EARTH BUILDING. MODELS, TECHNICAL ASPECTS, TESTS AND ENVIRONMENTAL EVALUATION

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ABSTRACT

Earth building is an ancient construction method, rarely in use in contemporary architecture. In skyscrapers, apartment blocks and other typical high constructions, reinforced concrete, metal and many other conventional materials are used in order for them to be build.

But the same methods and the same materials are in use for small-scale buildings, while it is not necessary to built with concrete or metal.

In order to evaluate earth building, a comparison between a prototype model and a typical construction is presented in this paper, in terms of technical aspects and environmental evaluation.

Models of suggested constructions in scale 1:20 are presented.

Key words: earth, building, economy, ecology

1. INTRODUCTION

"Architecture exists at the point where poetry crystallizes into structure."

Nader Khalili

In order to live in a sustainable world, new norms of society have to organize the existence of people in sustainable forms. Modernism said that “form follows function” and for the last century the function was: “to make money”.

But the world now is different. Money is lost and we have “produced” so much fake money which leads us to a fake word. Therefore we have to build a new world with “eco” (economical and ecological) principals in order to find the norms of the new century (Daly 2009).

New world (people) is moving, because of immigration, upcoming disasters, new economy balance. Until now there is enough space in the world, but “state of the art” living connects all the people to the big cities. Inside these cities, building blocks and ghettos are designed to keep the “spare” people.

Upcoming feedback of this function is that large areas of the cities are in use as “disposal centres” for people, with “no law” and high levels of criminality. So, instead of a “disposal centre”, the project is to design centres with respect of human dignity (Fathy 1968).

“Earth-building” gives the opportunity to be the design and the construction from the people and by the people (Roberts 2005).

Earth building is: fast, economic, recyclable and needs little energy in order to achieve thermal comfort (Minke 2000).

There are many methods to build using the earth. The simplicity of the construction and the ability of achieving a good quality construction with the minimum money, gives the hope that this action can provide answers to the big questions of our times.

2. MODEL DESCRIPTION

2.1. Design principles

In order to study a prototype form there is a need for moving people to find a temporary place to stay for a small period of time.

To make a comfortable presence it is possible to say that a prototype form can be designed for an area of about 20 m^2 , which two people with one child may use for living.

2.1. Materials and technique

There are four basic techniques to make this construction: adobe, cob, rammed earth and earth-bug (Khalili 1996, Minke 2006).

1. Adobe is a natural building material made from sand, clay, and water, with some kind of fibrous organic material (i.e. sticks, straw, dung), which is shaped into bricks using frames and dried in the sun.

2. Cob is a building material consisting of clay, sand, straw, water, and earth, similar to adobe. Cob is formed on the house itself by hand and is dried on site as a monolithic shell.

3. Rammed earth is a process of compressing a damp mixture of earth that has suitable proportions of sand, gravel and clay (sometimes adding a stabilizer) into an externally supported frame that moulds the shape of a wall section creating a solid wall of earth (Hall 2004).

4. Earth-bag construction is a method to create structures which are both strong and can be quickly built. It is a natural building technique that evolved from historic military bunker construction techniques and temporary flood-control dike building methods. The technique requires very basic construction materials: sturdy sacks, filled with inorganic material usually available on site. Walls are gradually built up by laying the bags in courses — forming a staggered pattern similar to bricklaying.

Almost the same earth materials are in use for the above techniques. But in each one the construction is different because of the difference of discontinuities or the condensation of the material.

Earth bag is the faster construction method because the elastic mould of the bag is very helpful to compress and stabilize the material. But the material has to dry on the construction and until then, the building is unstable for a small time period (Hunter 2004).

The walls are almost always curved to provide improved lateral stability, forming round rooms and domed ceilings like an "igloo".

Earth bag offers more structural integrity than adobe, more plasticity than rammed earth and more speed than cob. Although earth bag is new compared to these ancient building methods, it offers superior economy and durability in domed and vaulted assemblies.

2.2. Design

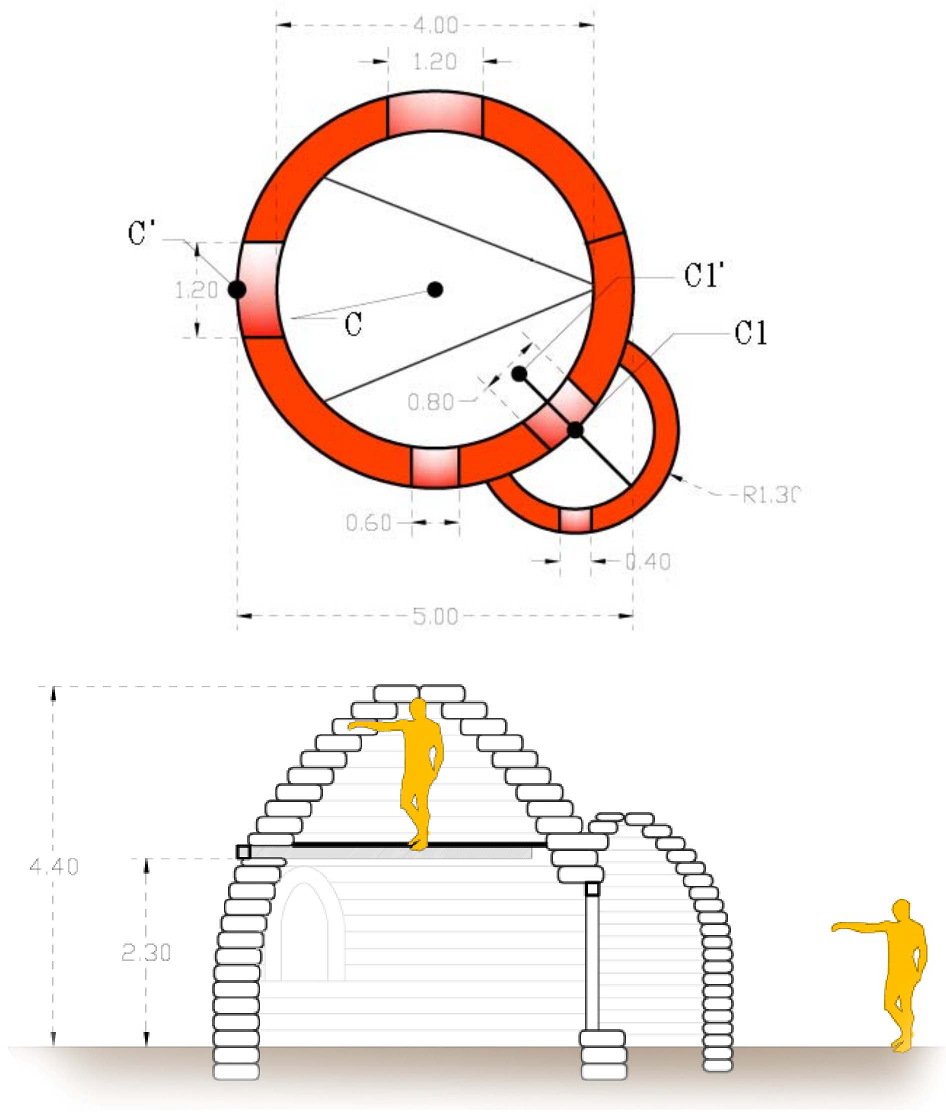

Figure 1: Plan and section of earth bag model

Figure 2: Models

3. MODEL TESTS

3.1. Design Analysis

The structure is analyzed using the Nastran NX commercial code under the FEMAP v9.3 postprocessor. The 18 degree of freedom (d.o.f) triangular shell element is implemented. A fine mesh of 32155 elements is constructed with a total of 97986 dofs. The structure is pinned at its base. Nodal Loads are computed and imposed into the structure, taking into account wind and snow actions, according to the EC 1 norm.

After drying, the earth bags are considered to be monolithically connected. In practice the connection is temporarily achieved in the first steps of the construction process using barbed wire. Therefore both the membrane and the wire should be checked to make sure they can withstand the shear stresses developed.

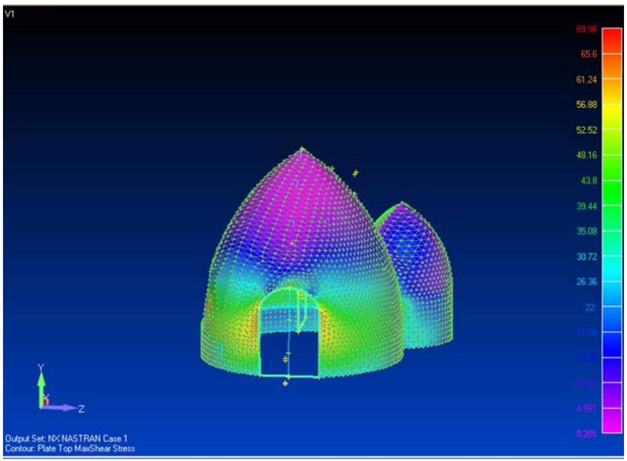

Figure 4: Maximum shear stress

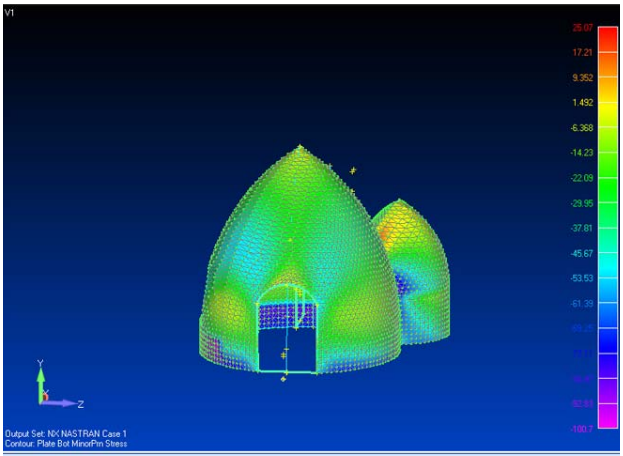

Figure 5: Maximum comprasive stress

In Figure 4 the maximum shear stresses are presented. A concentration of shear stresses (70 KPa) is developed at the door as expected due to the analysis method, but as a whole the maximum shear stress is met in the base of the construction and does not surpass the value of:

$$\tau_{sd} = 50 \text{ KPa}$$

In Figure 5 the maximum compressive stresses are plotted. Obviously, the maximal is developed in base of the construction: $\sigma_{cd}=100$ KPa

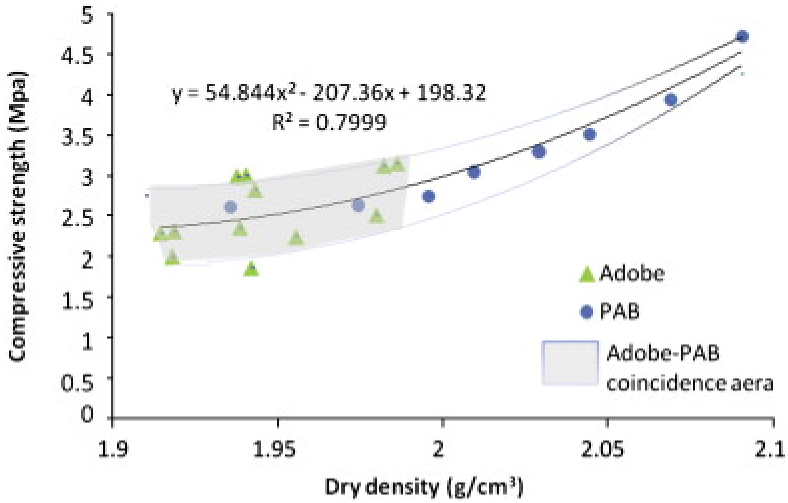

Figure 6: Relationship between ovens dried density and compressive strength (Kouakou 2009)

According to the results of the analysis and the results in presented in Figure 6 (Kouakou 2009, Morela 2007) concerning compressive strength measured experimentally : scd/scRd > 0,05 and Tsd=tsdXbcheck = 50X0,55 =27,5KN/m < 50KN/m the aspects of material is more than enough safe for construction.

3.2. Energy tests

The energy tests, in order to achieve thermal comfort, are calculated using the software "ECOTECT". Through this software there is a comparison of the prototype model with related, insulated, construction build with common/conventional materials.

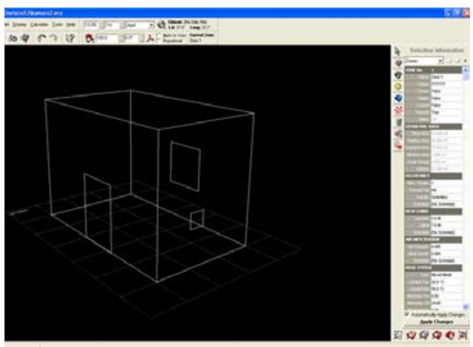

Figure 7: Conventional construction in ECOTECT

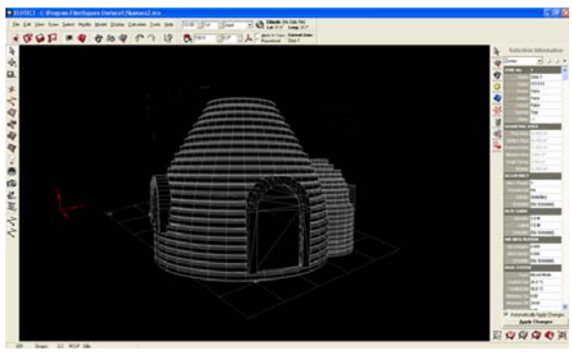

Figure 8: Prototype earth model

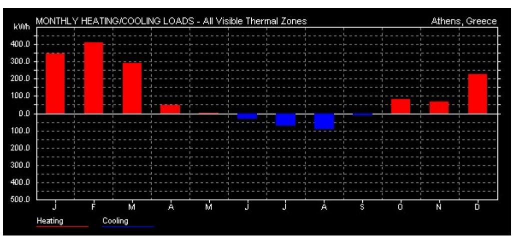

Figure 7: Results in conventional construction

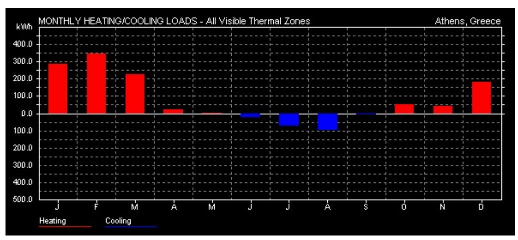

Figure 8: Results in earth model

So earth construction consumes 23% less energy than a conventional insulated construction.

4. ENVIRONMENTAL EVALUATION

Environmental evaluation of earth building (Sargentis 2007, Shukla 2009) shows that indicators as:

(1) The embodied energy of a built-up area is almost 10 times more than the embodied energy involved in maintenance of the adobe house.
(2) The energy pay back time (EPBT) is 1.54 years for the adobe house under study.
(3) The heating/cooling load for the adobe house has been found to be 23% less than an adobe house (Hyde 2005).

More parameters are evaluated in the following table.

Evaluated issues	**Typical construction**	**Earth building construction**
Materials	🟥	🟩
Flexibility of the construction and accommodation (recycling aspects)	🟥	🟩
Cost	🟥	🟩
Codes and standards	🟩	🟥
Embodied energy and energy of use	🟥	🟩
Development in high levels (the city as we know it)	🟩	🟥

Table 1: Multi-criterion Table of evaluation on sustainability issues

5. DISCUSSION

Even if earth-building and earth architecture is an ancient construction method in Greece and specially in Crete (Nodarou 2008), today there are not enough standards to build with earth in Greece. But codes and standards of earth building are trying to be solved in other countries (Khalili 1998, Walker).

More than that, earth is used in building as mortar building material (artificial stone) with less compressive strength than concrete but used and made up like concrete. It needs though a lot of experience and testing in order to find the proper material to build with (Delgado 2007).

So if concrete tests had a relationship with the earth as a building material, constructors, engineers and people in general would have new standards to work with this material and they would be able to build with earth.

Another problem is that earth building is not recommended for high-level development. But cities as we know them are hopeless anyway. So earth building gives the design principles of new forms of city (Khalili 2008).

But a main benefit of this construction is the organic development of architectural forms. “In Nature, no two men are alike. Even if they are twins and physically identical, they will differ in their dreams. The architecture of the house emerges from the dream; this is why in villages built by their inhabitants we will find no two houses identical. This variety grew naturally as men designed and built their many thousands of dwellings through the millennia. But when the architect is faced with the job of designing a thousand houses at one time, rather than dream for the thousand whom he must shelter, he designs one house and puts three zeros to its right, denying creativity to himself and humanity to man.” (Fathy 1968).

6. CONCLUSIONS

As presented, earth building gives the opportunity to the people to build their homes in an ecological and economical way and to be able to apply this method of construction in organic cities.

These cities will easily be constructed, recycled and transformed if necessary.

And this is how earth building may give dod-man his shell (shelter) in each place on mother earth.

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