Traditional rammed earth construction: conservation of built heritage in México

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Abstract

This paper exposes some of the main features that involve rammed earth architecture, with the purpose of contributing to its promotion, conservation, and re-development. The text is centered mainly on the characterization of the traditional way of executing this building technique in México, in order to improve its technological principles and as a way of promoting its application, not only in the restoration of heritage buildings, but also as a possibility for new sustainable architectural projects. Earthen architecture, when compared with other modern building methods and techniques, has outstanding qualities from a sustainable point of view. These characteristics derive, among other aspects, from the low environmental impact involved in the extraction and transformation of the raw material, as well as its great bioclimatic properties adaptable to a wide variety of geographic contexts.
Keywords: rammed earth, cultural heritage conservation, built heritage, low impact building materials, sustainable architecture.

1 Introduction

Among the existing types of earthen architecture, one that stands out for its extensive use throughout time as well as for its harmonious integration with the natural environment, is the building system known as rammed earth (*tapial* in Spanish or *pisé* in French). As it will be explained in detail throughout the article, this system is based on the construction of walls by compacting layers of soil in a wooden box or formwork. The soil used for this system requires small quantities of water in order to be adequately compressed. This last fact represents a great difference with other building techniques that use raw earth, in which the moisture of the soil mixture is a most important factor.

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Besides sharing ecological qualities with the other earthen building systems, rammed earth technology has the advantage of its material simplicity: all it requires is solar energy, local soil, a little amount of water and the work effort of three or four people.

Rammed earth architecture has been used for thousands of years and appears in different places all around the world generating structures of great heritage value. Unfortunately the lack of interest and knowledge of its characteristics and qualities are leading to the extinction of this extraordinary building technique in México.

2 The material components

The characteristics of the raw material, in this case of the soil that is to be used, are a determinant factor when building rammed earth walls. Soil, in its natural state, is made of certain particles with different sizes that help classify its components as follows: the bigger size elements are called *gravel*; then are the medium size particles, or *sands*; next in size are the *silts* and finally, the smallest particles known as *clays*. Each one of the former, have specific roles in the composition of the soil. The first three are considered "inert" materials because they are not affected by the water in the mixture. But their role as a whole is to create the 'skeleton' or supporting structure that maintains soil stable. The clay particles, on the other hand, have the dimension and crystal organization form that allow its easy hydration, movement and insertion in between the bigger particles, and once dry, becomes the glue that keeps the group together.

It is very important to talk about the so called "activity" of the clays. Because they are mineral compounds that have different elements, the behavior of the clays varies in function of their ability of reacting with water and, in this way they are able to fulfill their binding role in the ensemble. The more 'active' clays capture and loose more water, fact that gives them better adhesive properties, but at the same time they are more unstable. On the other side, the more 'inactive' clays react less violently to water but have less binding strength to keep the soil together.

Soil properties vary depending on the *type* as well as the *amount* of clay it contains. In this way, if the soil is "sandy" because it contains little amounts of clay or because it is "inactive", even if the earth has great stability towards humidity or temperature changes, it will be a fragile material that will degrade and erode easily to external conditions. In contrast, a "clayish" soil will have high cohesive properties, but can suffer from volume changes due to continuous dry and damp conditions, that can generate severe cracks that can jeopardize the stability and resistance of this building system [1].

Although it is almost impossible and inadequate to apply flawless "recipes", it has been observed that ancient rammed earth walls that have endured in adequate conditions had the following proportions of the soil components used for their

(a) (b)

Figure 1: (a) Ruins of rammed earth walls in Calpan, México. (b) Rammed earth walls with cracks for using a "clayish" soil.

construction: Gravel 30-40%, 25-35% of sand, 15-20% of silt and 7-12% of clay [2].

On the other hand, it is very important to point out that a soil that does not have a proper particle variety, that is, if it tends towards a homogeneous texture, it is likely to be more fragile because of the spaces left in between particles, which make the compound less dense and resistant. A balanced proportion of different particle sizes are necessary, so those smaller ones (silt and clay) can insert themselves in the spaces left in between gravel and sand, gaining density in the building material and consequently more stability. As far as building rammed earth walls is concerned, it is highly recommended to eliminate rocks and gravel that are over 2 cm. in size, because these kinds of fragments can weaken the structure in the case of earthquake events.

Water is another essential ingredient involved in the rammed earth building process and has two main functions: in the first place it allows the movement of solid particles in the mixture by transporting the smaller elements in between the larger ones; secondly, water 'activates' the "adhesive" properties of clay crystals, which, once hydrated, generate electrostatic attraction on the other components [3].

There is no strict 'rule' to be followed, but usually, moisture content needed for rammed earth walls is around 10%. Less humidity produces heterogeneous mixtures that become brittle with time, while excess moisture makes compacting layers quite difficult and generates alterations or deformations in the structure during the drying phase. The low water consumption is an ecological advantage of rammed earth when compared with other techniques, such as adobe, daubed earth walls or cob.

2.1 The building system

The traditional building process consists basically of filling a wooden box or cast with superimposed layers of soil, successively compacted until a whole block is conformed. In order to maintain a continuous process, the formwork was horizontally displaced until the perimeter was closed, finishing the first row of blocks. This procedure was repeated putting a new row on top of the other until

the desired height was achieved. The constructive process basically follows the next steps.

To begin with the process the use of recently unburied soil is important so the material still maintains its natural moisture.

The soil must then be thoroughly "split up and any lumps disintegrated with beak and shovels until the earth is well spread out. Next a pile must be made with the soil, which is essential because when the workers throw shovels of soil to the top of the heap, rocks and big size gravels are forced to roll down to the bottom of it. There they are easily taken out with a rake that will only seize rocks bigger than the size of a walnut" [4].

The earth walls must be built on top of a foundation made of rock or brick that rises at least 40 to 80 centimeters above ground level to protect the bottom wall from moisture. On top of this basis, the formwork is settled and firmly put in place, beginning at one corner of the building and checking horizontal and plumb levels of all sides. It is recommended before putting the first layer of soil to level the top of the foundation with mortar to prevent the soil spilling out the joints when tamping.

Then, the workers who are to begin the process, climb in the cast and receive the buckets of soil and spread it out with their feet to then start to tamp or compact the layers of soil of about 15 to 20 centimeters thick. It is important to begin the pounding strokes at the edges of the wall moving then towards the center, but trying to tamp in all directions to achieve the most homogeneous pressure possible. After repeating this operation until the cast is completely full, the formwork is dismantled and set up again on the side of the finished block. Horizontal and vertical alignments are again checked and the process of filling and compacting layers of soil is repeated as well as moving the formwork until the entire perimeter of the construction is completed. By then, the first row will be dry enough to support the weight of workers, cast and soil, so the construction of the next row can begin.

Something that must not be forgotten is that the vertical joints of the rammed earth blocks must not be aligned in the same position between rows, that is, in the same way brick or cut rock masonry must be overlapped at the middle of each piece [5].

The elements for openings in the walls for doors and windows can be set before the rows of blocks are made. However due to the complexity of this preparation, it is very common to 'open' holes in the rammed earth walls, once they are finished. The walls can be drilled to make these openings, as far as the job is done carefully and their position and size doesn't weaken the structure.

Once the walls of rammed earth blocks have been finished, it is possible to build the roof structure, element that due to the flexibility of this system can be solved with wooden beams or trusses, vaults, horizontal or slanted rooftops depending on the local climate conditions.

3 Evolution of rammed earth technology

Unfortunately, historical studies related to earthen architecture have not been developed or documented systematically. Academic interest for this material is fairly recent, so many archeological investigations prior to the 1960's, do not even mention earth architecture, concentrating their attention on more "noble" materials such as stone, brick or wood. Furthermore, due to the fragility of earthen structures when they are abandoned, most of the material evidence has been lost or is in decay and not fit for proper analysis [6].

However, there is much evidence that proves that soil has accompanied urban development of most known civilizations during various stages of their evolution. Something that is quite interesting about earthen architecture is the fact that many similar building techniques were developed in an unrelated way, in different cultural regions. In other words, earthen construction had independent evolving processes in places as far away from each other as Northern Africa, India, or China, since many centuries before the Christian era.

Until today many evolutionary processes have been identified, as well as diverse cultural influences that allow putting together some parts of the puzzle. This information indicates that all over the world the technique that reached a more sophisticated level and is the most known, was the adobe, while the use of rammed earth structures is much less common.

Even though it is difficult to establish a place of origin, there is evidence that around the Mediterranean Sea, compacted earth was used at least since the time of the Phoenicians and Greeks. In the book of *Natural History,* Plinio wrote that "the walls made of compacted earth that can be seen in Barbaria (Cartago) and in Spain, where they are called 'molded walls', soil is set between two wooden boards… there is no cement or mortar that is harder than soil… the watching towers built by Anibal in Spain… are made of compacted earth". Excavations conducted in Carthage specifically on the hill of Byrsa, confirmed that the rammed earth walls were used to build houses. It is known that in this city, which once had 700,000 inhabitants, during the second century BC, it was common to build with compacted earth, sometimes coated with lime or marble [7].

In our continent there is evidence of the use of rammed earth before the European conquest of America. An important example is found in Peru, where sophisticated structures from pre-Incaican periods were built, sometimes exclusively in rammed earth, but also mixed with other techniques such as *quincha* and adobe. The palaces that make up the city of Chan Chan are silent witnesses of technological progress reached by the Mochica and Chimu cultures where impressive ramparts were built in rammed earth.

In northern México, two extraordinary examples of ancient earthen architecture are the city of Paquimé, as well as the cliff houses in the mountains of Chihuahua. For many years it was accepted, almost without question, that the technique used to build the monumental walls of their housing was rammed earth [8]. Recent discoveries have opened the possibility that the former is not exactly true. The decay process of the earth structures, as well as the non existing joints

between blocks, which are produced by the formwork used to confine and compact the material, are pointing towards another system that involves highly moist mixtures [9] also known as "poured mud".

This technique, which is closely related to rammed earth, but differs basically because the mixture poured into the form work is mud in a plastic condition (high content of water), consistency that makes compacting layers impossible. Of course, monolithic pieces are produced, but its consistency is gained in a drying and curing process, much like poured concrete made with cement.

In our country's architectural examples of rammed earth are proportionally much scarcer than adobe. And, as happens in most of Latin America, the building tradition of rammed earth walls that has survived to this day is derived mainly from technology brought by European settlers and perfected during the nineteenth century.

4 Rammed earth architecture in central Mexico: a built heritage on the verge of disappearing

In Mexico an important fact related to rammed earth architecture is that the only region where historic and traditional building made with this technique can be found is an area between the states of Puebla, Tlaxcala, and Veracruz in the mid east part of the country. However, there is not enough research developed, that could help in order to have a more accurate idea of when rammed earth building began in these places. In this region there are a many pre-Hispanic sites where the use of adobe structures has been found, but there is no archeological data linked to rammed earth in this time period. It is believed that the settlers after the 16th century of this area probably came from Spanish provinces where this technique was used and they brought and taught this constructive tradition from then on.

Another hypothesis sustains that rammed earth technology in México was introduced towards the end of the nineteenth century by architectural influences that came from France. In this time period, many agricultural haciendas and textiles industries had an important development in this area, when the use of rammed earth structures gained importance and was used until the 1940's-50's, as it has been documented with old people who still participated as workers in some sites. Besides its regional origin, it is strange that rammed earth technology, with all its qualities, was not disseminated in neighboring provinces considering that there was always a great cultural contact between them.

Rammed earth blocks in this area were used basically for border walls, or external perimeter walls of houses. In the interior of buildings dividing walls were made of adobe, as well as the forging of the slopes of the roof tops. The blocks measurements are approximately 1.8 meters long and tall and 60 centimeters wide. The formwork or *case* made with wooden boards was set in place and reinforced with vertical timbers on the sides, as well as horizontal timbers on top and interior to hold the mold in place and maintain a constant separation [10].

Figure 2: Traditional house in Calpan, México.

Despite the fact that these kind of buildings as well as the constructive system that makes them unique have survived until now, the lack of knowledge and appreciation of its historical significance, have put them at the verge of disappearing completely. For over forty years, the communities of this region have stopped building with rammed earth and only a few elder people still have the knowledge related to this building technique. Now days most of the buildings and houses are made of cement blocks and other industrialized materials, straying far away from economic, ecological and traditional local logic.

5 Research and teaching for the conservation of rammed earth building in México

Finally we would like to mention a series of activities that are taking place at the Metropolitan Autonomous University, Xochimilco Campus, aimed towards the documentation of traditional earth building systems in order to generate alternative technologies that can be applied for new buildings as well as in the repair of heritage constructions.

At the university we are working with the National Association of Lime Producers (ANFACAL for its initials in Spanish) the Iberoamerican network of PROTERRA, the National School of Conservation, Restoration and Museography, the Autonomous University of Nuevo Leon and the Autonomous University of Tamaulipas with the common objective of obtaining and expanding knowledge of sustainable building techniques to be applied in existing heritage buildings, but at the same time to develop contemporary design with rammed earth.

Besides the results obtained from research, we give much of our attention in the organization and participation in technological transfer workshops. The main idea is to make traditional building techniques, available to students and local communities. With this in mind four to five workshops are organized year round in different parts of the country so that those who participate can “learn by doing”. The workshops seek the recovery of the traditional building techniques

Figure 3: A rammed earth wall sample made at a workshop for architecture students at UAM-Xochimilco in 2007.

Figure 4: Rammed earth wall samples made at a workshop for architecture students at UAM-Xochimilco.

that include rammed earth, adobe and daubed earth. Additionally, practice with soil selection, lime mortars, lime paint and the use of mineral pigments are included.

The results obtained so far in these workshops are very encouraging; not only for the enthusiasm that participants demonstrate during the event, but mainly for the skills they develop through the practice of traditional building techniques.

6 Final remarks

Earth construction systems are part of our culture, not only because of its ancient origin, but also because they continue to be valid today, thanks to their extraordinary economic and ecological qualities. However, the recognition of these values is remarkably limited.

Although many of the people who live in earth built houses recognize the high degree of thermal comfort these have, they despise their materiality because of social association of earth with poverty and backwardness. Traditional communities dream to have enough money so that they can finally demolish their old "old walls" and make themselves a "decent house" made of "real material".

In order to be able to preserve heritage buildings made of earth, especially those made of rammed earth that is even scarcer; we must start from their correct identification. It is curious how in many cases when people are interviewed either by academic or social institutions to recollect information on housing conditions, rammed earth walls are usually confused with adobe walls, due to the lack of knowledge in their differences. As it has been repeated many times, it is impossible to appreciate and value things you do not know or distinguish. That is why it is very important to continue progress in the characterization of these materials and building systems as the basis for its dissemination.

We hope that this documentation work, research and workshops we have undertaken at our university may contribute to expand knowledge related to rammed earth architecture, aimed to the needed conservation in our country of this tradition that is about to be lost forever. It is a tangible and intangible heritage to be valued and conserved.

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