Earthen construction in Spain

Current regulations and introduction of the CEB Blocks

E. Cruz

Universitat Politècnica de Catalunya (Espanya)
Contact: eric.cruz@estudiantat.upc.edu

ÍNDEX

I. INTRODUCTION AND RATIONALE FOR THE CHOOSEN THEME

I.1. Introduction

Earth construction has been used for centuries as the main building material. However, due to technical and regulatory problems, earth construction is not feasible in many territories. With this research, we first analyse the global regulatory landscape, and then we study the state of the art of standardisation of earth as a building material in Spain. We look at the most relevant parameters of each of the regulations, such as stabilisation, selection of materials, testing and requirements for finished products. Finally, the work is presented as a seed to promote the creation of a state regulation that serves as a reference for architects and to promote construction with earth.

With this objective, it is proposed to study the state of the art of the standardisation of earthen construction in the world, paying special attention to the proposal of the Spanish state in this respect, and to compare this with the different regulations in order to propose a joint document, which will serve as a basis for designing with earth and, in the future, to be able to create a regulatory document within the Spanish state.

Keywords: earth construction, legislations and regulations, compressed earth blocks (CEB)

I.2. Background to earthen construction


Figure 1 - Biblioteca de Alexandria, Egypt

The first examples of earthen architecture date back to ancient Mesopotamia. According to archaeological studies, earthen construction evolved until it was consolidated with the construction of the Tower of Babel or the Library of Alexandria, among other emblematic buildings. Throughout the world, earth has been used as a building material for residential buildings as well as for monuments and fortifications.


Figure 2 - Great wall of Xina, Xina

The Great Wall of China was built about 4,000 years ago, initially constructed with compressed earth and later covered with natural stones and bricks. The same is happening in the ancient Aztec civilisations, where the Pyramid of Teotihuacan maintains the same typology of construction, with compressed earth at the base and later covered with cladding.


Figure 3 - City of Shibam, Yemen

On the other hand, in the city of Shibam, in Yemen, we find the construction of the first skyscrapers. It is a territory with a population density similar to New York City (32 people per hectare), with some 500 buildings 9/10 storeys high, built entirely of adobe. In Morocco, there are fortifications built with declined walls of compost, with buildings of about 8 storeys.

In Vitruvius' book "De Architectura", earthen architecture is presented as the representation of the triad of values ("firmitas", "utilitas", "venustas"). On the other hand, Vitruvius speaks about Rome as "a labyrinth of multi-storey buildings made of manure bricks and wood". In the same treatise, he speaks extensively about architecture with earth and abobe bricks.

Figure 4 - X books of architecture, Vitrubius

In modern architecture, Frank Lloyd Wright used earthen architecture in two experimental projects: the "Hollyhock House" and the "Ennis-Brown House". The blocks are produced by using earth from the project site itself, mixed with cement. The blocks that clad the building can be considered as stabilised adobe construction.


Figure 5 - Ennis Brown House, Frank Ll. Wright

Le Corbusier, one of the most influential architects, developed a series of earthen architectural solutions for shellters. In 1942 he wrote a book about earth construction, "Las constructions murondins", in which he described systems for the construction of rammed earth and compressed earth blocks for use in residential, agricultural and civil constructions.


Figure 6 - Hollyhock House, Frank Ll. Wright

On the other hand, at about the same time, Hassan Fathy proposed the construction of domes and walls with adobe bricks, making an entire building entirely out of earth. He also used the principles of thermodynamics of earth construction to create passive systems at urban and residential scales. His commitment to earth construction led to his being commissioned to build the city of New Gourna, where one-third of the project was completed. A mosque, a school, a market and numerous houses were built.

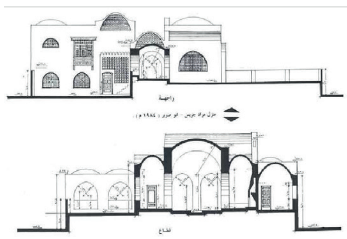


Figure 7 - Detail of New Gourna, Hassan Fathy

But, due to the ecological and oil crisis, combined with the possibility that the materials usually used will run out, earthen construction is becoming relevant again.

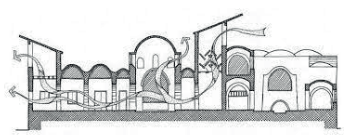


Figure 8 - Detail of New Gourna, Hassan Fathy

II. FITTING THE WORK INTO THE STUDIES

II.1. Personal experience

The theme in question was chosen because in my experience during my academic studies and later in the professional world, when it came to designing the construction system, there were not enough tools to justify the dimensioning or the characteristics of the system itself. In all cases, one ends up over-dimensioning or copying the system from some other project, but without having the certainty that the system really works. On a theorical level, construction with earth has been justified from many aspects, whether it be for its good thermal behaviour and its importance within the passive houses, for its minimal ecological footprint both with the supply of the material and during construction or for the possibility of obtaining the material within the territory itself, but all the implementation of the system itself ends up being justified with particular laboratory tests of the material, without understanding the system as a whole, and the parameters of the construction end up being applied with small elements such as the masonry work.

Unlike other materials used in construction, such as concrete, steel or wood, earth has no regulations that stipulate the requirements of the material, its characteristics and the conditions of the construction system. This means that, within the territory, there are few examples of recently built earthen constructions. Despite the fact that, historically, earth has been used for construction, with the appearance of materials such as steel or concrete, the use of this material has been lost. At the same time, given the technical difficulty of justifying the construction system, other systems have been prioritised.

II.2. Thematic within the academic world

The idea of the TFG comes from the experience received in the optional courses “Housing and Cooperation” and “Low cost technologies for construction”, taught by Sandra Berstraten and Emilio Hormias. On the other hand, the TFG allows me to study in detail the characteristics of earth construction, the different typologies and the implementations that they have in different countries, in order to study the feasibility of its use within our territory, not only at a practical level but also in a more bureaucratic and legislative aspect.

Together with the optional subjects, the theme of the TFG proposes to expand the knowledge taught in the subjects of Construction, where the different materials and the construction systems and details supported by these are studied, but leaving the construction with earth. Therefore, with the study of earth construction and its standardisation, the training received in these subjects is completed.

Finally, the subject of Legal Architecture is where architecture and its regulations come together, with the understanding that everything designed must have both a conceptual and technical justification, and that this must be supported by regulatory documents that establish the conditions and characteristics of both the material and the construction system.

II.3. Professional experience with earth construction

Thanks to the lessons taught within the mentioned courses, I have occasionally used earth construction in different projects, both in my academic life and in the professional world. In each case, the justification for the system employed was supported by a theoretical aspect of earth's behaviour and/or its scope and supply. In this way, I have experimented with the material in different construction systems depending on the project, in order to end up with a global knowledge of the different systems. In the appendices of this document, you can see the graphic information of the different experiences I have had with earth construction.

III. PRINCIPAL OBJECTIVES OF THE WORK

The objectives of this research work will be based on studying the state of the art of earth construction regulations in Spain and later at international level, in order to know the virtues and weaknesses of each one and, subsequently, to find similarities and differences between the different documents. Then, once they have been analysed, the final objective will be to generate a document combining the different parameters of the selected regulations, and to test it with a chosen project.

Next, we define the different objectives present in this project:

- Search for the different international regulations currently in force, and classification according to climate parameters that affect earth construction, such as temperature, average humidity and annual precipitation in each of the territories that have regulations.

- Comparison of the different regulations, chosen according to the above-mentioned criteria, naming the parameters that are defined in each of them and which parameters are not named in them.

- Analysis of Spanish regulations. We will analyse the different parameters on which Spanish regulations focus, and we will study their virtues and shortcomings.

- Proposal to improve Spanish regulations by providing criteria from the selected regulations. Generate a single normative document, taking the Spanish regulations as a base and adding the parameters of the different regulations chosen, to end up creating a justification document that will serve as basic criteria when designing with earth.

- Case study: putting the new criteria into practice. We will choose a project and, with the generated justification document, we will put into practice the criteria obtained in the previous study. In this way, we will see to what point the criteria are appropriate for use in a real case, and we will draw a conclusion as to the feasibility of using the justification document as a tool for designing with earth.

IV. METHODOLOGY

The methodology for analysis will be comparative. Once the different regulations have been searched for, the comparative method will be used to see the parameters that are conditioned by the different regulations, which points are focused on and which are not, generating comparative tables and summaries of the different characteristics of each one of them.

In order to classify the different regulations, we will apply some characteristics that are external to the regulations but which affect earth construction to a large scale. The characteristics chosen are linked to the analysis of the climate in each of the countries. We will choose the countries with climate values similar to those of the Spanish state, especially in terms of temperature, temperature changes over the year and the presence of water, since they greatly affect the design and projection of earthen architecture.

Finally, for the preparation of the normative document, the COAC's justification documents will be used as a reference for compliance with the parameters established by the CTE, to serve as a reference for the design phase of architectural projects with earth, and to make it an easy-to-use tool.

- Classification of the countries according to the climate in which they are located, and in this way take as valid the values applied in each of the regulations chosen and apply them in Spain. Generation of comparative graphs between the different countries.

- Analysis of the different regulations following the comparative method, by means of comparative tables and making a summary of the parameters to which each of them pay attention.

- Preparation of a synthesis document including different parameters of existing regulations, using the Spanish regulations as the main document and adding those aspects emphasised in the chosen international regulations. The final document is intended as a working tool to be used as a support during the design phase of the project, and at the same time as a basis for a possible justification of the admitted values used during the execution of the work.

- Case study: application of the methodology and parameters in a selected project. Finally, the document generated will be put into practice in a selected project in our territory in order to draw a conclusion about the efficiency of the document generated.

V. CONTENTS / ANALYSIS

V.1. State of art of international earth construction regulation

Over the years, many countries around the world have drafted legislation to regulate the status of earthen construction. Some were pioneers in this proposal, like India, Brazil or Turkey. On the other hand, countries like Spain or Burkina Faso have only recently produced a normative document.

Country	Regulation	Organization	Technique		
			A	BTC	RE
African Regional	ARS 670-683:1996	ARSO		X	
Brazil	NBR 8491-8492:1986	ABNT		X	
	NBR 10832-10833:1989			X	
	NBR 10834-10832:1994			X	
	NBR 12023-12024:1992			X	
	NBR 12025:1990			X	
	NBR 13553:1996				X
	NBR 13554-13555:1996			X	
Burkina Faso	NBF 0.2-001-008:2009	FASANORM		X	
Cameroon	NC 102-114:2002	ANOR		X	
Colombia	NTC 5324	ICONTEC		X	
EEUU	NMAC 14.7.4:2009	CID	X	X	X
	ASTM E2392 M-10	ASTIM	X	X	X
France	XP P13-901,2001	AFNOR		X	
India	IS 2110:1980	BIS			X
India	IS 1725:1982			X	
India	IS 13827:1993		X		X
Italy	Ley nº378:2004		X	X	X
	L.R. 2/06 2 Ag. 2006		X	X	X
Kenya	KS 02-1070:1999	KEBS		X	
Nigeria	NIS 369:1997	SON		X	
New Zealand	NZS 4297-4299:1998	SNZ	X	X	X
Perú	NTE E 0.80:2000	SENCICO	X		
	NTP 331.201-203:1979	INDECOPI	X		
Senegal	NS 02-43:02-56:1999	ASN		X	
Spain	UNE 41410:2008	AENOR		X	
Sri Lanka	SLS 1382-1:1382-3:2009	SLSI		X	
Tunisia	NT 21.33-21.35:1996	INNORPI		X	
Turkey	TS 537:1985	TSI	X		
	TS 2514-2515:1985		X		
Zimbabwe	SAZS 724:2001	SAZ			X

Figure 9 - Regulations of construction with earth around the world

TUNISIA
NT 21.33:1996
NT 21.35:1996
FRANCE
XP P13-901 2001
SPAIN
UNE 41410:2008
ITALY
LEY Nº378:2004
L.R. 2/06 2 2006
TURKEY
TS 537:1985
TS 2514:1985
TS 2515:1985
COLOMBIA
NTC 5324
USA
NMAC 14.7.4:2009
ASTM E2392 M-10
INDIA
IS 2110:1980
IS 1725:1982
IS 13827:1993
SENEGAL
NS 02-43:1999
NS 02-44:1999
NS 02-45:1999
NS 02-46:1999
NS 02-47:1999
NS 02-48:1999
NS 02-49:1999
NS 02-50:1999
NS 02-51:1999
NS 02-52:1999
NS 02-53:1999
NS 02-54:1999
NS 02-55:1999
NS 02-56:1999
SRI LANKA
SLS 1382-1:2009
SLS 1382-2:2009
SLS 1382-3:2009
PERU
NTE E 0.80:2000
NTP 331.201:1979
NTP 331.202.1979
NTP 331.203:1979
KENYA
KS 02-1070:1999
BRAZIL
NBR 8491:1986
NBR 8492:1986
NBR 10832:1989
NBR 10833:1989
NBR 10834:1994
NBR 10835:1994
NBR 10836:1994
NBR 12023:1992
NBR 12024:1992
NBR 12025:1990
NBR 13553:1996
NBR 13554:1996
NBR 13555:1996
BURKINA FASO
NBF 0.2-001:2009
NBF 0.2-002:2009
NBF 0.2-003:2009
NBF 0.2-004:2009
NBF 0.2-005:2009
NBF 0.2-006:2009
NBF 0.2-007:2009
NBF 0.2-008:2009
CAMEROON
NC 102:2002
NC 103:2002
NC 104:2002
NC 105:2002
NC 106:2002
NC 107:2002
NC 108:2002
NC 109:2002
NC 110:2002
NC 111:2002
NC 112:2002
NC 113:2002
NC 114:2002
ZIMBABWE
SAZS 724:2001
NIGERIA
NIS 369:1997
NEW ZEALAND
NZS 4297:1998
NZS 4298:1998
NZS 4299:1999

On the other hand, we observe that many of the regulations are found in countries with less economic growth, such as the countries of the African continent. The countries that have generated normative documents within the European continent are the Mediterranean countries, because of their influence and close contact with the African continent. In total, there are 8 countries on the African continent that contain regulations on earth construction. The next continent with the most regulations is the European continent with 4 countries. This is followed by the South American continent with 3 regulations, the Asian continent with 2 countries with regulations, and the North American continent and Oceania with 1 country each.

In the table, it is specified which building systems are covered by each of the regulations. In general terms, CEB construction is the system that is most discussed. CEB construction is the most feasible when it comes to controlling the parameters and material characteristics, as the composition of the small elements, their form and the way they are arranged can be controlled. In contrast, the other two systems do not have many regulations governing them. This, in contrast to CEB construction, is justified in the same way. The construction with rammed earth and adobe, because of the composition of water and the compaction and construction of the system, it is difficult to control and set parameters that regulate both the composition and the construction of the system.

Figure 10 - Regulations of construction with earth around the world

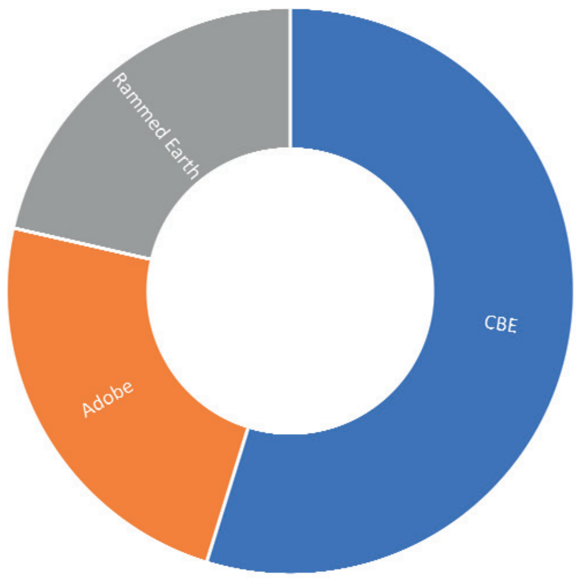


Figure 11 - Construction systems with earth regulateds

V.2. Analysis of climates

Once we have seen all the countries that have regulations, whether they are official or guidance documents, we study the climate of the different countries to see which ones can be taken as a reference to compare their regulations with the Spanish one.

The climate in Spain is a temperate climate, specifically located between the temperate zone and the subtropical climate. The difference between the maximum daily temperature and the minimum annual daily temperature is approximately 10°. The average annual absolute humidity is 68%, and the average annual number of rainy days is 70.8 days.

The climate of the USA, on a global level, presents general conditions similar to those of the Spanish climate. The climate is located between the subpolar zone and the tropics. The daily maximum and minimum temperature difference is approximately 11°, and the annual average absolute humidity is 67%. On an annual average, the USA has 85.2 days of rainfall.

Tunisia's climate has conditions close to those of Spain. The climate is located in the subtropics, with a daily maximum and minimum temperature range of about 9°. The average annual absolute humidity is 62%, less than the Spanish average, and it has about 42 rainy days a year.

Turkey's climate is very similar to that of Spain. The two climates are in the same climatic zone, between the temperate and the subtropical. The annual maximum and minimum temperature is about 11°. The average annual absolute humidity is 63%, and there are 75.6 days of rain per year, some more than in Spain.

The climates of France and Italy, given their proximity and the influence of the Mediterranean, share the same climatic zone.


TUNISIA
NT 21.33:1996
NT 21.35:1996
FRANCE
XP P13-901 2001
SPAIN
UNE 41410:2008
ITALY
LEY Nº378:2004
L.R. 2/06 2 2006
TURKEY
TS 537:1985
TS 2514:1985
TS 2515:1985
USA
NMAC 14.7.4:2009
ASTM E2392 M-10
COLOMBIA
NTC 5324
SENEGAL
NS 02-43:1999
NS 02-44:1999
NS 02-45:1999
NS 02-46:1999
NS 02-47:1999
NS 02-48:1999
NS 02-49:1999
NS 02-50:1999
NS 02-51:1999
NS 02-52:1999
NS 02-53:1999
NS 02-54:1999
NS 02-55:1999
NS 02-56:1999
INDIA
IS 2110:1980
IS 1725:1982
IS 13827:1993
SRI LANKA
SLS 1382-1:2009
SLS 1382-2:2009
SLS 1382-3:2009
PERU
NTE E 0.80:2000
NTP 331.201:1979
NTP 331.202:1979
NTP 331.203:1979
BRAZIL
NBR 8491:1986
NBR 8492:1986
NBR 10832:1989
NBR 10833:1989
NBR 10834:1994
NBR 10835:1994
NBR 10836:1994
NBR 12023:1992
NBR 12024:1992
NBR 12025:1990
NBR 13553:1996
NBR 13554:1996
NBR 13555:1996
BURKINA FASO
NBF 0.2-001:2009
NBF 0.2-002:2009
NBF 0.2-003:2009
NBF 0.2-004:2009
NBF 0.2-005:2009
NBF 0.2-006:2009
NBF 0.2-007:2009
NBF 0.2-008:2009
KENYA
KS 02-1070:1999
CAMEROON
NC 102:2002
NC 103:2002
NC 104:2002
NC 105:2002
NC 106:2002
NC 107:2002
NC 108:2002
NC 109:2002
NC 110:2002
NC 111:2002
NC 112:2002
NC 113:2002
NC 114:2002
ZIMBABWE
SAZS 724:2001
NIGERIA
NIS 369:1997
NEW ZEALAND
NZS 4297:1998
NZS 4298:1998
NZS 4299:1999

V.3. Comparison of the selected regulations

An important part of the regulations focus on a single building system, whether it is rammed earth, adobe or CEB blocks. In this aspect, the Spanish, French and Tunisian regulations focus exclusively on the CEB building system, while the Italian and American regulations cover all three building systems mentioned. The Turkish regulation finally focuses on the use of adobe. In this case, the Turkish standard will be dismissed because of the construction system and the age of the normative.

V.4. Field of application of the regulations

Each regulation focuses its content on different aspects of earth construction. The New Mexico regulation (NMAC 14.7.4), for example, determines requirements on the construction and execution of the different systems.

Both the Spanish and the American regulations talk about stabilisation of the different systems. In the case of the Spanish standard, the total content of stabilisers (cement, plaster, lime and others) has to be less than or equal to 15% of the block content. On the other hand, the American standard defines different values of water absorption depending on whether the system is with adobe, rammed earth or CEB.

Regarding the selection of substrates, the regulations generally talk about the plasticity and texture of the soils appropriate for the different systems, introducing the relevant diagrams in both cases. On the other hand, the Spanish and French regulations propose different scenarios for checking the composition of the soil where the work will be carried out, and evaluate it according to the chosen system, since there is no direct relationship between the behaviour of the product and the characteristics of the soil used. In this way, they propose tests to be applied and results with minimum values required according to the technique used. On the other hand, the American standards propose the testing of the resistance of the blocks once they have been made, with the same system that could be applied to bricks or to the construction with the system of small elements.

On the other hand, they also define requirements for the final product, both for adobe, CEB and rammed earth construction. These specifications refer to the classification of the products, dimensions, geometric, appearance, physical or mechanical characteristics, hygrometry, ... setting required and recommended values. In the American and French standards, these values must be obtained by means of tests, as these values are not standardised. So, the method to execute the tests is defined. In the case of the Spanish standard, a classification of CEB blocks is proposed according to the compression characteristics of the blocks. On the other hand, the standard allows the creation of blocks with perforations.

In this way, the Spanish and French regulations determine certain conditions regarding the reception of the blocks, the standards to be used and the conditions under which the different systems can be accepted.

Finally, the regulations in general describe a series of test methods to test the samples. All the regulations include other aspects in addition to those mentioned above to be evaluated in the different samples, such as erosion tests on CEB, the organic substance content of the material, the water absorption of the CEB blocks, linking the values to those of the bricks or applying humidification and drying cycles or compressive strength.

Regarding the compressive strength of the elements, we find that the French standard proposes tests on broken and stacked blocks, while the Spanish standard proposes tests on the whole piece as the presence of mortar is required by the regulation itself. The American standard, on the other hand, also proposes testing the tensile strength with modulus of rupture or the tensile strength of individual elements.

V.5. Spanish legislation

Looking at the Spanish regulations, it defines some parameters that are particularly interesting for the formulation of the normative document.

On the one hand, it distinguishes between two types of blocks: ordinary blocks and blocks with a visible face. The specifications and parameters that each block has to achieve are more rigorous for blocks with a visible face than for ordinary blocks, since the last ones have to be plastered and their characteristics have to be improved with external elements.

When defining the system, several characteristics are specified that both the blocks used during the work and the execution of the structure as a whole must have. One of the parts established by the regulations is the execution of the joints. The document determines that the vertical joint must be continuous and 15 mm thick. On the other hand, the horizontal joint only specifies that it must be continuous, without specifying its thickness.

On the other hand, the regulation speaks of another important component within the system, which it calls “accessory blocks”. Accessory blocks are elements such as lintels that form part of the system but work differently from the general block. Of these, it specifies that they must have the same nature as the blocks that join them in the structure, without going into more detail.

One of the aspects that the regulation takes into account is the presence of defects in the blocks themselves. So, it specifies what margins of error in the generation of the blocks are admissible while accepting or not accepting these blocks.

One of the most important aspects of this regulation is the delimitation of the different materials that can make up the block. On the one hand, we have the additives and/or stabilisers. In this case, only the use of materials such as cement, clay or chalk is allowed, up to a total of 15% of the dry mass of the CEB. Otherwise, the composition of the main material, the earth, is defined by the union of gravels, sands, slimes and clay, mixed with water. Only earth compositions with at least 10% of the total composition of clay are allowed.

To verify that the earth is apt to be used, the regulations present two diagrams, one of granulometry and one of plasticity, to highlight the optimum values of the two components.

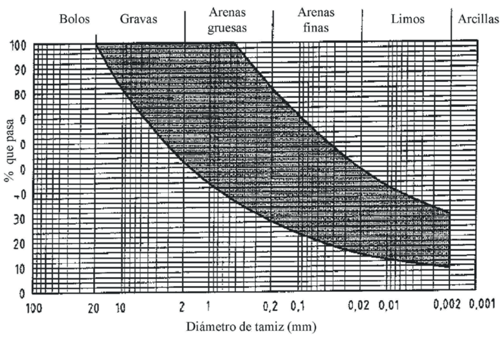


Figure 12 - Thickness diagram

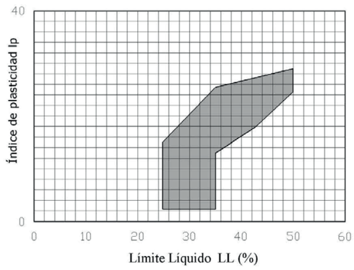


Figure 13 - Plasticity diagram

This is everything that the Spanish regulations specify in respect of the composition, the material, the system and the final result of the structure. From here, it goes on to specify in more detail the characteristics that the blocks themselves must have once they have been executed.

The regulations define 3 types of blocks, according to their resistance to compression, in N/mm2.

Another parameter is the resistance to wet/dry cycles. This test is a laboratory test, and is only applied to the blocks known as "severely exposed bricks". These blocks are the blocks intended to be used with an exposed face, without cladding at a later stage. Once the six cycles to which they must be subjected have been executed, no deterioration can be observed, such as cracks, fissures, local cavities, generalised loss of material, water penetration over more than 70% of their width, or efflorescence.

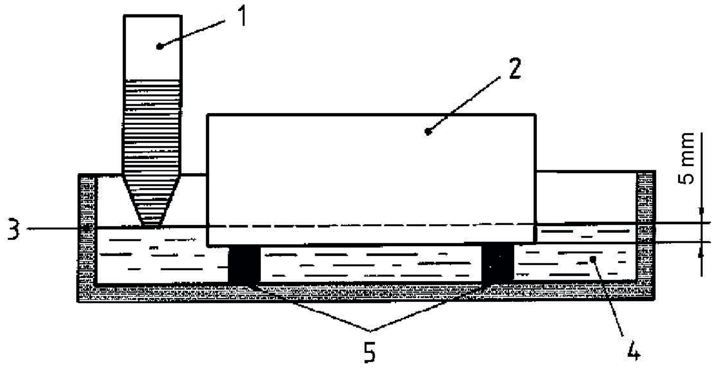


Figure 14 - Humidification and drying test

One of the tests to which blocks intended to be used with an exposed face are tested is the erosion resistance test. The article determines that, in order for a block to be apt for use, once the test has been executed, no blocks with cavities deeper than 10 mm can be observed.

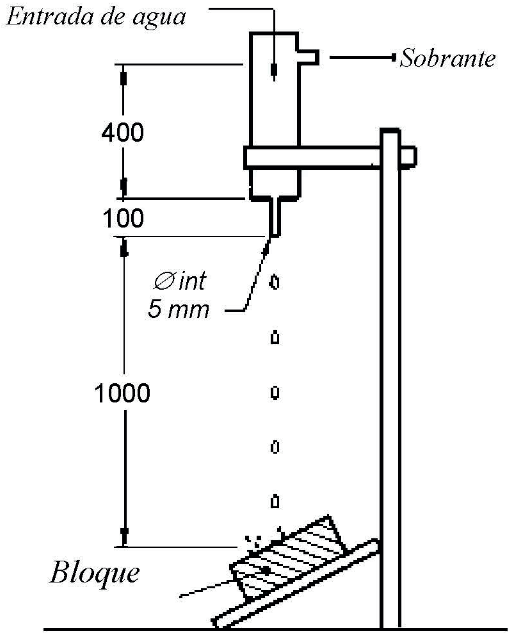


Figure 15 - Erosion test

So that's it, these are the points determined by the Spanish regulations on the use of CEB as a building material.

After taking a closer look at the other regulations, there are certain aspects of the Spanish regulations that are interesting and others that, on the other hand, the other regulations go into more detail.

Interesting points

- The definition of which materials are allowed and which are not allowed for earth construction, with precise values on the composition and possible materials that may or may not be used as additives or stabilisers.

- The standardisation of two important tests to verify the suitability of the blocks: the wet/ dry process and the erosion resistance test.

Deficiencies

- Poor specification of the system as a unit. The regulations do not contemplate the use of CEB as a single material in the structural system. If it was used as the only system, the whole building would not be covered by any normative document.

V.6. Contributions from other legislation

V.6.1. French legislation

French regulations are very similar to Spanish regulations. They use the same values to define the tolerances regarding the defects that the blocks may have, so that they remain efficient. Even so, there are certain aspects that may be of great interest:

-Classification of blocks by typology. Classification of the blocks according to their use in the general structure of the building. In this way, it determines requirements for each of the blocks according to their use. These blocks are:
Common blocks: blocks used to build walls or partitions, with dimensions of 14x9.5x29.5cm or 22x9.5x22cm
Accessory blocks: blocks for resolving particular points such as vertical chaining, lintels or angle blocks.
Service blocks: blocks to be used as service blocks for an existing wall, to improve its thermal and resistance conditions.

- Classification of blocks by categories. Classification according to the quality and resistance of the block.
Category O: blocks to be covered.
Category P: blocks for facing with the surface to be seen.
Category S: blocks for dry locations, where the wet compressive strength of the block is almost zero.
Category H: blocks for wet locations, with wet compressive strength.
Category A: blocks with resistance to human activity, resistance to erosion and abrasion.

- Classification by compressive strength. The regulations classify the blocks according to their compressive strength, indicating the following values:
BTC 20: bearing capacity of 2 MPa.
BTC 40: bearing capacity of 4 MPa
BTC 60: bearing capacity of 6 MPa

Therefore, from the French regulations, classifications of blocks according to the category and use of the block, and according to its compressive strength capacity, are of particular interest.

V.6.2. American legislation (New Mexico)

Regarding the American regulations, there are certain aspects that can be very useful when it comes to defining some of the parameters of the future single document.

One of the parameters is the maximum height depending on the thickness of the wall. The heights are therefore determined by the following thicknesses:

Wall Thickness	Maximum Height	
10	120"	3,05m
12	128"	3,25m
14	144"	3,65m
16	144"	3,65m
18	144"	3,65m
24	144"	3,65m

Figure 16 - Table 1: dimensions of the walls

One of the limitations described in the document is that buildings with CEB cannot exceed two storeys in height. At the same time, it delimits two typologies of blocks, according to the resistance of the blocks once saturated in water. If they do not achieve the resistance, these blocks cannot be used in the first four inches (10cm).

However, it prohibits the use of CEB for the foundation. The foundation is determined by footings at least 33% wider than the total thickness of the wall, with a minimum thickness of 25cm, with the footing centred. On the other hand, the upper finish will be by means of a perimeter strip, no bigger than 20cm and with a width equal to the thickness of the wall.

To join the CEB structure to the horizontal slab, the regulations propose two alternatives: concrete beams and wooden beams. Both maintain the same conditions: beams at least 15cm high and 25cm thick.

Finally, it describes and defines the additions that can be incorporated into the construction system. On the one hand, it talks about insulation, plastering, stucco and waterproof sheeting. In general terms, what it describes is the need to allow permeability and breathability for the system to work. Therefore, from the American standard, we will take the delimitations in the dimensions of the blocks, the walls, the determinations and characteristics of the different elements that make up the system, such as the foundation, the top finish and the connection with the horizontal slabs, and the determinations regarding the finishes and additions to the system, such as insulation, plastering and waterproofing.

Once we have analysed each of the documents and the factors that may be of interest to us in formulating the unitary document, we combine all the aspects in a unitary sheet, similar to the justification sheets used by the COAC (Association of Architects of Catalonia), to serve as a guide when designing the architecture with CEB.

Project reference:

Typology of construction: ☐ New Construction ☐ Reform

CONDITIONS FOR STRUCTURES AND CONSTRUCTIONS USING CEB BLOCKS

▪ **Use of the CEB blocks**	Structural walls and partitioning		☐
	Paraments		☐
	Accessory blocks (lintels, corner blocks, blocks, vertical chaining,...)		☐
▪ **Surface treatment**	Faced (O)		☐
	Covered (P)		☐
▪ **Category of blocks**	Dry environments (S) (no compressive strength against satuation of the block in water, not to be used in the first 10cm of row)		☐
	Wet environments (H)		☐
	Environments exposed to erosion, abrasion and humidity (A)		☐
▪ **Structural system**	**Foundation**	CEB blocks are not used for foundations	☐
		Reinforced concrete footings at least 33% of the width of the wall thickness	☐
	Structural walls	The height and thickness of the walls comply with the dimensions described in table 1 of the appendix to this document	☐
		The walls are finished with a 20cm high perimeter strip of the same thickness as the wall	☐
	Horizontal slab	The horizontal slab is connected to the structural walls with concrete or wooden bond beams of at least 15x25cm	☐
▪ **Compressive strength of blocks**	CEB 20 ☐	CEB 40 ☐	CEB 60 ☐
▪ **Insulation, stuccos, cladding and waterproof sheets**	The cladding, stucco, insulation and waterproof sheets are executed in accordance with the CTE and, at the same time, allow the permeability and breathability of the wall, in accordance with the thermal behaviour of the concrete blocks		☐
▪ **Composition of the blocks**	Additives and/or stabilisers, such as cement, lime or gypsum, do not exceed 15% of the total mass of the CEB block		☐
	The earth used for the production of blocks contains more than 10% clay, and is composed of gravels, silts and sands of small format		☐
	The blocks comply with the requirements of degradation, deformation and defects determined in the annex to this document		☐
	The blocks have been subjected to erosion and capillary tests as stipulated in the annex to this document		☐

APPENDIX TO THE SUPPORTING STATEMENT

- Allowable wall heights for CEB structures. All CEB structures shal conform to table 1. For purposes of using table 1, height is defined as the distance from the top of the slab or top of stem wall to the underside of the bond beam.

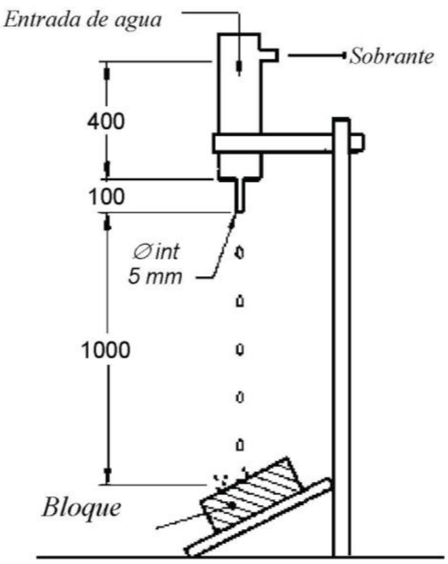
Wall Thickness	Maximum Height	
10	120"	3,05m
12	128"	3,25m
14	144"	3,65m
16	144"	3,65m
18	144"	3,65m
24	144"	3,65m

- Swinburne accelerated erosion test (SAET)

A continuous flow of water is allowed to fall on the block for 10 minutes through a Ø=5mm glass tube, connected to a constant level water tank, 1.5 m above the face of the block. The block shall be placed at 27º to the horizontal. Using a Ø=3mm rod, the holes are sized (D).

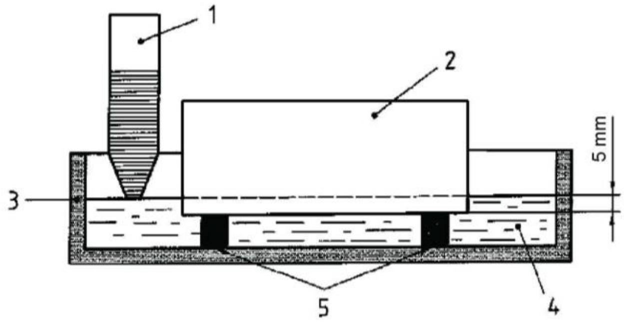
The CEB shall be classified as "suitable" or "unsuitable" depending on the following conditions:

$0 \leq D \leq 10$ → Suitable
$D > 10$ → Unsuitable



- Wet/dry test

The same procedure as indicated in the standrard UNE-EN 772-11:2001 i UNE-EN-772- 11:2001/A1:2006 shall be followed, but the drying shall be at 70ºC and the immersion time shall be 10 min.



VI. CASE OF STUDY

Once we have the justification document, we put it into practice with a building constructed with CEB, to see the viability of the document and its usefulness.

The chosen project is the construction of a single-family house in Mallorca. The goal of the project was to build a house as efficient as possible, following the bases of what is known as Passivhaus. The "EcoCreamos" team decided to design the house with CEB blocks, wooden beams and substructure, cork insulation and lime and clay mortar. The project, as described by the team itself, has followed the requirements described in the UNE41410 standard, the document described above and the only written document on earthen construction at a regulatory level in Spain.

Figure 17 - Image of the building to study

Figure 18 - Ground floor plan

Figure 19 - First floor plan

The project is located in Lluchmajor, near Palma de Mallorca. The project is developed on two stories, with supporting wall structure and with two covered terraces to the north-west and south-east. The living area of the building is about 142 m^2.

Construction elements

The composition of the slab in contact with the ground is:
- gravel base
- 10 cm of concrete foundation with steel mesh.
- 8 cm of natural black cork boards
- 8 cm of graba for installations and conducts.
- 6 cm of continuous concrete pavement as a finish.

The composition of the exterior walls is:
- 30 cm CEB, with a row of thermo-clay masonry base on the foundation.
- Waterproof-breathable sheeting

- Insulating panels of 18 cm of wood fibre.
- 3x3 cm wooden vertical strips forming an air chamber
- Waterproof-breathable sheet
- 7 cm brick partition wall
- 2 cm mortar plastering if necessary.

Intermediate floor slab composition:
- 15x24 cm wooden beams
- 15 mm gypsum board
- Concrete slab with 10 cm mesh
- 9 cm wooden battens and wooden decking

Final composition of the roof:
- 10x20 cm exposed laminated timber beams.
- 15 mm gypsum board
- Waterproof sheet
- 16 cm insulating panel
- Waterproof-breathable sheet
- Reinforced concrete compression layer with mesh, 6 cm thick
- Arabic tile with mortar

The composition of the openings and doors, are with wooden carpentry and low emissive double glass.

With these elements, we can check by means of the justification document, if this project would be feasible with the new parameters.

Figure 20 - Image of the construction system

Figure 21 - Image of the construction system

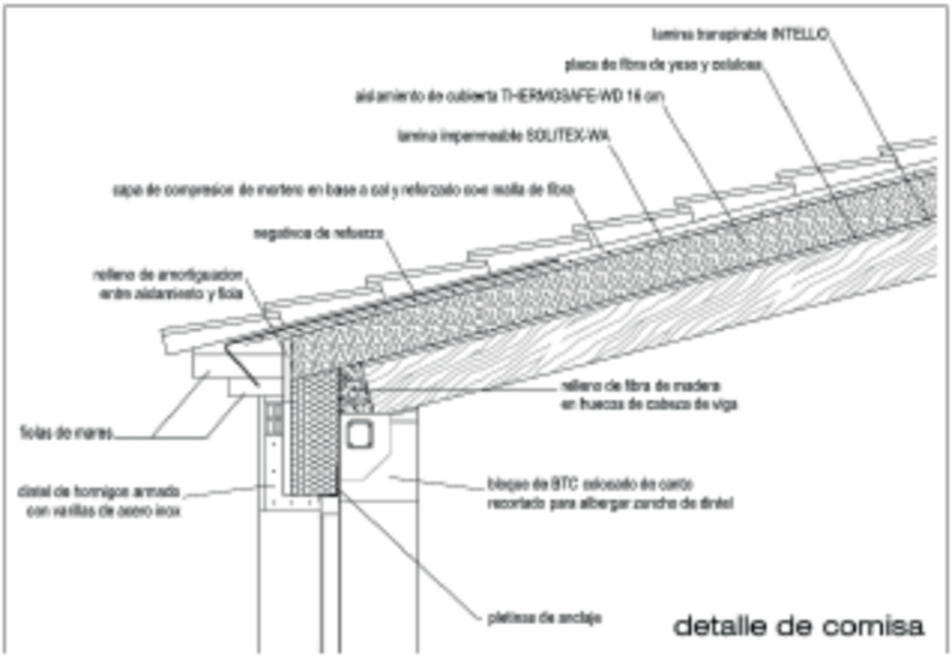


Figure 22 - Detail of the construction system

Project reference: Detached house in Mallorca

Typology of construction:

- [X] New Construction
- [ ] Reform

CONDITIONS FOR STRUCTURES AND CONSTRUCTIONS USING CEB BLOCKS

Use of the CEB blocks	Structural walls and partitioning		X
	Paraments		
	Accessory blocks (lintels, corner blocks, blocks, vertical chaining,...)		X
Surface treatment	Faced (O)		X
	Covered (P)		
Category of blocks	Dry environments (S) (no compressive strength against satuation of the block in water, not to be used in the first 10cm of row)		X
	Wet environments (H)		X
	Environments exposed to erosion, abrasion and humidity (A)		
Structural system	**Foundation**	CEB blocks are not used for foundations	X
		Reinforced concrete footings at least 33% of the width of the wall thickness	X
	Structural walls	The height and thickness of the walls comply with the dimensions described in table 1 of the appendix to this document	X
		The walls are finished with a 20cm high perimeter strip of the same thickness as the wall	
	Horizontal slab	The horizontal slab is connected to the structural walls with concrete or wooden bond beams of at least 15x25cm	X
Compressive strength of blocks	CEB 20 · CEB 40 · CEB 60		X
Insulation, stuccos, cladding and waterproof sheets	The cladding, stucco, insulation and waterproof sheets are executed in accordance with the CTE and, at the same time, allow the permeability and breathability of the wall, in accordance with the thermal behaviour of the concrete blocks		
Composition of the blocks	Additives and/or stabilisers, such as cement, lime or gypsum, do not exceed 15% of the total mass of the CEB block		X
	The earth used for the production of blocks contains more than 10% clay, and is composed of gravels, silts and sands of small format		X
	The blocks comply with the requirements of degradation, deformation and defects determined in the annex to this document		X
	The blocks have been subjected to erosion and capillary tests as stipulated in the annex to this document		X

APPENDIX TO THE SUPPORTING STATEMENT

- Allowable wall heights for CEB structures. All CEB structures shal conform to table 1. For purposes of using table 1, height is defined as the distance from the top of the slab or top of stem wall to the underside of the bond beam.

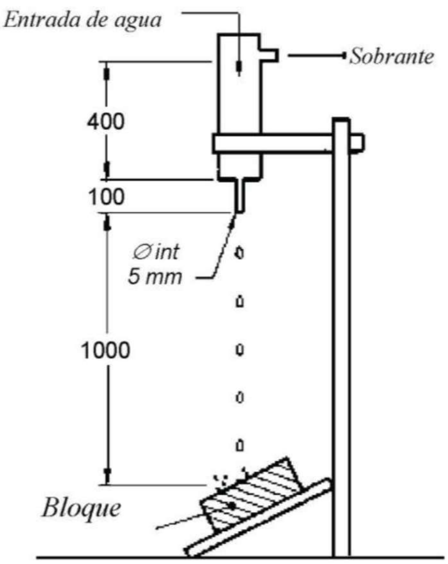
Wall Thickness	Maximum Height	
10	120"	3,05m
12	128"	3,25m
14	144"	3,65m
16	144"	3,65m
18	144"	3,65m
24	144"	3,65m

- Swinburne accelerated erosion test (SAET)

A continuous flow of water is allowed to fall on the block for 10 minutes through a Ø=5mm glass tube, connected to a constant level water tank, 1.5 m above the face of the block. The block shall be placed at 27º to the horizontal. Using a Ø=3mm rod, the holes are sized (D).

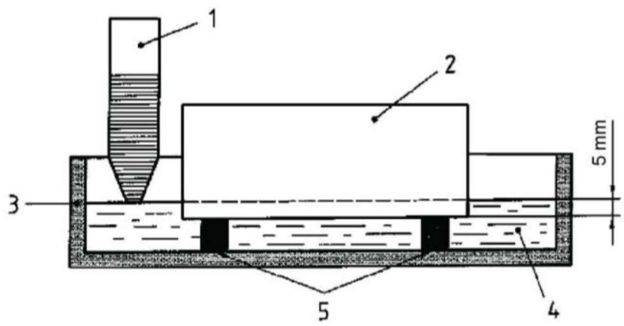
The CEB shall be classified as "suitable" or "unsuitable" depending on the following conditions:

$0 \leq D \leq 10$ → Suitable
$D > 10$ → Unsuitable



- Wet/dry test

The same procedure as indicated in the standrard UNE-EN 772-11:2001 i UNE-EN-772- 11:2001/A1:2006 shall be followed, but the drying shall be at 70ºC and the immersion time shall be 10 min.



VII. CONCLUSIONS

VII.1. Final result

Once the document has been put into practice, we can see how a project that was a priori designed to satisfy the requirements established by the current regulations does not achieve some of the new parameters. In particular, it does not satisfy the performance required for the finishes of the façade walls, since even though the ventilated air chamber allows the system to breathe, which is essential for the CEB to work, the second layer of brick means that the system works in two different ways, and the CEB block layer does not take advantage of all the features offered by the material. The rest of the elements do satisfy the parameters of the other regulations, so we can conclude that they are not parameters that cannot be achieved or that limit the design and projection with this system.

VII.2. Conclusions from the research

The purpose of the project was to find out about the situation of earthen construction in Spain, at a legal level, and if this was one of the difficulties encountered in the design and construction of earthen constructions.

From the beginning, the research work was faced with certain objectives. The main objectives were to investigate the state of the art of the legislation on earth construction, to make an analysis of the Spanish legislation following the comparative method with regards to other existing international regulations, and to draw up a unitary document that included various aspects of some of the previously chosen regulations.

The state of the art of regulations on earth construction at the international level is highly centralised in some regions. The African continent has the most countries with regulations, distributed in various parts of the continent. On the other hand, on the European continent, the countries with the most regulations are the Mediterranean countries, because of their influence and proximity to the African continent. Finally, the third continent with the most regulations, the South American continent, it is the countries in the north of the continent that standardise earth construction.

With this research, the virtues and weaknesses of the Spanish regulations have been found, in comparison to the rest of the regulations, and following the bases of the Spanish regulations, some criteria have been proposed that could be added to the proposed regulations suggested by AENOR, to complete the regulations and to include not only the composition and creation of the CEB blocks, but also the construction system as a whole.

Finally, the document created was tested with a practical case, which was executed following the recommendations of the regulations written by AENOR, to see if the parameters that have been added to the regulations were viable and followed the guidelines of the previous document.

This research is presented as a seed so that, in the future, it can become a reality. The construction with earth, given the current global situation generated by climate change and the more than possible end of the materials used today in the world of construction, has to be a more than viable option when designing architecture.
There are many countries that, due to their tradition, have standardised the construction system. On the other hand, other countries such as Spain have forgotten it, despite the fact that it is also part of our tradition. It is time to propose this system as a viable system in the national territory, and to offer the tools and resources to facilitate its implementation within our territory. And an important part of this is to create a document that compiles the system and the materials.

VIII. LEGISLATIONS

LEGISLATIONS

- AENOR: Normalización y actividades relacionadas. Vocabulario general. UNE-EN 45020. (Guía ISO/IEC 2:2004) Madrid, 2007
- ABNT: Tijolo maciço de solo-cimento. NBR 8491 EB1481. Associaçao Brasileira de Normas Técnicas, Rio de Janeiro, 1984
- ABNT: Tijolo maciço de solo-cimento - Determinaçao da resistencia à compressao e da absorçao d´água. NBR 8492 MB1960. Associaçao Brasileira de Normas Técnicas, Río de Janeiro, 1984
- ABNT: Fabricaçao de tijolo maciço de solo-cimento com a utilizaçao de prensa manual. NBR10832 NB1221. Associaçao Brasileira de Normas Técnicas, Río de Janeiro, 1989
- ABNT: Fabricaçao de tijolo maciço e bloco vazado de solo-cimento com utilizaçao de prensa hidráulica. NBR 10833 NB1222. Associaçao Brasileira de Normas Técnicas, Río de Janeiro, 1989
- ABNT: Bloco vazado de solo-cimento sem funçao structural. NBR 10834 EB1969. Río de Janeiro. Associaçao Brasileira de Normas Técnicas, 1994
- ABNT: Bloco vazado de solo-cimento sem funçao estructural - Forma e dimensoes. NBR 10835 PB1391. Associaçao Brasileira de Normas Técnicas, Río de Janeiro, 1994.
- ABNT: Bloco vazado de solo-cimento sem função estrutural - Determinação da resistência à compressão e da absorção de agua. NBR 10836 MB3072. Associação Brasileira de Normas Técnicas, Río de Janeiro, 1994.
- ABNT: Solo-cimento - Ensaio de compactação. NBR 12023 MB3359. Associação Brasileira de Normas Técnicas, Río de Janeiro, 1992.
- ABNT: Solo-cimento - Moldagem e cura de corpos-de-prova cilíndricos. NBR 12024 MB3360. Associação Brasileira de Normas Técnicas, Río de Janeiro, 1992.
- ABNT: Solo-cimento - Ensaio de compressão simples de corpos-de-prova cilíndricos. NBR 12025 MB3361. Associação Brasileira de Normas Técnicas, Río de Janeiro, 1990.
- ABNT: Solo-cimento - Ensaio de durabilidade por molhagem e secagem. NBR 13554. Associação Brasileira de Normas Técnicas, Río de Janeiro, 1996.
- ABNT: Solo-cimento - Determinação da absorção d´água. NBR 13555. Associação Brasileira de Normas Técnicas, Río de Janeiro, 1996.
- ABNT: Materiais para emprego em parede monolítica de solo-cimento sem função estrutural. NBR13553. Associação Brasileira de Normas Técnicas, Río de Janeiro, 1996.
- ICONTEC: Bloques de suelo cemento para muros y divisiones. Definiciones. Especificaciones. Métodos de ensayo. Condiciones de entrega. NTC 5324. Instituto Colombiano de Normas Técnicas y Certificación, 2004.
- CID: New Mexico Earthen Buildings Materials Code. NMAC 14.7.4.2003. Construction Industries Division CID of the regulation and Licensing Department, Santa Fe, 2004.
- ASTM International: Standard Guide for Design of Earthen Wall Buildings Systems. E2392 M-10. Pennsylvania 19428-2959, United States, 2010.
- AENOR: Bloques de tierra comprimida para muros y tabiques. Definiciones, especificaciones y métodos de ensayo. UNE 41410, Madrid, 2008.
- AFNOR: Compressed eart blocks for walls and partitions: definitions - Specifications - Test methods - Delivery acceptance conditions. XP P13-901, Saint-Denis La Plaine Cedex, 2001.
- BIS: Code of practice for in-situ construction of walls, in building soil.cement. IS 2110 Bureau of Indian Standards, 1980.
- BIS: Improving earthquake resistance of earthen buildings - Guidelines, IS 13827, BUreau of Indian Standards, 1993.

- Italia. Legge 24 Diciembre 2003, n.378: "Disposizioni per la tutela e la valorizzazione dell'architettura rurale". Gazzetta Ufficiale, nº13 (2004).
- Italia. Regione Piemonte L.R. 2/06: "Norme per la valorizazzione delle costruzioni in terra cruda". B.U.R. Piemonte, nº3 (2006).
- KEBS: Specifications for stabilized soil blocks. KS02-1070:1993 (1999) Nairobi: Kenya Bureau of Standards, 1999.
- SON: Standard for stablized eart bricks. NIS 369:1997. Lagos: Satndards Organisation of Nigeria, 1997.
- SNZ: Engineering design of eart buildings. NZS 4297:1998. Wellington: Standards New Zealand, 1998.
- SNZ: Materials and workmanship for earth buildings. NZS 4298:1998. Wellington: Standards New Zealand, 1998.
- SNZ: Earth buildings not requiring specific design. NZS 4299:1999. Wellington: Standards New Zealand, 1998.
- SENCICO: Adobe. NTE E 0.80. Reglamento Nacional de COnstrucciones, Lima, 2000.
- INDECOPI: Elementos de suelo son cocer: adobe estabilizado con asfalto para muros: Métodos de ensayo. NTP 331.202. Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual, Lima, 1978.
- INDECOPI: Elementos se suelos sin cocer: adobe estabilizado con asfalto para muros: Muestra y recepción. NTP 331.203. Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual, Lima, 1978.
- ARSO: Compressed earth blocks, Standard for terminology. African Regional Standard 670:1996 Nairobi, 1996.
- ARSO: Compressed Earth Blocks, Definition, classification and designation of compressed earth blocks. African Regional Standards 671:1996 Nairobi, 1996.
- ARSO: Compressed Earth Blocks, Definition, classification and designation of earth mortars. African Regional Standard 672:1996 Nairobi, 1996.
- ARSO: Compressed Earth Blocks. Definition, classification and designation of compressed earth blocks masonry. African Regional Standard 673:1996 Nairobi, 1996.
- ARSO, Compressed Earth Blocks. Technical specifications for ordinary compressed earth blocks. African Regional Standard 674:1996 Nairobi, 1996.
- ARSO: Compressed Earth Blocks-Technical specifications for facing compressed earth blocks. African Regional Standard 675:1996 Nairobi, 1996.
- ARSO: Compressed Earth Blocks-Technical specifications for ordinary earth mortars. ARS 676:1996 Nairobi, 1996.
- ARSO. Compressed Earth Blocks-Technical specifications for facing earth mortars. ARS 677:1996 Nairobi, 1996.
- ARSO: Compressed Earth Blocks-Technical specifications for ordinary compressed earth block masonry. ARS 678:1996 Compressed Earth Blocks-Technical specifications for ordinary compressed earth block masonry. Nairobi, 1996.
- ARSO: Compressed Earth Blocks-Technical specifications for facing compressed earth block masonry. ARS 679:1996 Nairobi, 1996.

- ARSO: Compressed Earth Blocks. Code of practice for the production of compressed earth blocks. ARS 680:1996 Nairobi, 1996.
- ARSO: Compressed Earth Blocks. Code of practice for the preparation of earth mortars. ARS 681:1996 Nairobi, 1996.
- ARSO: Compressed Earth Blocks. Code of practice for the assembly of compressed earth block masonry. ARS 682:1996 Nairobi, 1996.
- ARSO: Compressed Earth Blocks. Standard for classification of material identification tests and mechanical tests. ARS 683:1996 NAirobi, 1996.
- SLSI: Specification for compressed stabilized earth blocks. Part 1: Requirements SLS 1382-1. Sri Lanka Standards Institution, 2009.
- SLSI: Specification for compressed stabilized earth blocks. Part 2: Test Methods. SLS 1382-2. Sri Lanka Standards Institution, 2009.
- SLSI: Specification for compressed stabilized earth blocks. Part 3: Guidelines on production, design and construction. SLS 1382-3. Sri Lanka Standards Institution, 2009.
- INNORPI: Blocs de terre comprimée ordinaires . Spécifications techniques. NT 21.33:1996. Tunisian Standards, 1998.
- INNORPI: Blocs de terre comprimée - Définition, classification et désignation. NT 21.35:1996. Tunisian Standards, 1998.
- TSE: Cement Treated Adobe Bricks. TS 537. Turkish Standard Institution, Ankara, 1985.
- TSE: Adobe Blocks and Production Methods. TS 2514. Turkish Standard Institution, Ankara, 1997.
- TSE: Adobe Buildings and Construction Methods. TS 2515. Turkish Standard Institution, Ankara, 1985.
- SAZ: Standard Code of Practice for Rammed Earth Structures. SAZS 724:2001. Standards Association of Zimbabwe, Harare, 2001.
Keable, J.: Rammed Earth Structures. A code of Practice. Intermediate Technology Publications, London, 1996.

IX. BIBLIOGRAPHY

ABERBACHE, Sabrina, MAINI, Serge, 2013. Production et utilisation des blocs de terre comprimée et stabilisée: code de bones pratiques. Auroville: Auroville Earth institute

ARTTERRE Mayotte. Règles professionelles. Blocs de terre comprimée. BTC Mayotte. Juliet 2022

BARAMBIO Buisán, Amarante; RODRÍGUEZ Ramos, Eduardo. Proyecto Tierra – Passivhaus de BTC en Mallorca

BESTRATEN S., HORMÍAS E., ALTEMIR A. Informes de la Construcción, vol. 63, 523, 5-20, julio-septiembre 2011. Construcción con tierra en el siglo XXI

CDI, Center for the Development of Industry, BOUBEKEUR S. (CDI), HOUBEN H. (CRATERRE-EAG). Technologies series nr.11. Compressed earth blocs. Standards

CDI, Center for the Development of Industry, CRATERRE. Compressed Earth Blocks. Selection of production equipment

CIB W90 CEB, 1996. Blocs de Terre Comprimée: essais d'identification des matériaux et essais mécaniques. Méthodes de vérification de terrain. Document provisoire

CID-FALCETO, Jaime, MOSQUERA, Pablo, MARCOS, Francisco, CRUZ CALLEJA, Perucho, CAÑAS, Ignacio. Approximation to earth material from International normative. Polytechnic University Madrid

HERNANDEZ, Basilio O., 1984. Normas de diseño para Construcciones a base de adobe estabilizado "Tabicote"

HOUBEN H. (CRATERRE), MATUK S. (CRATERRE), DOAT P. (CRATERRE). Construire en terre

LE CRATERRE. ecologik 12, construire en terre

LE MONITEUR. Technique & Chantier. Matériau, La terre crue rentre dans le moule. 18 Janvier 2013

PHYSICO-CHIMIE. Pour la science nº423 – Janvier 2013

RED HABITERRA, 1995. Recomendaciones para la elaboración de normes técnicas de edificacions de adobe, tapial, ladrillos y bloques de suelo-cemento

TERRES CRUES. La revue de la céramique et du verre. Numéro 146, Jan-Fév 2006

UPC Universitat Politècnica de Catalunya, BARREDA, Xavier, TOUS, Victoria, MARTIN, Andrea. Step on Step: BCN FES XAU 19-20: International Laboratory of Collaborative Architecture

X. ANNEXES

A.1. Projects 3: Campus for artists at Vilafamès. ETSAB

Project for the creation of a campus for temporary stays for artists in Vilafamés, a village protected for its heritage importance, with great influence in the artistic world thanks to the importance of the Museum of Contemporary Art of Vilafamès.

Small spaces dedicated to the different types of users of the campus are projected: a space for the students, for the teachers and for the custodian, as well as a workshop and an exhibition room. The site inspires work with traditional materials, and its difficult accessibility offers the opportunity to work with the earth of the field itself, a terrain with a lot of clay. The walls are made of rammed earth, with sandwich panel roofs with steel plates to blend in with the surroundings, an environment with a strong presence of reddish stone and tile.

Figure 23 - Campus proposal

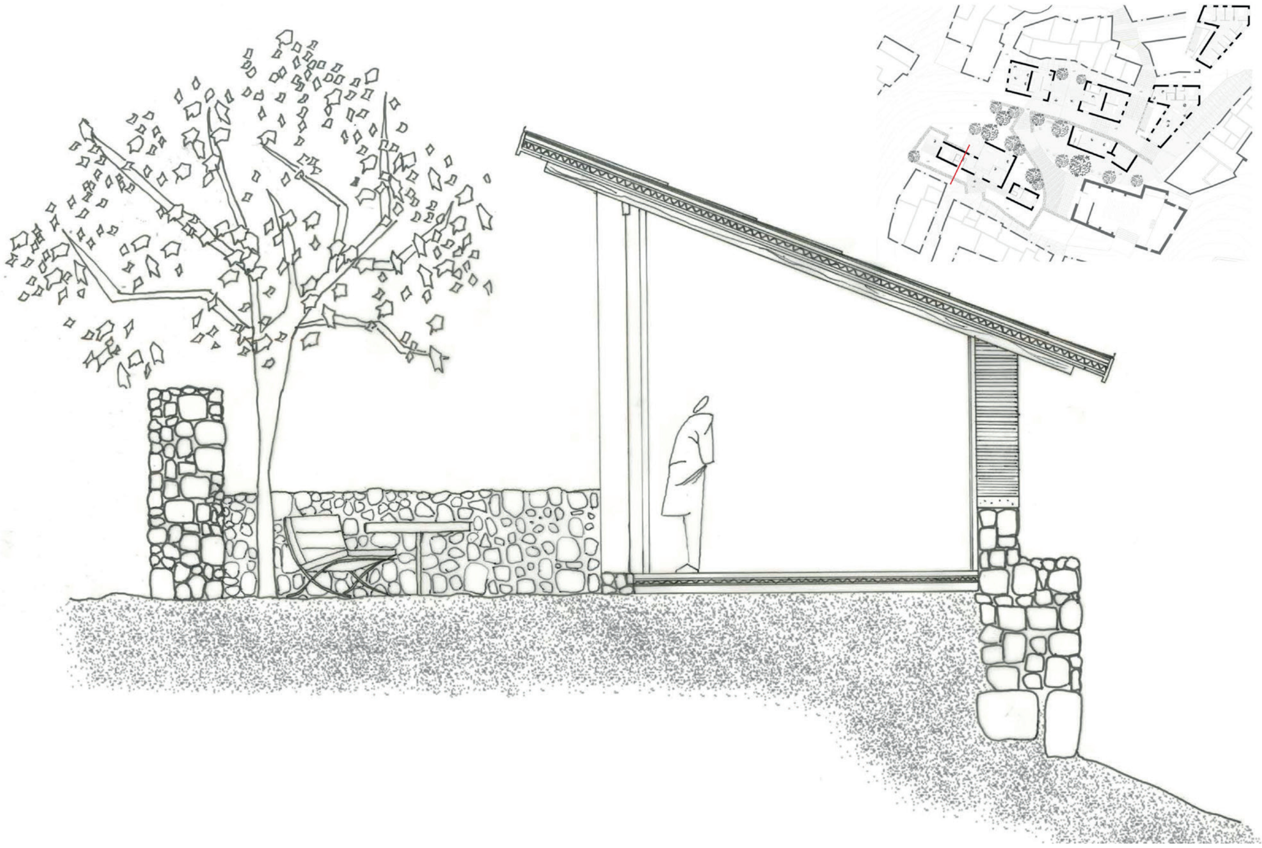


Figure 24 - Detail of the construction system

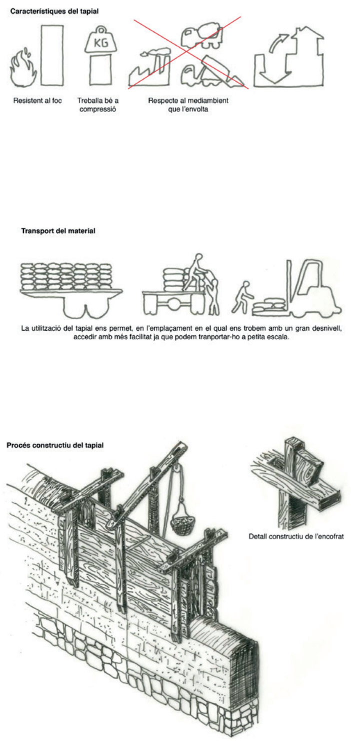


Figure 25 - Construction method

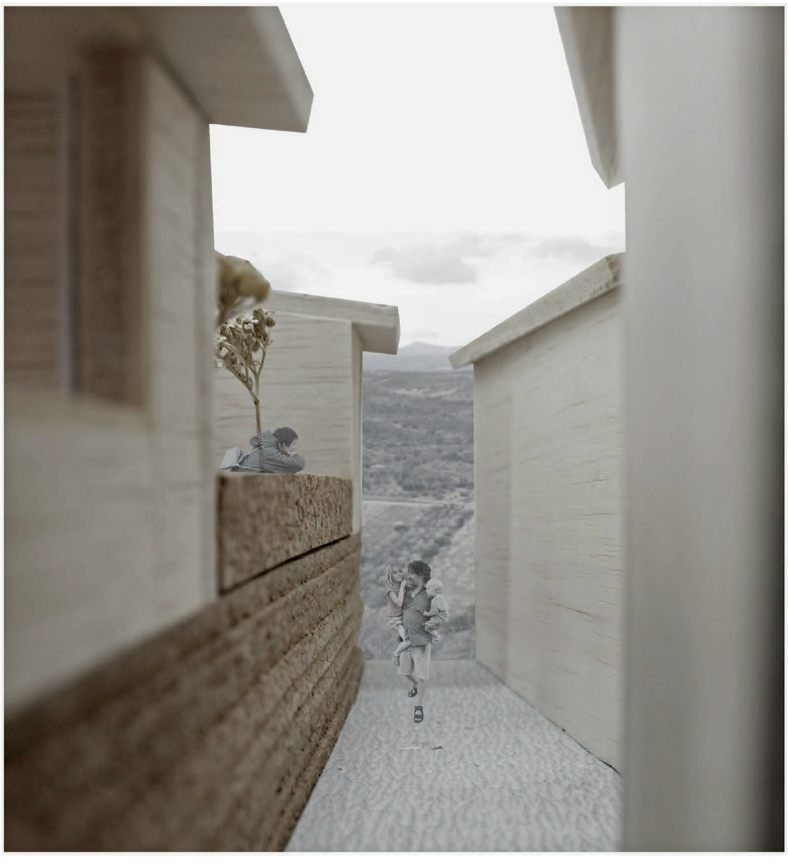


Figure 26 - Montage of the proposal

A.2. Urban space with "superadobe" in Chefchaouen, Morocco. UPC-CCD/Base-A

Chefchaouen had a fairly significant commercial activity in leather for a long time, and the Dbendiben tannery was one of the many tanneries in the city.
The raw material, particularly the ruminants skin, was available in the Chefchaouen region, encouraginf artisans to become interested in this trade and even to export their leather products to Fez and its Kharrazin district, known as the place where shoe and leather manufacturing trade takes place.
The authorities decided to transform it into a public square, since the accumulation of waste in the unused ponds caused hygiene and discomfort problems for the neighbours.

Dbendiben square is a meeting place for young people living around. Throughout the day its image is changing and shows different faces. This passing of time is present in the use as well as in the shape of the square. Former uses left footprint: the story marked by the tradition of leather merchants that characterizes this part of Morocco. Fussing past and present, the design proposal aims to make the past visible by bringing the materials of the past back to the present. We propose to change leather for superadobe elements that works as flower pots or as playground for children and resting sports for adults, to give utility, more liveable and inclusive.

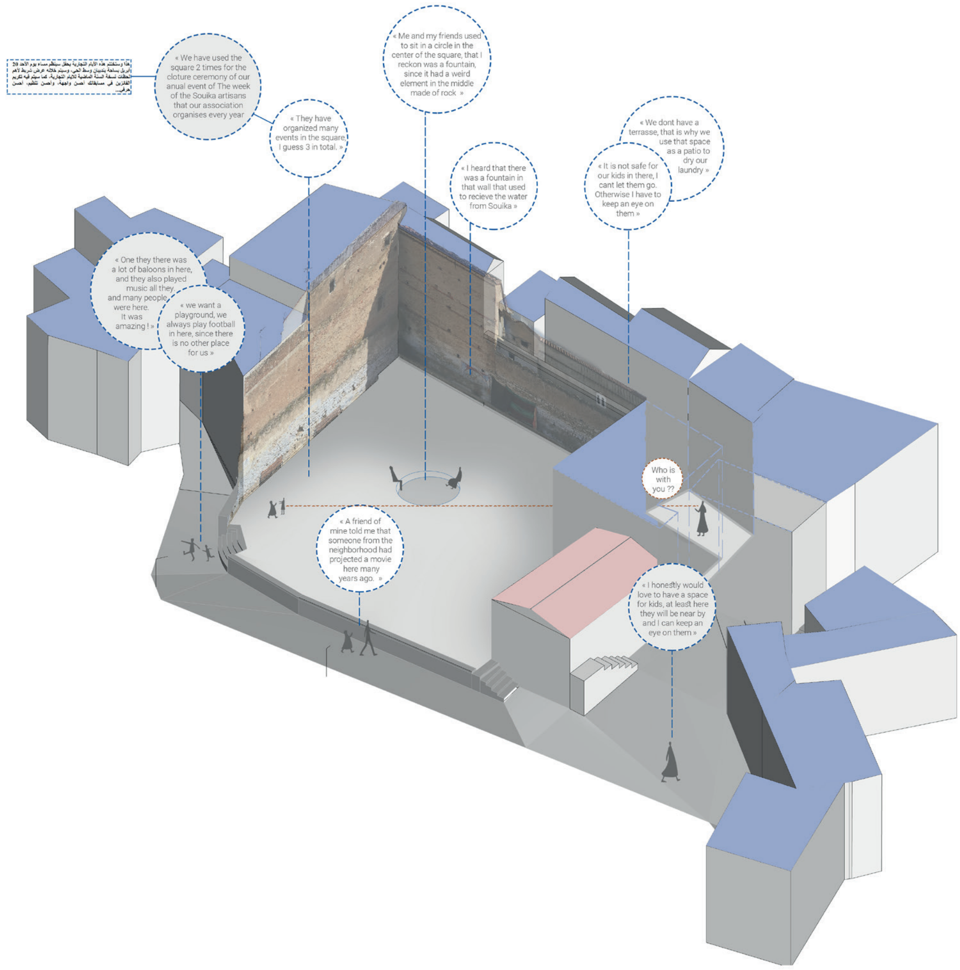


Figure 27 - Analysis of the current state

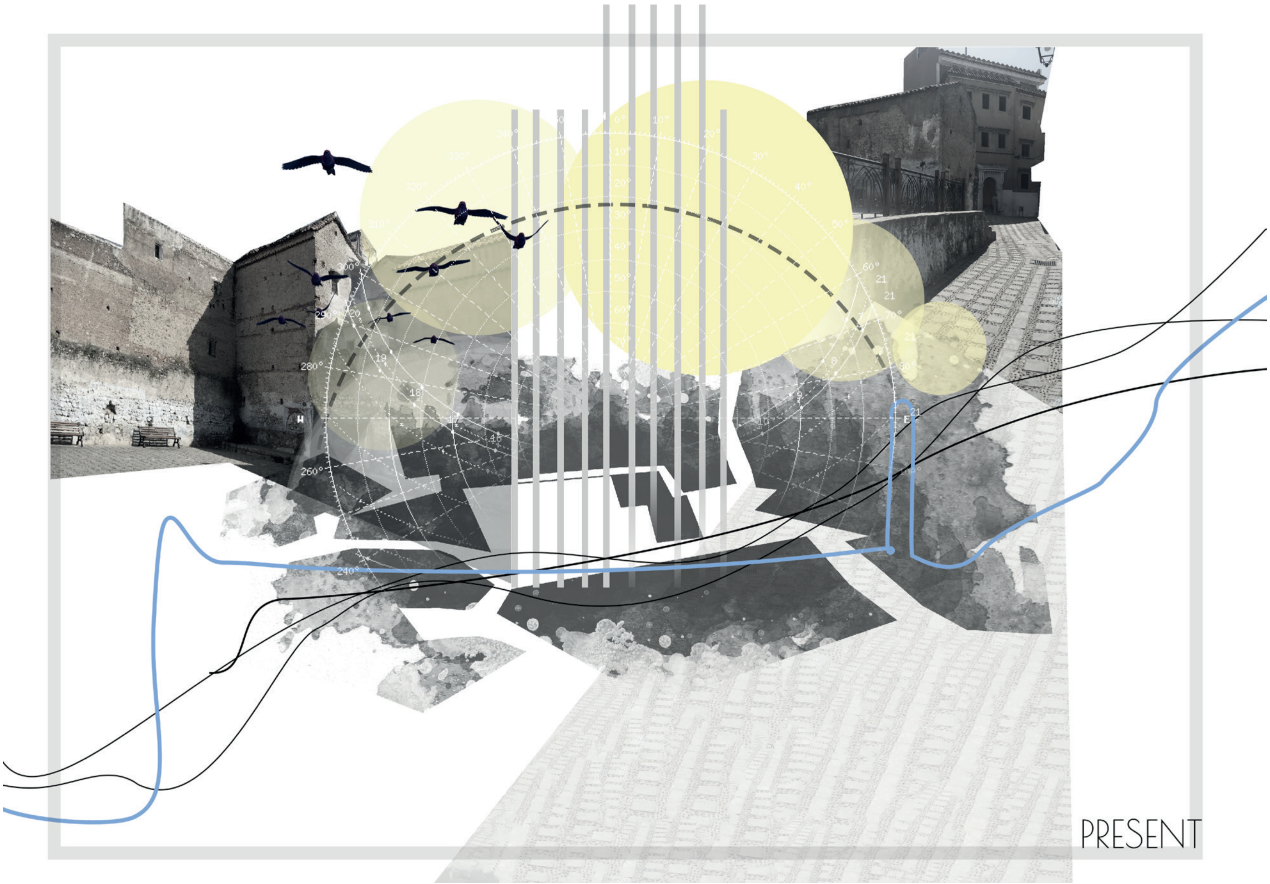


Figure 28 - Sketch of the current state

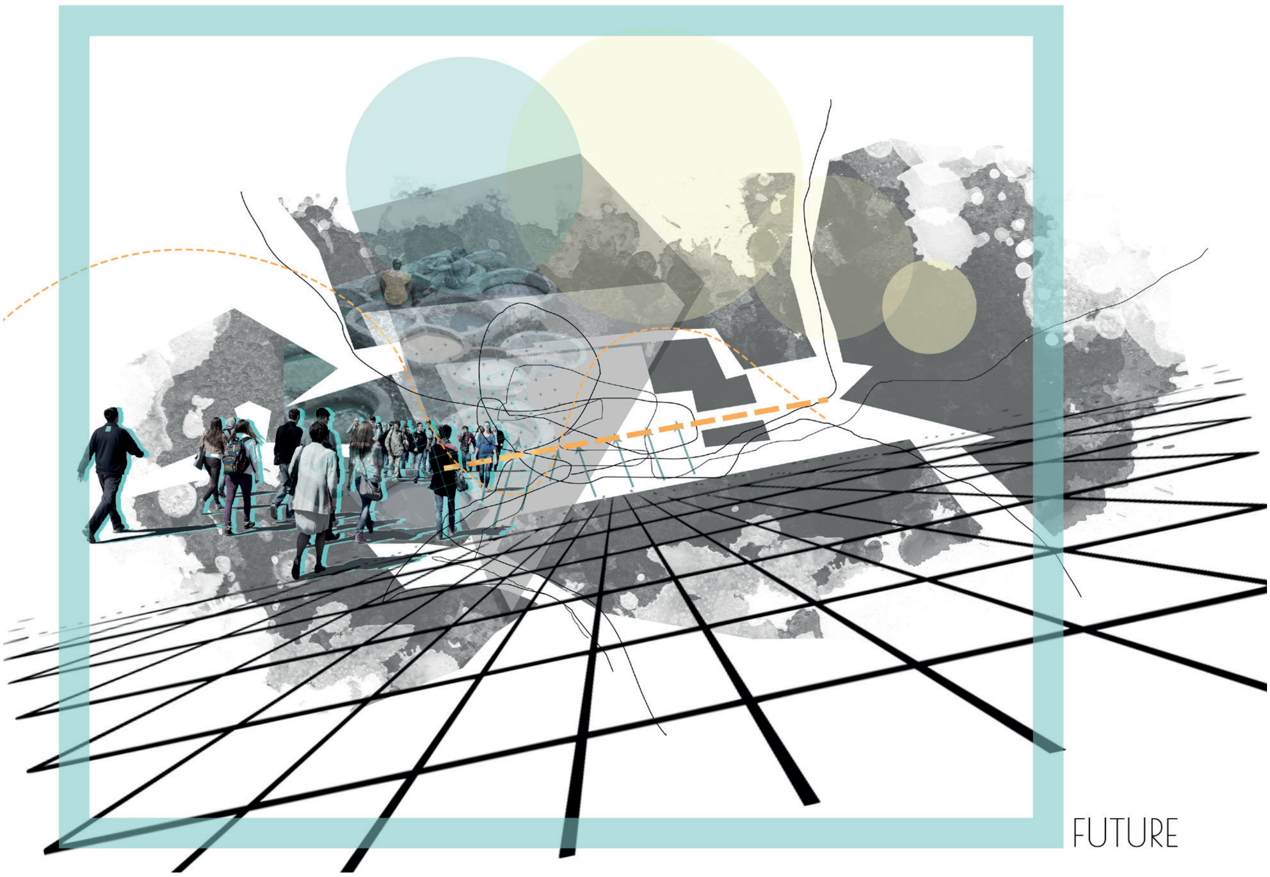


Figure 29 - Sketch of the proposal

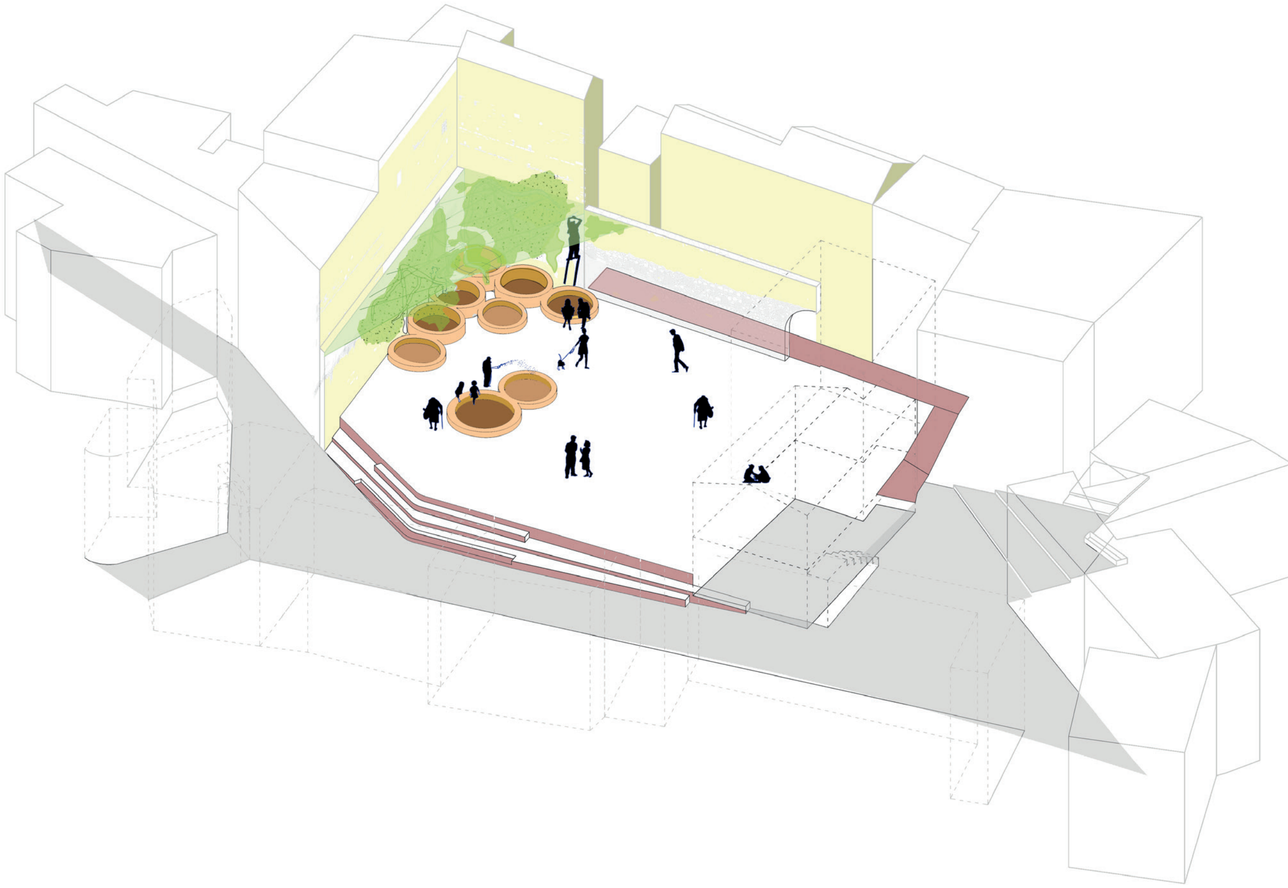


Figure 30 - Proposal

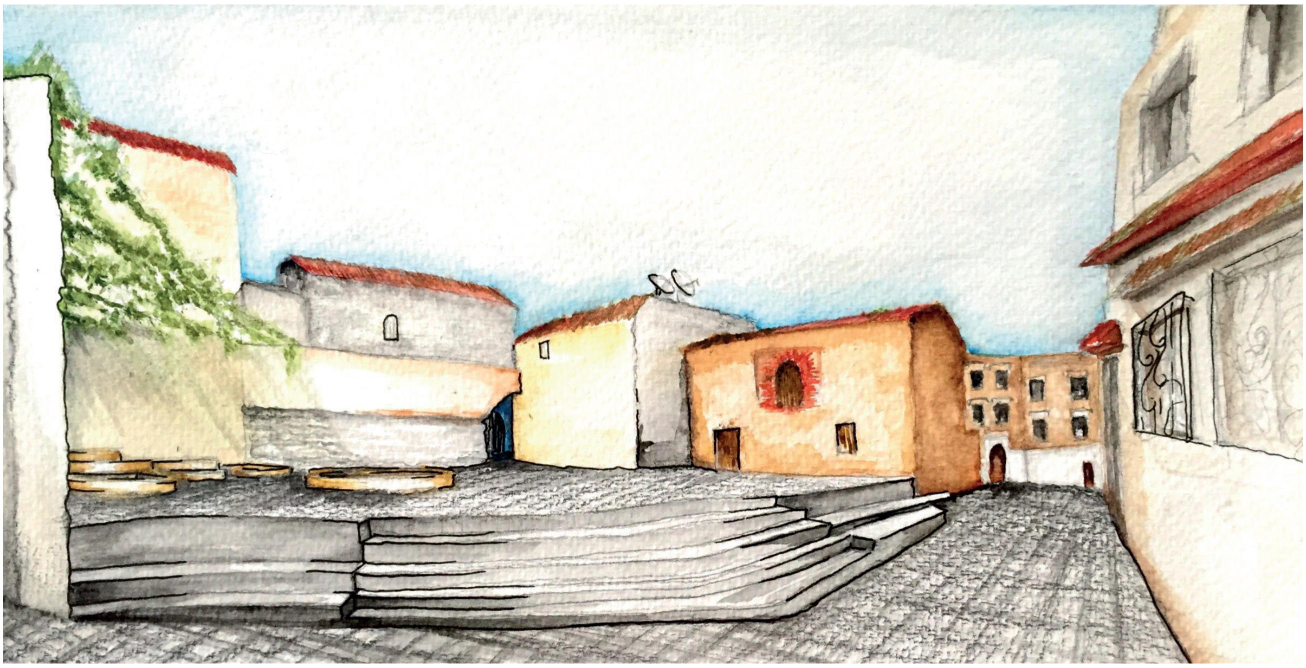


Figure 31 - Sketch of the proposal

A.3. Construction of a school in Mahandougou, Ivory Coast. SUMUM ONG

A global project with three objectives: formation and education, support for the agricultural women's cooperative and the construction of a school. The main objective is to promote the socio-economic development of the area with the community participation of both associations and local entities.

With the construction of the school, the goal is to improve educational services, adapting the architectural design to local conditions; to raise awareness and educate the local population about the importance of construction methods using local materials; to boost the technical capacity of university students and young graduates to develop cooperation projects for development; and to raise consciousness and involve the populations of the first and third world in the power of direct and indirect participation in cooperation projects for development.

Figure 32 - Current plan. Situation

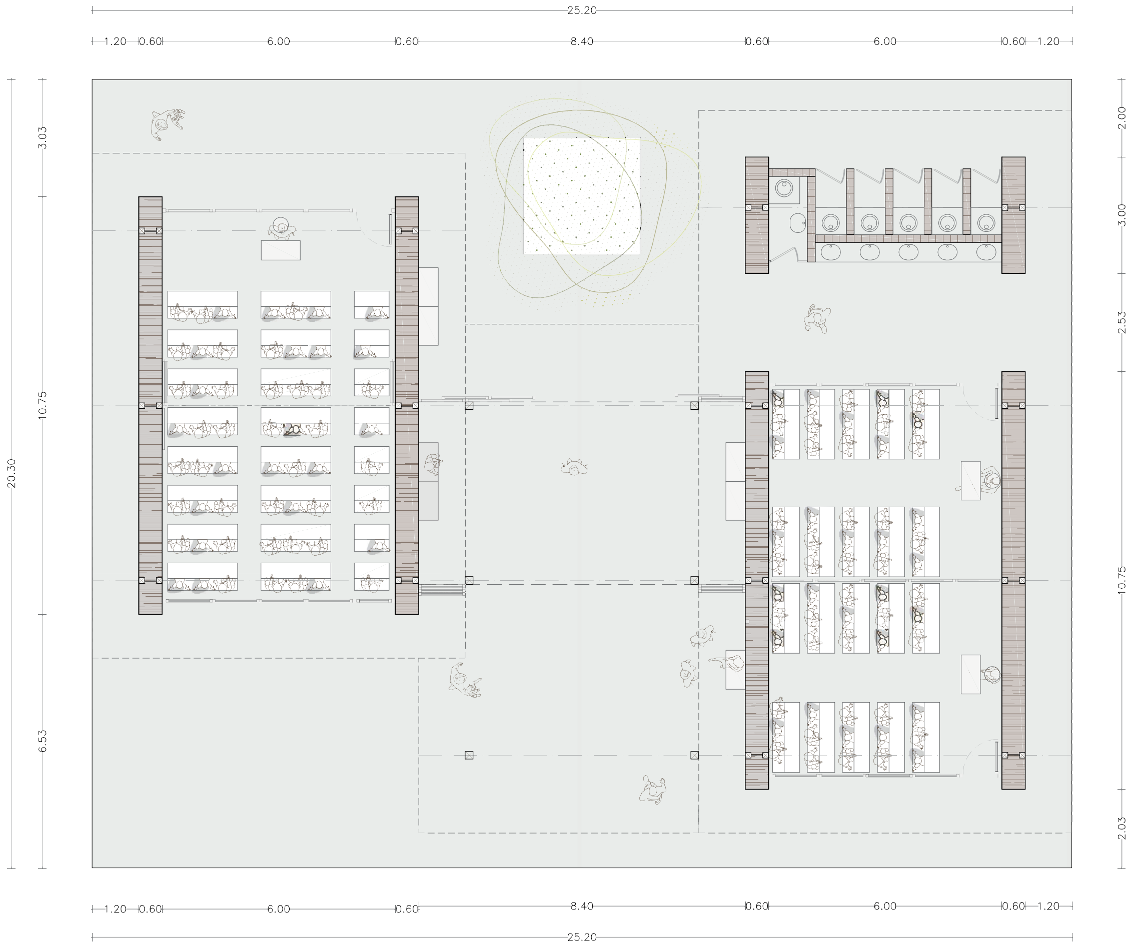
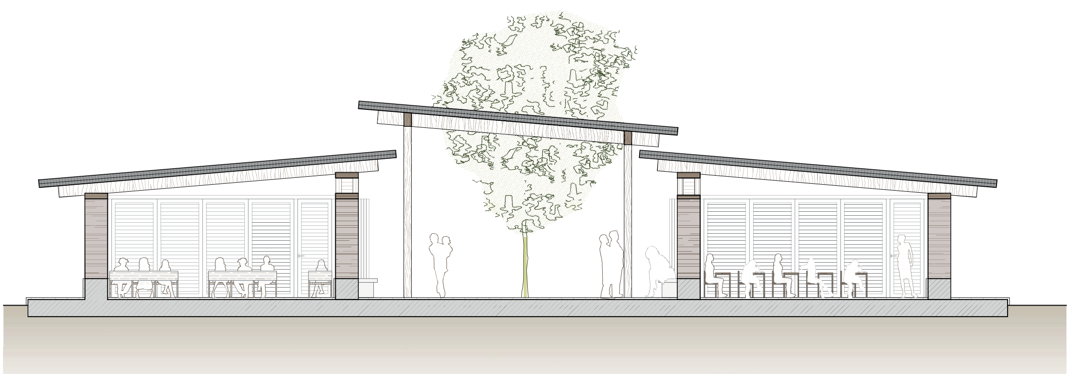
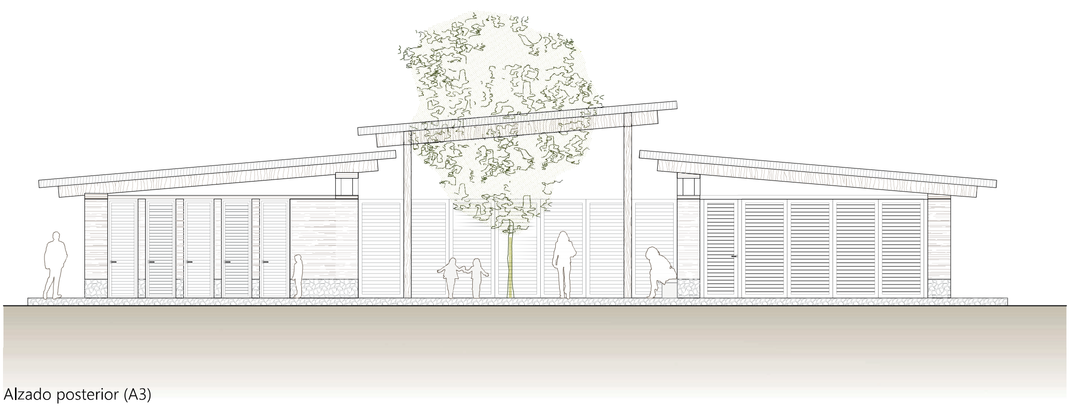


Figure 33 - Proposal plan. Floor



Sección transversal (S2)



Alzado posterior (A3)

Figure 34 - Proposal plan. Section

Figure 35 - Image of the construction process. Footings and basement

Figure 36 - Image of the construction process. Rammed earth walls

Figure 36 - Image of the construction process. Wood bond beams

Figure 37 - Image of the construction process. Lasts additions