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Theme:

THE ROLE OF ENGINEERS IN DEVELOPMENT OF SUSTAINABLE BUILT ENVIRONMENT AND AFFORDABLE HOUSING IN TANZANIA

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THEME: THE ROLE OF ENGINEERS IN DEVELOPMENT OF SUSTAINABLE BUILT ENVIRONMENT AND AFFORDABLE HOUSING IN TANZANIA

SUB-THEME: PROVISION OF AFFORDABLE HOUSING

TITLE: ENERGY AND CARBON INTENSITIES OF COMMON BUILDING MATERIALS IN TANZANIA

CASE STUDY: WALLING MATERIALS

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Abstract

This paper presents a study on the energy embodied in the common housing materials in Tanzania. Different masonry walling materials have been discussed with the purpose to evaluate their embodied energy and carbon intensities. One typical rural residential house was analyzed based on the geographical location, technology employed and methods of manufacture. The estimation of embodied energy/carbon is based on the energy consumed in the production of material, its transportation and that energy required to construct a square meter of habitable floor area. The results revealed that energy and carbon intensities in soil cement interlocking bricks and its building construction methodology in rural areas, may not contribute significantly to environment and climate change.

Key words: Embodied Energy, Building materials, Environmental and climate changes and Carbon dioxide emissions.

Introduction

Tanzania like many other African countries, despite the fact that they are endowed with abundant natural resources that can meet their need for building materials production, depend largely on imported building materials and technologies. The choice of building materials is one of the most obvious factors affecting energy use in buildings (Rosenlund et al., 2006). Therefore, the selection of appropriate building materials plays a key role in the durable house construction (Kwanama et al., 2002). Ogunsemi (2010) opined that, building materials form the main factors that restrict the supply of housing and ascertained that they account for between 50-60 per cent of the cost of buildings.

Currently, Tanzania suffers from a terrible shortage of good quality and affordable housing. So dire is this shortage that carries a 3 million housing deficit coupled with a 200,000 units annual demand (NBS, 2013). It is apparent that there has been a significant increase in the proportion of houses constructed using burnt bricks and concrete blocks between 2007 and 2011/12 as shown in Table 1:

Table 1: Percentage Distribution of House Walls and Area, Tanzania Mainland.

Construction Material (House Walls)	**Dar Es Salaam**			**Other Urban**			**Rural Areas**			**Tanzania Mailand**		
Year	2000/01	2007	2011/12	2000/01	2007	2011/12	2000/01	2007	2011/12	2000/01	2007	2011/12
Mud	2.2	1.9	0	12.1	10.3	-18.1	18.1	12	0	16.1	10.7	0
Mud Bricks	3.2	1.3	0.3	30.8	22.6	19	23.5	26.4	31	23.3	23.2	24.7
Burnt bricks	1.3	1.6	0.2	15.9	29.9	42	13.7	18.8	28.1	13.2	19.3	27.3
Concrete blocks	87.2	88.3	96.9	22.4	20.7	25.8	3	3.1	5	11.5	14.8	20.9
Others	6.1	6.9	2.6	18.8	16.5	13.2	41.7	39.7	35.9	35.9	32	27.1

(HBS, 2011/12)

Interpretation of Embodied Energy

The energy consumed in the production of building materials for use in construction industries, associates with environmental pollution and greenhouse gas emissions. This energy is defined as the embodied energy; which is the energy demanded by the construction plus all the necessary upstream processes for materials such as mining, refining, manufacturing, transportation and erection (Langston et al., 2008). Others explain the embodied energy as comprises the energy consumed during the extraction and processing of raw materials, transportation of the original raw materials, manufacturing of building materials and components (Ding, 2004).

Carbon emissions can be defined as those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring (Sanglimsuwan, 2011). **C**arbon emission (CO_2) is among the greenhouse gases which cause depletion of ozone layer hence resulting into global warming. Among the causes of global warming are fairly known as the result of increased and uncontrolled human activities at different stages such as construction activities and transportation.

The first step in the embodied energy analysis is to determine the amount of building materials required for each building component from bills of quantities. For each contributing material, the analysis starts with the final production process and works backwards. Much material energy data can be found from published statistics; this enables determination of energy from a particular industry. The hybrid method of analysis was used in this study; this is the energy analysis method which mixes process analysis and input-output analysis which includes case-specific data while retaining some of the comprehensiveness of the input-output models. Hybrid models use input-output tables to identify and analyze all of the major energy pathways but then substitute data for specific material (Malvaney, 2011).

Data Collection

The study addressed its objectives by using field study, work study, laboratory experiments and literature review. Survey of the most common dwellings, types of building materials used, building materials, production processes and the efficiency of the material were investigated. A total of nineteen (19) villages were surveyed in Morogoro, Dodoma,Tanga, Mwanza, Shinyanga and Dar es Salaam regions. Site observations together with structured interviews were conducted to brick makers and the residents during data collection.

Limitation of the Study

In this study the embodied energy/carbon required in the manufacturing of building materials (walling materials) and the embodied energy/carbon required for assembling the various materials to construct the building have been computed.

Field Survey

The survey reveals that the common walling materials in Tanzania are mud, adobe, burnt bricks, sand cement blocks and stabilized soil bricks. The type of walling materials varies considerably from one place to another. This may be attributed to the fact that different locations have different resources which facilitate the use of particular walling materials over the other. Mud and adobe walls (un-stabilized soil/block) are common in Dodoma and Singida regions. Un- stabilized soil construction is a widespread construction material in rural areas but is generally seen as undesirable being the bottom rung of the materials ladder. Use of un-stabilized soil is likely to continue in rural areas where it is freely available (dug on site) and the cost of construction is primarily determined by the cost of labour (which is considered free in self-help builders). In areas where soil walling is common it is seen as a temporary structure, built because no other alternative material could be afforded, even if it may last longer as it can be seen from a house in Dodoma which was built since 1960's but to date the house is still standing. Houses in Singida and Dodoma have three rooms; two bedrooms and one room which is used as inner verandah (see Plate 1).

Plate 1: House in Singida (left) and Dodoma (right) regions

On the other hand, burnt bricks are commonly used in Morogoro, Tanga and part of Mwanza and Shinyanga regions; fuel for burning the bricks is available in the areas. Traditionally, wood was the most common source of fuel for brick firing in these areas but supplies are rapidly diminishing and have already been exhausted. The traditional materials although indigenous are becoming scarce, particularly wood, and consequently more expensive. Houses in these regions have three bed rooms; sitting room and front verandah (see Plate 2).

Plate 2: House in Morogoro (left) and Tanga (right) regions

Sand cement blocks and stabilized soil bricks are predominantly used in urban areas. At present the majority of cement blocks, are not reaching their potential strength or durability, defined by the quantity of cement used in their production. This is contrary for the case of interlocking bricks, which is still produced in good quality and is achieving the minimum required strength as illustrated in Table 2, since, the quantity of cement used is well determined by the simplified field tests common to producers (see Table 2).

Table 2: Compressive Strength of Available Walling Materials

Sample	**Compressive Strength (N/mm^2)**		
	Sand-Cement Block (450x230x150) mm	Interlocking Bricks (300x150x100) mm	Burnt Clay Brick (270x145x70) mm
1	1.1	4.5	7.15
2	1.34	4.3	7.92
3	1.04	4.2	5.11
4	1.22	3.5	4.85
5	1.31	3.6	6.90
Average	1.202	4.02	6.38

The values provided in Table 2 indicate that, mean compressive strength values obtained from sand-cement block samples tested are lower than the value specified by British standard (2.8 N/ mm^2) and the Tanzania Standard (3.0 N/mm^2 for individual units and 4.0 N/ mm^2 for an average of five specimens) for 28 days of curing. The sand cement blocks were collected se values are from the blocks made by small vendors of sand cement blocks.

Production process

Adobe bricks production involves digging of soil on site, mixing with water and moulding them. Burnt bricks need to be stalked in such a way that, it allows the brick to burn easily. A common fuel used for burning bricks in Tanzania is wood and rice husks. The fuel is inserted until the whole stalked piled of bricks were burned. On the other hand, sand cement blocks are produced by a mixing of sand and cement together with small amount of water, compacted into a mould to a required shape.

Plate 3: Production of adobe (upper left); burnt bricks (upper right); sand cement block (lower left and right)

CASE STUDY

The case study was devised from an analysis of bills of quantities for current housing construction practice using a common type of a rural house. The focus was to collect Tanzania construction data on embodied energy/carbon derived from published embodied energy/carbon coefficient database prepared by other researchers. After a general description of the housing area and selected building material; the embodied energy/carbon for constructing a house using sand-cement blocks, adobe, burnt bricks and soil-cement interlocking bricks were analyzed.

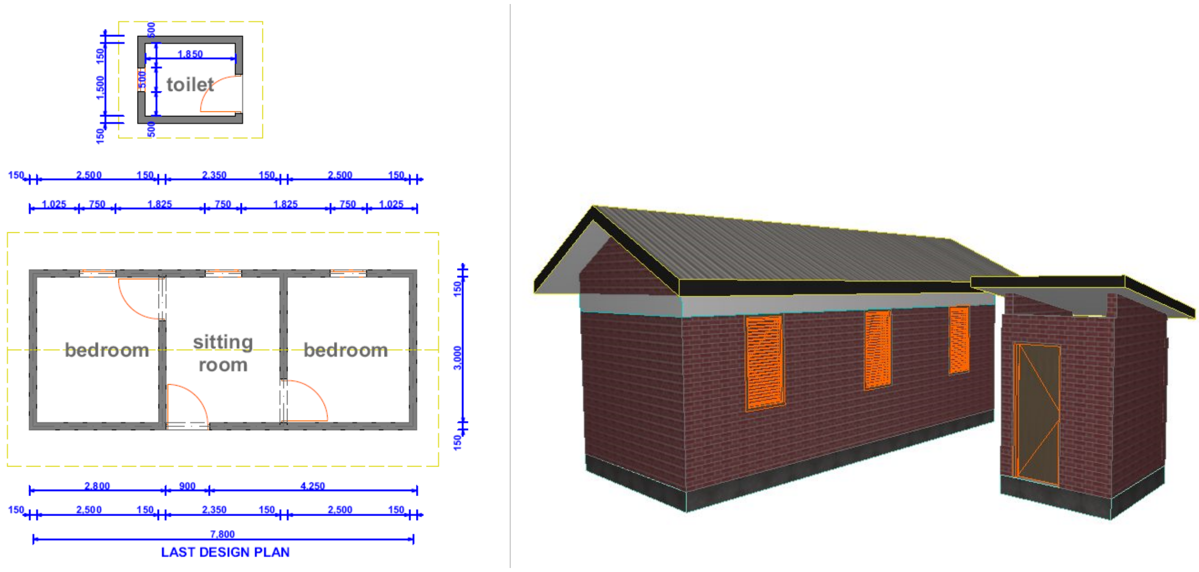

Figure 1: Typical Rural House Common in Dodoma and Morogoro

The house in Fig. 1 above has about 26.235 square meters (m^2) outside area of which 15 m^2 living areas and 7.05 m^2 service area (inside areas), the remaining is taken by the walls. The house has a pit latrine of about 2.775 m^2 inside area at about ten meter distance. Therefore, the floor area under the study includes both living and service areas as well as pit latrine area but excluding other external areas between a house and pit latrine.

The embodied energy for different walling materials was firstly computed per brick/block based on the embodied energy/carbon coefficients of building materials derived from published research documents and their values are summarized in Table 3. Total Embodied energy and carbon for the whole building was then calculated based on the individual bricks/ block values and results are shown in the Table 4.

Table 3: Summary: Embodied Energy in Brick/Block Production

S/N	Wall Material	Embodied Energy (MJ)	Embodied Carbon ($KgCO_2$)
1	Burnt Brick	7.59	0.54
2	Cement - Sand Block	9.51	1.50
3	Soil Cement Interlocking Brick	5.08	0.59

Table 4: Summary of Embodied Energy and Carbon in Construction Stages

S/N	Phase	Burnt Bricks		Sand – Cement Blocks		Soil Stabilized Interlocking Bricks	
		Embodied Energy (MJ)	Embodied Carbon ($KgCO_2$)	Embodied Energy (MJ)	Embodied Carbon ($KgCO_2$)	Embodied Energy (MJ)	Embodied Carbon ($KgCO_2$)
1	Substructure	22,786.03	1,817.17	20,136.34	1684.54	20,136.34	1684.54
2	Superstructure	51,128.24	4,235.13	38205.51	4744.09	29,320.37	3087.87
3	Roofing	8,154.41	420.17	8154.41	420.17	8154.41	420.17
4	Finishing	8150	910.66	9831.6	1223.4	9725.04	1216.9
6	Doors and Windows	9064.23	318.6	9064.23	318.6	9064.23	318.6
Total		**99,282.91**	**7,701.73**	**85,392.09**	**8390.8**	**76,400.39**	**6,728.08**

CONCLUSIONS

- There is a direct link between embodied energy and carbon emission i.e. the higher the embodied energy the higher carbon emission. Therefore, the use of burnt bricks has higher contribution to global warming as compared to other walling materials.
- The strength value for sand cement block from informal small scale producers is lower than a minimum 2.8 N/mm^2 given by the standards, while the interlocking bricks strength and that of burnt bricks exceed the values specified by the standards.
- Soil cement interlocking bricks have the lowest embodied energy value for individual brick as well as for the built up structure.
- Although the embodied energy value for sand cement blocks is higher than that of burnt bricks, the construction methodology results into a higher embodied energy for the building built by using burnt bricks because of the use of sand cement mortar.
- The houses built by adobe are expected to have the lowest embodied energy but also have the lowest durability among other walling materials.

RECOMMENDATIONS

The following recommendations can be drawn from the study findings as summarized in Conclusions drawn above as follows:

- The use of soil cement interlocking bricks should be emphasized in rural housing since it has minimum contribution to carbon emission and achieves minimum required strength.
- Burnt bricks production process should be improved (e.g. by using rice husks) in order to avoid deforestation which results into environmental degradation.
- Production of sand cement blocks should be regularly checked in order to ensure they are on the recommended quality of, strength, durability and aesthetics.

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