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CHARACTERIZATION OF THE "BANCO," A BUILDING MATERIAL FOR A TROPICAL AND RURAL ENVIRONMENT

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ABSTRACT

The population's access to comfortable modern accommodation and food security are major issues in developing countries [1]. To achieve these objectives, the use of local building materials associated with agricultural by-products is a solution for the future. This work focuses on the valorisation of local building materials in Benin to provide to the people of modern, comfortable accommodation and lower cost. The studied material is composed of a mixture of stems of rice, clay soil, and the infusion of nere which are all traditionally used for construction in rural areas, especially Northern Benin [2, 3]. Our study therefore focused on characterization physical, mechanical and thermal composite material called, "banco granary." The land of bar that can be used in the banco is available in the municipality of Abomey-Calavi. The resistances tension by bending and simple compression of the banco are 2,188 MPa and 4,948 MPa, respectively. Furthermore, the punching-bending strength (NF EN 15037) at 28 days, of blocks in banco in length 50 cm is 210,762 daN, significantly greater value than specified by the standard. Which allows the use of blocks in banco and resistant semi renderd in floors in blocks and beams. Also we obtained from the thermal tests, the values of conductivity, the effusivity and thermal diffusivity for two formulation methods. In general, these thermal properties increase proportionally to humidity. The conductivity values obtained are all below that of a brick. That confirms the improvement of the conductivity of the banco by the contribution of the stems of rice.

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INTRODUCTION

In traditional societies in Africa, the activities of the communities followed a seasonal pattern. While the rainy season was devoted to agriculture, the dry season resulted in constructive activity. Thus, traditional society met in a cyclical way to two fundamental needs of the human being: is food and shelter.

The promotion of so-called building materials 'local' and appropriate techniques may be interesting in sub-saheliens countries especially in campaign for the following reasons [4, 5, 6, 7]:

- combating poverty through the creation of jobs through the exploitation of natural resources;
- meet the demand of habitat through the production of natural resources-based materials;
- combating the precariousness of the habitat by building the skills and the improvement of the products;

In terms of local construction in Benin materials, include inter alia the cement, the banco, stone, wood, bamboo, rattan, straw, Palm etc... As revealed by the RGPH3, the most used material in the construction of habitat in Benin is the Earth representing more than 55% of building materials [5, 6].

Among these local materials, it is the banco which is the subject of this study. Indeed the banco, which combines land agricultural residues without another addition, including no stabilization in the advantage of serving and in the construction of grain storage lofts and the construction of land habitats. This material has the advantage that the Earth is available.

Environmental concerns to rediscover the many qualities of the banco material. Banco is a material with high thermal inertia regulator hygrothermal, it is also a very good acoustic insulator [4, 8].

Several works were conducted in the context of the recovery of this material [9, 10].

So far work on banco material, particularly in Earth's bar held rigour to the conditions to be fulfilled by the constituents of the banco material. In this study, we propose to check the possibility of use of the land of bar in the banco, in the light of the requirements of stabilization of the Earth, to formulate the banco material in determining its physical, mechanical and thermal characteristics in the light of the difficulties of handling of previous formulations and present possible applications in the field of construction.

1. THE BANCO

The adobe (or banco) is the Earth block raw, Sun-dried, and used as material of construction [11]. These bricks are obtained from a mixture of clay, water and possibly a charge used in small quantities: for example, chopped straw. All traditionally mixed with feet or mechanically until a good plasticity. It is being implemented in various forms depending on the country or locality considered. It is one of the first materials of construction: the first known cities were built in mud brick. This material is still one of the most used in the world.

The structures mounted in adobe may include reinforcements from wood, which can also be used for improved insulation. The largest structure built in adobe was the - Arge Bam, Citadel of Bam in Iran, which suffered significant damage during the earthquake of December 26, 2003. Other buildings of great size are present for example in the Peru: The Huaca del Sol with 100 million bricks, and Chan Chan. Several mosques in West Africa are made of adobe: for example, to Timbuktu and the great mosque of Djenné in Mali.

Photo 1. Mixing raw Earth and vegetable fibres.

Banco is an economic material [3]: extraction of the Earth doesn't require important technological means; the use is carried out without processing; the delivery is reduced. These factors limit the costs. Technically it is a highly insulating material also well soundproofed that thermally [8].

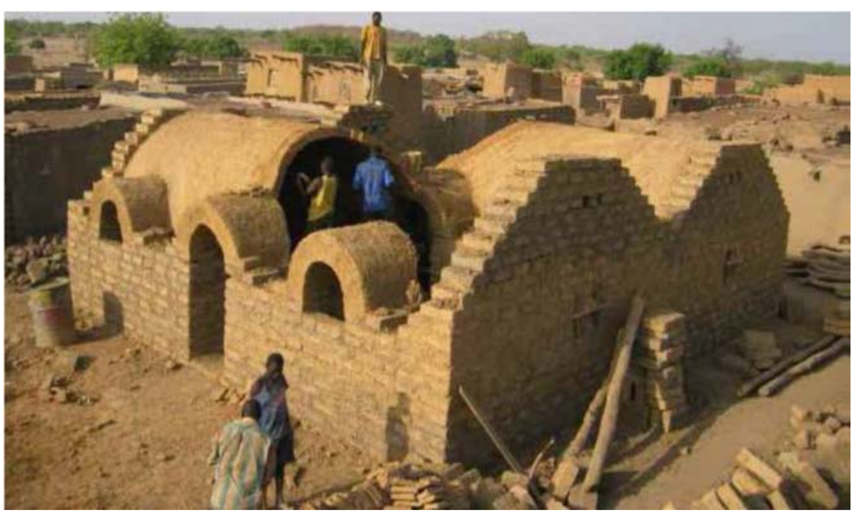

Photo 2. Construction with banco Nubian Vault.

Photo 3. Granaries in banco in the North of Benin [12].

2. Physical Characteristics

2.1. Identification Tests

2.1.1. Analysis Particle Size

- Particle size analysis by sieving

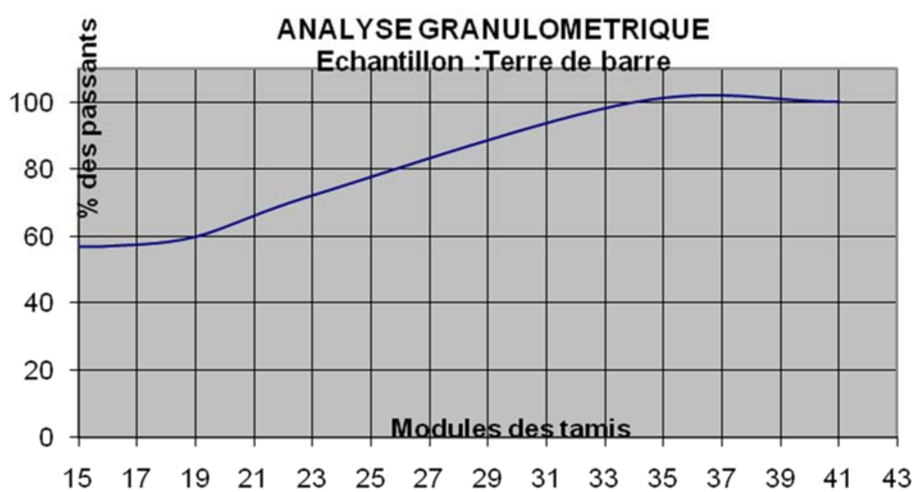

Figure 1. Grading curve.

Table 1. The percentage of fines of the sample

Sample	AG (% fines)
Land of bar	57.06

Particle size analysis allowed us to know the percentage of fines found in our sample. From our results, it is evident that our sample to a percentage of fines above 35%. In comparing this percentage of fine soil that can be used for the banco, we note that our sample fulfills a first criterion (CNERTP, February 1993).The second criterion for a soil that can be used to make the banco is that the soil must have a percentage of sand between 50% and 80% (Rural Structures in the Tropics, Rome 2011) which is the case here because our sample to almost 65% of grain whose diameter is greater than 0.2 mm.

Similarly we are seeing from the granulometric analysis by screening all of our samples were almost 65% of grain whose diameter is greater than 0.2 mm, which shows that our sample contains an average ratio of sand on the classification of the agronomist Swedish Atterberg.

Referring to the classification of granular soils U.S.C.S, our material is clayey sand.

- Particle size analysis by sedimentometrie

Table 2. Percentage of clay + silt

Sample	a (cm)	h (cm)	% Clay + silt
Land of bar	4.6	13	35.38

Sedimentation test has enabled us to know the percentage of clay silt content in our sample. This test gives an impression of the grading of the soil and allows the combined silt and clay content to be calculated. Our results indicated the height held clay + Silt is 4.6cm, the initial height is 13 cm and the percentage that equals this is 35.38%. This value is between 20% and 50%.

Our sample fulfills the criterion of the table in annex n°1 (Rural Structures in the Tropics, Rome 2011) which provides information on the classification of the soil that can be used to make the banco.

2.1.2 Atterberg Limits

Table 3 Sample plasticity index

Sample	Atterberg limit		
	W_L	W_P	I_P
Land of bar	47	29	18

We find that the land of bar from Abomey - Calavi has an index of plasticity of 18%. The second criterion of choice of the type of soil that can be used for the banco is plasticity index, which must be between 12.5 and 29. Therefore, we can say that our sample meets the second test.

Analysis of results of particle size analysis by sifting through sedimentometrie and the Atterberg limits, we can conclude that our sample perfectly fulfilled the conditions of manufacture of the Banco.

2.1.3. Density

Unit: (mg/m^3)

Table 4. Density

Sample type	apparent density	absolute density
Land of bar	1.12	2.65

Apparent density represents the bulk of the material per unit volume, this one incorporating both grains and gaps.

Absolute density represents the mass per unit volume of material which constitutes the aggregate, regardless of voids that may exist inside the grain.

2.1.4. Bar Shrinkage Test (Test of Withdrawal)

This test gives an indication of the plasticity index of the soil, because the shrinkage ratio of the soil when dried in its plastic state is related to its plasticity index [13].

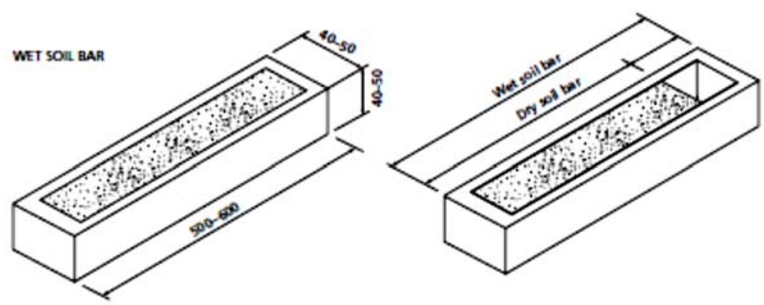

Figure 2

Table 5. Removal of the sample results

Types of samples	% of withdrawal
N° 1	8.68
N° 2	5.67
N° 3	6.94

The samples have a withdrawal percentage less than 10%, while according to the recommendations of the test soil is likely to be stabilized.

2.1.5. Slump Test (The Abrams Cone Test)

In accordance with the requirements indicated in the Document test protocol (Rural structures in the tropics design and development, Rome, 2011) we got a SAG h = 3 cm.

0 cm < h < 4cm then the material is firm and is therefore the S1 class.

2.1.6. Absorption of Rice Stalks

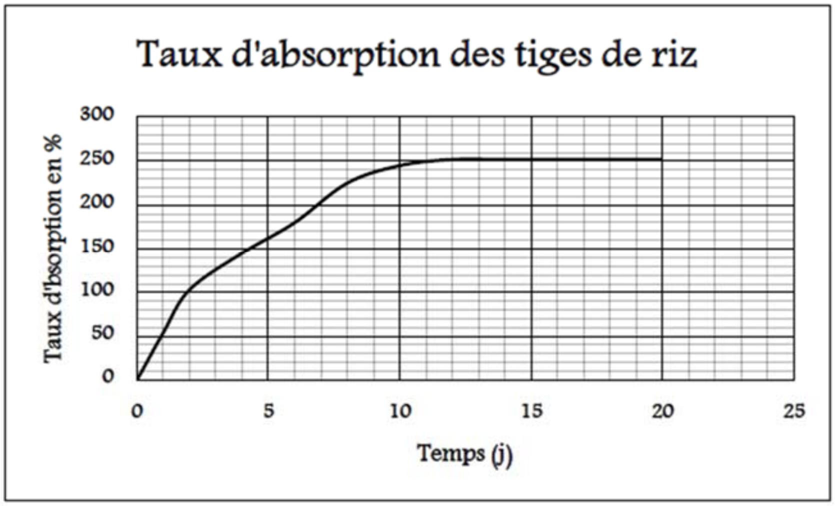

Figure 3. Kinetics of water absorption of rice stems.

The stems of rice have a relatively high (nearly 252%) percentage of absorption. Found kinetics of classical absorption with increasing speed in the early hours and a stabilisation at the end.

2.2. Test Proctor

At the end of this test, we have charted the Proctor curve to determine the maximum dry density and the optimum water content.

Maximum dry density: 1.8 t/m3 content in water optimal: 15.85%.

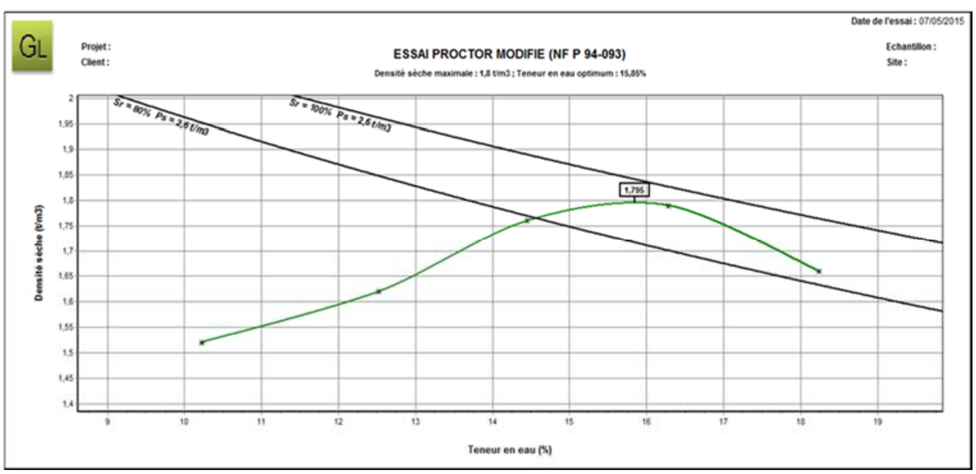

Figure 4. Proctor curve of composite.

2.3. Formulation

Element of the composite	Mass (g)	% compared to Earth
Earth bar	451.8	
Rice straw	9.04	2.00%
Infusion of nere	27.11	6.00%
Mixing water	45.9	10.16%

2.4. Measurement of Density of the Composite Material

Table 6. Densities of the banco

Test piece	Density (Kg/m3)		
	14 days	21 days	28 days
Average	1568,303	1565,592	1563,263

The density of the banco runs averaged around 1565 (Kg/m3) and does not really change with age.

2.5. Measurement of the Rate of Humidity

Table 7. Moisture content of the banco

Test piece	Humidity (%)		
	14 days	21 days	28 days
Average	3,877	2,593	1,874

Humidity varies with age. It decreases as age increases. It notes that this reduction is done with the density of the banco.

3. Mechanical Features

3.1. Single Fibre Tensile Test

The following table shows the average resistance simple traction of the stems of rice used for the manufacture of our specimens and all.

The stems of rice have considerable resistance thereby contributing no doubt to the tensile strength of our material.

Table 8. Stems of rice simple tensile strength

No. stem of rice	Effort to failure (N)	Tensile strength (MPa)	Average strength tensile strength (MPa)
1	107	15,1451	15, 1805±1, 2562
2	102	14,4374	
3	95	13,4466	
4	125	17,6929	

3.2. Tensile Bending and Compression Test

We present here only the resistors obtained at 28 days. The resistance is increasing with age.

Table 9. Traction by 28 days bending resistances

test piece	Tensile strength by flexural strength (MPa)	
	Without infusion of nere	With infusion of nere
N ° 1	2,098	2,180
N ° 2	2,057	2.386
N ° 3	2,034	2.315

Table 10. 28 day compressive resistances

test piece	Compressive strength (MPa)	
	Without infusion of nere	With infusion of nere
N ° 1	3,140	4,653
N ° 2	3,080	4,968
N ° 3	3.125	4,946

The highest value recorded tensile bending on the specimens without infusion of nere is 2,098 MPa while obtained on the specimens with infusion of nere is 2.386 MPa.

Same great compressive strength recorded on specimens without infusion of nere is 3,140 MPa and that obtained on the specimens with infusion of nere's 4,968 MPa.

It is worth noting that the mechanical resistance obtained in compression and tensile-bending are in the standards required in the Nubian Vault construction which requires a compressive strength between 2 MPa and 5 MPa of the banco material [11]. Then our banco material can be used in the construction of habitat and attic because has the mechanical characteristics required.

Analysis of the different results obtained in compression on specimens with and without infusion of nere we note initially that the compressive strength increases with age and secondly that it believes significantly at the level tubes with infusion of nere. We can therefore from this note concluded that the infusion of nere improves the compressive strength of the banco material.

4. THERMAL CHARACTERISTICS

Hot tape method was used to determine the thermal properties of the material [14, 4].

Content in water	Conductivity(Λ) in W. m-1.K-1		Effusivite (E) in J. m-2.K-1.S$^{-1/2}$		Diffusivity (has x 10) -7) in m2.S^{-1}	
W1	0.854		1280,889	1290,412 ± 6,3484	4,445	
	0.863	0.869 ± 0.0144	1291,234		4,467	4,5387 ± 0,1102
	0.891		1299,112		4,704	
Wopt	0,897		1302,584	1352,384 ± 33,1998	4.742	
	0.952	0.942 ± 0.03	1355,423		4,933	4,8504 ± 0,0722
	0.977		1399,144		4,876	
W2	0.983	1.008 ± 0.03	1411,952	1428,625 ± 14,406	4,847	
	0.988		1423,689		4.816	4,9783 ± 0,1958
	1.053		1450,234		5,272	

The results of the thermal tests show that thermalconductivity varies according to the water content, result already proven by several researchers (DOKO, 2013; Ball, 2011)

- Thermal conductivity (l): 0.942
- Effusivity (E): 1352,38
- Diffusivity (a): 4,8504
- heat capacity: 1 350 kJ/M3.°C

CONCLUSION

Physical, mechanical and thermal Banco characterization leads us to subdue the Earth from bar to Bar Shrinkage test (test of withdrawal) which is the characteristic test that allows to say that land can be stabilized. Mechanical characterization of the stems of rice revealed that these rods have an important simple tensile strength, an average of 15,1805 MPa.

Resistance tensile bending and simple compression of the composite material are 2,098 MPa and 3,140 MPa specimens, respectively, without infusion of nere and respectively 2.386 MPa, 4,968 MPa specimens with infusion of nere. Let's say that the infusion of nere increases resistance to compression of the banco. The punching shear-bending test (NF EN 15037) conducted on the rest gave an average strength of 209,262 daN and the smallest value is 201,762 daN. Results helped the renderd in banco are resistant semi springbreak.

The land of bar is existing material in abundance and is also used in construction in rural areas. This study shows that are adding stems of rice and the infusion of nere greatly improves its mechanical properties. The knowledge of this aspect by the general public would use it to benefit at the expense of the concrete-based materials and so dramatically could be used in construction projects of habitats and structures of storage of cereals in rural areas. So therefore we can use banco for several applications, including the manufacture of the rest, full chipboard and hollow all dimensions that can be used in the elevation of wall in the construction of Nubian vault and any kind of construction in land.

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