Proposta de procedimentos normativos para a caracterização mecânica de blocos de terra compactada estabilizada com cimento

Proposed normative for mechanical characterization of cement stabilized compressed earth blocks

Mariana Filipa Felisberto Neves

marianananeves@tecnico.ulisboa.pt

Resumo Alargado

Extended Abstract

Orientadores

Professor Doutor José Alexandre de Brito Aleixo Bogas

Professora Doutora Maria Paulina Santos Forte de Faria Rodrigues

Júri

Presidente: Professor Doutor Jorge Manuel Caliço Lopes de Brito

Orientador: Professor Doutor José Alexandre de Brito Aleixo Bogas

Vogal: Doutor Luís Pedro Monteiro Simões Mateus

Outubro 2019

Proposed normative for mechanical characterization of cement stabilized compressed earth blocks

Mariana Filipa Felisberto Neves
mariananeves@tecnico.ulisboa.pt
Master's in Civil Engineering
Instituto Superior Técnico, Universidade de Lisboa, Portugal
October 2019

Keywords: Earth construction; mechanical property; compressive strength; normative proposal

Earth is one of the oldest building materials in the world. However it has fallen into disuse with the appearance of new materials. Nonetheless, earth construction is progressively re-gaining popularity because of its many advantages, such as cost, thermal and acoustic insulation, hygroscopic capacities and minimal impact on the environment. Compressed earth blocks (CEB) appear as the most widely accepted earth construction technique, given the possibility of standardization of the blocks and greater quality control in their production process. However, there are still some constraints for its applicability such as the lack or incompatibility of standards. Therefore, this work aims to achieve a proposal of normative procedures for the mechanical characterization of CEB. For this reason, an experimental analysis of distinct types of cement stabilized CEB, from different manufacturers, was conducted to identify their characteristics and compressive strength. The tests were conducted with whole and half blocks, overlapping half blocks layered with mortar, use of plywood or Teflon on the press equipment or varying CEB moisture content (tested saturated and dry). Additionally, CEB masonries were constructed to extract cylindrical samples.

1. Introduction

Being earth a resource available around the world, its use as a construction material emerged thousands of years ago (Minke, 2006). In Portugal, different earth construction typologies, from distinct epochs, exist around the country (Fernandes, 2006), even though there are no Portuguese or European standards for its use.

In the absence of normative documents referring to the construction with earth in Portugal, this dissertation emerges following the work developed by the Technical Commission of the Portuguese Institute of Quality (IPQ) CT 176, which was requested to present a proposal for normalization of compressed earth blocks (CEB). Thus, it is necessary to define a normative proposal for mechanical characterization of this type of blocks.

1.1. Existing standards

European normatives include standards for the characterization of masonry units of various materials. In particular, standards EN 771 (2011), establishes specifications for several masonry units. However, it does not contemplate any type of earth masonry.

The standard EN 772-1 (2011) establishes compressive strength test methods for masonry units, basing the methods on the specifications of standards EN 771 (2011). This standard proposes testing the blocks directly on the press under increasing load to measure its rupture point. This standard allows the test specimens to be tested in four different conditions of relative humidity (RH): oven dry, air dry, saturated and 6% RH.

There are standards in various countries for adobe and CEB compression test. Some standards, such as HB 195 (2002), UNE 41410 (2008), ASTM C67 (2005), NMAC (2009) and NZS 4298 (1998), suggest that tests should be performed similarly to EN 772-1 (2011) proposal, i.e., directly on whole blocks. The DIN 18945 (2013) standard claims that this procedure is only possible for blocks with nominal height greater or equal than 71mm. For non-compliant blocks this, standard suggests that testing should be done with two half blocks superimposed together with a mortar, as further supported by NBR 8491 (2012), NTC 5324 (2004) and NF XP P 13-901 (2001) standards. The specimens can be tested under dry, saturated or other environmental conditions as defined in each standard.

To measure the compressive strength of the blocks, some standards propose correction factors (e.g., HB 195 (2002) and NZS 4298 (1998)), while others organize the results by resistance classes using statistical means (e.g., NTC 5324 (2004), NF XP P 13-901 (2001), DIN 18945 (2013), UNE 41410 (2008)) and others define only a minimum value (e.g., NBR 8491 (2012), ASTM C67 (2005), NMAC (2009), RPTC (2011) and E080 RM 121 (2017)).

1.2. Effects influencing simple compression tests

Different factors can influence the compression resistance. According to literature, the compression resistance is strongly influenced by the relation of the specimen's height divided by its minimum width, H/W (Krosnowski, 2011). With the increase of compression strength, the specimen tends to expand sideways. However, due to friction between the long interface of the plates and the sample, the expansion side of the sample becomes confined. This confinement of the samples by retention of the plates increases the apparent resistance of the material (Morel *et al.,* 2007). This effect has the most impact when applied to whole blocks. To overcome this, the press plates' friction can be reduced by using Teflon or plywood plates, or overlapping half blocks, reducing H/W. However, the latter introduces some disadvantages. More specifically, this type of specimen is strongly subject to the effects of eccentricity and the quality of the mortar joint, that strongly depends on application (Aubert *et al.,* 2015; Moret *et al*., 2007).

Another important factor in the tests is the moisture content of the blocks. The strength decreases as the moisture content increases due to the softening of the agglomerants by water, the development of pore stresses and the liquefaction of unstabilized earth. Although there is some variation, depending on the earth properties and eventual cement content for stabilization, the compressive strength of the stabilized blocks after saturation is reduced by about 50%, compared with the corresponding dry values (Walker, 1995; Morel *et al*., 2007; Riza *et al*., 2010).

2. Methods

In order to analyze and validate the tests suggested by several standards and authors, four types of blocks were tested:

- TI blocks, produced in Montemor-o-Novo, under the master's thesis of Lopes (2015). The constituent materials are 80% local earth, 20% recycled aggregate, 8% cement (earth and recycled aggregate mass) and 9.5% water (earth, recycled aggregate and cement mass). The CEB compaction was performed using a manual press and the dimensions were 22 x 10.5 x 5.5 cm^3.

- TM blocks, produced in Montemor-o-Novo, under the master's thesis of Silva (2015). The constituent materials are 85% local earth with 35.4% of clay, 15% recycled aggregate, 8% cement (earth and recycled aggregate mass) and 9.5% water (earth, recycled aggregate and cement mass). The CEB compaction was performed using a manual press and dimensions were 30 x 14 x 9 cm^3.
- Ceyfor blocks, for which the global composition is unknown because they were industrially made by the Ceyfor company. However, it is known that they were stabilized with 5% white cement (mass). These blocks were subjected to compaction with a hydraulic press and dimensions were 29.5 x 14 x 9 cm^3.
- N blocks, produced at the Faculdade de Ciências e Tecnologia of Universidade NOVA de Lisboa, in the framework of a CEB workshop held in 2015. These blocks were previously tested of the master´s thesis of Ribeiro (2016). The constituent materials are 50% local earth (very silty, without coarse aggregates), 50% sand and 5% Portland cement (percentages of constituents in volume). The compaction was done with a manual press and dimensions were 25.9 x 14 x 9 cm^3.

2.1. Determination of blocks to be tested

To perform a pre-estimation of the number of samples required in each compression test, it is assumed that the population regarding the resistances follows a normal distribution. Thus, Equation 1 can be considered to estimate the number of samples (Lipschutz, 1965):

$$n = \left(\frac{a\times\sigma}{\bar{X}-\mu}\right)^2 = \left(\frac{a\times CV}{E}\right)^2 \quad (1)$$

where n is the sample size, a is the critical value for a given confidence interval, σ is the standard deviation, $\bar{X}$ is the sampling mean, μ is the actual mean, CV is the coefficient of variation and E is the error maximum permissible.

Using results previously obtained by other authors regarding these blocks, an overall coefficient of variation of 17% is assumed. For a permissible error of 5%, and a confidence interval of 95%, the minimum number of CEB to characterize in each test is 6.

2.2. Performed tests

The compression tests were performed at a load rate of 0.5 kN/s, as suggested in the Brazilian standard NBR 8491 (2012).

In table 1, the tests performed for each type of block are synthesized.

2.2.1 Moisture content assessment

To evaluate the moisture content, after the tests, the CEB were weighed and dried at 60 ºC until they reached constant mass conditions - when after three consecutive weighings with a minimum interval of 24 h, they had a variation of less than 0.1% of the total mass.

2.2.2 Standard tests

For all CEB, the standard tests were performed in order to have a global parameter of comparison. The tests are performed with whole blocks, in the direction perpendicular to the layering face (Figure 1). In this test, the CEB was always tested with the laboratory moisture content (CL).

Procedure:

- The load cell was placed centered on the lower plate of the press and a 4 cm thick steel plate was placed above the cell.
- The specimen was directly centered between the steel plates of the load cell and the press, being loaded until the rupture.

Figure 1.Standard test

Table 1. Tests performed for each type of block

Tests	Humidity conditions	N º of tests			
		TI	TM	Ceyfor	N
Standard	CL	8	6	6	10
Whole blocks	Dry	-	-	-	6
	Saturated	-	-	-	6
Half blocks	CL	12	-	6	-
	Dry	6	-	-	-
	Saturated	6	-	-	-
5X5 Plate	CL	6	-	-	-
Teflon Plate	CL	6	-	-	6
Plywood board	CL	6	-	-	-
Two half overlapped blocks	CL	4	-	6	-
Three half overlapped blocks	CL	-	-	6	-
Cylindrical Ø5H5	CL	7	6	-	
Cylindrical Ø10H20	CL	-	6	6	-
Cylindrical Ø10H10	CL	-	10	-	-

2.2.3 Test in half blocks

In order to evaluate the influence of the geometry of the CEB, namely the H/W ratio, tests were carried out in half blocks. The half CEB were obtained by sawing and were tested in the direction perpendicular to that of the laying face, according to the procedure referred by 2.2.2.

2.2.4 Test in dry conditions

As suggested in HB 195 (2002) and IBC (2009)/ASTM C67 (2005), tests were performed with dry blocks. For this purpose, the CEB were dried at 60 ºC to a constant mass. This test was performed only in half blocks or whole blocks, accordingly to the procedure referred by 2.2.2.

2.2.5 Test in saturated conditions

As suggested in HB 195 (2002), CEB were also tested under saturated conditions. For this purpose, the CEB were immersed for 24 hours and their surface was dried before subsequent tests. Tests were performed only with half or whole blocks, in accordance with the procedure referred by 2.2.2

2.2.6 Tests with Teflon plates

In order to reduce the effect of friction introduced by the press plates, tests were carried out using Teflon plates on CEB. Therefore, two Teflon plates with a thickness of 4 mm and two plywood plates with a thickness of 2 cm were used. Each of the Teflon plates was glued to a plywood plate in order to increase its resistance. The remaining of the test procedures were performed as described in 2.2.2

2.2.7 Tests with the plywood plates

As suggested in HB 195 (2002), marine plywood plates were used when measuring the compression performance, in order to allow a better distribution of the load on the blocks' surface, and to reduce the friction between the press plates and the CEB. For this purpose, 2 cm thick plywood plates were used. The tests were performed according to 2.2.2.

2.2.8 Teste with 5 x 5cm plate

To analyze the effect of using a plate with width equal to the CEB height, obtaining a ratio H / W = 1, two steel plates with dimension 5 cm X 5 cm were used. These plates were placed aligned and centered with the CEB and the press plates. The tests were performed according to 2.2.2.

2.2.9 Tests with two and three half blocks

As suggested by DIN 18945 (2013), NTC 5324 (2004), NF XP P 13-901 (2001) and NBR 8491

(2012), tests were carried with half overlapped CEB, layered by cement mortar (Figure 2). Consequently, the CEB H/W ratio was increased, reducing the effect of the press plates. For this purpose, after sectioning the CEB with a cutting saw, they were layered using a trowel and level. The used mortar thickness was around 1 cm. The tests were performed after 30 days of curing of the mortar in a laboratory environment, according to the procedure presented in 2.2.2

Figure 2. a) Two half blocks test b) Three half blocks test

2.2.10 Test on cylindrical specimens

In order to analyze the relation between compressive strength in CEB and in-situ resistance of masonry produced with these CEB, a total of five experimental masonry walls were built: three using TM CEB, one with Ceyfor CEB and one with TI CEB. Figure 3 illustrates an example of a wall built with Ceyfor CEB.

Figure 3. Ceyfor blocks wall

The cylindrical specimens were extracted (using water) with the aid of a Hilti DD130 beetle and two drills of 5 and 10 cm in diameter. After the extraction, the specimens were stored in the chamber at 60% HR for at least two weeks. After this period, the cylindrical specimens were conditioned in the laboratory environment. Due to the need to ensure proper grinding of the cylindrical specimens, the resulting test specimens were prepared and tested in the concrete department of the Laboratório Nacional de Engenharia Civil (Figure 4).

Figure 4. Cylindrical specimens test

2.2.11 Layering mortar

A cement mortar with a 1:3 volumetric ratio of Portland cement: sand was used to build the walls and the half blocks specimens. The mortar used for testing is distinct from the mortar that should be used for CEB layering. i.e., a mortar with higher resistance than the CEB was used to warrant that the rupture occurs in the block.

The production procedures and preparation of the mortar followed the specified in EN 196-1 (2016) and the tensile and compressive strength tests were performed, after flow consistency tests performed following the EN 1015-3 (2006).

2.3. Compressive strength test

To obtain the compressive strength fc (in MPa), the rupture strength Fc (in kN) is divided by the CEB contact area with the press plates A (area of the smallest half block, in mm^2.

3. Results and discussion

3.1. Mortar characterization

The result obtained in the mortar flow tests shows that this is a dry mortar (152. 7 mm). A flexural rupture tension of 4.1 and 5.4 MPa was obtained at the 7^{th} and 28^{th} day, respectively. Additionally, a compressive strength of 26.3 MPa and 35.3 MPa was registered at the same ages.

3.2. Moisture content

For the CEB moisture content analysis, seven samples were collected from the tested blocks (2 TI blocks, 3 TM blocks, 1 Ceyfor blocks and 1 N blocks) in laboratory environment. The obtained moisture content was close in all blocks, with an average of 0.96 ± 0.02% (mass).

3.3. Compression strength

Table 2 summarizes the distinct test results obtained for the various CEB.

Surprisingly, the compressive strength obtained in the standard tests was higher when using half blocks of equal H/W ratio. This is likely due to the differences in geometry and the side effects of cutting the CEB, which can lead to block weakness and reduced friction effect due to the smaller contact area. The progressive increase of the H/W ratio due to interlocking blocks overlap with mortar led to an expected decrease of the compressive strength. However, it should be noted that tests with half overlapped CEB are more sensitive to eccentric tears due to the difficulty of guaranteeing their verticality. In general, these tests led to higher coefficients of variation, which admonish its use. For the same reason, three overlapped half blocks compressive strength was lower than the Ø10H20 cylindrical specimens with the same H/W.

The use of plywood and Teflon led to a reduction of compressive strength, confirming that they are effective reducing friction of the plates of the press. The observed strength variation with and without Teflon (approximately 58% for TI CEB and 53% for N CEB) was much higher than the observed in Aubert *et al.* (2015), i.e., 10%. The difference was not substantial between the Teflon and the plywood, showing plywood as a good candidate for these tests as it is cheaper than Teflon. The tests performed with a square metal plate with lateral dimension identical to the height of the CEB, led to similar results to those of CEB tested with identical H/W ratio.

In all tests, and as previously verified by Riza *et al.* (2010), Morel *et al.* (2007) and Walker (1995), the CEB resistance, when tested on saturated conditions, was considerably lower than CEB tested under laboratory humidity conditions, and the latter lower than CEB under dry conditions. Thus, it is concluded that it is important to consider the CEB moisture condition in the normative proposal.

The cylindrical specimens' compressive strength was significantly lower than the observed in standard tests. In addition to the lower CEB H/W ratio, these blocks are less prone to eccentricity problems and damage caused in their preparation. It is also confirmed that the standard test variability tends to be inferior than the obtained for the cylindrical specimens. The eccentricity and damage problems are due to the process of cutting, which can lead to a cylindrical specimens' resistance of H/D = 1.0, which is inferior to the CEB tested with a square plate of equal width to their height. Considering the results obtained in the tests with the different cylindrical specimens, it was verified that the compressive strength was affected by its geometry. The cylindrical specimen ϕ 10H20 resistance was lower than the ϕ10H10. On the one hand, the resistance tends to decrease with the increase of the H/W ratio. On the other hand, slenderer specimens are more affected by eccentricity problems, which may justify the greater variability obtained. However, despite the higher H/D ratio of

Table 2. Results obtained for the various blocks in the different tests.

Blocks	Test	Compressive strength (MPa)	Coefficient of variation (%)
TI	Standard test	17.4	13.5
	Half blocks CL	13.4	12.1
	Plywood in half blocks	9.0	5.4
	Teflon in half blocks	7.8	14.6
	5X5 Plate	7.4	5.6
	Cylindrical specimens Ø5H5	5.2	17.5
	Half Dry blocks	18.3	9.3
	Half saturated blocks	6.2	18.3
	Two half overlapping blocks	7.8	20.4
TM	Standard test	11.5	9.0
	Cylindrical specimens Ø10H10	5.6	11.3
	Cylindrical specimens Ø10H20	4.9	21.4
	Cylindrical specimens Ø5H5	4.5	15.4
Ceyfor	Standard test	15.6	8.1
	Half blocks CL	13.1	9.8
	Two half overlapping blocks	10.0	4.9
	Three half overlapping blocks	8.4	10.5
	Cylindrical specimens Ø10H20	10.0	7.4
N	Standard test	2.9	33.7
	Teflon	1.5	41.6
	Saturated	0.8	35.4
	Dry	4.9	33.1

the ϕ 10H20, the resistance was lower than in the ϕ5H5. This may be due to the weakness of this type of specimen. Except for N CEB, all tested CEB, have an average compressive strength higher than the recommended minimum in most standards i.e., 2 MPa. In addition, the N CEB variation coefficient was higher than 25% For these reasons, N blocks were given least relevance in a proposed normative.

For all the other CEB the mean coefficients of variation obtained in the standard tests were 10.2%, and always below 14%. The highest coefficient of variation was 21.4% and occurred in the Ceyfor's CEB ϕ10h20 cylindrical specimens. The N block's variation coefficient was not considered, since it was to high due to CEB poor quality and resistance. Forasmuch as the variation coefficients obtained, it is considered that a maximum acceptable value for CEB tests will be around 15%.

3.3.1 Resistance correction factors

Since the compressive strength varies with the H/W ratio, the standards HB 195 (2002) and NZS 4298 (1998) suggest correction factors to be applied when standard tests are performed on blocks of different geometries. The objective is to normalize the resistance to a given H/W reference, so that it is independent of the CEB geometry and type. Figure 5 shows the curve suggested by the standard HB 195 (2002), as well as the curves obtained by Krosnowski (2011), and in the Ceyfor CEB tested in the present study.

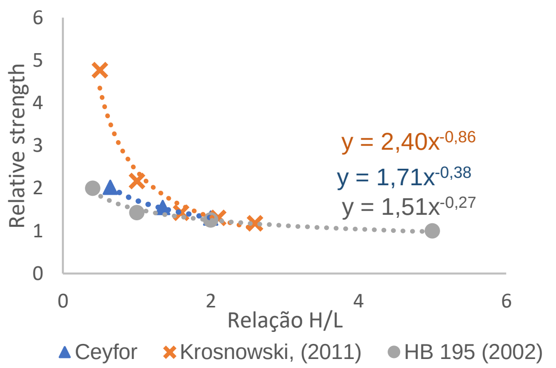

Figure 5. Correlation between H/W and compressive strength

Likewise Krosnowski (2011), the Ceyfor curves presented in this study were performed based on the variation of the H/W ratio at the expense of overlapped blocks. Thus, the resistance is reduced with the increase of H/W, not only due to the decrease of friction with the press plates, but also due to the increase of the eccentricity phenomena resulting from the greater difficulty in guaranteeing the verticality of the overlapped blocks. Unlike these tests, in standard HB 195 (2002), the specimens are tested with the aid of plywood plates, which decreases the influence of the press plates' friction. For the aforementioned reasons, there is a greater increase in resistance with the reduction of the H/W ratio in this Kronoswski (2011) studies when compared to the HB 195 (2002) curve. Given that the proposed normative is performed with whole blocks using plywood, it was considered as reference the curve suggested in HB 195 (2002).

3.3.2 Block and cylindrical specimen relations

Collecting cylindrical specimens for tests is an efficient approach to study the properties of existing constructions. Table 3 shows the various tests carried out and correlations of at least 6 cylindrical specimens and 6 blocks of each composition. Since the cylindrical specimens and standard blocks were tested without the aid of plywood, the correlation was established based on the Ceyfor curve indicated in Figure 5. Fundamentally, Table 3 shows the H/W ratio of the blocks leading to a compressive strength equivalent to the cylindrical specimens with a given geometry and height/diameter ratio (H/D).

Table 3. H/D ratio and H/W equivalent

Cylindrical specimen type	H/D ratio (cylindrical specimen)	Equivalent H/W ratio (block)
Ø5H5	1	4.8
Ø10H10	1	2.2
Ø10H20	2	1.5

3.4. Proposed standard

In the present normative proposal, the suggested equipment and utensils follow the recommendations of EN 772-1 (2011), likewise the ones adopted in most CEB compression testing standards. As obtained in 2.1 and recommended by the DIN 18945 (2013), NF XP P 13 – 901 (2001) and NTC 5324 (2004) standards, a minimum of 6 test specimens is considered.

The sample selection is defined according to the EN 771-1 (2011) and HB 195 (2002) standards. The preparation of the samples' surface follows EN 772-1 (2011) suggestion. The surface regularization with mortar, when necessary, is also suggested by most of the standards that include CEB compression tests, e.g., HB 195 (2002), NBR 8492 (1984), DIN 18945 (2012), NTC 5324 (2004) and NF XP P 13-901 (2001).

Considering that the moisture content significantly changes the compressive strength, CEB tests should be carried out under saturated or dry conditions. To ensure the test conditions, the sample must be oven dried or saturated by immersion, as described in standard EN 772-1 (2011).

As the present study confirms, a higher compressive strength is obtained when the CEB are tested according to the standard tests. Thus, in order to prevent this problem, it is recommended to use correction factors, as suggested by the standards HB 195 (2002) and NZS 4298 (1998). The use of plywood plates is also recommended to reduce the friction between the blocks and the press plates, which in turn reduces the containment effect. This is also recommended in the HB 195 (2002) standard.

Additionally, it is recommended that the H/W ratio is rectified according to the HB 195 (2002) standard, and CEB classified according to the NTC 5324 (2004) and NF XP P 13-901 (2001) standards. An additional class was added to this classification - CEB 80 - considering the high compressive strength results obtained in this study (i.e., for TI and Ceyfor blocks) and in Aubert et al. (2015), which obtains a result of 10.4 MPa (Table 4).

Table 4. CEB classes

CEB Classes		20	40	60	80
Minimum resistance for quantile 0.05(MPa)	Dry compression	2	4	6	8
	Saturated compression	1	2	3	4

In terms of the tests' accuracy, and according to this study, more than 12 blocks should be tested per composition, and covering different CEB provenances, variation coefficient of up to 15% is considered an acceptable value.

In the present normative proposal, relations for cylindrical specimens and block tests, which may be useful for in-situ resistance evaluation, are suggested. However, these correlations are only established for cylindrical specimens and blocks tested in the perpendicular direction to its nesting bed, which limits its usefulness in current construction.

4. Conclusion

As shown by the compression tests performed in this study, there is no single existing method that proves to be the most reliable. Each method presents advantages and disadvantages, and none proved to be unequivocally overturned. Thus, it was determined that tests with individual whole CEB at controlled humidity are the most favorable, mainly due to their ease of execution and the fact that they are less dependent on external factors. Although the half-block tests with mortar shown to be effective in reducing the H/W effect, they depend heavily on who performs the test specimens, they are a fairly laborious and time-consuming, and frequently lead to eccentric ruptures. Finally, cylindrical specimen tests and tests with overlapped half CEB reduce the H/W effect and, although very practical for existing masonry constructions, are quite lengthy and complex when it comes to evaluating individual CEB compressive strength.

It was determined that two 2 cm thick plywood plates should be used when testing; this preference over Teflon glued to plywood was mainly due to its wide availability and reduced cost.

The CEB test under controlled conditions, saturated or dry, while quite different from the conditions of service, allow for greater control of the environment humidity. So, for both these, it is important to consider the minimum values and different classifications.

At the end, it is considered that this study makes a clear contribution towards the standardization of the compressive strength test procedure and classification for low cement content stabilized CEB and subsequent production and marketization in Portugal.

5. References

Aubert J., Maillard P., Morel J., Al Rafii, M. (2015). Towards a simple compressive strength test for earth bricks? Materials and Structures 49:1641-1654.

Fernandes, M (2006). Construction techniques on earth, Earth: Way to build. Architecture. Antropologia. Arqueologia – 10ª Mesa Redonda de Primavera. Porto. Argumentum (in Portuguese)

Krosnowski, A. D. (2001). A proposed best practice method of defining a standard of care for stabilized compressed earthen block production. Master thesis. University of Colorado.

Lipschutz S. (1965), Theory and problems of prabability, Schaum Publishing Co., McGrae_Hill, ISBN 0070379823

Minke, G. (2006). Building with earth. Design and Technology of a Sustainable Architecture. BIRKHAUSER, Berlin, ISBN-13: 978-3-7643-7477-8

Morel, J.; Pkla, A.; Walker, P. (2007). Compressive strength testing of compressed earth blocks. Construction and Building Materials, 21:303-309.

Riza F. V., Rahman I.A., Zaidi A.M.A, (2010). A brief review of Compressed Stabilized Earth Brick (CSEB). CSSR 2010 - 2010 International Conference on Science and Social Research, 999–1004. Doi:10.1,109/CSSR.2010.5773936

Walker, P., (1995). Strength, durability and shrinkage characteristics of cement stabilised soil blocks, 9465(95), 17:301–310. Doi: 10.1016/0958-9465(95)00019-9

ASTM C67 (2005). Standard test methods for sampling and testing brick and structural clay. ASTM

DIN 18945 (2013). Earth blocks. Terms and definitions, requirements, test methods. German standard (in French).

E 080 RM 121 (2017). Design and construction with reinforced earth. Peru. NTE (in Spanish)

EN 771 (2011). Specification for masonry units. CEN.

EN 772 -1 (2011). Methods of test for masonry units. Part 1: Determination of compressive strength. CEN

EN 1015-3 (2006). Methods of test for mortar for masonry - Part 3: Determination of consistence of fresh mortar (by flow table). CEN.

EN 196-1 (2016) - Methods of testing cement- Part1: Determination strength. CEN.

HB 195 (2002) – The Australian earth building handbook. Standards Australia. SAI

IBC (2009) – International building code. ICC.

NBR 8492 (2012) - Soil-cement brick-dimensional analysis, determination of compressive strength and water absorption-test method. ABNT (in Portuguese).

NF XP P13-901 (2001) - Blocks of compressed earth for walls and partitions. Definitions, specifications, testing methods, reception conditions. AFNOR (in French).

NMAC (2009) - Housing and construction. Building codes general. New México. NMAC

NTC 5324 (2004) – Cement floor blocks for walls and divisions. Definitions. Test methods. Conditions of delivery. ICONTEC (in Spanish).

NZS 4298 (1998) - Materials and workmanship for earth buildings. New Zeland. SNZ

UNE 41410 (2008) - Compressed earth blocks for walls and partitions Definitions, specifications and test methods. AENOR (in Spanish).