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Transdisciplinarity in rammed earth construction for contemporary practice

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ABSTRACT: For centuries rammed earth has been a method of construction in various parts of the world. It is an economical building technique as earth is an abundant cheap resource. It is durable, safe and a desirable building technique for hot climates. This paper is discussing a workshop activity in building with sustainable rammed earth construction methods in Egypt. It adds to previous research in vernacular rammed earth a transdisciplinary and participatory dimension. Believing that they are assets to promote for rammed earth benefits and applicability in contemporary practice. The central philosophy of this workshop is to enable researchers, practitioners, decision makers and interested laymen from different disciplines to interact in a transdisciplinary action approach to awaken the importance of adopting green affordable building practices. This paper shows how to initiate a low cost and an energy efficient earth buildings and discuss the criteria on which rammed earth structures is assessed.

1 INTRODUCTION AND BACKGROUND

In the world's history of architecture, earth has been the most popular structural building material. However concrete and steel have become the most common and conventional building material in the 20th century due to the modernization movements in building technology. As a result standardized modern architecture has prevailed and has been sweeping away the architectural characters of every region.

Earth behave like no other building material available in the Egyptian market today (Fathy, 1973), in addition it fulfills the current ecological and economic local requirement (Schijns et al., 2003). Earth is an abundant natural resource in the Egyptian desert, it requires few aggregates or additives to improve its properties (Morgan, 2008). Building with earth is an easy yet labor intensive process, a fact that can be considered an advantage in developing countries (UN report, 1986).

The majority of vernacular buildings in Egypt, either in the agricultural or desert areas has been built using adobe bricks (Fathy, 1973). However from our observations there were regions were "*Touf*" technique is used which is laying earth in several courses without formwork, which is similar to the cob technique used in England and France.

Rammed earth is an ancient construction technique that utilizes earth to create thick durable load bearing wall. It is low-cost, with heat-storing capacity and is recyclable (Minke, 2000). It has been developed independently in many parts of the world, and is also commonly known by its French name "Pise" (Keable, 1996). The technique of Rammed earth is simply based on compacting soil between vertical formwork boards, which are then removed leaving a mass soil wall. Usually this technique is used in regions whose soil composition is unsuitable to make sun dried clay bricks (McHenry, 1986).

Rammed earth technique was also used in the arid regions of North Africa and the Middle East, where earth was the only logical building material. The Romans and the Phoenicians transferred the technique of rammed earth to Europe in the early 16th century (Easton, 1996). It is not yet common in Egypt but there are some promising contemporary trials as shown in Figure 1.

This paper is discussing a workshop activity organized in Egypt during February 2014. It is trying to fill in a research gap on wider applicability of rammed earth. It aims at raising the awareness of using such environmental and economic technique for possible contemporary applications. In addition, the main objective is to promote using rammed earth as a sustainable, energy efficient and a low impact building technique. The paper shows how transdisciplinary participatory approach was applied through an action intensive two days

Figure 1. Center for building crafts in Sinai built with rammed earth and stone. Photo credit Nashwa Ibrahim.

workshop training. Where practitioners, decision makers, laymen, members of a local NGO and international initiatives come together to discuss in a practical way the possibilities, challenges and obstacles that hinder implementation and proposing feasible future action plans.

2 PROBLEM DEFINITION, POTENTIALS AND CHALLENGES

Egypt is currently facing a critical problem in terms of energy security. The residential sector accounts for 50.7% of the country's energy consumption (EEHC, 2012). That is for building materials manufacturing, construction and energy needed for running buildings. Moreover, Egypt is suffering from severe housing problems and the government is still unable to provide decent affordable residential units especially for the low-income sector. Which led to the crisis that 50% of the urban housing stock is informal (World Bank report, 2007).

The embodied energy of rammed earth is three time less than those of conventional techniques using fired bricks (Reddy et al., 2014). Also using stabilized rammed earth improves its thermal properties and reduces the energy consumed for heating and cooling (Serrano et al., 2012) which is negligible when compared to conventional methods using concrete and fired brick. However to be able to apply such notion there are still many challenges towards taking further practical steps in the construction field.

Till now there is no national standard or published reference documents in Egypt for earth construction in general or for rammed earth construction in specific. In addition the current regulations and legislations for building permits are considered a main obstacle for any initiative to build using rammed earth.

To create a segment of potential architects and designers who are aware and skilled in building with earth, we have to start by education. Earth construction is not a core curriculum at architecture schools, in some rare cases it is an elective course, but in most cases it is totally missing. When it comes to craftsmanship, there are few vocational trainings on earth construction and skilled masons are rare, and if available their wages are higher than other workers.

There are wide spectrum of good types of soil in Egypt that can be a good potential for the applicability and feasibility of building with rammed earth. However there is no updated precise documentation for the properties of the soil types and the supply chain for raw materials is either not complete or missing. Also the quality control measures for earth structures are not fully established in Egypt or widely recognized and still there are variations between certified tests.

3 METHODOLOGY

The workshop is an experimental research that applied a transdisciplinary participatory action research (PAR) method. Transdisciplinarity was adopted as it suits best the nature of this workshop. The aim of the methodology is to improve this area of concern and to politicize this workshop design process as a base from which power relations can be created and transformed to possible collaboration between researchers and practitioners with national authorities, decision makers and community partners.

It is discussed in literature that transdisciplinarity is an intellectual space where participants from diverse disciplines can express their views and provide input of different types (Somerville & Rapport, 2002). Also transdisciplinarity is a sort of interdisciplinary approach but within a system or structured plan through encouraging participation and involvement of different social members in an action collaborative research plan (Lawrance, 2004). While the participatory component applied in this research is a kind of a social progression. That is aligned with Gramberger's definition to transdisciplinarity as a social process in which a group of individuals decide about the future of a specific issue (Gramberger, 2001).

The authors with two co-instructors were in charge in teaching and monitoring the whole workshop phases. The four instructors are architects with experience in vernacular and traditional earth buildings. They acted as catalysts for the workshop idea, planners for the workshop phases and facilitators for the building process. The transdisciplinary and PAR in this practical training gave the chance to bring scientific research with everyday experience of field practitioners, engineers, decision makers, NGOs and business owners together. The dialogue created between the participants enabled all parties concerned to express ideas about problems, challenges and possible future applications. The workshop process and the project planning after are explained in the below sections.

4 WORSHOP IDEA, HOW AND WHY IT STARTED

A total of 29 participants joined the workshop, including a representative from the Egyptian Housing and Building Research Center (HBRC) who is in charge of green building codes and rating systems. In addition to a representative from MED-ENEC project, which is an EU project for energy efficiency in south Mediterranean countries. Their presence was important as they are in charge of developing guidelines for energy efficiency in buildings. Among the group of participants there were two civil engineers specialist in sustainable structures, two electrical engineers specialist in renewable energy—at the same time they run an NGO-, one product designer and one secondary school student. The rest were architects, six in academia and research, and the remaining are practitioners. There were also three local workers who helped in the building practical phase. The workshop started with an introduction on the site characteristics including local climate, topography, wind direction, and sunlight orientation. Then it was followed by a discussion on how to control energy consumption using energy modeling and simulation programs in designing energy efficient and low-tech rammed earth building. The discussion showed how to achieve preliminary assessment for energy efficiency before construction.

Participants were also introduced to the concept of how to build a low-impact house using practical examples. In addition how to pay attention to the importance of indoor thermal comfort and air quality through cross ventilation, night-flush ventilation and thermal mass. That is to reduce cooling loads and counteract daytime heat gains. Together with how to control daylighting and in the same time reduce glare and heat gain from openings. These factors, together with others, will influence the location and orientation of the building within the boundaries of the site. This phase ended with a theoretical introduction on rammed earth building techniques which was followed by a practical phase for the physical building steps explained below.

5 BUILDING WITH RAMMED EARTH TECHNIQUE: THE PRACTICAL EXPERIENCE

In order to experiment rammed earth as a building technique, practice it, explain it and even promote it, a practical hands on training was held. The following steps were undertaken:

5.1 *Soil identification*

The soil used in rammed earth technique has to be identified to know its components and whether it needs other additives to enhance its characteristics. Accordingly a series of field tests were conducted using a sample from the site taken from a depth of 0.5 meter, to ensure that the surface organic materials are not included.

5.1.1 *The drop test*

A handful of un-sieved soil was taken, moisten and made into a ball, which was held in hand and left to dry for a few minutes before dropping it. Fortunately the soil excavated from the site was suitable as the ball broke into a few lumps.

5.1.2 *The roll test*

Although the drop test applied indicated that the soil dug from the site is suitable, it was important to apply another simple test to double check the suitability of the soil in the building process. So a lump of moist soil was taken and rolled by hand to form a cigar-like roll, which was almost 20 cm in length and 2.5 cm in diameter. The roll was placed on a table and pushed gently over the edge, and the length of the broken part was measured to indicate the amount of clay within the soil. The roll broke almost at half the length, as usually if the broken part is less than 8 cm then this indicates that there is no enough clay and also if the broken part is longer than 12 cm, then this means that there is too much clay.

5.1.3 *The jar test "particle size test"*

In order to know the proportions of different particle sizes of the soil used, the jar test was applied.

Figure 2 & 3. Left: participants testing the soil, the roll test. Right: participants testing the soil, the drop test. Photo credit: M. Dabaieh.

That is to get a preliminary assessment of the ratio of coarse to fine particles in the soil. Two thirds of a bottle was filled by soil taken from the site, and water was added to fill the bottle. The bottle was shaken till all the soil particles were suspended then it was left to settle for a few hours. As the water cleared, we realized the formation of three different layers separated by clearly visible lines. The sand layer settled at the bottom as its particles were heavier, then two layers of silt and clay were formed on top.

5.1.4 *The result*

These simple field tests indicated that the soil of the site contained more sand and gravel than silt and clay, in a rough ratio of 3:1. Although the site soil was suitable to be used in rammed earth, the addition of lime to the soil was suggested as a natural and environment friendly stabilizer that will hold the coarse particles of the gravelly soil together. Accordingly lime was added to the soil in a ratio of 1:9.

5.2 *Soil mixing*

The soil was sieved to ensure that no large size gravel included, and then mixed with lime. After the thorough dry mix process water was added gradually. The mixture had to be turned over while water is sprinkled to ensure that all the particles will be moistened. The amount of water added to the soil is very important, because if the mixture contains little water the soil will not be properly squeezed, and with too much water the soil becomes too wet and water will resist compaction.

The amount of water added depended on a number of factors, the drop test gave an indication of the amount of water needed to achieve plasticity, but the site conditions also had an effect, as water evaporates while mixing in hot weather. Generally speaking water forms 10%–15% of the mixture, and the mixture should look quite dry after adding it.

Figure 4. Participants mixing & preparing the soil for ramming Photo credit: M. Dabaieh.

Figure 5. The formwork when assembled to ram a new layer. Photo credit: M. Dabaieh.

Figure 6 & 7. Left: ramming the first layer. Right: installing the formwork. Photo credit: M. Dabaieh.

5.3 *Formwork*

While the soil was mixed and prepared, another group was assembling the forms. Formwork can range from simple to complicated systems, however in our workshop we decided to use simple, easy to assemble and dismantle and in the same time affordable forms. So these forms were composed of a number of items:

- 16 mm thick plywood boards
- Long metallic bolts to assemble the boards
- Metallic pipes (whose length corresponds to the require width of the wall) to ensure a uniform spacing between the two boards
- Wooden planks that are placed along the length of the plywood boards to keep them in place, and also to be used as scaffolding
- Wooden planks were used as “stays” whenever needed, they were wedged diagonally between the formwork and the ground to keep the formwork in place.

The design of the formwork proved to be practical, as components were easily and quickly assembled to start the next process.

5.4 *Ramming*

The mixed moist soil was poured in the formwork creating a uniform level of almost 15 cm, which after ramming was compressed to 10 cm. As soon as the first layer was rammed properly another was poured to be rammed, and so on.

Metal rammers were used to ram the soil, which were composed of a steel rod with a flat steel plate, the weight of the rammers and the size of the plates differed to suit the users and enable them to ram the corners. A layer was considered to be properly rammed as soon as an echoing sound was heard from the rammers, an indication of the compactness of that layer.

The width of the formwork enabled users to stand inside it and ram, an advantage that ensured that all the corners and the edges were rammed properly.

5.5 *Inserting electricity conduits*

It was important to insert electricity pipes and boxes for electricity sockets in their exact place while ramming. This would save a lot of effort in trying to chisel the walls after drying to place the pipes and then repair them. Placing these pipes proved to the participants that rammed earth is a building technique that is appropriate and suitable to contemporary needs.

5.6 *Dismantling the formwork*

The formwork was left for one day and then the metal bolts were removed slowly and the plywood was slid upwards slightly before being removed from the wall. The process had to be done slowly and gently so that earth does not stick to the formwork and damage the surface. The wall was covered by plastic sheets to protect it from direct sunshine. After one or two days, and depending on the weather conditions, the rammed wall would be dry enough to carry the formwork, and work can be proceeded vertically.

5.7 *Plastering and rendering*

One of the advantages of using smooth formwork is to achieve a smooth fair-faced surfaces. Rammed earth walls do not need plastering at all, it is advisable to sponge the surface with a moist towel immediately after dismantling the formwork. In case there were any small holes in the walls, they can be filled by hand from the same soil mixture. In the workshop we experimented a number of materials to render the walls, such as clay and lime, which are natural materials that are dissolved in water and are easily applied to the walls using brushes or sponges.

6 PARTICIPANTS' REFLECTIONS AND PARTICIPATORY DISCUSSIONS

Although the participants joined the workshop willingly based on their passion and interest to learn more about rammed earth. The majority of them were involved in earth construction in a way or another but the discussion revealed a lot of concerns and fears about using rammed earth. It was crucial to discuss all the challenges and try to propose a road map towards promoting rammed earth construction in Egypt. Some of the participants were still skeptical about safety issues, maintenance cost and construction time in addition to fire and water resistance. Also the land cost and the possibility to extend vertically in case of building in urban areas were among the major concerns.

From the discussion, several questions were raised regarding the applicability of building with such technique. Participants pointed out that building with rammed earth might need more time during the design development phases, something that will be translated to extra cost. But the long term benefits cannot be compared to the long-term running costs and the environmental impacts of our conventional techniques. Which are more expensive to construct and to run in addition result in numerous environmental and health hazards. Their concerns are understood as it is always a major problem that clients pay attention to initial cost but not to the running cost.

Some participants raised the issue of the design of the super structure with the main focus on the compressive strength. Plus water absorption and weather erosion of the earthen walls, including details for visual inspection. That is in addition to the structural stability of the walls. These concerns show a need for and importance of developing tests to improve reliability. Together with performance requirements and tolerances which should be explicitly defined prior to the construction phase.

One important discussion topic was concerning the national building code that should be a guide on soil suitability and moisture content, and sets out requirements for formwork, methods of construction, testing and curing of rammed earth. Also detailed information on material testing is very important. In addition the code should be designed and written in conjunction with all other appropriate building standards. Many countries like Germany, Spain, USA and Zimbabwe have already robust codes and standards. By examining such codes one will find that they are combined experiences presenting the current state-of-the-art in rammed earth construction around the world. The building culture and climate of these countries may differ from the conditions of Egypt but they can still be important basis for the development of national standards and guidelines.

Also the discussion highlighted the material and production parameters and how they have a considerable effect on the quality of rammed earth walls. As optimizing material handling and production can be decisive for the acceptability of the end-product.

Maintenance issues was discussed as being burdensome compared to conventional building methods as absence of regular maintenance can be more damaging in earthen structures than in other building types. Water is a major agent of decay in rammed earth buildings. Maintenance should mainly be for protecting rammed earth from water deterioration.

Concerning the high U value of rammed earth, it was discussed that thick walls which provide high thermal mass could be a common design solution. Through the absorption and release of moisture it regulates the relative air humidity naturally and maintains comfortable surface temperature. Some questions and concerns were on openings, which could be formed easily in various ways, including arched openings, timber lintels, concrete lintels or even steel lintels. When it comes to economics generally building with rammed earth should not be expensive especially when compared to conventional techniques using industrialized building material. The cost ranges from 30 to 40 Euros/m^2 which is even less than 50% of the cost of current conventional techniques for low income housing in Egypt.

Ecological objectives and criteria for the building material and the use of sustainable resources were also of a concern. Rammed earth buildings could be fully recyclable after useful lifetime with low energy production and with nearly zero emissions in the whole building life cycle phases. The conclusion of this discussion revealed that there is a need for low-cost, affordable, energy efficient buildings with minimal carbon and ecological footprints. Building with rammed earth revealed to be a feasible solution.

There are several challenges starting from building standards and legislation till the craftsmanship and implementation. This transdisciplinary approach facilitates taking action steps to move forward towards an action plan. The workshop ended with a design proposal for a pilot project of a model house under the supervision of (HBRC). The participants formed teams for design, building simulation for energy efficiency measurements, material investigation and testing, fund raising and a technical writing team. That will end up with technical recommendations, a manual for rammed earth building best practice in Egypt. Then this technical recommendation could be a draft for a guidelines or standard for earth construction like the German DIN.

7 CONCLUSION

As we are moving towards an era of increasing environmental awareness and with several energy and environmental challenges. The current situation drives responsible researchers and professionals to explore ecological yet economical construction methods. The transdisciplinarily and participatory contribution in this workshop bridged academic research with professional practices together, while involving NGOs and public authorities. The outcome concluded that adopting earth construction techniques should be one of our first natural choices for future building practice. Rammed earth is an optimized construction method with guaranteed product properties for the Egyptian market. Despite all the revealed challenges in this workshop, the demand for earth-based buildings products and services is still developing both on the private and commercial building or construction level. The market is still virgin and there is a big potential to support the local economy and create job opportunities especially in the remotest villages in Egypt. Building using rammed earth can save energy consumption in the building sector and at the same time can offer low cost and self-help housing.

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