THE POTENTIALS OF EARTH AS A SUSTAINABLE BUILDING MATERIAL

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ABSTRACT

The recent rise in energy cost spent in modern buildings accentuates the need to harness energy saving strategies of buildings, thus, the need to go back to traditional building materials-Earth. Sustaining local development means also preserving a cultural heritage of construction knowledge natural to regions. Research methodology used in this paper was descriptive analysis. This paper looked at different aspects of earth materials construction. In order to underscore the importance of earth materials, review was made identifying some of the environmental benefits associated with it. It includes earth as a renewable resource, low waste generation, low energy consumption, carbon dioxide emissions and indoor air quality. The most relevant environmental advantages related to earth materials are: no need of transportation; less energy intensive production process, lower embodied energy and CO2 emissions and low environmental impact. Therefore, the use of earth materials as it happens with earth construction should be prioritized.

Keywords: Construction, Earth, Energy, Material, Sustainable

INTRODUCTION

Earth is one of the most ancient building materials known to man; also seen as an ecological material with a low environmental impact. As a building material, earth is commonly available in the construction site and does not require high energy consumption for processing (Hall, Lindsay & Krayenhoff, 2012). There is no consensus about the date when man began to use earth in construction, but in Mesopotamia (present-day Iraq), in the Indus

valley (India), along the banks of the Huanghe (China) and the Nile (Egypt); the main cradles of civilization earthen architecture was prevalent. Earth as a building material when applied in construction is capable of being used without any coating, to maximize its aesthetic potentials and hydrothermal properties. Although building with earth was a common type of construction until the late 19th century, the advent of the industrial revolution, the development of new materials and construction systems made it grew out of fashion. By the 20th century, new earth constructions almost ceased in developed societies, whilst the majority of new earth buildings were confined to poor settings in developing regions (Nazaré-Falcão, 2014).

The construction industry is one of the most active sectors in the world as it keeps on growing at a fast pace (Pacheco-Torgal & Jalali, 2012). This industry is clearly an unsustainable industry because it accounts for 30% of carbon dioxide emissions into the environment and consumes more raw materials than any other production activity (Gartner & MacPhee, 2011). Dobbs (2010) noted that the projected rise in world's population by year 2030 with the expected increase in needs in terms of buildings and other infrastructure, there would be further increase in the consumption of non-renewable materials, as well as waste production. Therefore, the use of more sustainable construction materials (Earth) represent a major contribution to the eco-efficiency of the construction industry and thus to a more sustainable development.

Houben and Guillard (1994) opined that about 50% of the population in developing countries (including the majority of the rural population and urban population) live in earthen structures. This figure though worldwide, does not represent the situation in Nigeria where even the poorest man dreams of upgrading from an earthen house to a concrete house. Skilled technicians (engineers and architects) are generally not involved in earth construction; hence the term, "non-engineered construction," is used to describe the result. Schroeder (2012) stated that, in order for earth to be accepted as a current alternative in the construction industry, its various materials and construction systems have to be technically recognized. To achieve this, they

have to be able to respond to set parameters and precise criteria which require the use of laboratory testing.

Sustainable building materials have to consider the different aspects of sustainability which are: the environment, economy, social and cultural systems. The following aspects should be considered as part the goals of any sustainable building materials: conservation of the cultural character; reduction of energy consumption; protection and conservation of water resources; use of environmentally friendly materials and products; provision of a healthy and convenient indoor climate; and optimisation of operational and maintenance practices (Mateus, Bragan & Koukkari 2008). Going by the crisis in the environment occasioned by different construction systems, return to use of sustainable materials have been on the front burner. There has been increasing number of research works on earth, to help it regain impetus in the construction industry as an alternative to contemporary building material. This paper seeks to address some important aspect related to earth material and construction which would include: economic advantages, renewable resources, waste generation, energy consumption, carbon dioxide emissions and indoor air quality. Descriptive analysis is adopted as methodology for the purpose of this paper.

Earth as a Sustainable Building Material

Materials are essential for construction but those materials whose production is high energy intensive cause significant environmental impacts. Earth is the most basic building material known to man that has the advantage of being easily worked, using the simplest of tools (Walker & McGregor, 1996). Easton and Easton (2012) noted that there is still little universal information regarding the behaviour of earth as a building material. According to the Advanced Learner's English Dictionary, Earth was simply defined as Soil. Soil in the same dictionary was defined as: ground, earth, especially the upper layer of earth in which plants, trees etc grow. Then, Earth was defined as: Soil, the loose material that covers the land surfaces of the Earth and supports growth of plants. From the foregoing, it is clear that the terms - earth and soil can be used interchangeably. Soil therefore is a layer of loose material, varying in thickness over the Earth's

crust, formed from bed-rock after a very long process of weathering and the complex migration of particles.
Earth construction has increased significantly in developed countries such as: USA, Brazil France and Australia mostly due to the sustainable construction agenda in the countries, in which the earth construction assumes a key role. In France, the CRATerre French laboratory (founded in 1979) recorded success in educational project undertaken there which consisted of a scientific workshop with over 150 interactive experiences within 4 years and had 11,000 visitors attended (Houben, Doat, Fontaine, Anger, Aedo & Olagnon, 2008). In Germany, Schroeder, Rohlen, and Jorchel (2008) reported that there was existence of vocational training on earth construction as well as courses earth materials. In Nigeria, Abdulkarim (2005) opined that one of the key aspects of the Nigeria's National Housing Policy is to 'Promote the use of locally produced building materials as a means of reducing housing construction costs. Earth construction is not only dependent on adequate training but also on specific regulations.

Earth's weak mechanical characteristics, low tensile resistance and susceptibility to water make its application difficult. This implies that extensive precautions should be observed to protect the material from these shortcomings (Augarde, 2012). The reduction in earth construction, due to its traditionally intensive labour requirements and that it refers to a poor construction technique hinder its institution as a common building material. The industrial revolution led to increased use of new industrially-produced and standardized materials in different construction approaches. This made the dependent on available local materials to dwindle; the use of these materials became predominant and traditional techniques and materials were neglected. Modern architecture, based on the use of industrially-produced materials with a low thermal resistance, has made buildings extremely vulnerable to outdoor temperature fluctuations. This has led to high level of dependence on air-conditioning systems to ensure conditions of indoor comfort which represents a substantial energy consumption (Montaner 2001 as cited in Fernandes, Mateus, & Bragan, 2009). Furthermore, industrially-produced materials require a high energy-intensity and have considerable

environmental impacts, while natural materials have positive impacts in the overall life-cycle assessment. Using natural materials (earth for the purpose of this paper) and techniques, the total embodied energy of a building can be significantly reduced, as well as environmental impacts. Shittu (2008) noted the constraints of earth construction as follows: lack of trained craftsmanship; earth construction is labor intensive, dearth of earth related courses in schools and that earth construction are associated with low income status.

The limitations of earth as a building material do not automatically mean limits to architectural appearance, complexity and its modernity. They are more dependent on the quality of the projects than the characteristics of the material. The soil used in earth construction consists of mineral particles including clays, silts and sandy material, which are mixed together in varying proportions. The soil stabilization could be described as changing the soil characteristics to improve its mechanical or physical characteristics. The stabilization processes aim at the reduction of the soil plasticity, improvement its workability and also the resistance to corrosion (Pacheco-Torgal & Jalali, 2012). It can, however, be inferred that earth's limitations as a material can promote the development of alternative constructive solutions which, if well used, add value to projects (Nazaré-Falcão, 2014). Thus, this article focuses specifically on the importance of using earth materials as well as local construction techniques for sustainable development.

Properties of Earth as a Building Material

Diverse kinds of earth materials possess different characteristics that may or may not be fit for construction. Little and Morton (2001) noted the following properties of earth materials that are relevant to its success as a building material may include:

1. Humidity regulator- Earth materials are able to take in humidity and thereby balance indoor climate. For example, when bathrooms built with earth materials, the humidity is absorbed by the walls. This is released back into the atmosphere bit by bit, thus inhibiting fungal growth.
2. Thermal properties- Walls made of mud and rammed earth have high thermal mass and are able to store heat and

release it slowly to balance indoor climate. Earth blocks are resistant to heat flow and provide good insulation. The thickness and weight of the earth materials can be changed to achieve different thermal effects.

3. Fire resistance- Earth building materials have good fire resistance properties unless they contain significant amounts of fibre.
4. Strength- Earth is good in compression, but weak in tension. The compressive strength of earth can be increased by compaction, which raises the density of the material.
5. Durability- The long-lasting qualities of earth as a building material are evident in the traditional buildings that have survived over long period of use.
6. As a preservative- Timber can be conserved in a dry state within walls built with earth, due to earth's low balance moisture content and high capillarity. Evidence of this, is apparent in old buildings that contain timber within earth walls.

Techniques of Earth Construction

Earth construction includes several techniques such as:

a. Adobe/ Earth Brick: The word adobe also means sun-dried brick. Adobe is a natural building material made from sand, clay, and water, with some kind of fibrous or organic material (sticks, straw, dung), which is shaped into bricks using frames and dried in the sun. The production of adobe bricks consists of filling wooden moulds with moist earth which are then placed in the sun to dry. Usually adobe is shaped into bricks that can be stacked to form walls.

b. Wattle and Daub: In the wattle and daub technique, the earth is pressed against a woven lattice of wooden strips. It also consists of wattle work of vertical wooden posts driven into the ground with horizontal strips of sticks tied together with rope and covered with mud or clay.

c. Rammed Earth or Pise-de-terre: this consists of moist, loose sub-soil compacted between shuttering in layers and this also resembles modern poured-concrete technology. Wooden frames are filled with wet earth, which is compressed with hammers.

Walls built in this system are hard and durable and they can carry significant loads. Rammed earth walls have greater structural capability and are subject to less shrinkage. Rammed earth is also suitable for floor construction.

d. Compressed Earth Block (CEB): This earth block is produced in a manually operated press, which applies pressure on the earth in the mould producing blocks in standard sizes. The blocks can be stacked immediately which reduces the need for large drying and storage spaces. Use of the CEB is suited to skills that are already present in the construction industry.

e. Stabilised Compressed Earth Blocks (SCEB): This is a further improvement on the CEB. Stabilisation in this context means the modification of the properties of soil by adding another material to improve its durability. Examples of such materials may include: cement, lime, bitumen, gypsum, animal dung, anthill materials, bird droppings and plant extracts. The technology has been used for decades in road construction. The achievements of stabilization are: increased strength and cohesion, reduced permeability, water repellent, increased durability and reduction in expansion and shrinking in wet conditions.

f. Interlocking Stabilised Earth Blocks: there are two problems with the SCEB– need for masonry skills to lay the blocks and the quantity of cement used for mortar. The Human Settlements Division of the Asian Institute of Technology modified the CINVA-RAM machine used for compression to create the Interlocking Earth Blocks. This interlocking system eliminated mortar and skilled labour thereby considerably reduced the cost of construction and enhanced the structural stability of the wall (UN-HABITAT 2009).

Benefits of Earth as a Building Material

The following are the benefits of earth material which also make it sustainable:

1. Accessibility and inexpensive – suitable earth for building is found almost everywhere. Thus, is easily available everywhere. Also, since earth is readily accessible, it is cheap to acquire.

2. Sustainability – Earth offers a sustainability advantage because it is a renewable resource. This is a good model of fitting sustainable construction technology, as the practices help protect the natural environment, make use of local resources and add to local economic empowerment.
3. Energy Efficiency – The increasing demand for energy in the world is a major cause for the unsustainable development of our Planet. Given that buildings consume throughout its life cycle, more than 40% of all energy produced, there is high energy saving potential in earthen buildings. This would contribute to reducing carbon dioxide emissions in the environment. A building well built with earthen system possesses a high thermal mass enabling the house to stay cool in hot weather and warm in cool weather. Also, passive energy is used in achieving thermal comfort level in such a building.
4. Environmental affability – Earth is biodegradable and non toxic matter to the environment. The raw material is dug out from the earth and is returned to the earth after a usage in a low impact way.
5. Fire Resistance – The fire rating of the earthen wall is high, performing better than the popular steel and concrete.
6. Environmental Waste Reduction – with regard to earth construction wastes, the wastes can simply be dumped at the site of its extraction without any environmental hazard involved. Even when the soil is stabilized with cement, it can be reused in this type of construction, so earth construction hardly generates any waste. When compared to the traditional ceramic brick masonry which generates a relevant amount of wastes because the use of broken pieces takes place quite often in this kind of masonry.
7. Durability – An earthen building when well built is extremely durable. Some national monuments in Nigeria were built with earth. Examples of the monuments include: Main Post Office, Enugu – built in 1920, First Magistrate Court, Kaduna – built in 1920, and Native Authority Treasury, Borno – built in 1926.

The following images report represent traditional buildings constructed with earth materials locally available in Nigeria such as: mud and stone. These traditional buildings adhere to the principles of energy consumption reduction and utilization of materials within the environment to create good thermal comfort conditions.

Plate 1: A building in a Traditional Ruler's palace in which walls were constructed with locally available stone.

PLATE 2: This building was a residential quarter for a German missionary who died in 1924, constructed with a combination of locally available stone and mud

PLATE 3: A fence constructed with Interlocking Stabilized Earth Blocks

Conclusion

The apt choice of building materials can add positively to reduce the energy consumption of the building sector. Earth mining normally involves the removal of the top layer of the soil; this is an

operation that can be done manually without energy emission. The local production of materials is economically cheaper and creates jobs for unemployed people in the locality. Furthermore, the need for skilled workmanship in earth construction systems leads to more training on the subject. Also contributing to preserve and continue a local heritage and cultural legacy.

The following measures may be useful: (a) Implementation of earth as an alternative building material - Recognition of earth as an alternative building material has been included in the National Building Code, where it recognizes Sun dried soil bricks/blocks. But the implementation has not commenced in full force. The allied professions in the building industry should also adopt earth in designs. (b) Standardisation: The Standards Organisation of Nigeria (S.O.N) needs to set standard for earth materials. This would help in its acceptability to the people. There is also need for development control, to enforce the standards and regulations to improve the appearance and environment of earth buildings. (c) Setting the Example: Government needs to set the example by using earth as cheap technology in some of its projects to illustrate to the public that it is acceptable.

Earth construction is also guarantees an indoor air relative humidity beneficial to human health; therefore, earth construction has advantages in the field of sustainability over conventional construction.

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