Climate-responsive Vernacular Swahili Housing

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ABSTRACT
Vernacular architecture is manifested by a large variety of forms that have a diversity of explanations. This arises from the idea that people of different backgrounds and cultures respond differently to wide-ranging physical environments and the interplay of socio-cultural factors. In this paper, the authors introduce the development of Swahili architecture in Kenya as a response to warm-humid climate. Initially, to encapsulate generic design recommendations for this climate, bio-climatic design responses were derived using Mahoney Tables analysis and reinforced by guidelines obtained from previous research. This revealed conspicuously supportive arguments for lightweight air-permeable buildings in contrast to the existing Swahili form that is noticeably heavyweight. An exploration of the influence of socio-cultural factors and building materials enabled the authors to explain how these and other factors may have masked or overridden the sole effect of climatic parameters resulting in the heavyweight typology. Further, field study investigations of a series of Swahili buildings in Mombasa were conducted during the warmest periods of two years. In this paper the authors focused on the findings from the investigations of one of those buildings. Results showed indoor temperatures lower than corresponding outdoor temperatures by up to 7°C during peak times. Additionally, an occupancy survey conducted during the study periods found that up to 70% (during the warmest months) and 99% (during the coolest months) of the occupants found the studied building thermally comfortable. These analyses of the environmental response of this architectural typology revealed the suitability of plan, form and fabric characteristics. It was concluded that vernacular Swahili housing could offer insights into a different and valid approach for design of passive contemporary buildings within the local warm-humid climate.

Keywords: Swahili architecture, heavyweight architecture, climate-responsive design

INTRODUCTION
Steeped in history, the East African coast covers the coastal region of Kenya, Tanzania and Mozambique. The region developed largely as a result of trans-oceanic trade with Arabs and Indians that was facilitated by alternating monsoon winds. This led to the establishment of a number of coastal towns whose inhabitants share history, language and cultural traditions of which some scholars claim to date to at least 100 A.D (Ghaidan, 1975). The lifestyle of the immigrants combined with the impact of their religion, Islam, and much else of their tradition, had a strong influence on the local inhabitants. This interaction eventually resulted in a distinctive cultural mix referred to as ‘Swahili’ (Oliver, 2007). As a result, there evolved in these coastal cities, a civilization having a character of its own, not least in respect of its architecture. Today, the region continues to thrive as a trade and transport hub.

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WARM – HUMID CLIMATE

This climatic region is located between 15° North and South of the equator. Major cities found within this region of Kenya include Mombasa and Lamu, both of which showcase a rich heritage of Swahili architecture. Little seasonal variation is experienced with no distinct seasons apart from instances of heavy or light rain - slight differences may arise from variations in altitude and exposure. Annual temperature averages range from 27°C to 32°C (daytime) and 21°C to 27°C (night-time) with on and off shore breezes occurring throughout the day. Humidity levels range from 55% to 100%, and with an annual average of 75% (Koenigsberger, Ingersoll, Mayhew, & Szokolay, 1974, p. 26). Due to the regional proximity to the equator, the sun is almost always directly overhead resulting in high radiation intensities, especially at the zenith and the western orientation.

Recommended architectural responses in Warm-Humid climate

A review of past building trends in warm-humid climates for a significant period of the 20th century reveals that the widely accepted house type was lightweight and elevated on stilts so as to enhance full cross ventilation – much like the traditional Malay house type (see Figure 1). The typology showed quick thermal response and would cool down rapidly after sunset while exploiting breezes to offer relief to occupants (Koenigsberger et al., 1974; Szokolay, 1996).

Using the ‘Mahoney tables’ design aid, as introduced by Koenigsberger et al. (1974), recommended bio-climatic design strategies were derived using recorded climate data for Mombasa. This analysis revealed main design recommendations as illustrated in Figure 2. Results revealed a typology that is principally lightweight. It works on the premise that: since the temperature differences between the outside and inside show little variation, the only substantial relief that can be gained by users is from air movement for physiological cooling.

Figure 1 Examples of building types found in warm humid climate regions Top: Traditional Malay house, Malaysia. Bottom: Mijikenda house, Kenya (images produced by the authors).
SWAHILI ARCHITECTURE

The predominant building type is the Swahili house - usually a one, two, or three storey structure set in irregular rectangular plans as shown in Figure 3. Much unlike the aforementioned lightweight typology, it is characterized by heavyweight structures made of thick coral rag walls, timber framed doors and windows, timber balconies and flat coral rag or pitched palm leaf frond roofs (more recently, these were replaced with galvanized iron roofing sheets).

It has been suggested that form is not merely as a result of physical constraints or individual factors, but rather the effect of an entire range of socio-cultural factors, modifications by climate and the availability of materials and technology (Rapoport, 1989). Indeed, initial analysis revealed that the Swahili house manifests a complex interaction of various factors that could be responsible for this deviation from the expected lightweight typology. It is suggested that without compromising on the aesthetics, physical and social functionalities, this architectural type was adapted to fit into the milder warm humid climate. An examination of these influences sought to explain how they may have worked towards creating Swahili architecture as we know it.
Socio-cultural Influence

It has been noted that Swahili architecture borrowed heavily from that of the hot-dry architecture of the Arab world as a direct result of cultural integration (Ghaidan, 1975; Mombasa Municipal Council & National Museums of Kenya, 1995). Indeed, the Islamic heritage of the Swahili people is strongly manifested in their architecture through the form and spatial arrangements of their settlements. Writing on the Swahili concept of space, Ghaidan (1975) suggested that spatial organisation is culturally determined. As is typical of Islamic settlements, aspects of privacy are significant and evident in use of screens and the ‘inward’ organisation of space. Owing to the strict requirements for visual and acoustic privacy it seems highly unlikely that the prescribed lightweight solution would have been deemed socially acceptable. Also, this might explain the prominence of architectural elements such as screened balconies/windows and courtyards which not only enhance privacy through provision of semi-private outdoor spaces but also promote shading and cross ventilation.

In older settlements such as Lamu, buildings were primarily double storied and used mainly for residential purposes (Oliver, 1997). In more recent Swahili settlements such as those in Old Town, Mombasa there is a slight variation to this plan; commercial activities are on the ground floor and living spaces on the top - resulting in a mixed-use building (Mombasa Municipal Council & National Museums of Kenya, 1995). Also evident is the use of ornate architectural elements for aesthetic purposes. This is apparent in the use of ornately carved doors, highly decorated balconies and decorative frieze motifs (figurative representations are rare due to the discouragement of imagery in art by Islam).

Climatic Influence

The typical Swahili town consists of an irregular maze of buildings arranged in dense clusters with streets measuring an average of 1.5 to 6 metres wide and punctuated by a series of open spaces, as shown in Figure 4. Climate analysis revealed that the air temperature in warm humid climates is almost always very near to that of skin temperature. This leaves sensible air movement as the main means of relief through physiological cooling. In response, the streets - considered to be public living rooms and constantly abuzz with activity - are laid out to channel cooling sea breezes, as is the case in Mombasa and Lamu (Ghaidan, 1975). Subsequent work by Deogun, Rodrigues, and Guzman (2013) and field studies conducted by the authors reveals this to be a logical assumption.

Aspects related to enhanced air movement and solar sun shading appeared to be the main strategies showcased in Swahili houses. As air movement is essential to cope with the humid heat, elements such as screened balconies, window shutters and courtyard spaces were used to facilitate effective cross ventilation and thermal regulation. Additionally, narrow streets and alleyways, balconies and small enclosed courtyards played a big role in mitigating high intensity solar radiation as illustrated in Figure 5. By closely aligning the buildings, mutual shading worked by the heat transfer potential through the external walls. Similarly, balconies and window shutters worked as sun shading elements by screening of direct sunlight and prevention of glare. For open spaces, vegetation was used to shield direct solar radiation. To lower the impact of direct solar radiation, it is advisable for buildings along or near the equator to be laid out with the shorter sides facing East and West. However, mainly due to the need to channel breeze or due pre-existing street layout constraints, this was not always possible. To counter this, walls would be effectively shaded to minimise direct insolation as explained earlier. In addition to this, the reflective qualities on the outer surface of the white lime washed walls also helped reduce the impact of incident solar radiation.

The typical Swahili house is relatively deep, has thick walls and roofs and single or double banked rooms. In hot dry climates, use of a heavyweight walls and roofs is valid as the warmth accumulated in the thick fabric is dissipated during the significantly colder nights. In warm-humid regions, heavyweight walls act by minimising heat conductivity potential. Despite the slightly warmer night temperatures, heat that builds up in the heavy fabric during the day may still be dissipated by facilitating air movement during the night or during periods of cooler outdoor temperature - done mainly by opening of windows. Also, where houses had flat coral rag roofs, most were eventually covered with a pitched roof with open
gable ends (Oliver, 1997), thereby creating an attic-type space that effectively reduced the impact of direct solar radiation at the zenith. In Swahili houses, windows had integrated shutters that could be opened and adjusted as necessary to encourage air movement and heat dissipation (see Figure 6). To improve occupant comfort, windows were located at body level and could be up to 2.1 metres in height. Occasionally, the buildup of temperature and humidity indoors may result in an increase above outdoor conditions. However, when the outdoor temperatures are cooler, the shutters could be opened to allow for a comforting breeze. Similarly, the screened balconies would provide zones where one could enjoy the benefit of the sea breeze.

Figure 4 Left: Sectional plan of Old Town, Mombasa. Centre: Children play within one of the open spaces. Right: Ndía Kuu Road, one of the narrow streets - note the mutual shading of buildings (Plan is author-modified from Google Earth, images from the authors).

Figure 5 Shading configurations found in a vernacular Swahili setting (images from the authors).

Figure 6 A typical vernacular Swahili house (Old Post Office) showing A: a screened balcony and B: Window shutter C: Sketch of a typical window in use (images from the authors).

Materials and Construction Influence

Records indicate that earlier settlements had houses made of palm fronds, mangrove poles and wattle, and mud brick. With the onset of immigration, one was held in higher esteem if they owned a ‘stone’ coral house (Ghaidan, 1975). Correspondingly, as benefitted by its readiness of availability and usability, coral became a major building material on the East African coast. It is available in two varieties: hard terrestrial coral and soft reef coral, used for structural and non-structural purposes,
respectively. As is still done in some places today, the coral was burnt to provide the lime for mortar and plaster. The coral walls were made to be notably thick, ranging between 440 to 560mm thick (Ghaidan, 1975, p.24). Field studies by the authors have found evidence of walls of up to 700mm thick in the Old Post Office building that would be able to provide a time-lag of up to 8.5 hours (Kiamba, 2010a). This facilitates delay of peak indoor temperatures thus extending periods of thermal comfort indoors.

As mentioned earlier, in more recent settlements, roofs are made of locally available mangrove poles with palm leaf fronds or galvanized iron sheets with an attic below. Externally, carved doors and intricately designed balconies enhanced the facades. Inside, the use of niches, carved into the walls for display of items and decorative friezes on the plasterwork were used to enrich the interior spaces.

ENVIRONMENTAL RESPONSE

Despite the fact that the Swahili typology (see Figure 7) is a deviation from the lightweight norm, further research has indicated that closely packed heavyweight buildings are potentially feasible for warm humid climates. The basis behind this premise is that the heavyweight buildings which are mostly closed up during the day would allow for significantly lower solar heat gains. At night, they would then be opened up to allow for sufficient cross ventilation that would in effect get rid of stored heat. Szokolay (1996) suggests that the inherent thermal capacity of the heavyweight structure facilitates heat storage, release and dissipation as opposed to a lightweight structure that closely follow outdoor temperature variations. Related studies by Tenorio (2002) reached a similar conclusion.

In an initial field study, temperatures of up to 7°C below that of corresponding outdoor temperatures were recorded during peak outdoor temperature times within a typical vernacular Swahili building (Old Post Office). Further analysis through computer simulations confirmed this reduction in temperature swings inside the house (Kiamba, 2010a, 2010b). This suggested that the heavyweight construction had a significant impact on indoor conditions, especially during the warmest hours of the day. Figure 8 shows corresponding indoor and outdoor daily temperatures recorded on the ground floor of the Old Post Office building, during the initial study period in March, 2010 (Records over the last 50 years indicate that the warmest month of the year in Mombasa is usually March). In a subsequent and substantially longer period of study undertaken in March, 2014 (see Figure 9) corresponding indoor and outdoor daily temperatures recorded in the same location and building show a similar trend. The lower (daytime) and generally more stable indoor temperatures were suggested to be due to thermal inertia provided by the heavyweight fabric and solar sun shading that effectively reduced the rate of and amount of heat gain absorbed. Also, air movement through screened openings not only provided physiological cooling for occupants but also promoted indoor heat dissipation through cross-ventilation.

![Figure 7: How a typical vernacular Swahili house (Old Post Office) works (image produced by the authors).](image-url)
A post occupancy study was undertaken to determine occupant satisfaction levels, including that of thermal comfort, within the building. The respondents consisted of 10 occupants, both male and female, ranging from 55 to 18 years of age, of generally good health and who were accustomed to warm-humid tropical climatic conditions. Typically, occupants had a metabolic rate ranging from 0.7 to 1.6 met and a clothing insulating value of less than 0.6 clo. It was established that up to 70% of the occupants found the building thermally comfortable and satisfactory during both periods of field study (conducted during the warmest time of the year) and up to 99% during the cooler months. For 95% of occupants, access to ventilation controls (primarily windows) was satisfactory and enabled them to adjust indoor conditions as required. As the building is naturally ventilated all year round, air movement is largely dependent on channeling of breezes. Whereas mechanical fans were installed in the late 1970s, occupants noted that they preferred not to use them, citing that the incoming sea breeze was adequate. Indeed, the authors found that it was quite pleasant to sit by the windows or in the balconies as one would experience a refreshing sea breeze, especially in the afternoons. Occupants indicated that the only time fans tended to be used was if there was an increase in the number of users of a space, and even then, mainly in the afternoon period in the warmest periods of the year. During the study, recorded outdoor air velocity was

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Figure 8: Recorded temperatures for corresponding indoor (T<sub>i</sub>) and outdoor (T<sub>o</sub>) temperatures for a typical Swahili house (Old Post Office) in Mombasa (graph produced by authors).

Figure 9: Recorded temperatures for corresponding indoor (T<sub>i</sub>) and outdoor (T<sub>o</sub>) temperatures for a Swahili house (Old Post Office) in Mombasa (graph produced by authors).
almost always greater than 0.25 m/s with monthly averages of approximately 3.7 m/s. Similarly, indoor air velocity measurements varied with recordings of 0.2 to 2 m/s measured at window openings with higher readings in the afternoons, indicating that air movement levels could possibly have aided comfort.

CONCLUSION

Swahili houses serve as an example of a vernacular typology that developed as a result of the interplay of social-cultural and physical factors. An analysis of these factors has shown how this seemingly ‘out of place’ architecture came to be influenced by its interactions over a long period of time. In the initial part of the study, design recommendations were found to pointedly recommend a lightweight solution that capitalises on low thermal capacity and the physiological cooling effect of sensible air movement to make higher temperatures acceptable to users. On observation, Swahili architecture was found to be the anti-thesis of this strategy as it is densely packed, notably heavyweight and with comparatively fewer and smaller openings. Initial analysis suggests that the Swahili house exhibits a potentially suitable architectural and environmental response to the local context and climate. Identified design strategies included the use of:

1. Heavyweight building fabric to reduce the impact of solar radiation.
2. Mutual shading of the 2 to 3 storey high buildings to mitigate heat gain.
3. Pitched roof with a ventilated attic space to reduce impact of solar radiation at the zenith.
4. Screened balconies and shuttered windows to promote thermal regulation by channeling breezes and sun shading while meeting requirements for acoustic and visual privacy.
5. Light coloured envelopes enhanced reflective capabilities of exposed wall and roof surfaces.

Having thrived over centuries, Swahili architecture is manifested by a distinct typology that enriches the fringe of the East African coast. Even so, with increasingly rapid urbanization and the influence of 20th century modern architecture, cities in the region continue to grapple with deterioration of their built environment. This ‘newer’ and mainly lightweight architecture has been marked by the introduction of active measures that are costly and unsustainable. This has created the need to find viable climate responsive design alternatives. It is possible that implementable solutions lie in the architecture of vernacular Swahili housing - this paper is the start of this investigation. Although initial investigations suggest that the typology in combination with the aforementioned strategies is potentially an appropriate strategy in moderating the impact of the external climate on indoor conditions, further analysis is currently underway to outline in greater detail the suitability of this approach to warm-humid climate.

REFERENCES