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RESEARCH ARTICLE

DETERMINING MECHANICAL CHARACTERISTICS IN COMPRESSED EARTH BLOCKS

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ABSTRACT

In order to reduce construction costs and the energy consumed in heating and cooling, the use of laterite and cement are the essential element to install stabilized earth blocks. For this work, the main purpose is to study the effect of the use of bricks of raw earth stabilized with the help of cement. Its objective is to assess the evolution over time of mechanical resistance to the compression and traction of these bricks as well as the speed of water absorption. The mass dosages used for cement are: 25%, 20%, 15%, 10% and 00%. All bricks were tested for compression, traction and permeability testing at 14 days. The results obtained show that the dosage at 25% cement is optimal; it gives compression resistance of 5.84 MPa and 0.99 MPa in 14-day traction for soils collected from Site 2 at a depth of 0.7 m. However, the demands of the bricks to the traction give lower values compared to those obtained in com pressure for all soils. On the other hand, the presence of cement has a positive effect on the mechanical behaviour of the composite material.

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INTRODUCTION

Since ancient times, the use of land as a plastic or construction material has always been an obvious reality because of its abundance and manoeuvrability. Today, as a building material specifically, the land is experiencing a resurgence of interest following the housing crisis that continues especially in developing countries (EdP) and especially in Côte d'Ivoire. However, unlike other traditional materials; cement, concrete, wood and steel, the earth in its natural state can be used in construction without too much energy expenditure. It also has many environmental, social, cultural and economic benefits (Bahar, 2011). It also has good thermal insulation performance once stabilized in ideal conditions (Meukam, 2004). However, the disadvantage is that this material does not always withstand bad weather and many buildings made of raw earth are washed away by rains like Ouagadougou (Burkina Faso). With this in mind, a careful study of the geobeton project in the laboratory of (LECAT) in November 2018 was set up to make resistant geoconcretes, at a lower cost and whose raw material is easily Accessible. Also, in order to enhance this material, we were led to do a study on stabilized earth bricks using cement in order to highlight the performance of the cement as a binder in such use.

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Numerous studies of local materials for stabilizing earthen bricks with cassava flour gel, flaxseed oil or other adjuvants have shown satisfactory results (Meukam, 2004; Ngouama, 2008; Barro, 2009; Talla et al., 2010). The performance of a stabilized earth brick is assessed by determining its strength in compression, traction, holding with water, shrinkage due to drying, durability. It was in this context that this study, "Determining Mechanical Characteristics in Compressed Earth Blocks" was undertaken to characterize samples tested for compression, traction and permeability. In general, it is a matter of showing that the use of cement can be an important contribution in the manufacture of stabilized earth bricks.

Geographical location of the study area: The city of Abidjan is located south of the Ivory Coast, on the edge of the Gulf of Guinea and crossed by the Ebrié lagoon. It is on an area of 57,735 hectares. It represents an area of a dozen kilometres from north to south and a dozen from east to west. These geographical coordinates are: longitude 4-01'3"W and latitude 5-20'1'N (Figure 1). The sampling sites were taken in the same locality, namely Bingerville, specifically at the company's construction site (ENSBTP) whose geographic coordinates are recorded in Table I.

Weather: Bingerville enjoys a sub-equatorial climate, hot and humid, which includes a long rainy season (May-June-July), a short rainy season (September-November) and two dry seasons. The long dry season starts from December and ends in late March. Precipitation is abundant: more than 1500 mm of water per year. In the rainy season, it may rain continuously for several days in a row or rain intensely for an hour, followed by strong sunlight. The temperature is almost always around 27 ° C and the average annual hygrometry is above 80% (Yao et al., 2013).

MATERIALS AND METHODS

Equipment: The determination of the mechanical characteristics of the compressed earth blocks requires the use of field and laboratory equipment.

Data: Laterite located directly below different depths, and cement are the main materials used in this work. This choice is made according to the concern of the laboratory (LECAT). All samples were taken at different depths ie at Site 1: at 50 cm depth, Site 2: 0.7 m depth, Site 3: 1m deep and Site 4: 1.5 m deep.

Field equipment.

In the field we used

- a field notebook to record all the information that is relevant to the study.
- a compass to take the coordinates of the sampling sites
- a marker to label the samples;
- a pickaxe for pickling the plant layer (F);
- a shovel to collect the samples (E);
- plastic bags, bags for sampling and preservation (D);
- a camera to photograph the samples;
- a safety helmet for cushioning the shocks of the skull (B);
- a pair of safety shoes for protecting the feet (A);
- gloves for protection of bulbs, When using tools (C).

Laboratory equipment

Laboratory equipment consists of:

- Laterite, which is the bulk of the sample in the laboratory (O).
- A series of sieves for sieving the clay sands samples to perform the granulometric analysis (L), for making geobotton was used the mesh screen 38 (A);
- Concrete liner: used for the compression and traction test (N);
- an electronic scale for weighing the samples (H);
- an oven for drying the samples (M);
- a graduated cylinder to take the volume of water (G);
- a tare to take the samples (I);
- a brush to clean the mold (J);
- a hammer for the reduction of clay sand blocks (K);
- a hand scooped to serve the samples (F);
- a tarpaulin for spreading the samples (E);
- the Proctor boat for mixing (D);
- plastic loops when handling materials To avoid contact with cement (C);
- a can of water to facilitate its catch (B)

Methods

The methodology implemented in this work is carried out in two phases.

Firstly, it consists of soil identification tests (sieving analysis with filtering, compaction tests (Proctor test), determination of Atterberg limits and determination of water content). Secondly to make the geobetons which will be subjected to the test of compression, traction and permeability in the laboratory, and to interpret the results obtained.

Sampling

On the ground the works consisted in

Make a cut of the Arablesoil layer at different depths. Method for sampling laterite for the different analyzes. The first step in conducting a material study is to take representative samples of the sites. These sediments are collected by shovel after removing the surface (the Arabian soil layer). Samples are labeled and stored in bags and bags for transport to the laboratory.

Laboratory tests: To study the mechanical properties of soils in order to better locate the behavior of the latter, it is therefore necessary to know their nature and to classify them. To do this, reference will be made to the classifications developed (French and / or American classification) which are based on main identification tests, namely:

- Sieving analysis with filtering according to standard NF EN 933-1;
- determination of the Atterberg limits by the Casagrande diagram In accordance with standard NF P 94-057;
- Compaction tests (Proctor test) In accordance with standard NF P 94-093 (October 2014);

To identify thoroughly the different soils used in our study.

Identification tests: As part of this thesis, we will use scientific soil characterization techniques in the LECAT laboratory in order to have a concrete idea of the types of soils used for the realization of our geobetons for construction. For this phase of scientific identification, the soil samples taken from the various sites are described in several complementary ways.

Particle size analysis: It is a set of operations resulting in the separation of the grains according to the size of the sediments constituting a sample, by using square mesh sieves in order to obtain a representation of the distribution of the mass of the particles in the dry state. according to their size (Table II).

The table above represents the values of sieve size analysis. Following the American classification. We can say that the soils are all soils more or less grainy with a percentage of elements of diameter less than 80 .mu.m below 50%.

Atterberg limits: The limits of Atterberg are determined according to the French standard (standard NF P 94-051) and by the method with the cup with the apparatus of Casagrande; Its purpose is to determine the water content of the various soils sampled as they pass from the liquid state to the plastic state. These limits do not represent a specific physical state. They have a conventional character and are defined from standardized tests.

- WL liquidity limit
- WP plasticity limit

- The plasticity index IP.

It gives the extent of the plastic field of the soil between the limits of liquidity and plasticity:

IP = WL – WP

The plasticity of a soil (that is to say, its ability to become highly deformable by absorbing water) is appreciated by the couple (WL, IP) which depend on the nature of the clay minerals contained in the soil and of their quantity. This is how Casagrande has defined a diagram called "Casagrande Plastic Abacus" which classifies fine soils. Following the steps above, we have the following results:

The Casagrande chart in Table 3 and Figure 2 represents the plasticity indexes as a function of the liquidity limit.

Compacting tests (Proctor test): The Proctor compaction characteristics of a material are determined from the so-called "normal" Proctor or Modified Proctor tests. For each value of water content considered, the dry density of the material is determined and the curve of the variations of this density is plotted as a function of the water content. The curve obtained is the Proctor test curve (Figure 3).

The tests carried out on this material made it possible to obtain a Proctor optimum of 1.81 kg / m3, an optimum water content of 14.7%.

Making Blocks: For the preparation of test specimens for the test program, a steel mold with a volume of 25x12.5x10 cm3 was designed. The mold is provided with a piston to ensure the transmission of the compacting stress of the press to the mixture. The mold in the press is shown in Figure 14. The making of the blocks is done according to the following steps:

Mixtures: The composition of the mixtures used in this study is presented in Table VI.

Mix preparation: After having been in the oven at 105 ° C. for 24 hours, the soil samples (clay sand) are cooled, crushed, sieved in the mesh screen 38, and weighed according to the proportions established in (Table VI). Subsequently, dry blending, mixing with water and mixing in the compacting mold are carried out.

Compaction of mixtures: Compaction aims to densify the earth. The mixtures are compacted in the single-acting static mode by means of a hydraulic press: when the director executes the operation, the lower plate of the press moves causing the assembly - mold + mixture + piston, the upper plate remains fixed. The demolding is done immediately after compaction.

Cure blocks: All soils do not behave the same, but a cure period of 14 days is essential. During this period, the material will be kept in a humid atmosphere, sheltered from the sun in the geobeton section, taking care to the wind; this is to avoid drying out too fast. All the blocks studied are kept in the laboratory at an alternative temperature for 14 days.

Mechanical properties: The following mechanical characteristics are of interest in this study: the compressive and tensile strength of dry BTCs through the simple compression, tensile test and the permeability test. For each test, two blocks were tested.

Simple compression tests: The compressive strength of the blocks is given by the formula:

RC = F / S

With:

- Rc: compressive strength in MPa
- F: maximum load supported by the two bricks in kilo newtons (KN)
- S: average surface area of the test faces in square centimeters (cm²)

The compressive strength of the blocks is the resistance achieved on each sample.

Tensile test: The tensile strength of the blocks is given by the formula:

$$\delta f = \frac{M_{max}}{I} \cdot y_{max}$$

$M_{max} = (f/2)*5$; $I=BH^3/12$,

$Y_{max} = H/2$

With:

- f: load at break of the bending brick in KN
- L0 = 20 cm
- B = 10 cm
- H = 5cm

So :

$$\delta f = \frac{f}{16{,}66} \ (N)$$

Permeability tests Dropped the samples in the water lake. After every five minutes they are extracted from the water and weighed to determine the difference in weight; for a start the weight increases when it begins to fall it is the beginning of the deterioration and the end of the test.

RESULTS AND DISCUSSION

Results

This chapter is devoted to the analysis and interpretation of the experimental results, which aims to study the effect of the hydraulic binder (Cement) on the mechanical behavior of the BTC and permeability. In the context of this work, the predominant characteristic sought is the compressive and tensile strength because BTCs work essentially in compression and traction. It will be done on the samples of bricks dosed at 10%, 15%, 20%, and 25% of cement obviously on blocks without cement as witnesses in order to appreciate the influence of the applied treatments.

Compressive Strength of Compressed Earth Blocks: The compressive strength is determined by the load required to cause the rupture of the specimen subjected to a compressive load uniformly distributed over one face of the specimen. As part of this work, we used the Compression Press to determine the breaking strength of compressed blocks. The results of the compression test are shown in Table VIII and Figure 4

increases with increasing percentages of cement. The results shown in FIG. 25 show that the tensile strength at 14 days at the four (04) sites increases with the increase in the cement dosage content.

Table 1. Position of the sampling place executed

Localities	Longitude (W)	Latitude (N)	Places (site)
Bingerville	03°19'57.8''	05°23'55.1''	RUE 6: (S1)
	03°19'59.8''	05°23'51.2''	STREET 5: (S2)
	03°19'58.5''	05°22'59.8''	ROUTE A: (S3)
	03°19'59.4''	05°22'57.3''	STREET 2: (S4)

Table 2. Sieve analysis by sieving

Sample number	Brief description	%<80µ	classification
N°1 : Site 1 : S_1	Laterite 0.5m deep	32,53%	Grained soil
N°2 : Site 2 : S_2	Laterite 0,7m deep	39,42%	Grained soil
N°3 : Site 3 : S_3	Laterite 1m deep	30,71%	Grained soil
N°4 : Site 4 : S_4	Laterite 1.5m deep	35,46%	Grained soil

Table 3. Atterberg limits of the different soils studied

Number and code of the sample	Liquidity limit	Limit of plasticity	Plasticity index
N°1 : Site 1 : S_1	47%	21%	26%
N°2 : Site 2 : S_2	60%	28%	32%
N°3 : Site 3 : S_3	56%	26%	30%
N°4 : Site 4 : S_4	54%	26%	28%

Table 4. Moisture content as a function of dry density

Water content (%)	10,46	12,34	14,26	16,35	18,63
Dry density (t / m3)	1,62	1,70	1,81	1,75	1,65

On reading the results of the tests carried out in the laboratory and recorded in the table above, the compressed earth blocks (BTC) of site 1 show its first cracks around 0.28 MPa (without stabilizer) at 3.24 MPa (cement stabilized blocks 25%) at 14 days air cure; For the second site (site 2) Parre from 0.63 MPa (cementless) to 5.84 MPa (25% cement stabilized blocks), Site 3 from 0.33 MPa (00% cement) to 5.56 MPa MPa (25% cement) and 0.81 MPa (without hydraulic binder) at 5.63 MPa (with 25% hydraulic binder). The results of the compression tests above show that the resistance of the BTCs to compression increases with the increasing percentages of cement. The results shown in FIG. 4 show that the tensile strength at 14 days at the four (04) sites increases with the increase in the cement dosage content. Growth is important by increasing the cement content. The addition of hydraulic binder plays an important role in increasing the strength. We also note that the cement reaches maximum tensile strength of (0.99 MPa) for 25% of cement. The cement has led to the improvement of the mechanical properties of the stabilized earth block.

Tensile Strength of Compressed Earth Blocks: The tensile strength expressed by the BTC capacity, withstood the destruction due to tensile stresses. The results of the tensile test are shown in the table below: In traction, the compressed earth blocks (BTC) of site 1 show their first cracks around 0.08 MPa (without stabilizer) at 0.46 MPa (blocks stabilized with cement at 25%) at 14 days of cure. air; For the second site (site 2) Parre from 0.12 MPa (without cement) to 0.99 MPa (25% cement stabilized blocks) Site 3 from 0.18 MPa (00% cement) to 0.93 MPa (25% cement) and 0.22 MPa (without hydraulic binder) at 0.83 MPa (with 25% hydraulic binder). The results of the tensile tests above show that tensile BTC strength

Growth is important by increasing the cement content. The addition of hydraulic binder plays an important role in increasing the strength. We also note that the cement reaches maximum tensile strength of (0.99 MPa) for 25% of cement. The cement has led to the improvement of the mechanical properties of the stabilized earth block.

Permeability test: In this part of our study we realized this test to know that it would be the behavior of the geobeton in the presence of water. This test is a special protection that may necessarily be within the reach of all manufacturers in BTC. In fact for this test, we used the previously manufactured blocks that we immersed in water. After every five minutes they are extracted from the water and weighed to determine the difference in weight; for a start the weight increases when it begins to fall it is the beginning of the deterioration and the end of the test. The results of the test are shown in Table X and Figure 26.

The results of the immersion tests carried out on bricks with variable cement content after 14 days of air curing are recorded in Table X Each result of this table is the average of the results of two coherent tests. Furthermore, it can be seen in the curve of FIG. 26 that the time of water absorption by the bricks dosed at 0; 10; 15; 20 and 25 percent of cement are respectively higher than each other. Bricks without binder reach water saturation faster than others. However, the rate of water absorption varies with percentage of cement. Thus we can see in Figure 26 that the untreated blocks reach their optimum saturation at the fifth minute; in the tenth minute for the blocks processed at 10%, at the sixth for the blocks treated at 15%, at the twelfth minute for the blocks treated at 20% and at the fifteenth minute for the blocks treated at 25% (Figure 4).

Table 5. Composition of the different mixtures used in this study

mixtures	% of clay sand	% of sea sand	% Cement	% of water	Quantity in (g)
A	50	25	25	16	9 000
B	50	30	20	16	9 000
C	50	35	15	16	9 000
D	50	40	10	16	9 000
E	70	30	00	15	9 000

Table 6. Compressive strength at fourteen (14) days depending on the cement content

Compressive strength of geo-concrete of compressed earth sites					
site	Percentage of cement				
	25 %	20 %	15 %	10 %	00 %
Site 1	3,24	2,77	2,46	1,55	0,28
Site 2	5,84	4,85	3,1	2,70	0,63
Site 3	5,56	4,97	3,68	2,84	0,33
Site 4	5,63	4,05	3,71	2,92	0,81

Table 7. Tensile strength at fourteen (14) days depending on the cement content

Tensile strength of geo-concrete of compressed earth sites according to the percentage of cement in (MPa).					
site	Percentage of cement				
	25 %	20 %	15 %	10 %	00 %
Site 1	0,46	0,33	0,30	0,17	0,08
Site 2	0,99	0,93	0,35	0,28	0,12
Site 3	0,93	0,71	0,64	0,51	0,18
Site 4	0,83	0,51	0,39	0,36	0,22

Table 8. Capillary lift test of cement stabilized bricks.

Weight of specimens as a function of time	Cement dosage				
	0,00 % cement	10 %cement	15 % cement	20 % cement	25 % cement
before immersion	4024.6	3999	3965	3960	3950
Weight after 5min immersion	4048.07	4026.07	4018.78	3998.37	3960
Weight after 10min immersion	4055.4	4030.84	3987.88	4006.28	3963.57
Weight after 15min of immersion	4057.83	4014.8	3934.03	3997.76	3964,42
Weight after 20min of immersion	4046.01	3972.66	3932.66	3959.08	3938,8

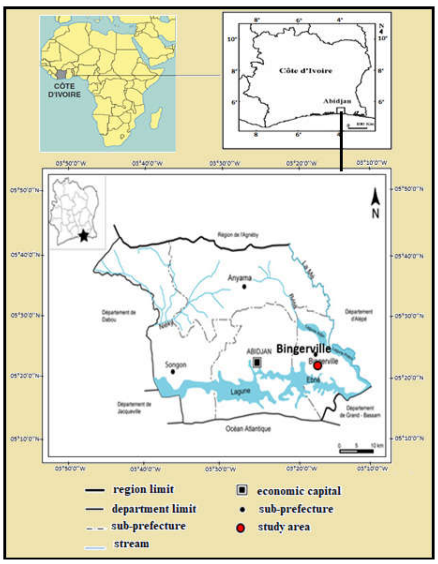

Figure 1. Study area localization

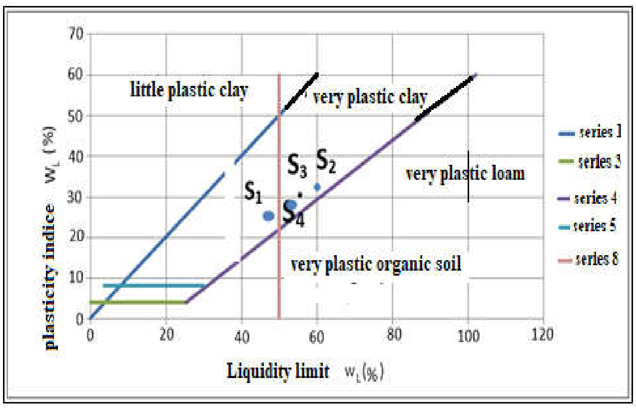

Figure 2. Casagrande diagram

As the BTC is pressed, the material becomes very dense which will prevent the diffusion of the liquid water towards the core of the material. In case of rain, only a surface layer of the brick will become wet, and the mechanical qualities of it will not be altered.

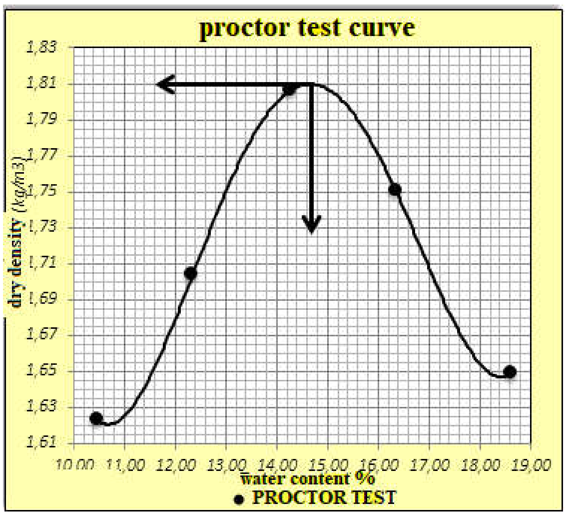

Figure 3. Proctor test curve

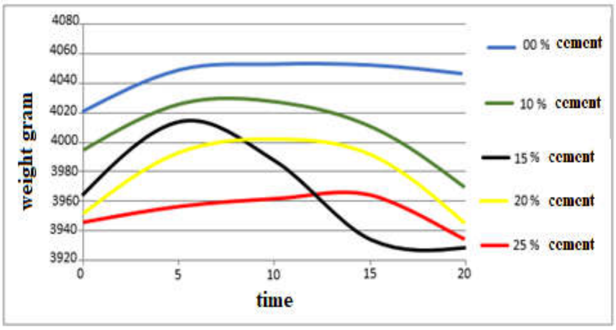

Figure 4, Curves of water absorption by cement stabilized bricks as a function of time

A: block made of 00% of cement taken from site 4
B: block made of 00% of cement taken from site 2
C: block made of 00% of cement collected on site 3
D: block made of 00% of cement collected on site 1

DISCUSSION

The results obtained reveal interesting mechanical performances, whatever the chosen formulation. It emerges that the compressive strength, tensile strength and permeability values obtained for the mixture at 40% lagoon sand, 35% clay sand and 25% cement appear optimal with 5.84 MPa in compression at the second site (site 2) and 0.99MPa in traction. Thus, this dosage can be retained for the manufacture of quality bricks. All these results suggest that cement appears as the essential element in the optimization of formulations and, consequently, it contributes to improving the mechanical performance of stabilized clay bricks. However, in view of the work reported by: Ngouama (2008) who showed that the starch incorporated in the clay, for a percentage of fines between 30 to 100%, reaches compressive strengths of the order of 6.070 MPa, improves the mechanical properties of the stabilized brick; Barro (2009) who improved the mechanical characteristics of stabilized earth bricks by relying on the influence of the introduction of fibers, cottonseeds and other residues into lateritic soil stabilization; Talla et al. (2010) highlighting the stabilization of soils including the waterproofness of earthen walls using extracts of "parkia biglobosa", a construction technique used by the "Kassema" people in Burkina Faso with decoctions of Hot-born giving 1.83 MPa compressive strength at 2 days.

We can note that our results show lower values compared to the Ngouama and Barro studies, but these results are better than those obtained by Talla. The permeability test results show that the more the brick is treated with progressive concentrations of cement, the less it absorbs water and the less it breaks up.

Conclusion

The study of soil identification tests of Bingerville, has highlighted two main types of soils that are clay soil very little plastic more or less grainy soil (S1), and clay soils very plastics more or less sandy soils (S2), (S3) and (S4) with an optimum water content of 14.7%. The compression test carried out on the compressed earth blocks with a concentration of 25% cement gave as resistance values 3.24 MPa; 5,84MPa; 5.56 MPa and 5.63 MPa for an air-cure duration of 14 days for the soils taken respectively from site 1; site 2; site 3 and site 4. On the other hand, the earth blocks compressed with the same compression forces and not containing cement give lower resistances, ie 0.28 MPa of site 1; 0.63MPa from site 2; 0.33MPa from site 3 and 0.81MPa from site 4 to 14 days. The tensile test gave as resistance values 0.46 MPa; 0,99MPa; 0,93MPa; 0.83MPa has a 25% cement concentration of site 1, site 2, site 3 and site 4 respectively. On the other hand, those made with 00% cement gave 0.08 MPa on site 1; 0.12MPa on site 2; 0.18MPa on site 3 and 0.22MPa on site 4. The results obtained reveal the mechanical performances of bricks and Cement appears as the essential element in the resistance of bricks.

The test permeability test shows that the less the cement is used the more the sample absorbs water and the less cement is used the sample absorbs water. The blocks absorb water by capillary rise more slowly depending on the cement content. Constructions in BTC require a lot of economic advantages (a construction in BTC allows the promoter to make a saving in the order of 30% compared to cement concrete), ecological (the BTC are recyclable on the building site) , comfort (no acoustic nuisance, weatherproof ...). The cement-stabilized BTC constructions are strong and can be a model for any earth construction.

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