Earth building sustainable potentials in the reconstruction scenery of central Chile. Reflexions after the earthquake on February 27th, 2010.
(Oral Presentation)

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ABSTRACT: One of architectures main concerns nowadays is the correct rationalization of natural resources; from the material selection, its optimal utilization in construction, up to its final discard. All of these concepts assure sustainability in terms of resources, internal comfort and waste disposal at the end of its useful life.

The earthquake occurred in Chile of February 27th, 2010, brought to discussions a large quantity of issues related to the way constructions were made in central Chile. The collapse of the mayor part of the patrimony constructed on earth, brought to light the high seismic vulnerability of the techniques (mainly adobe).

Earth building has shown to have a very low embodied energy in its extraction, transportation, manufacture, installation, disassembly, deconstruction or decomposition. Besides this, earth has important benefits in providing a healthy balanced indoor climate during the buildings use. Depending on which construction technique is used, if structurally improved using it as the filling of the wall, earth could still provide dwellings their wide benefits.

This article reviews the mayor benefits and virtues of the use of earth in construction, as well as the opportunities that represent the need of reconstruction in the vast area of central Chile where earth building has provided its benefits throughout the years and represents part of their cultural identity.

Keywords: earth building, sustainable, low embodied energy, reconstruction, Chile earthquake.

1. INTRODUCTION

As incredible as it sounds, half of the world population either lives or works in buildings constructed on earth [1]. Throughout the world´s different climates and geographies, earth has been used as a building material during the history of humanity. In China, the estimation of people living in earthen homes reaches 100 million [2].

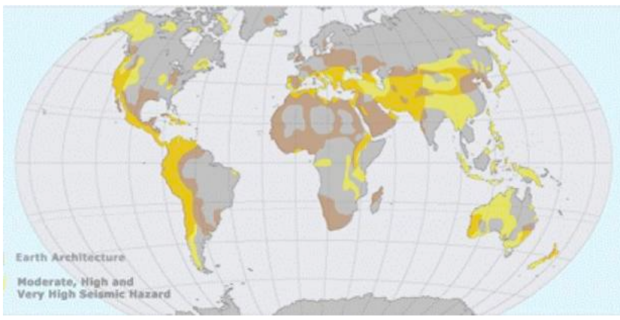

Figure 1: World map with earth building and seismic zones.

The 4000 year old Great Wall of China was mostly built with earth; the stone tiling we see today is the result of its later covering. Through its multiple kilometres, many geographies and types of soil were used to build it. Mostly with the technique of rammed earth, constructors used materials that were available, such as earth and stones. Where rock appears in the surface on mountainous territories, it was used in construction, but in valleys and flat vast areas such as the Gobi desert, earth was the only local available resource to build.

Figure 2: Rammed earth Great Wall of China.

The same way the Great Wall was built in different soils, in the world, each geographic situation imposes its own conditions: its own climatic challenges, type of soil, and therefore the suitable earth technique to be used.

After the first cities in Mesopotamia until the contemporary earth building examples, the extended use and evolution of this material and its techniques can be stated. In desert areas like Mali or Iraq earth has been used to build in the shape of adobes. This way the massive construction protects housing from overheating during daytime. In France and Germany where wood is available mixed techniques like wattle and daub are commonly found.

1.1 Earth building tradition in Chile.

In Chile, earth building was present before the Spaniards arrival. Tulor ruins were already constructed in the north of Chile about 2000 years ago. These buildings on rammed earth seem to be the oldest ever found in Chile.

Spaniards did their work in spreading earth techniques in America and our country. Afterwards Chilean people, as in the rest of the world, continued using earth developing new systems and techniques. Nowadays it is estimated that 80% of the National Monuments of Chile are built on earth [3], even though its contemporary use has begun to disappear.

The main earth techniques spread in Chile were adobe, rammed earth, wattle and daub and “adobillo”.

Figure 3: Rammed earth and adobe technique.

Adobe and rammed earth buildings have massive thick walls (1.50meters sometimes) and are constructed on rectangular plans with timber roofing. Earth is the load bearing material so it has to be thick and be protected from water.

In wattle and daub and “adobillo”, or standing adobe, earth is the filling of the wall supported by a wooden structure.

Figure 4: Adobillo Technique.

1.2 The embodied benefits of earth building.

Industrialization has improved and sophisticated materials to such point that nowadays one building component done in China has to be transported to Chile (on the other side of the world) to suit someone's requirements. The modernization paradigm has developed in people the need to consume the latest and reject the old. This has reached the spheres of building and construction too, leading to the loss of ancient materials use. This has brought the consequent ignorance about earth buildings benefits and its possibilities.

Indeed earth is more and more frequently conceived as dust. Therefore it has to be withdrawn and impermeabilization has to be done leaving earth only to the foundation of housing and gardens.

Earth as a building material is everywhere and all kinds of soils can be easily modified to suit a certain technique. This makes the material not expensive and available without the need of much energy. It makes a great difference with concrete since to produce 1 ton of concrete, another ton of CO_2 is produced with it [4].

In this same sense, an earth building has an optimal embodied climate control. It´s isolation, thermal mass and water content assure thermal comfort even in extreme climates. It also regulates internal air humidity; so when there is too much humidity it absorbs it and in its absence it releases it out to the ambient. This material also has no risk if inhaled because of its lack of toxic chemical substances. Finally, Soil is recyclable and can be used several times without producing pollution. If it´s well combined it can even be used for cultivate aims.

Earth buildings benefits have been a part of Chilean life and identity and are worth not leaving behind. Giving up these techniques means to leave a constructive history behind. By rejecting our past do we want to turn into a country of only bricks and concrete?

1.2.1 Thermal mass and insulation

In some climates indoor comfort is very important to the well being of habitants because they can spend up to 90% of their time in interior spaces [5].

For example a few years ago after Tarapacá earthquake in 2005, the Chilean government had to rebuild deserted towns. Because of the lack of knowledge and hurry, they built cement brick houses where earth houses had fallen or stand still in questionable conditions. House owners complained that houses weren´t suitable for the extreme climate; they were too hot in daytime, and freezing at night.

Thermal mass and insulation affect the internal thermal performance of buildings. Earth constructions have a high thermal mass, while insulation is only of reasonable quality. Contrary to what we may know, rammed earth walls may have isolation similar to one of a burned brick but still better than one of a concrete wall [6]. This occurs because of the low volume of air trapped inside the material of the walls.

What earth walls do to approximate an average indoor temperature is to use its thermal mass to balance the external temperature extremes. Many authors suggest considering a wall of about 30 to 40cms thick [7] in climates of high temperature ranges so that the time of trespassing correspond to daytime and night.

1.2.2 Earth capacity to absorb humidity. Earth as a natural PCM.

Another important property of earth building is its capacity of absorbing air humidity. It is known that earth is not water resistant and has to be sheltered against water in liquid state. However earth is able to absorb and give off air humidity in a way that any other building materials can´t. This assures a comfortable indoor climate without exceeding earths equilibrium moisture content (5% to 7% by weight [8]) or becoming wet or lose.

An ultimate publication of earth building in France states that earth is a natural Phase

Changing Material [9]. These materials change its physical state responding to ambient temperature changes due of their heat absorption or liberation during the process. Earth as a building material, even dry, has an amount of liquid water inside in equilibrium with that of the external air. This lately studied feature explains its characteristic of natural climatic regulator. Not because of the addition of paraffin, nor for its high thermal insulation, but because it already contains a matter able to phase change on ambient temperature: water.

It is known that water frizzes at 0°C and evaporates at 100°C, but in the capillarity of clay, it can evaporate and condense at lower temperatures. When the temperature rises, some humidity from the earth evaporates absorbing the air heat. On an inverse way, when the ambient temperature lowers, some water is condensed on earth.

"The energy exchanged by one liter of water that evaporates is equivalent to the one exchanged by the melting of 22 kilograms of paraffin" [10].

1.2.3 Low embodied energy

Overall, earth has even better advantages in energy savings through its whole life cycle considering all stages: manufacture, building and destruction. Energy embodied in earth buildings has always been said to be very low. This is not a minor issue since for example the manufacture of concrete itself causes 5% of worlds CO2 emissions [11].

Earth on the other hand frequently has no need of transportation or manufacture. It is available on almost all geographies of the world. As it is water soluble it can be reused and repaired producing no waste and be reused indefinitely without recycling processes. If desired, it can even be left to return to the ground causing no pollution.

In this sense earth ecologic footprint is close to zero. This footprint is said to be 1% of the one for preparing, transporting and using of baked bricks or concrete [12]. In a study of the University of Illinois cement and common bricks were analysed resulting that their energy costs were 381 Btu and 13 Btu respectively (1Btu = 1.06 kilojoules). Although adobe was not included in the study, the same methodology would drop 2 Btu. This corresponds to 0,5% of cement and 15% of common bricks [13]. This difference shows the significance of its reduction in energy costs still not considering pollution after the useful life of these materials.

2. 2010 EARTHQUAKE IN CHILE

Throughout the years, Chilean people have seen how nature tends to clean our cities pulling everything down once and again. This has made construction techniques develop and adjust to these specific site requirements.

Figure 5: Earthquake catastrophe.

The earthquake on February 27th, 2010 affected one half of our territory in the most populated area. Fifth strongest earthquake in the world, this 8.8 Richter earthquake had tremendous results and even tsunamis occurred in some coastal areas.

In general, construction overtook the movements in a pretty good way but many new buildings as well as old ones where destroyed. With it, most of the earth building patrimony was pulled down.

This facts made people think about the way construction was been developed in the last years, as well as the worries about old buildings and the danger they meant to the people who lived in them. Much was said about construction with earth. Many people strictly suggested that it remained prohibited due to its unpredictability and because it was a dangerous material. On the other hand some claimed that it was part of our identity and that the collapsed structures had resisted several previous earthquakes with few or none repairs until their final collapse.

The best earth building enemy would have said that earth as a structure is weak compared to industrialized materials and can be unpredictable dew to his raw material. Resistance may vary from one soil mixture to another without an easy way to find reason depending on its content of sand, silt and clay. This last element defines the cohesion in the mixture and so the structural resistance. These characteristics added to the buildings morphology are responsible for its performance during an earthquake. As it is difficult to predict and engineers fear to assume the risk they prefer to avoid its use.

On the other hand some would say that submitting people to live in earth buildings is irresponsible as we have seen homeless people and death after their collapse. Restricting poor people to this material can be exposing them to the same consequences that we are trying to avoid in the future. Some would even say that this people don´t need to be hippies forever and that if do-it-yourself methods are being considered, then bricks and timber are materials that people know how to build with in Chile.

In the same sense some people would comment that saving the patrimony is nonsense and that the world is about changing.

5. SUCCESSFUL NEW TECHNIQUES FOR SEISMIC AREAS

The earthquake has meant a great loss of patrimony constructed on earth as well as common architecture. The losses are not yet measurable and have affected many cities and towns. Many coastal villages have disappeared because of the tsunamis. The reconstruction costs are estimated to raise the 20 thousand million dollars.

The earthquake also made some people think that earth buildings weren´t able to resist earthquakes due to the high number of antique constructions that collapsed.

As much as can be said, structural problems on bearing earth walls are not always due to the materials characteristics but to other reasons. In occasions the way walls are built can influence their performance during an earthquake. If for example a wall is too thin, then collapse can be imminent.

On another hand, after earthquakes if massive walls are not well repaired and cracks remain, then a collapse might happen in another similar event.

Figure 6: Constant humidity in base of the wall due to impermeable coverings.

The same way, maintenance has an important role in keeping the walls capacity to resist earth movements. Water is the main enemy of unburned earth buildings as it reduces the walls resistance when exposed for long continuous periods. Maintenance also considers the later interventions done to the buildings; combinations with walls of burned bricks or emptiness of the earth walls are very frequent and erroneous interventions to be found in rural homes.

Having knowledge of these treatments of earth building can assure the use of earth for building purposes. This makes earth a useful material because of its various benefits on internal comfort and cooperates with the contemporary aim of sustainable construction.

During the last years a lot has been done to take advantage of earth buildings benefits. Mixed structures have been developed by architects and engineers using earth as the filling of wooden or metal structures. These systems are the result of the reinterpretation of antique techniques that enjoyed the benefits of earth. They use the ancient technology of earth but are informed by the new paradigms of contemporary architecture. Some have been tested in seismic areas and have shown to resist without important cracks or damages.

In Chile Marcelo Cortés developed a mixed structure with folded metallic meshes. Many houses and buildings have been constructed with this "technobarro" technique and this earthquake showed their performance success. Only small harmless cracks appeared in some of the structures.

Figure 7: Metal and earth building by Marcelo Cortés.

Another traditional system developed on central Chile during the last century consisted on wooden framed earth walls. Also called as the "wall of the poor" or in spanish "tabique del pobre", this structure consisted on timber columns and diagonals filled with rammed earth. Many houses built with this system in the central south countryside of Chile had little to no damage during this powerful earthquake. Some of them in Curicó city surroundings, near where the epicenter was situated.

Figure 8: "Tabique del pobre" in countryside housing.

Based on the same seismic problems Peruvians of the Catholic University have been studying the earth building phenomena developing new mixed systems that allow reinforcing old or new structures by adding meshes to massive earth walls. This system allows not only maintaining old buildings but also permits new constructions to have thick walls of adobe and rammed earth with less seismic risk than ancient times.

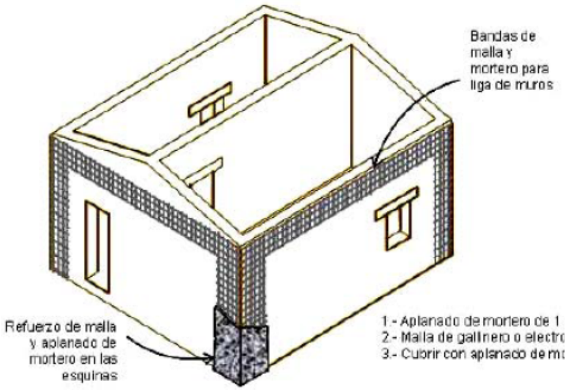

Figure 9: Adobe houses with polymer mesh in pillars and beams.

6. FUTURE OPPORTUNITIES

We live in a changing world towards industrialization and technification of the building business where construction materials are more and more expected to be standardized throughout the world. In this context earth might never fit as an expanded building material due to its local characteristics.

In this sense, taking the opposite position might be the only way to meet sustainable requirements. In an ecological view of the building business earth might reach the green standards as no other material would.

Earth can be useful in a context of lack of resources and the urgent need of reconstruction. Identity is waiting for us to maintain it.

Architects have been working and developing earth techniques since the beginning of time. Vitruvios writings of the Ten Architecture Books first mentioned this material. Francoise Cointraux recommended this material to reconstruct Paris after it had burn down. Even Le Corbusier and Frank Loyd Wright talked about after war popular housing reconstruction on earth.

Nowadays industries would continue producing sophisticated construction materials that can benefit our lives. This sophistication developed altogether with nobel materials may be the answer to sustainable development.

Companies would continue producing at high level energy costs, we in the construction business can make the difference in designing the change.

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