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Selection of Building Materials towards Sustainable Building Construction in Urban Tanzania

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Abstract: ***Building materials are essential components of building construction. In urban Tanzania, sustainable building construction process has been a problem for the low-income households for years. The trend to prioritise the desire for application of innovative materials without a professional analysis contributes to this major setback. On the other hand, technically uninformed people with minimum knowledge on building construction are indirectly convinced to adopt building designs and approaches which are not sustainable, and in the long run they become economically not viable. Meanwhile, professionals dealing with housing issues are not taking serious consideration to this trend. Construction industry experts involved in housing production process use design solutions and building materials that are not appropriate for local use, thus, leading to an undesired situation. In view of this, there is a need for Tanzania to consider revising different issues and factors related to sustainable building, including materials, standards and guidelines. This paper discusses the issues on proper selection and use of building materials towards sustainable building construction in a developing country like Tanzania.***

Keywords: Appropriate design, Building materials, Environment, Building construction, Urban Tanzania.

1. Introduction

Many developing countries in Sub Saharan Africa including Tanzania are facing serious problems which are related to provision of affordable housing [1]. Efforts to address this issue have been included in various national development agendas for years. However, achievements seem to be comparatively low against expectations which are normally included in the formulated objectives. This might be attributed by a number of factors, among them, lack of priorities and harmonisation of different activities related to building design and building materials optimisation. At the same, the traditional trend has been to adopt the western developed world approaches in housing issues by local professionals, even in conditions where it could have been better to adopt local approaches.

Another contributing factor to this situation is the rapid urbanisation which is facing most developing countries including Tanzania. The rapid urbanisation is mainly based on the rural-urban migration. Under normal circumstances, people migrate to large cities and towns in search of reliable employment, social services and even other facilities which may provide a large room for comfort and security, which are somehow difficult to achieve in rural areas.

The estimated population growth rate for Tanzania was at 2,8% in 1995, and the population of Tanzania was approximated to be 34 million people in 2000. This is also verified by the national census held in 2002, which recorded a population of 34 million people [2]. It is stated in the National Environment Policy [3] that demographic factors and trends are directly linked with development and environmental issues. Therefore, a rapid growing population implies an increase in absolute terms. This in turn affects the use of land, water, energy and other natural resources. The accompanying rapid increase in the number and size of urban centres pose dramatic additional demands in the capacity of providing serviced land, shelter, infrastructure and employment.

In consideration with the above facts, Tanzania has to, and needs to get out of this complex situation by prioritizing timely actions which are monitored and controlled on regular basis.

1.1 Agendas on Sustainable Building for Developing Countries

As pointed out in the Agenda 21 for Tanzania in "Social Aspects of Sustainable Development in the United Republic of Tanzania", the highest priorities in sustainable provision of services were on water supply and sanitation, whereas human settlements sector was still hampered by high investment, operational and maintenance costs.

More than a decade has passed since the 1992 Earth Summit in Rio de Janeiro. The summit addressed the issues of human developments and environment. The Agenda 21 report, highlights a number of issues to be dealt within the next century. The issues are mainly related to the promotion of sustainable human settlement development. Among the programme areas, one was intended to focus on how to provide adequate shelter for all.

As a basis for action, it was agreed that access to safe and healthy shelter is essential to a person's physical, psychological and socio-economic well-being, and should be a fundamental part of national and international action. It was then revealed that approximately 1 billion people do not have access to safe and healthy shelter, and that if appropriate action was not taken, the number will increase at

the end of the century and beyond [4]. Suggestions from the report insist that, all countries especially the developing ones, should appropriately, formulate and implement programmes that address the specific problems of the concerned populations in their respective countries.

The "CIB Agenda 21 for Sustainable Construction in Developing countries [5]", in response and support of the UN Agenda 21 report, discusses in detail a number of issues which relate to the situation in most developing countries. The report, in very critical statements mentions that "the developing world has very little time left to decide the future of its settlements. It can choose to blindly follow the model laid down by the developed nations, or it can choose to opt a more sustainable model of development". Thinking in a positive direction, it means to seriously address issues such as adequate housing, rapid urbanisation and lack of infrastructure. The report further suggests that the developing countries still, have the opportunity to avoid the problems currently experienced in the developed countries. Hence, these countries have an advantage to choose and base all their future development programs on the principles of sustainability.

2. Methodology

The information used in this paper is drawn from literature review collected from various sources. Besides, information from a study conducted by the authors on building challenges in the City of Dar es salaam has been used. This study involved interviews with key stakeholders including architects, planners and artisans in the local building construction industry. Besides, discussions were also carried out with those involved in production of building materials and users at various sites in Dar es Salaam city.

A total of fifty (50) interviews were carried out. In addition, observations were made focusing on newly constructed buildings in various areas of Dar es Salaam and Mbeya City, Iringa and Morogoro Towns where there is increase use of modern materials. Observations were carried out with regard to building form, treatment of facades and type of building materials used.

3. Results and Discussion

3.1 The Choice of Materials for Sustainable Building Construction in Tanzania

Umar *et al* [6] states that, a considerable number of building materials have environmental effects which is caused by pollution and natural resources depletion. This usually takes place when extraction, production and manufacturing process and transportation is taking place. It is therefore important to make application of stable and environmentally responsible building materials, use and application of natural and healthy materials contributes to the well being of occupants.

The appropriateness of a building material or construction technology can never be generalized. Preference is often based on materials that are available locally rather than imported ones. Where cheap materials are available in large quantities, the preference is also higher. The place of production process is also important, which means production at site can be more attractive and economical since transportation cost will be minimized.

In terms of technology, considerations on whether the material requires special technology or whether it can be produced locally at lower costs are also critical considerations. Generally, a good technology is that which produces a durable and quality product, at an affordable price. In addition, often preference is given to a material with low energy input, with less wastage and pollution. In this regard users also check whether there is an alternative for other better materials. Materials and technologies ought to also comply with the local climatic conditions. And the best technology is the one that can be easily understood by the local artisans/workers with adequate skills. Running and maintenance cost of materials are also a critical considerations when making a choice.

Major buildings used in Tanzania today are still of classical type. Materials such as cement, cement blocks, concrete and reinforced concrete, timber, GI sheets and recently roofing tiles, dominate the building industry. This is the case in most urban cities and towns including Dar es Salaam, Mbeya, Morogoro and Iringa [7].

Majority of people continue to adopt new trends in selecting building materials, probably from the western developed countries, where applied building materials reflects a symbol of wealth. The traditional way of thinking and the wish to use locally available building materials is rarely practised. Umar *et al* [6] further contends that sustainable building materials need to be contextualized in their use in developing any community. The use of sustainable building materials despite of minimizing cost of transportation and emissions of carbon, it also offers employment and opportunities in development of skills for members of a community.

In Dar es Salaam city, concrete blocks continue to dominate as a basic material in residential and commercial building. In Morogoro and Iringa municipals, both use of concrete blocks and soil burnt bricks is common. The case is similar in Mbeya city. However, in Iringa and Mbeya there is an additional desire of local people to use clay burnt bricks, concrete blocks and timber products in residential buildings (Figures 1 and 2). This decision is probably based on the fact that timber products are produced in large quantities in these regions [7] [8].

Figure 1: A concrete block house in Iringa town

However, on the other hand, sand-cement floors finishes are also common in these cold highlands regions. The temperatures are low especially in the May-July months and cement floors tend to be cold especially in the nights. One would have expected local people could prefer and opt for an alternative combination of materials. But this is exactly what can be reflected as a struggle to own houses using modern industrial materials just for the sake of prestige.

Figure 2: A clay burnt brick house in Iringa town

The traditional way of using building materials in combination which looks natural and beautiful, and yet environmentally friendly, is no longer a desired option. This is even happening amid professionals who have vast experiences in the building and construction industry.

Clay building bricks, red soil burnt bricks, natural roofing materials are nowadays regarded as inferior, even though they are functional, comfortable and contain aesthetical values (Figure 3).

Figure 3: Locally produced burnt bricks in Morogoro town

Traditional African huts from Sub Saharan Africa are nowadays very rare to find in large scale, and if found, then are only existing in remote districts or tourist attractions centres. Figure 4 presents a traditional Chagga house in Kilimanjaro, north of Tanzania. As can be observed, the house is built using natural and locally available materials, which meet social aspect, comfortable and functional requirements.

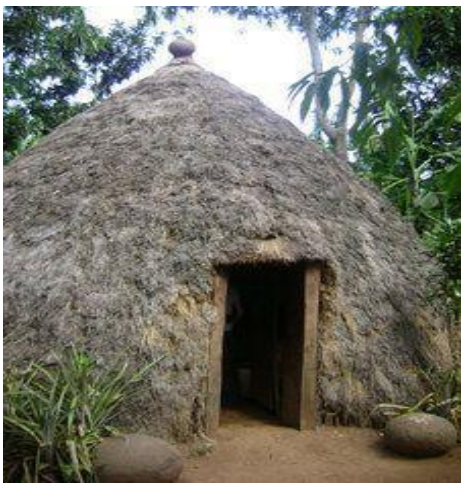

Figure 4: A Traditional Chagga House in Kilimanjaro region, Northern Tanzania

Woolley [9] summarizes the various benefits that can be achieved if one applies the so called natural building as related to building materials as shown in Table 1.

The author further argues that, work on environmental assessment tools largely fail to take a global perspective on resource consumption and thus continue to use expensive materials at a high rate. To avoid such a problem, an alternative is the development of the so called 'natural Building' which attempts to use materials and building methods which have a lower impact and use renewable energies.

In this approach, few changes must be proposed in terms of better energy efficiency, construction management, less wastage and the inclusion of new appropriate technologies. The conclusion is that mass materials like cement and concrete cause significant pollution, use a lot of energy and

non-renewable resources. Although many professionals may assume that using green materials or technology will be much expensive, however, the principal aim of the natural building alternative is for such materials to be economical, of high standard and with good life cycle performance.

Table 1: Comparison of possible benefit of conventional and natural materials

Conventional building	*Natural building*
Uses non-renewable resources and materials	Uses renewable materials, which can be grown and provide cash to the local people, e.g. farmers
Uses a lot of energy in extraction – high embodied energy	Uses materials which need little energy to extract
Extraction is often damaging and causes social problems	Materials are extracted and processed locally
Significant energy and chemicals are used to create energy efficient solutions	Generally, little energy is used
External air pollution caused by manufacturing processes	Virtually no external pollution
Internal pollution due to the use of toxic additives like solvents	Natural materials rarely cause health problems if handled properly and not treated with toxic fire retardants, etc.
Waste in manufacturing and installation is a normal part of process	Little waste if care is taken
Damage to eco-systems at end of life disposal	End of life can be recycled or returned to the earth and decompose naturally.

(Source: Woolley, 2004)

Towards appropriate Designs for the Building Construction Industry in Tanzania

Appropriate building design is not a new concept for building designers/ professionals around the world. However, putting it into practice in actual daily industrial activities seems to be unrealistic; and a contradiction to the objectives of sustainable development and the building industry at large. This observation is applicable to the current situation in Tanzania.

Appropriate design is considered as an important component in order to achieve a financial balance return, social contribution, energy efficient and minimal environmental impact objectives. There are various ways in which built facilities can reduce their dependence on environmental resources. Examples of such strategies may include appropriate materials selection and radical designs that embody both passive and active solutions to create more comfortable spaces at reduced cost and energy input [10]. Environmentally-compatible design which is sometimes referred to as 'green design', apply designs that exhibit reduced dependence on energy for maintaining comfortable internal environments. The results are anticipated to meet the requirements of high productivity levels and increased satisfaction by the occupants.

In analysing the challenges facing urban development in Dar es Salaam city, Nguluma and Lyakwipa [8] are concerned with the negative effects associated with designs, construction activities and unregulated development of buildings in both formal and informal settlements.

For the case of Dar es Salaam cement is regarded as a basic building material, however, architects and designers need to formulate designs which can reduce the use of cement. Regarding the social aspects of design, the need for security, privacy and territorially is among the key consideration in the design process. Due to this reason, massive concrete blocks or metal fences are erected to justify security measures in most residential areas in Dar es Salaam.

Architecture has to respond to ecological demands and designs that take into account the local conditions, culture and identity, emphasize on environmental friendly design and energy efficiency.

In a related study, Nguluma [1] highlighted that families construct fences around their houses to improve security. Some walls are as high as three metres, and in most cases constructed of massive concrete blocks. Such walls are constructed using a lot of materials, which are not healthy and socially interactive. In regard to building design and materials, Nguluma [1] comments that, people's admiration of concrete blocks as good 'modern' materials could be interpreted as a mere ignorance on the performance of building materials. This is simply because not much effort is done to educate and convince people the positive aspects of traditional building materials.

In agreement with the arguments related to sustainable building design in Tanzania, it is important to consider and regularly update building standards to meet local needs. The popular British standards that are commonly used in the building industry in Tanzania need to be updated to suit local use. And Tanzanian standards (TBS), whether developed or modified from the International standards, need to be realistic and justify local requirements. They should consider and include basic factors such as climatic conditions. As an example, the 230 mm thick concrete blocks wall commonly used in wall construction design is not compatible to local climatic conditions of areas like Dar es Salaam. Initially, this British standard size (BS) is meant for use in countries with low temperatures. The thermal conductivity (k) of concrete is comparatively high, i.e. 1.44 W/mK. The resulting effect is high indoor temperatures in most households in the region in extended periods of the year. Other materials, e.g. earth brick is having a k value of 0.14 W/mK and cement-sand mixture is 0.53 W/mK which are considerably low.

Thomas [11] discusses various aspects and alternative approaches which can successfully be applied in dealing with various problems in architecture and the urban environment. He pinpoints that, sustainability in construction relates not only to the extraction and production of raw materials, but also consideration in efficiency in terms of the design execution of the structure. Such approaches can be very useful if carefully studied and adopted in the building and construction industry in urban Tanzania.

3.2 Sustainable Building and Environmental Issues

A series of Agenda 21 based documents including NEP (National Environmental Policy) [3] and CIB Agenda 21 for Sustainable Construction [5] indicate that, sustainable development means achieving a quality of life that can be maintained for many generations because it is socially desirable, economically viable and environmentally sustainable. Development is sustainable if it takes place within nature's tolerance limits, both in the short and in the longer-term perspective.

Environmental issues are definitely fundamental, and need to be considered and integrated in the sustainable building programs and actions. Development is certainly associated with building and construction, and the built environment. Natural resources are consumed by modification of land, the manufacture of materials and systems, the construction process, energy requirements and waste products that result from operation, occupation and renewal. Building projects continue to be a major contributor to both economic growth and environmental degradation, as such, is directly concerned with sustainable development. Based on these facts, the concept of sustainable development has stimulated the search for building and construction solutions that do not result in clash between living standards and environmental protection.

We live in an environment age where valuable resources are further depleted and limits to growth are approached. The lives of Tanzanians, just like the people from the rest of the world, are intimately connected to the environment. Therefore, the survival and that of their future generations depends on the harmonious relationship with the natural elements. Indeed, they have no choice but strive to manage the environment and its natural resources in ways that enhance the potential for growth and opportunity for sustainable development of the present and future generations. Every individual must realize and accept that environmental problems are real, and not someone else's problem.

3.3 Optimization of Building Materials for Sustainable Construction

Sustainable building, also known as green building or green construction, refers to both a structure and the using of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: that is, from sitting to design, construction, operation, maintenance, renovation, and finally demolition.

The appropriateness of a building material or construction technology can never be generalized. Selection and choice preference is often based on materials that are available locally rather than imported ones. Where cheap materials are available in large quantities, the preference is also higher. The place of production process is also important, which means production at site can be more attractive and economical since transportation cost will be minimized.

In terms of technology, considerations on whether the material requires special technology or whether it can be produced locally at lower costs should critically be considered and analysed. Generally, a good technology is that which produces a durable and quality product, at an affordable price. In addition, often preference is given to a material with low energy input, with less wastage and pollution. In this regard users also check whether there is an alternative for other better materials. Materials and technologies ought to also comply with the local climatic conditions. And the best technology is the one that can be easily understood by the local artisans/workers with adequate skills. Running and maintenance cost of materials are also a critical considerations when making a choice [5].

According to [6], building materials are very important components of building construction. Therefore designs of green buildings should commence with selection and use of materials which are eco- friendly but taking into consideration technical function and financial requirements.
In brief, selection and optimization of building materials can be explained as the process meant to achieve the best use of available materials, in order to make their use as useful and effective as possible. In such a process, several factors are included to get the best optimized values. Such factors must include the following items:

- Availability of the material in a given case
- Production costs
- Local climatic conditions
- Environment impact
- Durability properties
- Predicted service life based on lca (life cycle assessment) models
- Materials transportation (whether locally or imported), and the
- Related environmental impact.

To optimise building materials for building construction is of significant value if we need to achieve sustainable building, especially in the developing countries of Sub Saharan Africa, and Tanzania in particular. Proper selection of materials that have minimum environmental burden is useful in the sustainable development of a nation like Tanzania.

The earth's crust resources are usually defined as being 'renewable' or 'non-renewable'. Renewable resources are those that can be harvested in regular intervals, for example timber. These resources are renewable provided right conditions for production exist. Non-renewable resources are those that cannot be renewed through harvesting, e.g. iron ore. However, research reports indicate that most of these resources will be exhausted in the near future [12].

Another established fact is that, the building industry is the largest consumer of raw materials in the world today. Thus, a major guiding principle for the future should be a drastic reduction in the use of raw materials. Another important consideration is to reduce the loss of resources during production, the construction process and throughout the life time of the completed building. The re-use of materials after demolition should be taken into account. Likewise, recycling

processes models should be developed and encouraged at all levels. Figure 5 represents a good explanation on how the cycle of materials can be included in sustainable building design process.

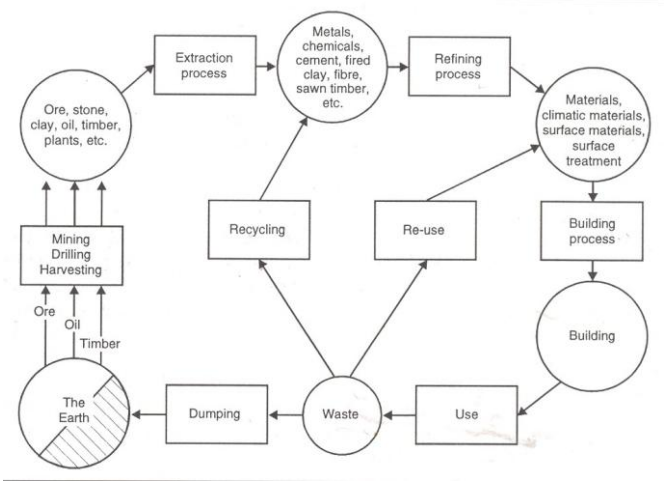

Figure 5: The cycle of materials
(Source: Berge, Bjorn, 2000)

4. Conclusion

This paper has discussed challenges concerning sustainable building construction and materials in urban Tanzania, in a direction supporting the concept of construction for development. It shows that sustainable construction should be considered as an important component in creating a sustainable development to the country. And therefore a need to make a proper selection of construction materials which have minimum environmental burdens is of great significance in order to boost a building environmental performance. One important consideration is to integrate building design and building materials from the design process stage. This can easily be implemented by using optimization models. The paper further reveals that:

- The design approaches and materials used in the building process in urban Tanzania do not really comply with the principles of sustainable construction.
- Building professionals are reluctant to use their entire knowledge in a realistic approach.
- There is a lack of proper coordination between the various professionals involved in the building industry.
- Building standards are not realistic, i.e. they are not affordable and compatible with the local needs.
- The majority of the people lack knowledge on the various performance properties of building materials and rational designs.
- Environmental impact consideration in most cases is neglected during the design process.

As best explained in the CIB Agenda for Sustainable Construction; sustainable construction means that the principles of sustainable development are applied to the construction cycle from the extraction and beneficiation of raw materials, through planning, design and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste.

The Agenda concludes that, creating a sustainable built environment in the developing world requires a different approach from that used in the developed world. In fact, this concept is not normally understood, and unfortunately, not included for discussion related to building issues in developing countries.

As such, Tanzania as a country needs to take these remarks strongly for action. It must be noted that, in order to achieve sustainable development, the society, the environment and economy should be linked together with the application of appropriate technology. In this connection, consideration for proper selection of building materials for building construction is indeed important.

References

[1] Nguluma, H.M., 2003, Housing Themselves: Transformations, Modernisation and Spatial Qualities in Informal Settlements in Dar es Salaam, Tanzania. Doctoral Thesis. KTH, Sweden.
[2] Www.tanzania.go.tz. Online Tanzania Government website. Accessed: October, 2016.
[3] NEP, National Environmental Policy Report (1997). The United Republic of Tanzania, Vice Presidents Office. Dar Es Salaam..
[4] Agenda 21. June 1992. Report of the United Nations Conference on Environment and Development. UN Department of Economic and Social Affairs: Division for Sustainable Development.
[5] CIB Agenda 21 for Sustainable Construction in Developing Countries, 2002, A discussion document. CIB and UNEP-IETC. Printed by Capture Press, Pretoria.
[6] Umar, U.A., Khamid, M.F and Tukur, H. 2012. Sustainable Building Materials for Green Building Construction, Conservation and refurbishing: Management in Construction Research Association (MiCRA) Post graduate conference.
[7] Field Report (Unpublished), UCLAS (University College of Lands and Architectural Studies). Building Economics Department: Field Training Program Reports (Unpublished Report). 2005-2006, Dar es Salaam.
[8] Nguluma, H.M. and Lyakwipa, B., 2006, *"Design Challenges facing urban development in Dar es Salaam city, Tanzania".* The Journal of Building and Land Development. University College of Lands and Architectural Studies, UCLAS, University of Dar es Salaam, Tanzania. Vol. 13 No. 1 pp. 1-12.
[9] Woolley, T. 2004, SB'04 Conference. Sustainable Settlement in Southern Africa. Sponsored by CIB, UNEP & iiSBE, in South Africa.
[10] Langston, C.A and Ding, K.C., 2001. Sustainable Practices in the Built Environment, Second edition. Reed Educational and Professional Publishing Ltd, 2001.
[11] Thomas, D., 2002, Architectural and the Urban Environment: A Vision for the New Age. Architectural Press.

[12] Berge, Bjorn, 2000. Ecology of Building Materials. Architectural Press, Oxford.

Author Profile

Dr. Huba M. Nguluma received the PhD. Degree in Built Environment Analysis in 2003 from Royal Institute of Technology, Stockholm, Sweden. She is an architect and a Senior Research Fellow with the Institute of Human Settlements Studies of the Ardhi University where she has been employed since 1993. Dr. Nguluma used to work with the Building Research Unit of the then Ministry of Lands and Human Settlements as a Research Architect from 1986 to 1993. Dr. Nguluma also lectures and supervises postgraduate and undergraduate students in the school of Architecture, Construction Economics and Management (SACEM), School of Spatial Planning and Social Sciences (SSPSS) and Institute of Human Settlements (IHSS) at Ardhi University. Her major fields of specialization are Architecture, Built Environment and Housing. Dr. Huba Nguluma has carried out a number of research and consultancies in the field of Architecture and Human settlements to public, private and International institutions like NSSF, PSPF, LAPF, GEPF, UN Habitat, CBOS and NGOS like WAT, Habitat for Humanity and Plan International. She has also published in the field of Human Settlements. She is also a Registered Architect with the Board of Architects and Quantity Surveyors (AQRB) and a member of Architects Association of Tanzania (AAT).

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His major areas of specialization are Civil engineering, Building materials and technology, and Sustainable Construction. He has accomplished a number of researches in Building and construction materials and Sustainable Construction; and has attended and presented papers in international conferences, seminars and workshops. In addition, he has been engaged in consultancy works in Sustainable construction and Environmental standards. In his professional career, Dr. Makenya has also worked and participated in various research programs with the CIB (International Council for Building Research and Innovation), The TSI (The Sulphur Institute) in Washington, DC, The BRE (Building Research Establishment) in Watford, London, NIST (National Institute of Standards) in Washington DC and Shimberg Centre for Affordable Housing (at the University of Florida) in Gainesville, Florida.

Dr. Makenya has been an active and member in international organization including the CIB where he participated in working committees such as Affordable housing (Coordinator, Northern Europe) and Design for Durability (Secretary). He lectures and supervises both undergraduate (BSc) and postgraduate (MSc) students in the School of Architecture, Construction Economics and Management.