Managing Context-Specific Cultural Drivers and Barriers to Sustainable and Resilient Building Systems: Lessons from Tanzania

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Abstract

This identifies obstacles to, and opportunities for advancing high performance building systems using context specific cultural and other factors in the East African country of Tanzania. The authors discuss specific ways through which such factors can impede or facilitate the adoption and use of sustainable and resilient technologies in building systems. The case of sustainable earthen masonry in Tanzania is examined in detail as an example of a sustainable building technology impacted by a variety of technical and cultural factors. In addition to identifying some technical flaws that limit the update of the technology, the authors also identify some socio-cultural nuances. They draw lessons on context-responsive design from Swahili Architecture (a style of building along the eastern and south-eastern coasts of Africa). Selected buildings are analysed as elements within wider socio-technical systems consisting also of knowledge, capital, labor, social practice, and cultural meaning. These cultural factors are embedded in everyday practices and routines, social norms and values, and aesthetic preferences. They are also embedded in a demographic context. Over half the population of Tanzania and East Africa in general is under 20 with large waves of migration to cities and among rural areas are already generating an enormous boom in housing and other construction demand in both rural and urban areas that will continue for the next several decades. Communication is has emerged as a key factor in making earthen masonry more culturally responsive. The paper identifies the potential role of famous people such as celebrities and the social media in popularizing a culture of earthen construction.

Keywords: Sustainability, Green Materials, Social-cultural Factors.

1. Introduction

In the recent years, the sustainable construction movement has greatly influenced the design and construction of the built infrastructure across the globe. There is a growing interest in delivering "high performance building" systems. In 2008, the US building

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enclosure community launched a formal initiative efforts directed at delivering high-performance buildings. This initiative underscored the linkages between energy efficiency, durability and the quality of the indoor environment (Bomberg and Onysko, 2009). A “high-performance building” has been defined by the Energy Policy Act of 2005 (EPA, 2005) as: “a building that integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, life cycle performance, and occupant productivity.” The authors seek, through the research described in this paper, to contribute to the realization of this goal through focusing on the potential of using earthen masonry to deploy durable, resilient and sustainable houses for low income communities.

Building materials can be classified rated as best for the environment if they contain the following characteristics: 1) materials made with salvaged, recycled, or agricultural waste content; 2) materials that conserve natural resources; 3) materials that avoid toxic or other emissions; 4) materials that save energy or water; 5) materials that contribute to a safe, healthy, built environment (Lazarus, 2002). There has been a specific concern over greenhouse gases (GHGs) that has resulted in several efforts being directed towards reducing their release into the atmosphere. In Condition 2 of LP Hedelberg’s movement, The Natural Step, there is a caution against the use of man-made materials that take a long time to decompose where dioxins are explicitly identified as examples of compounds that will almost never be broken down by nature. Given that building materials are largely inert, key areas of concern from an ecological perspective are ensuring that the manufacturing is done with the least impact and also designing the products for easy disassembly and recycling (Kibert, 2005).

Some construction materials are more problematic than others. Cement-based materials such as concrete blocks, which constitute one of the most widely used materials in the building industry, are not rated favorably against this assessment. In the recent years, there have been significant efforts directed at “greening” the use of cement within the construction industry, through for example, incorporating organic components in the mix. Options that have been explored over the years range from using the organic components as additives to using cement as stabilizer for organic component (earth). The latter is often pursued as a way of addressing structural concerns of using earth as a building material in low cost construction. It is not uncommon for additives such as lime and natural fibers to be included in the mix design for such masonry units.

Buildings erected using earth-based technologies are economical and environmentally friendly because of their use of naturally occurring raw materials. They can also be used to promote energy efficiency through leveraging their thermal mass. This notwithstanding, earth-based technologies are still not as widely used as other conventional construction materials. This paper identifies obstacles to and opportunities for advancing their structural use in the East African country of Tanzania. Like many developing countries, Tanzania is faced with shelter problems both in rural and urban areas. Forty to 70% of the urban population lives in slum and squatter settlements characterized by poor and unhygienic living conditions; overcrowding; inadequate and unsafe water supply; and problems in human waste disposal and sanitary conditions. Although the country is endowed with vast resources of indigenous building materials (BRU WR No 8 1978), the formal housing has persistently depended on imported construction materials, many of which are not affordable for the majority of the population. The reliance on the less sustainable options suggests that there is a social acceptance issue with respect to green materials and products.

This paper aims to identify obstacles to, and opportunities for advancing high performance building systems. In addition to discussing some of the performance-related technical concerns, the authors also discuss specific ways through which social-cultural factors can impede or facilitate the adoption and use of sustainable and resilient building technologies and systems.

2. Research Approach

The research discussed in this paper is a subset of a larger research program directed at advancing the structural use of earthen masonry. The deployment context for the research focus is the hot and humid Tanzania coast. The initial assessment of the quality of walling elements erected using earth-based bricks was done through an NSF supported International Research Experience for Students program in between May and July, 2008 in Tanzania. The deterioration of the brick walls was very apparent. The main problem was moisture damage. Interviews with the Tanzanian stakeholders identified two possible explanations for the deterioration of earth bricks: poor soil quality and breathability. Some of them indicated that some of the flaws could be attributed to flaws in the brick production process. These three possible causes were investigated through laboratory-based testing.

During subsequent field visits to Tanzania in 2009 the brick production processes and their assembly into a masonry-walling unit. The steps involved in the production of CSEB (compressed stabilized earth bricks) were replicated to investigate the block-production process with a view to identify the critical sub-processes that influences the quality and performance of blocks. These activities were done in collaboration with Tanzania's NHBRA (National Housing Building Research Agency). During this field study, a visual analysis of performance of earthen masonry during the post-occupancy phase was also performed. This was based on a comparative analysis of relatively new earthen masonry structure and older buildings representative of Swahili Architecture. Swahili Architecture is used in this context to refer to a hybrid building system that was prevalent along the East African coast between the 17^{th} and 19^{th} Century. It emerged as a fusion of African, Arabic and Portuguese design and construction techniques

Some of the primary data was also collected during a two-day NSF workshop which was held in Tanzania in July 2009. The workshop provided a forum for sharing best practices in earth-based building technologies and developing a research and development roadmap. Top priority research included optimizing the physio-mechanical properties of earth as a building material and managing socio-cultural impediments. The key findings from the field work and the workshop are discussed in details in the subsequent sections.

3. Key Technical Barriers to the Use of Earthen Masonry

Several operational difficulties were observed when studying the entire compressed brick production process through a series of field visits. These difficulties increase the margin of error as far as compliance the existing engineering guidelines is concerned. During the manual soil extraction process, it is difficult to ensure that material from the top soil, a layer known to be rich in organic matter, does not end up in the final mix. The ground is hard making digging very strenuous especially if the extraction process is done on a hot, sunny day. Inevitably, some top soil material will end up in the brick. In addition to visually observing some root fragments in compressed bricks, the presence of organic matter in the finished masonry units confirmed through lab-based testing. Samples of fabricated bricks were crushed into powder. The smoke released when the powder was burnt was indicative of organic matter being present in the final brick. A lab-based chemical analysis using the EDS-SEM technique validated the initial findings (see Obonyo et al, 2010a for the detailed results).

Some performance-based technical concerns can also be attributed to the rules of thumb methods being used to determine the suitability of the soil. For example, the field test executed on the soil appeared to work adequately as far as ensuring that the soil did not have excessive clay. However, it failed to reveal the other extreme problem – too little clay which ended up emerging as an issue for the selected case study projects. The primary author brought some of the soil to the UF Material Characterization laboratories where detailed characterization of its properties was done using EDS/ SEM analysis (Obonyo et al, 2010b). In general, the clay context should be around 20%. From the primary authors' experience it is possible to produce quality bricks with less than 20% clay content through carefully selecting a suitable stabilizer (see Obonyo et al, 2011). However, then this percentage is too low (less than 10%) it will be difficult to produce bricks attain acceptable strength values. The figures for compression can end being as low as 100psi which would not comply with the stipulations of, for example, the Adobe Specification in the New Mexico Building Code.

There were concerns related to the efficiency and the effectiveness of the stabilization strategy. Within the case study context Portland cement is used to chemically stabilize the soil. A manually operated device is used to mechanically stabilize the soil-cement mixture. The manual process of mixing the soil with the stabilizer resulted in a non-uniform distribution of the binder (Portland cement in this case). The manual device used to exert force on the soil also operated very inefficiently. The first few bricks produced disintegrated during ejection indicating that the mix was not fully compacted. In addition to the physical input force, being too high for the average person to sustain over an 8-hour work day, there is no way of ensuring that the more or less the same force is exerted when producing different brick (see Figure 1). Such factors result in variations in performance that remains a key area of concern for compressed bricks (see Obonyo et al, 2010b). While inspecting the use of compressed bricks during the construction of masonry walling on job site it was observed that many units had visible damage (Figure 2).

Figure 1: Manual compression of blocks and example of damage

Figure 2: Cracking during construction

On a different site, there was also evidence of the onset of efflorescence. Over time bricks in such walls can be expected to decay and mould, something that was observed in some 10-15 year old brick buildings in Dar es Salaam (Figure 3).

a) Efflorescence on a building that is still under construction

b) Rotting and Decay on a 10 to 15 year old building

Figure 3: Efflorescence, decay and mould on Masonry

Because of such problems, there are concerns over the structural adequacy of earthen masonry in conventional buildings. Many of these issues can be address through the use of a robust stabilization strategy. The current practice in low cost construction application integrates both chemincal and mechanizal stabilization. Chemical stabilizers such as cement and lime are added to the soil prior to compression to improve the physio-mechanical properties of the resulting wall. When the process is optimized, the bricks can attain the set building code requirements (Obonyo, 2011, Obonyo et al 2010a, b). Because soil is highly variable, the mix-design must be tailored to a specific context.

In addition to the technical flaws discussed in this section, the widespread structural use of earthen masonry is also impeded by some socio-cultural nuances. To address these, one must develop strategies that are responsive the local cultural and social context. In the subsequent section, the authors illustrate the opportunities for doing just that through drawing lessons from Swahili Architecture, a style of building along the eastern and south-eastern coasts of Africa.

4. Leveraging on the Cultural and Social Context

As previously indicated, a visual analysis of the older buildings (at least 150 years old) that represent Swahili Architecture was included in the study. Many of these buildings use earthen masonry for their walling element. Investigations based on visual inspection revealed that they have performed better during the post-construction phase in terms of resisting weathering and physical deteriorating. This can be attributed to their designers and builders' concurrent use of several strategies to mitigate against moisture damage, a key threat to durability in the hot and humid East African Coast. Earthen masonry, if left exposed (something observed in some of the new earthen masonry buildings discussed in Section 3) will deteriorate progressively through wind-driven rain erosion. From the building in Figure 5a it is clear that the external surface of the earthen masonry in Swahili Buildings was rendered.

The selected render should be compatible with the substrate otherwise it will peel off exposing the vulnerable earthen material. In the previously cited NSF workshop, some participants proposed the use of a soil-cement based render that can also be painted to enhance its weather resistance (Obonyo et al, 2010b). Generally speaking coatings that incorporate green materials can be expected to perform better in terms of compatibility. However, it is important to note that the use of an organic material-based plaster has some disadvantages. Within the hot and humid context moisture-related deterioration can be expected. Without a robust periodic maintenance strategy, the render can progressively fail (peel of). The selection of the render material should also promote breathability, used here to refer to the ability of the material to breath out any absorbed moisture. Failure to factor in such issues can be expected to result in moisture-related problems including but not limited to blisters, cracking, efflorescence, decay and rotting. Figure 5a depicts an extreme case of the protective render peeling off in an abandoned building.

a) Roof overhang, elevated plinth and lime –based coating

b) Abandoned building with desirable features - similar to the building in Figure 5 (a)

c) Clustering around narrow streets, minimizing exposure to sun & wind-driven rain

Figure 5: Swahili Architecture

Other interesting moisture protection features in the older Swahili buildings include use of elevated plinth to minimize damage through rainwater splashing on the ground the provision of adequate roof hang as depicted in Figures 4(a) & (b). Another desirable strategy was the incorporation of narrow alleys at the street level to reduce weather-related deterioration through direct exposure to wind-drive rain and shrinkage-related cracking as the brittle masonry material is exposed to the sun.

From the field investigations Swahili Architecture, which as previously indicated is a fusion of mainly African, Arabic and Portuguese techniques appears to yield structures that are both functionally appropriate and economical. The emergence of this genre of buildings was strongly coupled to the East African Coastal Culture (Swahili Culture). The Swahili Culture-sensitive approach to design and construct has been superseded by Western approach largely because of material scarcity. In addition to requiring the use of traditional mason (a trade that outside a small group of artisans tied to historic preservation efforts is almost extinct), the Swahili Architecture also use coastal resources that have been over-exploited over the years and are no longer widely available. The authors propose the use of these historic buildings as a reference point for defining earthen masonry construction techniques that are context-sensitive. It addition to addressing some of the technical performance issues from a systemic level, such an approach being more responsive to the local culture is expected to be more acceptable to the beneficiary communities.

This approach requires proponents of earth-based technologies to incorporate culture as playing a pivotal role in the key drivers and barriers to its widespread use. Raymond Williams (1983: 11 - 13) in his book entitled “Culture” points out at least four contested definitions of culture: 1) A developed state of mind (for example, a person of culture or a cultured person); 2) The processes of this development (for example cultural interests, cultural activities); 3) The means of these processes (for example, the arts and humane intellectual works), and; 4) ‘A whole way of life’, ‘a signifying system’ through which a social order is communicated, reproduced, experienced and explored. Although all these four definitions of culture are integral to achieving sustainable earthen masonry, the authors consider notion of an “entire social order” (Williams, 1983) as more encompassing. When perceived as an “entire social order,” culture informs the underlying belief systems, worldviews, epistemologies and cosmologies that shape international relations and human interaction with the environment, which lies at the heart of sustainability.

The area of culture has grown in salience in global development issues. The significant role played by cultural factors in the uptake and sustained use of innovations previously (fronted as appropriate technologies) is emerging as an area of interest among people doing work in the developing communities. As Nurse (2006) pointed out “Sustainable development is only achievable if there is harmony and alignment between the objectives of cultural diversity and that of social equity, environmental responsibility and economic viability.” Consequently, there have been some efforts directed at elaborating on the notion of culture as the fourth pillar of sustainable development along with the social, economic and environmental dimensions (see Figure 6).

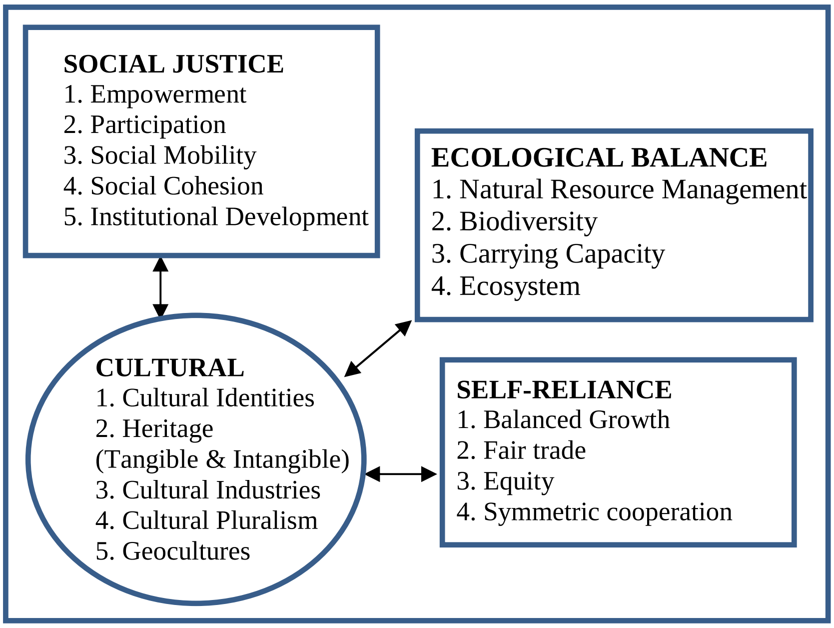

Figure 6: Culture as the Fourth Pillar

The authors operate from the methodological standpoint that “it is the meaning of sustainability in the different contexts to which it is being applied that should be the central concern” (Nurse, 2006 quoting Jacobs, 1994: 241). “Appropriate is not enough” (Frenierre, 2008). Non-conventional approaches required for high performance buildings such as earthen masonry need to be analyzed as elements within wider socio-technical systems consisting also of knowledge, capital, labor, social practice, and cultural meaning (Leach, 1998).

5. Discussion and Further Work

The findings in the preceding section are consistent with problems reported elsewhere. The use of earth-based technologies has been greatly limited by concerns of their physio-mechanical properties. Compressed bricks are also less durable than conventional building materials (Lazarus, 2005, Obonyo et al, 2010a, b). Consequently, there are restrictions on their use. For example, in the New Mexico Building code Section 12.7.4.23, which governs the use of Compressed Earth Block Construction, a general clause “A” forbids their use in any building more than 2 stories in height.

A significant proportion of the physio-mechanical properties can be enhanced through implementing a robust quality control strategy. Some of the errors triggered by reliance on manual processes can be minimized through the design and development of more efficient and more effective production equipment particularly the device used for compressing the bricks. A hydraulic-operated press should be used where possible as it ensures that the forces exerted on the bricks remains the constant throughout the brick production process. In low cost construction applications, these may not be a feasible option. The primary author has in a separate publication described a prototype that demonstrates that with some improvements, the manually operated compression device can be used to produce better quality bricks (Obonyo et al, 2010b).

Despites these developments in enhancing the structural performance of earthen masonry, field studies done by the authors established that a significant proportion of the targeted end users perceive it as a “cheap” material for poor people. Because of such labeling, there is a social stigma associated with the use of the material. Unless such social-cultural issues are adequately addressed, the progress towards sustainable buildings will remain slow. Factors such as the prevalent view of earthen material as a “cheap” material can impede or facilitate the adoption and use of sustainable and resilient building technologies and systems.

Efforts should be made to educate the general public about the capability and quality of earthen construction. There are some examples of simple and elegant, sustainable earthen structures. However, unless someone is specifically searching for earthen masonry, such examples remain largely invisible to the masses. Prior to Satprem Maini of Auroville earth institute shared examples of such work at the 2009 NSF US-Tanzania earthen masonry workshop (see URL 1), with the exception of the first author (Dr Obonyo), all participants were not familiar with his work. A similar thing happened when Satprem made a presentation at the 2010 NSF earthen masonry workshop held in Colorado in 2010 (see URL 2). The mere fact that access to information even among people working in the areas of sustainable technologies is this limited is indicative of a bigger information dissemination problem that proponents of such technologies need to address. Possible solutions that can be explored include the use of famous people such as celebrities. Such people can play a very critical in shaping a new culture in any society. Specific examples include the extensive media coverage of the green, adobe-style residence Stephen Samuelson designed for Will and Jada Pinkett Smith. Though featured in Architectural Digest (see URL 3), it was cross referenced and broadly disseminated through several other avenues thereby promoting public awareness.

These cultural factors discussed in the preceding section are embedded in everyday practices and routines, social norms and values, and aesthetic preferences (Leach, 1998). They are also embedded in the demographic context. Well over half the population of Tanzania, and East Africa, is under 20. This trend is expected to continue. Large waves of migration to cities and among rural areas are already generating an enormous boom in housing and other construction demand in both rural and urban areas that will continue for the next several decades. It is very critical therefore for proponents of sustainable and resilient technologies such as earthen masonry to develop a good understanding of what people in this generation are thinking and what is informing their thinking.

Clearly, communication is a key driver of social acceptance. There are some key questions that need to be addressed: 1) At what scale sustainable technologies such as earthen masonry construction being are talked about? 2) What is the role of an indigenous national lingua franca which is Kiswahili in Tanzania in facilitating societal discourse regarding such technologies? Media campaigns targeting the younger segment of the population are beginning to advantage of social media to inform them about sustainable building options. A Google search on low cost housing options revealed a compressed earth brick story posted on one of the Swahili-medium blogs (see URL 4). In follow up research the authors will investigate other specific ways through which such developments can be strategically used to advance the structural use of earthen construction techniques.

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