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The efficiency of current glazing materials in the central business district of Kumasi (Ghana)

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ABSTRACT

The high energy use of curtain wall buildings around the globe is well-known. In Ghana, the situation is not different as new buildings are being constructed with inefficient materials. In this context, the study outlined here sought to analyse the existing glazing types in Adum, the Commercial Business District of Kumasi, capital of the Ashanti Region, and to come out with recommendations on efficient strategies to be used in conserving energy. The process required knowledge on the thermal properties of the glazing used in constructing buildings (curtain wall) and a mathematical approach was used to generate data for the evaluation exercise. The results showed that there are inefficient glazing types (high shading and solar heat gain coefficient values) currently being used in the construction industry. Highly reflective glazing types could have a positive influence on the reduction of cooling loads, the use of sustainable design principles (shading and orientation) will be a benefit for mankind (climate change) and educating professionals and the public will help to contribute to a better built environment.

Keywords: Building Fenestration; Energy Use; Thermal; Shading.

INTRODUCTION

Buildings come in a variety of shapes and functions, due to factors such as availability of materials, weather conditions, land prices, ground conditions, specific uses and aesthetic reasons. Buildings serve several purposes in the society, primarily as shelter from weather, as a living space, the provision of privacy, a place to store belongings, and a space to comfortably live and work. A building as a shelter represents a physical division of the human habitat and the outdoor environment [1].

In order for buildings to admit light, enhance ventilation, allow visual contact with the environment, etc., openings are created on the envelope. Some of these openings are windows and doors which, together with its accessories, form the building’s fenestration. Building fenestration is therefore the physical arrangement of openings in a building's exterior envelope. This typically involves the design and disposition of window assemblies and doors [2]. According to [3], building fenestration does not only include windows and curtain walls as well as accessories, but also installations, glazing, sun screening, etc.

It has been observed that the trend of building fenestration (specifically glazing) is drastically shifting towards curtain walls in commercial structures. During the past ten years, almost every commercial building (multi-storey) constructed in Ghana has its envelope made of a high portion of glazing (curtain wall) with fixed and few operable windows (buildings in the Central Business District (CBD) of Kumasi (Adum), are no exception). The thermal and energy implications of curtain walls are mostly not considered. Moreover, design decision making is not supported by scientific processes (simulation probe based on properties of materials) but rather on aesthetic preference [4]. The result of curtain wall buildings (offices) on energy use is well-known (about 40% of every nation’s energy [5, 3 and 6]. The recent load shedding exercise and the state of energy production in Ghana are also known [7]. In this context, the present research seeks to find out the thermal properties and efficiency of available glazing being used as curtains walls in Adum. The lessons from the efficient and appropriate types of glazing will contribute to the body of knowledge (awareness with regard to designers, clients and construction industries) and energy performance of buildings (especially curtain wall types).

According to the Kumasi Metroplitant Assembly [8], the energy situation of the metropolis is satisfactory. The monthly electrical energy consumption is 120 MW on average. Some sub-stations have about 31% overloading and there are efforts to upgrade, replace switch gears, facelift and construct additional overhead lines. Despite the efforts taken by the Assembly, if precautions are not taken, the energy situation of Kumasi (Adum-CBD) will further deteriorate due to the unsustainable use of building elements (glazing).

A brief history on the production of glass has been given by [9]. It is stated that glass manufacturing began around 1500 B.C. in Egypt and Mesopotamia. The production of glass into countless shapes was then invented by the Syrian glassmakers. Further development of glass making was done by the Romans by producing flat glass through blowing huge glass bubbles or cylinders which were opened and flattened. As a result of the industrial revolution, the production of glass has developed with a lot of inventions, one of which was the machine invented by William Pilkington that automated the production of glass. Around the turn of the century, glassmakers discovered that glass could be "tempered" by reheating it and then cooling it again quickly. The unique property of glass is its transparency to shortwave (solar) and long wave (thermal) radiation. Different types of glasses transmit different fractions of solar radiation spectrum from 0.4 to 2.5 micro meters [10]. Glazing in the building industry is normally used to allow ventilation, admit natural light and allow visual contact with the outdoors. Furthermore, [10] illustrates the behaviour of incident solar radiation on glass. When solar radiation incidents on the glass, it is divided into three fractions; one is reflected outwards without any effect on building temperature, one is absorbed within the glass, raising its temperature, and one is transmitted through the glazing into the building (raising the temperature of the space which will have to be cooled towards comfort). The different fractions of reflection, absorption and transmission of the solar radiation spectrum are determined by the composition and treatment of the glass.

The thermal properties and definitions of glazing have been outlined by [11] and [12].

- U-Value: This is the conductivity of the glazing which is the rate of heat flow through a window assembly due to the temperature difference between the two sides of the window. The lower the U-value, the greater the insulating value of the window.
- R-Value: This is the resistivity of the glazing. This is the ability of the glazing to resist heat flow. If a window's R-value is high, it will lose less heat than one with a lower R-value. The R-value is inversely proportional to the U-value.
- Shading Coefficient (SC): The shading coefficient is the ability of glazing to block the sun's radiant heat. The SC is the ratio of solar heat gain of a window compared to single-pane 1/8" clear glass. The lower the SC, the lower the solar heat gains through the window.
- Solar Heat Gain Coefficient (SHGC): This is the measure of the fraction of solar radiation passing through a window as heat compared to the amount of solar radiation striking the window. The SHGC is becoming a standard performance metric and is becoming more common in the performance ratings of manufacturers. It is similar to the shading coefficient in that the lower the SHGC, the lower the solar heat gains.
- Visible Light Transmittance (VLT): The amount of visible light that passes through the glazing is the VLT.
- Ultraviolet Transmittance: This is the measure of the amount of ultraviolet radiation striking the glazing that passes through it. Many energy-efficient glazing also reduce UV transmission.

Therefore, the choice of the type of glazing to be used in a facility greatly depends on the above parameters. It is a scientific design decision to be made and not an aesthetic adventure. To achieve energy efficiency in curtain wall buildings, factors that ought to be considered (in relation to glazing) are the size (percentage of floor area per orientation), the type (heat reflecting, low-emissivity, etc.), the orientation of the glazing, and shading devices [13]. According to [3], the right combination of sun shading in glazing prevents high energy consumption. This is buttressed by [14], stating that shading devices should always be incorporated in the design. This is because shading cuts down the amount of sunlight entering the building, consequently, less heat will transcend into the building. The less heat enters the building, the less energy will be required to cool the building [15].

MATERIALS AND METHODS

The aim of this study is to bring to light the impact of glazing (curtain walls) on the performance of buildings. Thereby, the objective is to establish the different types of glazing that exist on multi-storey structures within the

Central Business District of Adum and to show which types are suitable to use as far as energy conservation is concerned.

Six buildings were chosen for the study. Most of the buildings have recently been completed and are representative of existing and new structures coming-up in the CBD. The use of extensive glazing can be seen on the envelope of the mechanically ventilated buildings. They are the Inter-Continental Bank (ICB), Agricultural Development Bank (ADB), Agyaba House (AHB), Kama Plaza (KPB), Oak Arcade (OAB) and Royal Aluminum (DUT) Buildings (see Figs. 1-6).

Fig 1 Inter-Continental Bank (ICB)

Fig 2 Agric. Development Bank (ADB)

Fig 3 Agyaba House (AHB)

Fig 4 Kama Plaza (KPB)

Fig 5 Oak Arcade (OAB)

Fig 6 Dufie Towers (DUT)

To ascertain the thermal properties (U-values, Shading coefficients, etc.) of the glazing used in the construction of the buildings, the contractors had to be contacted. The designers also gave the requested information (architectural) on sizes and areas of the buildings.

To calculate the heat gain through the glazing, the U-values were multiplied by the area covered by glass [16] (Equation 1). For comparative reasons, a unit area (50m²) was used to illustrate the effect of heat gain through the envelope.

$$H\ [W/K] = U\ [W.m^{-2}K] * A\ [m^{-2}] \qquad (1)$$

where H is heat gain, U is the U-Value and A represents the area

The indicator which shows how glass is thermally insulating (shading) the interior of a building when there is direct sunlight on the panel or window is known as the Shading Coefficient (SC). The SC is a factor of the colour and the degree of reflectivity of glass and ranges between 1 and 0 [17]. Equation 2 clarifies the method.

$$SC_e = SC_g * SC_{sd} \qquad (2)$$

where SC_e is the effective shading coefficient, SC_g is the coefficient of glass and SC_{sd} represents the coefficient of the shading device

Further parameters are needed to determine the shading coefficient of the shading device. This requires computing the projection factor of the shading device (PF) (see Fig. 7 and Equation 3).

$$PF = P/H \qquad (3)$$

where P is the distance measured horizontally from the furthest continuous extremity of any overhang, eave, or permanently attached shading device to the vertical surface of the glazing. H is the distance measured vertically from the bottom of the glazing to the underside of the overhang, eave, or permanently attached shading device

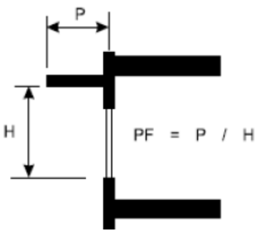

Fig 7 Projection factor of the shading device
(source: ASHRAE Handbook)

Table 1 shows the Solar Heat Gain Coefficient (SHGC) of the shading device based on calculated PF.

Table 1- SHGC multipliers for permanent projections

Projection Factor	SHGC multiplier (all orientations)
<0.00 - 0.10	1.00
<0.10 - 0.20	0.91
<0.20 - 0.30	0.82
<0.30 - 0.40	0.74
<0.40 - 0.50	0.67
<0.50 - 0.60	0.61
<0.60 - 0.70	0.56
<0.70 - 0.80	0.51
<0.80 - 0.90	0.47
<0.90m – 1.00	0.44

(source: ASHRAE Handbook)

According to [18], the shading coefficient (SC) of a shading device in relation to its solar heat gain coefficient (SHGC) can be obtained from Equation 4.

$$SC_{sd} = SHGC / 0.86 \qquad (4)$$

RESULTS AND DISCUSSION

The results obtained showed that 4 types of glazing are being used in the construction of curtain wall buildings in Adum. Out of the four, three of the glazing have similar thermal properties (see Tables 2 and 3). The U-values do not deviate much from each other. The DUT building has a lower U-value (0,35W/m²K) and the concomitant heat gain of 17.5 W/K (the others have values around 260 W/K).

Table 2- Glazing properties for all buildings

Building	Glass type	Thickness [mm]	Visible light transmittance [%]	Visible light reflectance [%]	SHGC
ICB	Dark blue reflective glass	5	23,35	13,46	0,546
AHB	Dark blue reflective glass	6	18,79	11,79	0,517
KPB	Blue tinted glass	5	71,07	7,78	0,654
DUT	Reflective, tinted, low-e, insulating glass	25	56	12	0,34
ADB	Dark blue reflective glass	6	18,79	11,79	0,517
OAB	French green tinted glass	5	74,86	8,03	0,691

Table 3- Tabulated heat gain and effective solar coefficient (SCe) values for all buildings

Building	U-Value [W/m²K]	Area[m²]	Heat gain [W/K]	P[m]	H[m]	PF	SHGCsd	SCsd	SCg	SCe
ICB	5,272	50	263,6	0	7	0	1	1,16	0,59	0,69
AHB	5,243	50	262,15	0	15	0	1	1,16	0,55	0,64
KPB	5,272	50	263,6	0	13	0	1	1,16	0,55	0,64
DUT	0,350	50	17,5	0	16	0	1	1,16	0,4	0,47
ADB	5,272	50	263,6	0,3	7,5	0,04	1	1,16	0,8	0,93
OAB	5,243	50	262,15	0	15	0	1	1,16	0,734	0,85

The values of the solar heat gain coefficient are on the high side (an exception is the low-e glazing). About 50% incident solar radiation will be transmitted into the spaces and will have the effect of increasing cooling loads of the buildings. In a study conducted [19], cooling loads could be reduced by 14% when an efficient glazing (shading coefficient of 0.29) was used to predict the thermal performance of office buildings.

The effective shading coefficients derived are also on the high side (0.47 to 0.93). The effect will be increases in cooling loads as a result of heat gain through the aesthetically pleasing glazing. The cost of cladding buildings with glass and its related high energy use needs to be considered when designing curtain wall buildings. The lack of shading and improper orientation of glazed walls to the eastern and western sides are unsustainable measures that need to be addressed [20 and 21].

During interaction with the building designers, it was discovered that knowledge on the thermal properties of the materials (glazing) employed in their buildings was lacking. This presupposes that not only are clients to be educated, but also those in the building industry.

Considering the spectrum of design decisions on the properties of glazing, available building materials and cost of the products, a simulation attempt which probes different U-values with shading coefficients would lead to an effective result [15, 22, 23, 24 and 25].

CONCLUSION

The study presented had the aim of investigating the type of glazing being used in the CBD (Adum) of Kumasi. This led to the selection of recently constructed buildings with extensive glazing for the study. The results obtained demonstrate that the shading coefficient and the U-values of the glazing were high, resulting in high heat gains and cooling loads. There is the need to enforce sustainable design principles and educate the public on the use of efficient building systems. The employment of quality and efficient building products suitable for the climatic conditions in Ghana will help benefit the country in the long-run.

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REFERENCES

[1] Wikipedia, *Wikipedia Encyclopedia*, www.wikipedia.com, **2010**, Accessed: May 2010.
[2] Deal B.M., *Energy Conservation Strategies for Windows and Glazed Surfaces*, U.S. Army Centre for Public Works, U.S.A, **1998**.
[3] Eurowindoor, *The Role of Fenestration for Less Energy Consumption and Greenhouse Gas Emission Reductions*, Bruxelles, Belgium, **2008**.
[4] Koranteng C and Mahdavi A, *CLIMA 2010*, **2010**, Antalya, Turkey, May 9-12, 2010.
[5] Langthaler M, *"Efficiency Wins, Hi!Tech – The Innovative Magazine"* Siemens Austria, (available at www.hitech.at), Austria, **2009**, pp. 2-3.
[6] EIA, *A Thermal Modelling Comparison of Typical Curtain Wall Glazing Systems*, **2007**, www.downcorning.com/content/publishedlit/thermal_modeling_comparison_carbary_GPD_2200.pdf, Assessed: May 2010.
[7] Volta river authority (VRA) and Electricity Company of Ghana (ECG), *Special Press Briefing on the Electrical Energy Situation in Ghana*, **2007**.
[8] Kumasi Metropolitan Assembly (KMA), *Informal Interview on the State of Energy Provision for Kumasi*, KMA, Kumasi, April 2011, **2011**.
[9] Garg N.K., *Guidelines for Use of Glass in Buildings*, Newage International Publishers, New Dehli, India, **2007**.
[10] Cowan H.J., *Handbook of Architectural Technology*, Van Nostrand Reinhold, New York, USA, **1991**.
[11] EAB, *Windows and Window Treatments, Energy Answers for Business*, APS Business, **2010**. www.aps.com/main/services/default.html-United States, Assessed: June 2010.
[12] NREL, *Advances in Glazing Materials for Windows*, U.S. National Renewable Energy Laboratory, Nabraska Energy Office, **2010**.
[13] ACC, *Energy Efficient Glazing*, Adelaide City Council Green Building, Australia, **2010**.
[14] Brambley M.R. and Penner S.S.S., *Fenestration for Energy Conservation*, Elsevier Science Limited, USA, **1979**.
[15] Koranteng C, *An Evaluation of the Thermal Performance of Office Buildings in Ghana*, **2010** pp. 65-89
[16] MEA, Conventions for U-Values Calculations-BR443U-Values, **2007**, www.bre.co.uk/filelibrary/pdf/rpts/BR_443_(2006_Edition).pdf, Assessed May 2010.
[17] Wikipedia, *Wikipedia Encyclopedia*, www.wikipedia.com, **2011**, Accessed: May 2010.
[18] PNSG, *Pilkington NSG Group Flat Glass Business*, Pilkington North America Inc. Toledo, USA, **2011**.
[19] Koranteng C. and Mahdavi A, *Energy and Buildings*, **2011**, 43 (2011), pp. 555-563.
[20] Szokolay S, *Introduction to Architectural Science: The Basis of Sustainable Design*, First Edition, Architectural Press, Oxford, **2004**, pp. 20-21, 64-70, 225-227.
[21] Lauber W, Tropical Architecture, First Edition, Prestel Verlag, Munich, **2005**, pp. 9, 101-105.
[22] Mokamelkhah E.K., *Lighting, Shading and Ventilation Controls: A Study of User Behaviour in Office Buildings*, Technology University of Vienna, Austria, **2007**, pp. 62-98.
[23] Mohammadi A., *Modeling Occupants' Control Actions and their Energy Implications in an Office Building*, Technology University of Vienna, Austria, **2007**, pp. 35-63.
[24] Mahdavi A., Mohammadi A., Kabir E. and Lambeva L., *Clima* **2007**, **2007**, 10-14 June, Helsinki, Finland, Seppänen O, Säteri J, (Ed.), ISBN: 978-952-99898-2-9, Paper-No. C03.
[25] Hyde R., *Climate Responsive Design*, United Kingdom, *E & FN Spon*, **2000**, pp. 67, 76-81.