Adaptation of Glass as Walling Material in Warm Humid Zones of Nigeria

Folorunso, C. O[*] and Bruce-Agbogidi, T. L.
Department of Architecture, Federal University of Technology, Akure, Nigeria
[*]Corresponding Author Email: cofolorunso@futa.edu.ng

Abstract
Different walling materials that provide varying levels of thermal comfort are used traditionally in different climate for buildings. Glass provides a more climate compliant, thermal comfort than some traditional materials. However, lack of proper understanding of glass performance and work-ability has hampered proper adoption in the erection of buildings within the area. This paper assesses the use of glass as a walling material in warm humid climate of Nigeria, using Akure the state capital of Ondo State as the study area to ascertain its level of thermal comfort, effectiveness, compatibility with the climate, functionality and durability. Studies have shown that in these climates, glass isn't properly utilized as a walling material, and where it is used, the thermal comfort of the users isn't taken cognizance of. The methodology employed was the use of questionnaires, 109 buildings were assessed, with inhabitants of the buildings filling the questionnaires. Findings from the study was then analyzed and discusses descriptively, charts also used to represent the data. At the end of the study, several problems associated with the use of glass as a walling material were discovered and highlighted some of which includes issues with thermal comfort as well as improper knowledge of glass and its applications to suite the climate among others. The thesis ended on the note of highlighting recommendations to enable the use of glass as a walling material in the warm humid zone of Nigeria without compromising the thermal comfort of the building occupants when adopted.

Keywords: Building, glass, performance, thermal comfort, walling materials

1. Introduction

Buildings are built with different walling materials in different climes to achieve different thermal comfort in different ways. Most of the time, alternatives to traditional or popularly used materials are not looked at, and in cases where such alternatives, for example, glass is used as a walling material or for the façade of the building, proper attention is not given to make use of it in a way to fit the climate, take cognizance of the thermal comfort of the users or to showcase the architectural identity or character of the environment resulting in buildings with a need for high energy to cool down internal environment or the use of glass without regarding the architectural character of the country (Sayed & Fikry, 2019). In parts of the world, especially in developed countries glass is used as a walling material to achieve thermal comfort and also for sustainable design to achieve day lighting and other passive design solutions in order to reduce the overall energy need of buildings.

Thermal comfort can be considered as one of the most important discussions in building design. BS EN ISO 7730 (2023) stated that dissatisfaction with thermal comfort hinders the ability of building occupants to function optimally. Suhendri, Sunanda, & Budiarto (2018) observed that 30% of building occupants are dissatisfied with indoor temperature and 80% of building users complaints are related to thermal comfort in a survey carried out in the US. The most influential factor in some clime is air temperature and solar radiation that penetrates a building through its glazing. Solar radiation, therefore, has a relation to thermal comfort within a building, and the cooling load of the building especially in hot and humid regions (Teleghani, Tenpierik, Kurvers & Dobbelsteen 2013, Suhendri et al., 2018). Windows and other openings thus play a vital role to provide thermal comfort to the interior (Alwetaishi, 2016).

In warm humid zones, especially in developing countries like Nigeria glass has been misused primarily to achieve aesthetic purposes. Little or no research has been done to check the type of glass, or the way to use it to make it compatible with the climate of the region, this has led to problems in its use. Attempts to remedy it sometimes lead to more problems that could be avoided at the beginning if glass was properly incorporated in the design. The use of glass as a walling material in warm humid zones need to be discussed extensively due to this, in a bid to highlight the advantages, disadvantages and possible ways its effect on the thermal comfort of the internal environment of the building can be alleviated.

Air conditioning (AC) and artificial illumination are responsible for the highest percentage of energy consumption in a commercial building. Over 1000 buildings were surveyed in Greece (Sosa, 2006) showing 140KWh/m' as the typical annual energy consumption for buildings without air conditioning and a range of 226-250KWh/m" for buildings that use ACs (Filippin & Larsen (2009). What dominates the electricity sector demand in Nigeria is energy requirement for cooling, lighting, hot water, powering of appliances in buildings (Nkoro, Ikue & Joshua 2019). It is necessary to implement energy conservation and efficiency in electricity usage to reduce the loads on a failing network and reduce greenhouse emissions from existing building stock. (Batagarawa, Hamza & Durek 2012) A way to reduce it can be the use of glass walling, thus reducing the amount of energy needed for lighting. This paper examines the use of glass as a walling material in warm humid zones of Nigeria, in order to determine its appropriateness in terms of functionality, durability, climate compatibility for the purpose of achieving thermal comfort. The target area is Akure South Local Government Area of Ondo State within the southwest region of Nigeria. This lies within the warm humid zone of the tropical climate with its attendants climatic challenges.

In warm humid zones like Nigeria, glass as a walling material has seen little use, and in cases where it is used it is done so inefficiently. This leads to problems in the thermal comfort of the building. Also, when glass is used as a walling material or for the façade of the building, proper attention is not given to make use of it in a way to fit the climate, take cognizance of the thermal comfort of the users or to showcase the architectural identity or character of the country resulting in buildings with need for high energy to cool down internal environment due to the architectural character of the environment (Sayed & Fikry, 2019)
When properly deployed, glass can be used to achieve great architectural marvels, but most times it is avoided due to glare and other related issues that can be avoided or prevented using simple solutions, limiting its use to fenestration like windows and sometimes doors, and hence limiting the effectiveness that can be achieved when glass is incorporated into design.

2. Literature Search

Warm humid zones is characterized with high humidity. The difference between the indoor and outdoor temperature is primarily not significant. It covers an area around the equator extending from 15°N to 15°S. Some of the characteristics also include hot, sweaty conditions and the continual presence of dampness near the equator. Air temperature is also relatively high at about 21-32°C having little differences between day and night (Oppong & Badu, 2012). It is characterized by high relative humidity at 75% most of the time, but it varies between 55 – 100% with a vapour pressure of 2500 – 3000 N/M2, high precipitation all year round with an annual rainfall of 2000-5000mm. It has a low wind velocity that is calm and periodic but can be strong at the beginning of the raining season (Kumari & Goswani, 2015). These factors of climate combine to impact on any building material that is applied on the walls of buildings both internally or on the exterior.

A walling material is any material that is used to define the space or enclose the boundary of a building. They are materials used to construct the walls of buildings. They are vertical constructions used to partition or demarcate spaces within a building envelope. Walls can be either load bearing or non-load bearing inside a building or as a part of the external envelope. There are different types of materials used for wall construction. Dugall (2008) identified various materials that are used for building wall, these are:

1. Brick masonry walling: this type of walling system comprises bricks that are arranged and bonded together using mortar (cement or lime mortar). There are various brick bonds that can be used namely: Flemish bond, English bond, stretcher bond, header bond or common/ American bond. The purpose, geometry and design load determine the size or thickness.
2. Block masonry walling that are either hollow or solid involves the arrangement of block units that are then bonded together with mortar along a course depending on the design to a required height.
3. Concrete walling: this type of walling system is used mainly for shear strength and to construct retaining walls that offer good structural performance against adverse shear, bending moments and axial stresses. Steel is used in their reinforcement to increase the load-bearing capacity, thus decreasing thermal cracking of the concrete. They can be applied in water tanks, cement silos, and storage tanks due to their good resistance against leakage.
4. Stud walling (dry walling): this is a type of walling that involves having a frame that acts as a structural member before the final covering material is added onto the frames. Examples of

stud walling are: Metal stud wall: this type of stud walling comprises a steel or aluminum framework on which the plasterboard or any other type of panel that is to be employed in the construction is attached. Plasterboard aids in the provision of visual separation, fire protection and a level of acoustic insulation. This type of wall can be used for partitioning internal spaces and lining existing walls. Timber stud-work are timber frame of studs that are upright and transoms are nailed together, or joined using metal brackets or sleeves. Attached on top of this frame is plasterboard, hardboard, chipboard or gypsum board.

5. Freestanding walls: this includes perimeter walls that enclose a building or structure, usually along the boundary of the site. If not properly designed, they are susceptible to wind or impact damage. They can be attached to fixed structures at one or both ends.
6. Aluminum walls: this wall is usually used to partition internal space. It comprises aluminum frames and composite panels. Their construction is fast compared to other walling types, although expert knowledge is needed. They are versatile and can be dismantled and re-mounted.
7. Niches: these are recesses in walls that are useful for the purpose of decoration. For a wall to accommodate a niche, it has to be of minimum thickness.
8. Steel walls comprise of steel frames made of struts and studs that are then clad with steel panels. They can be used for both internal and external finish in buildings if properly treated against corrosive elements (Walling Systems, 2021). Steel offers good performance for stability in areas that are prone to sudden movement like land tremor and earth quake.

9. Glass Walls: It can be defined as a substance that is inorganic in a continuous condition with the liquid state, but due to the reversible changes in viscosity that occurs during cooling, it has attained a high degree of viscosity, making it practically rigid (Morey, 1954). The ASTM (1999) defines glass as a product of fusion that is inorganic and has been cooled to a rigid condition without crystallizing. Glass is an amorphous solid that has been around in various forms for thousands of years. The history of creating glass can be traced back to 3500 BCE in Mesopotamia (Douglas, 1972) It is typically brittle and optically transparent. The term *glass* developed in the late Roman Empire at Trier now in modern Germany. The status of glass as a liquid, versus a solid, has been hotly debated. It is a super cooled liquid, meaning that it is rigid and static but does not change molecularly between melting and solidification into a desired shape. Glass is one of the most versatile substances on Earth, used in many applications and in a wide variety of forms, from plain clear glass to tempered and tinted varieties, and many others.

It occurs naturally when rocks high in silicates melt at high temperatures and cool before they can form a crystalline structure. Volcanic glass is a well known example of naturally occurring glass, although it can also be formed by a lightning strike on a beach, which contains silicate-rich sand. Early forms of glass were probably rife with impurities and subject to cracking and other instability (Douglas, 1972).

Glass is a mixture of silica, soda, and lime. Other materials are sometimes added to the mixture to “frost” or cloud the glass or to add colour. The elements of glass are heated to 1800°. The resulting fused liquid can be poured into molds or blown into various shapes, and when cooled, glass is a strong, minimally conducting substance that will not interact with materials

stored inside. As a result, glass is frequently used in scientific laboratories to minimize inadvertent chemical reactions and to insulate power lines.

Major components in glass are silica and alumina. Others are additives which include sodium carbonate, lime and some others. Silica is found in a wide variety of natural sources, including, most commonly, sand. Sodium carbonate, or soda, is used to lower the fusion point of silica, making glass light and workable. Soda is called a flux, because it brings the melting point of the mixture down. Lime is ground from limestone and makes the mixture more viscous, as well as making the glass less susceptible to the erosive qualities of water and acids and saline air. The use of glass in building covers various areas such as windows, doors, curtain wall and partitions. It provides a high resistance to saline air, solar radiation and wind abrasion.

The use of glass as building finishes has become extensive over the years. Being a material whose major component is silica sand which exists in abundance in some parts of the world, access to it is not restricted. It was also used as decorative materials suitable for art objects and glazing but the current level of technology has improved its production such that glass is now been reinforced for use in various capacity both in buildings and automobile industry.

It has various applications in acoustic and sound proofing of buildings as well as creating and enhancing the green house effect. It does not yield to salt attack and provides little adhesion for paint. It has a network of strongly bonded atoms which does not yield to high temperature below 1400°C (Ellis, 1998). It is a non-combustible material which does not burn even at the exposure to flame, though cracks at higher temperature do occur. As an amorphous solid material, its main characteristic properties are hardness, rigidity and transparency. It is also resistant to weathering and most chemicals except hydrofluoric acid. There are numerous types of glass, these are:

Soda-lime glasses- This is the most familiar type of glass used for windows and doors of ordinary buildings. They are made of about 75% silica (SiO_2) plus Na_2O, CaO, and several minor additives. They can resist a temperature as high as 460°C (Schwartz, 2002). The rate of thermal expansion is high while resistance to brittleness is very low. Borosilicate glasses have high resistance to chemical attack and are most versatile in application. It endures high temperature, thermal shock and has high thermal expansion.

Lead glasses are manufactured with either low or high content of lead. The refractory index-heat capacity and electrical resistivity is relatively low. The quantity of lead determines the corrosion resistance. The resistance to chemical attack is low compared with other glasses. Its application is majorly outside building except in the production of electrical light bulbs. Aluminosilicate glasses are essentially used in places that require higher temperature because of its high brittleness and thermal resistance. They can withstand a temperature as high as 649°C (Schwartz, 2002). Resistance to water percolation, weathering and chemical attack is very high. The application in building is majorly in cooking appliances and doors to chimneys. Silica glass is easier to fabricate and cut into sizes for various uses in building. The use covers window,

general glazing and doors. The coefficient of expansion is higher. It can withstand 799°C of heat (Schwartz, 2002).

Fused silica in its natural occurrence is referred to as fused quartz; it contains silicon dioxide in its entirety. It is the most transparent glass with high purity. The resistance to heat at 899°C-1260°C is the highest among glasses. It has maximum transmittance to ultraviolet rays. The brittleness characteristics are better than other glasses. Due to difficulty in cutting it to shape, it is rarely used in buildings as finishes. Though Phosphate glass can withstand hydrofluoric acid and fluorine chemicals, it is non-resistant to water and so cannot be used as finishes in building. Plate glass are rolled into sheets and polished. It is of good grades which contain less calcium oxide. Additives are added to improve its ability to absorb ultraviolet or infrared. It is widely used in office partitions, large building facade and on external surfaces even as walls. Conductive glass is used as wind shield in cold regions to prevent icing where conductive coating dissipates static changes. It has a high refractory index and good resistance to solvents.

Other types of glasses are transparent mirrors, industrial glass, boric oxide glasses, optical glass, coloured glass, polarized glass, opal glass, porous glass, and oxycarbide glass. Flat or sheet glass- plain, coloured or tinted is mostly used in buildings as panels. The possibility of sand blasting increases aesthetics and customization. The use of glass ceramics is also applicable in building finishes, though it could be very expensive. It is very stable at high temperature with high resistance to oxidation and corrosion. The weight is light which adds to its advantages as it reduces the overall weight of the building on the supporting frame. Being a non-porous material, it is water resistant and good for external finishes. The reaction to salt is not pronounced. Glass ceramics can be reinforced with fibre to improve the brittleness characteristics.

In science, however, the term *glass* is usually defined in a much wider sense, including every solid that possesses a non-crystalline structure and that exhibits a glass transition when heated towards the liquid state. Glasses can be made of quite different classes of materials, these materials include: aqueous solution, metallic alloys, molecular liquids, ionic melts, and polymers. Glass, as a substance, plays an essential role in science and industry. Its chemical, physical, and in particular optical properties make it suitable for applications such as flat sheets that are cut into various sizes for buildings fenestration, thermal insulator and reinforcement materials. Fused quartz is used for some special applications, because of its high glass transition temperature of over 1200°C (De Jong, 1989). Addition of some additives such as sodium carbonate will lower the transition temperature which provides for a better chemical durability. The resulting glass contains about 70 to 74% silica by weight (Pfaeder, 1996)

Material deterioration occur in glass with its attendant internal thermal discomfort due to ultraviolet radiation. To enhance ultraviolet protection for spaces such as museums, libraries, etc. Mitigating strategies such as laminated glazing (the Polyvinyl butyral (or PVB) interlayer absorbs ultraviolet rays), applied films, curtains and shades are required. Almost all of ultraviolet radiation can be filtered out, depending on the thickness of the Polyvinyl butyral (or PVB) inter-layer of the laminated glass. Applied films are easily scratched and their colour eventually undergoes changes, this makes them less durable than laminated glazing.

In designing for warm humid zones, heat absorption and heat storage should be avoided, this can be achieved by making use of low thermal masses, outer surfaces that are high in reflection or double-skin structures such as double-glazing units. Also due to high solar radiation character, it is a must for shading devices to be employed in buildings especially those that make use of glazing or that use glass as a walling material in a vast majority of the building façade. A low-cost solution to shading is providing an environment that is rich in vegetation thus creating a localized climate. Although shading devices are essential to a building, they could impede air flow and thus they should be designed in a way that it does not hinder air flow (Subramanian & Kamalesvari, 2016)

3. Research Methodology

A mixed method of qualitative and quantitative approach was adopted in this research. Questionnaire was designed to elicit information from respondents on their perception about the performance of glass, its functions, durability, acceptance and compatibility to the warm-humid climate of the study area. In the course of the field survey, personal observations were carried out to determine the rate of use and number of buildings that are involved for effective distribution of the research instrument. Buildings were divided into various categories based on use. These categories are: commercial, educational, religious and residential. Particular attention was given to commercial buildings because almost 95% of buildings enumerated are commercial. Only a fragment of other typologies applied glass in their buildings except for windows and other fenestration. In the process of collating and analyzing the retrieved data for this research, a descriptive statistical technique was used. For accuracy, Microsoft Excel was used during the stage of the collation of the data from the questionnaires, the data was then entered into SPSS, included in the descriptive statistics are frequency distribution, percentages, mean and standard deviation. The frequency distribution and percentages is used in the interpretation of the data.

4. Study Area

The study was carried out in Akure the Ondo State capital. Ondo State is one of the Yoruba dominated states withing the southwest geopolitical zone of Nigeria. Akure became the state capital at creation on the first of February, 1976. Akure is situated on latitude 7° 17’ N of the equator and 5° 4’ E of the Greenwich Meridian. It has an altitude of 370m above the sea level. Base on its location within the tropics, it is subject to the two popular season of wet and dry. The wet season spans a period of eight months between March and October while the dry season is between November and February according to the Koppen classification. The type of climate in the study area show that rain and humidity is relatively high with its attendant high temperature. That is why the area is further classified as warm-humid zone within the tropical climate. There are two Local Government Areas (LGAs) that make up Akure. These designated as: Akure North and Akure South with a corresponding land area coverage of 676.7 km2 and 318.0 km2 respectively.

5. Results and Findings

For ease of analysis, the type of buildings is narrowed down to commercial, educational, religious and residential as earlier discussed. The commercial categories which are the major buildings investigated because of the material in focus consist of any building used for one form

of business or another either purposely built or converted. This category varies from small shops to big establishment and also include pharmaceutical outfits, restaurants/ eateries, showrooms, and the likes are listed for better comprehension. The results show that the use of glass is predominant in commercial buildings when compared to other building types, and it is used for beautification, and also to showcase the business, and for advertisement purposes.Close to 94% of buildings investigated are commercial because of this reason as shown in table 1.

Table 1: Types of Building

Type of Building	Number of questionnaires administered	Percentage
Commercial	102	93.6
Educational	3	2.75
Religious	1	0.9
Residential	3	2.75

The results as shown in table 2 indicate that respondents have different perception about the effectiveness of glass in the study area. More than half of the respondents (59.93%) submitted that glass is effective for climate control in the study area. This maybe predicated on the fact that all the respondents uses glass for the windows of their buildings of any typology. Although the climate is warm, the application of glass to large fenestration allow for a mild control of the interior climate of the buildings. However, 11.01% of the respondents did not agree that glass is effective in the climate control because most of the openings can only allow 50% ingress due to the extensive use of sliding window. Sliding windows are cheaper and more cost effective in the study areas. Folorunso & Ahmad (2013a) observed that cost is one of the major consideration for materials specification and use in Nigeria. They further stated that client most often choose materials based on ability to purchase such material without minding its performance. One of the most effective window type in the area is the casement window which allows maximum air flow and opens from 90-180 degrees as submitted by Anunobi, Adebayo, Oyetola, Siman & Audu (2015) opening but because of the price which doubles the sliding type, only the well-to-do in the society are using it. However, The most effective which in the louver blades is seen by the populace as archaic and old fashion despite the fact that it can permit over 75% ventilation (Anunobi et al 2015) it is no longer embraced by the people in the study area. The remaining 29.36% of the respondents are neutral. Most likely this category do not have knowledge about the performance or are simply not affected due to other salient reasons like body weight, intrinsic clothing and similar issues.

One of the major reasons for this research is to find out the thermal comfort of glass in warm humid zones, and then figure out how to improve it so as to make glass adaptable to the climate of the zone. To achieve this, the researcher asked a few questions to the inhabitants of the building. In evaluating the effectiveness of glass as a walling material in warm humid zones, the advantages it provides were looked at to determine the degree to which the glass is successful in providing a desired result. One of the advantages of glass is that it transmits 80% of daylight in all directions. This will reduce the dependence of interior space users on electricity for day lighting (Liu, Sun, Wilson & Wu 2020). To determine if the climate condition would affect the inside of the building, and if this will reduce the effectiveness of glass in warm humid zones, respondents were asked if glass affects the heat condition in the building. A larger percentage of

respondents 56.88% agree that it usage increases the interior temperature of the, 27.52% disagree while 15,60 are neutral. It is an established fact that glass is one of the greatest mean of achieving the green house effect (Mikhaylov, Moiseev, Aleshin & Burkhardt 2020) It is one of the best material to trap heat in a space. However, this could become a disadvantage in the tropical environment that already has high temperature for most part of the year. Almost 60% percent of respondents (59.69%) observed that sun directly penetrate their buildings through the glazing surfaces even where window blinds are used. The incursion of this direct sunray is responsible for the increase in temperature of the interior spaces. When sunray penetrate the interior, other building fabrics also react to its effect. Apart from the discolouration of the exterior substrate as observed by Folorunso & Ahmad (2013b), it also lead to the wearing away of interior decorations especially materials that are made of plastics. It had also been observed that the window blinds that have direct contact with the sun changes colour fast just like the painted exterior surfaces as noted in Folorunso & Ahmad (2013b).

Due to the adverse effect of sun to the interior climate of buildings in the warm humid zone of the tropics and the discomfort it brings, the paper also seeks to propose possible remedies to building owners. Respondents were ask about the possibility of introducing double skin facade. This was explained to them for comprehension. A little above average (50.46%) of the respondents who understand the topic agree that its adoption will mitigate the negative effect of heat, 49.54% either disagree or undecided. However, studies have shown that double skin facade is effective in reducing heat penetration buildings (Alqaed, 2022). Majority of the respondents (75.42%) agree that glass causes glare. Whereas, it had been established that when right choices of glass are used, glare will be eliminated.(Teleghani et al 2013) This buttress the fact majority of the people within the study area do not have adequate knowledge about glass. They are just adopted due to trend as shown in the results which indicated that 76.09% of the respondents are uneducated about the material only 13.76% have little knowledge while 10.09 are undecided.

To further assess the compatibility of glass with the climate, a series of questions were asked, these questions comprised the reasons for the choice glass within the tropical climate. A series of possible reasons were laid out for the respondents to access the reasons for their choice. In fact, almost half of respondents (48.62%) see the choice of glass as walling material as a bad choice because of the heat it generates, yet they kept on using it. The continual usage is predicated perhaps on the aesthetics it provides, the uniqueness required in commercial buildings and its relatively cheaper cost compared to solid tiles. Folorunso & Ahmad (2013a) submitted that the choice of building materials in southwest Nigeria is primarily based on affordability and not durability. The purchasing power of the people determine what they use for their building construction. This may also suggest the occurrence of incessant building collapse in the zone of the country.

However, the results show that the use of glass in the area helps in reducing the volume of energy that is required for day lighting. Respondent submit that electricity may not be required for the greater part of the day for the interior spaces due to the penetration of the sun. The results show that 89.91% day light effectiveness is achieved through the use of glass as walling material. Only 6.42% disagree. Those who disagree are found to install double layer of window blinds in their spaces because of privacy and glare while 4.67% are neutral. The use of glass

encourages the use of passive energy which in turn helps ameliorating the negative effect of energy generation within the environment. Buildings are found in the study of (Cao, Dai & Liu, 2016) to be responsible for higher energy consumption, any way of reducing its usage withing the interior spaces will help the total well-being of the environment.

To assess why glass is not properly utilized as a walling material in the country, and what factors affect its use, the respondents gave their opinion on a series of questions. Another key aspect of the research was to find out how durable glass is in the course of its lifespan; does it last long, and is it susceptible to wear and tear. In the course of this study, it was noted that majority of the respondent (51.38%) see glass as a non durable material, despite the fact that only 6.59% and 7.68% of the respondents have changed or replaced the glass used as exterior wall material bi-annually and annually respectively, 85.32% of them have not at any time replace or change the material. Only 48.62% agree that glass is durable. This might be due to the inadequate knowledge about the material as earlier observed. The level of expertise of artisans in the study area regarding the method of fixing glass- mode of application- which respondents identified as 'carelessness also suggest the doubt been expressed by the users. Ware and tear also contribute to the frequency of maintenance among the buildings that have done some replacement. The results indicate that respondents are not satisfied with the application method. Majority agree (62.38%) that glass is wrongly applied on their buildings. This was noticed in the vibration of the material especially during rainfall as earlier discussed. The absorbers are found to easily go out of place apart from the fact that the quality of these material cannot be guaranteed. It is worthy of note that most building materials in the Nigerian market are of low quality (Ikechuckwu, 2021). When glass is used wrongly, it affects the inhabitants of the building, and may discourage use in the future, as the level of comfort was hampered. the wrong use of glass has affected its use and the likability for it.

Table 2: Thermal Compliance of Glass in Warm Humid Zone and other Characteristics

Variables	Agree	Neutral	Disagree
Climate control	59.93	29.36	11.1
Temperature modulation	56.88	15.60	27.52
Sun penetration	59.63	23.85	15.60
Double Skin Facade	50.46	25.69	23.85
Glare Attribute	75.42	5.31	19.27
Knowledge	13.7	10.09	76.09
Choice Option	25.69	22.94	48.62
Daylight Effectiveness	89.91	4.67	6.42
Durability	48.62	14.68	36.70
Frequency of change	6.59 biannual	7.68 annual	85.32 never
Application Effectiveness	62.38	15.60	22.02

6. Conclusion

Glass as a building material can be used beyond just being placed in windows and occasionally doors in buildings. It is an established material for walling system in many countries. In warm humid zones, the climate is not entirely favourable to glass as a walling material, because it hampers the thermal comfort of the interior of the building and thus it may be seen as not

effective or compatible with the climate of these regions due to issues like sun glare, heat and even the green house effect. There are also problems that glass causes that go beyond thermal comfort, like the issue of security, and its durability. It is a known fragile material, especially when it is not properly handled, thus significantly reducing its life span, because of its susceptibility to breakage. In order to improve the thermal comfort levels of the buildings where glass is used as the walling material, certain things need to be put in place. For example, reducing the amount of glare in the building would improve the thermal comfort of the space. This is possible through the application of different types of glass such as tinted or opaque glass. Also, the adoption of double skin facade will eliminate the amount of heat that enters the building thus enhancing the thermal comfort of users and of the buildings.

The study shows that glass can be used to control the interior climate of a building when properly applied. The proper use of glass would go a long way in making it adaptable in warm humid zones, as there are a different range of glass that are well suited to the climate, coupled with techniques that are available for their manipulation. Another technique that can reduce glare and reduce interior temperature is by planting trees around the buildings. However, this is only effective for low rise buildings. This will improve the micro climate, reduce temperature and enhance the ecosystem. Shading devices and techniques can also be introduced to reduce glare and improve thermal comfort of the space.

The study concludes that glass is effective for day lighting. This is a method that will reduce the amount of energy required for running the buildings within the tropics. Measures should be developed to enhance the durability of glass. Incorporating measures to prolong the lifespan of glass and guiding against breakage due to carelessness and the likes will encourage building owners in the usage of the material. In all, the compatibility of the type of glass been deployed with the climate should be considered at all times. While the integrity and the aesthetic requirements of the buildings are not compromised.

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Biography

Folorunso, C. O
Dr Clement Oluwole Folorunso is an Associate Professor in the Department of Architecture at the Federal University of Technology, Akure, Nigeria. He holds a PhD in Architecture from the Universiti Teknologi Malaysia, Master of Technology in Architecture from the Federal University of Technology, Akure, and a Master in Environmental Management from the University of Ado Ekiti. His area of research interest covers building materials specifications, performance and pathology. He has taught architecture at all levels both at the Polytechnic and the university in Nigeria. He has scholarly publications in various areas in architecture but with major focus on building material performance and pathology. His works has provided many solutions to buildings' decay. He is currently beaming his search light on decaying infrastructure in cities located at close proximity to the Atlantic Ocean.
Corresponding Author: cofolorunso@futa.edu.ng

Bruce-Agbogidi, **T. L.**
Tam Lydia Bruce-Agbogidi holds a Bachelor degree in Architecture and is at present a post graduate student in the department of Architecture at the Federal University of Technology, Akure. She is currently working on different building materials that are applicable to drug rehabilitation centers in Nigeria