortar Production." Journal of Building Engineering 40 (August 2021): 102273. doi:10.1016/j.jobe.2021.102273.

[34] Slama, Abdelwaheb Ben, Nesma Feki, Daniel Levacher, and Moncef Zairi. "Valorization of Harbor Dredged Sediment Activated with Blast Furnace Slag in Road Layers." International Journal of Sediment Research 36, no. 1 (February 2021): 127–135. doi:10.1016/j.ijsrc.2020.08.001.