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A Review of Compressed Stabilized Earth Brick as a Sustainable Building Material in Nigeria

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ABSTRACT

Compressed stabilized earth brick (CSEB) was reviewed for its sustainability using online data-base. The study revealed among other things that CSEB has less embodied energy compared to most other walling materials. This implies a reduction in the emission of greenhouse gases (GHGs) like carbon (IV) oxide, carbon (II)oxide, Sulphur (IV) oxide among others. It has good fire resistant property, its environmental responsiveness regarding thermal comfort due to its thermal mass is also another quality that enhances its sustainability. Besides, CSEB can be locally made, and it is socially acceptable. The paper suggested that, although CSEB is a sustainable building material, caution must be taken against inappropriate stabilization. Also, for optimum performance, there should be a good maintenance culture, and it should be used in appropriates places during construction bearing in mind its low tensile strength. These constitute the panacea to the challenges of CSEB.

Keywords: Compressed, Stabilized Earth Brick, Sustainability, Building Material, Embodied Energy, Nigeria

I. INTRODUCTION

Man depends on nature for his necessities of life [1,2]. These include food, clothing, and shelter. Among these, shelter has more impact on the environment owing to its demand on natural resources [3]. For instance, wood or timber, cement, thatch, zinc, marble, granite, stone, sand among others are building material from nature. Although man is expected to depend on nature for his survival, the resources of nature ought to be tapped responsibly [4-9]. The rate at which these natural resources are tapped especially for the production of shelter or houses is far more than the rate at which they are replenished. Moreover, while some of these materials like trees thatch take biological years, others like steel, iron, granite among other take geological years for their replenishment [10]. Unfortunately, in many countries including Nigeria, even replenishment of trees through afforestation is not vigorously pursed which has led to desert encroachment. This is an eloquent testimony of the irresponsible attitude of man to the environment which has brought about disequilibrium in nature and the attendant consequences.

Building is made of several components such wall, doors, windows, roof among others. Out of these, wall constitutes the larger percentage of building components. Incidentally, the main walling material in Nigerian is sandcrete block. [11] submitted that 90% of physical infrastructure in Nigeria is made of sandcrete block. The sandcrete block is largely made of cement. The production of cement involves, extraction of the calcium carbonate and several industrial processes are involved in its manufacture. There is also a high level of transportation in the course of moving raw and finished products. The implication of this is high embodied energy which is the energy required for the extraction raw material, processing, its transportation and placement during construction [12]. Fossil fuel is the main source of energy in many countries of the world including Nigeria. Burning of fossil fuel for energy production results in the release of greenhouse gases (GHGs) like carbon (IV) oxide (CO2), carbon monoxide

(CO), sulphur (IV) oxide (SO_2) among others. This causes depletion in the ozone layer in the atmosphere, a phenomenon that results in global warming and climate change [3]. It is the quest to reverse or mitigate this anomaly that led to the evolution of the concept of sustainable development in which sustainable material is a subset.

Sustainable development is about meeting the needs of the present generation without compromising the ability of the future generations to meet their own needs [13]. The concept of sustainable building or housing material is, therefore, the use of building materials that will not have a much adverse impact on the environment, a kind of building material that meets the need of the present generation and without compromising the ability of the future generation to meet their own needs. The United Nation's Conference on Environment and Development- Earth Summit held in Rio de Janeiro in 1992 [3], created an International framework for the sustainable development of the human settlement. Environmental issues became essential guidelines for the realization of sustainable shelter globally. Before the Rio de Janeiro international awareness, the techniques of handling the relationship between ecology and the built environment had already become a subject of interest among governments and professionals. Architects, Planners, Environmentalists, and Engineers were informed on issues such as energy consumption, use of environmentally friendly materials and design approaches that reduce environmental impact. Besides, HABITAT II, the United Nations Conference on Human Settlement held in Istanbul in 1996 addressed the issue of 'sustainable human settlements that ensure productive life in harmony with nature, environmental protection, the protection of the world's natural resources, through limiting human impact on the natural environment among others [14]. For instance, in many parts of the world, including developed nations, as opined by [15] building with earth is an effort is a right direction in achieving sustainable building. However, earth brick as a walling or building material has a limitation regarding durability, size of spaces that can be created among others. There is need to improve the performance of earth as a building material in the form of stabilization.

II. STATEMENT OF THE PROBLEM

Buildings are responsible for 40% of the world energy consumption [16-24]. A Greater percentage of this energy is derived from fossil fuel. For instance, [25] gave 80%, 13.5% and 6.5% of fossil fuel, renewable energy, and nuclear energy consumption respectively globally. This situation is not different in Nigeria. Fossil fuel burning for energy production emits carbon IV oxide (CO_2), sulphur (IV) oxide, carbon monoxide (CO) and other GHSs [18]. The emission of greenhouse gasses into the atmosphere causes a reduction in the ozone layer in the atmosphere. This situation results in the penetration of ultra violet radiation to the earth surface which causes global warming and climate change. The emission of (680.39g) of carbon dioxide, (5.67g) of sulphur dioxide and (2.27) of nitrogen oxide will be prevented from each saving of a kWh of energy [26]. One of the strategies for the reduction of this ugly trend is the deployment of building materials that have low energy demand for its production and utilization. This strategy gave birth to the evolution of the concept of sustainability. This paper, therefore, sets out to review the sustainability of compressed stabilized earth brick as a building material in Nigeria.

III. METHODS AND MATERIAL

This paper aims at reviewing CSEB to determine its sustainability using online data-base. To achieve this aim, the specific objectives are to; examine the effects of stabilization of brick as a sustainable building material, evaluate the sustainability potentials of CSEB, and also evaluate the merits and challenges of CSEB with a view to providing the appropriate panacea.

IV. RESULTS AND DISCUSSION

The results and discussion are based on the stabilization of earth bricks, the sustainability potentials of CSEB, merits, and challenges of CSEB in building construction.

A. Stabilisation of Earth Bricks

Soil stabilization according to [27] is the alteration of any property of soil for improved performance when incorporated into a building material. The main factors affecting stabilization are cement, compaction, soil type, and method of mixing with soil type being the most important [27]. The modification of the properties of the soil-water-air system makes the soil compatible with desired applications in construction [28]. The most important function of the stabilizing material is to minimize the swelling properties of the soil by making a solid framework with the soil mass, improving its durability and strength [29]. The most popular earth stabilizer in Nigeria is the Portland cement. Cement can reduce liquid limit and increase plasticity index and thus enhances the workability of soil. The application of chemical stabilizers like lime and cement have dual effects of speeding up flocculation and promote chemical binding. The chemical binding is dependent on the type of stabilizers employed [30]. The study of [31] revealed that soils with a plasticity index less than 15% are suitable for cement stabilization. In cement stabilization, [32] observed that the content of the cement binder in the mix ranges from 4% and 10% of the soil dry weight. Similarly, [33] posited that if the content of the cement binder exceeds 10%, it becomes uneconomical for CSEB construction.

The strength of stabilized soil can further be enhanced through compaction which brings about higher densities and by implication, higher compressive strength and better resistance to erosion. Through the application of stabilization and compacting techniques, a cheap but strong and durable brick wall will be obtained.

B. The Sustainability Potentials of Compressed Stabilized Earth Brick

One of the important questions in environmental sciences is how human welfare can continuously be improved within the limits of the earth's natural resources responsibly. A possible solution to this dilemma is sustainable development, a term popularized by ‘’ Our Common Future’’, the 1987 report of the World Commission on Environment, chaired by Norwegian Prime Minister Gro Harlem Brundtland and consequently called the Brundland Commission [34]. In the words of this report, the sustainable building material is the one that does not have much negative impact on the environment. It also means the utilization of resources available to the present generation without depriving the future generation of resources for their effective living. This definition implies that sustainability advocates the satisfaction of social, environmental and economic goals of utilizing building materials putting into cognizance safety, health, an efficient and productive life that is in harmony with nature. The concept of sustainability in all its facet- ecological, economic and social is vital. This involves amelioration of weather pattern and climate, provision of clean air, protection of biological diversity, protection of soil and food crops, carbon sequestration, provision of employment opportunity (poverty alleviation) and provision of recreational facilities.

According to [35], a sustainable material should possess the following characteristics: easily available and affordable, preferably locally; meets the requirements as specified in the National Standards; in terms of durability and maintainability; should be environmental friendly and should not constitute any health hazard; and should be versatile in usage, that is, it could be used for different purposes (as walling materials, flooring, etc). It is obvious that stabilized earth bricks have these qualities.

Stabilized compressed earth bricks, apart from its warmth create a welcoming environment and also blends naturally with nature while at the same time creating an authentic appeal that most other materials do not have. Stabilized compressed earth brick degrades after its structural life span without much impact on the environment. Building construction with compressed stabilized earth bricks can, therefore, be seen as an agent of green architecture. Stabilized compressed earth brick require less energy to make, which reduces reliance on fossil fuels.

The embodied energy of materials in buildings forms a significant component of the total life cycle energy consumption. Embodied energy measures the total energy required to transform raw material into ready-to-use building products [36]. It is expressed in gigajoules per tonne (GJ/t) or megajoule per kilogram (MJ/kg). Embodied energy includes the energy required to obtain raw materials and process them, as well as the energy used in transporting the material at all stages and construction. The consumption of energy during each of the above stages can have similar environmental impacts to the consumption of energy in the operation of the building. Manufacturing of compressed stabilized earth bricks requires comparatively little energy. Low energy consumption of a building material is the main determinant of its sustainability from the environmental angle because there is over dependence on fossil fuel globally and Nigeria in particular.

The low energy consumption and carbon (IV) oxide emission which is key to the determination of the sustainability of a building material is revealed in the study carried out by [37]. This study considered some common building materials and asserted that the contribution of primary energy demand for the manufacture of the materials needed for the construction of $1m^2$ is 25.5%, 21.5%, 1.9%, 1,5%, 4.0%, 7.7%, 2%3,5%9.1%3.0%11.7% 8.8% for steel, ceramic, PVC, wood, additives, aluminium, pre-fabricated concrete, gravel, mortar, lime, cement respectively. 18%, 203%1.0%, 1.1%1.5%2.3%,2%,2.9%6.7%, 7.9%, 30.3% and 5.0% were given for the contribution of carbon (IV) oxide emissions associated with the manufacture of the above building material in the construction of $1m^2$ respectively. From this finding, it is obvious that any practice that will reduce the use of cement will undoubtedly reduce energy consumption and carbon (IV) oxide emission into the atmosphere which is in line with the concept of sustainability.

C. Merits and Challenges of Stabilized Compressed Earth Bricks.

CSEB just like any other building material has some advantages and weak points. There is an attempt to bring these to the fore in this subsection.

i. Merits of Stabilized compressed Earth Bricks:

Compressed Stabilized Earth Blocks (CSEB) offer some advantages which include excellent fire resistance, thermal mass, low embodied energy, affordability, appropriate technology and society acceptance.

a. Fire Resistance:

Stabilized compressed earth brick has a good fire resistant property [38-40]. These allow for evacuation of occupants and properties in the event of fire outbreak. This satisfies the safety aspect of sustainability and gives CSEB an edge over other common building materials such as steel, wood among others.

b. Thermal Mass:

Compressed stabilized earth brick has the high thermal capacity [41,42]. The implication of this property is that, when this material is used as a walling material especially for the external, it is capable of absorbing a reasonable quantity of solar radiation [39]. Another complimentary property to this is thermal conductivity. These two properties enable compressed stabilized earth bricks to absorb heat and delay its transmission into the interior spaces in the daytime. At night, the exterior or ambient temperature is lower than the interior temperature hence the transmission of heat absorbed in the day time to the outside environment [43,44]. This phenomenon prevents interior air temperature from reaching its peak thereby improving the interior thermal comfort of the occupant. This in effect equally reduces cooling load in the tropical climate like Nigeria and by implication the burning of fossil fuel and the GHGs.

c. Low Embodied Energy:

In addition to operational energy, embodied energy is a key determinant of the total energy consumption in the building industry. The embodied energy comprises of the energy for the extraction of raw materials, processing it, transporting it to the warehouse, the site as well as its placement during construction [12]. The earth which is the main component of compressed earth bricks does not require much energy for its excavation, processing, and transportation compared to other common building materials such as cement, steel, zinc, aluminium, glass among others [45]. The use of material with low embodied energy results in a decreased negative impact on the environment. This also has cost effectiveness dimension [38] which has to do economic aspect of sustainability.

d. Availability/Affordability:

Soil which is the main component of CSEB is available in large quantities almost in any region in Nigeria. This also makes it affordable [46]. This makes it a familiar building material that the members of the society can relate with. Further, owing to its availability in most places, the cost of importation which eventually adds up to the cost of building material and eventually the cost building is minimised if not eradicated. This position is the same with [38] in a related study.

e. Appropriate Technology:

One of the cardinal factors usually considered by architects, engineers and other professionals that are concerned with building design and construction is the availability of the technical know-how. Any design or specified building material that the society lacks its technical know-how has failed in that society. Contrastingly, stabilized compressed earth bricks can easily be used even by the local measons in the construction of the building [38]. This saves time, energy and money that would have been spent in importing the appropriate technology from somewhere else

f. Society Acceptance:

Sustainability has environmental, economic and social dimensions. The social aspect deals with the level of acceptability of compressed stabilized earth brick in the society. In contrast to mud wall which is seen by the society as a walling or building material for the poor, the CSEB has a high level of acceptance by members of the society even among people that a well to do [47]. Its utilization in the construction of residential, educational or institutional buildings is an eloquent testimony to this fact. For instance, figures 1a and 1b give examples of some residential buildings built with compressed stabilized bricks in Nigeria.

Figure 1a Kuje, Abuja Hosing Scheme

Source: htt://www.gismania.com(talk)topic305271.0htm/# . WddE5iYvik.google

Figure 1b Kubwa Abuja, Affordable Housing.

Source: htt://www.gismania.com(talk)topic305271.0htm/# . WddE5iYvik.google

ii. Challenges of Stabilized Compressed Earth Bricks

Every building material has its challenges but in different magnitudes. These challenges may be short life span, structural problem, inappropriate stabilization, inconsistency in moulding equipment, among others.

a. Durability

It is essential that compressed stabilized earth bricks be maintained at a regular interval and protected especially in areas or regions with medium to high percentage of rainfall per annum. The practice of using parapet or exposed wall, though inappropriate with most building materials is worse if not waste with stabilized compressed earth bricks. If compressed stabilized earth bricks must attain its designed economic, functional and structural life span, it must be protected and regularly maintained [39].

b. Low Tensile Strength

Compressed earth brick has poor tensile strength [49]. Also, it cannot efficiently accommodate reinforcement owing to its low percentage of cement as a binding agent. Its utilization is therefore practicable mostly where compressive strength is required such as a wall, vaults, domes among others where it will not be subjected to bending moment [39].

c. Inappropriate Stabilization

An important consideration of compressed stabilized earth brick is to minimise the use of cement but at the same time achieving brick of adequate or optimum strength for performing the desired function(s). However, due to ignorance, compressed earth bricks are usually over stabilized due to excessive addition of cement. This situation tends to diminish or defeat the essence of stabilizing earth brick. On the other hand, compressed earth brick may also be under stabilized. This usually leads to structural failure. This is consistent with the findings of [50] that the compressed stabilized earth is not well organised, technically ill prepared with very little know-how about it and few engineers and scientists have interest in this industry.

d. Un-Adapted Production Equipment

One of the drawbacks of stabilised compressed earth bricks is dimensional instability. This is traceable to non-standardization of the moulding equipment. Although the construction of houses with mud or un-stabilized earth is as old as man, CSEB which came as a product of technological advancement through research work is relatively new. Many people are either used to the mud as a walling material or sandcrete block, and these two extremes have a negative effect in the sense of dimensional appropriateness when it comes to CSEB as an alternative building material. [49] also noted that variation in the dimension of CSEB its compressive strength. However, this anomaly can be improved with the entrenchment of CSEB in the building code to encourage more of its application by developers.

[28] conducted a study on CSEB. This study revealed the following additional challenges.

- CSEB is denser than some concrete masonry blocks. The high density is usually considered as a disadvantage if it has to be transported over a long distance.
- CSEB is usually smaller than sandcrete blocks and consequently increases the laying time.

D. Panacea to the Challenges of Stabilized Compressed Earth

The challenges of CSEB can be ameliorated through its utilization at the appropriate places, exposing it to only the load it is designed to bear. Adequate stabilization and dimensional consistence should be equally ensured.

i. Appropriate Application

Due to the low quantity of stabilizer, e.g., cement, the water resistance capacity is low. Hence CSEB should be used where it will not be over exposed to too much water. When used as a walling material it should be well covered or protected by roof.

ii. Compressive Strength

CSEB is poor in tensile strength but good in compressive strength. Care must be taken to ensure it is not exposed to tensile stress for its optimum performance. It can also be used as a non-load bearing wall or cladding where it is expected to bear only its load or dead load. Hence, there is the need not to subject it to tensile stress or inappropriate load for optimum performance.

iii. Adequate Stabilization

The cardinal objective of using the CSEB is a reduction in the use of cement and the inherent environmental friendliness as well as cost reduction. However, this aim will be defeated if it is over stabilized due to the addition of an excessive stabilizer, a phenomenon that is usually a product of ignorance or incompetence. This problem can be solved if the producers are informed, better skilled, with better production and testing equipment and more diligent quality control [28].

iv. Dimensional Consistency

The problem of irregular sizes or dimensional inconsistency associated with alternative building material such as CSEB can be improved if not solved through the use of standard equipment for moulding. The moulding equipment of a particular size can be adopted by the appropriate government agency as a standard to avoid conflict in dimension as it is in the case of the sandcrete block which has become a very popular walling unit in Nigeria.

The challenge of the comparatively high density of CSEB and the consequent relatively difficulty in its transportation can be reduced by preparing it close to the construction site as much as possible while that of time wasting in laying due to its small size when compared to other common walling materials can be improved if investigations and findings are made on the appropriate stabilization of the CSEB that is of the same size with sand crete block which has higher dimension [28].

V. CONCLUSION

The findings from this review revealed that compressed stabilized brick is a sustainable building material in Nigeria. This is because earth which is the main component of this material is locally sourced. This also explains why less quantity amount of fuel is consumed for its transportation. The reduction in the quantity of cement in this building material is as well a great merit as cement production is usually associated with the emission of GHGs among other things. However, there is the need for an empirical study on the quantity of reduction in embodied energy and by implication the level of reduction in the emitted GHGs. These, the authors seek to address in the nearest future.

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