MINISTRY OF LANDS, HOUSING AND HUMAN SETTLEMENTS DEVELOPMENT

NATIONAL HOUSING & BUILDING RESEARCH AGENCY (NHBRA) TANZANIA

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

CASE STUDY: WALLING MATERIALS

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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

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Abstract

This paper presents a study on the energy embodied in the common building materials for housing in Tanzania. It is a part of Energy and Low Income Tropical Housing (ELITH) programme which is restricted to low-income tropical housing, with participating countries – China, Tanzania, Thailand and Uganda and is funded under the Research Support Services University of Warwick Coventry United Kingdom by the DFID/EPSRC funding programme entitled 'Energy & International Development'. Initial training in Tanzania on "embodied energy of building materials" was provided to the building industry by Prof. Sandy Halliday, Principal of Gaia Research Group UK in January 2015.

The programme is intended to identify scope for reducing the energy intensity of building materials by changes in their method of production and construction technology. 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 the energy required to construct a square meter of habitable floor area. The results revealed that, soil cement interlocking bricks has the lowest embodied energy and embodied carbon in both the production process and construction method as compared to sand cement blocks and burnt bricks; hence, the least contribution to environmental and greenhouse gas emission,

Key words: Embodied Energy, Building materials, Environmental and climate change; and Carbon related emissions.

1.0 Introduction

Tanzania like many other African countries, despite being endowed with abundant natural resources that can meet their need for building materials production, depends 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) suggested 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: Distribution of Walling Materials (%) for Housing Construction in 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	0	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

Source: *(HBS, 2011/12)*

2.0 Interpretation of Embodied Energy

The energy consumed in the production of building materials for use in construction industry associates with environmental pollution and greenhouse gas emissions. This energy is defined as the embodied energy, which is the energy demanded by the construction process 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 comprised of 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 through carbon dioxide (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 where this enables determination of energy from a particular industry. The hybrid method of analysis was used in this study where the energy analysis method which mixes process analysis and input-output analysis including 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).

3.0 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.

3.1 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 obtained (ref. table 3 and 4).

3.2 Field Survey Results

The survey reveals that the common walling materials in Tanzania are mud bricks, burnt bricks, concrete blocks and stabilized soil bricks. The type of walling materials varies considerably from one place to another. This may be attributed by the fact that different locations have different resources which facilitate the use of particular walling materials over the other. Mud (un-stabilized soil) and mud bricks (unstabilized bricks) walls are common in Dodoma and Singida regions. Unstabilized bricks construction is a widespread construction material in rural areas but is generally observed as undesirable. Use of unstabilized bricks is likely to continue in rural areas where the soil 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 unstabilised bricks 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 figure 1).

Figure 1: Left to right - Typical houses in Singida and Dodoma regions respectively

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. Most of the houses in these regions have three bed rooms; sitting room and front verandah (see figure 2).

Figure 2: Left to right - Typical houses in Morogoro and Tanga regions respectively

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

Source: Field surveys

The values provided in Table 2 indicate that, the mean compressive strength values obtained from sand-cement block samples tested are lower than the value specified by British standard of 2.8 N/ mm^2 and the Tanzania Standard of 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. These values are from the blocks made by small vendors of sand cement blocks.

4.0 Production process and its effect to the environment

Mud bricks are basically made by mixing earth with water, placing the mixture into moulds and drying the bricks in the open air. Straw or other fibres that are strong in tension are often added to the bricks to help reduce cracking. Mud bricks wall are joined with a mud mortar. Virtually all the energy input for mud brick construction is human labour (indirectly fuelled by the sun) and after a lifetime of use, the bricks break back down into the earth they came from. Their embodied energy content is potentially the lowest of all building materials. In a similar way, the greenhouse gas emissions associated with unfired mud bricks can (and should) be very low. These bricks are unlikely to have any adverse environmental effects, since, there would be little or no processing of the raw material and all the energy inputs would be directly, or indirectly, from the sun.

Figure 3: Production process of mud bricks

The production process of burnt bricks is similar to that of mud bricks, except that, after drying, the bricks are arranged in a furnace and fired. The fuel used for firing these bricks is normally wood or rice husks which emit carbon dioxide in their combustion process. . The average embodied energy obtained from research findings of burnt bricks in Tanzania is 7.59 MJ. The intensive consumption of non-renewable energy and associated emission of greenhouse gasses such as carbon dioxide (CO_2), is likely to contribute to environmental degradation.

Figure 4: Burnt bricks at their production point.

On the other hand, concrete blocks are produced by mixing sand, water and cement at a specified ratio and compacted into a mould to a required shape. Curing is done for at least seven days after allowing the block to solidify in the open air. The embodied energy of concrete block obtained in this research work is 9.51 MJ. Concrete block is not primarily attributable to energy consumption in the block making process. However, production of the cement used in these blocks emits large quantities of carbon dioxide (Chusid et al., 2009) which is considered to contribute to environmental damage.

Figure 5: Production of sand cement blocks

5.0 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, burnt bricks and soil-cement interlocking bricks were analyzed.

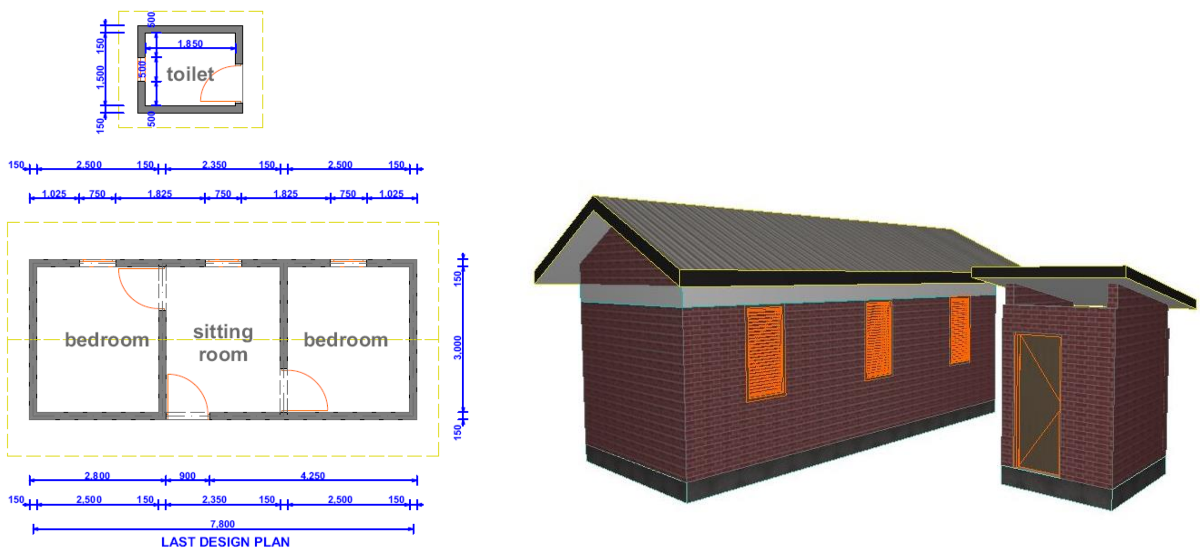

Figure 6: Typical rural house common in Dodoma and Morogoro

The house in Fig. 6 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	Country Burnt Bricks	7.59	0.54
2	Cement - Sand Block	9.51	1.50
3	Soil Cement Interlocking Brick (SSIB)	5.08	0.49

Table 4: Summary of Embodied Energy and Carbon in construction stages

S/N	Phase	Burnt Bricks		Sand – Cement Blocks		Interlocking Bricks (SSIB)	
		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	1,684.54	20,136.34	1,684.54
2	Superstructure	51,128.24	4,235.13	38,205.51	4,744.09	29,320.37	3,087.87
3	Roofing	8,154.41	420.17	8,154.41	420.17	8,154.41	420.17
4	Finishing	8,150	910.66	9,831.6	1,223.4	9,725.04	1,216.9
6	Doors and Windows	9,064.23	318.6	9,064.23	318.6	9,064.23	318.6
Total		**99,282.91**	**7,701.73**	**85,392.09**	**8,390.8**	**76,400.39**	**6,728.08**

Table 4 shows that the superstructure (walling) constitutes about half of the total impacts in each category for both, embodied energy and embodied carbon and as such should be the biggest contributor to climate change and global warming.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

From the foregoing analysis and discussion it can be concluded that:

- There is a direct link between the 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 with mud bricks are expected to have the lowest embodied energy but also have the lowest durability among other walling materials.

6.2 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 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.
- Further research is to lead towards proposals for improved, more sustainable housing models, not only for affordable housing but also for other types of buildings, in East Africa.

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