Mitigating High Energy Consumption for Residential Buildings in The Gambia.

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Abstract

As the price of energy goes up, more and more concern has been focused on the sustainable development of residential houses. One of the best solutions would be construction of low energy consuming "passive" houses. A study of residential buildings in The Gambia shows that most occupants of the buildings have persistent and growing problems with the indoor environment. Most buildings are characterized by poor design in relation to the climate, which requires a great deal of energy for cooling during extreme climate. Other problems are poor natural ventilation, inadequate surface volume ratio and poor building orientation. The main question analyzed was whether comfort is achievable solely by the use of passive design strategies, or if energy consuming mechanical systems are required. However, there is no official residential passive housing standard at the present time in The Gambia. This paper focus on the experimental and numerical investigations to determine how the building construction mass, the climatic parameters and the management of air changes rates behave on the effectiveness of natural ventilation and on indoor comfort conditions. Using portable thermometers monitoring instruments data were acquired during a period of a hottest summer phase, in parallel with occupancy survey. Passive cooling techniques can reduce the peak cooling load in buildings, thus reducing the size of the air conditioning equipment and the period for which it is generally required. This paper reviews and critically analyzes various passive cooling techniques and their role in providing thermal comfort and its significance in energy conservation.

Keywords-

Climate; Environment; Innovation; Passive House; Ventilation; Residential Building; The Gambia.

1. Introduction

Technologies and measures which are aimed at reducing the use of energy in buildings could have several advantages, such as lower energy bills, increasing comfort of living or working, and reduced impact on the environment, including reduction of CO2 emissions. [1] the buildings sector has the greatest potential for climate change mitigation The options considered for energy savings particularly leading to CO_2 emission reductions include the following: Use of renewables for heating, cooling and electricity; improvements to the building envelope, including materials, natural ventilation and daylighting De Dear, Richard J., et al. [2]. The hot dry climate with its extremely high temperatures and intense solar radiation is becoming hotter and drier in this era of climate change and global warming. Thus providing for indoor thermal comfort and reducing energy use in residential buildings is become in increasingly difficult. This has called for new ways of thinking and re-evaluation of the existing methods of tackling this problem.

Almost all the residential buildings in The Gambia depend on artificial lighting and ventilation. However, frequent power disruption and load shedding in The Gambia, sometimes over six hours or more a day, amid hot and dry conditions, have made the life of urban dwellers miserable Sanneh, Edward Saja, et al.[3]. As the load-shedding situation continues to worsen, the excessive heat drives people to use more electricity at their homes and offices. The situation becomes worse during the peak dry season from mid-March to early May when the ambient temperature becomes very high. During this period, the demand for electricity use goes up to its highest level because of hot weather, as well as a huge need for cooling energy.

Reduction of energy consumption in buildings can be achieved by simple methods and techniques using an appropriate building design and energy-efficient system and technology, such as passive cooling system. The passive air cooling system provides cooling through the use of passive process without using customary mechanical units such as fan, compressor, etc. in regions where cooling is a dominant problem. Passive cooling strategy maximizes the efficiency of the building envelope by minimizing heat gain from the external sources and assisting heat loss to the natural sources of cooling such as air movement, cooling breezes, evaporation and earth coupling. The principle of passive cooling is to prevent heat from getting into a building during a warm day and bringing in cool air from outside when the temperature drops.

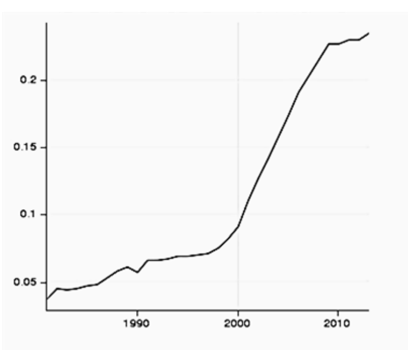

Figure 1. net energy consumption

Particularly energy-efficient buildings offer economic benefits in the face of rising energy prices, help combat climate change and provide a very pleasant room temperature. In The Gambia buildings that meet the low-energy house standard has not been officially been pronounce. Africa is said to be the hottest continent as well as the world's largest consumer of biomass energy, which accounts for two-third of total energy consumption, contributing about 3.7% of total world energy-related carbon emissions. According to UNEP [4] annual report, "per capita levels of commercial energy consumption and energy related carbon emissions tend to be lower in Africa than in developed countries, with the levels projected to remain roughly flat through 2020." [5] Give a clue to future impacts of climate change. The net energy consumption of the Gambia, as of 2011, is 0.2 TWh. See figure 1. For detail

2. Research Problem Statement

In order to achieve the goals two research objectives were laid. The key research questions articulated to facilitate the inquiry are:

- The potential for energy saving: the comparison of Design and operational effects
- The possibility of house design for mixed-mode Operation.

In order to identify innovative concrete technology that are sustainable, an intensive review of literature was done to identify the various innovation in concrete technology being used worldwide that are environmentally friendly. The purpose of this paper is to study the feasibility of passive house in The Gambia. In order to achieve this goal, several passive house projects in hot humid regions in Africa have been studied to gain valuable experience and mature technical skills. This will be of great help for the just started passive house field in The Gambia. However, economic aspect and technology aspect will be analyzed for developing passive house. It is not only getting a better understands of passive house from both technical and economic aspect, but also the paper will include the information and technique use on passive houses based on the examples in Europe.

3. Research Methods

3.1 Characteristic of local climate

The Greater Banjul area is about 93sq km and a population size of 357,000 (26% of the total country's population). Greater Banjul Area, which includes the City of Banjul and the Kanifing Municipal Council. Is located in the west-eastern part of The Gambia at latitude: 13° 27' 9.86" N and Longitude: 16° 34' 40.91" W 9º 49'E [6]. The Gambia's climate is a sub-tropical climate with two variations of distinct dry and rainy seasons. The dry season is between November and May and a rainy season from June to mid-October, due to the African monsoon. The dry season weather in the Gambia is influence by the northeasterly dry winds call Hamattan from the Sahara desert [7]. See figure 2, 3 below for detail. The raining season it's hot during the day, with highs around 32°C to 34°C on the coast and 34°C to 36 °C in the inland areas, but with peaks of 38°C to 40°C even on the coast. The wet season is in the summer beginning June until October.

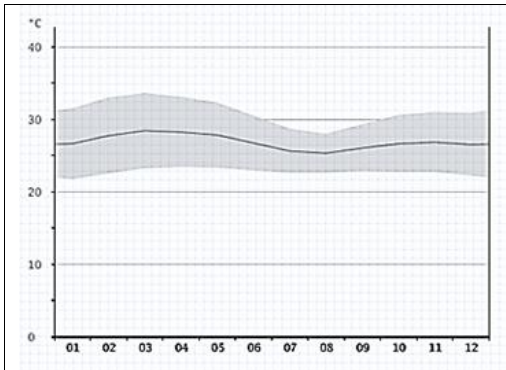

Figure 2. Shows The temperature in March averages 28.4 °C. The coldest month, August with temperatures averaging 25.3 °C.

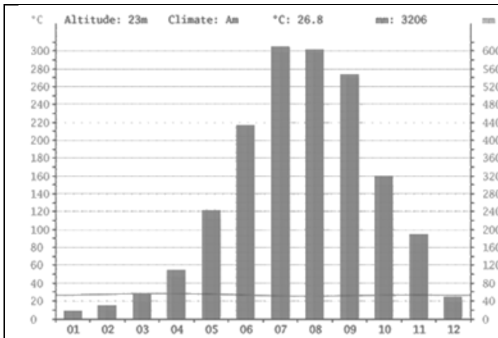

Figure 3. The driest month is January, with 18 mm of rain. Most of the precipitation here falls in July, averaging 608 mm.

3.2 Outline of survey

In this study, 100 structured questionnaires were distributed to samples of the target population in eight wards in Kanifing municipality. The questionnaire, which had the aim to get information on the user-satisfaction and on the building use, covers the following issues. Temperature and humidity (comfort) from the user point of view. The questionnaire were distributed to

Each household depending on the number of adults in the family, using a short term monitoring with portable instruments thermometers was applied with the aim to assess the main thermal performance of the buildings. Thermometers were fixed onto the wall at window level, one for the living room, bedroom and the other for outside under a shaded wall. Residents were required to fill the questionnaires while the research personnel record the environmental measurement three times in a day 7-10am, 12-3pm, and 5-8pm. The contents of the questionnaires mainly include resident's demographic and socio economics characteristics, building characteristics, thermal comfort perception of the living spaces etc. The temperature measurements in the buildings shows that the conditions are bad since the indoor temperature rises to extremely high value of 37ºC in the afternoon see figure 4.1,4.2

3.3 Outcome of investigation

Cement sand Crete structure plays an important role in the building enclosure with the proportion of 48%, while 20% of the buildings are built with mud bricks and another 15% with stone structures, 6% with burnt clay bricks and compressed earth bricks while just 5% are built of thatch. The mean size of sleeping room per-household floor areas is from 10.28m 2 while the average room height is 2.7m.The average window area is 0.89m 2. The windows play a dominant role in inducing indoor ventilation due to wind forces. See figure 5 below. From the environmental measurement carried out, the temperature measurements in the buildings shows that the conditions are bad since the indoor temperature rises to extremely high value of 38ºC in the afternoon as shown in figure 4.3, 4.4

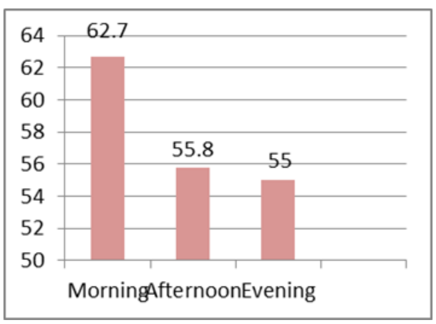

Figure 4.3 indoor relative humidity

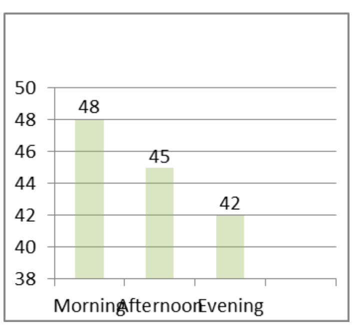

Figure 4.4 Outdoor relative humidity

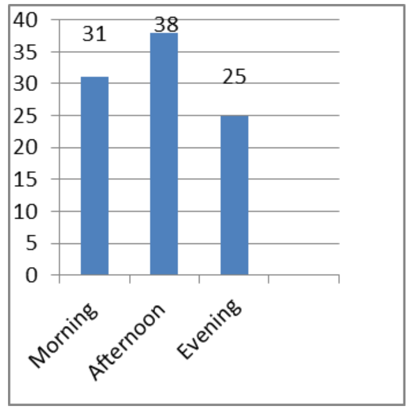

Figure 4.1 Mean indoor temperature

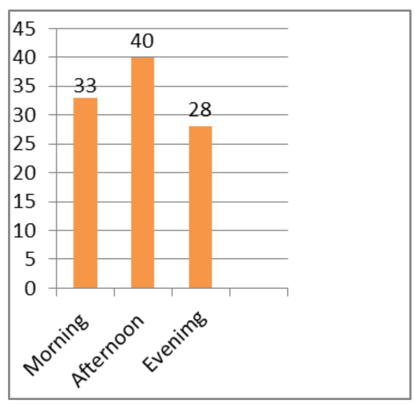

Figure 4.2 mean outdoor temperature

4. The need and benefits of passive design approach in residential buildings

To be comfortable, buildings in all Gambian climates require some form of cooling at some time of the year. There are many ways you can design or modify your home to achieve comfort through passive (nonmechanical) cooling, as well as hybrid approaches which utilize mechanical cooling systems.

The quality of lives of human beings to a very large extent depends on the quality of their indoor environments because people spend most of their time indoors. Human beings partake in various activities within building enclosures and these activities can only be performed best when the environmental conditions are favorable. The hot-dry climate poses environmental challenges of high temperature and this extreme temperature has to be catered for at the design stage to avoid absolute dependence on active energy systems for indoor comfort. In the Gambia, where power supply is epileptic and erratic, most residential buildings depend on energy excessively to attain indoor comfort particularly in buildings that are not passively design. Passive design is a low energy-intensive method of keeping a building cool by relying on architectural design Knowles, Ralph L. [8]. Heat avoidance techniques, natural lighting and natural cooling methods are incorporated in the structure to minimize energy consumption while improving the indoor comfort level Santamouris, Matheos, and Dimosthénis [9]. The benefits of passive design are obvious; considerable peak load reduction for the utility company, improved comfort, lower utility bills and little additional cost to the builder.

4.1 Ecology and Sustainability

Passive Houses are eco-friendly by definition [10].They use extremely little primary energy, leaving sufficient energy resources for all future generations without causing any environmental damage. This seems so obvious that there is no immediate need for additional illustrations. It is rather worth mentioning though, that the Passive House standard provides this level of sustainability for anyone wishing to build a new construction or renovating an older one at an affordable price contribution to protecting the environment [11].

4.2 Heat gain prevention techniques

The interaction of solar radiation by the building is the source of maximum heat gain inside the building space. The natural way to cool a building, therefore, is to minimize the incident solar radiation, proper orientation of the building, adequate layout with respect to the neighboring buildings and by using proper shading devices to help control the incident solar radiation on a building effectively Akbari et al. [12] Good shading strategies help to save 10%-20% of energy for cooling. Properly designed roof overhangs can provide adequate sun protection, especially for south facing surfaces. Vertical shading devices such as trees, trellises, trellised vines, shutters, shading screens awnings and exterior roll blinds are also effective. [13]. these options are recommended for east-facing and west-facing windows and walls. If ambient temperatures are higher than the room temperature, heat enters into the building by convection due to undesirable ventilation, which needs to be reduced to the minimum possible level. Adequate wind shelter and sealing of windows reduces the air infiltration and this requires proper planning and landscaping. See figuer 5,5.1 for detail.

4.3 Window opening type and opening percentages or angles

Several studies have been carried out in recent years regarding air change rates, indoor air quality and window opening habits in residential buildings [14]. There is a large variety of window opening types available. Different window opening types have different properties regarding weather protection, maximum achievable ventilation rates, adjustability of opening sizes and possible interferences of opened windows with furniture. In warm climates, the effective opening size and the adjustability might be more important than protection from weather or rain. Generally, the choice of window opening types can be essential for the resulting air exchange rates as well as for the resulting user behavior. Some window opening types can be adjusted either steeples or in several steps like for example sliding, pivoted, side or top hung windows. Others, e.g. bottom hung windows in contrast are typically either opened to a fixed angle or closed. Figure 5 provides an overview on the properties of different window opening types. Therefore it can be assumed that opening properties predefine the related window opening behavior. [15] Indicate that as long as window design allows, occupants take advantage of continuous window opening adjustment possibilities.

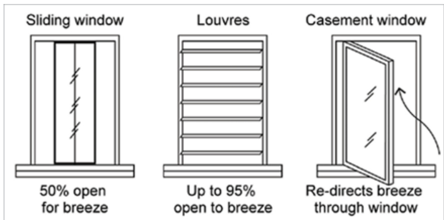

Figure 5. diagram shows three different types of windows:

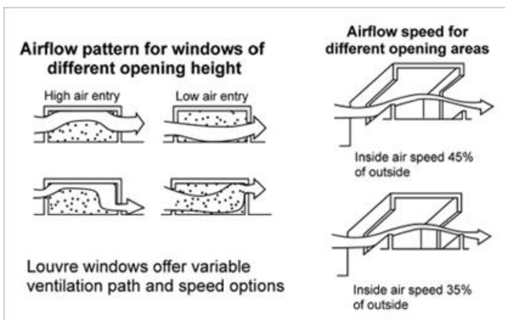

Figure 5.1 How different openings can affect the design

4.4 Proper Orientation of Building

In the Gambia, proper orientation of most houses are not given due considerations. According to Knowles, et al. [16,17] the longer axis of the building should laid along east-west direction for minimum solar heat gain by the building envelope [18,19,20] Proper orientation of buildings to reduce the impact of unfavorable weather conditions like solar radiation, driving rain and thunderstorm. In the house, the rooms should be located in such a way that the ones frequently used should be elongated along the east- west dimensions to mitigate heat gain in summer and also making efficient use of sun. The passive design feature on orienting the longer axis of the building towards east-west direction, as suggested [21] may not always be possible, especially due to actual orientation of the site, that is, when the site itself is longer on the west and east sides. In such a case, the west facade needs more attention because it heats up in the afternoon and important rooms such as bedrooms are generally used later during the day when residents return from office. The east side is less problematic as it warm only in the morning when only few households occupy the major rooms.

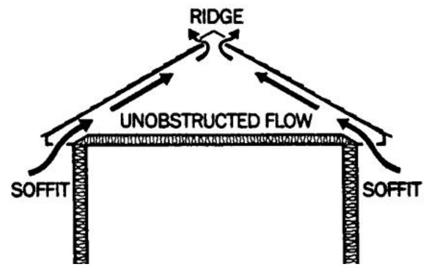

Figure 5.2 This picture shows the typical attic ventilation requirements as well as how ridge vents work. Click image to enlarge

4.5 Utilizing natural resources as building materials

Natural Building includes a variety of building techniques that focus on creating sustainable buildings which minimize their negative ecological impact [22]. Natural Buildings often rely on non-industrial, minimally processed, locally available, and renewable materials and can also utilize recycled or salvaged materials. Natural Building ideally incorporates sustainable design practices to integrate the building into its environment. It may also integrate electricity production, water catchment, passive heating and cooling, and alternative waste-treatment.

In the Gambia, buildings are usually built with cement blocks but in recent times, in the construction industry the use of local materials is not being promoted and a lot of research should be done to look into its efficiency and sustainability for achieving good indoor climate. In almost all localities, nature has provided us with some good quality materials to build with and some of these materials require little processing or transporting [23]. Some of these materials are renewable resources like trees and straw, and some may be so abundant that their supply seems almost inexhaustible like rocks, clay and sand. One of the beauties of building with local materials is that they seem to fit well with the feeling of the place naturally [24].

5. Improving thermal comfort and natural cooling in residential buildings

Some common design elements that directly or indirectly affect thermal comfort conditions and thereby the energy consumption in a building includes:

5.1 Vegetation, landscaping and greenery

Landscaping which can be used to enhance a passive cooling system. The use of vegetation to shade a house is a cooling technique that can be very effective [25]. A well-placed plant can deliver effective, cool shade, as well as add to the aesthetic value of a building. Trees control climate by moderating the effects of the sun, rain and wind. Leaves absorb and filter the sun's radiant energy, keeping things cool in summer. Trees also preserve warmth by providing a screen from harsh wind [26, 27]. In addition to influencing wind speed and direction, they shield us from the downfall of rain, sleet and hail. Trees also lower the air temperature and reduce the heat intensity of the greenhouse effect by maintaining low levels of carbon dioxide.

5.2 Courtyard Basics

A courtyard is also an open-air space. It typically offers little to no cover from the elements. Buildings and homes are built up around an outdoor area, which is then outfitted with benches, paved areas, plants and other elements to create an aesthetically pleasing and functional design.

5.3 Interior layouts

A good interior layout will facilitate many of the passive strategies recommended in this paper. Following is shown the ideal location for the different rooms of the houses.

- Kitchens should ideally be located within the building in such a way as to avoid over-heating, either the kitchen itself or the rest of the building. One way to ensure this is to avoid placing kitchens on the western elevation. In most instances, this will cause overheating in the warm summer months, so an ideal location for a kitchen is on the eastern side of the building. This catches the morning sun but not the warmer, late afternoon sun.
- Rooms that are occupied predominantly in the evening should be located on the western side of the building, in order to take advantage of the evening sun.
- Frequently used rooms, should be located on the southern side where they can be warmed but sunlight throughout the day.
- Bedrooms generally require less heat. Decisions for the location of bedrooms can largely be based on aesthetics and occupant or designer preferences in addition to thermal comfort considerations.

6. Conclusion

Gambia is the only country in the world that pays the highest electricity bills according to European Union (EU) programed manager. Siylvain Lequere. However, this research work has shown that the thermal discomfort in the study area is aggravated by the epileptic power supply, high cost of air conditioning systems, absence or scanty vegetation around houses, improper positioning of windows for cross ventilation, lack or poor insulation of floors, walls and roofs, activities of non-professionals in the industry, use of good conducting materials on buildings, and the use of incandescent bulbs and kerosene lamps as lighting devices. By adopting the general rule for energy efficient building in The Gambia as follows:

- Building openings should be of suitable size and should be orientated to enable natural airflow from the windward to the leeward side. A building should not have too deep a plan and should be relatively free of major obstructions within the interior.
- Retractable awnings or fixed overhangs over north-facing windows can provide complete shading from the direct sun during summer, and still enable solar penetration in winter. By adapting to these design strategies it will limit the energy demand for cooling and will also result to an adapted architecture to the climatic environment which will encourage innovation design solutions for building professionals in hot-dry climate.

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