

Sustainable Construction in Ghana - Factors That Influence the Extensive Use of Glass on Facades of Office Buildings in Accra, Ghana.

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Abstract - Sustainable construction enables stakeholders in construction industries to be mindful of the way and manner construction is undertaken, in order to minimise the misuse of natural resources and pollution of the environment. Buildings in Ghana which is in a tropical climatic region were tailored to make the most use of the climatic elements to give comfort to occupants. However with the advent of mechanical aids like air-conditioning, extractor fans and artificial lighting, these climatic conditions have been relegated to the background, whilst building styles from other climatic regions have been copied. Glass is now being used extensively on facades of buildings, especially office buildings. This raises a few questions in relation to sustainable construction. In order to answer these questions there is the need to find out why the increase in extensive use of glass in buildings.

Keywords: *sustainability, Sustainable Construction, Tropical Buildings, Glass facades*

INTRODUCTION

The Brubdtland report (1985) brought to the fore the need for nations to consider the harm that is being done to the earth and biosphere by actions of human beings. Man's quest to develop has resulted in the depletion of the earth's resources. Many countries especially in the developed countries have set out policies to check actions that are likely to compromise the sustainability of the earth and its resources. Sustainability has been defined by the United States Environmental Protection Agency as 'social and environmental practices that protect and enhance the human and natural resources needed by future generations to enjoy a quality of life equal to or greater than our own'. www.epa.gov (2011)

'The goal of sustainable development is to enable all people throughout the world to satisfy their basic needs and enjoy a better quality of life, without compromising the quality of life of future generations. Globalisation has brought with it the copying of modern lifestyles by the inhabitants of developing countries like Ghana, from developed countries like the United Kingdom and the United States of America. The most glaring global change

is in that of buildings worldwide, with features like extensively glazed areas and the use of air-conditioning which more often than not ignore the use of natural climatic components, thus overlooking sustainability. Over the years there has been this revolution of the use of glazing (aluminium doors and windows, curtain walling), as against the use of traditional doors and window (louvers and timber doors) and sandcrete block walls. Traditional features of tropical buildings like shading devices (awnings, overhangs, and trellises) and courtyards have given way to enclosed high rise buildings with curtain walls. One wonders if these buildings are sustainable in the hot /warm and humid climates developing countries where energy efficiency among other factors is supposed to be of paramount importance.

PROBLEM STATEMENT

The climate of Ghana can be described as warm and humid. With this type of climate the most prominent characteristics are hot, sticky conditions and continuous presence of dampness. Recently, over the past ten years office buildings that have been constructed in Accra have been characterized by multiple floors, the extensive use of glass on the facades and the general use of air conditioners. Old or existing buildings that have been or are being renovated also have the above mentioned characteristics. Preliminary interviews of some residents in Accra have revealed that they believe that extensive use of glass makes a building 'modern'. Preliminary interviews with stakeholders in the construction industry agree with the residents in that these types of features are what clients request for, thus that is what they provide. The question however is do these features (glass walls, etc.) correspond with sustainability of buildings in the warm humid climate?

Ghana has been having problems with the water levels in the Akosombo dam reducing to the extent of the supply of electricity being rationed. The use of airconditioners and artificial lighting (during daytime) in homes and offices has become a necessity due to the manner in which our buildings are constructed and this need for mechanical ventilation has resulted in an increase in energy consumption. Even though some of these office buildings

have the kind of features that are needed to be incorporated into buildings in tropical areas in order for them to be comfortable, (like sun shading devices, the orientation of buildings to take advantage of air movement, etc.), there are others that have ignored or abandoned these features for 'the modern look'. Is it not possible to combine the use of glass with these tried and tested features for sustainable tropical buildings in order for the office buildings that are being constructed to make maximum use of elements like natural ventilation and natural lighting? This paper seeks to find out answers to some of these questions.

Hypothesis - Glass is used extensively on facades of office buildings in Ghana mainly for aesthetic reasons and not for reasons of sustainability.

This research aims at finding out the reasons behind the extensive use of glass on the facades of office buildings in Accra and whether considerations are given to sustainability when these buildings are being designed and constructed. It also seeks to establish whether the use of such buildings is effective without mechanical ventilation and artificial lighting.

LITERATURE REVIEW

Sustainability has been researched into and written about by many authors and researchers. They all agree that it is about living presently in a way that even though the needs of human being are being met, care is being taken so as not to compromise or damage the ability of future generations to meet their own needs.

What is Sustainable construction?

Sustainable construction involves the provision of built developments that are efficient and affordable, socially acceptable and less damaging to the environment.

'Sustainable construction not only refers to the buildings and spaces themselves but also the processes or activities used to construct them. It also includes the infrastructural elements such as waste management, transportation, and utility transmission systems put in place to serve this building space'. Presley and Meade. (2010)

According to the United Kingdom Department of Trade and Industry (DTI) (2006), there are three key strands involved in Sustainable construction:

1. Environmental responsibility
2. Social awareness
3. Economic profitability

Sustainable Construction includes the following actions:

- Minimising pollution during construction Halliday, (2008), DTI (2006)
- Preserving and enhancing biodiversity Halliday, (2008), DTI (2006)

- Conserving resources
'There should be the conscious efforts not to consume a disproportionate amount of resources during construction and also not to cause unnecessary waste of energy, water or materials due to poor design, inefficiency, or less than ideal construction processes.' Halliday (2008), DTI (2006)
- Respecting people (Communities) and local environment Halliday (2008), DTI (2006)
- Creating healthy environments Halliday (2008), DTI (2006)
- Managing the process through the identification of appropriate targets, tools and benchmarks, and management of its delivery. Halliday (2008), DTI (2006)

Sustainability of the Building Envelope

'In the life time of an average building most energy is consumed mostly during the period when the building is in use. That is, when energy is being used for heating, cooling, lighting, cooking, ventilation and so on. Typically more than 80% of the total energy consumption takes place during the use of buildings and less than 20% during construction of the same'. United Nations Environment Programme (UNEP) (2007) Since buildings, especially office buildings are noted to be major electricity or energy consumers, it is important that stakeholders in the construction industry, especially architects take a look at the planning and designing of buildings (especially office buildings) in Ghana in order to make the most of the climate and environment to produce environmentally friendly buildings.

Below are some sustainability requirements relating to the design and construction of the building envelope.

- It is essential to consider the local climatic conditions (temperature, moisture, wind) in order to know the materials for construction of the building envelope, the amount of and effectiveness of glazing used specific to each orientation, and the overall energy performance of the building. Bolin (2009)
- Designing to make maximum use of natural light whilst being aware of its limitations Bolin (2009), Smith (2006)
- Using Effective Solar Shading Devices especially exterior shading devices such as overhangs, vertical fins and light shelves as energy efficiency measures. Bolin (2009)
- Integrating photovoltaic panels as part of the building envelope system or solar shading system as a way of generating on-site, renewable energy. Bolin (2009)
- Providing windows that afford building occupants views outside but do not negatively impact the visual and acoustic comfort of the work environment. Bolin (2009)

- Components of the building envelope should adequately address issues of thermal comfort at the building perimeter, particularly thermal and solar performance of glazing or fenestration. Bolin (2009), Smith (2006)
- The potential for natural ventilation in the context of an overall climate control strategy must be exploited while minimising energy use and maximising comfort. Where appropriate, the use of operable windows for natural ventilation and occupant control must be considered. Bolin (2009), Smith (2006)

SUSTAINABLE CONSTRUCTION IN THE TROPICS

Climatic forces have been an important factor ever since man first constructed shelter. Throughout architectural history, local builders have used great resourcefulness in providing the most comfortable internal conditions possible within the constraints and requirements of the local climates. Jones (1998)

Countries in the tropics have a long history of sustainable buildings in their vernacular architecture. The hot and dry regions for instance, developed over centuries, appropriate materials, a perfect balance of shading and daylighting, natural ventilation and heat storage to suit their climatic conditions. In the hot and humid regions natural ventilation and shading systems were perfectly adapted to the local climate as well. Laar and Grimme (2002).

'However a lot have changed with the introduction of airconditioners, extractors, artificial lighting, etc. Design and construction of buildings have become independent from the prevailing climatic conditions. Aesthetics has become the main aim for the design of buildings, overshadowing sustainability'. Laar and Grimme (2002)

Sustainable construction in the tropics is no different from sustainable construction in other climatic conditions. The actions listed in the previous sections that are needed to be undertaken to achieve sustainable construction are the same. The problem lies in the fact that while buildings in temperate regions are being improved to meet requirements on sustainability by using appropriate materials and methods, buildings in the tropics are being changed to imitate those in the temperate regions regardless of whether the changes are sustainable or not.

REQUIREMENTS FOR BUILDINGS IN WARM HUMID CLIMATES

The requirements for buildings built in this climatic region has been discussed by many writers over the years and they all agree to the fact that buildings in this region like all other buildings elsewhere are supposed to provide comfort, be functional, and environmentally friendly or sustainable.

According to Koenisberger et al., (1980), buildings have to be opened up to breezes and orientated to catch available air movement in order for heat to be removed from the occupants' body into the environment. Other features that were suggested by Koenisberger et al. (1980) are shading devices to reduce radiation from the sky.

More research has been conducted on buildings in different places on the globe with different climates including the materials that are used in construction buildings and some of their requirements. According to Jones (1998), some of the important considerations for buildings in tropical regions are 'natural ventilation, mechanical ventilation, night ventilation, artificial cooling, free cooling, light weight construction, daylighting and solar shading/control'.

Another writer, Stagno (2001) also suggests that in order to achieve an acceptable level of habitability and comfort in buildings in the tropics, consideration must be given to variables like 'the problems of excess rainwater disposal, air-cooling, decreasing relative humidity levels and reduction of excessive glare from the sun' and existing environmental factors.

According to Bay and Ong (2006), 'shading devices with verandas, sun breaks, and appropriate openings, is always more efficient and cheaper than any glass technology for climatic control in subtropical regions'.

REASONS FOR USING GLASS IN BUILDINGS

The introduction of glass in buildings was brought about due to certain needs that designers, occupants and owners had to meet. Some of these are the need to make building lighter, the need to have high amount of natural daylighting in order to reduce electricity consumption through the use of artificial lighting, the need to create views and blending interior and exterior views, the need to control the solar and thermal heat in interiors thus maintaining temperatures at comfort levels, the need for designers and architects to have least restriction in capturing desired shapes and forms and the need to control noise.

In order to be able to satisfy the above stated needs however, different types of glass with different characteristics and properties are required; failure to match the correct type of glass with the specific needs may result in the creation of problems in the building. For example, according to Bay and Ong (2006), 'many designers are eager to find innovative glass technologies, such as reflective glass, double skin glass, and low -E glass, to cut down the cooling load of glass skin but still cannot change the basic material performance that bigger solar heat gain comes from bigger glass opening'. This means that the use of glass should be determined by the climate as against the properties of the glass; and should not be used in spite of the climatic conditions or the requirement for sustainability in a region.

RESEARCH METHODOLOGY AND DESIGN

The methodology used in this study is survey questionnaire which can be categorised as quantitative research. Quantitative approaches are more specific and result oriented and it involves the collection of numerical data in order to explain, predict, and/or control phenomena of interest (Mojaheed, 2005).

SURVEY

Literature research was undertaken to extract all the available variables considered in the sustainable design and construction of buildings. The sources of the research were published professional journals, academic works, internet search and other relevant literature. A survey was then conducted among stakeholders in the construction industry made up of professionals in the construction industry and occupants.

DESIGN OF QUESTIONNAIRE

Structured questionnaires were formulated for the professionals in the construction industry and occupants of office buildings in Accra. Basically the questionnaire for the consultants was made up of three parts and consists of open and closed questions. The first part was made up of questions that enabled one to be familiar with the respondent. They included questions that sought to know the profession, contact number and email address.

The first part also had questions which sought to know whether respondents have been involved in the construction or refurbishment of office buildings and details of the projects. They also had to indicate whether they used glass extensively and the reasons for that.

The next section of the questionnaire asked respondents to rate seven hypothetical factors (which were put in a likert scale format) that are likely to influence the extensive use of glass on facades of office buildings in Accra; thus they rated 'Very Common', 'Common', 'Averagely Common' and 'Not Common'. Another section 'Do Not Know' was included to be chosen when appropriate. The factors were, namely, aesthetics, to achieve modern look s, to regulate indoor temperatures, to keep away dust from the offices, to control solar ingress, to create access to external view and to control draft/wind movement indoors.

Respondents were also asked to rate five hypothetical variables that should be considered in sustainable tropical buildings according to the amount of consideration applied. These variables are 'natural ventilation', 'thermal comfort', 'natural lighting', 'sun shading devices', 'orientation of building'.

The final section asked the respondent to give other variables they considered during design and construction and were also to indicate which among the stakeholders usually suggests the use of glass.

The questionnaire for the occupants sought to know the type of buildings they had their businesses in and how they feel generally in the building. This set of questions sought to find out the effect of glass facades on the interior space

A purposive sampling method was used to select the class of construction companies for the questionnaires administration. The targeted buildings were situated in and around the central business district of Accra.

ADMINISTERING OF QUESTIONNAIRES

A total of 65 questionnaires were administered to occupants of which 49 responses were obtained representing 75.38% response rate. A total of 25 questionnaires were sent out to professionals and clients. A response rate of 13 presenting 52% was received.

DATA ANALYSIS TOOLS

Two analytical tools were used in analysing the responses from the survey. These are statistics importance index and Kappa statistic for multiple raters.

Importance index facilitates the identification of tactical approaches to increasing productivity. The nearer the value of importance index of the identified factor is to unity (1), the more significant it as a factor for using glass extensively on buildings. A ranking of importance indices were undertaken to ascertain the most frequent factors.

Importance index (I.I.) = $5n_1 + 4n_2 + 3n_3 + 2n_4 + n_5$

$5(n_1 + n_2 + n_3 + n_4 + n_5)$

Where: n_1 –number of respondent answered 'strongly significant'

n_2 –number of respondent answered 'significant'

n_3 –number of respondent answered 'average'

n_4 –number of respondent answered 'not significant'

n_5 –number of respondent answered 'strongly not significant' Kadir et. al. (2005)

KAPPA STATISTIC FOR MULTIPLE RATERS

Kappa \hat{k} statistics for multiple raters using categorical classifications was employed to test the level of agreement for respondents. This analytical tool is used to test the consistency of values and is employed when there are more

than two raters and or subjects. The determination of \hat{k} is demonstrated as follows.

$$\text{The overall kappa value for occurrence } (\bar{k}) = \frac{\sum_{j=1}^k \bar{p}_j \bar{q}_j \hat{k}_j}{\sum_{j=1}^k \bar{p}_j \bar{q}_j}$$

Where: j = category of rating, k = number of category, \bar{p}_j = overall proportion of ratings

\bar{q}_j = overall proportion of non-ratings, \hat{k}_j = kappa value per category, \bar{k} = overall kappa value

The break down to find the overall kappa value for occurrence is as follows

$$m = \sum_{j=1}^k x_{ij} \quad (1)$$

$$\bar{m} = \frac{\sum_{i=1}^n m_i}{n} \Rightarrow \sum_{i=1}^n m_i = n \times \bar{m} \quad (2)$$

$$\bar{p}_j = \frac{\sum_{i=1}^n x_{ij}}{n} \quad (3)$$

$$\hat{k}_j = 1 - \frac{\sum_{i=1}^n x_{ij} (m - x_{ij})}{nm(m-1) \bar{p}_j \bar{q}_j} \quad (4)$$

Where $\bar{q}_j = 1 - \bar{p}_j$

m = number of different raters, x_{ij} = number of ratings on a subject,

i = subject, n = number of subjects, j = category of rating, k = number of category

\bar{m} = mean number of ratings per subject, \bar{p}_j = overall proportion of ratings,

\bar{q}_j = overall proportion of non-ratings, \hat{k}_j = kappa value per category, \bar{k} = overall kappa value

Green (1996) explained that a perfect agreement will exist when $\hat{k} = 1.00$. Also, a high degree of agreement beyond chance is said to occur when kappa value is $0.75 \leq \hat{k} \leq 1.00$. This means that there is no divergence in response from respondents. In addition when $0.40 \leq \hat{k} < 0.75$, a fair or good agreement is said to exist which gives the indication that there could be the possibility of divergence in opinions but not much. Finally when $\hat{k} < 0.40$, there is said to be the existence of low agreement beyond chance.

Survey Findings

A total of 65 and 25 questionnaires were sent out to occupants and professionals of which response rates of 75.38% and 52% respectively were obtained.

Response from Professionals

A total of 13 questionnaires were received comprising 6 Quantity surveyors, 2 Engineer and 5 Architects representing 46%, 15% and 39% respectively of which 43% work in the government sector and 57% in the private sector.

There has been rapid development in the central business district for the past 10yrs and it can be inferred that similar development is being replicated elsewhere. The research further revealed that 72% respondents have been involved in the design of office building whereas 43% have been on re-design and refurbishments within the last 10yrs. The office buildings under development within this period have about 30-70% of walls made up predominantly of glass. Some of the glass used for the buildings are reflective glass, translucent glass, and laminated glass. The buildings described by the respondents were storey buildings having between three and thirteen floors.

From the respondent's perspective, out of ten office buildings to be built in Accra in future, there is the probability of having between 5 and 9 buildings having facades made extensively from glass. This brings out the need for sensitization on sustainable construction among the stakeholders in the construction industry in Ghana to be able to have economical and environmentally friendly buildings.

It was found out from the response that most of the time the use of glass is suggested by either the client or the architect for the following reasons:

- To achieve lightness of structure,
- To achieve flexibility in composition,
- To show formality, and financial status of client,
- Because it is the order of the day.

These were reasons that were supplied by the respondents in addition to those provided in the questionnaire for rating (table 1).

Table 1: professionals' rating of the probable factors that influence the extensive use of glass on facades of office buildings in Accra, where 1-very common, 2- common, 3- averagely common, 4- not common and 5-do not know

From the response of the professionals, they all agreed that the factors that influence the extensive use of glass on facades of office buildings in Accra (table 1), was rated as follows:

1. Aesthetics
2. To control draft / wind movement indoors
3. To keep away dust from the office
4. To control solar ingress
5. To regulate indoor temperature
6. To create access to external view
7. To achieve modern looks

Sun shading device, Natural lighting, Orientation of building, and Thermal comfort.

PROBABLE FACTORS	Respondents on Significance					Importance Index (I.I.)	Rank (I.I)
	1	2	3	4	5		
Aesthetics	12	0	0	0	0	1.000	1
To achieve modern looks	10	2	1	0	0	0.262	7
To regulate indoor temperature	1	3	5	2	0	0.545	5
To keep away dust from the office	0	5	4	2	1	0.583	3
To control solar ingress	2	2	3	5	0	0.583	3
To create access to external view	5	3	3	1	0	0.400	6
To control draft / wind movement indoors	0	2	8	2	0	0.600	2

From the above it can be deduced that aesthetics is the main factor that influences the extensive use of glass on facades of office buildings.

VARIABLES	Respondents on Significance					Importance Index (I.I.)	Rank (I.I)
	1	2	3	4	5		
Natural ventilation	6	2	4	1	0	0.800	1
Thermal comfort	6	2	3	1	0	0.383	5
Natural lighting	6	3	4	2	0	0.427	3
Sun shading device	4	3	3	2	1	0.492	2
Orientation of building	5	3	4	1	0	0.415	4

Table 2: professionals' rating of variables to be considered in sustainable tropical buildings, where 1-highly considered, 2-considered, 3- averagely, 4-least considered and 5-not considered

The variables listed in table 2 are suggested variables that must be considered to achieve sustainability in a building. The ratings of the professionals indicate that all the variables are considered however, natural ventilation emerged as the most considered variable this is followed by the other variables as follows:

Response from Occupants

Response of the occupants revealed that:

- 88.89% of respondent were accommodated in public buildings.
- 69.39% respondents were reported have the office buildings predominantly of glass facade.
- 56.00% revealed unfavourable working condition without artificial lighting during the day. This gives indication that the light intensity in the rooms or offices are reduced due to the inadequate natural lighting.
- 76% cannot work or stay in the office building without mechanical or artificial ventilation, even though 61.70% had windows that can be opened.
- 55.88% occupants do not have favourable working conditions although majority indicated that the windows can be opened
- 35.42% do not open their blinds when in the office, despite the fact that 78.79% have good external view.
- 33.33% are affected by the ingress of the sun when windows are opened.
- 83.67% are satisfied with indoor conditions due to air conditioning and nice internal arrangements.

Concordance of response

As has been explained above, Kappa statistics for multiple raters using categorical classifications was employed to test the level of agreement among respondents.

The agreement among responses on factors that influence the extensive use of glass in office buildings was tested to establish the level of agreement among respondents.

The results obtained, indicates that there is a perfect level of agreement beyond chance in responses related to factors influencing the extensive use of glass in office buildings. This means that there existed no divergence in opinions on factors given, an indication that pertains throughout the understudied area.

The level of agreement concerning the variables that are usually considered in designing by professionals was also tested.

The results obtained, can be interpreted that there exists a perfect level of agreement with respect to ratings of the variables considered in designing office buildings. This means the all the variables are taken into consideration in designing so as to make the office buildings user friendly.

DISCUSSION OF FINDINGS

One aim of sustainable construction is to create buildings with comfortable indoor environment through the use of appropriate materials, without compromising on our natural environment.

The research conducted and the response from respondents indicate that

Glass is extensively used on facades of office buildings in Accra

The use is mainly for aesthetic purposes together with other reasons which are already stated.

Natural ventilation has also been cited as the most considered variable during design and construction of office buildings in Accra. However, from the response of the occupants there is a lot to be done when it comes to comfortability in these buildings without mechanical ventilation and artificial lighting. It was discovered that a lot of these occupants cannot stay and work comfortably without air conditioning and artificial lighting even though they love the internal arrangements of their office spaces and the buildings in which they work, and some enjoy great views from their windows.

CONCLUSION

Even though the use of glass is seen as the order of the day, its use must be done with consideration to the adverse effect it is likely to produce on our economy, society and environment.

It is important for professionals in the Ghanaian construction industry to pay more attention to what constitutes sustainable construction and takes steps towards achieving it.

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