

**THERMOMECHANICAL CHARACTERISATION OF COMPRESSED EARTH
BLOCKS ADDED WITH SAWDUST**

Abstract

The study of mechanical resistances twined to standards dispositions allows keeping a composition of CEB measured out 10% of cement and 2% of *Tectona grandis* sawdust. This composite equipment offered a greater resistance compared to the one obtained with Afzelia sawdust. The method of asymmetric hot plan had been used to determine the thermal conductivity of the equipment and deducted the thermal parameter as the diffusivity, the effusivity and calorific capacity. This method proceed by a quadripolar modelisation 1D allowed to represent with a good precision the temperature in the center of a drill linked to studied samples. The obtained results have shown that the addition of sawdust to the ordinary compressed earth blocks had clearly improved isolation performances of the final composite equipment.

Keywords: Compressed earth block, sawdust, Mechanical resistance, thermal parameters

Nomenclature			
a	Thermal diffusivity ($\text{m}^2.\text{S}^{-1}$)	F'	Resistance to tests compression, MN/m^2
BTC10	BTC dosed at 10% cement	GTR	Earthworks Road Guide
BTC8	BTC dosed at 8% cement	H	Height of tests (cm)
BTC6	BTC dosed at 6%	L	Width of CEB test (cm)
CEB	Compressed earth block	M	Mass of the material (kg)
Cp	Calorific capacity $\text{J}.\text{m}^{-3}.\text{K}^{-1}$	P	Charge at the break (KN)
E	Separatemen between (cm)	S	Average surface of tests face (cm^2)
F	Maximal charge supported by two half block (kN)	X	Water content ($\text{kg water.kgms}^{-1}$)
V	Volume (m^3)		
Greck symbols			
λ	Thermal conductivity ($\text{W}.\text{m}^{-1}.\text{k}^{-1}$)	ρ	Volumic mass ($\text{kg}.\text{m}^{-3}$)

Subscripts			
a	apparent	h	Wet
b	Test	i	Initial
e	Water	op	Optimal
ec	Sample	S	dry

20 1. Introduction

21 The recent researches on the locate equipments have shown earth offered a great potentiality to human
 22 needs. [1] have précised in their book: this types of equipment didn't really get , at natural statement,
 23 [2], [3], [4], [5], the thermal performances. Nethertheless, when the ground was mixed to other
 24 material , these external additional, like fibrous materials and the linking , participated to the
 25 improvement of its performances, as well mechanic as thermal one. So, the sawdust in general has
 26 been seen appropriated to serve as adjuvant inside the earthen composite materials [4]. In practices
 27 work, transformer societies in developing countries produced more than 30 to 50% of [6] waste in
 28 treated wood volume, according to the case [2] . These wastes were often used as solid fuel that
 29 favored consequently the substantial production of carbon dioxide (CO): a gaze with claw effect which
 30 participated to ozone layer depletion [5]. In order to participate to the fight against the degradation of
 31 environment many researches were interested by nowadays in the valorization of waste, by the
 32 recycling. It's in this context this study has permitted to explore possibilities of compressed ground
 33 blocks utilization with sawdust addition [5].

34 2. Materials and methods

35 2.1 Materials

36 Sample equipment which constituted the based element for out study was laterite composite+ cement
 37 + sawdust +water in good studied proposition.

38 2.1.1 The Earth

39 The laterite used was from Woba Karou in N'dali district (area located in Northern –Benin in the
 40 Borgou department).

41 2.1.2 The cement

42 The cement portland CPJ 35 was used for this study because of its relative quick adherence

43 2.1.3 The sawdust

44 The sawdusts of two species of tropical woods have been exploited. Afzelia and teck woods were
 45 concerned, and identified for their availability in Benin.

46 2.1.4 The stove and the scales

47 A ventilated stove of Memmert mark DO6060, functioning between the temperatures range (T) as
 48 $30^{\circ}\text{C} \leq T \leq 225^{\circ}\text{C}$ with a ventilation register, setting from 0 to 6, has permitted to dry the sawdust
 49 sample and to determine the dry extracts of compressed earth blocks (CEB). Two scales Sartorius type
 50 (precision 0.01g) and Roverbal with a respective weight expanse of 3100 g and 20 000g, have been

51 used for different internal weights forming the mixture. A belcher of 500 ml capacity allowed
52 determining the volume of water constituting block sample composition. The water used was the one
53 supplied by National Society in charge of water in Benin.

54 2.1.5 Hydraulic press (squeezer)

55 It's a mechanic squeezer type SATEC MKIII-60 TVI), equipped with a command console digital hill
56 porting. It's had been used for resistance tests in flexion of three points and in compression.

57 2.2 Methods

58 2.2.1 Physical characterization of the laterite

59 In this part of study, we interested on the characterization of the laterite of Woba Karou careers. This
60 characterization had consisted on the determination of physical properties like: the water content, the
61 granulometry, the Atterberg limits, the volumic mass in bulk, the compressibility, the equivalent in
62 sand and the real volumic mass of the produce ante-dried. (Specific weight)

63 2.2.2 The cement

64 The cement portland CPJ35 used had been preserved in better conditions of temperature and humidity
65 during 7 days in order to reach its maximal resistance to permit the relative quick use.

66 2.2.3 The sawdust

67 Sawdust samples treatment had consisted on soaking in hot water previously brought at 105°C during
68 48 h. The mixture obtained had been decanted and cooled down. The soaking water cooled down has
69 been removed and replaced by the current water. The sawdust had been neatly cleaned. The washing
70 water had been filtered and replaced by current water in which the sawdust has been rinsed out. This
71 approach permits in one hand to dissolve in water inhibition extractible substances contained in the
72 sawdust, and in other hand to eliminate the microorganisms eventually present inside the sawdusts.
73 The sawdusts neatly cleaned have been recuperated and piet inside the stove (oven) at 105°C during
74 72 h.

75 Out of the oven, they have been spreath on a tray and preserved in atmosphere conditions during 24h to
76 be adapted to atmosphere conditions. The sawdust of each wood genus have been examined closely
77 and the fractions of sawdusts of granular class 0.16-5mm have been packed and preserved shelter
78 humidity and heat under closed package until CEB realization.

79 2.2.4 Test realization (BTC)

80 ✓ Cycle of compressed earth production

A pre-treatment by sieving, with sieve of stitch of 10 mm laterite destined to the confection of EBC have been useful because of the presence of big particles in the earth samples, which have been spread in thin layers at atmosphere temperature during 7 days in order to assure a natural drying. The water content of laterite has been determined X_{cc} in order to deduce the indispensable water volume to the composite mixture. In the same way, the masses of different components contributing to the preparation of dry mixture have been obtained. An adequate mixture of laterite + cement + sawdust + water has been realized and introduced into the press for the confection of CEB.

✓ Water volume of production

Messing water has been progressively brought until bring the mortar to the optimal content in water (X_{op}) of the earth determined for Proctor test. So the volume of water in liter to add have been given by the following formula [3]:

$$V_e = \frac{(X_{op} - X_{ec})M_1}{100 + X_{ec}} \quad (1)$$

Tests production CEB have been done according to the big steps followed: extraction, preparation, mixture, pressing, treatment and storing.

✓ Massic composition of CEB tests

Table 1 informs on massic composition of different mixtures (laterite + cement + sawdust + water) realized for the sampling.

Table 1: Massic composition of CEB tests

	Laterite (Kg)	Sawdust (Kg)	Cement (Kg)	water (L)
CEB dosed at 4% of sawdust	7,74	0,36	0,9	0,5
CEB dosed at 6% of sawdust	7,56	0,54	0,9	0,5
CEB dosed at 8% of sawdust	7,38	0,72	0,9	0,5
CEB6	8,46	*	0,54	0,5
CEB8	8,28	*	0,72	0,5
CEB10	8,1	*	0,9	0,5
CEB dosed at 2% of sawdust	7,92	0,18	0,9	0,5

99

100 ✓ Treatment and storage of blocks

The local where the blocks have been manufactured was well isolated from solar radiance and the treatment have been done under a transparent covering of polyster. This precaution have permitted

103 after the 7th day of preservation to external opened treatment in the local aware of damagers to the
104 blocks.

105 2.2.5 Mechanical characterization of CEB

106 In the context of this study, we were interested in classical characteristics as below: the resistance in
107 inflexion three points, in compression. For the test of resistance in flexion in three points , the block
108 support face have been installed on two tubes spaced out of 20 cm and perpendicular to the block
109 length , in the middle of the superior face , a third tube parallel to the firsts has been installed .We
110 submitted the CEB test to a constant charge at the rupture . The resistance to the blocks flexion has
111 been determined by the formula:

$$112 \quad \sigma = \frac{1.5 * E * P}{L * H^2} \quad (2)$$



113

114 **Figure 1: Test of resistance in inflexion (three points) on CEB**

115 Nevertheless the adopted procedure for resistance in compression test has permitted to take the two
116 half of the test CEB stemming from flexion in three pints tests. The two half – blocks were not always
117 identical with regular from. To the section held for the calculations was the mean average of the
118 surfaces inferior and superior of the half block. The resistance to the compression has been obtained
119 by the formula [7]:

$$120 \quad F'_{\text{sec}} = 10 * \frac{F}{S} \quad (3)$$

121 2.2.6 Thermal characterization CEB

122 Thermal properties assessed in the context of this work were: thermal conductivity, thermal
123 diffusivity, the effusivity calorifical capacity, the method chosen here was the method « asymeric
124 hot plan » materialized by the picture below we have used a program of simulation on support «
125 Matlab » for the estimation of thermal parameters.

3. Results and Discussions

3.1. Mechanical characteristics of CEB

The laterite water content sampled at Woba karou was estimated to 1.3%. It's granularity was inferior to 35% and the percentage of fines was about 17.23%.

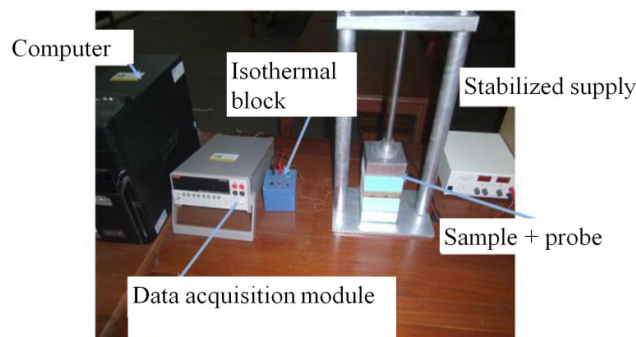


Figure 2: Experimental mechanism of thermic characterization of experience test

The maximal diameter of grains was about 10mm (inferior to 50mm). Referring to the standards of classification NFP 11-300 and the GTR 92, we could deduce the laterite used for our study belonged to class B (its has thus been sampled in sandy ground and grave lows one with fines). This assertion was reinforced by the theory of about Atterberg limits in which plasticity indice found was about 15.66% (superior to 12%), that allowed to conclude with precision laterite sample belonged to the under class B6. (Sand and clay grave to very clayer).Moreover, this type of laterite replied and to Ramillon and cratere granulometric standard, that recommended fines percentage might be comprised between 15and 30% in order to be used for CEB manufacturing. According to the standards ARS 681: 1996 compressed earth blocks good manufacturing process in manufacturing of earth mortar, earth of under –class B6 were acceptable for realization of CEB (4), consequently, Woba Karou laterite could be used for CEB realization .

Proctor test permitted to emphasize on followed characteristics for the studied laterite: an optimal water content (X_{op}) about 5,82% and a maximal dry density (γ_{dmax}) about $2,27 \text{ T.m}^{-3}$. Beyond these characteristics , we could notice consistence indice $I_c > 1.3$ So according to the standards NFP 11-300 and knocking down transport (KDT),the laterite used was at a very dry statement ; its equivalent in statement sand was $E_s=20\%$, this conferred to this material a perfect stability and a sawdous texture . It's using for the CEB was thus possible and could provide good results. The cement CPJ 35 from SCB Lafarge society have been used for the composition of the sampled mixture. It's have been produced according to the standard, **NF P15-301** and allowed a relative rapid taking. The third constituent of the mixture was the sawdust stemming from wood species: Afzelia africana and Tectona grandis.

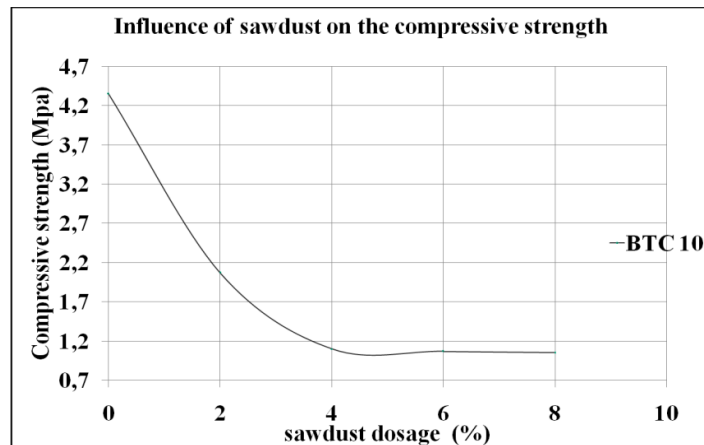


Figure 3: Influence of dosage of Afzelia sawdust on the resistance in compression

The figures 3 and 4 presented the influence of measuring out of Afzelia sawdust in the resistance in compression and inflexion in three points. Between 0 and 3% average, a rapid decreasing of CEB resistance was observed and stabilized to an average value about 1.Mpa for the resistance in compression and about 0.23 for the resistance in three point's flexion.

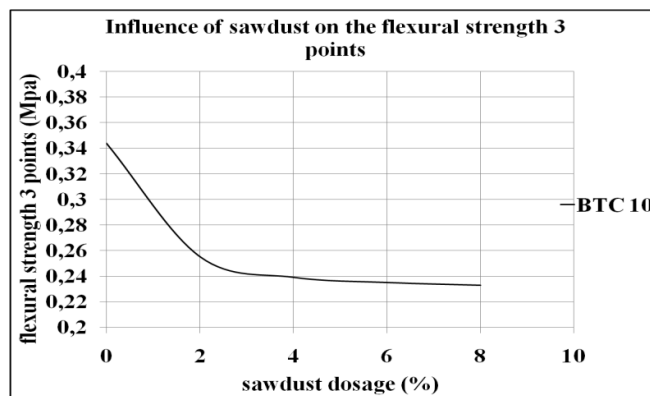


Figure 4: Influence of dosage of Afzelia sawdust on the resistance in three points flexion

The mechanical performances of CEB with addition of sawdust were reversely proportional to the sawdust quantity inside the compost mixture Solomon-Ayeh [5] works reinforced by the standards ARS 674:1996 [6] and ARS 675:1996 [7] indicated a CEB material could be used in building when resistance in compression was superior to 2MPa. We will also retain the content in cement got an influence on the mechanical resistances of CEB studied his influence got and increased look and linear for the case of resistance in flexion, with a minimum in the coordinates points (6; 0, 27). As for the resistance in compression, it have been proportional to the content in water, with a minimal value round 2.25 Mpa.

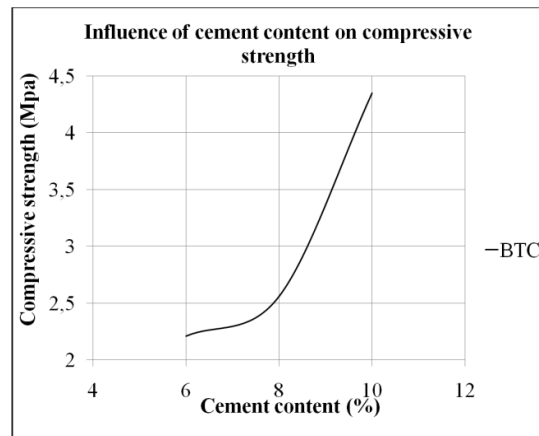


Figure 5: Influence of cement content on the resistances in compression

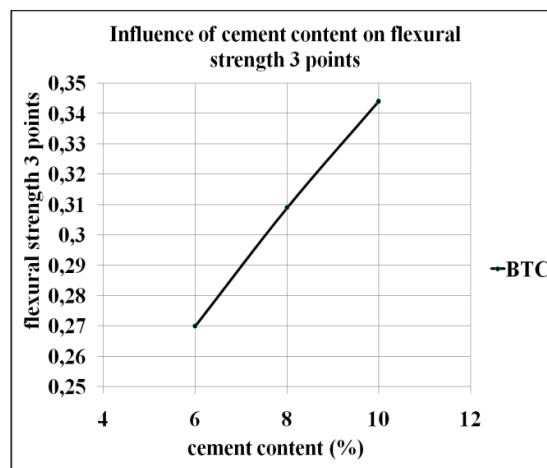


Figure 6: Influence of cement content on the resistances in flexion three points

The curves of figures 5 and 6 showed until an addition of 10% of cement, the mechanical resistances of CEB rise in proportion with cement dosage. Consequently, the mixture sample of CEB studied has been dosed at 10% in cement. Peller correlation (8) presented in the formula (3) expressed the optimal water content offering a maximal resistance for the test in flexion in three points. This expression has been retaken by Olodo [9] and Rigassi [10] who confirmed it had been applicable for the case that the CEB was without addition. For this study, the samples-test in CEB [10] has been realized by compressed earth block (CEB) with addition of sawdust. Assembling the sawdust to a granular material and making analogy between the two types of CEB with and without sawdust addition, we rhetorically deducted the optimal water content of CEB with Afzelia sawdust have permitted to reach a water volume of wasting in level of $V_e = 470 \text{ cl}$. The experimental curve of figure 7 presented a value $V_e = 460 \text{ Cl}$, which corresponded to a maximal resistance in flexion three points. So a relative very weak interval of (2. 12%) in touch with obtained values V_e has been noted; that permitted to conclude the correlation [3] was well applicable for the studied CEB with sawdust addition.

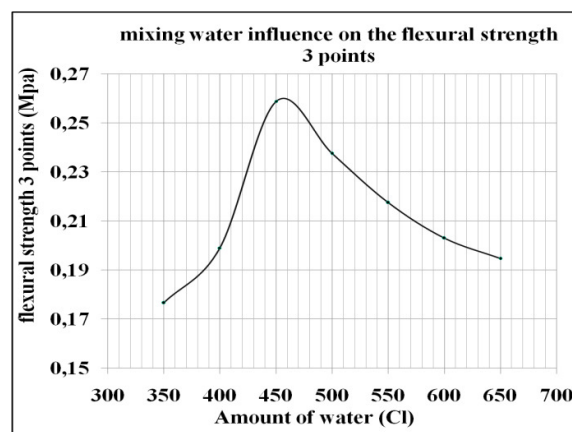


Figure 7: Influence of wasting water on the resistance in flexion three points

3.2 Mechanical characteristics of CEB with sawdust addition

The graphs of figures 8 and 9 gave a general idea of mechanical resistances of CEB with addition of sawdust coming from essences of *Tectona grandis* and *Afzelia africana*.

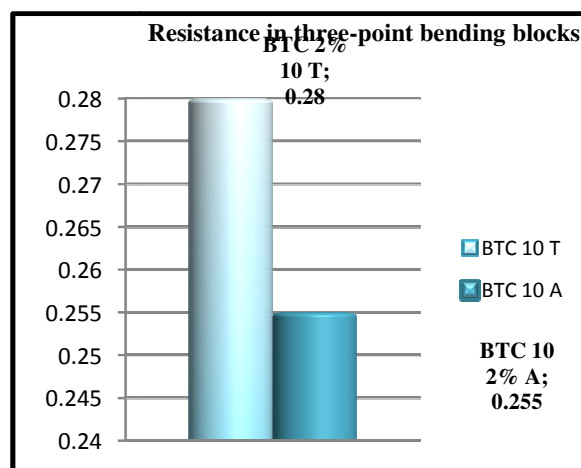


Figure 8: Resistance in flexion three points and in compression with *Afzelia africana* and *Tectona grandis* sawdusts

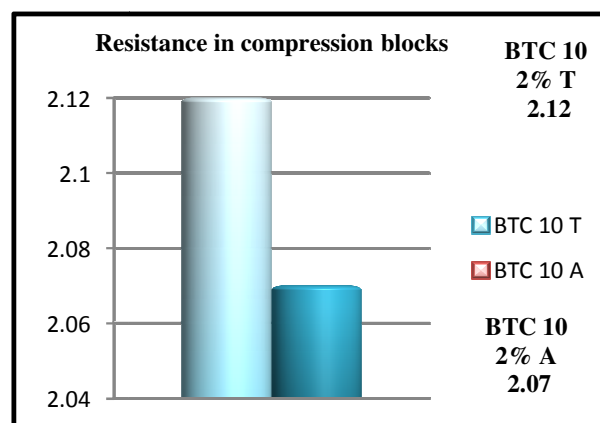


Figure 9: Resistance in flexion three points and in compression with *Afzelia africana* and *Tectona grandis* sawdusts

The composites on the basis of *Tectona grandis* sawdust offered a resistance sensitively superior to those elaborated on the basis of *Afzelia africana* sawdust. The values of the resistance obtained for the two realized tests respected the exigencies of Standards **ARS674: 1996** and **ARS 675: 1996**.

3.3 Thermal characteristics of CEB with or without sawdust addition

The results obtained for the CEB 10 at the end of thermal test were presented in the figure 10

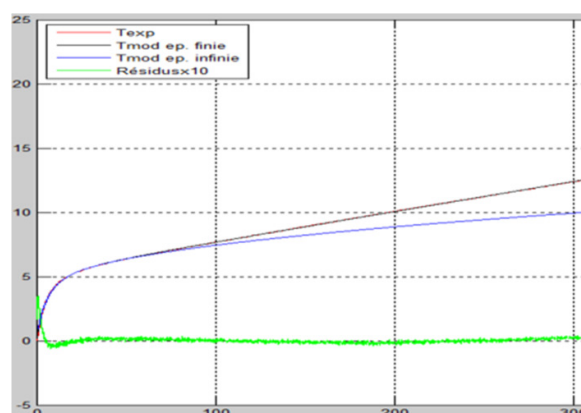


Figure 10: Model and experimental curve and test residues on CEB 10 sample.

The rhetorical and experimental curves were superimposed perfectly and the residues were well equally flat. This confirmed the accuracy of operations.

Table 2: Thermal characteristics values evaluated for CEB 10 and CEB 10- T-2%

Parameters	Average values						
	Thermal effusivity	Uncertainty on thermal effusivity %	Thermal conductivity λ w.m ⁻¹ .K ⁻¹	Uncertainty on thermal conductivity %	Thermal diffusivity m ² .S ⁻¹ .10 ⁻⁷	Calorific capacity J. m ⁻³ .K ⁻¹	Estimated times
CEBC 10	1811.00	0.45	1.70	1.10	8.91	1925759.79	350
Standard deviation	54.37		0.08		0.26	2932.49	
CEB 10-T-2%	1317.89	0.02	0.85	0.08	4.16	2042773.42	650
Standard deviation	1.83		0.01		0.09	22968.73	

4. Conclusion

These reports above enumerated showed CEB incorporating *Tectona grandis* sawdust constituted an isolant which could play an interesting role in the field of energy efficacy of the building N° 11 CDI and CRATerre-EAG, ARS 681:1996 PP87-98 Belgium March 1996. The values of thermal parameters

investigated for BTC 10-7-2% and BTC-10 as following: calorific capacity, thermal diffusivity thermal effusivity and thermal conductivity were summarized in the table 2. The blocks without sawdust addition presented effusivity and thermal conductivity values superior to those of CEB with addition. This translated heat of conduction by a material was intimately linked to thermal conductivity and to the effusivity. It stood out from this CEB incorporating *Tectona grandis* sawdust conducted less heat. It's the thing for the CEB with sawdust addition which diffused less heat than classic CEB. By elsewhere, as the table 2 presented it with 2% of sawdust addition; CEB got a better calorific capacity. That explained our material, in more to limit heat conduction, got a strong capacity of storing.

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