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A Preliminary Exploration Into The Interdependence of Climate And Energy Use in Sustainable Building Design in South-East Nigeria

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Abstract
We discuss the techniques and principles of sustainable building design by proposing an interaction between climate, energy use and comfort in buildings in South East Nigeria. It ensures reduction of energy consumption and provides comfort in homes and offices, especially in view of irregular and epileptic power supply.

Keywords: energy use, climate, comfort in buildings, sustainable buildings

1.0 Introduction

Most countries in the tropics have a long history of sustainable buildings, in their traditional architecture (Laar, 2002). In the hot and humid regions such as the South East of Nigeria, natural ventilation and shading systems were perfectly adapted to the local climate. With the introduction of air-conditioning systems, architecture became independent of climate and pure aesthetics became prevalent, most clearly expressed in the form of fully glazed office buildings, and residential home were lights are on all day long (Laar, 2002).

Cities and buildings planned and designed following historical precedents are attuned to particular climatic and cultural environments. In recent times many building developments have been insensitive to climate, thereby requiring large energy resources to allow the inhabitants to be comfortable (Grimmond, 2009). However with environmental protection a major global problem now, man has to reduce his energy consumption (Omer, 2008). A poorly designed energy inefficient building has a potential long term impact, both on its users and the environment (Lawal and Akarakiri, 2010).

In the tropics the natural climate is a major resource that should be used to achieve comfort in buildings. Energy efficiency improvements in buildings will make significant contribution towards the goal of achieving sustainable development in developing nations (Lawal and Akarakiri, 2010).

This work looks at the characteristics of the tropical climate and its relevance to building design. It also traces the relationship between energy use, comfort and building design in a warm tropical climate.

1.1 Climate and Building Design in the South-East Nigeria

South-East Nigeria belongs to the warm humid tropical climate zone. Tropical climate is that where heat is the dominant problem and for the greater part of the year buildings serve to keep the occupants cool rather than warm.

For building design purposes the tropical regions of the world are classified into three categories; Hot / warm and arid/semi arid regions, Warm and humid regions, Temperate, both arid and humid regions (Ajibola, 2001). He further asserts that a climatic classification useful for architectural building design must have a combined effect of temperature, relative humidity, mean radiation temperature and wind velocity.

Buildings in the tropics are constantly exposed to solar radiation daily. As a result, building design should aim at minimizing heat gain indoors and maximizing evaporative cooling, so that users of these spaces can have adequate thermal comfort. Buildings should also respond to passive energy and have minimal use of active energy for economic viability. To meet the above requirements, buildings should be bioclimatic responsive. A climatic classification useful for architectural building design must have a

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combined effect of temperature, relative humidity, mean radiation, temperature and velocity (Ajibola, 2001)

1.2 Climate-Sensitive Design in Warm-Humid Regions

Environmental protection has become a major global problem, and man has no choice but to reduce his energy consumption. Climatic design is one of the best approaches to reduce the energy cost in buildings, and the best defence against the stress of the climate. Buildings should be designed according to the climate of the site, reducing the need for mechanical cooling, thereby using maximum natural energy to create a pleasant environment inside the built envelope (Omer, 2008).

Several local micro-climate and site factors affect the actual environmental conditions of buildings. In making a climatic design the following site related factors should be considered: topography – elevation, slopes, hills and valleys and ground surface conditions; vegetation – height, mass, silhouette, texture, location, and growth patterns; built forms - nearby buildings, surface conditions.

The design variables in architectural expression that are important include: shape – surface to volume ratio, orientation and building height; building Fabric – materials and construction, thermal insulation, surface qualities, shading and sun control; fenestration – the size, position and orientation of windows, window glaze materials, external and internal shading devices; ventilation – air- tightness, outdoor fresh air, cross ventilation and natural ventilation.

2.0 Energy Use in Buildings

Energy provides comfort in buildings. For Nigeria, the main form of energy is electric power and different building types use energy in different ways, and therefore require different strategies. In an office building for example lighting is paramount and occupancy is during the day. Day lighting will be a principal strategy. For a hotel, water heating may be the largest use of energy, and day lighting may be less important since primary occupancy is at night.

Though it is appropriate to consider day lighting and water heating for all buildings, the difference of the end uses has implications for building design. The energy strategies used to address the different requirements will influence the mechanical systems in different ways.

In the South Eastern part of Nigeria energy is usually used in buildings to provide four main types of services: space cooling, water heating, lighting, and to power appliances. The actual amount of energy used in buildings results from a complex interaction between built form, location, energy using-equipment, occupants and the affordability of fuel (Wright, 2008).

Energy use in housing contributes to climate change, improvements therefore in energy efficiency has two potential benefits – by avoiding extremes of temperature, it protects the health of the occupiers for affordable costs; by reducing energy use it reduces the contribution to climate change from the housing sector.

Energy efficiency in buildings can be achieved by: passive solar design of buildings; use of renewable sources of energy; user-end measures in energy conservation. Passive design features of a building include orientation, shading, thermal conductivity of materials, type of glazing, roof design and massing. These design factors influence the building's energy consumption for heating or cooling, ventilation and day lighting.

2.1 Energy Efficiency in Nigeria

Most of the energy generated in Nigeria comes from fossil fuel (oil and gas). For every kilowatt of electricity consumed there is an equivalent emission of greenhouse gases (GHGs). Energy efficiency can help to reduce the emission of GHGs and reduce the reliance on petroleum.

Electricity demand in Nigeria is very high and has never been met. About 60% of Nigerians do not have access to electricity (CREDC 2009). This is because electricity generation is highly inadequate, hence the need to imbibe energy efficiency culture. However there are several barriers to energy efficiency development in Nigeria. These include; lack of policy and legislation; lack of awareness; lack of trained personnel and energy efficiency personnel; importation of used machinery; lack of research materials on energy efficiency; inefficient metering system and low electricity pricing; proliferation of inefficient equipment and desire to minimize initial cost.

2.2 Comfort in Buildings

Comfort is an abstract concept relating to contentment and well being, it goes beyond health needs to personal preferences (Stoops, 2004). Comfort standards are social constructs which reflect the beliefs, values, expectations and aspirations of those who construct them (Chappells, 2005).

Yehuda (2007) defines thermal comfort as a mental state induced by physiological conditions in which a human being feels comfortable. It differs with individuals, type of clothing, nature of activity being carried on and sex. This implies that comfort zones varies; the British comfort zone lies between 58 to 70^{o} F; United States 69 to 80^{o} F; and in the tropics 74 to 85^{o} F.

Thermal comfort is considered as a major influencing factor in indoor comfort level. Air temperature and relative humidity have been identified as the important factors in determining the comfort level in the hot and warm humid climate zone. Current research evidence by (Mallick, 1996; Feriadi, 2004; Karyono 2000) shows that International Standards such as American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) Standard which is often used to determine the thermal comfort condition in a building by architects and other professionals is inadequate for predicting the comfort conditions in tropical climate especially in the hot humid climate. This implies that more research is needed for this climate zone to establish a more relevant index or range of comfortable temperature for the tropics.

There are five parameters that are important in determining the indoor thermal comfort of a building. The physical parameters are air temperature, air movement and relative humidity and the external parameters are the clothing and activity of the occupants. However not much is known about how these external parameters act in the tropics as most studies in this area have been in the temperate climate regions. Based on the Equatorial Climate Index (ECI), the ideal air velocity is 0.2m/s with relative humidity of 70% and ideal temperature of 28.86^{o} Celsius. The major handicap of this prediction is that it is based only on the dry and wet bulb temperature and wind speed excluding activity level and clothing value in its derivation. These two factors are important parameters because they are closely related to social and cultural influences. Mallick (1996) in his investigations discovered that people are highly adaptive to the surrounding environment, and the basic modes of this adaptation are change in behavioural patterns and lifestyle preferences.

The typical climate of the hot and humid tropics is high air temperature at an average of 28^{o} Celsius with an average of 80% of relative humidity. These factors are the biggest challenge faced by architects in designing passive cooling buildings.

Further Chappells *et al.* (2005), postulates two contrasting concepts of comfort – one that comfort is a universally definable state of affairs and the other that it is a socio-cultural achievement. The two comforts however have different consequences for energy and environmental policy as can be seen in the Table 1. WHO (2007) notes that thermal comfort in dwellings depends upon energy policy as well as the quality of housing. The WHO comfort condition of 21^{o}C for people in a living room and 18^{o}C elsewhere in the home for residential houses is normally used as standard (Darby, 2005).

3.0 Principles for Sustainable Building Design

Passive design strategies reduce active energy budget of a building by close attention to passive energy/climate responsive design (CRD) parameters like building orientation, ventilation, illumination, location, size and orientation of windows, vegetation, day-lighting and energy transfer properties of the building materials used. (Lawal and Akarakiri, 2010). Passive design makes use of natural energy in the environment which is available to the building through the use of the microclimate, building form and fabric.

Passive buildings are bioclimatic and demands and encourages the interaction of many factors including the best use of the physical site conditions, control of the complete thermal envelope of the building, cost considerations, thermal and visual comforts and the lifestyle of the occupants. The main objective of passive design strategies is to achieve thermal comfort and conserve energy.

Ventilation is critical in the tropics and building designs must make it possible for maximum wind penetration and provide shade during thermally critical times of the day to enhance thermal comfort. The abundance of natural vegetation within the zone can be utilized to provide shade and evaporative cooling. Vegetation provides thermal benefits, remove air pollutants and absorb CO_2, relieve human stress, and mitigate run-off intensity during storms (Grimmond 2009).

An important component of passive cooling is the location of buildings. The ideal bioclimatic layout of tropical buildings is low density in dispersed patterns with access to ventilation on all sides by porches and verandahs. Low building densities have many advantages as is seen in traditional environments such as: maximum flow of air around all sides of the buildings; use of outdoor space as an alternative or complement to indoor functions; providing privacy by distance so that air movement is not impeded by walls (Lomas 2007). This is also clearly demonstrated at the Government Reserved Area (GRA) Enugu.

Application of simple passive cooling measures is effective in reducing the cooling load of buildings in hot and humid climates such as in the South Eastern parts of Nigeria. Over forty percent (40%) reductions can be achieved using a combination of well-established technologies such as glazing, shading, insulation, and natural ventilation (Omer 2008). Sustainable buildings are energy-efficient and friendly to the environment; promote healthy ways of living and be affordable for families with average income (Knudstrup 2009).

3.1 Energy-use-Building-Human Interactions

Energy use in buildings is closely linked to their operational and space utilization characteristics and the behavior of their occupants (Hoes 2009). The occupants have influence due to their presence and activities in the building and due to controls with the aim of improving indoor environmental conditions (thermal, air quality, light, noise). Furthermore (Robinson 2007) asserts that the most complex processes taking place within buildings are those that result from human behavior. These interactions have important implications for building energy balance, affecting both indoor microclimate and demands for applied energy.

Robinson (2007) identifies human interactions which influence the energy balance as interactions with-window and door openings; shading devices/blinds; lighting controls; electrical appliances; heating, ventilation and cooling system controls. The use and control of wind is an important factor in the design of bioclimatic buildings (Lomas 2007).

4.0 Discussion

To progress in the area of sustainable development in the built environment there must be a change in concept of architecture design. There is need for a

Table 1: Contrasting concepts of comfort and what they mean for policy and practice.

	Comfort as a universally definable state of affairs	**Comfort as a socio-cultural achievement**
Theory of comfort	Heat balance model	Historical and culturally specific experience
Characteristics of comfort	Definable universal condition	Social phenomenon
How to provide comfort	Deliver specified comfort conditions	Provide opportunities in which people make themselves comfortable, whatever that means
Policy response to the challenges of climate change	Develop and promote technical fixes and so increase the efficiency with which comfortable conditions are provided.	Debate and explore diverse meanings of comfort; construct new and varied infrastructures, contexts and experiences of comfort.

Source: Building Research and Information, 2005.

new approach, which will respect climate and culture of the South East region and therefore create an ecological and cultural sustainability in the built environment.

A lot of research and development work has to be done in order to achieve sustainability, and this calls for expansion in the training curriculum of future architects and engineers, and introducing inter disciplinary projects at faculties; initiating prototype and pilot projects for research and development; encouraging international cooperation to benefit from available knowledge in other countries and to join in developing new solutions; integrating energy calculations, ratings and certification in the design process.

Energy efficiency of new housing can be controlled through regulations; there is need for a review of the building code and building plan approval requirements to include provisions for energy standards. The Nigerian Architect should strive to design passive buildings with minimum technology that require the participation of the users to attain comfort. Users should be able to manipulate windows, louvers, screens, fans, doors and other elements to adjust the microclimate within the building as the external climate requires.

He must learn to design for the comfort of his occupants by giving full consideration to our traditional and cultural way of life such as integrating outside areas which will provide shade and a relaxing environment for social gatherings, evening entertainment, food preparation and domestic work within residential compounds.

The move towards energy efficiency in the built environment can only be supported and be possible when backed by research, government policy and legislature. The professionals in the built environment (architects, engineers, planners etc), university faculties, research institutes and centers in the environment have the expertise to review existing policies and laws (national energy policy, building code, building approval criteria) and make appropriate recommendations to Government.

5.0 Conclusion

The environmental function of a building is to mediate between the variable external climate and the stable conditions required for human comfort. Bioclimatic awareness in urban planning, architectural design, will result in lower energy consumption, relatively comfortable living conditions and a more benign effect on the physical environment. Bioclimatic practices or green architectural strategies if adopted will positively require the active intervention of users to regulate the internal climate and generate comfort.

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