



EXPERIMENTAL METHOD TO MEASURE THE MECHANIC BEHAVIOR OF COMPRESSED EARTH BLOCKS IN CONTINUOUS COMPRESSION

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ABSTRACT

This article presents the results of an experiment carried out in laboratory which aims at finding an experimental method to determine the mechanic behavior of compressed earth blocks through a very simple compressive test. As a matter of fact, the evaluation of the deformation of blocks under a progressively increasing load, by the means of a load cell and the Linear Variable Displacement Transducer (LVDT) put together on a manually operated press, has indeed enabled us to realize a strain-stress curve. Here, the analysis of this curve shows that the mechanic behavior of the earth blocks in compression is pseudo-elastic and ends off by a macro-brittle rupture because the stress is homogeneously distributed all over the surface of blocks. Therefore, we can use this device to draw up the behavior's law of compressed earth blocks.

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Keywords: Compressive behavior, Pseudo-elastic modulus, Experimental device, Macro-brittle, Compressed earth.

Contribution/ Originality

This work provides a new experimental methodology for the measurement of the behavior of mechanic items under ordinary compression using a simple device easy to handle. This is to make ways of featuring out the mechanic behavior of earth blocks formerly limited to found out the stress resistance only.

1. INTRODUCTION

Nowadays, many people are taking great interest in earth masonry for its ecological properties and high thermal inertia [1]. However, the use of compressed earth blocks for building should compulsorily be in accordance with the standard technical specifications: to have good compressive

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strength properties. In that view, many studies carried out about earth blocks have been limited to suggest methods to determine that resistance, according to the properties of the earth such as:

- the anisotropy *related to* blocks making;
- *the faces deformation due to their dry shrinkage*;
- the unsuitability of the dimensions of earth blocks: these dimensions can be neither useful to undertake a true compressive test nor to reproduce the same test [2-6].

On the other hand, there led studies to set up the conditions over the earth and the method to be used when making blocks so as to get the highest resistance values in compression [4, 5, 7-9].

The aim of these specifications is to predict the behavior of earth block masonries. This is not a mere way to determine or to improve some technical performances. Indeed, it is to establish a definite computer code for earth masonries, like Euro code 6 did for fired earth blocs or concrete blocks. To reach this goal, a campaign for the experimental determination of the mechanical behavior of earth blocks under compressive load had been initiated [10-12]. But the device for that experiment is too expensive, not every laboratory was able to realize those tests. That is the reason why, only few results are available. So, this study has been undertaken, in order to develop experimental process through a very simple compressive test, homogeneous and reproducible, using a less expensive device.

2. MATERIAL AND METHODS

2.1. Material and Process

For this test, blocks are made by using:

- Clayey sand extracted from Cocody. The characteristics of the soil are presented in table 1.
- Cement CEM II/B 32.5.
- Water to the mixture at respectively 5 % and 13.5 % of moisture content.

A constant volume of the mixture is compacted with a static press (CINVA RAM type) which develops a compaction pressure about 2 MN/m². The nominal dimensions of the block are 300 mm (length) x 140 mm (breadth) x 120 mm (height). Ten blocks are made and tested after 28 days of drying.

Tableau-1. Characteristics of earth

Sand (10 mm – 0,080 mm)	70.7 %
Silt and clay (<0,080 mm)	29.3 %
Liquid Limit	41 %
Plastic Limit	21 %
Plasticity index	20 %

2.2. Arrangement of the Equipment

The device for the test consists of a hydraulic press with a capacity is of 5000 KN, a force sensor and a displacement transducer (LVDT).

The block is put between the ramp of the press, on a load cell with a capacity of 300 KN, located under the inferior platen and the superior platen at the top. The constant piston displacement rate of the inferior platen is of 0.25 mm/min. A lubricant is applied on the two bearing surfaces of the trays, after each testing, in order to minimize the effects of the platens restraint.

2.3. Instrumentation

Blocks are instrumented for the measurement of the axial displacements using the linear variable displacement transducer (LVDT). The gauge lengths for the axial displacements are kept at 5 mm. The LVDT and the load cell, as shown in figure1, are connected to a data acquisition system by which the displacements and the weights of the loading are recorded and cached every 10 s.

2.4. Test Procedure

This test consists to follow the behavior of earth blocks under direct compression. The earth block is put between the trays of the hydraulic press under the loading. Then, the loading is progressively increased at a steady rate and made to move downward, according to the vertical axis. Whenever the earth block receives weight from the loading, it undergoes changes in its morphology. Here in this investigation, the specimens are compressed according to the NF P 18-406 standard. These are not tested in the direction in which they have been pressed, that is according to the direction in which they are generally laid but, they are posed so that the length to height ratio is 2 (fig. 1). And both the following compressive tests are performed:

- The direct compressive test: The procedure adopted in many national standards and codes of practice is similar to that which is used for fired clay and concrete blocks. Here, the blocks are not capped before but, they are put directly between the platens of the compressive device.
- The indirect compressive test: The procedure adopted is the same like in the direct compressive strength test. But in this case, the blocks aren't directly put between the platens of the compressive device. A sheet of steel thick of 10 mm and a ball of steel are put between the surface of the block and the superior tray. Most of the time, the surfaces of the block are not sufficiently flat and parallel thence capping is necessary. Five (5) blocks are tested for each method. The data collected are treated through calculation software like Excel. The strain (ϵ) and the stress (σ) are calculated respectively from:

$$\epsilon = -\frac{l-l_0}{l_0} \text{ and } \sigma = \frac{F}{S} \text{ Where: } l = \text{the length of the block at time } t \text{ (mm);}$$

l_0 =the initial length of the block (mm); F = the weight of the loading (N); S = the area of the area of the block (mm^2).

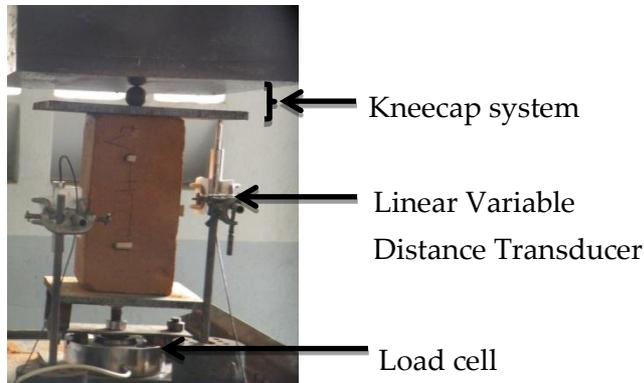


Figure-1. Experimental device

3. RESULTS AND DISCUSSION

3.1. Earth Blocks Behavior

Figure 2 indicates a sample of the stress-strain curves of earth blocks in continuous compression. The stress-strain is described by parabolic curves [10, 12]. We have found that it exists a substantial non-linearity in the pre-peak range which also exists in the post-peak stage. Nevertheless, the curves are similar to that of a cylindrical compressed earth block that has been observed in laboratory tests.

A detailed study of Figure 2 reveals that the stress–strain curves can be divided into four parts.

The first portions of the curves (the initial field) aren't similar, which indicates that the platens do not perfectly adhere onto the surfaces of blocks because of their deformation. In the direct compression test, this portion of the curve is more marked than in the indirect compression. Consequently, the curves are not much affected when the ball system is used.

The second portions of the curves (the elastic field) are similar in both compression tests and look like a line. However, a slight difference between the slopes of the stress–strain curves can be observed. The strain is not much affected by the stress, if it is in the elastic field. The randomly distributed micro-fractures have little influence on the blocks in this field.

But, when the stress becomes more important, about 75 to 85 % of the stress peak, the blocks tend to deform in a non-uniform way. This is the third field or the plastic field. The Specimens show a larger strain near the stress peak, which could be caused by the initial crack and its propagation path.

The fourth portions of the curves (the post-rupture field) are located after the peak. Here, the cracks are not stable but the breaking process becomes more stable. The blocks have a greater residual strength and deformation capability that could be attributed to the rupture mode.

[Kouakou and Morel \[12\]](#) have shown, after several loads and unloads in the field of blocks elastic behavior, that they have a permanent deformation and qualified this behavior as pseudo-elastic.

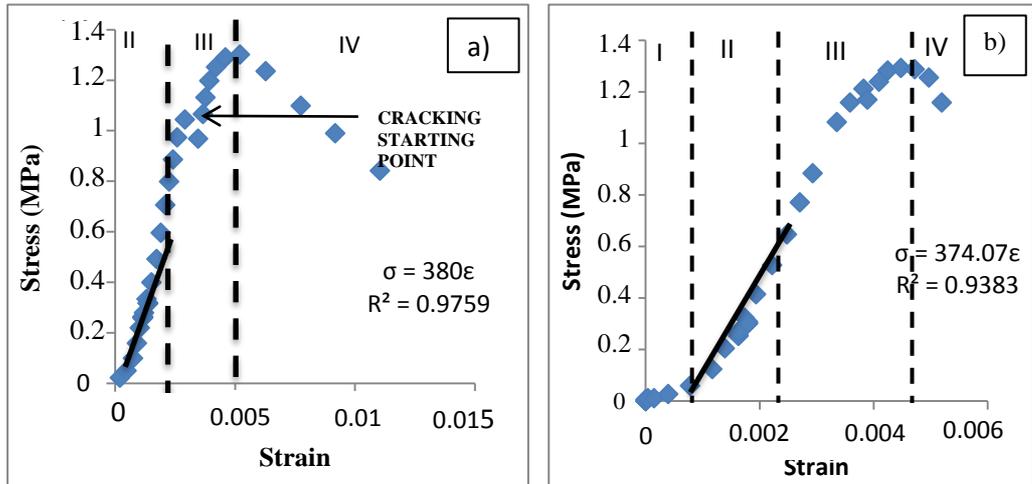


Figure-3. The stress-strain curve a) indirect compressive test b) direct compressive test

I= Initial field II=Elastic field III=Plastic field IV=Post-rupture field

3.1. Validation of the Test

Table 2 gives the results of the two tests. We can note that the ultimate stresses are similar for both tests but the ultimate strain and the pseudo modulus are very different from one test to the other. That could be explained by the confinement of blocks between the trays.

In fact, when the compressive stress increases, the specimen expands laterally, due to the friction along the interface between the platen and the specimen. This is the reason why the ultimate strain, in the direct compressive test, is more important while the pseudo modulus is less important. But, as the sample aspect ratio is approximately equal to 2, the trays restraint effects on the ultimate stress is reduced. According to P'kla, et al. [13], the confinement is responsible of the overestimation of the compressive strength when the aspect ratio is less than 2. Thus, Krefeld [14] and Heathcote and Jankulovski [15] suggested a factor to reduce the compressive strength. Unfortunately, there was no factor to correct the deformation and the pseudo modulus. Otherwise, the led experimentation was limited.

However, the pseudo elastic modulus determined by the indirect compressive test varies from 380 to 400 MPa. These values are similar to those obtained by P'Kla [10] confirming that the results found in the indirect compression test are correct.

Now because of the dry shrinkage, the surface of the blocks is not very flat. So, when the blocks are compressed, breaking appears in their angles, if the loading is not homogeneously distributed on the blocks surface.

Moreover, with the ball system, the breaking arises from the center of the longitudinal face (fig. 2). On the contrary, [16] has obtained a tilt crack due, not only to the shear in the isotope material but also to the homogeneous distribution of the loading. Hakimi, et al. [11] have obtained the same type of rupture as we did about earth blocks. They called it macro fragile rupture, due to

the homogeneous distribution of the load onto the blocks. That again confirms that the results found with indirect compression are correct.

Table-2. Results of the compressive tests

Sample number	Direct compressive test			Indirect compressive test		
	Ultimate stress (MPa)	Ultimate strain	Pseudo-elastic modulus (MPa)	Ultimate stress (MPa)	Ultimate strain	Pseudo-elastic modulus (MPa)
N°1	1.2	0.0047	374	1.3	0.005	380
N° 2	1	0.009	340	1.6	0.0044	395
N° 3	1.1	0.009	290	1.6	0.005	398

4. CONCLUSION

In this paper, we present the results of an experimental study over the influence of the two compressive strength tests methodologies about the mechanic behavior of compressed earth blocks. The main conclusions may be summarized as follows:

- In compressive, the compressed earth blocks have a non linear pseudo-elastic behavior which can be decomposed into three fields of behavior: elastic, plastic and post peak. To these fields, we can add the initial stage behavior, due to the contact between the surfaces of blocks and platens.
- The Stress-strain relationship is much affected by the testing procedure and the position of the *sample*. Therefore, when the experiment is correctly led, the loadings are applied homogeneously onto the samples whence the aspects ratio equal to 2 macro fragile ruptures has been adopted by earth blocks.
- The elastic modulus of the compressed earth blocks made with 5 % of cement ranges from 380 to 400 MPa, when blocks are put on their top.

The mechanic behavior of earth blocks can easily be determined experimentally with a compressive machine, a load cell, a linear variable displacement transducer (LVDT) and a ball system.

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