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Comparative study of the mechanical characteristics of sand mortar (cinder blocks) and compressed laterite bricks (BTC) stabilized with wement

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Abstract

The purpose of this study is to determine the dry and wet mechanical resistances after immersion in water of bricks of 15x20 x 40cm^3 in sand mortar (cinder blocks) and 10x14x28cm^3 compressed laterite mortar bricks(BTC) stabilized with cement. The experimental results obtained show that the 28-day compressive strength values of the 12% cinder blocks and those of the 10% cement Btcs are respectively 2.55MPa and 7.90MPa. These values are in accordance with the normative values recommended by the Building Materials Centre (CMC) in N'Djamena (2.4MPa) and the Land Materials Research Centre (Craterre) (5MPa). In the presence of moisture, the loss of resistance is only 28% for BTC and 46% for cinder blocks. Also, the bricks have a suction capacity ranging from 2.50 to 5.02g/cm² $S^{1/2}$ for BTC and 6.12 to 10.90g/cm². $S^{1/2}$ for cinder blocks. These values are all less than 20g/cm². $S^{1/2}$, a value imposed by NF P 554. A comparison of the results of this work shows that, with the same cement content, during dry seasons as in rainy seasons, BTCs are more resistant and more economical than cinder blocks.

Keywords: Mechanical resistance, brick, laterite, parpaing, immersion, suction, Chad.

Introduction

Chad, a country in Central Africa, is full of huge amounts of building materials; but during their use in construction, the in habitants ignore some of their mechanical characteristics. This leads to countless stability problems in the building and public works sector. However, to be economical, to ensure the stability and durability of these various works, their achievements require local quality materials.

It is with a view to enhancing them that this study focuses on laterite and sandy soils accessible by all social ranks. Laterite soils were collected in the province of West Tandjilé on the Kelo-Moundou axis at 12Km (Village Marbelem) on the right side. Sand is taken from the bed of the Chari River in the village of Klessoum.

The experimental work is carried out in the laboratory of the National Superior School of Public Works of N'Djamena (ENSTP). Laterite floor bricks or compressed earth blocks (BTC) are made using a manual press with a static compaction pressure ranging from 1.1 to 2.3MPa. Soil samples were subjected to some conventional geotechnical identification testing prior to being stabilized with cement to increase mechanical and water resistance. The bricks made from sand and laterite mortars were subjected to a wet cure under cover in a bag with a cure according to the compression test periods of 3, 7 and 28 days[1]. The measurement of compressive strength is done by crushing the bricks with a concrete hydraulic press[2-4].

Materials and methods

Laterite distribution in Chad: Lateritis are generally located in the southern zone where it is very hot and where rainfall is abundant either year-round or during a wet season.

Petrographic Characteristics of Materials: The characteristics of a mortar for making bricks depend on those of the materials used in its composition.

The two types of materials, laterite and sand, used in this study are of a different petrographic nature: i. The laterite taken is part of the lateritic graveleux family[5-7]. It comes from the village of Marbelem Kemssian in West Tandjilé and is collected from 30cm below the natural terrain. The quarry is located on the Kélo-Moundou axis at 12km on the right side (Figure-1). ii. The sand comes from the Chari River in the area along the village of Klessoum. It is taken from the river bed about 3m below the natural terrain and at an apparent density of 1.48kg/l. Dry sieving tests show that our sand is medium, clean and poorly graded.

Geotechnical Characteristics of Materials: The necessary geotechnical characteristics are determined by the identification tests and the Proctor test according to the French AFNOR standards[8-12]: i. Actual density: NF P 94-054, ii. Bulk density: NF P 98-250, iii. Particle size analysis by sieving: NF P 94-056, iv. Atterberg boundaries: NF P 94-051, v. Sand equivalent E_S: NF P 18-597, vi. Modified Proctor Test: NF P 94-093.

Figure-1: Location and Site of Laterite Sampling.

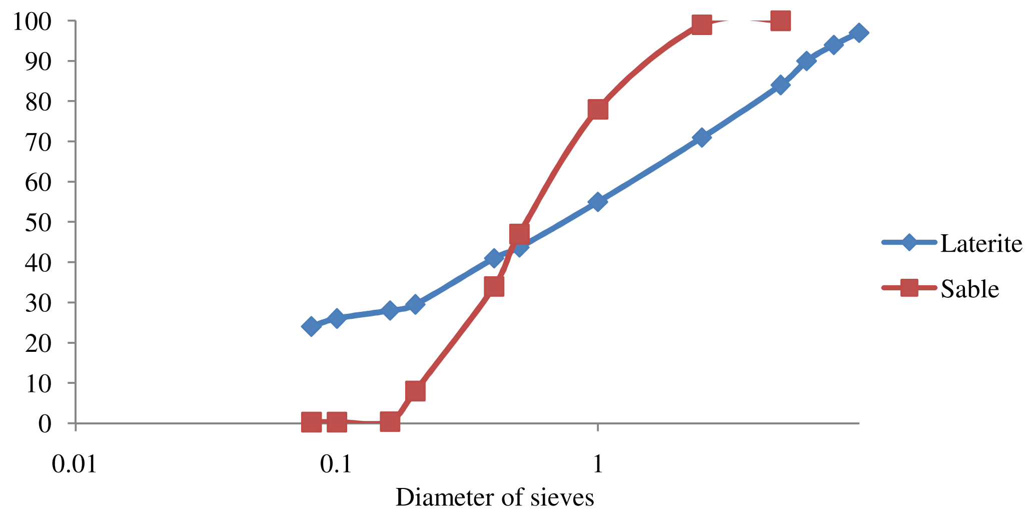

Figure-2: Laterite and sand particle size curves.

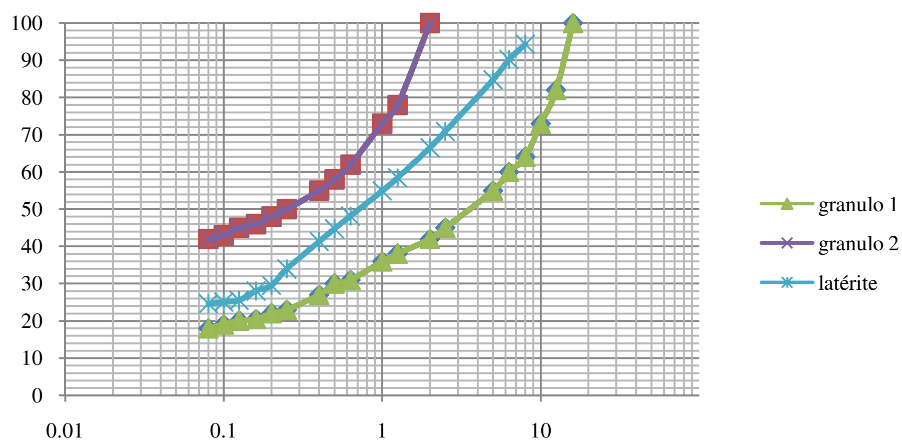

Figure-3: Reference grain size gauge[13].

During the preparation phase, the soil was dry-engineered to remove pebbles. After that, and according to Craterre's recommendations for the manufacture of compressed earth blocks (BTC), the particle size curve (Figure-3) must not leave the reference particle size zone (Figure-3). Otherwise, we have to do a particle size correction. We don't.

Table-1: Summary of laterite and sand characteristics.

Materials	Density Apparent ρ_a (g/cm^3)	Actual density ρ_r (g/cm^3)	Grain size					Limits of Atterberg			Proctor		Sand Equivalent
			< 2 mm	< 80 µm	M_f	C_u	C_c	ω_L	ω_p	I_p	γ_d	ω_{opt}	E_S
Laterite	1,87	2,60	66,51	24,63	2,74	-	-	25	22	3	2,03	11,4	-
Sable	1,48	2,71	97,63	0,75	2,00	3	1	-	-	-	-	-	90

Calculation of the dosages: The calculation of the dosages consists of determining the proportions of each element in the product formulation. For this study, this is cement and water. For the determination of laterite mortar, the calculation is based on the Technology Pole Method for the promotion of local materials POTEMAT-EPAC Cotonou-Benin. The measurements are made using a vessel (bucket) of known volume and the various proportions obtained are converted into suitable units

Cement dosage: i. Bucket volume: 10 litres, ii. Dry laterite bucket weight: 18.7kg, iii. Apparent density of laterite: 1.87kg/litre, iv. Wheelbarrow volume: 60litres.

An example of the 4% dosage gives: i. Dosage 4% = 4kg of cement per 100kg of soil, ii. ¼ bag or 12.5kg of cement equals (12.5x100) / 4 = 312.5kg of soil, iii. By volume, 312.5kg soil equivalent to: 321.5/1.87 = 167litres, iv. 167litres of soil equivalent to 2 wheelbarrows and 5 10-litre buckets, v. With a bag of cement, you need 11 wheelbarrows and 2 buckets of earth.

This operation is repeated for successive assays of 6%, 8%, 10% and 12%

Dosage in water: The aim is to determine accurately the quantity of water needed to obtain a good mixture and compactness. The principle is to determine the quantity of water that makes it possible to obtain the highest density, in other words the heaviest bricks. To obtain this parameter, a series of production error tests must be carried out and compared on a curve. The test consists of mixing the material with a quantity of water close to the optimum water content of 11,4% (Table-1) and making a few bricks (about 4) and then weighing and averaging them. Repeat the same operation at least four times, increasing the percentage of water each time. We obtain at least four points through which a curve passes. The abscissa at the top of this curve is the optimal water content to consider. For granular and less clay soils, an alternative method is to determine the optimum content by the modified Proctor test.

An example of a 6% dosage gives:

Dry density	1,8	1,84	1,82	1,81
Water content	11,1	12,53	14,04	15,16

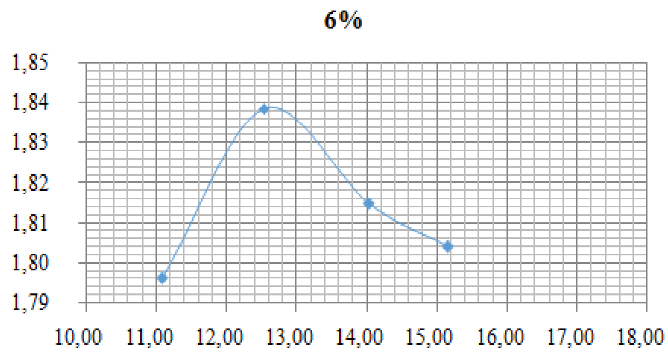

Figure-4: 6% water content.

Table-2: Summary of 6% Determination.

Cement in kg	¼ of bag (12.5)	½ bag (25)	1 bag (50)
Laterite in kg	208,33	416,66	833,32
Dry mix mass in kg	220,83	441,66	883,32
Volume of water (12.6%) in litres	27,8	56,65	111,29

Manufacture of 10 x 15 x 28 cm^3 laterite bricks: The stages of production are those recommended by the Technology Centre for the promotion of local materials POTEMAT-EPAC Cotonou-Benin. These are extraction, preparation, mixing, pressing (Figure-5), curing conditions (Figure-6).

Figure-5: Presse manuelle utilisée.

Figure-6: Conditions de cure.

Preparation of blocks of 15x20x40cm^3: The stages of production are those commonly carried out in Chad: Extraction, preparation, mixing, moulding, curing and storage. An example of calculation of the 6% dosage gives: i. Sand mass required for brick: Ms = 14.5kg, ii. Cement mass: Mc = (6/100)x14.5 = 0.87 kg, iii. Number of bricks per bag: (50/0.87) = 57bricks, iv. Sand mass per bag: 57x14.5=826.5kg, v. Volume of sand per bag: 826.5/1.48 = 0.558 m^3.

The composition of the 6% dosage is as follows:

Sand (kg)	826,5
Cement (Kg)	50
Dry Mix (Kg)	876,5
Waste water (in %)	9,5

The Mechanical Tests[14]: The aim is to determine the mechanical resistances of the manufactured blocks. Given the stresses they will experience during their use, the emphasis has been on simple compression and three-point bending. The results of these tests will lead to the determination of the best dosages to adopt while taking into account other criteria such as economic aspects.

Bending test: EN 12390-5: Bricks are subjected to breakage at a bending moment by applying an F load to the middle by means of a higher roller. The two lower rollers represent the supports. The maximum load reached during the test is recorded by a comparator and the bending resistance is calculated by the following relation:

$$R_f = \frac{F \, x \, L}{l \, x \, H^2} \quad (1)$$

L: length, l: width and H: height of the brick.

In reality, the bending test cannot be carried out on bricks for the simple reason that they are not specifically stressed in bending.

Compression test standard EN 12390-3: The principle is to load up to failure into a machine for the compression test (Figure-7a and b). The maximum load reached is recorded and the compressive strength calculated according to the following relation:

$$R_c = \frac{F}{A} \quad (2)$$

A: section of brick

After obtaining the characteristics of the elements in the dry state, it is also important to determine them in the unfavorable conditions that is that is, in the presence of moisture, because every structure must have a minimum of resistance to the elements. Thus, a sample of each 28-day-old assay was soaked for 24 hours (Figure-7c and d) in order to be subjected to compression, and the absorption coefficient is determined. For example, one sample of each 28-day-old assay was soaked for 24 hours for compression, and the absorption coefficient is determined. At the end of this operation, resistance losses were noted.

Capillary absorption test: NF P 554: This test makes it possible to determine the behaviour of the bricks in relation to the humidity conditions. It consists in drying the different bricks in the oven for 24 hours under a temperature of 105°C. At the exit of the oven and after cooling, they are weighed, M1; after this operation they are immersed on the underside at a depth of 5 mm (Figure-7e and f). Ten (10) minutes later, they are removed from the water to be weighed, M2, and measured on the submerged surface. The absorption coefficient is calculated by the relation:

$$C_b = \frac{M_2 - M_1}{S\sqrt{t}} \, x \, 100 \quad (3)$$

C_b: Absorption coefficient in g/cm^2.s$^{1/2}$, S: area immersed in cm^2; M_1 et M_2 in grams; t: time in seconds.

Results and discussion

The bricks in laterite: i. Bending Resistance Test Results, Using Relationship 1, we have the following results:

Table-3: Bending Strength.

Cement dosage	Length L (mm)	Width l (mm)	Height H (mm)	Charge (N)	Resistance (MPa)
8%	224	150	85	5000	1.03
10%	224	150	85	5000	1.03

ii. Despite the improvement of the physical and chemical quality brought to laterite to make the bricks, their resistance to bending is weak. These low values (1.03 MPa) reflect the perfect plasticity of the elements. Although these results are low, there should be no concern; in fact, the stress on bricks in masonry, bending and traction does not have a great effect. Even heavily dosed concrete has low resistance to bending and traction (BAEL 91 mod. 99). iii. Dry Compressive Strength Test Results.

Figure-7: Compression, Immersion and capillary absorption (a) Compression of laterite bricks; b) Compression of cinder blocks; c) Immersion of laterite bricks, d) Immersion of cinder blocks, e) Capillary suction of laterite bricks, f) Capillary suction of cinder blocks.

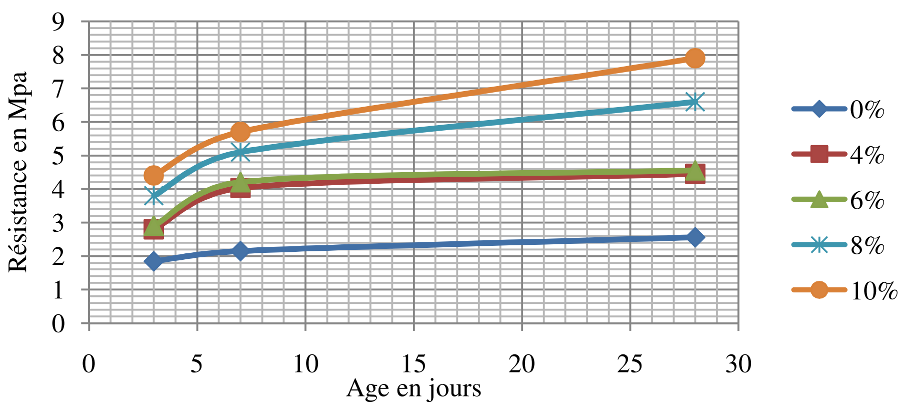

Figure-8: Dry Compressive Strength (Age) Curve.

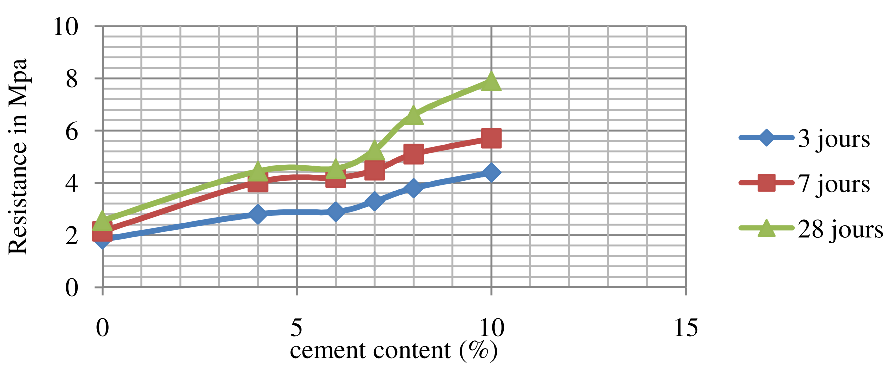

Figure-9: Dry Compressive Strength Curve (% Cement).

Figures-8 and 9 show the change in resistance as a function of the duration of treatment. The retention period is spread over 28 days to learn about the material's short- and long-term behaviour. For each dosage, the resistance increases with the cure time due to the soil-cement reaction which gradually increases the bond between the grains. This growth ranges from 1.18 to 1.3MPa between 3 and 7days and from 0.35 to 2.2MPa between 7 and 28days. The difference in variation between these two intervals shows that at an early age, the soil-cement reaction is accelerated; however, it is slowed down after the seventh day. In sum, the resistance increases strongly when the cement content is high. This is the case of 10% which offers a resistance of 7.9 MPa to 28 days.

Although the laterite grain size conforms to the technical standards in force recognized by the Craterre spindle and the mechanical resistance obtained is also appreciable, we wanted to bring an improvement from the aesthetic point of view on the walls. This is what led us to reduce the grain size from 10mm to 5mm and given the resistance offered by the 6% and 8% assays, we have recommended a formulation with an intermediate dosage of 7% cement with an optimal water content of 13% to see if this does not compromise the required mechanical characteristics, while checking the new particle size curve in relation to the Craterre spindle. As a result, we obtained the results presented in Figure-10.

The Table-4 gives the results of the behaviour of the elements towards the water. We see a decrease in the resistance of each of these determinations. Despite this decrease, the resistance offered is still acceptable without the 0% dosage which offers poor behaviour after immersion. The loss of strength ranges from 22% to 28% depending on the cement content. The higher the cement content, the smaller the loss. The absorption increases with the cement content.

According to Table-5 results, the capillary absorption coefficients are very low because all these values are less than 20%, below which the element is classified as low capillarity according to NF P 554.

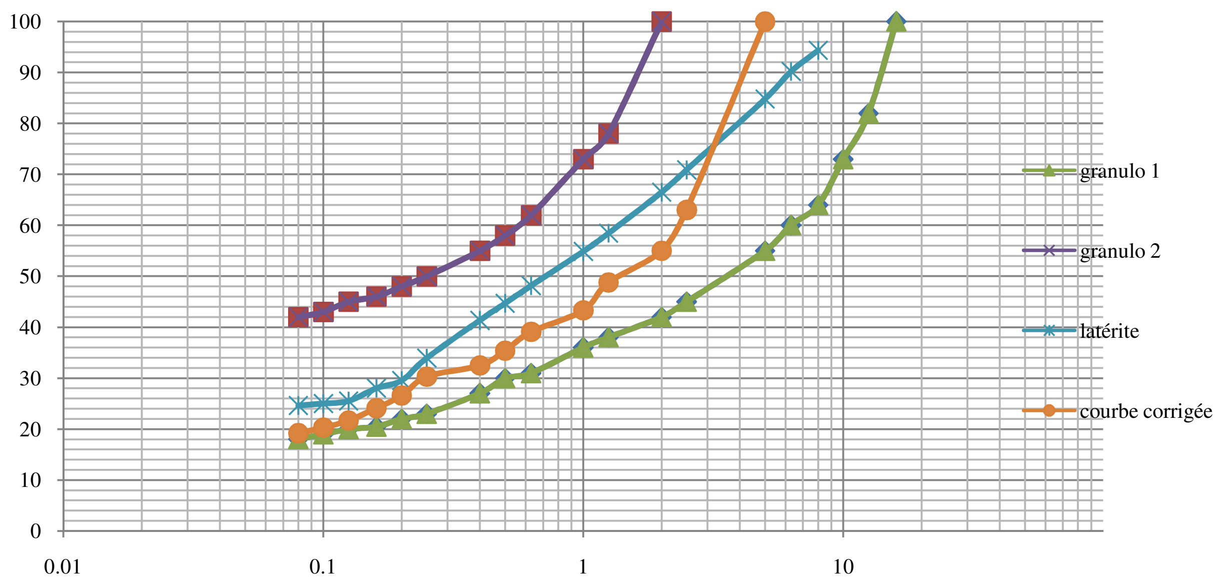

Figure-10: Corrected curve with respect to the Craterre spindle.

Table-4: Loss of resistance after immersion.

Cement Dosage	Dry weight (kg)	Wet weight (kg)	Abs. Coef. (%)	Wet Volume (mm^2)	Charge (N)	Resistance after immersion (MPa)	Dry Resistance (MPa)	Resistance Loss (%)
4%	6,3	7,2	14,3	38920	125	3,20	4,45	28%
6%	6,3	7,2	14,3	39200	135	3,44	4,55	24%
7%	5,5	6,2	12,7	45296	180	3,96	5,26	24%
8%	6,4	7,1	10,9	39200	200	5,08	6,6	23%
10%	6,3	6,9	9,5	39200	240	6,16	7,9	22,1%

Table-5: Capillary absorption coefficient.

Dosage	M_1 (g)	M_2 (g)	Surface (cm^2)	Cb ($g/cm^2.S^{1/2}$)
4%	6450	6985	435	5,02
6%	6500	6980	435	4,50
7%	6555	7017	435	4,33
8%	7699	7988	392	3,00
10%	7628	7866	392	2,50

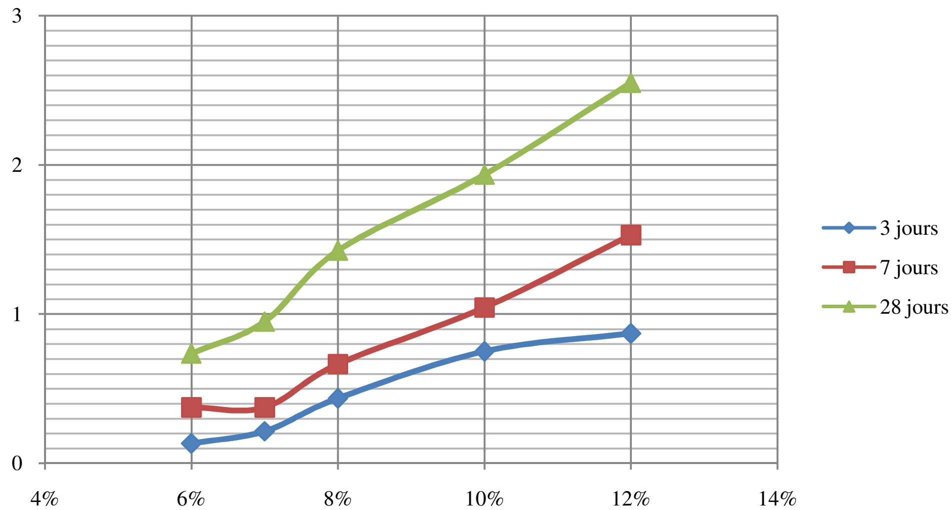

Figure-11: Dry Compressive Strength Curve (cement dosage).

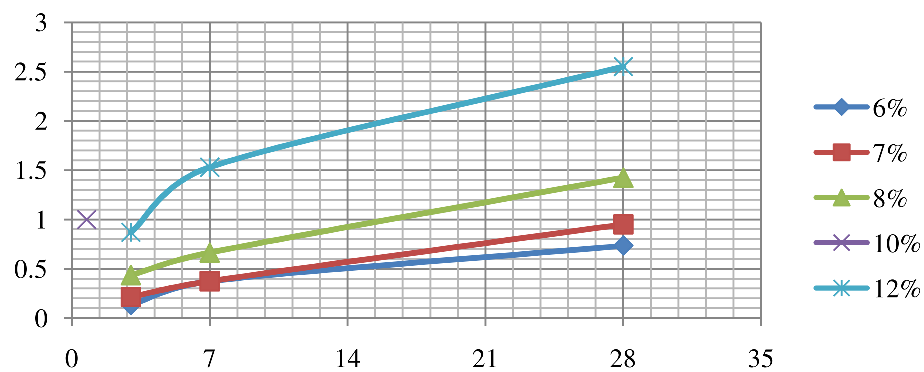

Figure-12: Dry Compressive Strength (Age) Curve.

Figures-11 and 12 present the results of the compression test on the blocks of parpaing. The values obtained increase with age and the cement content. The change in resistance relative to age is in the range of 0.160 to 0.660 MPa between 3 and 7 days and 0.360 to 1.02 MPa between 7 and 28 days. Depending on the cement content, we have the following variations after 28 days: 0.215 MPa between 6 and 7%, 0.475 MPa between 7 and 8%, 0.510 MPa between 8 and 10% and 0.615 MPa between 10 and 12%.

Table-6 summarizes the results of the crash of the block blocks after 24 hours of immersion. The absorption coefficients remain the same between 6, 7 and 8% followed by a sharp increase between 8, 10 and 12%. This behaviour shows that the absorption coefficient of a cinder block is not only dependent on the cement content but also on the compaction which reduces the volume of voids between the kernels. In this class of bricks, the loss of resistance after immersion ranges from 23% to 46%; this loss increases when the cement content is low.

The Cb values are always less than 20%, so these blocks are of low capillarity, on the other hand, they are higher than those of laterite blocks.

Discussions: After identifying the sand and laterite materials through the laboratory tests (Table-1, Results), they were used to make the bricks by chemical cement stabilization. The bricks made have undergone a 28-day cure, during which the latter have almost reached their maturity limit. In order to avoid an appearance judgment on these blocks, they have been subjected to various tests on which discussions will be based. These are the experimental results of dry and wet limit resistances to compression, absorption coefficient and cost.

Table-6: Loss of resistance after immersion.

Cement Dosage (%)	Dry weight (kg)	Wet weight (kg)	Abs. Coef. (%)	Wet Volume (cm^3)	Wet Density (g/cm^3)	Surface mm^2	Charge (N)	Resistance after immersion (MPa)	Dry Resistance (MPa)	Resistance Loss (%)
6%	13,7	15,7	14,6	8737,5	1,79	60000	24000	0,4	0,735	(46%)
7%	13,7	15,7	14,6	8737,5	1,79	60000	35000	0,58	0,95	(39%)
8%	14,0	15,9	13,5	8737,5	1,80	60000	62000	1,04	1,425	(27%)
10%	14,0	15,8	12,9	8737,5	1,83	60000	90000	1,50	1,935	(23%)
12%	14,2	16,0	12,6	8737,5	1.86	60000	117000	1,95	2.55	(23%)

Table-7: Capillary absorption coefficient.

Dosage (%)	M_1 (g)	M_2 (g)	Area (cm^2)	Cb (%)
6%	13700	15300	600	10,9
7%	13600	15200	600	10,88
8%	14100	15400	600	8,84
10%	14200	15200	600	6,80
12%	14400	15300	600	6,12

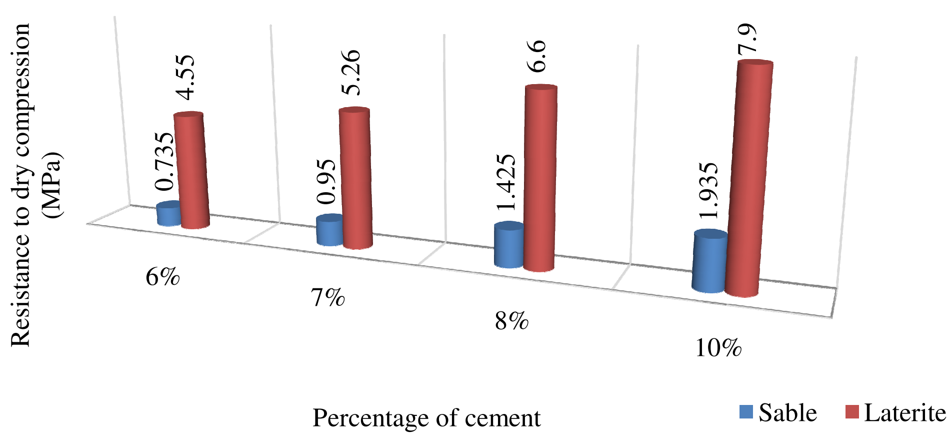

Figure-13: Comparison of dry resistance at 28 days.

Limit resistances to compression: In the dry state, laterite bricks dosed at 10% cement have a maximum average strength of 7.9 MPa at 28 days, whereas block blocks under the same conditions have a maximum average strength of 1.9 MPa. This large discrepancy is not due to chance because, on the one hand, according to the other dosages, the same phenomenon is observed and, on the other hand, the research work on the stabilized laterite of Mahamat Saleh Ibrahim Yacoub have shown that these soils have appreciable resistance to compression[15]. Also, according to Pierre Meukam, the laterite stabilized at 8% and 10% gave respectively 6.5 MPa and 8 MPa, values almost identical to those found here[16,17]. This large difference is also explained by a number of parameters such as the nature of the soil, the compaction energy, the grain surface condition and the density. Depending on the nature of the soil, laterite has a discontinuous particle size (25% silt or silt; 5% fine sand; 37% coarse sand; 33% severe) while sand has a continuous particle size (0.75% silt; 4.5% fine sand; 92% coarse sand; 2.75% severe sand).

Given the proportion of fine elements in each of these soils, laterite has many more than sand. These fine elements give it the advantage of cohesive grain. This makes that even the unstabilized laterite has a resistance of 2.56MPa; resistance that the parpaing achieves with 12% cement. Regarding compaction energy, cinder blocks are poorly compressed compared to laterite blocks. As a result, laterite grains tighten as much as possible under the effect of the compressive force. This tightness between the grains gives them very good adhesion and therefore a higher density than that of the cinder blocks. Ottou reports by Danson's work which considers that the compressive strength is proportional to the compressive pressure. From the surface condition point of view, the sand grains have a smooth surface, difficult to adhere with the binder, which does not allow this set to have an appreciable resistance. Compared with the density, the greater the density, the greater the resistance. This latter parameter has been proven by the Cormon research cited by Bidjocka which states that density is a criterion for variation in compressive strength.

After immersion, a decrease in resistance is observed on each element, a loss of 22-28% for laterite bricks and 23-46% for cinder blocks. These results show that in the presence of water, laterite blocks are always better than cinder blocks. To justify this change in behaviour, it is necessary to address the notion of the absorption coefficient of each of these blocks.

According to Figure-15, cinder blocks absorb more water than those of laterite bricks. This absorption can be explained by certain factors including the number of pores and their dimensions. The strong absorption of water by cinder blocks is due to the continuous particle size of the sand with small proportion of the fine elements. Despite the addition of the binder, the gaps left between the grains are not completely filled; also with the low manual pressure, the total tightening of these grains is not possible. In fact, these voids constitute water collection ports, causing a large drop in compressive strength. On the other hand, laterite blocks do not absorb too much water because the laterite grain size has a large proportion of the fine elements which, together with the binder, cause an obstruction of the gaps left between the grains. In addition, the effect of the compaction energy of the press ensures maximum grain tightness. This leads to a decrease in the size and number of pores. As a result, the latter are less sensitive to water and therefore the absorption coefficients are always low compared to those of the cinder blocks. From the above, water has little effect on the behaviour of laterite blocks.

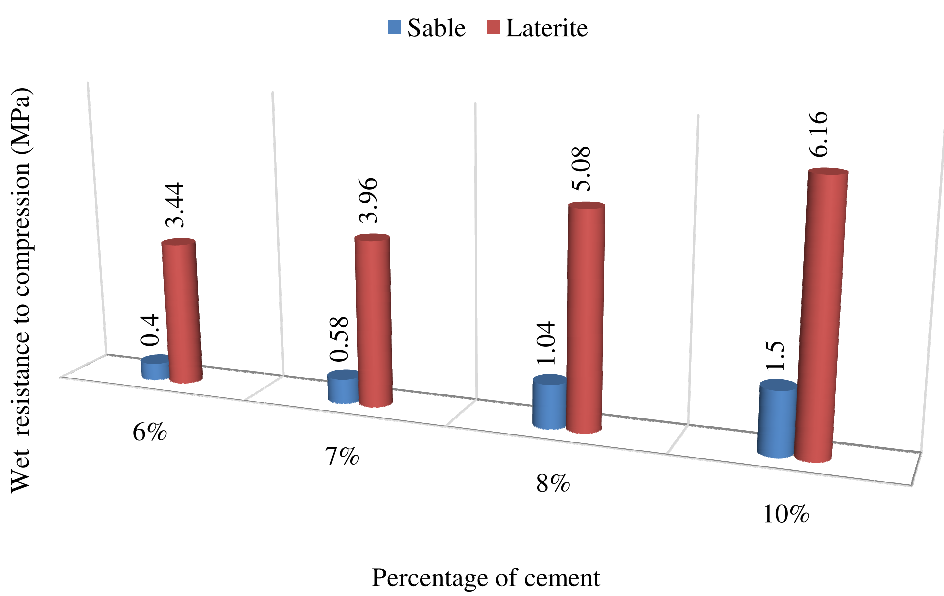

Figure-14: Comparison of wet resistors.

Figure-16 gives the results of the capillary absorption test on laterite and cinder blocks. These results show that cinder blocks have a strong water suction capacity compared to laterite blocks; this confirms absorption by imbibition. This behavioural inequality can be explained in the same way as the reasons cited in immersion absorption. In fact, the power of suction is a function of the porosity of the element. Despite the difference between the two types of elements, they are therefore of good quality in capillary absorption because their coefficients are less than 20%, imposed by the standard NF P 554: (2.5 to 5% and 6.12 to 10.9%), for laterite and parpaing respectively.

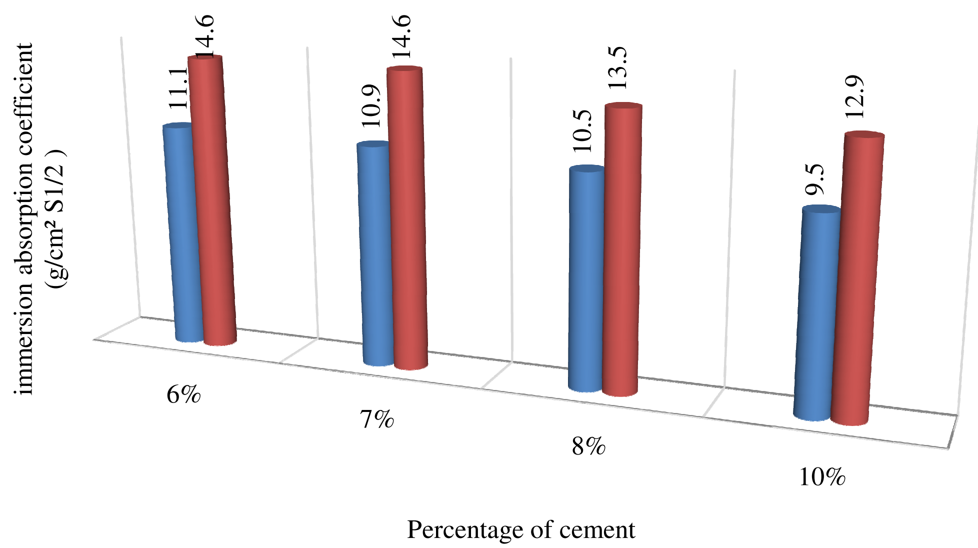

Figure-15: Comparison of immersion absorption coefficients.

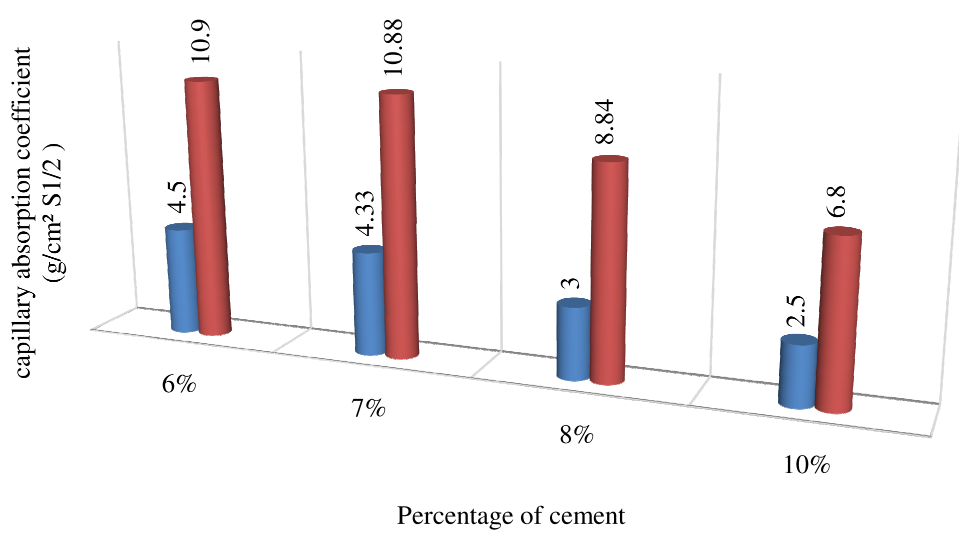

Figure-16: Comparison of capillary absorption coefficients.

Table-8: Comparison of cost studies.

Cement	6%			7%			8%			10%		
	$N_{b/sac}$	PU in FCFA	Cost/m^2	$N_{b/sac}$	PU (FCFA)	Cost/m^2 (FCFA)	$N_{b/sac}$	PU (FCFA)	Cost/m^2 (FCFA)	$N_{b/sac}$	PU (FCFA)	Cost/m^2 (FCFA)
Laterite	128	105	3150	110	117	3510	96	131	3930	77	157	4710
Sand	57	285	3563	49	312	3900	44	338	4225	34	405	5063

After assessing the production costs of the various components, it appears that cinder blocks are more expensive than laterite. Prices for laterite blocks vary from 79 to 157 F depending on the dosages and from 285F to 468F for cinder blocks. Because of these prices, we can estimate the cost of a square meter of masonry in blocks and laterite respectively 5063 F and 4710 F for the same dosage (10%). Taking into account the quality of the elements, the blocks of parpaing dosed at 10% should not be compared with those of laterite of the same dosage, but rather with those of 4%. In fact, the unstabilized laterite already offers a resistance superior to the parpaing dosed at 10%. Based on this principle of quality, the comparison between parpaings dosed at 12% and laterite at 4% seems reasonable. This cost 5850F and 2400F per square metre of masonry in block blocks and laterite respectively, a saving of 3450F per square metre. This coM Parison is made by considering local parameters. However, for use outside the non lateral zones, the transport cost must be involved to increase the price of the blocks.

Conclusion

The comparison of resistance laterite bricks (BTC) and sandy blocks (Parpaing), stabilized to cement in the same proportions, shows that laterite offers better resistance (7.9 MPa) at 28 days, while the sand has a very low resistance (1.9 MPa) at the same age. After 24 hours of immersion, a resistance drop is observed on both types of elements, but this does not prevent laterite from remaining the best because its resistance decreases slightly. There was a variation of 7.9 to 6.2 MPa for laterite and 1.9 to 1.5 MPa for sand, a loss of 22% and 23% respectively for laterite and sand. As for the absorption coefficient, the cinder blocks have a higher suction power than those of laterite. Nevertheless, both types of material have very appreciable suction values. There are 6.1 to 10, 9% for cinder blocks and 2.5 to 5% for laterite and according to dosages. With regard to the requirements of Craterre and the Building Materials Centre (CMC) of N'Djamena, the required resistance is achieved. In short, this work has made it possible to highlight on the one hand, the inequality of properties that resides between the sand and laterite materials through a stabilizer, the cement and, on the other hand, the advantage of using local materials.

References

1. Olivier M. and Mesbah A. (1986). Earth material: The test of static compaction for the manufacture of comprehended raw earth bricks. *Liaison Bulletin of Ponts et Chaussées Laboratories (LPC),* 146, 34-37 (France).

2. Abalo P’kla. (2002). Simple compression characterization of compressed earth blocks (BTC): Application to masonry «BTC- EARTH MORTAR». Ph. D. thesis in Civil Engineering. INSA Lyon (France), 234.

3. Olivier M., Mesbah A., Morel J.C. and El Gharbi Z. (1997). Test method for strength tests on blocks of compressed earth. *Materials and Structures*, 30(9), 515-517. https://doi.org/10.1007/BF02486394.

4. Olivier M. (1994). The earth material: compaction, behaviour, application to structures in earth blocks. Phd thesis, INSA Lyon, Order No 94 ISAL 0004.

5. Creuset Michel (1997). Materials and Components, Gros œuvres. Delagrave - Paris (France).

6. Coursnet Yves (2010). Properties and characteristics of building materials. Monitor. Paris (France).

7. Houben H. and Guillaud H. (1995). Treaty of earth construction. edition parenthesis, Marseille, France, 355.

8. AFNOR (2001). Earth Blocks Tablets For Walls And Partitions, Paris (France).

9. AFNOR NF EN 13286-53. (2005). Mixtures treated and not treated with hydraulic binders, Part 53: axial compression method for specimens made from materials treated with hydraulic binders.

10. NF EN 413-1. (1994). Masonry cement. European Committee for Standardization, Part 1: specification.

11. NF EN 413-1. (1994). Masonry cement. European Committee for Standardization, Part 2: Test methods.

12. Eurocode 6 (1996). Construction of masonry structures. European Committee for Standardization.

13. CRATerre (1985). Building in soil. alternative editions, Paris, 286.

14. Daniel Cordary (1994). Soil mechanics. rue Lavoisier, Paris cedex, 359.

15. Mahamat Saleh Ibrahim Yacoub (2010). Comparative study between the improvement of compressed earth bricks stabilized by cement and slaked lime. memory 2ie 46.

16. Meukam P., Noumowe A., Jannot Y. and Duval R. (2003). Thermophysical and mechanical characterization of stabilized clay bricks for building thermal insulation. *Materials and Structures*, 36(261), 453-460.

17. Meukam P. (2004). Upgrading of stabilized earth bricks with a view to the thermal insulation of buildings. Ph.D. thesis, 3rd cycle, University of Yaoundé I.