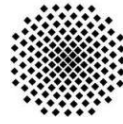




Ain shams university



University of Stuttgart

**Alternative Building Materials and Components
for Affordable Housing in Egypt
Towards Improved Competitiveness of Modern
Earth Construction**

A Thesis submitted in the Partial Fulfillment for the Requirement of the
Degree of Master of Science in Integrated Urbanism and Sustainable Design

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2013

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Disclaimer

This dissertation is submitted to Ain Shams University, Faculty of Engineering and University of Stuttgart, Faculty of Architecture and Urban Planning for the degree of Integrated Urbanism and Sustainable Design.

The work included in this thesis was carried out by the author in the Year 2013

The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

07/31/2013

Mona Farouk Elkabbany

Signature

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Abstract

Building material is an important aspect within the design and construction process, having a big influence on the cost and quality of the built environment. In Egypt, the construction sector has a large share in the national economy, yet, a significant shortage in the affordability and sustainability of housing occurs. Efforts for improving the competitiveness of sustainable building materials are a contribution to improve the quality and affordability of the built environment, as well as the ecological balance and sustainability. The current research aims to investigate the potential of using the techniques of modern earth-construction in the Egyptian construction sector, and the possible means to encourage its utilization, within appropriate contexts, to provide sustainable and affordable housing.

Earth has been an ancient and a widespread building material for vernacular and popular construction in Egypt, and in modern times, there have been several attempts for its revival with the same traditional techniques. A few experiments for using the techniques of compressed earth blocks (CEB) and Rammed earth (RE) have been undertaken; however, the potentials for its contribution towards offering affordable and sustainable housing are still undermined.

This research investigates the factors causing the underutilization of earth as a modern sustainable building material in the Egyptian construction sector through a group of interviews with experts and practitioners in the field, as well as analyzing some cases that experimented modern techniques of earth construction – particularly CEB and Rammed earth - in Egypt. The research uses the “Value Chain analysis” which is a concept from business management that was first created by Michael Porter (1980). It is a method for describing the activities taking place along a supply chain of a product, such as a building

material, and identifying the constraints it is facing and the opportunities for its improvement.

Recommendations based on the analysis of the constraints and opportunities were as follows: improving the social perception about earth as a building material, the appropriate choice of production methods and construction techniques, knowledge exchange and dissemination, promotion and marketing, creating a role model, offering incentives, improving planning policies and regulations, developing codes and specifications, encouraging industry and empowering local contractors.

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Abbreviations

| | |
|------|---|
| BM | Building Material |
| CEB | Compressed Earth Blocks |
| CSEB | Compressed Stabilized Earth Blocks |
| CS | Construction Sector |
| EECA | Egyptian Earth Construction Association |
| HBRC | Housing and Building Research Center |
| IEQ | Indoor Environmental Quality |
| RC | Reinforced Concrete |
| RE | Rammed Earth |

Chapter One: Introduction

Chapter One: Introduction

This chapter discusses the research background and motive, aim and objectives, research questions, methodology, and conceptual framework.

Background of the Research

Green building and sustainable construction are terms that are starting to gain interest among academics and practitioners in the field of construction in Egypt; especially with the current situation of shortage in energy, rapid urbanization, and high pollution rates. On the practical level, there is rarely any significant change in the construction practice towards sustainability except for a few scattered efforts based on individual and personal initiatives from experts and practitioners. Sustainable construction has many aspects such as passive design, selection of appropriate materials and construction techniques, and energy efficient systems for minimizing power and water consumption. Innovations in the field of alternative and green building materials are starting to gain interest especially in the research field, and many alternatives for building materials and components have been tested and have proven to be successful. The real challenge is to promote the idea of using sustainable

building materials into the construction sector, and especially to direct it towards supporting the affordability of housing.

Earth construction has been promoted in many countries in the modern age as a sustainable building material, with new techniques that were developed to improve the properties and performance of the material. Experiments for applying these building techniques in affordable housing have been successful in some developing countries especially in Africa.

A Brief about the History of Vernacular and Modern Earth Construction in Egypt

The popular architecture in Egypt has demonstrated the potentials of locally produced building materials, and how it can be wisely utilized to provide its inhabitants with an affordable shelter and a comfortable microclimate by using local raw materials and simple production technologies. Examples of this architecture can still be seen and experienced in the remaining mud structures in villages and in the desert settlements. However, this architecture is rapidly vanishing with the rise of industrialized building technologies, and due to many socioeconomic changes in the community, such as the migration of many Egyptians to work in Gulf countries, and consequently being able to afford to replace their old mud houses in their villages with new reinforced concrete buildings. This gradually became a sign of wealth and modernity. Moreover, with the construction of the 'High Dam' in 1965, the natural yearly renewal of the soil coming with the flood was prevented, and this consequently led to the government's decision in the 1980s to prohibit the use of mud from the fertile agricultural land in any act of construction. At that time, this mud was the main raw material for producing the red fired bricks in the villages, and so, alternatives for this brick like cement blocks, limestone and fired clay bricks (from desert clay) started to substitute it. Other consequences of the high dam

were the decisions to stop the sprawl on agricultural land, and hence, the rapid rise of land prices which led to the decrease in land areas available for building. So instead of having 1000 square meters, for example, to build a family house, the farmer had to build his house on a 200 square meter area, which made a vertical extension the only choice for accommodating the whole family and securing a residence for sons and daughters. This was in addition to cultural changes due to the modern way of life which required the use of building materials that supported the use of modern interior finishing and utilities, and a mistrust that became linked to 'mud bricks' as a non-durable and weak material. All these factors caused mud bricks to become undesired building material, and changed the culture of using local building materials to become more dependent on materials produced by mass production in factories centralized around the capital city and far from the villages and remote settlements.

Despite all these socio-economic changes, experiments and efforts to use earth as a building material have not stopped. It has been reintroduced in the modern times as a sustainable and appropriate building material with different techniques. However, most of these efforts have not proven to be successful in promoting the material to the people. The incorporation of earth construction in architectural and urban development in modern times can be classified within two main approaches. The first approach is represented in Hassan Fathy's early work in El-Gourna in the middle of the twentieth century, and in Ramsis Wissa Wassef's work in Harraneya; which aimed at the utilization of appropriate building materials and techniques for the provision of affordable housing for the poor and for local people; which can be described as the right utilization of the material or technique within its appropriate context.

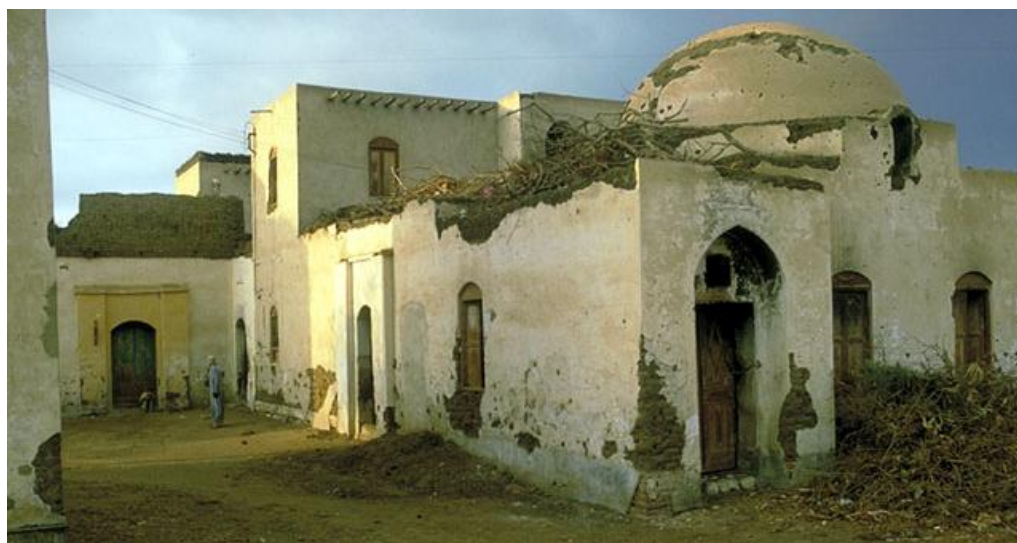


Figure 1: Street in New Gourna. (Source: Archnet.org¹)

Those trials unfortunately have ended up in failure in terms of achieving their goal, since the local people have abandoned these houses or refused to live in them in the first place. Contrary to what was intended, this style of construction attracted another category: the rich and the intellectual, as well as the foreigners living in Egypt. From this point the second approach appeared. This is represented by Fathy's late works of private residencies for foreigners and rich intellectuals, and later by the work of his followers and students, and is exemplified in the multitude of tourist villages on the Red Sea coast, eco-lodges and tourist facilities. This approach can be described as the utilization of the material or technique within an inappropriate context. This later approach has gained superficial success. The architectural style was highly appreciated by practitioners and academics in and outside Egypt, however, it had not succeeded in achieving its primary goal which was providing affordable and sustainable housing for the people.

Thus, the history of earth construction in the modern formal architectural movement in Egypt can be summarized as: some early attempts that were conducted for the right beneficiaries (the villagers) which ended up with a clear

failure, and later attempts that were conducted for another category of users (the rich society and tourists) which ended with a superficial success.

On the other hand, the interest in earth-construction has increased in modern times in many countries even in those countries where mud construction has never been a traditional practice. The rising interest in the notion of sustainability, the keen interest in preserving resources, and the worries about climate change and energy shortages, all of these factors have increased the interest in research in the field of earth-construction and in the development of new techniques to improve the material's properties. This is due to the fact that earth is a natural material that does not need high industrial processing, and thus has a low embodied energy, as well as the potential of being recycled at the end of its life.

Earth Construction: Between the Revival of a Traditional Material and the Technology Transfer of Modern Techniques

Modern techniques of earth construction have been developed and transferred as a sequence of contributions and modifications by researchers in different countries. Today, variations of techniques and systems have been developed and are available to choose from according to the appropriateness of every context.

The techniques of Rammed earth and CEB have emerged as an enhancement to the traditional adobe construction. The main idea behind these techniques is to produce building blocks or walls from unbaked soil with enhanced properties by using mechanical stabilization (compression) which works on the soil particles forming strong bonds between them, or by chemical stabilization by adding a small percentage of additives to the soil such as lime, cement, or other stabilizers, which performs a chemical reaction with the soil to enhance its properties and resistance to water. These techniques have gained a lot of

interest in Europe, Australia, and the USA, and have also been used in many African countries as a solution for providing affordable shelter to the people.

Although experiments of using these techniques in different projects and in different countries have shown success, the local context and specific conditions for each case and in every country have a significant influence on the success and the repetition of such projects.

There have been a few experiments to reintroduce earth as a sustainable building material with modern technologies such as the CEB and Rammed earth in Egypt. These were performed on a very limited scale and without having a good infrastructure to support the repetition of the experiments especially that these techniques were new to the Egyptian context, and thus the experiments were mainly dependant on technology transfer. On the other hand, there was a different approach by other practitioners in the field of earth construction who were still keen to work on the revival and preservation of old traditional technique of adobe mud brick construction as a local indigenous practice – which has not technically proven its failure - and considered the new technologies of improved earth construction such as CEB and Rammed earth as an alien and unnecessary complication to the simple and appropriate local technique of earth construction.

This consequently raises the following questions: What are the potentials of introducing modern earth-construction as sustainable building material into the Egyptian construction sector? How can the transfer of technology of these modern techniques be successful within the Egyptian context? And what are the factors that should be taken into consideration to adapt the technology to be appropriate for the local context?

“There are two primary avenues for introducing natural and alternative building methods to standard practice. The first is short term and project based specific, and the second involves change in the larger regulatory system. In both cases, gaining acceptance should be seen as a process, not an event.” (Elizabeth & Adams, 2005). Introducing alternative or natural building materials to the mainstream practice is usually a difficult and time consuming process, as the construction market is conservative and the rejection of new materials or techniques is very likely to happen for fear of risk taking. Many projects in developing countries have involved local building materials in the construction of low cost housing as a strategy for community development, by involving local people in the process and encouraging participation as well as encouraging local entrepreneurs and contractors to adopt the technique. CEB was experimented and used in several low cost housing projects in African countries such as Kenya, Tanzania, Botswana, Sudan, Ghana, and Uganda. Other countries such as Germany, France, New Zealand, and Australia have developed official codes and standards for earth construction, while in some countries industrialization was the key word for encouraging the widespread use of the material. In all cases, the cooperation and integration between the roles of all relevant actors was of high importance, and the presence of specialized entities for promoting the new materials and techniques, and the government’s role in encouraging this action through proper incentives and policies was very effective.

Research Problem

Although Egypt is a developing country that is suffering from a wide range problem of housing affordability, the contribution of local building materials such as earth construction - with its various techniques - is almost negligible. While earth as a building material is becoming gradually recognized in many countries through both building codes and in the practice; it is applied in Egypt on a very limited scope of casual building practices.

Several experiments have been and still are going on to incorporate local and sustainable materials such as earth construction techniques in building. However, there is still a need to study the factors hindering the widespread use of these materials, and the different possible approaches to promote them into the mainstream practice, in light of the context of the current Egyptian construction sector and the appropriate criteria of sustainability.

The research problem is investigated on two levels:

- Identifying the existing constraints and opportunities of modern earth construction; through interviewing experts and practitioners.
- Investigation of earth as a sustainable material, and the analysis of different approaches for its application in construction by studying different cases of using the material.

Research Aim

The current research aims to investigate the potential of using earth with modern techniques and applications as a sustainable building material in the Egyptian construction sector, and the possible means to encourage its utilization within appropriate contexts to provide sustainable and affordable housing.

To achieve this aim, the following points are researched within this study:

- The aspects of sustainability whether environmental, social, or economic in relation to the building materials production and use in construction.
- The current practice of construction and building materials production in Egypt.
- The spot actions and experiments done in Egypt using modern techniques of earth construction (CEB and Rammed earth).
- The constraints and challenges causing the underutilization of earth as a sustainable building material in the Egyptian construction sector.

Research Questions

The research is concerned mainly with investigating the factors hindering and encouraging the production and use of earth as a local building material in the construction sector in Egypt. The research is concerned with answering the following questions:

- What are the aspects of sustainability in relation to building materials? And where can earth be positioned within this criterion?
- What are the challenges facing the building materials and construction industries in Egypt?
- What are the existing spot actions that experimented modern earth construction techniques (CEB and Rammed earth) in Egypt? What are the obstacles and problems that faced its repetition?
- What are the constraints and opportunities to produce and use earth as a modern sustainable building material in the local context?
- How can technology transfer be successful within the local context and what are the challenges influencing this success?

Conceptual Framework

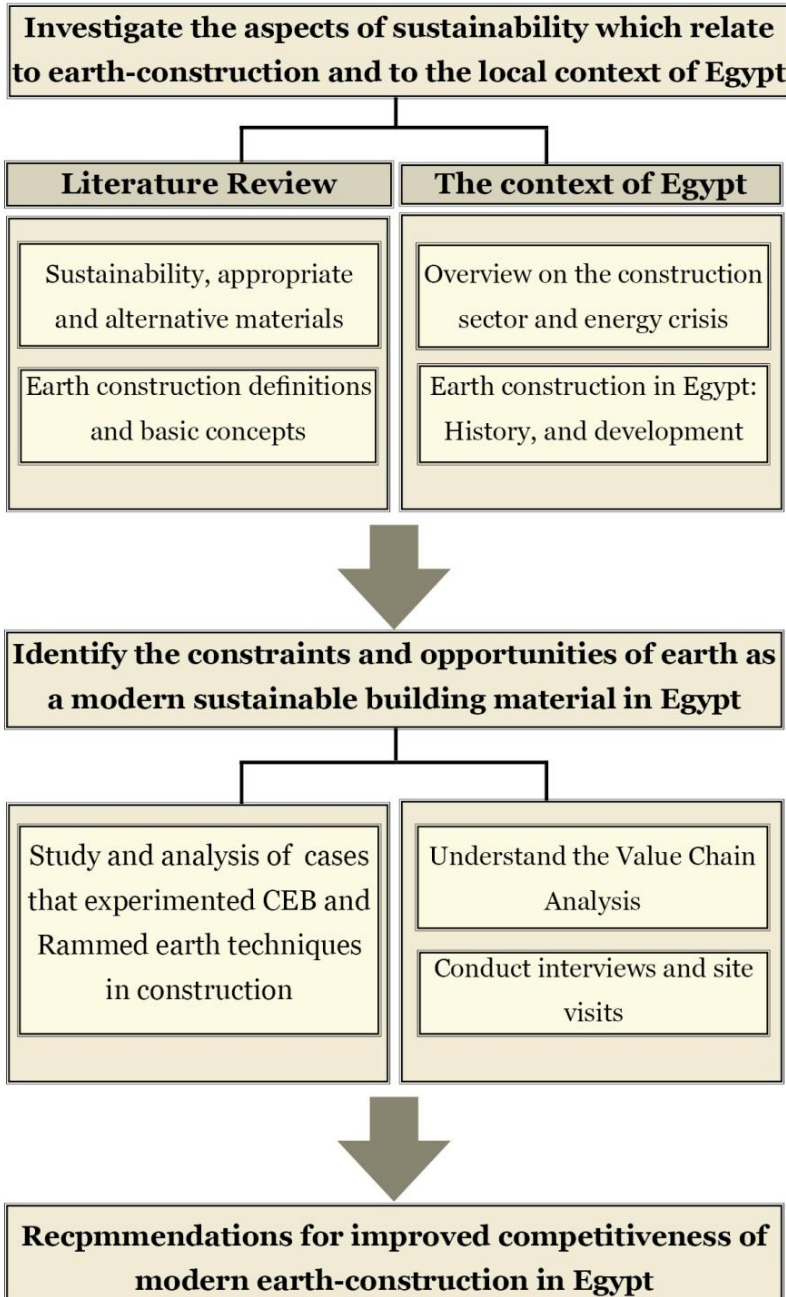


Figure 2: Conceptual framework of the research.

Research structure

Chapter one: Introduction: This chapter discusses the research background, aim and objectives, research questions, methodology, and framework.

Chapter two: Sustainability and Building materials: Positioning earth-construction techniques: This chapter is concerned with linking the concept of sustainability with building materials and techniques, focusing on the context of the global south, and positioning earth construction within this concept. This is based on a literature review as well as an overview on the history of earth construction and its modern techniques.

Chapter Three: Local building materials and construction sector in Egypt: This chapter provides an overview of the construction sector in Egypt. The aim is to shed light on the current challenges facing the construction sector, and discussing the role of local building materials throughout history and the need for its reintroduction into practice.

Chapter Four: Constraints and opportunities of earth as a modern sustainable building material in Egypt: This chapter provides an analysis to the factors causing the underutilization of earth as a modern sustainable building material. The analysis is based on developing a Value Chain Analysis for earth construction, through a group of interviews with experts, as well as studying some cases that experimented CEB and Rammed earth.

Chapter Five: Discussion and Recommendations: This chapter provides a discussion of the research findings and the recommendations for improving the competitiveness of earth-construction.

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**Chapter Two: Sustainability and
Building Materials: Positioning
Earth Construction
Techniques**

Chapter two: Sustainability and Building Materials: Positioning Earth Construction Techniques

This chapter is concerned with linking the concept of sustainability and its relation to building materials and construction techniques, focusing on the significance to the context of the global south and developing countries; and positioning earth construction within this concept. This is based on a literature review about the concepts of ‘appropriate and alternative building materials and technologies’, and an overview on the history of earth construction and its modern techniques, focusing on the techniques of CEB and Rammed earth.

Definitions and concepts

Appropriate Building Materials and Technologies

Building material is directly connected to the whole building process. For evaluating a building material as appropriate it has to be associated with the whole process of building, starting from the raw material extraction until the final assembly and finishing on site.

In their book “appropriate building materials,” Stulz and Mukerji (1993) list nine factors that determine the appropriateness of a building material or a construction technology:

- Whether it is locally produced, or partially or entirely exported
- Being cheap, abundant and renewable or not
- Location of the production factory and the machines and equipments required
- Energy requirements for the production, and the amount of waste and pollution caused
- Climatic acceptability and appropriateness
- Safety against hazards (fire, rain, earthquakes...etc)
- Whether its technology can be easily transferred to the local workers
- Possibility of repairs and replacements with local means
- Social acceptability

Alternative Materials and Technology

“Alternative technology is defined by contrast from what are perceived to be prevalent environmentally destructive practices. Alternative technology is aimed to be environmentally friendly, affordable, and to offer people greater control over production processes” (Sanya, 2010).

The term alternative material or technology is usually used to refer to materials that are not highly industrialized, or materials that are not the standard materials and methods that are used in the current construction practice. Hall (2012) argues that it is considered inappropriate to use the word “alternative” to describe earth-construction, which was once the prime building material on Earth, and that this is also unhelpful in the attempts to promote it as a mainstream construction material.

Intermediate Technology

Intermediate technology is another expression which also refers to the same concept of appropriate technology. The term was mentioned by Schumacher (1973), who defined the characteristics of intermediate technology as cheap to establish, small in scale, employing locals, using relatively simple production methods, and producing goods from local materials for local use. He pointed out that it would be more productive than the indigenous technology, but would be cheaper than the highly capital-intensive technology of modern industry.

Spence (1983) discusses the technical choice for the designer, especially in developing countries where choice is usually bound to the factor of cost. The author defines three criteria of building technology: low, intermediate and high-technology, distinguishing the intermediate technology from traditional technology in that it makes more efficient use of labour and raw materials, produces goods with better quality, makes use of scientific know-how, and is organizationally more efficient.

In this research, the terms **alternative, sustainable and appropriate materials** refer to materials which, unlike the heavily industrialized materials, are produced from local and recyclable raw materials, consume less energy, and use relatively simple technologies of production.

Sustainability and Building Materials: A Multi-Criteria Analysis

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (WCED, 1987)

Sustainability is widely mentioned in architectural and urban design literature, and building material is considered an important aspect of sustainability, due to its huge impact on the environment during its life cycle starting from raw material extraction, to production, transportation, construction, maintenance, and end of life. Environmental and ecological impacts are usually used as the only indicator for sustainability associated to building materials. Edwards (2004) defined sustainable materials as materials and construction products which are healthy, durable, resource efficient, and manufactured with regards to minimizing environmental impact and maximizing recycling.

Kim (1998), adds that a material is considered sustainable if it complies with any or some of the following:

- Prevents pollution during manufacture
- Reduces waste during manufacture
- Has recycled content
- Reduces embodied energy
- Is a natural material
- Reduces construction waste
- Is a local material
- Is reusable
- Is recyclable

However, there are also socioeconomic factors related to the process of material production and the construction process - especially in the developing countries - where a large percentage of people are employed in the construction sector, and the affordability of a building material is the most important criterion of selection.

“Sustainability is not about the material but more about the nature of the processes to which the material is subjected.” (Sanya, 2007). Sanya refers to Rigassi (2006), giving an example of cement which can be perceived as

“Portland cement” or as simply a “binder” that can be based on a local resource and a simple process such as lime.

Therefore, sustainability criteria for assessing a building material should consider the process of its production, especially when importing a building technology that might or might not be adequate to the socioeconomic factors. Kennedy (2004) defines sustainable building criteria such that they have to *“Improve quality of life, be comfortable and aesthetically pleasant, improve access to homeownership for the dispossessed and poorest members of society, use materials that are safe to work with, have minimal impact on the environment, be easily recycled at the end of its life, support biodiversity, be resilient to changing environmental and social conditions, be locally built, maintained, fixed and disposed of safely, promote community- building process, be energy and material efficient, be reusable or recyclable, be soft, fun, safe and healthful, build assets, be socially equitable and empowering.”* To conclude, the aspects of sustainability in relation to building materials can be classified into two categories: **environmental aspects** and **socio-economic aspects**. Both aspects are important within the context of developing countries and the Egyptian context.

Environmental Aspects

The environmental aspects of a building material have two criteria: the ecological impact on the environment due to the manufacturing of the material as well as the construction process, and the Indoor Environmental Quality (IEQ) indicated by indoor temperature and humidity. The ecological aspects are related to the building material’s life cycle.

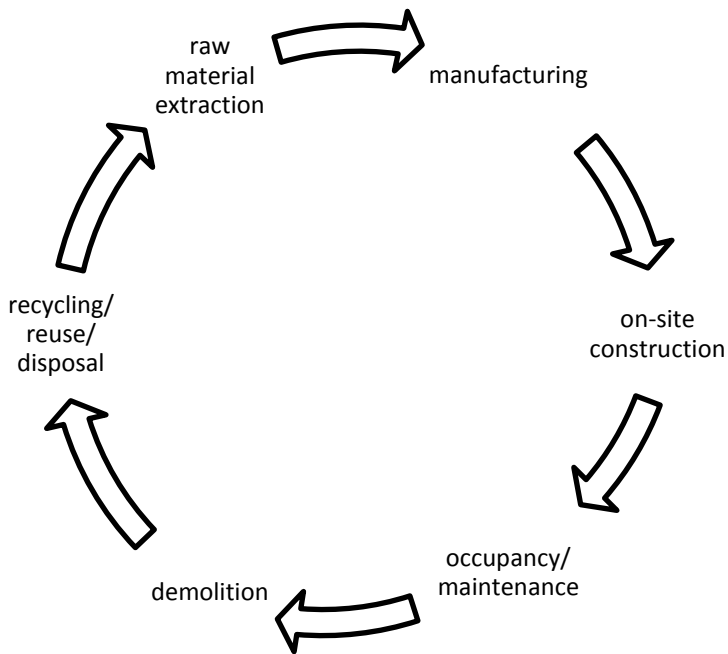


Figure 3: Building material life cycle.

Socio-Economic Aspects

The socio-economic aspects for a building material are related to the nature and level of technology of the production process, the cost of the material, as well as the social acceptance.

The following diagram shows a summary of the environmental and socio-economic aspects of sustainability which are related to building materials, based on the literature review.

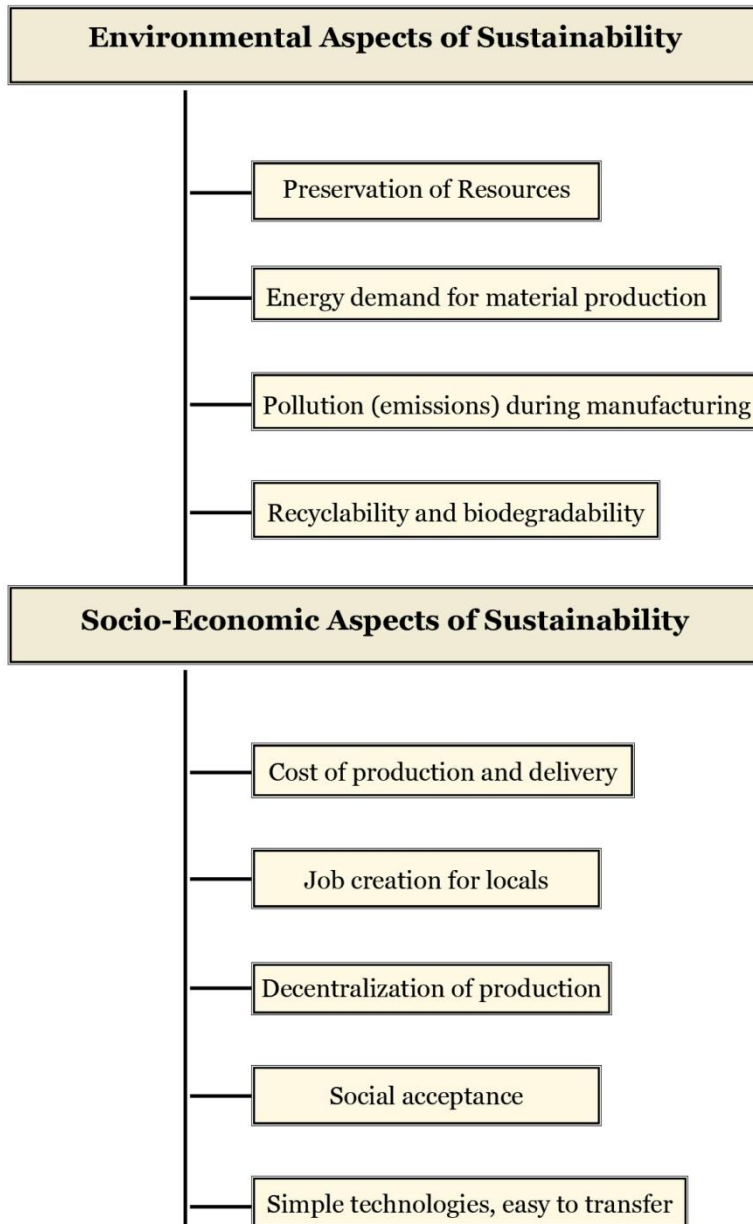


Figure 4: Aspects of sustainability that relate to building materials based on literature review. Source: author.

Overview of the History and Modern Techniques of Earth Construction

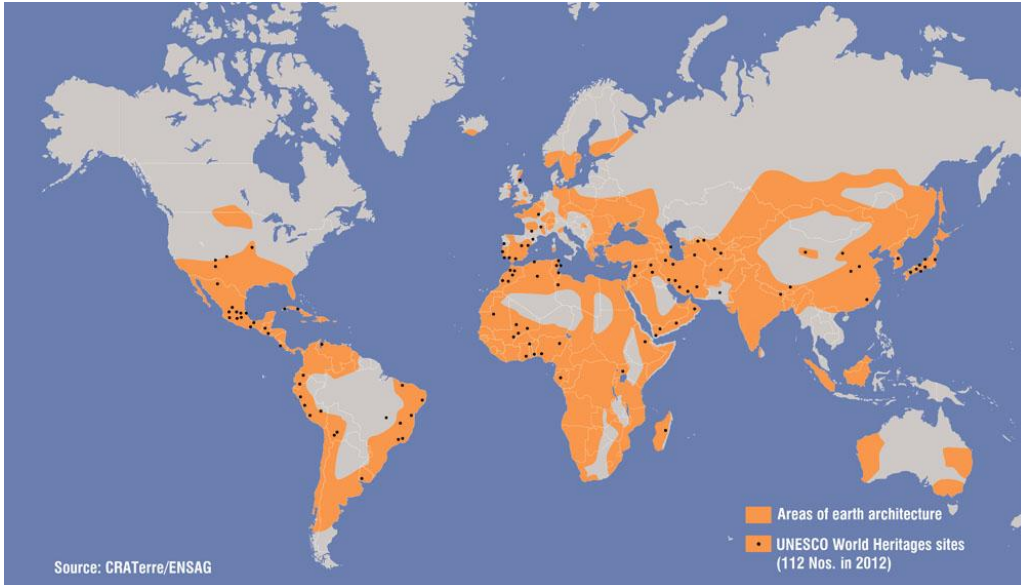


Figure 5: Map showing locations of earth architecture in the world.

“Thirty percent of the world’s population live in a home in unbaked earth” (Houben & Guillard, 1989). Earth is one of the oldest building materials in history. Existing ancient earthen structures demonstrate the potentials of the material such as the vaulted structures of the Ramesseum granaries in Luxor (3,400 years old), the Great Wall of China with have whole sections built with Rammed earth (3,000 years old), the city of Shibam in Yemen (16th century), and the historic adobe structures in west Africa such as the mosque of Djenne in Mali (13th century).



Figure 6: Earthen historic city of Shibam in Yemen

Earth was promoted in several occasions in modern times as a sustainable building material. New modern techniques have been developed to improve the material's properties, such as Compressed Earth blocks (CEB), Rammed earth and Cast earth. Modern practices of earth construction have become widespread in many countries like Australia, France, USA, and India. And a number of specialized institutes in earth construction have emerged in these countries such as CRATERRE in France, DVL in Germany, and Auroville in India.

Raw Materials

*“Earth, when used as a building material, is often given different names. Referred to in scientific terms as **loam**, it is a mixture of clay, silt (very fine sand), sand, and occasionally larger aggregates such as gravel or stones.”* (Minke, 2006). Clay acts as the agent that binds the mixture together while sand, silt, and gravel act as aggregates, i.e. they are the dead filling material in the mixture. Clay has diameters smaller than 0.002 mm, silt has diameters between 0.002 and 0.06 mm and sand has diameters between 0.06 and 2 mm. Gravel and sand have diameters larger than 2 mm. (Minke, 2006)

Raw material identification is the most important step in the process of building with earth. Soil identification is the base on which the material production is decided. It is depending on the type of soil and especially the type of clay, the mixture design, technique of material production, and requirement for stabilization. Minke (2006) describes the composition and varying properties of loam and its relation to earth construction techniques, stating that the *“Gravelly mountainous loams (if they contain sufficient clay), are more suitable for rammed earth, while riverside loams are often siltier and are therefore less weather resistant and weaker in compression. Like cement in concrete, clay acts as a binder for all larger particles in the loam.*

Silt, sand and aggregates constitute the fillers in the loam. Depending on which of the three components is dominant, we speak of a clayey, silty or sandy loam.”

Definition of Stabilized Earth

The word “Stabilized earth” is used to indicate the unbaked earth with improved properties utilized in construction. The soil stabilization is defined by Houben and Guillard (1989) as “*the modification of the properties of a soil-water-air system in order to obtain lasting properties which are compatible with a particular application.*” Stabilization is used to improve the compressive strength of the material and increase its density. Houben and Guillard (1989) define three basic stabilization procedures:

- Mechanical stabilization: soil compaction resulting in change in its density, strength, compressibility, permeability and porosity
- Physical stabilization: the properties of the material can be modified by acting on its texture
- Chemical stabilization: adding other material to the soil to modify its properties by physio-chemical reaction.

Stabilizers

Chemical stabilization means adding a small percentage of stabilizers to the mix design. Selection of stabilizers depend on the type of the soil, the most commonly used stabilizers being lime and cement. Auroville identifies the best soils for cement stabilisation to have these proportions of components: 15 % Gravel + 50 % Sand + 15 % Silt + 20 % Clay, while the best soils for lime stabilization are considered to have these proportions of components: 15 % Gravel + 30 % Sand + 20 % Silt + 35 % Clay. Other stabilizations of soils can be done with waste materials such as rice husk ash, blast furnace slag, and red brick powder. Chemical stabilization decreases the bio-degradability of the

material, the more additives to the mix the more it will become an artificial rock, and will be hardly recyclable.

Different Uses of Earth as a Building Material

The most common use of Earth would be as a walling material, however, other uses such as roofing, flooring and plastering can also be done with earth, depending on the techniques of material production and construction.

| | Rammed earth | Mud | Clay straw | Light clay | Loam filling | Earth Mortar | Earth Blocks | Earth Panels |
|-------------------|--------------|-----|------------|------------|--------------|--------------|--------------|--------------|
| Floor | ○ | | | | ○ | | | |
| Wall bearing | ○ | ○ | | | | ○ | ○ | |
| Wall freestanding | ○ | ○ | ○ | ○ | | ○ | ○ | ○ |
| Ceiling / roof | | | ○ | ○ | ○ | | ○ | ○ |
| Dry construction | | | | | | | ○ | ○ |
| Plaster | | | ○ | ○ | | ○ | | |

Figure 7: Uses of earth as a building material. (Source: DVL)²

The German code for building with earth (Lehmbau Regeln) published by the German association for earth construction DVL, specifies the different applications for building with un-stabilized earth, including structural and non-structural walls, domes and vaults, roof panels, floors, and plastering.



Figure 8: Different techniques of earth construction: CEB, Rammed earth, Adobe and wall plastering. (Fontaine, 2009)

Modern Earth Construction Techniques: Rammed Earth and CEB

Minke (2006) provides a simple definition for different earth techniques: “*If the material is used within a construction framework, it is referred to as ‘rammed earth.’ If it is handmade into building blocks, it is usually called adobe or clay bricks.*”

In the 18th century, the French architect Francois Cointeraux made a contribution to the revival of the Rammed earth technique – which was an ancient building technique in China - and in North Africa - where it was transferred to southern Spain and then to other European countries. Cointeraux’s several studies and publications spread throughout Europe at that time, and had the primary impact on the transmission of the interest in earth building to other countries such as Germany, Italy, Denmark, Australia and the USA. It was revived once more during the 20th century as a solution for housing due to the world wars and the need for affordable shelter. Following the energy crisis in 1973, due to the oil embargo proclaimed by the members of Organization of Arab Petroleum Exporting Countries (OAPEC), policies for encouraging renewable energies and sustainable construction were essential, and that was when earth was once again revived and promoted as one of the solutions for sustainable construction in Europe, Australia, and America. “*Rammed earth is now a well established construction technique in Western Australia and the south west United States where cement stabilized rammed earth is gaining mainstream use.*” (Jaquin, et al., 2008). As for the technique of compressed earth blocks, the first machine for pressing soil to produce CEBs was the Cinva-Ram, it was developed in the 1950s by Raul Ramirez in Colombia. Today there are many alternatives for production lines that range from simple manual production to highly mechanized mass production units for CEBs with different sizes and properties, as well as prefabricated Rammed earth walls.

Advantages and Disadvantages of Earth Construction

Minke (2006) summarizes the drawbacks of earth construction into three main problems. The first one is that “loam” is not a standardized material basically because it differs from one soil to another; this, in turn, makes industrialization and quality control more difficult. The second problem is shrinkage, which happens due to the evaporation of water content inside the material. The main consequence of shrinkage is the appearance of cracks which could affect the structure of the building. *“The linear shrinkage ratio is usually between 3% and 12% with wet mixtures (such as those used for mortar and mud bricks), and between 0.4% and 2% with drier mixtures (used for rammed earth, compressed soil blocks)”* (Minke,2006). Shrinkage is a common feature of most artificial stone materials, even for concrete, however this can be minimized in the case of earthen materials by reducing clay and water content and optimising the grain size distribution. The last point is that loam is not water resistant, which means that if it is subjected to heavy rain there is danger of erosion. Erosive effects happen on earth walls only in case the rain intensifies above 25 mm/m. (Torgal & Jalili, 2011). It is important to consider design aspects for protecting the building such as adding roof overhangs and building a good foundation. Laboratory tests are essential for measuring the strength, shrinkage, and durability of the material for developing the best mix design.

On the other hand, earth has several advantages that make it recognizable as a sustainable, green, and environmentally friendly material. Earth balances indoor air humidity because *“Loam is able to absorb and desorb humidity faster and to a greater extent than any other building material, enabling it to balance indoor climate”* (Minke,2006). Earth is a heavy material, and earthen walls with appropriate thicknesses have the ability to store heat due to its thermal mass, which is quite a good property specially for desert climates due to the big difference in temperatures between day and night (time lag), so the

wall has the ability to store heat during the morning keeping the indoor temperature cooler, and radiates it during the night when the outside temperature drops making the inside temperature warmer. This is a good property for both winter and summer days.

The preparation of the material on site requires a very small amount of energy and thus causes less pollution to the environment and decreases energy consumption when compared to other materials. Embodied energy is indicated by the Primary Energy Input (PEI) measured in MJ/m³. PEI in CEB is much less compared to other building materials which require burning at high temperatures such as fired bricks or cement. The amount of CO₂ emitted during the production of the material is indicated by the Global Warming Potential per 100 years (GWP₁₀₀) measured in kgCO₂/m³. Figures (9 & 10) show the embodied energy and the GWP for both CEB (stabilized with cement) and the traditional country fired bricks, based on studies done by Auroville Earth Institute in India.

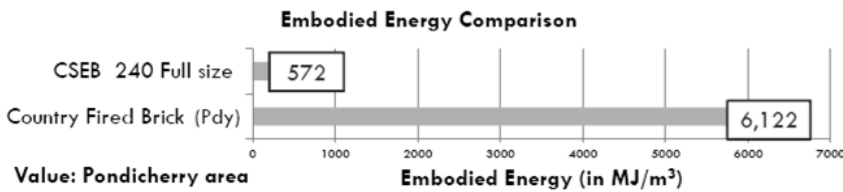


Figure 9: PEI measured in MJ/m³ for CSEB and Country fired bricks in India. (Auroville)

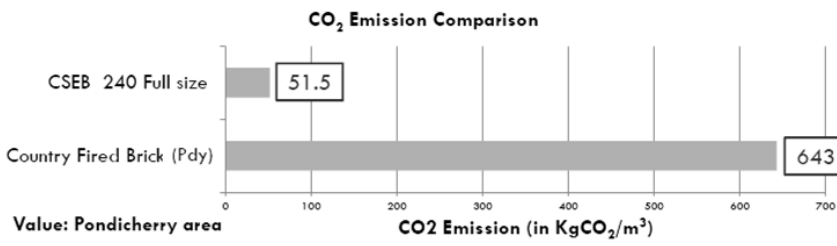


Figure 10: GWP measured in kgco₂/m³ for CSEB and Country fired bricks in India. (Auroville³)

Biodegradability is another advantage of earth, as it can always be recycled or simply returned to the soil at the end of its life, however, the more percentage of chemical stabilizers added to the mixture, the less recyclable it will become.

Economic aspects are very important in the context of developing countries, and earth construction is usually considered economically beneficial, especially that many projects that have used earth as a building material for low cost construction have proven a significant decrease in cost. The economics of earth construction depend on several factors which differ from one country to another, such as labour cost, availability of tools and equipments, appropriateness of construction technique, stabilization materials, and maintenance requirements. Therefore, economic benefits cannot be taken for granted without studying the local context where the technique is chosen and applied.

Conclusion

Aspects of sustainability that relate to building materials production and use in the construction sector can be classified into two categories: environmental and socioeconomic aspects. In the developing countries and the global south, the socioeconomic factors are as important as the environmental factors, and are very much related to the production and the construction process and to the level of technology used.

Earth is considered a sustainable building material, because it is a natural material which depends on local resources and local production techniques and does not consume a lot of energy in production. However, with modern techniques of earth construction such as CEB and Rammed earth, and with the

wide range of production systems and variations, the aspects of sustainability and appropriateness of the material to the local context is also variable, and is very much dependant on many factors including the location, building typology, availability of raw materials, social and economic circumstances of the community.

The next chapter will give an overview of local building materials and the construction sector in Egypt, highlighting the needs for affordable and sustainable building materials.

² Source: DVL website (Dachverband Lehm (e.v.), 1992)

³ <http://www.earth-auroville.com/>

**Chapter Three: Local Building
Materials and Construction
Sector in Egypt**

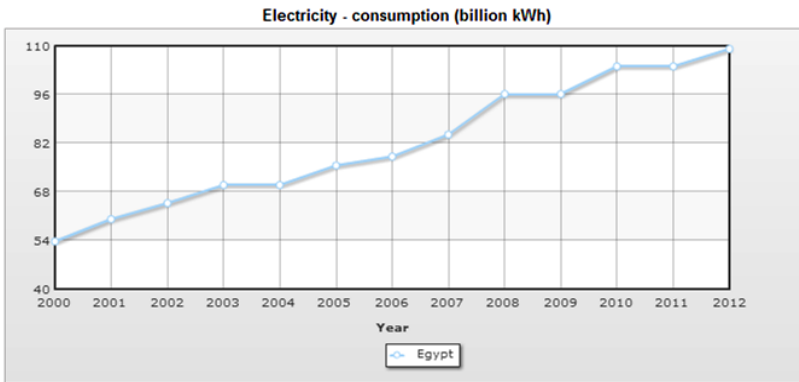
Chapter Three: Local Building Materials and Construction Sector in Egypt

This chapter provides an overview of the context of Egypt focusing on the construction sector, housing affordability, and shortage of energy. The aim is to shed light on the current challenges facing the construction sector, focusing on the role of local building materials throughout its history, and presenting the need for reintroducing local building materials into the mainstream practice.

The Energy Crisis

Buildings account for more than 40% of total energy consumption. (UNEP⁴) Energy is consumed through several phases of the life cycle of the building material, starting from the extraction of raw materials to the manufacturing phase, especially for heavy industries such as cement and steel which consume a great amount of energy during their production. This is in addition to the energy consumed during the construction phase as well as the energy used for cooling/heating due to the heat exchange through building envelopes.

It is well known today that Egypt is suffering from a shortage of energy. The country is already going into long hours of blackouts, especially during the summer season, because of the high pressure on the electricity grid due to the extensive use of cooling devices. This is also expected to increase, unless serious steps are taken towards using alternative energy sources. Strategies for decreasing energy consumption in buildings start from the passive design strategies, the selection of building materials which consume less energy in production, and creating a good building envelope which consequently decreases the need for huge amounts of energy for cooling.



| Country | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|------|------|-------|-------|-------|
| Egypt | 53.75 | 60.16 | 64.72 | 69.96 | 69.96 | 75.58 | 78.16 | 84.49 | 96.2 | 96.2 | 104.1 | 104.1 | 109.1 |

Figure 11: Electricity consumption in Egypt in the period from 2000 to 2012.⁵

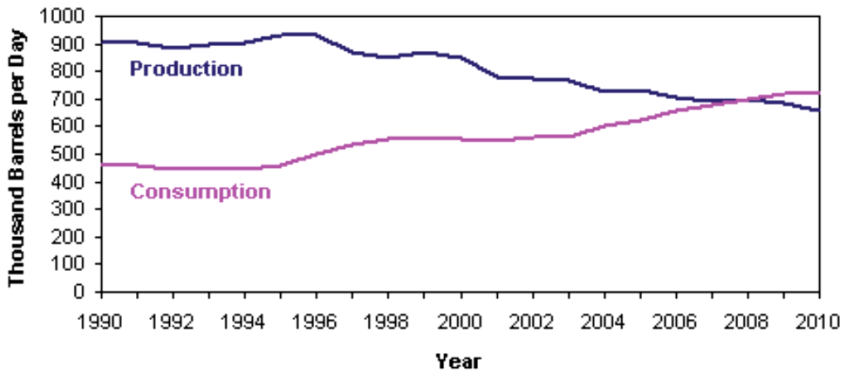


Figure 12: Egypt oil production and consumption from 1990 to 2010. Source: EIA

Construction Sector

The construction sector is one of the most active sectors in the Egyptian economy. According to the Business Studies and Analysis Center in the American Chamber of Commerce (Amcham, 2003), the construction market in Egypt ranked 36th in the global construction market in the year 2000, constituting 0.4% of this market, for a value of \$12.711 billion. In 2001/2002 its GDP share reached a value of LE16.56 billion, representing 4.7% of the total national GDP. The report classifies the factors affecting the development of the construction sector into five main categories: “*construction companies, government policies and strategies, available resources, institutional backing and supporting industries.*”

A percentage of 10.5% of the labour force are employed in the construction sector⁶, while a large percentage of employment in the industrial sector is in the industry of building materials production and its sub-sectors. According to Ibrahim (1987) the informal market comprises 80% of the construction sector. However, a shortage in housing provision, especially for the low income class, still exists. Ibrahim (1987) states that the factors causing the housing problem in Egypt are due to: increased population; deterioration of existing housing stock; rural migration to urban areas; lack of national housing strategy; increase in the cost of land, building materials and labour; lack of organized public participation. Other factors also include the lack of infrastructure in new development areas which make it undesirable for living, and the inefficient informal act of building.

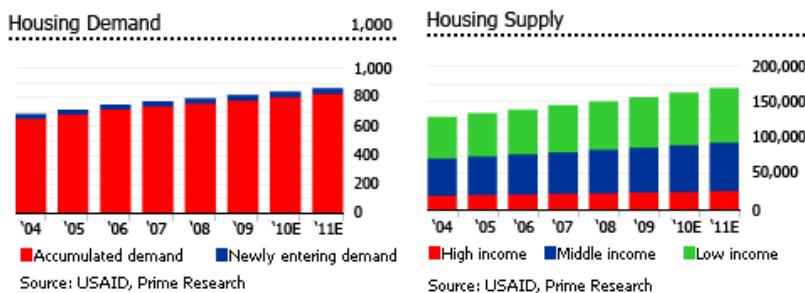


Figure 13: Housing demand and supply in Egypt.⁷

The Land

More than 90 % of Egypt's land is desert. The majority of the population live on less than 5% of the land, that is the Nile valley and a few desert oases. However, the rise in population resulting in rapid urbanization and continuous loss of fertile land is causing the inevitable expansion of urbanization towards the desert land, especially on the peripheries of the existing cities and villages. The government has been expanding by creating new cities on the desert fringes of cities along the Nile valley. The New Urban Communities Authority at the Ministry of Housing has announced in May 2013 that it is planning to construct 44 new cities in the desert to be finished within the next 4 years.⁸ This expansion in desert urbanization requires new strategies for construction, and the encouragement of using green construction and local building materials.

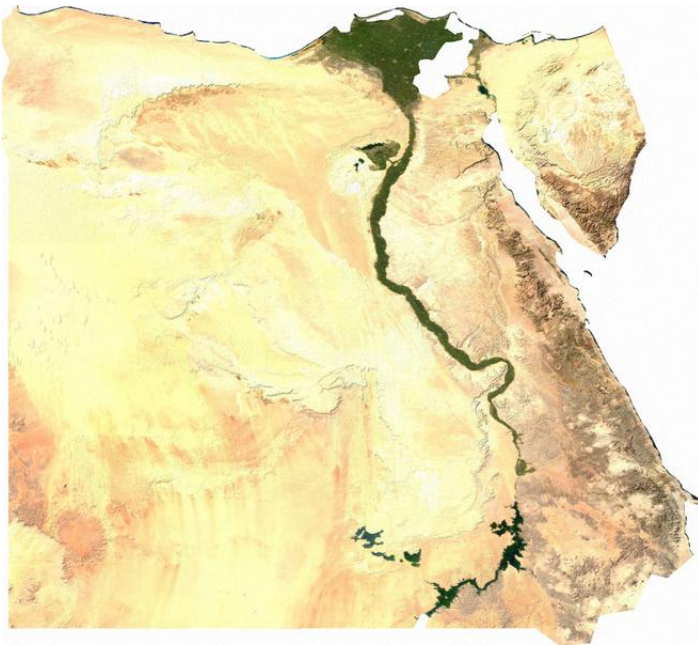


Figure 14: Satellite image of Egypt. Source: Wikipedia⁹

The land of Egypt is rich with raw materials that represent the main base for building materials industries. Sand, clay, gravel, kaolin and bentonite, as well

as lime and gypsum, represent the most important raw materials needed for building with earth. All these materials are abundant in Egypt's deserts on the outskirts of the Nile valley and in the Sinai Peninsula. *"The landscape of Egypt shows the richest natural resources for clay. North, south even west and east provide many different kinds of earthenware (white, red, yellow and black) which does not exist anywhere else but in the land of the pharaohs."* (GET, 2009).

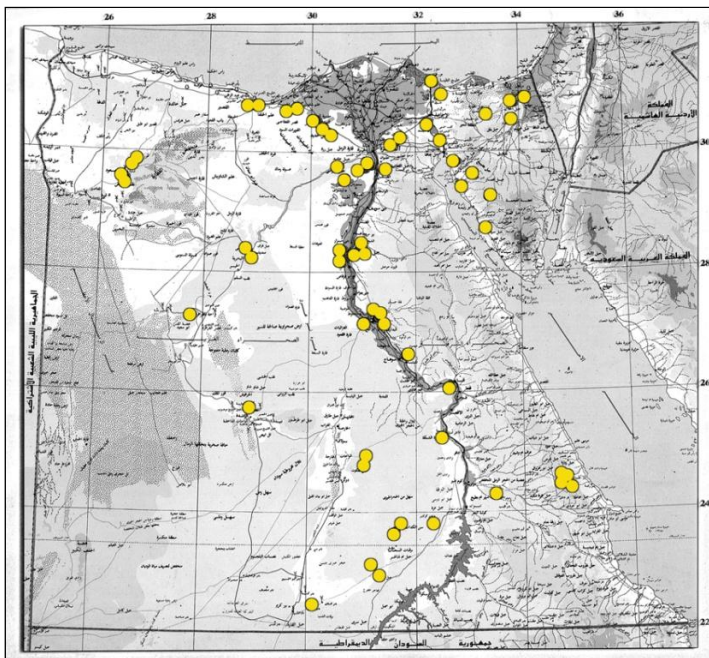


Figure 15: Desert Clay in Egypt. Source: (HBRC, 2001)

Desert clay quarries are the main suppliers of raw materials for the traditional fired clay brick factories, however, soil analysis and identification is not part of the process for the work of these quarries. The process of obtaining permission for these quarries is a very administrative issue.¹⁰ No soil tests are done to identify the type of clay, as it is not important for the quarry owner, who sells the clay to local clay brick manufacturers, who, in turn, do not care about the clay properties because it will eventually be burned. However, for earth

construction techniques such as CEB and Rammed earth, it is very important to identify the type of soil, and especially the type of “clay,” in order to be able to create the best mix design for a wall built with Rammed earth or CEB, with or without chemical stabilization based on the soil available on site.

Local Building Materials

Historical Background

Earth was a very important building material that everyone was able to use for constructing their own dwellings in Egypt throughout its history. Traces of ancient mud architecture are evidences for the good capabilities of earth as a building material.



Figure 16: Dimah A-Sibah city ruins, Al-Fayoum. Source: Panoramio¹¹

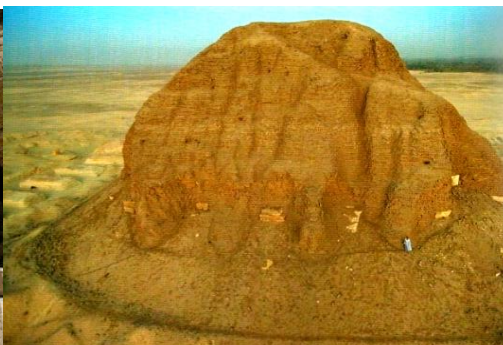


Figure 17: Al-Lahun Pyramid in Beni-Sweif, Egypt. (Fontaine, 2009)

With the industrial revolution and the rise of industrialized building materials and technologies, and the rapid desire for modernization due to various socioeconomic changes within the community during the second half of the twentieth century, local indigenous building materials were not capable of keeping up with the quick transformation and were thus replaced gradually and strongly with industrialized building materials. Reinforced concrete and fired clay bricks are the most common building materials in Egypt nowadays in urban, rural, formal or informal construction.



Figure 18: Modern rural housing.

The making of mud bricks used to be a local traditional skill known by the local people, and the traditional construction was a community social practice in which everybody collaborates in the construction of their own houses and the houses of their neighbours. This is not the case today with the rapid modern rhythm of life and the spread of the industrialized building materials that can reach the construction site easily even in the most remote areas. Today, the industry of building materials is strongly centralized and dominated by the private sector, and prices are affected by the market monopolization, especially for the strategic building materials such as steel.

The History and Development of Clay Brick Industry

The industry of mud brick casting started during the Pharaonic era, and inscriptions showing the process of mud brick casting indicate the importance of this industry. Mud brick casting was a common traditional process, whether in the Delta, where mud from the Nile sedimentation was used, or in the desert agglomerations, where desert clay was the main raw material.



Figure 19: Queen Hatshepsut casting mud bricks. (Fathy,1973)

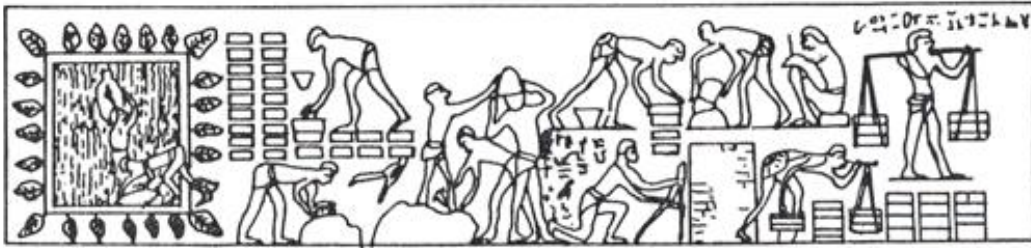


Figure 20: Brick industry in the Pharaonic age. (Ibrahim, 1987)

Later, when the technology of burning bricks for improving their specification was developed, a great number of clay brick factories were constructed on the Nile banks in the Delta cities, making use of the raw material (mud) from the Nile valley.



Figure 21: Old Traditional clay brick factories on the Nile banks.

It was in the 1980s that the use of mud from the agricultural fertile land was prohibited. This was due to the rapid loss of fertile land after the high dam that was built in the 1960s prevented the river sediments that used to feed the agricultural lands every year in the flood season from accumulating. The clay brick factories were moved to the outskirts of the cities, and shifted their raw material base to the use of desert clay extracted from the local governmental quarries.

Today, there are around 3000 clay brick factories operating in different cities in Egypt,¹² employing around 320 thousand direct employees and around 2 million indirect labourers. The clay brick production is concentrated around the capital, Cairo, and some of the delta cities.

Describing the traditional fired brick industry in Sudan, which is quiet similar to that in Egypt, Elkhalfa (2011) describes the low-quality of locally produced fired bricks as unrepresentative of the potential from existing raw materials and manpower skills, and perhaps all that is needed is to enhance management skills in order to raise their quality.



Figure 22: Existing traditional clay brick industry using desert clay.

The traditional fired brick industry is facing another challenge today with the rise of fuel prices. Diesel and natural gas are highly subsidized by the government, but with the start of 2013, the government announced the rise of fuel prices for all industrial activities. Diesel prices for brick factories were raised to be 1620 EGP per ton, with a rise of 60 % than the old prices, and this is expected to rise more during the coming years. On the other hand, converting to natural gas is considered a cheaper and more environmentally friendly solution, but requires a huge initial cost investment from the factory owners (around 2 million EGP) which is only possible for large industrial factories, but not for the common traditional ones.

There could be other alternatives for energy sources that can substitute Diesel, like biogas, for example. There is a strong need for research and innovation in this field to overcome this energy problem.

Despite their poor quality, traditionally manufactured clay bricks are used extensively in construction, although other alternatives such as the white limestone blocks from quarries in Upper Egypt, specifically in Menya, are gradually substituting them because of the cost factor. The Menya limestone block is a preferred alternative today in construction, especially in rural areas because it is easier and faster to use due to its dimensions (27x15x13 cm) which are larger than those of the traditional fired brick (20x10x5 cm). The problem with the use of this block is the way it changes the architectural identity of towns and villages, especially because most of the people leave the walls exposed without plastering. Moreover, this type of wall construction with half a block's width (15 cm) has a low thermal storage mass compared to the traditional mud brick wall of large thicknesses and higher insulation values.



Figure 23: Attempts to add a layer of mud brick or plastering to the exterior limestone walls for improving thermal comfort.

In the 1970s, six factories were established in Egypt to produce clay bricks with a fully automated system. They used to belong to the public sector, but now

they are all privatized. The brick production in these factories is fully dependant on machines, with a very small number of workers. Drying is done mechanically with electric power, unlike traditional brick which is dried in the sun. The quality of clay bricks from these factories is better than that of the traditional ones, but the prices are higher. Real estate developers and contractors of big projects are the clients for this type of brick.



Figure 24: Mechanized clay brick factory.¹³

Fired clay brick is perforated; so it is used as a filling material within the concrete skeleton structure and not for load bearing walls, and it has relatively good insulation properties. In the countryside, red bricks are produced using the same old technique of mud brick casting, and is then burnt in local ovens; in this case the bricks are solid and not perforated, and thus are used for load bearing walls.

Innovative Building Materials in Egypt

Recently, there have been several efforts to introduce green and sustainable building materials worldwide as a counteraction to the huge industrialization movement, the exploitation of natural resources, and rising carbon emissions. However, this has as yet a minor influence among the majority of the construction activities in Egypt. Besides that, it is not accessible to the majority of the population, which is in need for affordable good quality housing, since

they have no access to information, technology or technical advice. Green or sustainable material can either be a completely new innovation, a modification to the production process of an existing material, or a new construction technique. The following table shows some of the existing innovations in the field of sustainable building materials in construction in Egypt.

| Building component | Material | Application | Aspects of sustainability | Obstacles / limitations |
|---------------------------|-----------------|---|---|---|
| Bearing Walls | Natural Stone | Common in low rise buildings such as hotels and residences in remote areas | Decrease the energy consumption by elimination of unnecessary RC | Structural calculations and safety factors, difficulty of obtaining license |
| | Rammed Earth | Few experiments on an individual basis | Produced on site using local soil with little energy | Labour intensive, Lack of knowledge, and access to tools |
| | CEB | Few experiments on an individual basis | Can be produced on site and from local materials | Difficult access to tools, Lack of knowledge, and quality control |
| | Adobe bricks | A traditional building material, revived in some eco- lodges and private residences | Local, natural building material, produced on site | Large wall thickness, social acceptance, maintenance, durability |
| | Cast Earth | In the phase of research by the i- House network (PSDP-GIZ ¹⁴) | Optimized construction process (elimination of ramming and excessive form-work in RE) | Still under experimentation |
| | Earth bags | Experimented by HBRC ¹⁵ and EECA ¹⁶ | Using local soil, produced on site, reduce cost | under experimentation |
| | Straw Bale | Experimented by HBRC | A recycled material | under experimentation |

| | | | | |
|----------------------------|---|---|--|---|
| Ceiling | Domes and vaults: CEB/ Clay bricks/ Adobe | Traditional building technique, revived in some hotels, private villas and rest houses in remote areas | Local traditional skills, more economic and reduces concrete and steel consumption | Requires skilled masons who are becoming rare due to the vanishing of the tradition |
| | Flat vaults: Clay bricks and RC beams | Experimented in the Aga Khan project in Darb El-Ahmar housing rehabilitation | Reduce concrete and steel consumption, employs more people | Not a popular technique, requires prefabrication of beams |
| | Palm reeds (roof panels) | Experimented in few projects (ex. A rangers residence in Wadi Al Gemal ¹⁷) | Environmental friendly, and locally produced material | Used as non structural elements |
| | Palm reeds (space trusses) | In the phase of laboratory experimentation ¹⁸ | Environmental friendly, local material | Promoting from laboratory to production |
| | Palm reeds (rebars) | | Substituting steel inside concrete beams | Under experimentation |
| | Tree free wood from cotton stalk | Under Experiment by PSDP – GIZ | Produced from recycled content | Promoting from laboratory to production |
| Plaster & paint | Lime plastering and lime wash | Traditional technique, revived in some projects (ex. Aga Khan) housing rehabilitation in Darb Al-Ahmar) | Lime is more environmental friendly than cement, has more workability and is cheaper | Requires training and knowledge for achieving good quality |
| | Lime mixture | Produced by a private company (Hamco) | A ready mix of lime, cement and sand | Marketing |
| | Clay | Traditional technique, revived in some projects | Natural building material | Knowledge, maintenance, social acceptance |

Table 1: Examples of sustainable and green building materials in Egypt.

Sustainable and natural building materials are mostly promoted in certain building typologies, like hotels and eco-lodges, services and facilities inside natural protectorate areas (under the supervision of the Ministry of Environment), or private residences in remote areas. This is due to the existence of a market niche for these typologies, and clients' desire to construct environmental friendly buildings. Using sustainable materials in eco-lodges and tourist facilities is considered a good way to promote the material and show its capacities and qualities, however, the problem of linking the natural building materials with expensive luxurious spaces would consequently raise the cost of this type of construction instead of promoting it as an appropriate building material for the people.



Figure 25: Visitors Center in Wadi Al-Gemal protectorate in Marsa Alam constructed with local stone bearing walls and corrugated sheet roofs. Project architects: EECA¹⁹.



Figure 26: Visitors facilities at Wadi AL-Hitan protectorate in Fayoum constructed with adobe bricks bearing walls, domes and vaults from local desert clay. Project architects: Eco-Architecture²⁰



Figure 27: Adrere Amellal eco-lodge in Siwa Oasis built using traditional Siwan building materials and techniques. Project architects: EQI²¹



Figure 28: Modern private house with adobe bricks in Wadi Elnatroun.



Figure 29: Modern private house with adobe bricks in Fayoum.

Conclusion

Local building materials have played an important role in the construction practice throughout the history of Egypt, shaping the architectural identity in most of the towns and villages, and forming an economic base on the local scale through the local building material production process. Traditional clay bricks industry has succeeded as a model for an intermediate scale of production that achieves a high productivity rate while offering a large number of job opportunities for the local people and a decentralized economy, and at the same time providing an affordable product.

Today, local building materials - including mud bricks - are not commonly used in construction anymore, but are replaced with highly industrialized building materials due to socioeconomic changes that began in the second half of the twentieth century. Interest in reintroducing sustainable and local building materials to the construction sector has increased in recent years due to the awareness of the current energy crisis and the need for sustainable construction solutions to overcome it, however, most of the practices in this field are in the status of research or experimentation and are not being promoted for industrialization and widespread use, especially for providing affordable housing.

Modern techniques of earth construction such as CEB and Rammed earth have been experimented on a limited scale in Egypt. In the next chapter, these experiments will be analyzed, and the factors affecting their underutilization in the construction market will be discussed in detail.

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- ⁴ United Nations Environment Program (<http://www.unep.or.jp/ietc/focus/EnergyCities1.asp>)
- ⁵ Source: www.indexmundi.com
- ⁶ African Development Bank www.afdb.org
- ⁷ <http://www.globalpropertyguide.com/Middle-East/Egypt/Price-History>
- ⁸ Al-Ahram Newspaper: <http://www.ahram.org.eg/NewsQ/209464.aspx>
- ⁹ http://en.wikipedia.org/wiki/File:Egypt_sat.png
- ¹⁰ Information based on interview with the manager of the clay quarries department in Giza governorate
- ¹¹ <http://www.panoramio.com/photo/32652927>
- ¹² Salah Abu-Bakr, head of brick factories union, <http://today.almazryalyoum.com/article2.aspx?ArticleID=372452>
- ¹³ Photos copyrights for El-Fayoum clay brick factory
- ¹⁴ Private sector development program
- ¹⁵ The Housing and Building Research Center
- ¹⁶ The Egyptian Earth Construction Association
- ¹⁷ Project designed and implemented by EECA, funded by Life Red Sea Project (USAID)
- ¹⁸ Researched at the Center for Development of Small-Scale Industries at Ain Shams University
- ¹⁹ The project was funded by Life Red Sea Project (USAID) and was awarded the Hassan Fathy Award for Architecture in November 2009. Designer: Ramses Noshi, Photo copyrights: Nour Al-Refaey
- ²⁰ Photo copyright: Eco-Architecture: <http://www.egyptcd.com/architecture.html>
- ²¹ Environmental Quality International Company (<http://www.eqi.com.eg>)

**Chapter Four: Constraints and
Opportunities of Earth as a
Modern Sustainable Building
Material in Egypt**

Chapter Four: Constraints and Opportunities of Earth as a Modern Sustainable Building Material in Egypt

The aim of this chapter is to analyze the factors causing the underutilization of earth as a modern sustainable building material in the Egyptian construction sector. The analysis is based on developing a Value Chain Analysis for earth construction, through a group of interviews with experts and practitioners in the field, as well as analyzing some cases that experimented the modern earth techniques of CEB and Rammed earth.

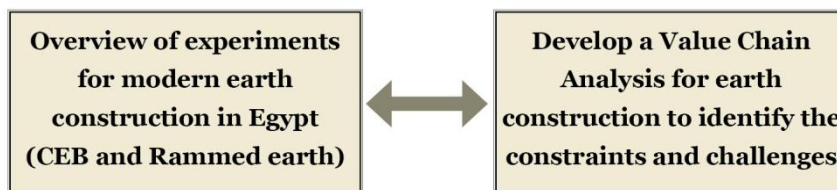


Figure 30: Methodology for identifying the constraints and opportunities of modern earth-construction.

Factors Affecting the Widespread Use of Sustainable Building Materials in Developing Countries

In Egypt, there is still a lack - in the research field - of identifying what kind of constraints and challenges the widespread use of such materials are facing, and why they are not ready to compete and contribute in the construction sector. Uncertainty, lack of accurate knowledge, fear of change and risk taking, time consumption, social refusal, impeding market forces, laws and regulations, lack of skilled labour, lack of governmental support, and the absence of cooperation between experts and practitioners - all of the previous - could be reasons that contribute to the lack of the wide spreading of alternative building materials.

A review of academic research in this domain was done to identify the common factors that affect the promotion and widespread use of alternative sustainable building materials in general, and earth construction specifically, in developing countries. Zami (2010) investigated the factors that influence the adoption of stabilized earth by construction professionals to address the Zimbabwe urban low cost housing. He adopted a methodology that combined a literature review and experts' opinions by interviewing construction experts in Zimbabwe, including academician researchers and practitioners in the field. Zami concluded a total of ten inhibitors and four drivers affecting the widespread use of stabilized earth in construction in Zimbabwe, which are as follows:

Inhibitors and drawbacks:

- Professionals make less money.
- People's mistaken perception and cultural problems.
- Credit and insurance are difficult to obtain.
- Conflict of professionals' prejudices.
- Lack of policies that encourage minimizing use of energy
- Lack of legislation protecting existing earthen architecture.

- Lack of technologies and resources.
- Inadequate market demand for earthen architecture from users.
- Lack of courses and training in the universities.
- Lack of knowledge, skills, and understanding amongst professionals and users.

Drivers:

- Technological development and innovation of earth construction.
- Promoting earth architecture and construction by all stakeholders through all public media.
- Introducing earth architecture and technology in university degree programs and courses.
- Organizing training programs for professionals, builders, users, and all building stakeholders.

The Sudanese researcher, Elkhalfa (2011), investigated the problems of transferring and disseminating knowledge on innovative and appropriate building materials and technologies in the Sudan, identifying the diversity of difficulties as *“the weak role of government in adopting, financing and encouraging the application of research results on a wide scale; absence of a single entity that is responsible for the screening, testing, evaluation and approval of new materials; the role of the private sector is very poor in research on appropriate technologies; local contractors are reluctant to apply and adopt new technologies unless these technologies are widespread and turn to be successful; the owners whom through their life savings finance most of the construction costs of their houses are usually reluctant to expose themselves to the risk of applying new technologies; each of the stakeholders performs on its own without any collaboration or coordination with other parties. Some appropriate materials and technologies which are locally available, affordable, and applicable might not be socially acceptable like earth technology.”*

Overview of Modern Earth Construction Experiments in Egypt

This section provides an overview of some cases of modern earth construction experiments in Egypt using CEB and Rammed earth techniques. Information was gathered through interviews with the projects' architects, as well as publications, documentaries, and field visits. The aim of analyzing these cases was to identify the constraints and obstacles that cause the undermined utilization of these techniques, and which stop these experiments from being replicated and promoted.

Case 1: A private House with CEB and Rammed Earth

This house is one of the works of the architect Adel Fahmy. He is an Egyptian architect who has more than 40 years of experience in adobe construction in Egypt and other countries. The house, located in Mansoureya, consists of two stories with 45 cm bearing walls of Rammed earth and CEB, roofs are constructed with CEB domes and vaults.



(Atkinson et al. , 2007)

The construction process was labour intensive, producing the material on site using the local soil (Sand, gravel and Tafla²²). The process included the training of local labour in the area on producing the blocks and building with them. An average number of 6 workers were required to prepare the blocks on site using a manual press, which can produce up to 800 blocks/day. This means that the 1000 blocks would cost approximately 450 EGP²³, which is almost equal to the price of the standard fired clay bricks produced at the fully mechanized factories²⁴, while it is more expensive than the traditional fired clay bricks

(which cost around 350 EGP²⁵). Lime was added to the mixture as a stabilizer for the blocks with 4-8 %. The mortar used for laying bricks was done with the same mixture. Compressive strength of the blocks ranged between 52-58 kg/cm² (Fahmy, Lectures).



Figure 32: Lime stabilized CEB samples used in dome construction.²⁶

The Rammed earth walls were constructed in collaboration with the Austrian architect Martin Rauch. “Rauch is regarded as one of the pioneers of modern technical and creative applications for traditional rammed earth construction in Europe. His work encompasses residential, hotel, ecclesiastical and industrial buildings, interior design and landscape design in Germany, Britain, Italy, Austria and Switzerland.” (Rael, 2003).



Figure 33: Wooden shuttering for rammed earth. Image courtesy of architect Adel Fahmy.

The Rammed earth mixture was composed of:

- Gravel & Sand: 50-70 %
- Silt: 15-30 %
- Clay: 10-20 % (Fahmy, Lectures).

The regular wooden shuttering commonly used for concrete had to be strengthened with additional posts and supports to bear the pressure of ramming.

The following table shows the actors involved in the activities related to the building material production and construction.²⁷

| Activity | Involved actors |
|--|--|
| Raw material identification | Architect (on-site) |
| Manufacturing of the building component | Architect + Unskilled labour |
| Use in construction | Architect + Skilled builders |
| Marketing / promotion | ----- |
| Codes, specifications, regulations, Policies | ----- |
| Training & Education | Architect + Foreign expert |
| Material research & development | Architect + Foreign expert |
| Equipments & machinery | Imported machinery for CEB, and modified local shuttering for RE |

According to the architect, the cost of constructing this building was less than 50% of the cost of a regular reinforced concrete house. This project represents a model of a simple self building project that all the activities were done on site, and the architect in this case has played all the roles from raw material identification, to mix design, material production and building construction, with the contribution of local labour and building owners.

Case 2: Experimental Building at the HBRC Headquarters

This experimental building was built by the HBRC in its Cairo headquarters in 2011, as a collaboration and technology transfer with the Auroville Earth Institute in India. Founded in 1989, Auroville's mission was to research, develop, promote and transfer earth-based technologies.



Figure 34: CSEB blocks produced at the HBRC headquarters.



Figure 35: Training at the HBRC headquarters. (AVEI, 2012)

The experimental building was totally constructed with CSEB. The structure was composed of bearing walls (25 cm thick), vaults and domes. The segmental cloister domes developed by Auroville were used in construction, and Egyptian team (composed of architects, masons, workers and technicians) were trained to build it. Training was given by the French architect Satprem Maïni, who is the director of Auroville Institute. He is an architect, builder, consultant, researcher, trainer and lecturer.

The blocks were stabilized with 5 % cement. Walls were built with large blocks (24 x 24 x 13 cm), while domes and vaults were built with mini blocks (14 x 7 x 5 cm). The production of the blocks was done manually using a manual press imported from India. Eight workers could produce approximately 800 blocks per day. This low production rate compared to the labour requirement consequently means that the cost is high. Mix design, soil analysis, structural design, and compression strength tests were all done in the HBRC laboratories.



Figure 36: Construction of experimental building at the HBRC (Farouh, 2012).

Reinforced concrete beams had to be cast and inserted below the roof on the whole periphery of the building to bear the loads of domes and vaults.

The following table shows an analysis of the actors involved in the different activities related to the building material production and construction.

| Activity | Involved actors |
|--|--|
| Raw material identification | Material science laboratory |
| Manufacturing of the building component | Trained unskilled labour + Architects |
| Use in construction | Skilled+ unskilled builders Architects, structural engineer |
| Marketing / promotion | ----- |
| Codes, specifications, regulations, Policies | Code of earth construction is under development by the HBRC |
| Training & Education | Auroville + HBRC |
| Material research & development | Research center (HBRC) |
| Equipments & machinery | Imported machinery |

This experimental project was done as a model for the “Productive Low Cost Environmentally Friendly Village”, called PLEV, which had been planned by HBRC to be constructed in Fayoum city. The initial plan was to build a house prototype on the project’s site, but due to delays that happened to the PLEV start-up, the plan was changed to the construction of an office and training centre, to be located on the premises of HBRC in Cairo. (AVEI, 2012).

On the other hand, and following this experiment, the HBRC is currently in the process of writing a code for stabilized earth construction to regulate the use of the material.

Case3: Locally manufactured CEB press

A local machine for producing Compressed Earth Blocks was designed and manufactured in 1999 by the Egyptian Earth Construction association (EECA), which is a local NGO concerned with appropriate building technologies, and particularly earth construction. EECA has an experience in research and development, training activities, as well as design and construction projects.



Figure 37:
The machine
for producing
CEB designed
and
manufactured
by EECA

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The machine was manufactured with the cooperation of the “Centre for Development of Small-Scale Industries” in Ain Shams University. Several training activities were conducted, following the manufacturing of the machine, to train architects, engineers, workers and local people on using the machine and producing the CEBs. The first training was conducted for architects in El-Tur city, and a second one was given to local builders for restoring the Anba Shenoda Church inside Deir El-Saleeb compound in Naquada (a village in Qena city in Upper Egypt). Another Training Program was implemented in collaboration with Hope Village Association for Street Children in 10th of Ramadan City to train the children.



Figure 38: Training by EECA for street children for producing CEB.²⁹

At that time, the technology was completely new to the Egyptian context, so the exposure to the technology was the main motive that encouraged the group of architects in EECA to research about it, considered that it is a potentially appropriate alternative for building in the context of Egypt, as a development to the traditional mud construction and a solution for the excessive use of reinforced concrete. As a result of the research about the latest technologies and innovations, they decided to manufacture the CEB pressing machine locally to save money compared to the money needed to import the machine, and also to experiment the capability of the local workshops. Among many options for the choice of the power source, mobility and production rate of the

machines, the choice was to use a motor-powered engine to have a high productivity. The engine used Diesel fuel, which was considered a cheap and available fuel especially in villages. It was decided as well for the machine to be movable in order to reach remote areas.

The machine was manufactured in the workshops of the Center for Development of Small-Scale Industries at Ain Shams University. The mechanical engineers in the center have worked on the design of the machine.

The following table shows an analysis of the actors involved in the different activities related to the building material production and construction.

| Activity | Involved actors |
|--|--|
| Raw material identification | Architects, EECA |
| Manufacturing of the building component | Trained unskilled labour Architects, EECA |
| Use in construction | Skilled+ unskilled builders Architects |
| Marketing / promotion | ----- |
| Codes, specifications, regulations, Policies | ----- |
| Training & Education | EECA |
| Material research & development | Material scientist's private office |
| Equipments & machinery | Research center (Ain Shams university) |

The machine was used to produce CEB for restoring the Anba Shenoda Church inside Deir El-Saleeb compound in Naquada village, Qena, Upper Egypt. The church was originally built with mud bricks, so the CEB was chosen for this

restoration project to offer a material with more strength and durability and at the same time uses the same raw materials of the original mud bricks.

The problems which faced the team in the first phases of manufacturing the machine were:

- To find a team of mechanical engineers interested and capable of designing the CEB pressing machine and adapting it to the local needs
- Securing a fund for the process of design and manufacturing
- The difficulty of creating a team due to the lack of available data about workshops and human resources or research centers that can contribute in the project (Sabry, 2002)

According to one of the EECA members who was involved in this experience, the problem with working with the CEB during construction was that it turned out to be less practical for roof construction (domes and vaults) because it is a heavy material, which consequently requires an additional structure to support it, like adding concrete beams below the dome or vault (which was done in the HBRC experimental building). So, the conclusion they drew from this experience was that CEB is a good material for walls, but not necessarily for roofs. After this experience EECA also started researching about the Rammed earth technique as another option for walls, and has used it in the construction of a building in Saint Katherine, South Sinai.

Case 4: A Mobile Mechanical Production Unit for CEB

ADEEM consult is a private company that started a project for producing CEB in the year 1999, by manufacturing a mobile mechanical production unit. The project was led by a group of researchers, including architects, civil and mechanical engineers. The project's aim was to design and implement a local production line for CEB in Egypt. The team has designed and locally manufactured a mechanical production line composed of a crusher, grinder, mixer, and compressor. It was designed to be movable in order to easily reach the remote locations in Egypt and decrease the cost of materials' transportation.



Figure 39: Mechanical production line of CEB by ADEEM. 30

The mechanical production line was designed to have a high production rate. The pressing machine has a productivity rate of 8000 blocks/day (Elrafey, 2007), which means that the cost of production in this process is much less than the manual production process, considering that approximately 8 workers are required to work on the production process. The reduction of production cost was calculated to be 26% less than the cost of fired brick in a pilot project done in Belbeis, and is estimated to decrease more if it's done in even more remote areas (Elrafey, 2007).

In terms of environmental aspects, the mechanical system uses more energy than the manual system, because the production line is dependent on either electrical or Diesel power, but this is considered a small amount of energy when compared to the energy used to produce fired bricks.

Technical data of the CEB

| | | |
|----------------------------|------------|-------------------------|
| Dimensions | 250x120x60 | mm |
| Weight | 3.45 | kg |
| Density | 1830 | 1900 kg/cm ³ |
| Dry compressive strength | 80 | 115 kg/cm ² |
| Moist compressive strength | 40 | kg/cm ² |
| Water content | 15% | |

(Elrafey,2007)

Although the team succeeded in manufacturing the production line, as well as producing and testing the blocks with several mix designs, and building a pilot project in Belbeis, the whole idea was not sustained because they were not able to promote it.

This experience highlights the main constraints facing the introduction of a new material or technology to the market without conducting several promotion activities and experimental projects that designate the potential of the material and provide the people with an opportunity to see and experience it. This sheds light on the importance of the choice of the pilot project; it has to be visible and accessible so the people can observe, experiment, and thus be able to judge it, but this was not the case in this experiment.

The local manufacturing of the production line proved again the capability of local workshops to manufacture the machines much cheaper than the imported ones; however, the time and effort spent, with trial and error, caused a lot of

delay, besides the difficulty of access to information or transfer of technology about other machines produced in different countries. It is the role of research institutes to work on the development and innovation for the improvement of such machinery; however, this is bound to the existence of a minimum interest in the technology.. Promotional activities and opening a market niche for the material is a kind of encouragement for such interest.

The following table shows an analysis of the actors involved in the different activities related to building material production and construction.

| Activity | Involved actors |
|--|---|
| Raw material identification | Architect + Local Clay Quarry |
| Manufacturing of the building component | Trained Unskilled labour |
| Use in construction | Skilled+ unskilled builders |
| Marketing/ promotion | Architect – private investment |
| Codes, specifications, regulations, policies | ----- |
| Training and education | ----- |
| Material research & development | Architect |
| Equipments & machinery | Architect, mechanical engineer, local workshops |

Case 5: Rammed earth in Saint Katherine

Saint Katherine is a very unique city in South Sinai with a special local context and identity. Rammed earth was used in the construction of a building that was designed to be a training center for building crafts. The project was implemented by EECA and funded by the EU (South Sinai Regional Development Program SSRDP).³¹



Figure 40: Training Center in Saint Katherine.

Rammed earth was introduced for the first time in Saint Katherine through this project. The aim was to experiment alternative building techniques that could be appropriate to the local context, and to train local builders to do it. Rammed earth was chosen as one of the appropriate building techniques because it is a cheaper and more sustainable substitute to the conventional building materials (cement blocks or fired bricks), which has to be imported from the nearest city, Al-Arish, 200 km away. The raw material desert clay or Tafla was obtained from a location near the area, and the mix design was done with the help of a material scientist's office in Cairo.

Un-stabilized Rammed earth was found to be very much cheaper than fired brick walls (only 10% of the price), while the cement stabilized rammed earth costed 45% of the fired brick walls.³²



Figure 41: Rammed earth construction in Saint Katherine. ³³

Lack of accessibility to the tools and equipments for the local people and builders who had been trained during the construction of the building, prevented the repetition of the experiment, or the establishment of private entities like local contractors who could take the initiative and start their own business, which is lamentable considering that people were interested and started to ask about the technique and if they can use it to build their own homes.³⁴ The shuttering had to be specially manufactured in a local workshop, as the regular shuttering for concrete was not capable of bearing the loads of ramming.

The unique context of Saint Katherine raises the issue of appropriateness and whether the introduction of a new building technique is suitable for any local context or not. In the case of this project, the architects have spent a long time in the area with the people to understand their customs and to study the local context and climate. An example of the issue of appropriateness was the

ramming technique, although the team had prepared the pneumatic rammers to make the rammed earth, as it is faster and needs less effort, but the local builders didn't interact with it and preferred manual ramming instead.³⁵

The following table shows an analysis of the actors involved in different activities related to the production and construction of the building material:

| Activity | Involved actors |
|--|--------------------------|
| Raw material identification | Architect + local People |
| Manufacturing of the building component | Skilled/unskilled labour |
| Use in construction | Skilled builders |
| Marketing /promotion | ----- |
| Codes, specifications, regulations, Policies | ----- |
| Training & education | Architect/NGO |
| Material research & development | Material scientist |
| Equipments & machinery | Architect, workshops |

Compilation of all Actors Identified in the Different Cases

| Activity | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 |
|--|--|---|--|--|---|
| Raw material identification | Local soil, tested on site by architect | Imported soil (waste material), tested by material scientist | Local soil, tested by material scientist | Imported soil, from local quarry (supplier) | Local soil, tested by material scientist |
| Manufacturing of building component | Architect, local labour | Architects, local labour | Architects, local labour | Architects, local labour | Architect, Skilled/unskilled labour |
| Use in construction | Architect, skilled/unskilled builders, | Architect, structural engineer , masons | Architects, local builders | Architect, unskilled builders | Architect, skilled/unskilled builders |
| Training and education | Architect, foreign expert | HBRC, Auroville | Architects, NGO (EECA) | ----- | Architects, NGO (EECA) |
| Material research and development (Mix design) | Architect performed on site mix design and testing | Architect & material scientist, tests performed in HBRC laboratory | Architects, laboratory test at material scientist office | Architect did mix design, tests performed in Cairo University laboratories | Architect & material scientist, tests performed in private laboratory |
| Equipments and machinery | Imported machinery | Imported machinery | Locally manufactured machinery, cooperation between EECA and research center | Locally manufactured by architect, mechanical engineer and local workshop | Locally adapted equipment by architect, and local workshop |

Table 2: Actor operating in the different activities of the process of earth-construction based on the studied cases

Based on the actors' identification, the following points are concluded:

- There has been very little cooperation or information exchange between experts during the execution of the projects or after its end.
- The architect is the main actor in most of the activities, due to the lack of cooperation with other entities, and lack of interest and awareness among other specialities in the issue of earth-construction.
- Local clay quarry was identified in one of the cases as a source for raw material, but to the others it was not recognized as a potential raw material supplier. This grabs the attention towards the possibility of having those quarries as potential suppliers of clay. This can be a potential for innovation in mix designs to achieve better results, especially that the clay is the most important ingredient in the mixture, and it is not necessarily available on site in every location.
- Specialized soil-analysis expert offices which offer the soil identification and mix design experimentation for earth-construction seem to be very rare. Only one expert office was recognized in all the cases.
- Foreign experts were involved directly in two of the cases, while the technology transfer in general – directly or indirectly – is the main source of knowledge for all the experiments. The exposure to the technology through books, publications, studies abroad, or cooperation with foreign institutes or experts was the motive for starting these initiatives. Local sources of information are critically missing.
- Three of the experiments have managed to manufacture the machines or adapt the equipments locally. They have all faced difficulties in finding mechanical engineers and local workshops that can cooperate.

Reflections on the Studied Cases

The previous cases presented different approaches for introducing modern earth construction techniques. The following main issues can be considered as

constraints against the improvement of the materials' widespread use in construction:

1. The lack of a strategy for promotion and continuity beyond the experiment.
2. The lack of integration between different specialities and entities.
3. Lack of dissemination of knowledge and availability of information
4. Lack of accessibility to tools and equipments for the local people and builders, which stop the continuity and replication of the experiment.
5. Absence of a strategy for adapting the technology to the local context. All experiments have been introduced as a process of self-building or a cooperative system, however, the common trend of building in Egypt depends on small local contractors while the culture of self building or cooperative building is not common.
6. Lack of material science or soil analysis experts, who are specialized in the field of earth-construction, to contribute in the process of soil analysis and mix design.
7. The machines for CEB production depend either on direct technology transfer through imported machinery, or the local manufacturing of machines which also depended on technology transfer throughout research done by the team (usually architects) through publications and other available sources of information. There is a lack in the integration between imported technology and the local circumstances of workshops, labour skills, and construction sites, for ensuring a successful transfer of technology that is appropriate to the local context.
8. No infrastructure exists to encourage the repetition or the transmission of technology to the people to enable them to adopt the construction technique in future building projects.

Reflections on the aspects of sustainability

- **Biodegradability** depends on the raw materials used in the building material production and the processes applied on it. In the studied cases, all the mix designs were developed using stabilizers, either cement or lime, with varying percentages that did not exceed 10%. This is considered a drawback in terms of the ability of the material to be recycled after the end of its life. Although it is argued as essential to add stabilizers for the mix to be water resistant, other experts claim it is not necessary at all. By asking the office of Martin Rauch about their mix designs they confirmed that they never add any stabilizers to their mixtures for Rammed earth walls, explaining that it is structurally unnecessary and destroys the natural properties of the material.
- **Energy demand and harmful emissions:** the process of producing CEB and Rammed earth consume a small amount of energy and consequently fewer emissions are produced, compared to reinforced concrete and fired bricks. There is a need for performing a Life Cycle Assessment for the material to calculate this difference.
- **Cost reduction:** in the studied cases, the cost was calculated by the project architects to be generally less than the conventional construction systems. However, the cost of producing CEB manually actually proved to cost more than the traditional fired bricks due to the labour cost, this is in contrary to the mechanical production which proved to cost less than fired bricks (approximately 75% of the cost) in case number four. In the case of Rammed earth, the cost proved to be 45 % of the fired bricks in case of stabilized walls, and 10% of the cost in case of un-stabilized walls.
- **Decentralization:** all the techniques of manual, mechanical CEB and Rammed earth are potentially suitable to be applied in remote areas.

Developing a Value Chain Analysis for Modern Earth-Construction in Egypt

Understanding the Value Chain Analysis

The value chain is a method for describing the activities taking place along a supply chain of a product: such as a building material or component. It is defined as *‘the full range of activities and services of market actors required to bring a product or service from its conception to its end use and beyond,’* (Porter, 1980). A value chain includes producers, processors, input suppliers, and retailers, and is defined by a finished product or service. *“The concept of value chain encompasses the issues of organisation and coordination, the strategies and the power relationships of the different actors in the chain.”* (M4P,2008)

This concept is derived from the business management discipline. Using the “Value Chain Analysis” in the context of this research is justified by the desire to identify all the activities and actors* liable to improve the use of earth as a sustainable building material in the construction sector, the constraints facing it, and the existing opportunities, as well as the value added due to the contribution of all fields of specialization. The required information is gathered through a series of semi-structured in-depth interviews with a selected sample of interviewees who represent the actors involved in the value chain. Each expert was asked to identify and explain the activities in which s/he is directly or indirectly involved during his/her practice and the connections with other actors or entities. The topics which relate to the value chain of earth construction include building codes and regulations, policies, labour force, education, research and development, equipments and machinery, raw material identification, production of building material or component(s) (onsite/offsite), architectural and structural design, marketing and promotion.

The aim of using the concept of the value chain analysis is to:

- Identify primary actors operating in the different activities, their roles and interrelationships, and define the missing activities that may contribute to the promotion of the material
- Identify constraints and opportunities that are holding back growth and competitiveness
- Identify market channels and trends within the subsector

The activities within the value chain are divided into two main categories:

- Basic activities, which in the case of a building material include the raw material, production of material or component, use in construction and marketing
- Supporting activities, which include building codes and regulations, policies, training and education, capital investment, access to machinery and equipments, research and development.

**the term 'actor' refers to any person who plays a role in the value chain*

| | | | | | |
|------------------------------|---|--|--|-----------------------|------------------------------------|
| Supporting activities | Administration and infrastructure | | | | |
| | Building codes, regulations and specifications | | | | |
| | Policies | | | | |
| | Human resources management | | | | |
| Basic activities | Training and Education | | | | |
| | Product technology development (R&D) | | | | |
| | Material research and testing | | | | |
| | Procurement (resources) | | | | |
| Value Added | Equipment and machines | | | | |
| | Capital investment | | | | |
| | In-bound logistics | Operations | Out-bound logistics | Marketing | Services |
| | Raw material | Manufacturing of building components | Use in Construction via: | Promotion | Adaptation to local context |
| -Geographical mapping | -labour or capital intensive | -Retailers | Demonstration buildings | -Technical solutions | |
| -Testing and identification | -Onsite/Offsite | -Contractors | -Lectures/conferences | -Material improvement | |
| -Extraction & transportation | -Centralized/decentralized | -Architects and consultants (design and specification) | -Publications/materials specifications | | |
| | | | -Media | | |

Figure 42: The suggested Value Chain for sustainable building materials. Developed after the model of Porter. (Porter, 1980)

Collection of Data

Data is collected using the following methods: in-depth interviews, site visits, observation and secondary sources including literature, scientific researches, newspapers, reports..etc.

Semi-Structured in-depth Interviews

“Interviews are particularly useful for getting the story behind a participant’s experiences.” (McNamara,1999)

The semi structured interview follows the general interview guide approach. *“The interview guide approach is intended to ensure that the same general areas of information are collected from each interviewee; this provides more focus than the conversational approach, but still allows a degree of freedom and adaptability in getting the information from the interviewee.” (Turner, 2010)*

The interview is a good technique in getting more in-depth information from the story behind the experience of the interviewee. The reliability of the results is dependent on the interaction between the interviewer and interviewee, and the setting of the interview. Questions were divided according to activities in the value chain. To ensure reliability, questions to interviewees were asked about their personal experience in projects implemented by themselves, but not in general. For every activity, questions were asked to the interviewee to understand his/her amount of involvement in this activity, to identify other actors involved, the obstacles and challenges, and the missing activities and actors. The wording of questions may differ from one interview to another.

Selection of Study Sample

The study sample selected is an “expert” sample from architects, engineers, researchers, material scientists, building material manufacturers and skilled builders. Based on activities related to value chain of earth-construction the following potential actors were identified:

| Activity | Identified actors |
|--|--|
| Raw material identification | Material scientists Clay Quarries |
| Manufacturing of the building component | Clay brick factories Contractors |
| Use in construction | Architects/consultants Civil engineers Real estate developers Contractors Skilled builders Users/Owners |
| Marketing/promotion | NGOs |
| Building codes, material specifications, regulations, policies | Ministry of Housing HBRC |
| Training, Knowledge & Education | Vocational training centers + Universities |
| Material research and development | Research institutes |
| Equipments & machinery | Local factories/workshops |

Interviews were conducted with the following set of interviewees:

- Seven expert architects/consultants with experience in earth construction (four of whom have experienced the techniques of CEB and Rammed earth and three have experienced adobe construction)
- One civil engineer
- One material scientist
- A board member in an NGO specialized in earth construction
- An expert from the national research institute (HBRC)
- A master builder of adobe
- The owner of a traditional clay brick factory
- Two owners of newly constructed mud brick houses

(The whole list of interviews and site visits is indicated in Appendix I)

List of Actors and their Roles

Architects/Consultants

Although the material technology is not the architect's main field of work, sometimes it is essential for the architect to get involved in this discipline due to the desire of using a certain new or innovative building material during construction. By asking the expert architects about their work procedures and activities it was obvious that the architect sometimes has to switch roles to bridge a gap, whether in knowledge, production, or in a service provision.

When asked about the difficulties in terms of codes and regulations, a consensus was gained from the interviewees about the difficulty of obtaining consent for buildings that are constructed using unconventional materials or construction techniques - even the regular load bearing structures. This was due to the lack of data and specifications available to the structural engineers for making the calculations or to the authorized officials who have to give approval. Therefore, this type of construction usually depends on the architect's own experience in calculating the structural behaviour of the building, and depends also on the experience of the local master builders who still have the knowledge of the local traditional building techniques, such as domes and vaults. Moreover, it is usually built on the peripheries and in areas distant from urbanization, that do not necessarily require official authorization, and where the land value is not so high.

It was obvious, when asking about the existing or previous incidents of cooperation or information from earlier experiments, that there was a big lack of knowledge transfer and dissemination, which makes the process repetitive.

Cooperation with research institutes and material scientists exists only on a minor scale and informally. Only one professional office for material testing was identified by all the interviewed architects that offered services in the field

of raw material analysis and mix designs for earthen building materials. When compared to the number of offices offering service provision for other regular concrete tests, for example, the gap can be clearly recognized.

Architects gather information about the existing raw materials in the area by asking local people and by surveying. If laboratory tests are required, architects usually approach research institutes based in Cairo to perform them as service providers. There is a lack in decentralized specialized research centers that perform local soil composition analysis.

There was a consensus that the best way to market a material is to use it in constructing many buildings so that people see it and experiment its quality. Public buildings are the best typology for promoting a material.

Architects deal with a client, who must be interested and convinced of the material; hence, social perceptions and cultural barriers are main factors influencing the promotion of the material.

Training and empowering local craftsmen, laborers, and contractors can help spread the idea, but this is not possible without access to equipments and scientific knowledge, and the existence of interested clients. Architects stated that they usually train local labourers during the construction of a project, but this does not ensure the continuity and replicability of the technique, even if the workers and masons show good skills and interest in the work, because in the end there is neither a market for this material or construction technique, nor tools or equipments available and accessible to the people, or any kind of incentive or support for starting a business in this field.

Research and Development Institutes

There is a gap between the research institutes and the industry of building materials. While industry is a very important factor in the promotion of

alternative building materials, and can exert pressure for changing regulations and specifications, investments will not be directed towards the manufacturing of a new material without support from the research field, and a push towards proving the reliability of the material. An example of a good and promising connection between research and industry in Egypt is the efforts done by the “Center for Development of Small-Scale Industries at Ain Shams University”. It has established connections with factories to perform several semi-industrial experiments using the factories’ full capacity for producing alternative materials derived from palm mid ribs. An experiment was done by the center in 1993 to operate Al-Nasr wood factory in Al-Mansoura with its full capacity to produce particleboard wood from palm midribs. The factory produced a total of 1.5 tons of particleboards that were tested and the results conformed to the standard specifications. (Elmously,2004). The semi-industrial experiments are very important to prove the possibility and applicability of transforming the alternative material from experimentation to the industry. However, in order for the material to enter into the industry, an investment is required, even on the level of small scale enterprises.

The connection between the architect and the research institutes is bound by service provision, which means that the architect approaches the research institute or material science laboratory to perform a test for a material or ask about a research that is being undertaken. There is another missing connection in the field of alternative building materials, which is the connection between practice and research. This connection is supposed to be a benefit for both architect and researcher, and has to be a two-way relationship. The architect or practitioner needs the scientifically based support and experimentation of materials, while the research institutes would definitely benefit from the opportunity of applying its researches in the field and test its success in reality. There is also a missing cooperation between material scientists and expert architects in the field of earth construction techniques. The main challenge is the development of mix designs and testing different mixtures of soils to avoid

the addition of a large percentage of stabilizers. The main concern of the material scientist is to prove the durability of the material, whether it is a building block or a wall section (in case of Rammed earth), as well as its water resistance, as indicated by the material scientist interviewed. It is of great importance to test the water resistance of the building block before any compression, to prove that it is chemically stable. The architect's role is to introduce design considerations for protecting the walls and foundations to avoid the exposure to water.

On the national level, there are no efforts done to encourage the decentralization of the research work on the soil analysis and raw material suitability for earth construction in cooperation with research institutes.

Skilled Builders

Skilled builders play an important role in the preservation and revival of the traditional building techniques and also in its development and improvement. Many of the expert architects have worked with skilled builders in their projects and learned from them. Fathy (1973) describes the relationship between the architect and the local craftsmen based on his experience of working in New Gournah, he states that the architect *“must set his authority against the glamour of the Malakan; he must find out the hidden and dying crafts and bring them to light, revive them, give the craftsman back his lost confidence, and encourage the craft to spread by giving new commissions.”*

According to one of the master builders from Aswan, there is no market nowadays for mud brick construction except in very few cases in special projects like hotels and resorts in remote areas. However, there is a rising market for building with traditional domes and vaults. The material commonly used for domes and vaults now is regular fired bricks and cement mortar - instead of mud bricks - because it is faster and easier, and does not require special skills like the mud bricks. *“One vault can be finished in one day with 2*

“masons, and an expert labourer can cast 2000- 3000 mud bricks per day” indicates the master builder. The clients who ask for this type of construction are private owners of villas or rest houses in Cairo suburbs and many other cities. In the remote areas, bearing walls, domes and vaults are much cheaper than building with reinforced concrete, because of the cost of transporting the materials, equipments and contractors' overhead, and many people are interested in building their houses with the traditional techniques as a trend or fashion.

One of the expert architects - experienced in building with CEB - explains the reason why he likes to work with the CEB rather than the rammed earth technique. He said it is more flexible and gives the skilled builder a space for creativity, for example to create motifs, unlike the rammed earth which is a very rigid and static technique that does not allow for creativity, however it also has its appropriate uses.

The modern techniques of earth construction like CEB and rammed earth are new and unfamiliar to the local builders, and offer no market niche for them. Expert architects and builders indicated that the heavy weight of CEB; although being beneficial in wall construction; is difficult, however, to deal with in domes and vaults. The interviewed skilled mason explains that he is not convinced of these new techniques because they entail too much complication compared to the traditional technique *“if we want to build with earth then the traditional way of casting mud brick is the best and most efficient way, it does not require a lot of labour or equipment, and has a high rate of productivity. The tradition is well known in all the Egyptian villages and not only in Aswan, so why do we need another technique?”*

Non Governmental Organizations

The Egyptian Earth Construction Association is an NGO that was established in 1997 for the purpose of promoting earth construction. EECA's main objectives were promoting appropriate building technologies, and encouraging research activities to develop innovative building techniques with local materials. EECA had several experimental projects utilizing earth as a construction material, as well as the manufacturing of a press for producing compressed earth blocks. The association also offered training to architects and students for appropriate building techniques including earth-construction. The earth-construction techniques experimented by EECA were Compressed earth blocks, Rammed earth and earth bags and is currently researching the technique of cast earth.

The role of an NGO specialized in the field of earth construction was discussed with a board member of EECA, who acknowledged that - to promote earth-construction - there is a need for a transformation of the association from an architecture oriented organization to an umbrella hub, gathering all the actors within the value chain, from material scientists, manufacturers of building materials, master builders, owners of clay quarries...etc. The lack of information dissemination and networking was the result of an institutional problem, and the existence of an NGO that can act like an umbrella association is very important. This kind of umbrella association should take the role of bridging this gap, by forming pressure groups in different directions like the coding, industry, policies... etc.

“Members would be encouraged to join the association if they see the benefit in collaboration that will form a pressure for a market transformation, which consequently means a financial reward. This would happen if the person sees himself as a service provider not a promoter for green construction. We are currently working on this target to attract as much interdisciplinary members as possible.”

Owners/Self Builders

Despite the decline of the traditional mud brick construction, some people are still interested to use it in building their houses. A few of them were interviewed to understand their motives and the obstacles they faced. One of the house owners in Tunis village in Al-Fayoum, who is a local peasant, built a small unit using adobe bricks and mud plastering, covered with a dome and a vault. He and his brother were influenced by the modern houses built with mud bricks in Tunis village and so they decided to build one for their own usage as a day time sitting area. This was not the main family house; they have another house adjacent to it constructed with concrete. He indicated that the family house had to be concrete to be able to accommodate 2 or 3 floors, and to make good modern finishing, especially for the bathroom, without any fear of humidity and water leakage destroying the structure. The owner acknowledged the good temperature and the comfortable indoor climate inside the mud brick house.

Another house owner in Wadi El-Natroun built his house using mud bricks. He brought the clay from the agriculture land in a distant village in the Delta because they did not know that the desert clay could also be used to cast adobe. The owner worked with his own hands along with his family members to cast the brick. They plastered the walls with clay as well.

The motive of using adobe bricks was the childhood image of their old house which was very pleasant and thermally comfortable. *“We leave the fruits and vegetables outside the fridge for weeks and it doesn’t get spoiled like it did in our previous concrete house. The fridge does not use as much power as it used to in our previous concrete house because the temperature inside the house is moderate. In winter the rooms are warm at night and in summer we don’t need to use a fan.”* He house is four years old now and they have not faced any problems. The difficulties during the construction phase were mainly to find good skilled masons who can build with adobe, especially for the vaults, as well

as the difficult access to information and technical solutions. The major difficulty was the lack of social acceptance from the neighbours and relatives, who perceived mud construction as poor and not durable and blamed them for this decision.

Another interviewee was a mason from Aswan, who talked about his experience in building his own house. *“I built my house in the late 1990s with mud bricks, it was very pleasant and I didn’t need any fan, the temperature inside was very good all the time. But I had to demolish it after 10 years because I wanted to build another floor, it could have supported another floor, but I preferred to build with modern techniques of reinforced concrete. Now, my new house is extremely hot especially in summer.”*

University Education and Vocational Training

Among all the universities in Egypt which offer architecture degrees there are no specialized courses for earth construction with the exception of a few elective courses that include some information about earth architecture in some universities. This is a very poor contribution to the knowledge being offered to architecture students in this field. In many countries, specialized courses in earth construction are offered for architecture students like by the University of Grenoble which conducts a two-year course on earth construction.

Building Material Producers

A field visit to a local traditional fired clay brick factory was conducted aiming to identify the existing supply chain for a traditional and very well established building material industry. The traditional clay brick factories depend on labour intensive work and old locally manufactured or imported machinery. The key success factors identified in the traditional fired brick supply chain can be summarized in the following points:

- The availability of a reliable source for raw materials (the local desert clay quarries). It is worth noting that the quality control of the products is not of any interest to the traditional clay brick factories, so there is no scientific identification done for the clay.
- The separation of the processes of raw material extraction, building material production, and construction, which makes it easier and reliable for the client or contractor to have the building material ready on site by another supplier.
- The process is high labour demanding, which is a good source of employment for the local people, moreover, it also has a high productivity rate, which means that the cost of production is kept within affordable ranges to the consumers.

The major obstacle facing the owners of the traditional fired clay factories is the fuel prices, which are rising rapidly, and which comprise 50% of the price of the material production.³⁶ The traditional fired clay bricks, however, have a low quality due to the primitive technology used.

According to the interviews, the following constraints, challenges and opportunities were identified:

Constraints and Challenges Causing the Underutilization of Earth Construction

| Activity | Constraints & challenges |
|---|---|
| Raw material identification | Lack of specialists as researchers and service providers for soil identification and mix designs. Lack of collective research efforts on the national level. |
| Manufacturing of the building component | No supply chain exists. No feasibility of the new techniques to normal people Lack of standardization for industrializing the process of building material production |
| Use in construction | No market demand Local and traditional building skills are disappearing The cultural habit of self building is disappearing Lack of support from structural engineering |
| Marketing/promotion | No role model by the government Missing connection between material producers and innovators and between consultants and contractors Poor social acceptance of the material due to the old perceived image of adobe |
| Building codes, material specifications, policies | Difficulty of obtaining consent for buildings No specifications for earth as a building material High land prices cause the desire of vertical extension |
| Training and education | No demand for training as no foreseen work opportunities Lack of knowledge dissemination from previous experiences No specialized university education |
| Material research and development | Only centralized research centers exist (mainly in Cairo) No integration between research institutes and practitioners |
| Equipments and machinery | No access to equipments and machinery to the local people or local contractors |

Table 3: Constraints and challenges facing earth construction in Egypt; identified by experts.

Opportunities for Improved Competitiveness of Modern Earth Construction

| Activity | Opportunities |
|---|---|
| Raw material identification | Raw material (clay, sand, gravel) is abundant in Egypt |
| Manufacturing of the building component | Existing skilled and unskilled labour Job opportunities offered by using intermediate technologies Mass production decreases the cost |
| Use in construction | The skills of the local builders |
| Marketing/promotion | The interest of some high income clients in sustainable building promotes earth as a material not only for poor Acknowledgement from the people of the good thermal qualities of earth |
| Building codes, material specifications, policies | The current activity in the Housing and Building Research Center to write a code for earth construction |
| Training and education | Existing vocational training centers that can be encouraged to cooperate in training activities |
| Material research and development | Cooperation with research institutes and material scientists (on a limited scale) exists |
| Equipments and machinery | Existing local manufacturers and workshops that can manufacture similar machineries and equipments |

Table 4: Opportunities for promoting earth construction in Egypt: identified by experts.

Recommendations for Improving the Competitiveness of Modern Earth Construction

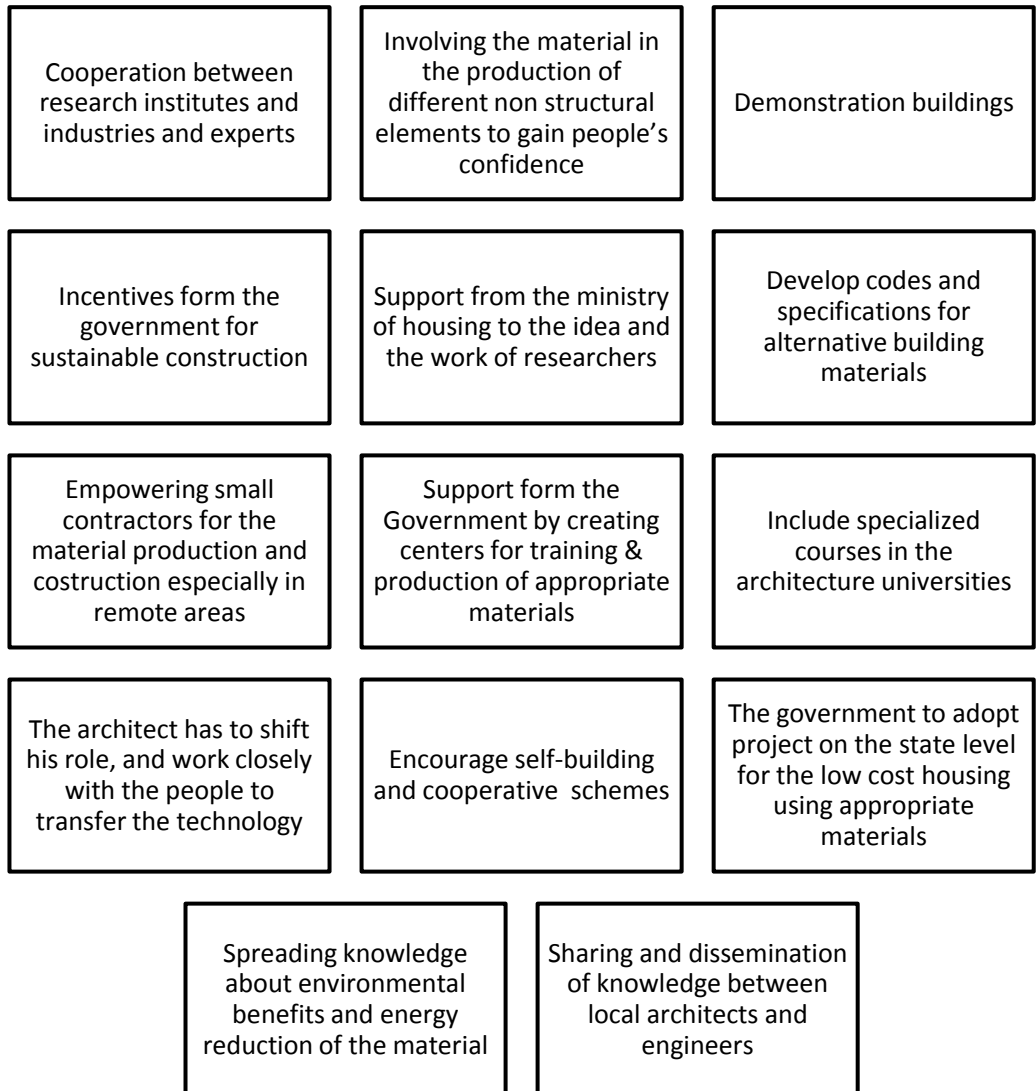


Figure 43: Recommendations for improved competitiveness of earth construction. Identified by experts.

Identification of Actors: The Value Network

As a result of interviews, field visits, and other sources of information, actors performing in the value chain are identified in the following figure.

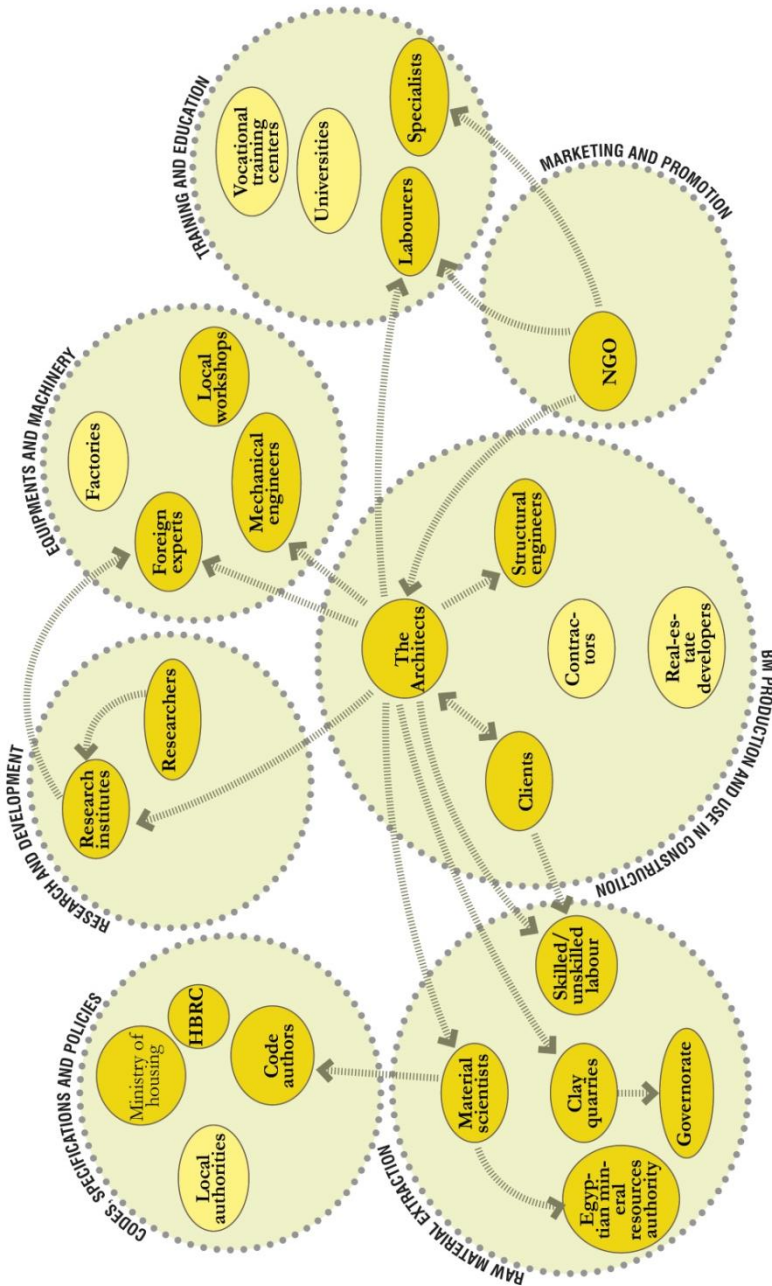


Figure 44: Connections between different actors in activities related to earth-construction.

The analysis of the actors' roles in the different activities shows the lack of integration and the missing roles and activities. The role of the architect extends beyond the design and construction to jump between one activity and another in order to overcome the gaps, to search for raw materials, produce the desired building component, train workers and even manufacture the needed machinery or equipment.

Marketing and promotion are the activities that have the least interest and attention. There are also inactive actors like the universities and the vocational training centers which play no role in training and educating labour, specialists and students about earth-construction.

Importance vs. Effectiveness of Actors

The following table shows the degree of connectivity and cooperation between different stakeholders in projects that involved earth construction, based on the response of interviewed architects.

The responses show weak cooperation with structural engineers, government authorities, contractors, code authors, or real estate developers during construction. One respondent indicated cooperating with research institutes in the material testing phase and another with raw material suppliers (clay quarry). Two respondents had cooperation with funding agencies and with NGOs. Three respondents had cooperation with material scientist, equipment manufacturers and universities.

| Architect | Cooperation in earth construction projects implementation | | | | | | | | | | | | | |
|-----------|---|-----------|--------------------|------------------|------------------|--------|-----|-----------------|------------|------------------|-----------|--------------|-----------------------------------|------------------|
| | Str. engineers | labourers | Material scientist | Research centers | Gov. authorities | Client | NGO | Raw m. supplier | contractor | Real estate dev. | Workshops | Code authors | Universities/ training centers | Funding agencies |
| 1 | No | Yes | No | No | No | Yes | No | No | No | No | No | No | Yes | No |
| 2 | No | Yes | Yes | No | No | Yes | No | No | No | No | No | No | No | Yes |
| 3 | No | Yes | No | No | No | Yes | No | No | No | No | No | No | Yes | No |
| 4 | No | Yes | No | No | No | Yes | No | Yes | No | No | Yes | No | No | No |
| 5 | No | Yes | yes | Yes | No | Yes | Yes | No | No | No | Yes | No | No | Yes |
| 6 | No | Yes | Yes | No | No | Yes | Yes | No | No | No | Yes | No | No | Yes |
| 7 | No | Yes | No | No | No | Yes | No | No | No | No | No | No | Yes | No |

Table 5: Cooperation between architects and other actors in earth construction projects.

The following table shows how the interviewees identified the importance of cooperation with other stakeholders or entities.

| Architect | Importance of cooperation with | | | | | | | | | | | | | |
|-----------|--------------------------------|-----------|--------------------|------------------|------------------|--------|-----|-----------------|------------|------------------|-----------|--------------|-----------------------------------|------------------|
| | Str. engineers | labourers | Material scientist | Research centers | Gov. authorities | Client | NGO | Raw m. supplier | contractor | Real estate dev. | Workshops | Code authors | Universities/ training centers | Funding agencies |
| 1 | Yes | Yes | --- | Yes | Yes | Yes | --- | No | No | No | --- | --- | Yes | --- |
| 2 | Yes | Yes | Yes | Yes | Yes | Yes | --- | No | --- | No | --- | No | Yes | Yes |
| 3 | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes |
| 4 | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes |
| 5 | Yes | Yes | Yes | Yes | Yes | Yes | --- | Yes | Yes | No | Yes | --- | Yes | --- |
| 6 | Yes | Yes | Yes | Yes | Yes | Yes | Yes | --- | Yes | No | Yes | --- | Yes | --- |
| 7 | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | No | --- | yes | Yes | --- |

Table 6: Importance of cooperation between entities in earth construction projects. Identified by interviewing expert architects.

The following figure is an illustration of the relationship between the importance of actors' contribution in improving the competitiveness of modern earth construction techniques and between the actual effectiveness and contribution of those actors in the executed projects.

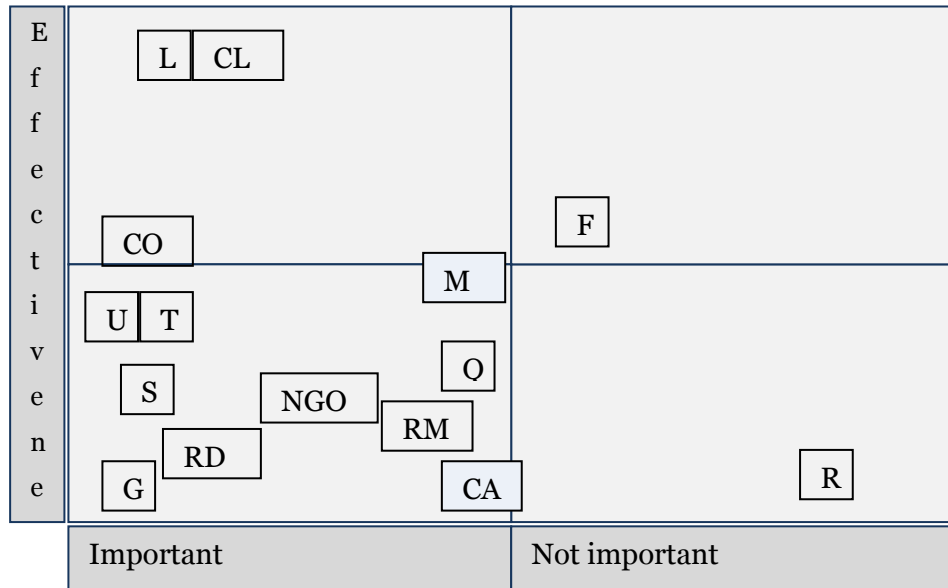


Figure 45: Effectiveness vs. Importance of actors in the value chain of earth construction based on interviews analysis.

| | |
|---------------------------------------|-----|
| Structural engineer | S |
| University | U |
| Material scientist | MA |
| Training centers | T |
| Skilled Labour | L |
| Contractors | CO |
| Real estate developers | R |
| Funding agencies | F |
| Government authorities (ministries) | G |
| Equipment and machines manufacturers | Q |
| Research and development institutes | RD |
| Raw material suppliers | RM |
| Code authors | CA |
| NGOs for earth architecture promotion | NGO |
| Clients | CL |

List of Abbreviations

The opinion of an external expert

A short questionnaire was sent out to the office of the architect Martin Rauch in Austria (*Lehm Ton Erde Baukunst*), in order to have an overview on the context of their work, and understand the factors that positively affect the widespread of the earth-construction practice in the countries where they mainly work (Switzerland, Austria and Germany), what are the main activities they perform inside their firm, and what entities do they cooperate with.

The main factors that encourage the widespread of earth-construction as indicated in their response were classified as follows:

High influence:

- Interest of clients (awareness about sustainability)
- The existence of private firms that work in material production and construction of earth buildings

Medium influence:

- Education and training
- Knowledge sharing and dissemination between practitioners
- Access to equipments and tools (like shuttering and rammers) to normal people and to contractors
- Cooperation between all the different entities

Low influence:

- The presence of active research institutes
- Market forces (supply and demand)
- The industrialization of the material production

No influence at all:

- Presence of a building code for earth construction
- Interest of the governments (by offering incentives)
- The role of NGOs

The firm also has experience in working in developing countries, by asking about the obstacles that face their work in those countries they indicated the following points:

“A certain different sense and perception of time, work ethic, along with workers know-how and autonomy can be factors sometimes considered as obstacles during the planning and construction process in an emerging or developing country.”

The firm works in cooperation with other entities like an Austrian laboratory for soil analysis, kiln builders in Austria and Switzerland, ceramic producers, Universities (ETH Zürich, Kunstuniversität Linz), and with architectural offices (Boltshauser Architekten and Arch. Anna Heringer). The activities performed inside the firm are:

- Raw material identification
- Mix design
- Training activities (for labour and engineers)
- Knowledge dissemination and Marketing
- Design and manufacturing of tools and equipment
- Construction on site

While Structural and physical testing for the material are delegated to external partners.

Conclusion

Experiments of building with modern earth construction techniques like Rammed earth and CEB are very few in Egypt, and are based on scattered individual efforts, mainly from expert architects. Those experiments show a need for a strategy for promotion and continuity, and reveal a number of factors inhibiting the material's widespread use in construction, such as the lack of integration, lack of knowledge dissemination, lack of accessibility to tools and equipments, absence of a strategy for adapting the technology to the local context, scarcity of material science or soil analysis experts in the field of earth-construction, depending only on technology transfer without integrating the local circumstances. Moreover, the interviews with experts in earth construction identified the main constraints inhibiting the promotion of earth as a modern sustainable building material, as well as the existing opportunities and recommendations for improving its widespread use.

The main constraints identified are the lack of knowledge dissemination, no accessibility to tools and equipments, the need for local adaptation of the technology, poor social acceptance, absence of codes and specifications for the material, lack of public policies and incentives to encourage its use in construction, and the lack of soil analysis and mix design specialists and researchers.

The identification of actors performing in the value chain of earth construction revealed the absence of the contribution and collaboration between the actors of the same or different specialities, and the need for integration.

²² Tafla is the Arabic word for desert clay

²³ An average of 60 EGP is assumed for each worker

²⁴ Prices according to the official prices published at the Ministry of Housing website:
http://www.moh.gov.eg/section3/Building_materials_DET.aspx

²⁵ Market prices in March 2013

²⁶ Photos were taken in the house of architect Adel Fahmy in Fayoum

²⁷ Information is based on interview with the architect

²⁸ Photo copyrights for EECA

²⁹ Photo copyright for EECA

³⁰ Picture copyrights for ADEEM consult: <http://www.adeemconsult.com/>

³¹ Picture copyrights for EECA

³² Calculations from project's documents of EECA

³³ Photo copyright for EECA

³⁴ Information is based on the interview with the project's architect.

³⁵ Information from interviewing the project architect

³⁶ Information from interviewing the factory owner

Chapter Five: Discussion and Recommendations

Chapter Five: Discussion and Recommendations

This chapter provides a discussion of the results and findings of the research, and suggests a group of recommendations for the improved competitiveness of modern earth-construction practice in Egypt.

Overview

Local building materials can make a significant contribution to overcoming the existing shortage of affordable and adequate housing in Egypt. This research investigated the potential of applying modern earth-construction techniques in Egypt and the reasons for its underutilization in the construction sector. A few experiments for building with CEB and Rammed earth were undertaken in Egypt by expert architects and research institutes. They were mainly experimental projects and were mostly based on technology transfer. Those experiments were all individual and disintegrated actions, and they were not properly promoted and disseminated among experts or to the public. On the

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other hand, the traditional mud brick construction is not accepted by the people anymore, and is replaced with industrialized building materials, due to many socioeconomic changes that have taken place within the Egyptian community. Although several attempts for reviving the traditional mud brick construction were undertaken in modern times, none of the trials were successful in fulfilling the aim of using local building materials to achieve affordable housing for the people.

The aim of the research was to investigate the potential of using earth as a modern sustainable building material in the Egyptian construction sector, and how to encourage its utilization; within appropriate contexts; to provide sustainable and affordable housing. The research used a methodology that is based on two main activities: interviewing a group of experts in the field, and studying a few examples for realized projects.

Based on a literature review; the aspects of sustainability which relate to earth-construction, and to the Egyptian context were identified and classified into environmental and socioeconomic aspects. In addition, the concept of the Value Chain Analysis – derived from a business development discipline - was used to identify the constraints and opportunities of the improved competitiveness of modern earth-construction techniques in Egypt.

Main Ideas for Discussion and Recommendation

Improving the social perception about earth as a building material

Earth construction is socially linked with poverty and retardation; while modernization and wealth are associated with the construction of reinforced concrete and fired bricks.

Gaining acceptance of a new material is difficult, as for most of the people, the house is their lifetime investment, and they are not ready to take any risk regarding its construction. In order to gain acceptance, the best strategy is to test the material many times in projects that are visible and accessible to the people, where they can monitor its performance through years. Spreading awareness about the benefits of the material through open sessions and public events can also help to promote its uses, but without a real constructed model that the people can perceive, the result will not be beneficial.

Appropriate choice of production methods and construction techniques

CEB and Rammed earth techniques offer a range of technology from low to medium scale production, and can also reach large scale production and prefabrication as well. The choice of the level of technology has a social influence on the people's acceptance and interaction during construction, and the appropriate choice of technology and construction scheme could be an access to social acceptance of the material as well. The analysis of the local context of each intervention will determine the choice of the system.

The traditional fired clay brick industry as discussed before, has mainly three advantages, which make it a successful and widespread material; the availability of a reliable source for raw materials, the separation of the processes of raw material extraction from building material production and construction, and the combination of high labour demand offering jobs for the local people, as well as the high productivity rate, which in turn leads to cost reduction. Learning from this and tackling these three issues will help in reaching the best production system that is appropriate to the local context.

Depending on large scale centralized production of building materials, like cement and steel, brings all the financial benefit to the investor or factory owner, especially with highly mechanized production systems, which offer no job opportunities to the local people, and enshrines the idea of centralization. The modern earth construction technique is more suitable to be undertaken on site with local materials and with equipments as simple as possible. Enabling local contractors and creating decentralized soil analysis research centers is a process that can be successful in many areas in Egypt, especially in remote areas. This should be done by creating mobile production units with all the equipments and machinery that can be transported to any area in Egypt.

A small scale production for earth construction incorporating a cooperative or a self-building scheme was experimented in several projects of low cost housing and public buildings in many countries. An example is the project constructed by the architect Francis Kere in Burkina Faso in 2001. This project used CEB from local materials to construct a public school, and it won the Aga Khan award in 2004 as a model for self help construction with local building materials.

However, the traditional cooperative construction method, which was an old practice in the Egyptian villages, is not socially accepted anymore. This is due to the socioeconomic transformation of the community which depended on agriculture as the main activity, but turned to employment in government or other jobs instead, which leaves no time for social collaborative building processes.

Knowledge exchange and dissemination

The technologies of CEB and Rammed earth are new to the Egyptian context, and there is a lack of literature and sources of information on these topics. The few experiments that have used these materials in construction in Egypt were dependant on the information and research of the experts who executed the

projects, who in turn, have benefited from international exposure. It is of high importance that the outcomes of these experiments are documented and disseminated among experts and to the community through reports, lectures, or seminars. The scarcity of the number of people who have the knowledge makes it inaccessible and unknown to others.

On the other hand, there is a lack of education and training for earth construction techniques, whether to students, architects, engineers, soil analysis specialists, or to craftsmen and workers. The EECA – within its training program - has offered a number of training courses in earth construction. Recently it has offered two courses for building with earth bags. However, this has a very limited influence, and there is a need for establishing a wide range of training programs that are not only restricted to offering courses for architects, but also to engineers, masons and other specialists. Also it should offer courses in the field of soil identification and analysis, structural testing and optimization, building techniques, ...etc.

There is a need to develop specialized courses in faculties of architecture that aim at giving a full package of knowledge about earth construction. Also vocational training centers should be encouraged to offer training activities to contractors and skilled or unskilled labour, in cooperation with expert architects, research institutes, and the Ministry of Housing. This cooperation would guarantee job opportunities for the trainees in the field, and encourage the contractors to start their own businesses.



Figure 46: Earth bag training by the EECA in 2013.

Promotion and marketing

“The construction market is in general very conservative and it is not always easy to introduce new ideas into well-established contexts. Promotional activities might have to be undertaken to penetrate the market.” (Joffroy, 1994)

The promotion of alternative building materials in the construction sector is considered a multi criteria task and a network of activities that requires the involvement and cooperation of different actors like government authorities, local contractors, real estate developers, research institutes and others.

The most effective strategy for promotion is through presenting a role model. An example for this is Tunis village in Al-Fayoum, which has become known for its unique architecture of adobe. In 1962, the Egyptian poet Sayed Hegab and his Swiss wife Evelyn settled there and built their mud house. Today, more than 60 mud-brick houses have been built in this village, which mainly attracted artists, writers, and intellectuals.



Figure 47: Betah association for pottery, Tunis village, Fayoum.

Another way of promotion and marketing is reaching out to consultants and contractors in the construction field in order to introduce the knowledge and information about the different materials and technologies and to bridge the gap between research and development in the field of building material production and between the actual practices in construction. This can be done through exhibitions and promotional activities, and the documentation of all the innovations and by creating a knowledge base for the innovative building materials.

A good initiative was undertaken recently by the PSDP (Private sector Development Program) at the GIZ in Egypt, which is working on supporting the different innovations in the field of green building materials. They reserved a booth for green material producers - for the first time in Egypt - in the largest annual exhibition for building materials and equipments in Egypt (INTERBUILD). The booth included several green products such as prefabricated wall panels and building blocks made from rice straw, environmental friendly paints made with the nano-coat technology and lime based paint, alternative wooden boards and panels made from palm reeds and other products. All these materials were scientifically experimented and tested, but the problem facing the developers of these materials was how to take it a step further towards production, and how to reach out to the market.

Consultants and designers are not aware of the presence of these products, nor are contractors willing to try a new product unless it has been tested and its success and demand in the market proven. This is the missing link between research and development and between the market, which requires strategies for promoting the materials and raising awareness.



Figure 48: Green building materials booth in 'Interbuild' exhibition 2013.

Another incentive for promoting the material is to use it in public spaces and highly exposed areas, and it can be introduced first into no- structural elements such as furniture, fences, landscape elements... etc.

Creating a Role Model

The government has been giving a wrong example to people for years by building all its new governmental buildings, schools, public facilities and social housing in villages and towns with reinforced concrete, no matter where or in which climatic region, and even in the desert oasis with its very special architectural identity. It does not consider whether it is structurally essential to make a reinforced concrete construction or not. The government should adopt the change and start to construct its public buildings and facilities using local building materials.

Mass housing is one of the strategies for creating a role model. The HBRC is planning the construction of a new village in Al-Fayoum (the Productive Low-cost Environmentally friendly Village - PLEV). One of the aspects of

sustainability for this village is to use green building materials. The experimental building made in the HBRC premises was part of the preparation phase to this project. There is no information available yet about the production system that will be used for building with CEB in this project it is known however that the experiment adopted a manual production system that is high labour demanding and is low in productivity, which in the case of a large-scale project will not prove efficient, unless a community participation construction model, or a self building scheme will be encouraged.

Offering incentives

In the project of “*Ebny Betak*” (*Build your own house*), which was a national project to sell pieces of land to the youth to build their own houses on it, the Ministry of Housing made an agreement with the steel company “Ezz el-Dekhela” to provide every owner of a unit in the project with one free ton of steel as an incentive and encouragement to build his unit. It is worth to mention here that Ezz el-Dekhela is the largest steel company in Egypt which is totally monopolizing the market. The project management has also obliged the owners to stick to a set of requirements and specifications, which are all based on reinforced concrete construction. Although this project was not a success due to other reasons, the idea of offering incentives for using local or sustainable building materials was a good opportunity for improving its widespread use. This should involve providing a good infrastructure for the material production and offer incentives also for local contractors in the area.



Figure 49: "Ebny betak" (Build your own house) housing project in 6th of October city.

Improving Planning Policies and Regulations

Planning policies affect the type of construction. The high price of land especially in rural areas forces the people to build on a small land area, and due to traditions and social norms, they need more space for their extended families (sons and daughters), so they tend to increase the number of floors. People are discouraged to build with a wall-bearing system due to the common belief that it's not possible to raise more than one or two floors with this structural system. Changing the policies should start from the level of urban planning of new cities, by first studying the social norms and the people's needs before deciding on the land areas and height restrictions.

Another aspect related to policies is the building regulations and procedures of obtaining legal consent for construction with alternative materials or techniques. These are considered obstacles facing innovation in this field. Only the conventional reinforced-concrete skeleton structure is recognized by the local authentication authorities. Attempting to work with unconventional techniques is very difficult and requires searching for one of the officially recognized structural engineers who would be willing, and capacitated, to calculate the loads and to approve the documents. Change is required in local authorities' regulations to be more flexible for alternative materials and construction techniques.

Developing codes and specifications for earth construction

There are currently no codes or specifications that consider earth construction as an officially authorized building material in Egypt.

Currently some efforts have been done in this aspect. The HBRC has issued a draft for the Green Pyramid Rating system which identifies the categories of evaluating the projects in terms of energy efficiency. The Green Pyramid identifies a category for “materials and resources” accounting for 10% of the score. The objectives identified for this category are:

- *“To encourage selection of materials with a low environmental impact and cost over the full life cycle of the building, particularly:*
- *Regional and local materials (to reduce the environmental impacts resulting from transportation);*
- *Renewable materials;*
- *Recycled materials;*
- *Highly efficient materials (to reduce the need for maintenance, construction energy or skill or can be easily dismantled for reuse).*
- *Materials re-use: to promote the re-use of previously used materials and avoid wastage.” (HBRC , The Housing and Building National Research Center, 2011)*

This rating system is not legally binding and has not yet been subjected to application.

Moreover, a code for recycled materials and another for stabilized earth construction are currently under development also by the HBRC. This should be a good step towards the promotion of alternative materials in construction. The code will specify the “stabilized earth” techniques as indicated by the HBRC. This means only chemically stabilized earth by adding either cement, or other industrial waste materials liable to improve the mix properties by

chemical reaction will be used. As yet there is not enough information about the details of the code which is supposed to be finished by 2014.

The code authoring is an ongoing process, and is usually a response to a need and a reflection of practice, so it should not be a final product that is written once and applied for all, but should rather be considered as an experimental document that will be tested in practice and amended according to the lessons learned through practice. Therefore, it is recommended that, during the code development process, open sessions for experts be conducted to discuss and debate the code articles, as well as to work closely with the existing experiments and construction practices, with all actors including masons, contractors, and house owners. The construction industry, building material production, and the market forces are all factors that form pressure on the code and influence it.

Encouraging Industry

“Building codes alone do not control the building industry, nor do they determine what is designed or built. The greatest influence on the building code is the building industry itself. Industry proposes the majority of code changes, pays for research and testing to back its claims, spends the most time and money supporting those code changes through the process of development, adoption and enforcement” (Elizabeth,2005)

It is recommended to encourage small and medium scale production of the building material, empowering local contractors and adding policies and regulations to encourage the industry in this field.

There is a need for cooperation between the Ministry of Housing and the Ministry of Industry in this field. This can be done through a hub organization, which could be an NGO like the DVL in Germany or Craterre in France, or be

an inter-ministerial body that adopts the transformation of the new and innovative materials from the phase of research and development to the one of industrialization.

Involving Real-Estate Developers

Large contractors or real estate developers are potential supporters for investing in the establishment of production units introducing and spreading the technology of modern earth-construction techniques, especially those who show a desire for a green-oriented construction, or who made an attempt at low cost housing developments like Haram City, for example, which was one of the low-cost housing projects that started in 2007 with the support of the Ministry of Housing and was constructed by Orascom. In this project, they tried to lower construction cost by using some alternative building techniques like domes and vaults and bearing walls, however, there was no innovation in using any alternative materials other than the conventional existing materials in the market. This was due to the lack of knowledge about these alternative materials, and the lack of interest from real estate developers in searching for new materials because of the time and effort required.



Figure 50: Residential buildings with vaulted roofs in Haram City.

Despite the potential of making the real estate developers support the utilization of alternative construction materials and techniques, there is a risk of monopolizing the technology and raising the price of the end product taking advantage of the large scale of a company like Orascom.

Small scale contractors are very important actors in the construction sector. However, Contractors, whether large or small, would not risk using a new material or technique unless it was previously experimented and its success proven. Empowering small scale contractors in different areas in Egypt and especially in remote areas, with knowledge and skills of building with sustainable materials, is very important in promoting the idea; however, it must be controlled by a scientific base and quality control, and has to be permitted by the legal authorities.

Summary of Recommendations for Improving the Competitiveness of Modern Earth-Construction in Egypt

- Improving the social perception about earth as a building material through demonstration buildings
- Encouraging cooperative and self-help projects
- Offering educational and training programs through universities and vocational training centers
- Documentation of innovations and creating a local knowledge base
- Creating a role model through a national housing project
- Offering incentives for owners and contractors to use the material, while providing a good infrastructure for the material production
- Improving planning policies and regulations regarding land divisions and building heights

Discussion and recommendations

- Developing codes and specifications for earth-construction
- Encourage small and medium scale production, by empowering local contractors and interested entrepreneurs
- Creating a hub-institute that would be responsible of the coordination and integration between all entities, this can be in the form of an NGO
- Spreading decentralized research centers and application centers in remote areas for soil identification and experimentation of the material

Limitations of the Current Study

The limited number of experts in the field of earth construction in Egypt, as well as the limited sources of information about the existing projects that were built using CEB or Rammed earth, are due to the lack of any published documentation about them.

Target Audience

The target audience of this research are expected to be architects, consultants, research institutes, policy makers, and relevant governmental authorities such as the Ministries of Housing and Industry. Other audiences could be entrepreneurs, business developers, or contractors interested in green construction.

Recommendation for Future Research and Lessons to Learn

Further research is needed on the thermal performance and life-cycle assessment of CEB and Rammed earth in the context of Egypt.

Also research on the social acceptance of the material is needed in order to examine people's perspectives and attitudes towards the reintroduction of earth as a modern building material with different techniques.

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Annexes

Annexes

Annex I: List of Interviewees and Site Visits

| Name | Profession | Entity | Date |
|----------------------------|---------------------------|---------------|-------------|
| Adel Fahmy | Architect | Self employed | 17-04-2013 |
| Ramsis Noshay | Architect | MADA | 16-04-2013 |
| Mohamed Serag | Civil engineer | Cairo Uni | 21-04-2013 |
| Hany Al-Miniawy | Architect | ADAPT | 28-04-2013 |
| Emad Farid + Ramez Azmy | Architects | EQI | 18-04-2013 |
| Nashwa Ibrahim | Architect | EECA | 29-03-2013 |
| Ramy El-dahan | Architect | RD&SF | 02-06-2013 |
| Hanaa Ghorab | Material scientist | G&W | 20-05-2013 |
| M. El-Rafey | Architect | ADEEM | 20-05-2013 |
| Wael Sabry | Architect/Board member | EECA | 04-06-2013 |
| Hend Farouh | Senior researcher | HBRC | 08-06-2013 |
| Mohamed Ramadan | Master Builder | Self employed | 31-05-2013 |

| Site Visits |
|---|
| Traditional Brick factory. Interview with the owner Mr. Abdelkareem |
| Fayoum Brick Factory. Interview with the production Engineer |
| The Department of Quarrying in Giza Governorate. Interview with the department manager |
| Field visit to Tunis village in Fayoum for the houses built by architect Adel Fahmy, as well as interviewing local inhabitants in the village |
| Field visit to a newly constructed mud brick house in Wadi El-Natroun and interviewing the owner Mr. Mohamed Ragab |

Annex II: Interview Guide Sheet

Purpose of the interview (explained to the interviewee at the beginning): I am currently a student in the Msc. IUSD program in Stuttgart University and Ain Shams University. I am conducting several interviews with experts and practitioners in the field of sustainable building and earth construction, as part of my research work for the preparation of the final thesis titled “ Alternative building materials and components for affordable housing in Egypt, Towards improved competitiveness of modern earth construction.” Any information given will be used only for the purpose of the research. The purpose of the interview is to identify the obstacles and challenges facing the widespread use of sustainable building materials in the Egyptian construction sector. I am very grateful for your kind assistance in answering my questions.

| Broad Topic | Examples of Specific questions |
|--|--|
| Raw material geological mapping Raw material identification and testing Raw material extraction and transportation | How do you manage to find information about the existing raw materials suitable in the site? Do you have to do your own research for the best locations to find the raw material needed to produce the required building material (stabilized earth)? Do you depend on the official large quarries to bring your raw material? Do you have to perform your own testing for samples of the soil? What kind of tests? Do you depend on observation and experience? Who is responsible for extracting and transporting the raw materials to the production site? How long is the distance usually needed for the raw material to reach the site (depending on the interviewee’s specific case study or experience) Have you ever studied the ecological impacts of using these specific raw materials? Do you search for alternatives in case of discovered negative ecological impacts? |
| Manufacturing of the building component | Do you manufacture building components? Please specify. Is it an on-site manufacturing or an industrial based mass |

| | |
|--|---|
| On site/off site | production? What kind of equipments and labour skills do you need? (Is it labour intensive or capital intensive?) Simply describe the process of manufacturing. |
| Reach out to the construction site via specification of the designer or consultant/real estate or contractor | Do you recommend/specify alternative building materials/components in your design specifications? (for architects and consultants) Do you try to convince your clients to use alternative building materials (Earth, stone ... etc.) instead of RC and fired bricks? How likely do you succeed in convincing them? What are the obstacles you face? Do you perform structural calculations for the building materials used in your design? Do you consult a structural engineer? Have you implemented a building with Stabilized Earth or other alternative techniques (as a contractor)? Do you as a designer/consultant/contractor gain more/less or same amount of money when working with alternative building materials. |
| Demonstration buildings Lectures/publications Trained personnel | Are you interested in marketing or promoting the alternative construction system (ex. Stabilized Earth)? What is the means of promotion that you used during your work? (Demonstration buildings – lectures – publications – trained personnel ... etc) How do you evaluate the effect of these promotion efforts on the widespread use of the building material/technique afterwards? |
| Technical support during construction Architectural and structural details | Do you make on-site modifications or construction details tailored for the special needs of the project? Do you design solutions for technical installations specified for the Earth construction techniques? Do you give recommendations for improving the material composition and method of manufacturing as per the implementation experience? |

| | |
|--|---|
| <p>Building codes, material specifications, regulations, building license requirements</p> <p>Policies encouraging/affecting the promotion of alternative construction</p> | <p>Building codes and regulations:</p> <p>Does your work involve designing building codes or material specifications? (for code authors and specialists)</p> <p>Do you use the Egyptian building code during your work?</p> <p>Which sections of the code?</p> <p>Do you face any obstacles during the process of design or construction of buildings due to insufficient code items or shortcomings in the code?</p> <p>Do you find it easy to get consent for your buildings? What are the reasons of difficulty if any?</p> <hr/> <p>What are the policies encouraging/affecting the promotion of alternative construction?</p> <p>What are the suggestions for promoting alternative building materials such as stabilized earth?</p> |
| <p>Training of labor force</p> <p>Education of architects and specialists</p> | <p>Do you face any trouble in finding skilled labor for the type of construction you wish to use? What are the problems specifically (high cost – lack of skills – lack of interest ... etc.)</p> <p>Do you train workers during your construction process? If yes, do you prefer to train those with previous experience in construction (skilled labor) or totally unskilled labor?</p> <p>Do you teach students and young professionals during your work? In which phases (design, construction ...etc.)</p> |
| <p>Material research and development</p> <p>Structural and physical laboratory testing</p> | <p>Are you mainly concerned with the research and development of the building materials?</p> <p>Do you need to perform any tests for the materials properties (physical – structural)? Do you perform the tests on site or in the laboratory? What entities do you cooperate with in order to perform these tests?</p> |
| <p>Equipments, machines, capital investment</p> | <p>In order to produce your building component, do you need to buy or manufacture your own equipments or machines?</p> <p>What entities do you cooperate with in order to do that?</p> <p>How can you describe the kind of equipments or machines</p> |

| | |
|--|--|
| | you use for producing the required building components (high labour demanding – high capital demanding) and whether it is chosen for its best suitability or for availability and affordability? |
|--|--|

General questions:

What are the other entities that have been involved as partners or contributors during the different phases of your projects?

What other entities would make a contribution to the widespread use of sustainable materials in the construction sector if it became involved in the process? And what is their expected contribution?

What are the obstacles and challenges facing the widespread use of earth construction?

What are the existing opportunities that help the process of building with earth or other alternative materials?

In your opinion, what are the most important strategies for promoting sustainable construction materials and the earth construction techniques to the common stream market in Egypt?

In your opinion, who is the most important actor/player, to lead the approach for promoting sustainable construction materials in Egypt?

Annex III: Questionnaire sent out to the office of Martin Rauch

What **obstacles or problems** do you face while working in projects in **developing countries**?

A certain different sense and perception of time, work ethic, along with workers know-how and autonomy can be factors sometimes considered as obstacles during the planning and construction process in an emerging or developing country.

How do the following factors **positively affect the widespread** of the practice of earth construction in the countries where you mainly work **(Switzerland, Austria and Germany)**?

| | High | Medium | Low | No effect |
|---|------|--------|-----|-----------|
| Presence of a building code for earth construction. | | | | ✓ |
| Education and training. | | ✓ | | |
| Interest of clients (awareness about sustainability). | ✓ | | | |
| The presence of active research institutes. | | | ✓ | |
| Interest of the governments (by offering incentives) | | | | ✓ |
| Knowledge sharing and dissemination between practitioners | | ✓ | | |
| The role of NGOs. | | | | ✓ |
| Market forces (supply and demand). | | | ✓ | |
| Access to equipments and tools (like shuttering and rammers) to normal people and to contractors. | | ✓ | | |

| | | | | |
|--|---|---|---|--|
| Existence of private firms working in material production and construction of earth buildings. | ✓ | | | |
| The industrialization of the material production | | | ✓ | |
| Cooperation between all the different entities. | | ✓ | | |
| Other factors: | | | | |

Does your firm work in **cooperation with other entities** (like research institutes, soil analysts, contractors, NGOs, raw material suppliers)?

We cooperate with an Austrian laboratory for soil analysis, with kiln builders in Austria and Switzerland (www.lehmo.at), with ceramic producers (www.karak.at) with Universities (ETH Zürich, Kunstuniversität Linz) and with architectural offices (Boltshauser Architekten and Arch. Anna Heringer)

Which activities do you perform inside your firm ✓ and which activities do you need to delegate to other entities *?

- Raw material identification ✓
- Mix design ✓
- Structural and physical testing for the material *
- Training activities (for labour and engineers) ✓
- Knowledge dissemination and Marketing ✓
- Design and manufacturing of tools and equipment ✓
- Construction on site ✓

Do you make **different/unique mix designs for each project** or you have your own **pre-developed mix designs** that you use for your walls (like the prefabricated walls)? Do you prefer to add **stabilizers** to the mix or not?

Every mixture is unique for every project, because we always try to use local material, which is different from one to another. That means that the receipt will change according to the type of soil we have on site.

We never add stabilizers to our mixtures, not only because there's no structural need for them, but also because even small percentages of concrete in the mixture make it lose its natural qualities (humidity regulator, completely recyclable material!!)

Is the **cost** for constructing a rammed earth wall generally considered **high/moderate or low**, compared to other conventional construction systems like concrete or wooden structures? And are the prefabricated walls cheaper than the construction and ramming of walls on site or not?

The cost is generally high compared with conventional materials and techniques, mainly due to high labour costs in Europe. In this context industrialization and prefabrication may positively influence this economical factor (decrease of ca. 30%). This is however not really going to be the case for our current project in Basel

(<http://www.lehmtonerde.at/en/projects/project.php?pID=87>) as we'll need to cover the costs of design and development of machinery and equipment.

Thank you very much for taking the time to answer my questions.

You are more than welcome.

—
Laura Marcheggiano

Architektin

On behalf of Mag. Art. Martin Rauch

Lehm Ton Erde Baukunst GmbH

إقرار

هذه الرسالة مقدمة في جامعة عين شمس وجامعة شتوتجارت للحصول على درجة العمران المتكامل والتصميم المستدام. إن العمل الذي تحويه هذه الرسالة قد تم إنجازه بمعرفة الباحث سنة 2013.

هذا ويقر الباحث أن العمل المقدم هو خلاصة بحثه الشخصي وأنه قد اتبع الأسلوب العلمي السليم في الإشارة إلى المواد المأخوذة من المراجع العلمية كل في مكانه في مختلف أجزاء الرسالة.

وهذا إقرار مني بذلك،،،

التوقيع:

الباحث: منى فاروق القباني

التاريخ: 07 / 31 / 2013

مكونات ومواد البناء البديلة لإسكان فى متناول اليد فى مصر

نحو تنافسية أفضل للتقنيات الحديثة للبناء بالترربة المثبتة

مقدمة للحصول على درجة الماجستير فى العمران المتكامل والتصميم المستدام

إعداد: منى فاروق القبانى

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تاريخ المناقشة:

الدراسات العليا

أجيزت الرسالة بتاريخ:

موافقة مجلس الجامعة .../.../...

ختم الإجازة
موافقة مجلس الكلية .../.../...

جامعة عين شمس



جامعة شتوتجارت



07/31/2013

من التوصيات التي يطرحها البحث بناء على النتائج والتحليلات: ضرورة العمل على تحسين الصورة السلبية النمطية للبناء بالتربة، مراعاة اختيار تقنيات وطرق البناء المتوافقة مع البيئة المحلية، نشر وتبادل المعلومات، التسويق والترويج للفكرة، عمل نماذج باستخدام هذه المواد في أماكن يسهل الوصول إليها كالأماكن العامة، تقديم محفزات، تطوير سياسات التخطيط وقوانين البناء، تشجيع التصنيع وتمكين المقاولين المحليين للعمل على تطبيق الفكرة.

ملخص البحث

تعتبر مواد البناء عنصراً أساسياً ومؤثراً في عملية التصميم والإنشاء من حيث سعر وجودة الناتج البنائي. وبالرغم من أن قطاع الإنشاء في مصر من أهم القطاعات الحيوية التي لها إسهاماً كبيراً في الإقتصاد القومي، إلا أن هناك نقصاً ملحوظاً في وفرة المسكن الملائم إقتصادياً وبيئياً للكثير من المواطنين. وبناء على ذلك، فإن الإهتمام بنشر مواد البناء المستدامة يعتبر إسهاماً في تحسين الحالة البنائية بشكل عام.

يهدف هذا البحث الى دراسة إمكانية استخدام التقنيات الحديثة للبناء بالتربة المثبتة كمادة متوافقة مع البيئة في قطاع الإنشاء، وإمكانية التشجيع على استخدامها - في البيئات الملائمة لذلك - لتوفير مساكن مستدامة وفي متناول اليد.

لعبت تقنية البناء بالتربة دوراً أساسياً ومحورياً في تاريخ حركة البناء المحلية طوال العقود الأخيرة. فضلاً عن دورها الأساسي في تاريخ البناء العفوي غير الرسمي منذ بدء الخليقة وحتى اليوم. ومنذ تجربة المعماري حسن فتحى الشهيرة في القرنة بالأقصر قرب منتصف القرن الماضي، فإن هذه التقنيات أصبحت مجالاً أساسياً للعديد من الدراسات والبحوث. أما عن التقنيات الحديثة للبناء بالتربة المثبتة ومنها البناء بطوب التربة المكبوسة *compressed earth blocks* وحوائط التربة المدموكة *rammed earth*، فرغم انتشارها في العديد من دول العالم المتقدم والنامي، إلا أنها في مصر لم يتم استخدامها في البناء إلا على نطاق محدود جداً.

من خلال هذه الدراسة يتم التعرف على العوامل التي تحد من استخدام التربة المثبتة بتقنياتها الحديثة في قطاع الإنشاء بمصر وذلك من خلال مجموعة من اللقاءات الحوارية مع خبراء وممارسين في هذا المجال، بالإضافة الى دراسة عدد من التجارب المنفذة والتي تم فيها استخدام طوب التربة المكبوسة وحوائط التربة المدموكة. يتم دراسة هذه العوامل من خلال تحليل سلسلة القيمة، وهو أسلوب تحليلي يستخدم في مجال إدارة الأعمال يتم عن طريقه دراسة الأنشطة التي تتم في دورة حياة أى منتج، واستنباط العوائق التي تحول دون انتشاره والإمكانيات التي يمكن استغلالها لزيادة قدرته التنافسية.