GLAZED SURFACE AS A TOOL FOR ENHANCING ENERGY EFFICIENCY IN THE DESIGN OF ULTRA-MODERN SHOPPING MALL, KATSINA.

BY

KACHALLA BUKAR ABBA

P14EVAT8147

DEPARTMENT OF ARCHITECTURE

FACULTY OF ENVIRONMENTAL DESIGN

AHMADU BELLO UNVERSITY, ZARIA

DECEMBER, 2017

GLAZED SURFACE AS A TOOL FOR ENHANCING ENERGY EFFICIENCY IN THE DESIGN OF ULTRA-MODERN SHOPPING MALL, KATSINA.

BY

KACHALLA BUKAR ABBA
P14EVAT8147

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,
AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A
MASTER OF SCIENCE DEGREE IN ARCHITECTURE.

DEPARTMENT OF ARCHITECTURE
FACULTY OF ENVIRONMENTAL DESIGN
AHMADU BELLO UNVERSITY, ZARIA

DECEMBER, 2017

Declaration

I declare that the work in this dissertation entitled “GLAZED SURFACE AS A TOOL FOR ENHANCING ENERGY EFFICIENCY IN THE DESIGN OF ULTRA MODERN SHOPPING MALL, KATSINA.” has been carried out by me in the Department of Architecture. The information derived from the literature has duly been acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

Kachalla, Bukar ABBA		DEC. 2017
Name of student	Signature	Date

Certification

This dissertation entitled "GLAZED SURFACE AS A TOOL FOR ENHANCING ENERGY EFFICIENCY IN THE DESIGN OF ULTRA-MODERN SHOPPING MALL, KATSINA." by Kachalla Bukar ABBA meets the regulations governing the award of the Master of Science Degree in Architecture of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Chairman Supervisory Committee Dr. R.B. Tukur	(Signature)	(Date)
Member Supervisory Committee Dr. A. Batagarawa	(Signature)	(Date)
Head of Department Dr. A.S Salisu	(Signature)	(Date)
Dean, School of Postgraduate Studies Prof. S.Z. Abubakar	(Signature)	(Date)

Acknowledgement

I give thanks to Allah subhanahu wa ta,,ala for giving me the support needed over the period of my study. I would like to thank my parents, Aisha and Abubakar Kachalla. To my various friends and colleagues who ensured I see this project through, I appreciate you support.

I would like to thank my supervisor Dr. Rukayyatu Bashiru Tukur whose constant guidance from start to finish made it all possible. Thank you also to Dr. Amina Batagarawa for your supervisory role for going through the corrections and making it a better whole.

Dedication

I dedicate this effort to Allah subhanahu wa ta’ala without whose blessing I will not be alive and able.

ABSTRACT

Designing to make use of the climatic conditions of the site has always been a Challenge, especially for energy efficient building. The current investigation assesses how effective orientation, window-wall ratio and types of windows as a parameter for the reduction of annual cooling energy demand and the annual total energy consumption in commercial buildings. The research approach is experimental where study of commercial building in northwest Nigeria is analysed with parametric analysis. Simulation with Ecotect software applied is conducted. The results predict annual cooling load for the energy demand is 164.6kWh/m²yr; a reduction of 20.7kWh/m²yr when optimum orientation is used away from the actual. Again, results show that the total energy consumption increased when the window-wall ratio is also increased, in terms of annual cooling loads per unit floor areas, 60:70% window-wall ratio performed better. In addition, energy consumption in east and west axis is a little more (around 2-3%) it appears more obvious when the window orientation is east or west than north orientation. Energy consumption in South orientation corresponds to maximum annual cooling energy demand and it is minimum for north orientation. This fact-finding holds good. Annual energy consumption load for east and west orientation are almost equal (within 1% variation). Furthermore, in terms of energy efficiency, double glass with aerogel filled performs better than low-emissivity (Low-E) glass. For 90% increment in glazed area, the corresponding increase in energy consumption is 13.3 kWh/m^2yr for single-clear, 11.1 kWh/m^2yr for double clear, 8.7 kWh/m^2yr for double low-e-clear, 5.3 kWh/m^2yr for solar control reflective, and for 2.3 kWh/m^2yr double glazing aerogel filled. From this study, it can be concluded that the influence and sensitivity of window-wall ratio on the total energy consumption are related to the orientation of outside window, and the glazing types of window. The influence of the factors can be regarded as reference mode for the window-wall ratio when designing

commercial buildings. This indicates that if attention is paid to orientation and window-wall ratio as parameters during the design of a shopping malls, it would go a long way in ensuring that the design save cost to user. It recommended that Windows facing the east and west contribute to the greater effect on the energy consumption. Windows facing east or west should be avoided or the window-wall ratio of them should be limited, and external windows with suitable shading coefficient should be applied or movable sun-shading for the windows should be set up. In consideration of the building energy efficiency design, the windows should be on the north façade or the south and ventilation and natural lighting need to be considered. Reducing the window-wall ratios of a commercial buildings in northwest Nigeria would provide significant energy saving benefits. The energy efficiency performance would be significantly increased by reducing the window-wall ratio for external windows of single glass compared to when it is double glass-aerogel filled.

Table of Contents.

Declaration ..... **ii**
Certification ..... **iii**
Acknowledgement ..... **iv**
Dedication ..... **v**
ABTSRACT ..... **vi**
LIST OF FIGURES ..... **xii**
LIST OF TABLES ..... **xiv**
LIST OF PLATES ..... **xv**
Abbreviations ..... **xvi**
1.0 BACKGROUND PROBLEM 1
1.1 Introduction **1**
1.2 Problem Statement **3**
1.3 Justification **4**
1.4 Aim and Objectives **4**
1.5 Research Questions **5**
1.6 Limitation of Study **5**
1.7 Scope of Study **6**
2.0 LITERATURE REVIEW 7
2.1 Introduction **7**
2.2 Orientation **7**
2.3 Window to Wall **8**
2.3.1 Building applications and importance of glazing 9
2.3.2 Components of the glazed surface 11
2.3.3 Different glazing types 12
2.3.3.4 Low-e single glazing 14
2.3.3.5 Double clear glazing 16
2.3.4 Solar control (reflective) glazing with coatings 26
2.4 Glazing frame material and spacer **27**
2.4.1 Aluminum 27
2.4.2 Wood 28
2.4.3 PVC (polyvinylchloride) 28
2.4.4 Fiberglass 29

2.4.5 Spacer 30
2.4.6 Optical and thermal glazing properties 31
2.4.7 Solar radiation and spectrum 32
2.4.8 Solar Radiation through glazed surface 33
2.4.9 Visible transmittance (vt) 34
2.4.10 Heat transfer mechanism through glazing 34
2.4.11 Conduction 35
2.4.12 Convection 35
2.4.13 Radiation 36
2.4.14 U-factor (insulating value) 36
2.4.15 Solar heat gains coefficient (shgc) 37
2.4.16 Insulation 38
2.5 Energy Conservation in Buildings 41
2.5.1 Selection of site 42
2.5.2 Built form and grouping of buildings 42
2.5.3 Building shape and size 43
2.5.4 Building's orientation 43
2.5.5 Solar radiation 43
2.5.6 Energy and building's materials 45
2.6 Insulation Used as a Resistance to Heat Flow 50
2.6.1 Mechanism of thermal mass 50
2.6.2 Insulation location 52
2.7 Definition of Shopping Mall 53
2.7.1 Shopping mall 54
2.7.2 Regional differences 54
2.8 Classification of Shopping Mall 56
2.8.1 Regional 56
2.8.2 Super regional mall 57
2.8.3 Outlet mall 57
2.8.4 Dead malls 57
2.9 Shopping Trends in Nigeria **58**
2.9.1 Development of shopping trends in Nigeria 58
2.10 Current trends 59
2.10.1 Shopping activities 59
2.10.2 Shopping centers 60
2.10.3 The Patterns of Shopping Activities 61

2.11 Shopping Standards **61**
2.11.1 Shopping facilities 62
2.12 **Facilities required in the shopping mall** **63**
2.12.1 Categories of shops 63
3.0 METHODOLOGY 66
3.1 Introduction **66**
3.2 Dependent and independent variables **68**
3.3 Research method **68**
4.0 RESULTS AND DATA PRESENTATION 69
4.1 Introduction **69**
4.2 Results **70**
4.2.1 Physical building characteristics 70
4.2.2 Building descriptions 71
4.3 Modelling The Base Case **73**
4.3.1 Weather profile; 73
4.3.2 Building envelop 73
4.3.3 Effect of glazed area on annual cooling load (kwh/m^2 yr.) 76
4.3.4 Effect of glazed area on annual cooling load (kwh/m^2 yr.) 77
5.0 DISCUSSION OF FINDINGS 82
6.0 SITE REPORT 83
6.1 Site Selection Criteria **83**
6.1.1 Site selection 83
6.2 The Project Site **84**
6.3 Site Analysis **85**
6.3.1 Site analysis; climate 86
6.3.2 Site analysis; (views and noise) 90
6.3.3 Site analysis (soil and vegetation) 91
6.4 Effects of Environmental and Climatic Factors On Building Design**.** **91**
7.0 DESIGN REPORT 95
7.1 Introduction **95**
7.2 Energy Efficient Design **95**
7.3 Form Concept Development **95**
7.3.1 Site planning concept 96
7.3.2 Ventilation and lighting concept. 98
7.3.3 Landscaping 98

7.3.4 Plan concept 99
7.4 Building Structure 99
7.4.1 Form 99
7.4.2 Floor loading 100
7.4.3 Foundation 100
7.5 Design Consideration 100
7.5.1 Sustainability 101
7.5.2 Space organization 101
7.5.3 Circulation 101
7.5.4 Accessibility 101
7.5.5 Maintenance 102
7.5.6 Flexibility 103
7.5.7 Means of escape 103
7.6 Services 103
7.6.1 Water supply 103
7.6.2 Power supply 103
7.6.3 Refuse disposal 104
7.6.4 Waste water and sewage disposal 104
7.6.5 Firefighting system 104
7.6.6 Storm water drainage 104
7.7 Materials 104
7.7.1 Stabilized earth blocks 105
7.7.2 Reinforced concrete 105
7.7.3 Steel 105
7.8 Building Finishes 105
7.9 Construction Methods **105**
8.0 CONCLUSION 107
8.1 Conclusion 107
8.1.1 Performance of the glazed surfaces. 108
8.1.2 Contribution to knowledge 109
8.1.3 Further work 109
REFERENCES 118
APPENDICES 110

LIST OF FIGURES

Figure 2-1 : Physical Properties of Glazed surface..... 12

Figure 2-2: Clear Ordinary Glazing with Highest Solar Transmission. 13

Figure 2-3: Solar heat and Visible Transmittance in Low-E Coated Glazing. 15

Figure 2-4: Solar heat and Visible Transmittance in Double Clear Glazing. 17

Figure 2-5: Solar heat and Visible Transmittance in Low-E Double Glazing..... 18

Figure 2-6: Double aerogel glazing solar heat and Visible Transmittance detail..... 19

Figure 2-7: Double aerogel glazed glazing solar heat ,Visible Transmittance 20

Figure 2-8: Double aerogel glazed glazing solar heat and 21

Figure 2-9: Double aerogel glazed Visible Transmittance detail 22

Figure 2-10: Double aerogel glazed glazing solar heat 23

Figure 2-11: Double aerogel glazed Visible Transmittance detail 24

Figure 2-12: Double aerogel glazed glazing solar heat 25

Figure 2-13: Low-E Coating and Solar Heat Gain Reduction..... 26

Figure 2-14: Glazed surface Frame and Its Material 29

Figure 2-15: Aluminium spacers with high thermal conductivity..... 30

Figure 2-16: warm edge spacer with low thermal conductivity 31

Figure 2-17: Szolar Radiation of Four Wavelength in Spectrum 32

Figure 2-18: Heat Transfer Mechanism through Glazing..... 34

Figure 2-19: Spaces Gap in Between Glazing and Gas Filled with Relationship.. 39

Figure 2-20: Air infiltration through glazing. Source: Bernier and Halle, 2005. 40

Figure 2-21: Solar radiation for different H/W ratios. Source: Ludwig, 1970. 44

Figure 2-22: solar striking glass,..... 48

Figure 2-23: Stabilizing effect of chapter on internal temperature..... 51

Figure 2-24: Annual cooling loads as a function of mass heat capacity..... 53

Figure 3-1: Overall research methodology 67

Figure 3-2: Dependent and independent variables 68

Figure 4-2: four-stage process conduct during the investigation. 69

Figure 4-1: Stage Process 69

Figure 4-3: Data Collection Instrument for Case Study. .....

Figure 4-4: Effect of glazed area on building energy consumption. 76

Figure 4-5: Effect of area on comparison with different glazed surface 77

Figure 6-1: Site Diagram 85

Figure 6-2: Site Analysis 85

Figure 6-3: Katsina Temperature. 87

Figure 6-4: Sunshine: Katsina. 88

Figure 6-5: Sun Path Diagram 88

Figure 6-6: Number of Rain Days in Month Katsina. 89

Figure 6-7: Wind Speed. 90

Figure 6-8: Orientation Consideration More Wind Than Sunlight. 93

Figure 6-9: Orientation Consideration More sunlight than wind. 94

Figure 7-1: Concept: Form and Site Plan. 96

Figure 7-2: Proposed Site Plan. 97

Figure 7-3: Proposed Ground Floor Plan 99

Figure 7-4: Proposed Facade 100

Figure 7-5: Design for the physically challenged. 102

LIST OF TABLES

Table 2.1: Energy Use in USA (Quadrillion Btu)..... 45

Table 2.2: Example average solar gain factors_ taken from CIBSE Guide..... 49

Table 2.3: Standard Schedule of Accommodation..... 65

Table 4.1: Case study building description used to create base case model. 71

Table 4.2: Different kinds of glazed surface used in this study.. 75

Table 4.3: Effect of different glazed area on building energy consumption..... 77

Table 4.4: Effect of different glazed area on building energy consumption..... 80

Table 4.5: Effect of different glazed area on building energy consumption. 79

Table 6.1: Site Comparison..... 84

LIST OF PLATES

Plate I: sun path in North Hemisphere, Source: www.nachi.org/building-orientation-optimum-energy.....24

Plate II: Single glazed, bronze tinted, aluminium framed glazing…….86

Plate III: Single glazed tinted, aluminium framed glazing…….86

Plate IV: Single glazed, bronze tinted, aluminium framed door and windows…….....87

Abbreviations

ASHRAE	American Society of Heating, Refrigerating And Air-Conditioning Engineers
DBT……	Dry Bulb Temperature
MRT …….	Mean Radiant Temperature
RH ……	Relative Humidity
PMV……	Predicted Mean Vote
PPD……	Predicted Percentage Dissatisfied
SET…	Standard Effective Temperature
CFS…	Complex Fenestration Systems
DV……	Displacement Ventilation
SHGC ……	Solar Heat Gain Control
EPB	Energy Performance of Building Directive

CHAPTER ONE

1.0 BACKGROUND PROBLEM

1.1 Introduction

Architecture and the advancement of technology have led to the recent influx of heavily glazed commercial buildings all over the world of which Nigeria is no exception.

The availability and the use of energy in a building are pivotal to the building's functionality within the confines of its purpose. However, if energy use in buildings is not control, can steadily led to costly waste to the building users and more importantly to through continuous release of greenhouse gases (GHGs) emission into the atmosphere leading to global warming and climate change (Oluwafemi,2015). Adeleke, (2010) report that the United Nations Environmental programme (UNEP) sustainable construction and Building Initiative (SCBI) noted that 30-40% of the global energy use comes from the commercial sector. This implies that achieving energy efficiency in buildings could mitigate the GHGs by 30-40%, which could have emanated from the commercial sector thereby saving the climate from the negative effect of these gases (Nwofe, 2014).

With the massive growth in new shopping malls construction coming up having front facade completely glazed in developing countries such as Nigeria and the inefficiencies of existing building stock worldwide, if nothing is done, GHGs emissions from buildings will be more than double in the coming years (Adeleke, 2010). These makes energy efficiency in buildings to be taking seriously by the governments in the developed world (Oluwafemi , 2015).

The major and the single most significant end use of energy in Nigerian shopping malls has been attributed to space cooling, (ECN-UNDP, 2005). Another analysis of the

building energy consumption in Nigeria commercial buildings gives a result that, the building envelope design, accounts for 40% of the peak cooling load respectively (Batagarawa, 2013). The substantial contribution by cooling is an indication that targeting this end-use will provide significant energy savings.

Energy consumption of up to 36% is attribute to materials making up the building fabric (Haase and Amato, 2006). Integrating active and passive design features in initial design phase by all professionals in a project can contribute in energy savings of between 50-55% (Ochoa and Capeluto, 2008). A building's envelope/facade is one component that when designed, can reduce energy use in the building. With the advent of glass technology, current trends of shopping mall buildings involve large glazed facades without any sustainable design principles such as, orientation external solar device etc. According to Pino (2012), the size of glazed area on a building highly influences the energy demand. A much glazed façade building might reach up to 155kWh/m^2 a year on total cooling and heating demands. On the contrary, in a building with a window to wall ratio (WWR) of 20%, with external solar shading and selective glazing, demand might be as low as 25kWh/m2 a year. Sambo (2008), report that energy conservation and efficiency practices and technologies should be actively promoting to ensure rationalized consumption of energy in the country. To moderate these problems, demand for energy consumption needs to be minimized and sustainable approach needs to sold with consideration for better energy consumption and more importantly, reduction in GHGs emissions. Shopping mall building is identifying as a useful area for investigating energy consumption due to its contributions to GHGs emissions. According to (Adebamowo, 2014) numerous researchers have conducted well-documented studies on energy consumption in shopping mall buildings. However, little known about how glazed surface affect cooling load of a building in hot dry climate of Katsina. This identified gap thus

formed the basis of conducting current investigation assesses orientation as a factor for reducing cooling loads in glazed commercial buildings in Katsina. Aim is to find out proportion at which the energy consumption increases with the glazed area depends upon, selection of glazing types, and their optimum orientation as a factors to be consider for cooling load reductions.

1.2 Problem Statement

Energy efficiency in buildings is one of the fundamental steps towards reducing the factors that could lead to temperature rising and climate change and save on energy costs for the building users. In shopping mall buildings, private generator back-up power provision are methods of coping with the consistent power supply experienced in Nigeria (Oyedepo, 2012). The major and the single most significant end use of energy in Nigerian shopping malls has been attributed to space cooling, (ECN-UNDP, 2005). An analysis of the building energy consumption in Nigeria commercial buildings gives a r result that, the building envelope design, accounts for 40% of the peak cooling load respectively (`Batagarawa, 2013). (Adenikinju, 2005) postulate that small-scale enterprises spend as much as 25% of the initial investment on self-provision of a back-up generator. With the massive growth in new shopping malls construction coming up having front façade completely glazed in developing countries such as Nigeria and the inefficiencies of existing building stock worldwide, if nothing is done, GHGs emissions from buildings will be more than double in the coming years (Adeleke, 2010).

In the wake of the worsening energy crisis burdening Nigeria now, the challenges that these glazed façade buildings poses cannot be met in terms of the provision of energy efficient whiles reducing annual cooling loads. Generally, buildings in the hot/dry with extensive glazed surface consume high levels of energy. In what proportion the energy consumption increases with the glazed types depends upon, selection of glazing area, and

their optimum orientation, from cooling point of view. This is the subject matter of the present investigation. The aim is to find out how effective is window to wall ratio is a factor to be consider for cooling load reductions.

1.3 Justification

There were several investigations about overall energy saving methods for buildings and there is various investigation about energy simulations focusing on numerous energy saving measures. However, little known about how glass-curtain wall affect cooling load of a buildings in hot-dry climate of Katsina. Effect of climatic conditions, glazings types, glazed areas, and orientations on annual energy consumption will be analysed.

To design any building, it is important to consider glazing as an aesthetic satisfying view both toward outside and inside of the building, for daylighting, fresh air and even for the occupants' psychological aspect. These criteria, however, were consider as traditional purposes.

Thus, investigation will help to get better awareness about relationship between the buildings' and climatic condition. More importantly, investigation will be able to get reasonable results, as it depends on using computer simulation program.

1.4 Aim and Objectives

The aim is to find out proportion at which the energy consumption increases with the glazed area and their optimum orientation as a factors to be consider for cooling load reductions. In order to minimize the amount of energy that a building consumes in shopping mall.

The research intends to achieve the aim through the following objectives

I. To identify different glazed area and their optimum orientation, used for energy conservation within the hot/dry climate of Katsina

II. To design a base-line model for testing the performance of the glazed surfaces and their optimum orientation.

III. To calculate energy and cost savings that can be achieve by applying each glazed surfaces and their optimum orientation, identify most suitable within the hot-dry climate of Katsina.

IV. To propose a design of an energy efficient ultra-modern shopping mall by applying most suitable glazed area with best orientation for hot-dry climate of Katsina.

1.5 Research Questions

The research will answer the following questions:

1. To what extent can the glazing area affect energy and cost saving to users?
2. What proportion the energy consumption increases with the glazed area?

1.6 Limitation of Study

Several limitations have been encounter in the conduct of this investigation, methodology limitations encountered during the simulation stage: Climatic data errors, erratic power supply, Validation of software, Cost of software, training, Researcher's inexperience and other human error.

The researcher complied with all research ethics especially the confidentiality on information obtained.

1.7 Scope of Study

The scope of this investigation covers electricity conservation in shopping mall building in hot-dry climate of Katsina, the capital city of Katsina State.

Energy storage is access as an energy conservation mechanism in shopping mall building. Shopping mall buildings consume 40% portion of total energy globally and in Nigeria (Adeleke, 2010).

Shopping mall building are chose as opposed to residential or industrial buildings due to its contribution to GHGs (carbon dioxide, carbon monoxide, and methane) (CO2, CO, CH4) emissions, industry is few, mostly due to the energy crisis within the nation and the expensive nature of cooling appliance (electrical) in commercial buildings.

Finally, investigation will develop a theoretical solutions as well as design solutions for not just cost-effective shopping malls, but also healthier and more productive living environment.in hot-dry climate of Katsina.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Literature covering this study would include orientation, energy efficiency and different glazed surfaces area and shopping mall. These subject areas will help readers become conversant with the main theme.

2.2 Orientation

The orientation of a building eventually determines how much energy it would use to provide cooling load for its occupants. Seok-Hyun (2013), affirms that the amount of sunshine is affect by the orientation of a building. During summer, the amount of sunshine at the East and West is small but the west requires a larger cooling load in the afternoon because of the afternoon sunshine.

The South has a larger amount of sunshine but the solar radiation can be blocked easily by shading. Salmon (1999), establishes the fact that "buildings should be able to respond to changes in climate by the rejection of solar heat and have the thermal integrity to maintain energy efficiency, despite the influence of climatic forces acting on the building envelope. Salmon (1999) however establishes that, analyses of sun paths and wind directions have shown that elongated buildings should be oriented to the South.

Aspect ratio which is the ratio of the longer dimension of to have a relationship with the orientation of a building. Szokolay (2004), further explains that depending on the temperature and radiation conditions, North and South walls should be longer than the East and West with an aspect ratio of about 1.3 to 2.0.

2.3 Window to Wall

The WWR is a ratio of window (glazing) area to wall area. This relationship can also be expressed as a window to wall percent (or glazing percent). Too high a WWR can result in too much light in the building, creating glare on computer screens and fading upholstery, artwork, printed materials and carpets. It can also contribute to the building being too hot in tropics region from all the sunlight and heat coming in. The envelope of any building is the exterior fabric that protects the building's interior from the harsh conditions of the outdoor climate. In other words, the envelope of a building acts as a shell in the transfer of heat from the external (exterior) to the internal (interior) and vice versa. (Koranteng, Tawiah and Nkrumah, 2016).

In modern day construction, it is unfortunate that building envelope designs are developing to meet the client's requirements without much concern to the local climate and with no objective to conserve energy (Al- Tamimi and Syed-Fadzil, 2011).

An analysis of the building energy consumption in Hong Kong, Singapore and Saudi Arabia and Nigeria for example gives a result that, the building envelope design, accounts for 36%, 25% and 43% and 40% of the peak cooling load respectively (Seok-Hyun, 2013; Batagarawa, 2013, Al-Najem. 2010).

Glazed surface were just like a hole in the wall at first; little by little, they were cover with wooden material, rags and animal fur. Since ancient time, humankind have been used glass materials in their buildings to benefit from solar radiation for providing daylight as well as heat in order to have a comfortable space for living or a working environment. In addition, glass materials help to protect against rain, wind, harsh weather. The history of glazed surface goes back to 4000-6000 years in history according to the following citation (Zerwick, 1980). Glazing materials made out of sand or silica, and to be able to change the chemical substance of silica from solid to liquid there has to be an approximate

increase of 1700 °C in the temperature. The second element of glass is soda ash, which reduces melting temperature to near 800 °C and gives a flexibility feature to the glass. Overall, the glass composition consists mainly of 65% sand, 20% soda ash and 15% limestone (Flavell and Smale, 1974).

2.3.1 Building applications and importance of glazing

To design any building, it is important to consider glazing as an aesthetic satisfying view both toward outside and inside of the building, for daylighting, fresh air and even for the occupants' psychological aspect. These criteria, however, were consider as traditional purposes. By the popularity of glazing material and their feature in building design, it was then vital to consider the other aspects beside these functions to achieve the best optimization.

Mostly glazed surface are considering as the weakest point in building envelop which have negative impacts on the energy load. The cooling and heating demand in summer and winter respectively, should also be taken into account, which makes it not possible to reach optimization unless the designer is aware of the heat transfer mechanism through glazed surface in order to reduce the amount of heat loss in or heat gain the building envelop.

Moreover, recent technologies, which enable the designer to add low-e coating on both or a single part of glazing surfaces, give an opportunity to transmit solar radiation and to have daylight and visible transmittance into the interior space. However, it is necessary to avoid unwanted heating in a warm climate or a hot season by using different glazing materials so to reflect the solar radiation into outer space (Jelle, 2013; Arasteh, 1994).

Furthermore, ultraviolet rays, visible transmittance, and infrared rays are three primary emissions that come from solar radiation. In what way the sum of solar transmission and

reflection is up to the glazing material is discuss in details. Besides, to reduce energy loss in building, it is important to know about the orientation and placement of glazed surface and how they effect and help in minimizing the energy load (Selkowitz., 2004).

In addition, the percentage of glazed surface to the exterior walls in building envelop is an important issue which has crucial effect on building energy flows as well as daylight. However, in this study, glazed surface are considering only as transparent glazing area and there is no referring to opaque the layers or frames. It is acceptable to have the highest glazed surface to wall ratio in a warm climate, in a cold climate, this percentage should be minimized to 40% or even less to have sufficient insulation. Moreover, it is possible to have a larger ratio where glazed surface is creating with low U-value to minimize the heat loss in winter or heat gain in summer. For instance, there is direct relationship between glazed surface to wall ratio and the solar heat gain. When there is an increase in the glazed surface to wall ratio, solar heat gain will increase accordingly (Su and Zhang, 2010; Inanici and Demirbilek, 2000). Since solar radiation has a different performance for achieving sufficient light and heat regarding to different geographical locations (North or South hemisphere) and different seasons, it needs to be considered significantly and much attention should be put on it. For instance, when sun position is low in winter, the south orientation has different solar radiation achievement in comparison to summer time. This is consistent with east and west façade as shown plate 1.

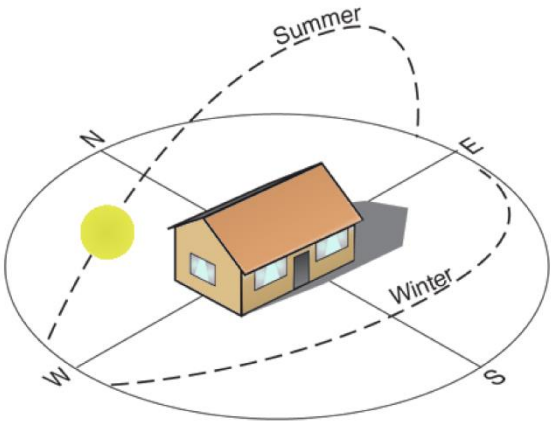


Plate I: sun path in North Hemisphere,

Source: www.nachi.org/building-orientation-optimum-energy.

It is good to mention that North orientation achieves indirect radiation in both summer and winter periods (Persson, 2006). Thus, glazing materials should be categorized according to the glazed surface orientation, their light and heat requirement, so to have better performance. It should be somehow to prevent overheating in warm climate by different glazing material while optimizing the energy performance, which will be discuss in the following sections.

2.3.2 Components of the glazed surface

Glazed surface include glazing, frame and spacer as its physical property and a large part of it is only glazing. Therefore, glazing is a drawback for it lacks the sufficient insulating quality and leads to an increase in the energy consumption. However, to optimize the energy performance in glazing materials, the importance of gas filled, spacer, and glass material should be considering as well as the possibility of adding coating on glass surfaces for making better energy performance. Figure 1 Physical Properties of Glazed surface (Karlsson, 2001)

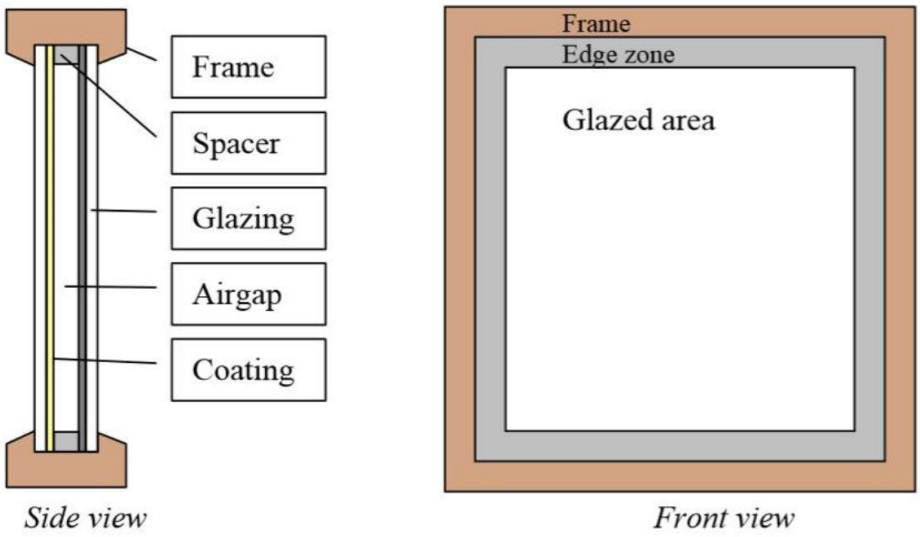


Figure 2-1 : Physical Properties of Glazed surface.

Source: Karlsson, 2001.

2.3.3 **Different glazing types**

Glazing transparency and their characteristic, whether leading to transmit solar radiation through reflect, is due to its material and its components. For instance, a single clear glazing has the highest amount of solar transmittance in terms of both light and heat, while reflective low-e with tinted gray glazing go with the minimum transmittance. Hence, it is important to design the building function according to the occupants' needs as well as the climate conditions.

There are many glazing types on the market, for the purposes of this investigation the following five types are explore, Single Clear Glazing, Low E Single Glazing, Double Clear Glazing, Low E Double Glazing

2.3.3.1 Single Clear Glazing

Single Clear Glazing. Relative to all other glazing options, single-glazed with clear glass allows the highest conductive transfer (i.e. heat loss or heat gain) while permitting the highest solar heat gain and daylight transmission.

Traditionally, single clear glazing is being made for most glazing materials in buildings to provide daylighting and view to outside, with lack of privacy for the occupants. However, glazing material has direct impact on the rate of solar transmittance in glazing surface. For instance, in Figure 2-2 ordinary clear glazing with 3mm thicknesses transmit the highest solar radiation, roughly 90%, which hits the surface of the glass; only 8% of it reflected and the rest is absorbed and converted into heat (Bülow-Hübe, 2001).

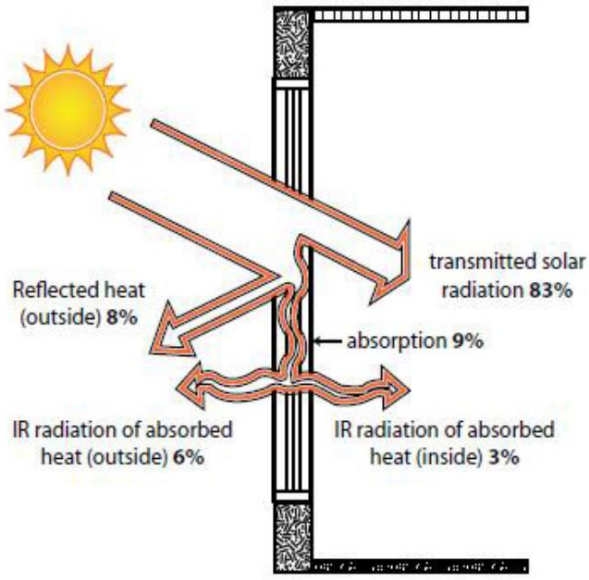


Figure 2-2: Clear Ordinary Glazing with Highest Solar Transmission Source: www.commercialglazed surface.org/shgc.

2.3.3.2 Tinted Glazing

Tinted glazing refers to the type of glazing, which has balance between the visible light and solar heat gain. It has two sorts and the traditional one minimizes visible transmittance as well as heat gain with two gray and bronze colors in the market. What is more, tinted glazing has initially been formulate to increase the level of heat absorption. Visual privacy and day lighting has been increase by it, while the amount of glare, shiny and bright light, which is not suitable for human eye, has been reduce. Although, tinted glazing absorbs

large amounts of solar heat and the glazing temperature rises, but the level of transmittance is minimizing by it at the same time. In addition, to be successful with this trade-off, glazing manufactures have released a new type of tinted glazing material; by changing the chemical substances to the float glass process, which absorbs a large part of near-infrared radiation. Furthermore, it is possible to work and joint with Low-E. Moreover, there is a well-known spectrally selective tints glass with blue and green colors, which gives opportunity to transmit more daylight and reduce solar heat gain.

2.3.3.3 Laminated Glazing

Laminated glazing refers to a type of glazing material, which consist Polyvinyl Butyral (PVB) and bond with two or more sheets of tough interlayer plastic material like a sandwich, which occurs under heat and pressure. Since the chemical process and sealed will be finish, it acts as single normal glazing material and provides multifunctional benefits, resolving many design problems such as aesthetic appearance and durability. It minimizes the amount of noise transmission, and protects against disasters such as earthquakes and explosion that makes it safer than conventional glazing (Bulow-Hube, 2001).

Moreover, it is possible to apply patterns and reflective coating on the laminated glazing sandwiches and assemble it together. Hence, placing double panel-laminated glazing and Low-E coating will optimize the effect optimized where facing air space (Alvarez, 1998).

2.3.3.4 Low-e single glazing

In the next part of this investigation, solar radiation through glazing will be review. Understanding solar radiation advantages for reducing energy consumption in building envelop has brought a new technology in glazing materials (Smith, 1998). After discussing about clear, tinted and laminated glazing with their advantages and

disadvantages in glazed surface, recently Low-Emissivity or (Low-E) coatings are coming to the market and are designed to reduce the thermal conduction amount (U-Factor). Typically, coated glass's range is divide into two main categories, which refer to "low-emissivity" and "solar control" coatings for different weather conditions and can be apply into clear, tinted or laminated glasses. In addition, the Low-E coating, for instance in warm climate coated, can be apply on the outside of the panel to keep the heat out, and in cold climate coated, it can be applying on the inner side of the panel to keep the heat in Figure 3. Low-e products are categorizing into "soft" and "hard" coatings.

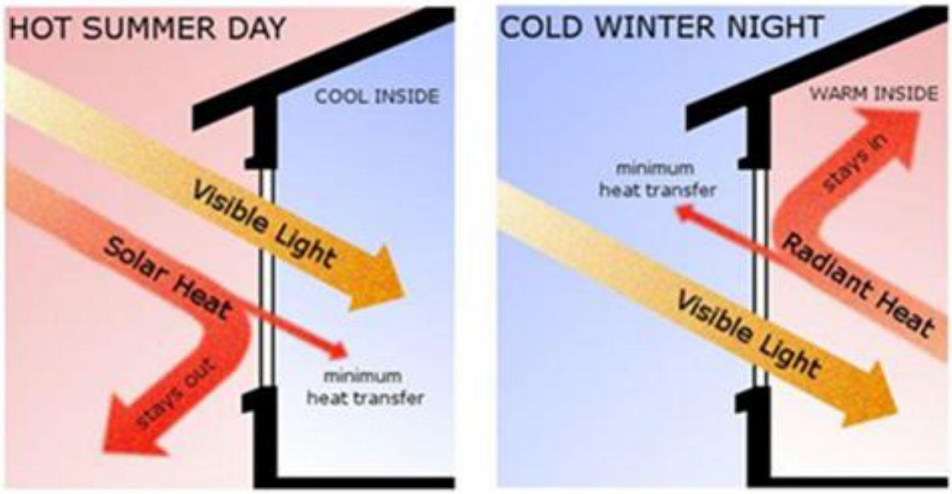


Figure 2-3**:** Solar heat and Visible Transmittance in Low-E Coated Glazing Source: www.replacementglazed surfacenj.org.

Hard coating is based on tin oxide material whereas soft coating is usually made out of thin layers of silver. Soft coatings have high levels of infrared reflectance and can reduce solar transmittance intensify compared to hard coatings (Pfrommer, 19951).

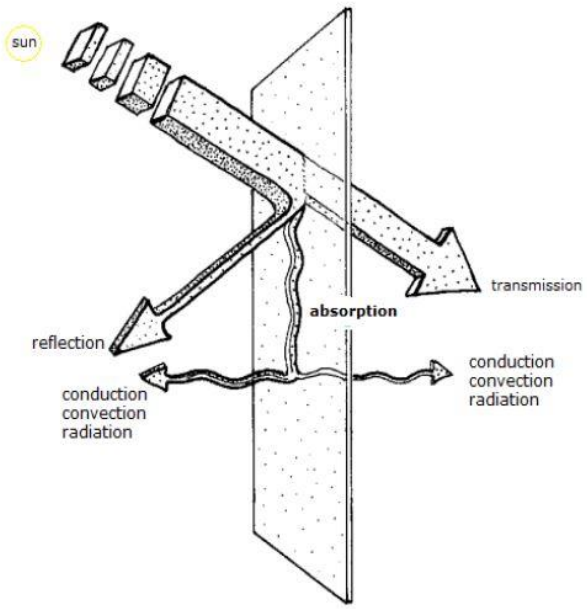
Since coating, process applies to the glazing panel whether one or multiple, it changes the material and optical properties of glazed surface glazing and the incident angle of solar radiation accordingly (Karlsson and Roos, 2000). For glazed surface coating design, it is important to consider the optical properties and the theory of thin films, which depends

on the quality, and composition of glass substances (Hardy and Perrin, 1932; Rubin, 1982; Pfrommer et al., 1995; Berning, 1983).

In addition, in most western countries, there is a new standard for building regulation and that is to use coated low-e glazing in their products. That is why manufacture procedures have been increased (Wegener, 1997). Since 1980, the coating glass technology has been developing and extremely improved glazed surface performance, which is available in the market (Nilsson and Roos, 2009; Lampert, 1981). Recently another coating type has been release to the market known as switchable coating (Lee, 2006). Low-E Single Glazing. Low emissivity (low-e) glass has a coating that minimizes re-radiated heat. It has a clear appearance and good thermal properties and can be use as single glazing or double-glazing. Low-e glazing sometimes called spectrally selective low-e glass helps to reduce the invisible, near infrared solar radiation that contributes to unwanted heat gain while permitting daylight transmission.

2.3.3.5 Double clear glazing

Double Clear Glazing. This offers some thermal insulation. It is made of two clear glass panels separated by an air gap. The air gap acts as an insulating barrier between the window panels and is an effective way of reduce conductive heat transfer. Compared to single glazing, it can cut heat loss in half due to the insulating air space between the glass layers. In addition to reducing the heat flow, a double-glazed unit with clear glass will allow the transmission of high visible light and high solar heat gain



.

Figure 2-4: Solar heat and Visible Transmittance in Double Clear Glazing.

Source: www.replacementglazed surfacenj.org

2.3.3.6 Low E Double Glazing.

Made from coated glass panels separated by argon/krypton gas. This type of low-e glazing, sometimes called spectrally selective low-e glass, reduces heat loss in winter but also reduces heat gain in summer. Compared to most tinted and reflective glazing, this low-e glass provides a higher level of visible light transmission for a given amount of solar heat reduction.

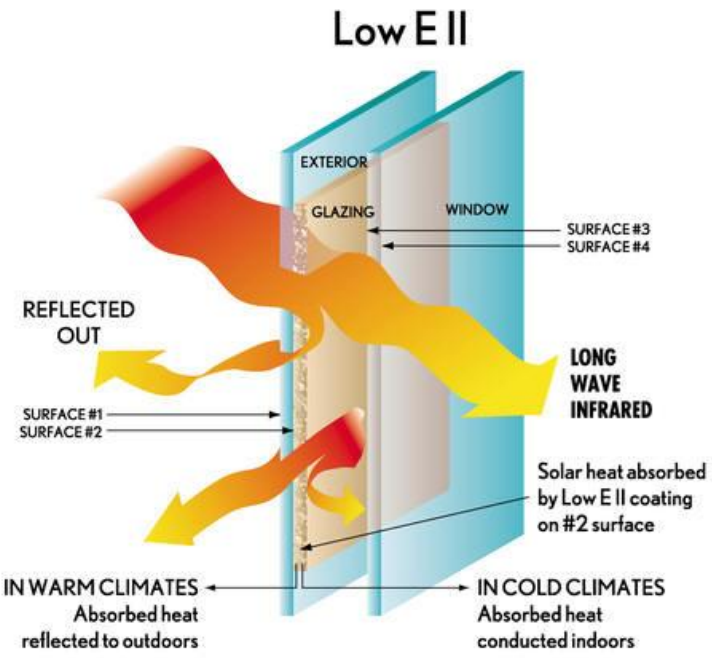


Figure 2-5: Solar heat and Visible Transmittance in Low-E Double Glazing.

Source: www.replacementglazed surfacenj.org

2.3.3.7 Double aerogel glazed material

The primary element of the double aerogel glazed System is a flat or curved, structural composite sandwich panel formed by permanently bonding specially formulated, fiberglass-reinforced translucent faces to a grid core constructed of interlocked, structural aluminum/composite, thermally broken I-beams. The natural thermal properties of the sandwich panel can deliver increased energy performance by the inclusion of translucent fiberglass “batts” or aerogel during the manufacturing process and by specifying a fully thermally broken grid core. U-value options range from .29 to .05 (1.57 to .28 W/m2K) by NFRC for the 70 mm thick panels and .15 or .08 (.83/.45 W/m2K) for 100 mm thick panels.

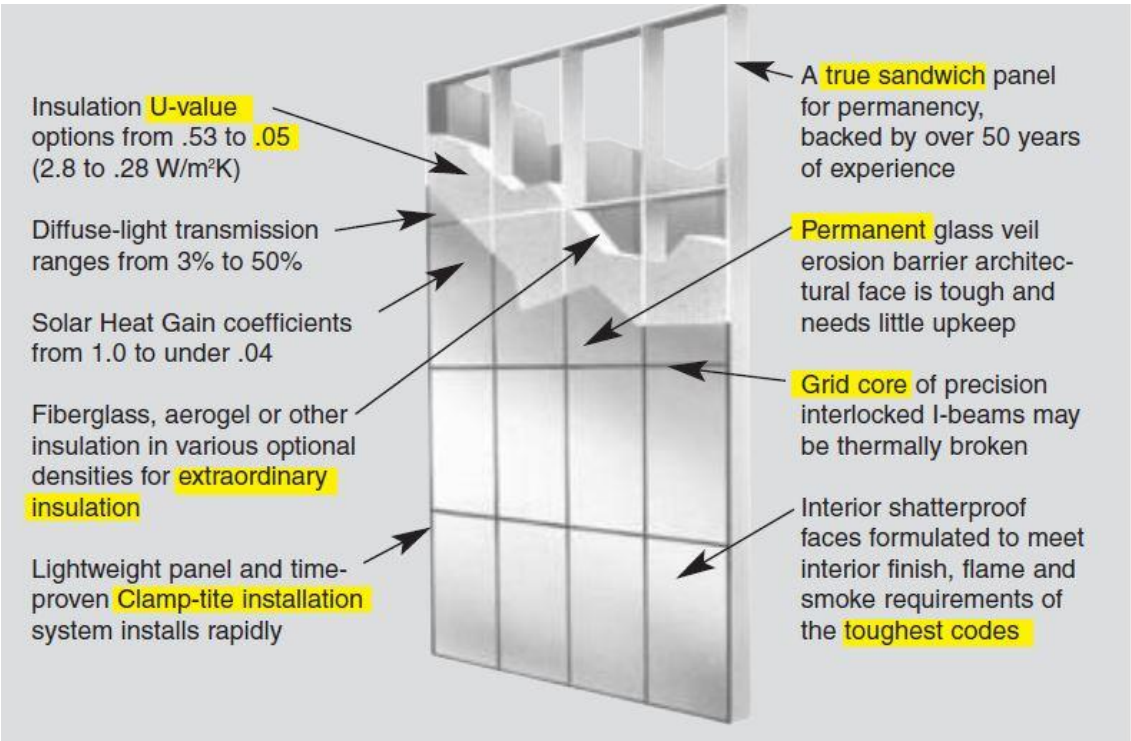


Figure 2-6: Double aerogel glazing solar heat and Visible Transmittance detail.

Source: www.Double aerogel glazed glazing.com

2.3.3.7.1 Translucent Colours

White and Crystal are standard but other colors are available. The Kal-tint series and pebble finish are options. Colored translucent insulation inserts are available in an endless palette of colors. Sandwich panel construction with fiberglass, aluminum or other faces can be combine in the same system for aesthetic value or energy performance.

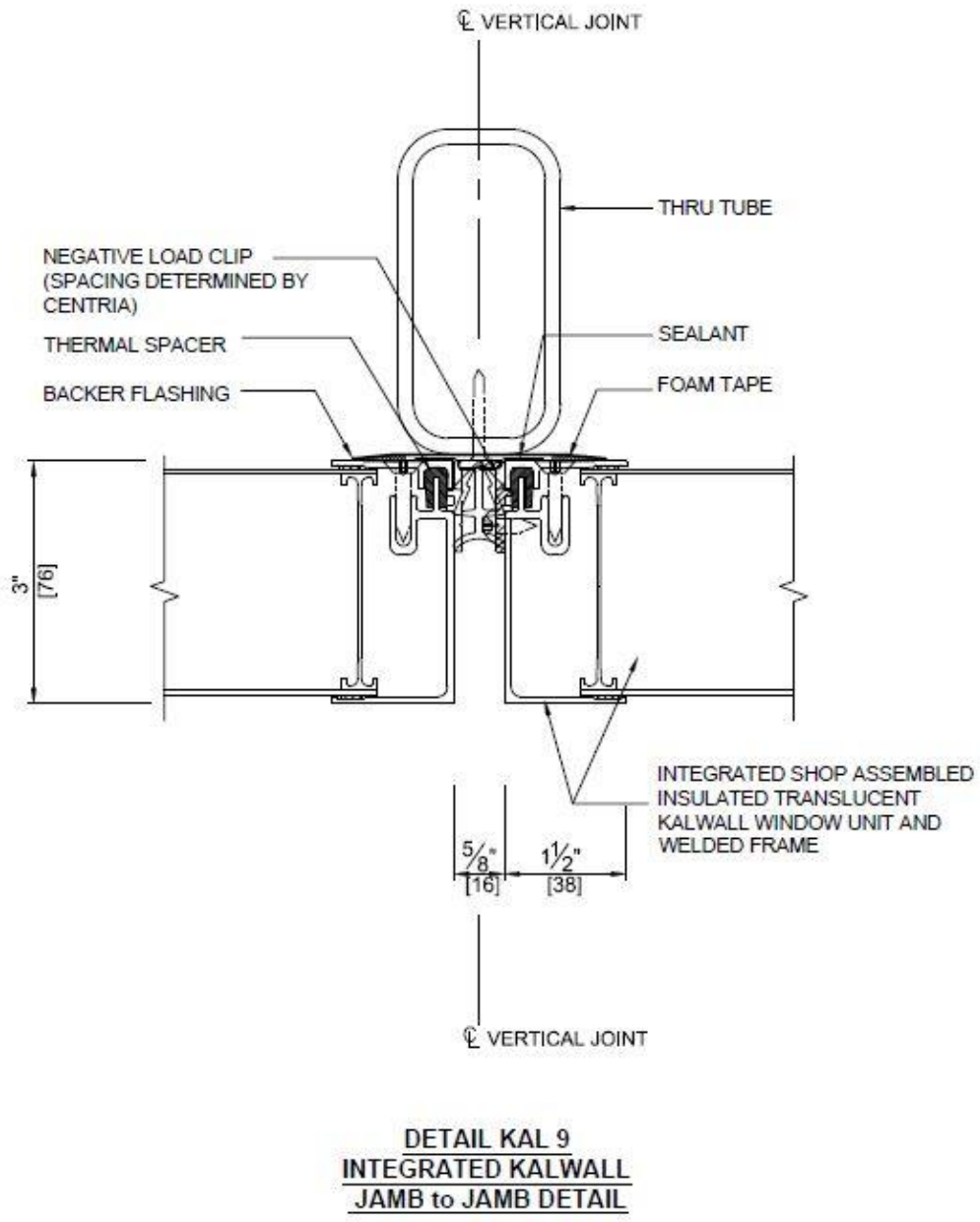


Figure 2-7: Double aerogel glazed glazing solar heat and Visible Transmittance detail

Source: www.Double aerogel glazed glazing.com

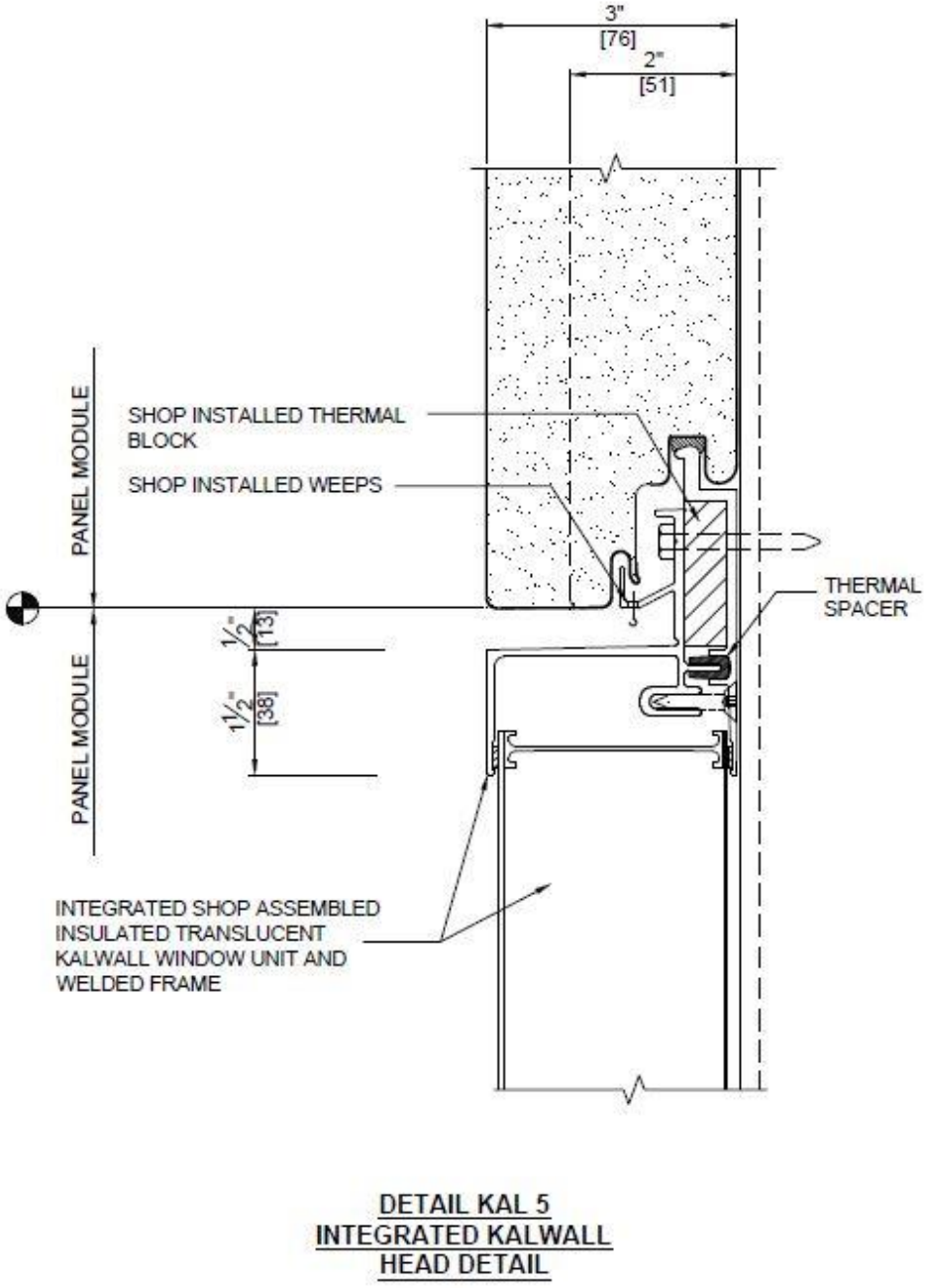


Figure 2-8: Double aerogel glazed glazing solar heat and Visible Transmittance detail

Source: www.Double aerogel glazed glazing.com

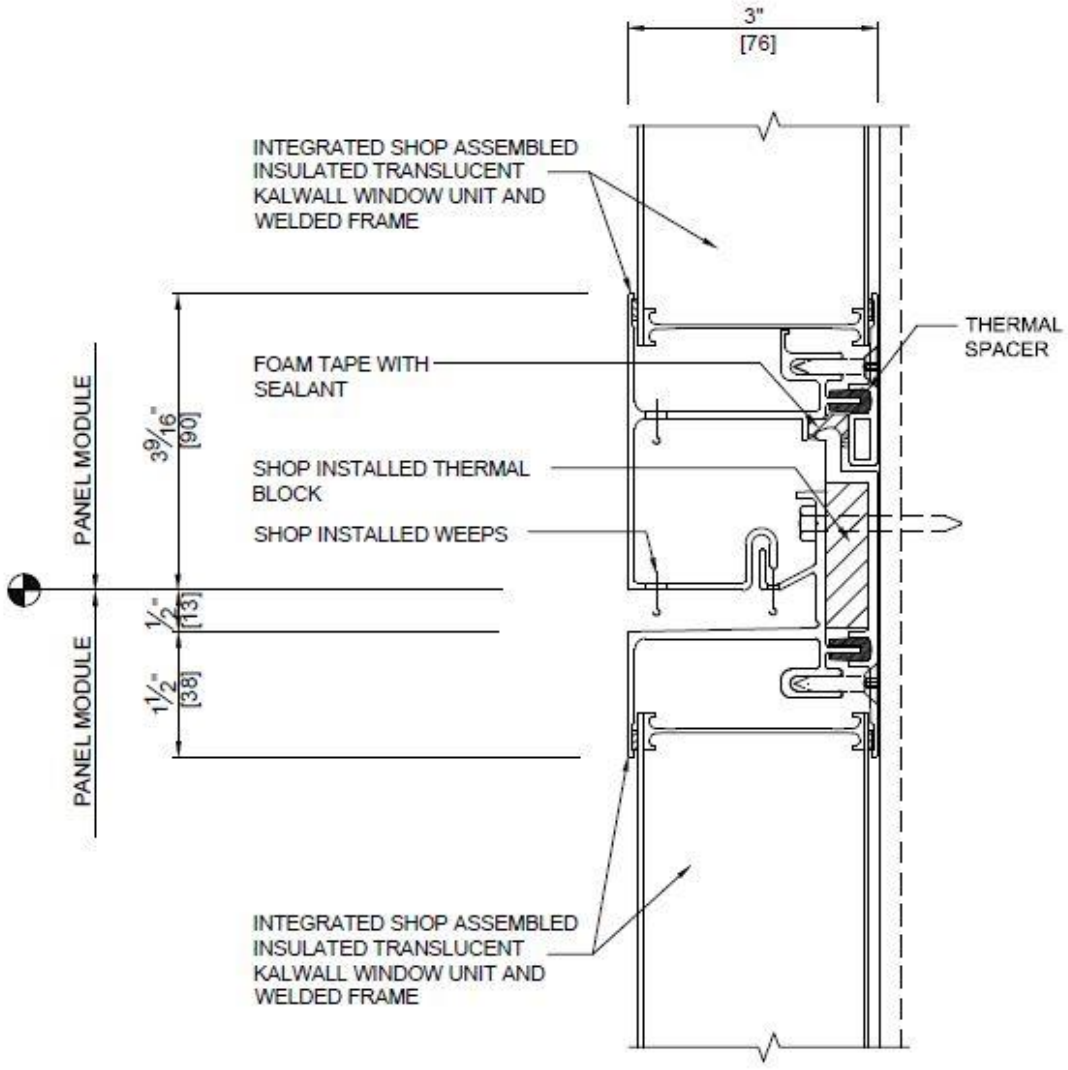


Figure 2-9: Double aerogel glazed glazing solar heat and Visible Transmittance detail

Source: www.Double aerogel glazed glazing.com

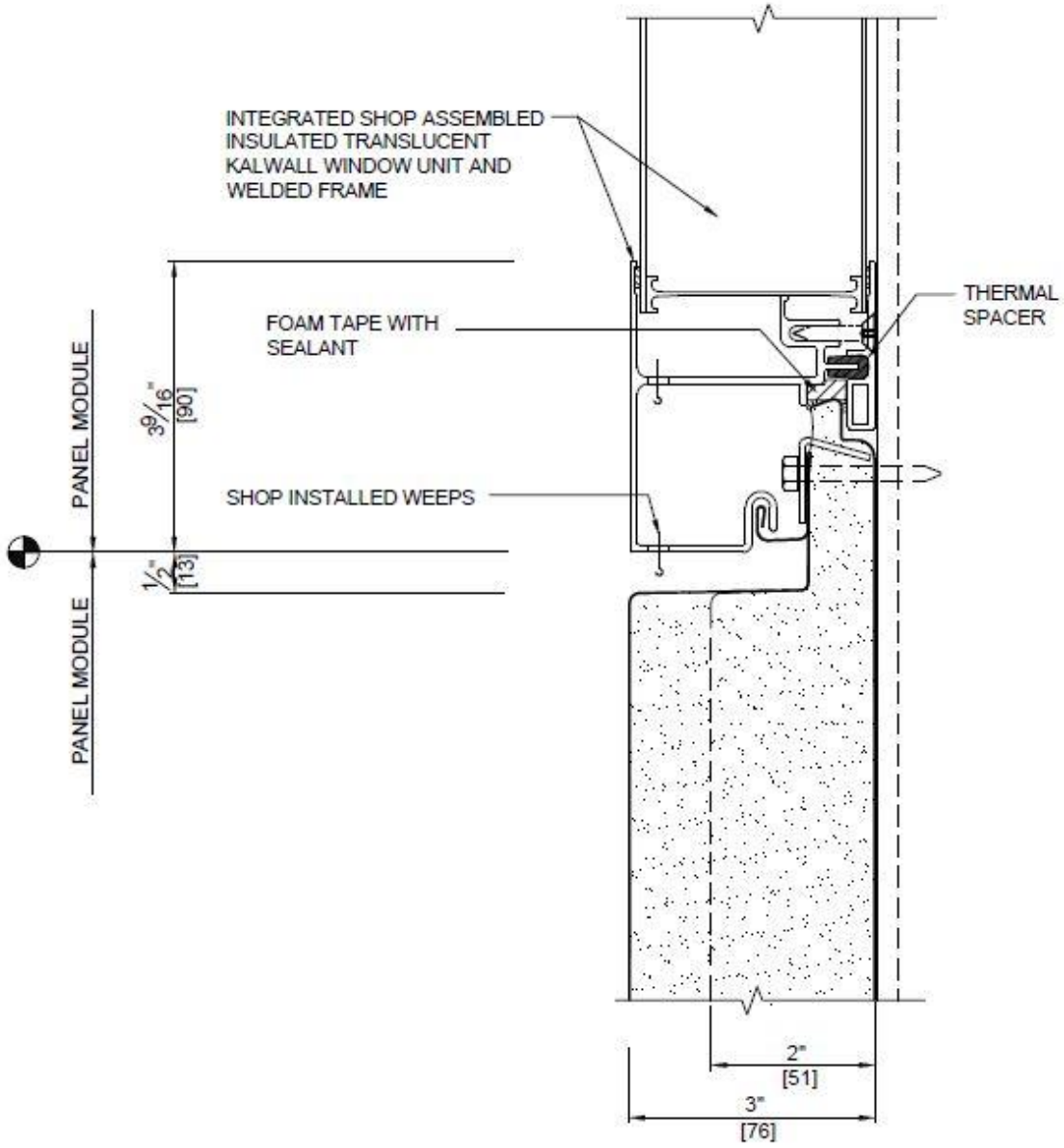


Figure 2-10: Double aerogel glazed glazing solar heat and Visible Transmittance detail

Source: www.Double aerogel glazed glazing.com

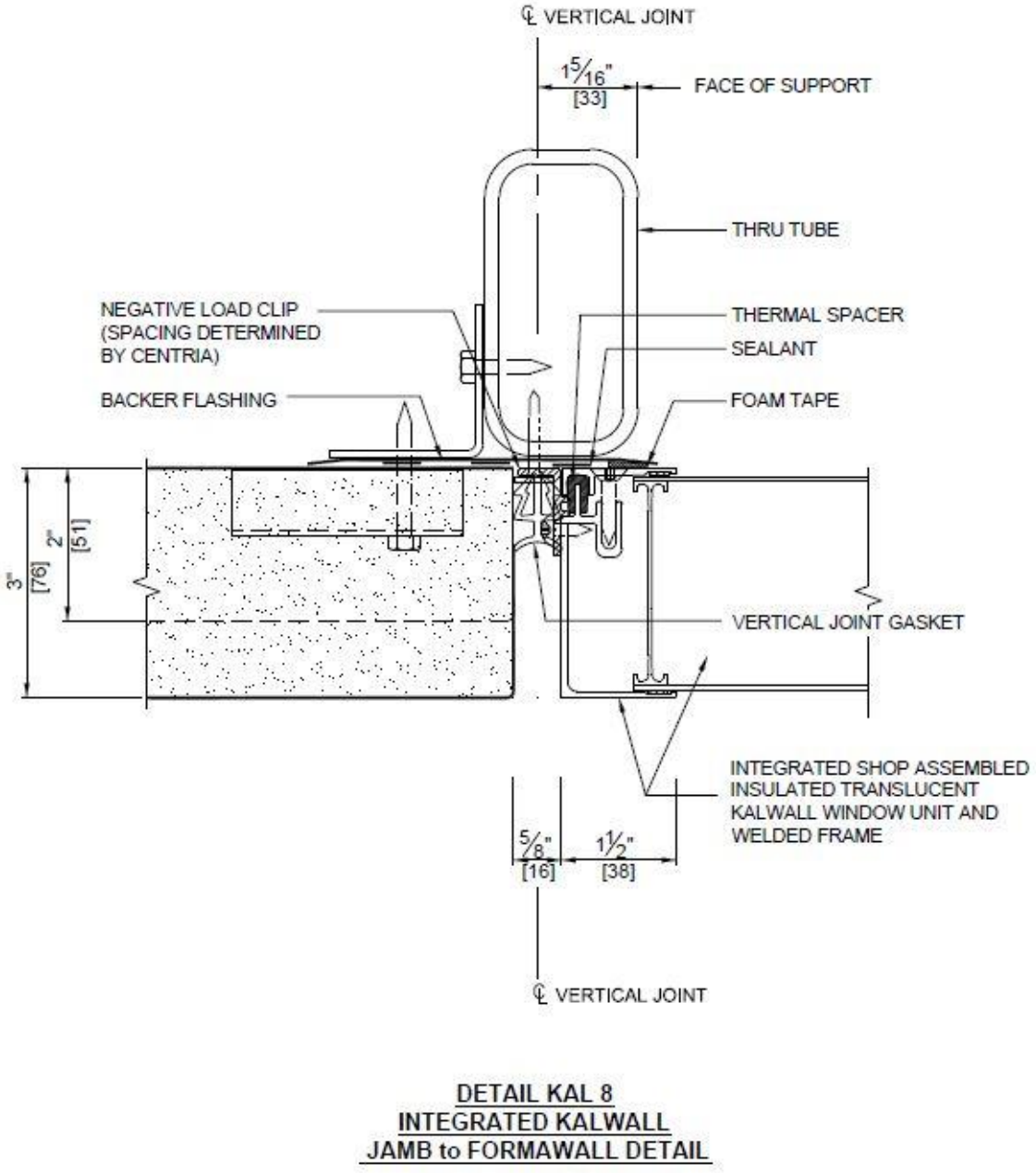


Figure 2-11: Double aerogel glazed glazing solar heat and Visible Transmittance detail

Source: www.Double aerogel glazed glazing.com

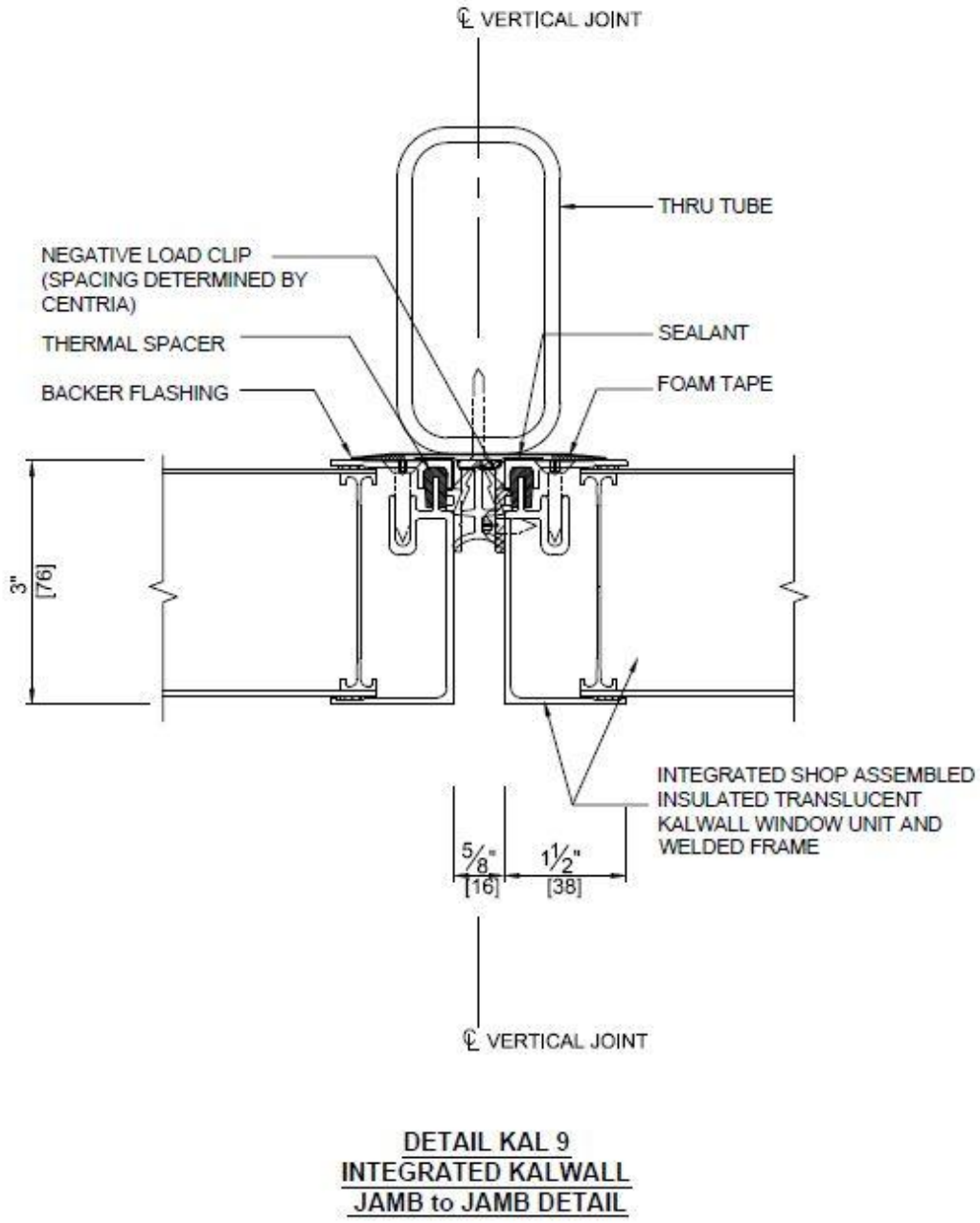


Figure 2-12: Double aerogel glazed glazing solar heat and Visible Transmittance detail

Source: www.Double aerogel glazed glazing.com

2.3.4 Solar control (reflective) glazing with coatings

If more reduction is required in solar heat gain coefficient, reflective coatings are applying on glazing surfaces. They can be use on clear or tinted glass with variety color such as silver, gold, bronze. In addition, when solar radiation emitted from the sun and hit the glazed surface, it is limited to reflect high level of infrared radiation, depending on its thicknesses and material component, so to change the optical properties in the creation process (Smith et al., 1998; Berning, 1983; Johnson, 1991; Robinson and Hutchins, 1994). The coating acts as a mirror to reflect solar heat gain and unwanted heating to become useful for warm climates.

(Glenn et al., 2009; Balcomb, 1992; Mohelnikova, 2009). Report, that the amount of visible transmittance and daylighting it keeps is able to transmit through glazing as illustrated in Figure 13, hence also, it helps in reducing heat loss through glazing in the building envelop

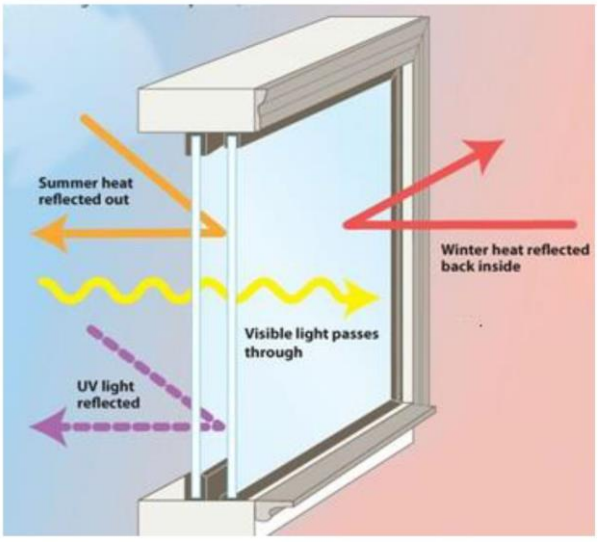


Figure 2-13: Low-E Coating and Solar Heat Gain Reduction

Source: www.myimageglass.com

2.4 Glazing frame material and spacer

After discussing the importance of glass and glazing, it should be mentioned that frames and spacers play a significant role in reducing the amount of heat loss in glazed surface glazing (Gustavsen, 2001; Asif et al., 2005). Frames represent 20 to 30% of the total area of glazed surface, which is crucial when considering the heat transfer rate by making a high insulated frame as well as a U-value reduction in the overall glazed surface (Gustavsen, 2011). In addition, it is important to focus on design, dimension, size, and shape of the frame to reduce heat transfer in glazed surface. The common materials for glazed surface frame are aluminum, wood, PVC and fiberglass which are explained below in details and different window frame.

2.4.1 Aluminum

Glazed surface with aluminum frame has 160 W/m·K thermal conductivity which represents a poor insulating material. This high thermal transition probably occurs due to its natural material characteristic, which helps in raising the temperature as well as increasing U-value in the glazing product.

Consequently, whenever there is a difference between the temperature outside and inside, the aluminum window frame becomes cold in winter - time and just the contrary in summer period.

Thermal breaks or barriers are to prevent heat transition in aluminum frames by a separator material, which is use in between inner and outer part of the frame to join them. Designers need to consider shape, size and even location of thermal break into the glazing product to decrease the amount of U-Value as low as possible (Ben-Nakhi, 2002; Duer, 2002).

Apart from the poor insulation, aluminum has flexibility which makes it possible to create complex shapes. Also its weight being light makes it easy to carry out while still being strong. It is further possible to airtight and seals it easily to avoid air infiltration and leakage against dust, rain and harsh weather. That is why aluminum frames are the most widely used in the industry with minimum maintenance.

2.4.2 Wood

The second glazed surface frame is wood which is organic and has porous material which shows good insulation with 0.13 W/m·K thermal conductivity and has more thermal resistance which acts well enough in comparison to steel or aluminum. However, it needs to be treated regularly and painted or sealant against rot, thus requiring more maintenance compared to the others

In addition, wood frame and its thicknesses influence thermal resistance. By increasing the wood frame thickness, more insulation is provided against temperature fluctuation and the rate of heat loss will decrease accordingly (Byars, and Arasteh, 1992).

2.4.3 PVC (polyvinylchloride)

The third glazed surface frame which is going to be discussed is Polyvinyl chloride, also known as the PVC with 0.17 W/m·K thermal conductivity. These plastic materials prevent heat loss through frame and symbolize well insulating by reducing the energy load through easy maintainable glazing. Polyvinyl chloride is roughly comparable to wood materials in terms of U-value and amount of thermal resistance. However, there is a negative point and that is PVC not being able to perform well against temperature fluctuation.

However, the number of PVC frame used recently has increased due to its well-known heat resistance and good thermal performance, with the most energy efficient glazed

surface frame for the consumers that is available in reasonable prices in the market (Beck and Arasteh, 1992).

2.4.4 Fiberglass

The last glazing frame material under investigation is Fiberglass with 0.40 W/m·K thermal conductivity which is not good in insulating and has high thermal conductivity after aluminum. It requires high maintenance and has a low popularity among the other frames in market nowadays because of its cost (Gustavsen, 2001).

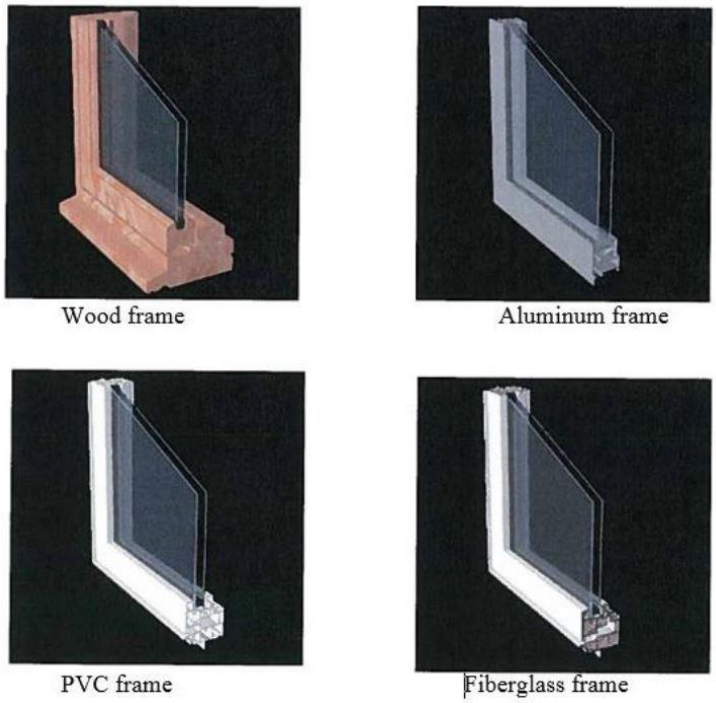


Figure 2-14: Glazed surface Frame and Its Material

Source: (Linera & Gonzalez 2011)

2.4.5 Spacer

Spacers are acting as junctions between glazing and frame. They are typical made out of metal and aluminum, which are lightweight but strong. Spacers are flexible, that make them able to form into different sizes, and shapes, hence, more than single panel glazed surface glazing separated via aluminum spacers to keep distance and create a kind of gap in between glazing to avoid thermal conductance. However, aluminum contributes to high levels of conductance and performs as a thermal bridge which hot increase the amount of U-value roughly 0.2 W/m2K compared to warm edge technologies (Karlsson, 2001).

However, to have a better performance and decrease the level of heat loss for double glazed surface or multiple panel, warm edge spacer has been used in buildings to provide better results figure 15.

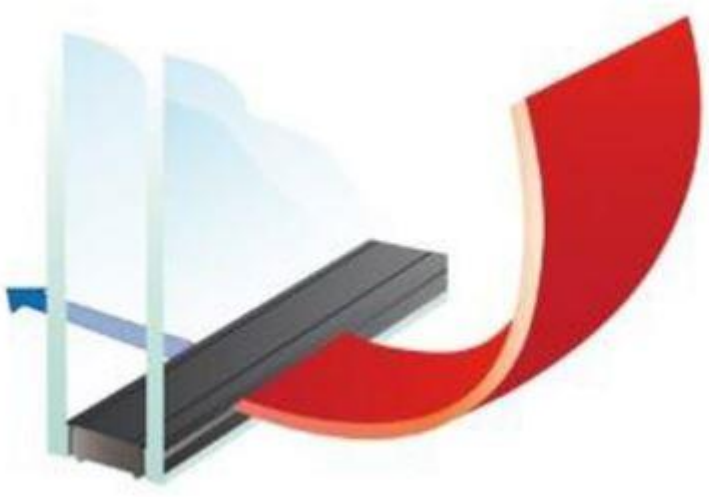


Figure 2-15: Aluminium spacers with high thermal conductivity

Source: www.weatherproof-glazed surface.co.uk



Figure 2-16: warm edge spacer with low thermal conductivity

Source: www.weatherproof-glazed surface.co.uk

It is also known as thermal break, which is made out of fiberglass material and replaces the conventional aluminum. In addition, it helps to reduce thermal heat through glazing. Although it is more expensive than conventional aluminum but it is available in variety of colors in market (Song, 2007; Van Den Bergh, 2013).

2.4.6 Optical and thermal glazing properties

In this part, the optical and thermal properties and their importance through windows glazing will be highlight. Optical properties are defining as solar radiation and wavelength in spectrum that influence windows glazing (Roos, and Karlsson, 1994) by means of transmittance, absorbance and reflectance. In next part, the importance of thermal properties, which is in the same category with heat transfer mechanism, will be talk of, as well as the ways to avoid heat loss and the importance of U-factor.

2.4.7 Solar radiation and spectrum

Solar radiation and electromagnetic of spectrum are divide into four main groups (Bube, 1983), First of them is Ultraviolet (UV) with $\lambda<380nm$ radiation which is not sensitive to human eye. Even though the level of this wavelength through glazing is very little, it can have a harmful effect on the interior furniture, decoration and even injury impacts on people and plants with minimum effect in balance of energy gain or loss. For better understanding of this issue, please refer to the illustrations in Figure 17.

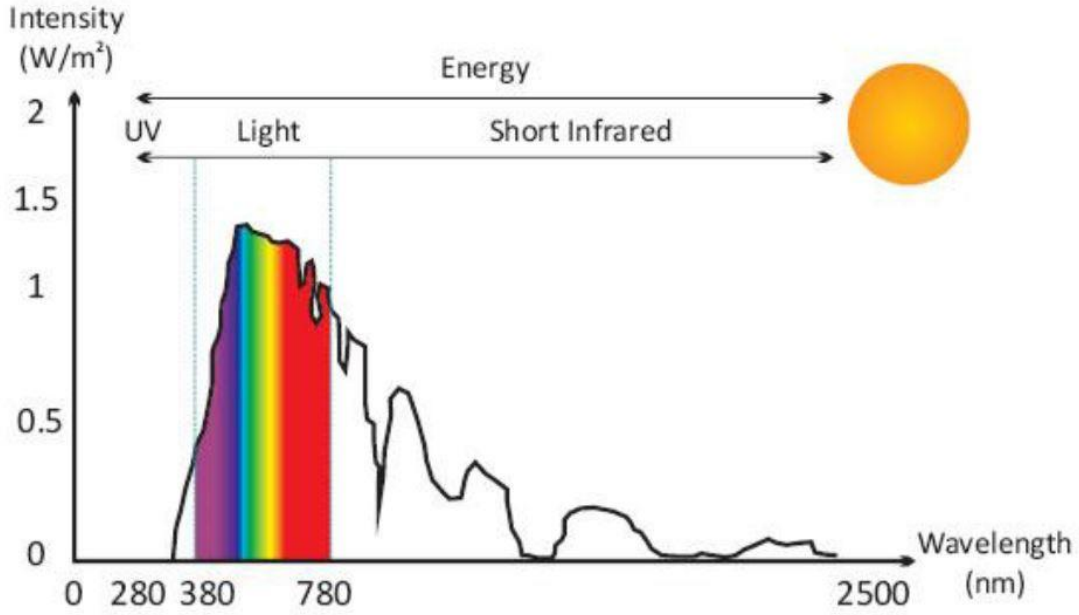


Figure 2-17: Solar Radiation of Four Wavelength in Spectrum

Source: www.jc-solarhomes.com/css/understanding-sunlight.html

The second type of solar radiation goes to the visible portion with $380nm<\lambda<780nm$. It consists 50% of the solar radiation and is vital to be consider as a wavelength interval. In addition, it is the only portion of this spectrum, which is sensitive on human eye, and humans interpret it as a light and illumination to use in their living spaces and building. Furthermore, it is interesting to know that an ordinary clear glass has the highest

transmittance in this interval and with an addition of panel in the glazing; the radiation will be absorbed and changed into heat.

The third interval of solar radiation is near infrared (NIR) with 780nm<λ<2500nm in between which is located above the visible radiation and therefore is not visible by human eyes. It consists approximately 40% of the solar energy, which transmitted to the earth.

The Infrared Radiation (IR-radiation) is the last type, which has over 2500nm wavelength, and most of this radiation is emitted from outside of the building into different directions. Although ordinary glasses absorb the radiation then reradiated into the outer space, energy is emitted in this interval. Hence, large amounts of heat loss might occur because of this mechanism (Bulow-Hube, 2001).

2.4.8 Solar Radiation through glazed surface

Generally, solar radiation through glazing is transmit, absorb or reflect and the level of them depends on optical properties, which can be the wavelength of radiation or incident angle (Jelle, 2013).

Since radiation cannot pass through glazing surface or be reflected off, it may be absorbed. This energy may change into heat, raising the glass temperature and make it warm (Hass and Waylonis, 1961). In addition, no changes occur in glass color if they absorb infrared or ultraviolet radiation unless they absorb the visible light, which makes them appear almost dark in surface (Wall, 1997). This change occurs based on the glazing material. For example, tinted glasses absorb large amounts of light while transparent clear glazing absorbs only a little (Jelle, 2007).

2.4.9 Visible transmittance (vt)

Measures how much light comes in through a product It is an optical property that indicates the amount of visible light transmitted the level of light transmittance through glazing in solar spectrum is called visible transmittance and it stands between zero and one as numerical. Visible transmittance is based on the number of glazing, glass coating or etc. In addition, the concept of keeping the visible transmittance as much as possible is an important factor along with reducing the solar heat gain in warm climate. For instance, uncoated single clear glass represents the highest visible transmittance, roughly 90%. However, reflective tinted coating glass reaches only less than 10%, which is important to be consider for occupants' necessity (Szczyrbowski, 1989).

2.4.10 Heat transfer mechanism through glazing

The process of heat transferring through glazing is a complicated subject and is not easy to be calculated (Rubin, 1982) when windows glazing leads to a significant heat loss through the building envelop (Handbook, 1997). In the following part conduction, convection and radiation categories, it will be discussing in details Figure 18.

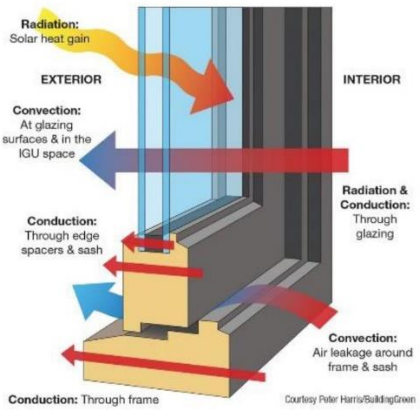


Figure 2-18: Heat Transfer Mechanism through Glazing.

Source: www.homepower.com

2.4.11 Conduction

Conduction is a kind of heat transfer process happening through objects when there is a direct contact between two sides of the object with different temperatures where atoms move freely as a group. The energy transfers by vibration of hotter molecules, which are faster than their cooler neighbors, are. Wilson et al. (1998) have discussed about heat loss and how it can be decrease through well insulating the exterior part of the wall in buildings.

Generally, heat loss occurs while there is a difference in temperature. When outside or inside is cold, heat transfers from the warmer section to the cooler one. For windows, on the other hand, frames and spacers are playing an important role in minimizing the conduction.

By using low conductivity materials such as wood and vinyl for the frame and warm edge spacers instead of current aluminum owns, the amount of heat loss in windows glazing will be reduced (Karlsson, 2001; Gustavsen, 2001).

2.4.12 Convection

This term defines the energy movement between molecules in fluids, such as air and water, which carry something to another place. When warm air replaces its position with cool air, heat is raise upside and it helps to moderate the temperature inside the building.

However, in windows, air leakage with both infiltration and exfiltration as well as heat loss might occur due to the lack of sufficient materials for frame. The use of double-glazed and space gap which can be filled with variety of gas needs to be considered therefore to avoid convection.

2.4.13 Radiation

Typically, short wave radiation via emission of electromagnetic is transmit through a transparent area. That means a large number of solar radiation is able to pass through glazing and gradually warm up the temperature and convert it into the heat energy. The number of transmittance or reflectance depends on the glass material and its component; that is why in opaque layers or walls it is absorbed or reflected off (Henderson and Roscoe, 2010).

2.4.14 U-factor (insulating value)

Measures the rate that heat transfers through glazing and window assemblies. The lower the U value the better the window's insulation value and its ability to resist heat flow.

The difference temperature between inner and outer space of glazing occurs heat loss (Wright, 1998), the level of this conductance in glazing called U-factor, and where there is a low heat transfer it means there is low U-value.

On the other hand, to be able to measure resistance of heat loss through glazing called R-value (Arasteh et al., 2006; Presley and Christensen, 1997).

By increasing the number of glazing, panel type, air filled, spacers and size of windows the u-value will be improve while the amount of heat loss will be decreased (Jelle et al., 2007). Therefore, it is possible to achieve a thermal resistance optimization and be highly insulated through glazing. For instance, by increasing one more panel to a single glazing, the result roughly changes by halves from 5.9 to 2.9 W/m^2K; and by adding one more glazing to triple it, the result will reduce again from 2.9 to 1.9 W/m^2K (Karlsson, 2001).

The overall U-Value of windows contains both glazing and frame. In other words, there are three different U-values needed to be considered: glazing, frame and overall U-value

of the window. The formula below shows how heat transfers coefficient calculation in the whole window including glazing and frame:

$$Uw = \frac{(Ag \times Ug \times Af \times Uf \times lg \times \Psi g)}{(Ag + Af)}$$

Here Ug refers to heat transfer coefficient of the glazing, Uf refers to heat transfer coefficient of the frame, Ψg refers to the linear heat transfer coefficient of the insulated glazing edge seal, Ag refers to the glass area, Af refers to the frame area,

Aw refers to Ag+Af, and last one, lg, refers to the length of inner edge of the frame profile.

This value contains both frame and glazing as an overall value to demonstrate U-factor unit is Watts per square meter Kelvin (W/ (m2 K)) (Karlsson, 2001).

High insulating glazing units have U-value as low as 0.3-0.5 W/ (m2 K) within three layers of glass with low-e coating in both surfaces. High insulating frame have u value as low as 0.6 - 0.8 W/ (m2 K) and this reduction is caused by the low thermal conductivity material frame (Gardon, 1961).

2.4.15 Solar heat gains coefficient (shgc)

Measures how well a product blocks heat from the sun. To evaluate energy performance of glazed surface, it is important to be aware of the ability of the solar radiation through windows glazing. In other words, the solar radiation proportion which is able to transmit

through glazing is called Solar Heat Gain Coefficient or SHGC (G-value in Europe) and its ranges are somewhere between 0 and 1 as a numerical. If this number is close to one, high solar heat transmission occurs which can be achieve with clear glasses or hard low-e locating, and is highly recommended for south facing facade in a warm climate. It is extremely recommend using coating glass types to reflect solar radiation as much as possible so to avoid over heating in the summer season (Arasteh et al., 2006).

To have solar heat gain coefficient, two important factors are needed to be considered. First, is the latitude of the specific region and second is the geographical location where the building is located in terms of its orientation. In the cold season, however, having a solar heat gain is beneficial for the building's interior temperature; while in a summer season, it makes overheating and causes discomfort for the occupants. To decrease this value as much as possible, the substantial material can be changed to add a Low-E coating on a glazing surface. The average value of SHGC is lower than the center of the glazing where the amount of frame area has low SHGC in windows. Moreover, the radiation can be directly transmitted through the glazing into the interior space, some of it be absorbed by the glazing, and frame indirectly while radiating later into the interior building. The number of panel, glazing type and coated or uncoated layers impact solar heat gain (Arasteh et al., 1989). More than 80% of the solar heat gain can pass through glazing for uncoated clear glazing. For reflected coating glazing, most of the radiation will be reflect and only less than 20% of it is able to pass into the interior space.

2.4.16 Insulation

Since single glazing was improving to multiple glazing, the importance of gas filled in between the glazing, its gap differences and the way to reduce the amount of air leakage for providing a better insulation are matters of importance.

2.4.16.1 Gas Filled

Typically, for multiple glazing it fills with different gas to provide better insulation and minimize the amount of current conduction and convection and even overall heat transfer (Ismail, 2008),

For instance, air and argon gases are mostly common gas filled which is both of them are clear, nontoxic, odourless and nonreactive with considerable reduction in thermal conductance in between the glazing layers. Hence, it has become favourable for manufacture to use it more and more in building construction, however, krypton has better thermal performance among air and argon (Weir and Muneer, 1998) but it is more expensive to produce. In addition, they can use pure or even mix between glazing layers to consider both its cost and thermal performance at the same time.

Furthermore, the mostly common gases filled between the glazing layers, which are air, argon and krypton, are illustrate in the graph below Figure 19, and as can be seen, the optimum thermal performance occurs in between 10 and 15mm.

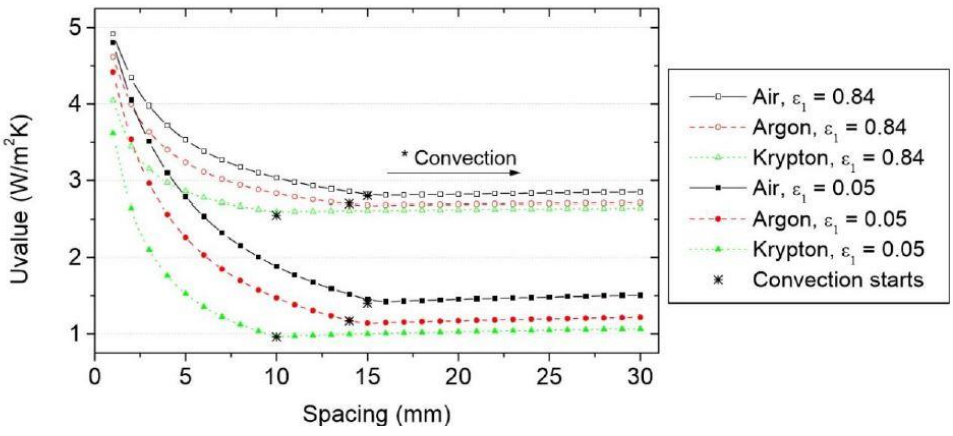


Figure 2-19: Spaces Gap in Between Glazing and Gas Filled with Thermal Conductivity Relationship.

Source: Karlsson, 2001.

2.4.16.2 Airtightness and Air leakage

Airflows through glazed surface occurs due to difference in temperature and wind movement between inner and outer spaces, which is often unwanted is called, air leakage Figure 20 When air wants to penetrate into inner space, it is called 'air infiltration', whereas, when air tries to escape from the inner to outer space, it is called 'air exfiltration'. These movements of air allow the warm or cold temperatures to move out of building envelop, because of which, more energy is required to be loaded.

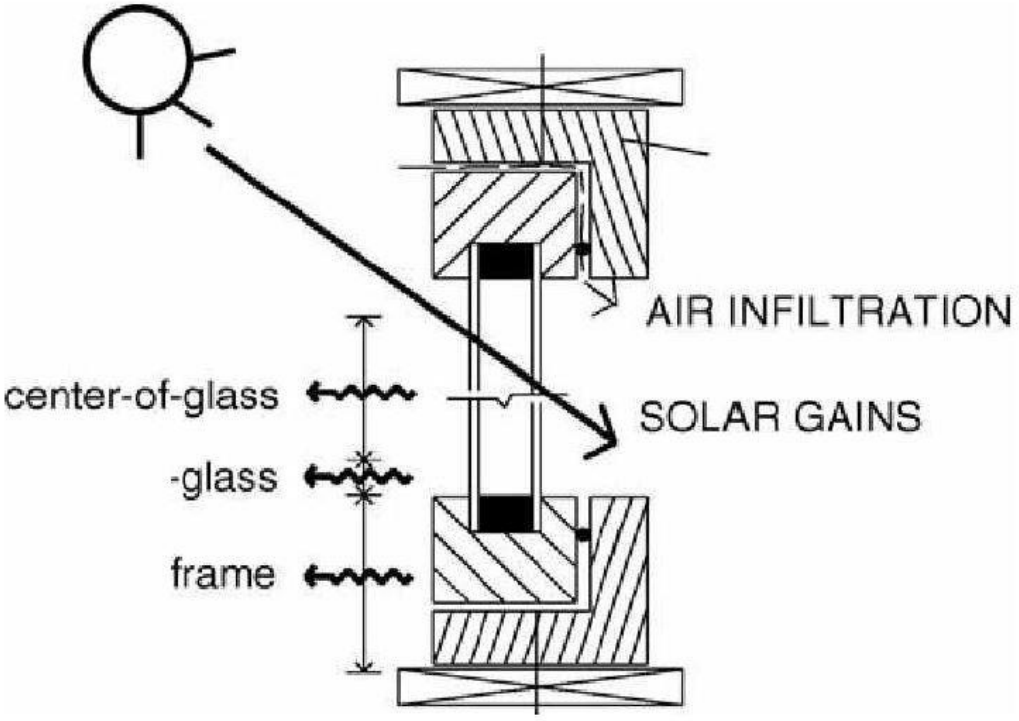


Figure 2-20: Air infiltration through glazing. Source: Bernier and Halle, 2005.

The air movements might occur due to the lack of sealed gaps and even poorly joints in glazed surface frame, its surrounding glass or its frame (Relander, 2010). In addition, operable glazed surface has a desire to increase the level of air leakage rate and it is difficult to eliminate their frame gap to control them (Binamu, 2002). Hence, using fixed glazed surface is an easier way to control the air movements. Fixed glazed surface keep

the airtight and air leakage will be minimizing, that is why it is more effective than conventional operable glazed surface (Hagentoft and Harderup, 1996). Climate condition, temperature and wind speed as well as the building surrounding are the other parameters that have impact on the level of air leakage in glazed surface products.

Bearing in mind the energy loss rate in building envelops through glazing due to uncontrollable air change and air leakage, it is important to consider airtightness. In addition, previous studies of Laverge (2010) and Kalamees (2007) have shown the importance of airtightness through glazed surface glazing in Belgium and Estonia respectively.

2.5 Energy Conservation in Buildings

Energy efficiency is defining largely as cost-effective ways to reduce energy consumption through existing and improved technologies as well as through sound energy use 27 practices. The idea behind energy efficiency is quite simple if people consume less energy, there will be less emission of greenhouse gases as the result of the burning of fossil fuels. That, in turn, means a greater supply of fossil fuels, which can then be used for other purposes in both developed and developing nations. Energy efficiency technologies and practices can therefore play a significant role in reducing the threat of global climate change. (NAIMA, 1996) One of the easiest and most effective energy efficient technologies available today is insulation. Overall benefits from insulation are numerous, including thermal performance, personal comfort, sound control, condensation control, fire protection and personnel protection. (Burberry, 1997) Looked at some factors that govern energy consumption in buildings in which he believes designers need to consider careful in order to reduce energy consumption; these factors are briefly described in the next subsections.

2.5.1 Selection of site

Town planners control this factor while the architects are rarely able to have much influence on allocated sites for development. For example, an exposed site with increase wind speed can increase ventilation rates and decrease surface resistances. (Burberry, 1997) Claimed that a 20% increase in energy consumption may result if the wind speed is high throughout the year, also elevated sites will be colder and more subject to rain and mist.

2.5.2 Built form and grouping of buildings

A variety in heat loss from dwellings can be significantly large even if these dwelling were built with same standard of insulation, this differences can be influenced by internal layout and built forms (Building Research Establishment (BRE), 1978). Each dwelling has a volume of 200m^3 and each is assuming to have the same fraction of external walling as glazing. On the base of conduction losses, with a common ventilation loss, a single storey intermediate floor flat has the lowest heat load for a given inside to outside temperature difference. Unlike, a center terrace 2 storeys dwelling when its heat load was about two-thirds. A single level top flat, on the other hand, has a heat load about equal to that of center terrace dwelling because of the increased conduction losses through the roof. The end terrace dwelling and semi-detached have a load some 40 to 50% larger than the center terrace. The detached house has heat load almost twice as much. Comparing the two extremes, the on level intermediate flat is likely to have a heat load only about a third of that for detached house, for the same volume and same fraction of exposed walling as glazing. To conclude, grouping building to take a high density buildings form could have an important influence on energy consumption in these buildings and in the whole country

as well and then compact design is the most favorable when it comes to energy consumption.

2.5.3 Building shape and size

Extreme variations of shapes, such as transforming a compact building into a tower block, have major effects on energy consumption. Not only is the surface area extremely greatly increased, the exposure of the upper part is made worse and in many cases the solar gain wind and stack effects will dictate that air conditioning must be used (Markus, 1994). Demonstrates the relationship between volume and energy more clearly where is shown that the bigger surface area to volume the quicker it will lose heat, as it has a bigger surface where the heat can rise and travel out from. If the volume is the same but the surface area is smaller, heat will stay in for longer as there is only a small area for the heat to escape from, meaning that the heat that is lost does not account for the mass. conservation that glazed surface are orientated as far as possible towards south.

2.5.4 Building's orientation

Building orientation affects the quantity of solar radiation falling on its different faces at different times of the day. Radiation and temperature are both acting together to produce the heat experienced by the surface. Therefore, architects must consider the direction of their building in relation to the predominant climate. For example, in the hot zones under

2.5.5 Solar radiation

An observation made by (Ludwig, 1970) whose Figure illustrates solar radiation for different H/W ratios (Figure 21). On the flat plan, most of the absorbed solar radiation is re-radiate to the sky as long-wave radiation. In a medium density of H/W= 1, most of the reflected solar radiation hits other buildings, as well as the ground, until it is absorbed

near or at the ground. For higher densities of H/W= 4, most of the absorption takes place at a high level of the canyon, reducing the amount of radiation that reaches the ground.

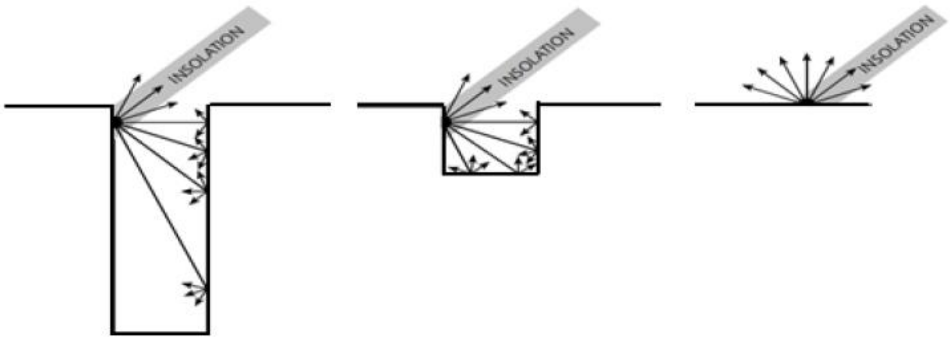


Figure 2-21: Solar radiation for different H/W ratios. Source: Ludwig, 1970.

Range of techniques used to prevent solar radiation from reaching building surfaces:

1 Shading Devices: devices such as wide roof overhangs, shading fins, thick vegetation or external shutters can be used to protect glazed surface and wall surfaces. It is also often possible to shape the building such that some parts of it are self-shading.

2 Surface Colouring: if opaque building elements exposed to solar radiation are painted white or very light colour, much of the incident radiation can be reflected away from the surface.

Insulation: any surface that is exposed to high levels of solar radiation in hot season should be well insulated to reduce the transfer of heat.

3 Double Roof Systems: a ventilated air gap between an upper exposed roof and a lower protected roof. The air carries much of the solar gain from the upper leaf away before it can pass to the lower leaf. A study by (Behzad, 1991) investigating the effect of roof shading on the ceiling surface temperatures, in this study two types of roofs were modelled; un-insulated, and insulated having 50mm of insulation material in the form of the "warm roof" type and both roofs were with same colour and have a solar absorptivity of 0.5. External surface temperatures of roofs on 21 July when there is no obstruction to

intercept direct solar radiation together with those when they are shaded were calculated. The study found that shading the roof could significantly reduce the surface temperature of the asphalt. For example, the maximum surface temperature of the asphalt in a well-shaded (90% shaded) un-insulated roof is 11.6°C lower than the corresponding value when it is not shaded.

2.5.6 Energy and building's materials

The materials of construction should provide adequate insulation and appropriate thermal response. Construction with low thermal capacity internal layers used with heating system capable of controlled and variable output can give considerable economy during the hot season where heating is not required, these low thermal capacity lining require less heat to warm them and also lose less at night. While, high thermal capacity linings absorb a great deal of heat to raise them to comfort temperatures then lose part of it when temperatures are reducing at night. In 1996, a study carried out in USA by Energy Conservation Management found that "because of home insulation, drastically less energy is needed to heat and cool homes in the United States today when compared to the same homes without insulation, this difference results in energy savings of 51% or 10.4 quadrillion Btu nationwide". Table 2.1 below summarizes the energy savings realized from insulation examined by the above study.

Table 2.1 :Energy Use in USA (Quadrillion Btu)

	No insulation	Baseline (existing)	Savings	% Savings
Residential	20.41	10.00	10.41	51%
Commercial	8.21	6.70	1.51	18%
Residential & Commercial	28.62	16.70	11.91	42%

Source: "Green and Competitive: Energy, Environmental, and Economic Benefits of Fiber-glass and Mineral Wool Insulation Products," by Energy Conservation Management, 1996.

The study also considered the potential for additional energy savings and environmental impact if insulation levels were increase to meet standard energy codes. For example, if all residential buildings were insulating according to the Council of American Building Officials' Model Energy Code (MEC) 1992, a minimum energy efficiency standard for houses, and an additional two quadrillion Btu in energy savings would be achievable. Add in energy savings potential from the commercial and industrial sectors, and the study estimates that it would be possible to save 2.2 quadrillion Btu of energy annually.

2.5.6.1 Opaque Materials

There is a continuous exchange of heat between a building and the outside climate. The amount of heat penetrating depends mostly on the nature of the building materials used (Alsousi, 2011). For comfort, air movement is essential and internal surface temperatures should be kept as low as possible during the day and the night. Light and reflective roofs are need to reduce solar heat gain during the day and avoid the storage of heat, which will increase discomfort at night. (Koenigsberger & Lynn, 2011) Recommended that the reflectivity and the insulation should not rise more than 4.5°C above air temperature when the external surface is subject to solar radiation. (Koenigsberger & Lynn, 2011)

In general, each climate has its suitable materials (for walls, roofs and floors) which have been recommended by many researches and can be funded in many standard references such as ASHRAE and SIBCE, for example, earth and masonry are the favorable

Construction materials for an area with low rainfall, heavy walls and roofs are suitable for hot regions because of that they are associated with advantages time-log where the maximum heat load is delayed until the cooler hours of the evening affect the interior. the

route of sun heat into an opaque surface, this route is differing if the surface (wall or roof) is insulate. On other hand, if the surface (wall or roof) is un-insulated, and if the element is thermally massive, it will absorb the solar energy striking it and delay the entry of this energy into the room for a number of hours. If there is sufficient thermal mass, it may delay the entry of energy until nighttime when cooler outside air can be used to cool the structure. Yet, if the element is thermally light the solar energy heats up the external surface and this energy is quick transferred through the structure resulting in rise in internal air temperature.

2.5.6.2 Transparent Materials

The issue is compound by the fact that glazed surface do not let all of this radiation into the building some is reflect, some absorbed and some transmitted. Glass is transparent in the visible and in the near infrared portion of the sun's radiation. It is opaque, however, for radiation emitted by a heated room. Tinted "heat absorbing" glass absorbs much of the near infrared emitted by the sun while remaining largely transparent over the visible portion. Part (a) in Figure 2-22 below illustrates how glass indirectly transmits infrared from a heated room. The thermal radiation from the room is absorb by the surface of the glass. This absorbed heat is conduct through the thickness of the glazing and then radiated, conducted and converted to the outside. A small amount of the incident radiation is reflecting back into the room. This process occurs in conjunction with conduction and convection heat transfer to and from the air on both sides of the glass. The transmission of solar radiation through standard window glass is illustrated in (b) drawing of Figure 2-22. Some of the solar radiation incident on the glazing is reflect. The reflected fraction increases as the angle between the radiation beam and the glass decreases. The fraction absorbed by the glass is dependent on the thickness and absorption coefficient of the glazing. The absorbed radiation is convert to heat, which raises the temperature of the

glass. In some cases, the glass temperature will be greater than either the indoor or the outdoor temperature. Some of the heat absorbed by the glass will be re-radiated and convert into building.

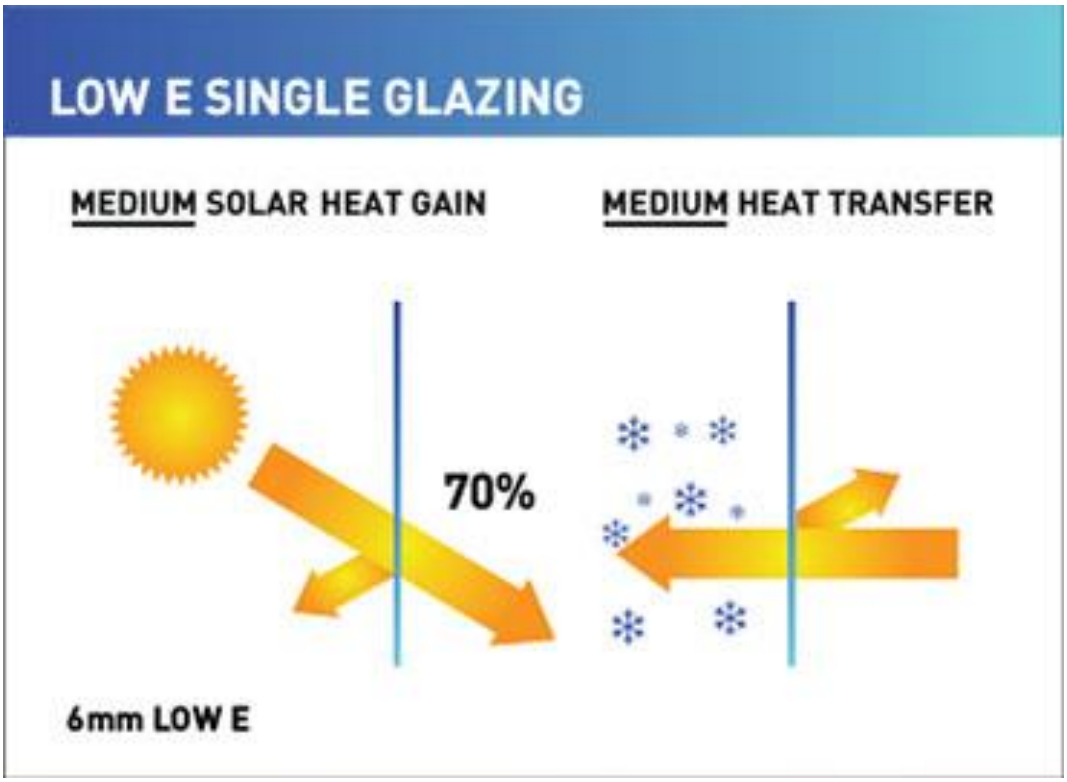
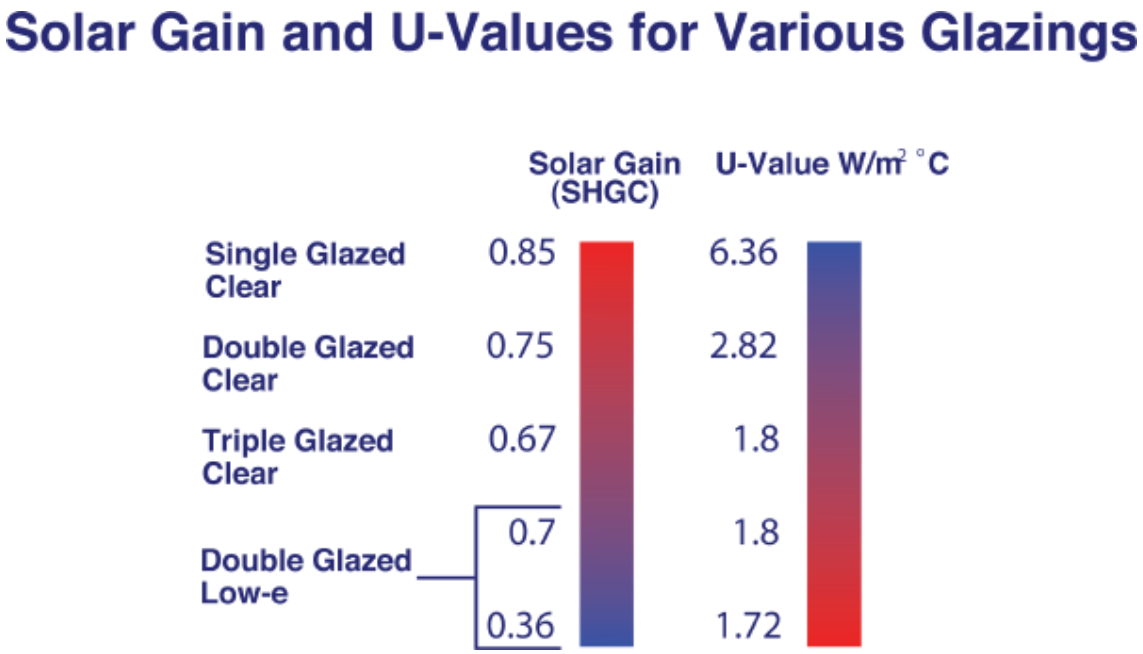


Figure 2-22: solar striking glass, a. the transmission of infrared through glass & b. the transmission of solar radiation through glass.

Source: plotted after (Ludwig, 1970)

Different glazed surface' types and window/blind systems, an example on that is approve by CIBSE as included in guide (A) under table, also affect the above process Clearly, the highest type of glazing to transfer the heat is single glass type and if reducing the cutting solar heat is desirable so the obvious way of reducing that gain is to reduce the area of glazing. If this is not possible or desirable, then glazed surface can be shaded. Alternatively, tinted or reflective glass can be used to cut down on the solar heat gain as shown in the below Table where the solar gain reduced from 0.76 Sc in single glass to 0.29 Sc when double glazed with blind has been used.

Table 2.2:Example average solar gain factors_ taken from CIBSE Guide



CIBSE also has provide the importance of the glazing role on thermal comfort to a building's occupants, this role can be underlying as principles briefly outlined below;

Comfort criteria dictate that there should not be more than 4 K between any surface and air temperature. Outside of this margin, extra heat is need to compensate for the increased feeling of discomfort.

I- in a building where the walls are well insulating the temperature difference between the wall surface and room temperature is minimal, but the temperature differences between glazing and room temperature (assuming an indoor room temperature of 21 K) can be significant according to glazing type: Between single glazing and air, temperature can be around 20° C.

II- Between double-glazing and air temperature will be around 8° C.

III- Between triple glazing and air temperature will be around 4° C

2.6 Insulation Used as a Resistance to Heat Flow

2.6.1 Mechanism of thermal mass

It is important, to understand the mechanism of thermal mass performance in order to achieve the best possible results. Thermal mass, in the most general sense, describes the ability of any material to store heat. For a material to provide a useful level of thermal mass, a combination of three basic properties is required:

i. High specific heat capacity to maximize the heat that can be stored per kg of material.

ii. High density to maximize the overall weight of the material used.

iii. Moderate thermal conductivity so that heat conduction is roughly in synchronization with the diurnal heat flow in and out of the building.

Heavyweight construction materials such as brick, stone and concrete all have these properties. They combine a high storage capacity with moderate thermal conductivity. This means that heat transfers between the material's surface and the interior at a rate that matches the daily heating and cooling cycle of buildings. Some materials, like wood, have a high heat capacity, meaning that their thermal conductivity is low, which limits the rate at which heat is absorbed. This combination, which results in low thermal mass, can be useful in other ways. Steel can also store a lot of heat, but in contrast to wood, steel possesses a very high rate of thermal conductivity, which means heat is absorbed and released too quickly to create the lag effect required for the diurnal temperature cycle in buildings. Concrete and masonry steadily absorbs heat that is expose to its surface, conducting it inwardly, and storing it until the surface is expose to cooler conditions and its temperature begins to drop. When this occurs, heat will begin to migrate back to the cooler surface and be release. In this way, heat moves in a wave-like motion alternately being absorbed and release in response to the variation in day and night time conditions. The ability to absorb and release heat in this way enables buildings with thermal mass to

respond naturally to changing weather conditions, helping stabilize the internal temperature and provide a largely self-regulating environment. When used appropriately, this stabilizing effect helps to prevent overheating problems during the hot season and reduces the need for mechanical cooling. Similarly, the ability to absorb heat can help reduce fuel usage during the heating season by capturing and later releasing solar gains and heat from internal appliances. Figure 2-23 below illustrates outdoor and indoor temperature fluctuations as a result from applying thermal mass. The red line is the outdoor temperature fluctuation and the orange line is the indoor temperature fluctuation. The indoor temperature curve is delay behind the outdoor temperature curve by some time. This delay of the peak of the orange line curve behind the peak of the red line curve is refer to as the time lag (φ) measured in hours. The reduction in cyclical temperature on the inside surface compared to the outside surface is knows and the decrement factor. Thus, a material with a decrement value of 0.3, which experiences a 20-degree diurnal variation in external surface temperature, would experience up to 6 to 8 degrees' variation in internal surface temperature.

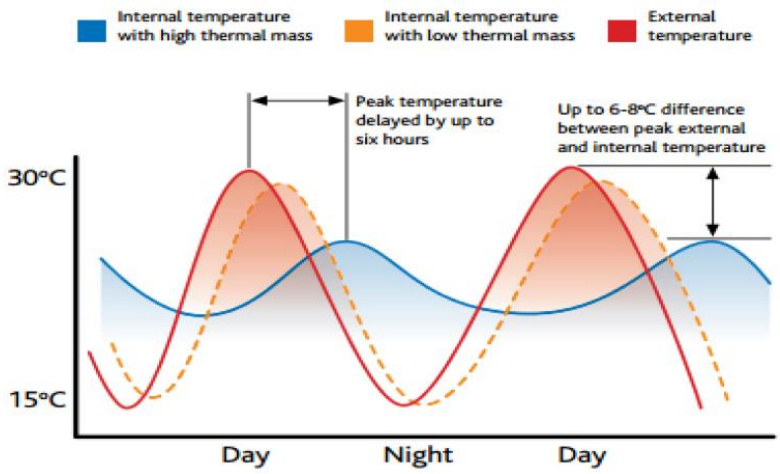


Figure 2-23: Stabilizing effect of chapter on internal temperature.

Source: (Tom de Saulles, 2009)

2.6.2 Insulation location

The location of the insulation relative to the mass layer affects both the time lag of the heat, flux through a wall and the ability of the wall mass to dampen interior temperature swings. A study by (Byrne & Ritschard., 1985) on three wall configurations (insulation inside or outside of the mass or with the insulation and mass well mixed) shows that the wall with insulation outside always performed better than the wall with insulation inside of the mass,

The savings in heating load for the integral insulation case was normally greater than either of the other wall type and the cooling load savings was normally between the performances of the other walls. However, the relative performance of the three wall types changed slightly with climate, building design and total wall U-value, see Figure 2-23. Same study also stated that "In general, if the wall mass is exposed directly to the interior space it will be more effective in dampening interior temperature

fluctuations and in reducing both heating and cooling loads, for this reason, many commonly built masonry walls that are furred out (with gypsum board and a narrow airspace or insulation) on the interior surface do not make the most effective use of the available wall heat capacity.

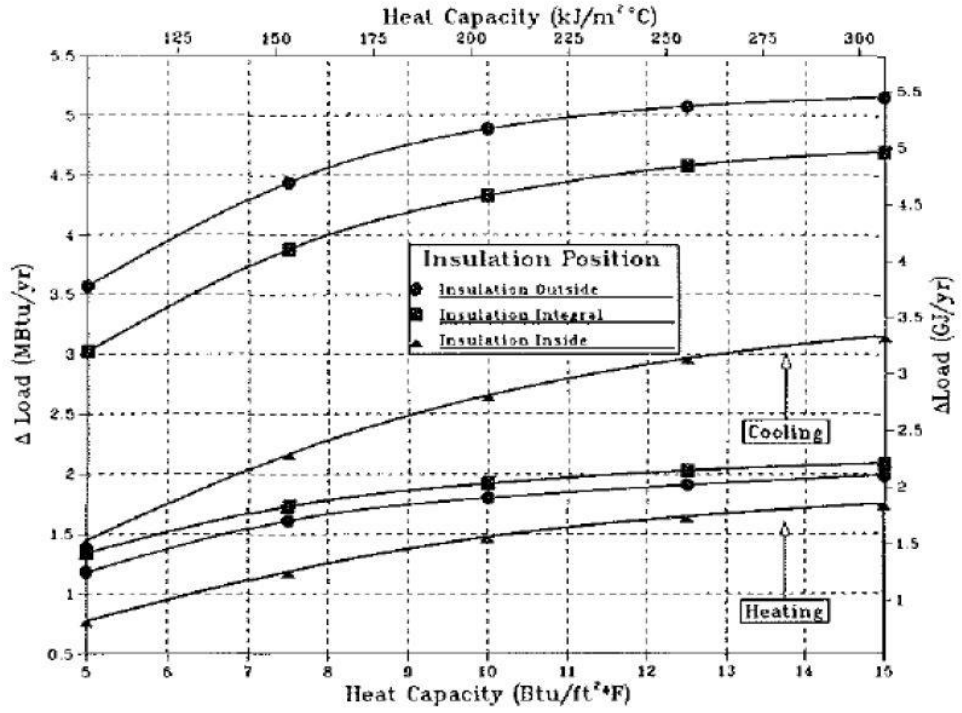


Figure 2-24: Annual delta heating and cooling loads as a function of mass heat capacity

Source: (Byrne & Ritschard., 1985).

2.7 Definition of Shopping Mall

The Definition of shopping mall differs from places and circumstances. The general idea behind a shopping mall is a collection of different commercial activities taking place in one entity. There are two basic perspectives gearing towards defining what a shopping mall is or should be. The encyclopedia Britannica (2009) defines a shopping mall as "a collection of independent retail stores, services, and a parking area conceived, constructed, and maintained by a management firm as a unit. Shopping malls may also contain restaurants, banks, theatres, professional offices, service stations, and other establishments". The oxford advanced learner's dictionary defines shopping mall as "a large group of shops or stores built together under one roof and closed to traffic". The Wikipedia encyclopedia (2007) defines a shopping mall as "a building or set of buildings that contain a variety of retail units, with interconnecting walkways enabling visitors to easily walk form unit to unit".

The Microsoft Encarta (2008) defines shopping malls as "collection of retail businesses in a building or set of buildings under one ownership or management".

Cyril (2006), defines a shopping mall as "A shopping center enclosed within a large structure; often two or three stories high, often designed around a central atrium; may have numerous stores, as well as entertainment facilities such as movie theatres, fast-food outlets, restaurants, and public areas." For the purpose of this research the definition below shall be adopt: A shopping mall is defined as a fully enclosed collection of independent retail units and services in a climate-controlled environment, with covered pedestrian walkways and restricting vehicular access at its periphery, run and by one management.

2.7.1 Shopping mall

A shopping mall, shopping center, shopping precinct or simply mall is one or more buildings Forming a complex of shops representing merchandisers, with interconnecting walkways enabling visitors to easily walk from unit to unit, along with a parking area a modern, indoor version of the traditional marketplace. Modern "care-friendly" strip malls developed from the 1920s, and shopping malls corresponded with the rise of suburban living in many parts of the Western World, especially the United States, after World War II. From early on, the design tended to be inward facing, with malls following theories of how customers could best be enticed in a controlled environment. Similarly, the concept of a mall having one or more "anchor" or "big box" stores was pioneer early, with individual stores or smaller-scale chain stores intended to benefit from the shoppers attracted by the big stores.

2.7.2 Regional differences

In most of the world the term shopping center is use, especially in Europe, Australasia and South America; however, shopping mall is also use, predominantly in North America and

the Philippines. Outside of North America, shopping precinct and shopping arcade are also used. In North America, the term shopping mall is usually applied to enclosed retail structures (and is generally abbreviated to simply mall), while shopping center usually refers to open-air retail complexes; both types of facilities usually have large parking lots, face major traffic arterials and have few pedestrian connections to surrounding neighborhoods. Shopping centers in the United Kingdom can be refer to as "shopping centers", "shopping precincts", or "town centers". The standard British pronunciation of the word "mall" is as in "The Mall, London" the tree-lined avenue leading to Buckingham Palace, London and like "pal" (Friend).

Mall can refer to either a shopping mall a place where a collection of shops all adjoin a pedestrian area or an exclusively pedestrianized street that allows shoppers to walk without Interference from vehicle traffic. Mall is shopping area usually composed of a single building that contains multiple shops, usually "anchored" by one or more department stores surrounded by a parking lot, while the term arcade is more often used, especially in Britain, to refer to a narrow pedestrian-only street, often covered or between closely spaced buildings (see town center). A larger, often partly covered and exclusively pedestrian shopping area is in Britain also termed a shopping center, shopping precinct, or pedestrian precinct. The majority of British shopping centers are in town centers, usually inserted into old shopping districts and surrounded by subsidiary open air shopping streets. A number of large out of town "regional malls" such as Meadow hall, Sheffield and the Trafford Center, Manchester built in the 1980s and 1990s, but planning regulations prohibit the construction of any more. Out-of-town shopping developments in the UK focused on retail parks, which consist of groups of warehouse style shops with individual entrances from outdoors. Planning policy prioritizes the development of existing town centers, although with patchy success. The Metro Center, in Gate head (near

Newcastle upon Tyne), is the largest shopping center in Europe with over 330 shops, 50 restaurants and an 11 screen cinema and Westfield London is the largest inner-city shopping center in Europe. Bullring, Birmingham is the busiest shopping center in the UK welcoming over 36.5 million shoppers in its opening year. In Hong Kong, the term "shopping center" is the most frequently used," The same is true for Portuguese-speaking Brazil, though with America spelling "shopping center".

2.8 Classification of Shopping Mall

In many cases, regional and super-regional malls exist as parts of large superstructures that often also include office space, residential space and amusement parks. See this trend in the construction and design of many modern supermalls such as Cevahir Mall in Turkey. The International Council of Shopping Center's 1999 definitions were not restricted to shopping centers in any particular country, but later editions made specific to the U.S. with a separation set for Europe.

2.8.1 Regional

A regional mall is, per the International Council of Shopping Centers, in the United States, a shopping mall that is design to service a larger area (15 miles) than a conventional shopping mall. As such, it is typically larger with 400,000 sq. ft. (37,000m2) to 800,000 sq. ft. (74,000m2) gross leasable area with at least two anchor stores and offers a wider selection of stores. Given their wider service area, these malls tend to have higher-end stores than need a larger area in order for their services to be profitable but may have discount department stores. Regional malls are as tourist attractions in vacation areas.

2.8.2 Super regional mall

A Super regional mall is, per the International Council of Shopping Centers, in the U.S. a shopping mall with over 800,000 sq ft (74,000m2) of gross leasable area, three or more anchors, mass merchant, more variety, fashion apparel, and serves as the dominant shopping venue for the region (25 miles) in which it is located.

2.8.3 Outlet mall

An outlet mall (or outlet center) is a type of shopping mall in which manufacturers sell their products directly to the public through their own stores. Other stores in outlet malls operated by retailers selling returned goods and discontinued products, often at heavily reduced prices. Outlet stores found as early as 1936, but the first multi-store outlet mall, Vanity Fair, located in reading, PA did not open until 1974. Belz Enterprises opened the first enclosed factory outlet mall in 1979, in Lakeland, TN, a suburb of Memphis.

2.8.4 Dead malls

In the U.S, as facilities more modern are now built, many early malls have become abandon, due to decreased traffic and tenancy. These “dead malls” have failed to attract new business and often sit unused for many years until restored or demolished. Interesting examples of architecture and urban design, these structures often attract people who explore and photograph them. This phenomenon of dead and dying malls is examining in detail by the website Deadmalls.com, which hosts many such photographs, as well as historical accounts. Until the mid-1990s, the trend was to build enclosed malls and to renovate older outdoor malls into enclosed ones. Such malls had advantages such as temperature control. Since then, the trend has turned and it is once again fashionable to build open-air malls. According to the International Council of Shopping Centers, only

one new enclosed mall built in the United States since 2006. Some enclosed malls been opened up, such as the Sherman Oaks Galleria. In addition, some malls, when replacing an empty anchor location, have replaced the former anchor store building with the more modern outdoor design, leaving the remainder of the indoor mall intact, such as the Del Amo Fashion Center in Torrance, California.

2.9 Shopping Trends in Nigeria

Before the colonial period, there was no existence of a shopping mall, what we had was a traditional market place influenced by the socio-cultural values of the people. The Nigerian indigenous settlements had their first market place at major crossroads along the streets leading into central area to attract many buyers and sellers. Meeting place in form of a forum and street mall was what we had that was close to a shopping mall.

The shopping system was a personal adaptation of a group of people that had relationship with the socio-cultural values of the people. The recreational activities were wrestling, holding meetings and festival. These activities done in fields, which was the only facility as at that time. There was an improvement over the indigenous shopping pattern, resulting in the emergence of new business and general trading activities. Sales of luxury goods imported into the country from abroad, by large companies like U.A.C Johnholt, began to flourish in our markets.

2.9.1 Development of shopping trends in Nigeria

However, retailing activities was universally identified and accepted as an element of urban structure in large urban centers like Lagos, Kaduna, Kano and Warri over the years. Retailers now tried to define the changing behavioral pattern of consumers by building specialist consumer shop. Thus, as the free-market situation could not cope, our shopping streets prospered and expanded as an unplanned structure along major roads and highways

in our urban centers as may be notice in broad streets in Lagos Ahmadu Bello way in Kano and Kaduna. There had been a recent trend towards the erection of shopping plazas, mall of various dimensions, scales, and multiple floors in the country. Due to the breaking points because of over stretching shopping streets, there was need for a proposal for an organized shopping mall to provide a better and efficient shopping requirement for the ever-growing urban population.

2.10 Current trends

Because of the small number of shops in towns, it is difficult to appreciate their success or failure since their present popularity must be compare with their popularity before conversion.

Other trends of considerable importance since there has been a tendency towards what we call greater mechanization in retailing, with a view to increasing productivity. The establishment of Self-service shops on a small scale that was license in 1949.

2.10.1 Shopping activities

Commercial activities include wholesale, retail, services trade, as well as business establishment. There are three hierarchies of commercial activities. These includes light, medium and heavy usually differentiated in terms of their volumes of commercial activities. For example, while you find perishable and non-perishable goods in high commercial areas, the heavy commercial areas, have banks, business offices, department stores and among others. Most residential areas have light commercial activities while the heavy commercials are located in the city central business district. (C.B.D)

Shopping activities refers to the ways of purchasing or buying goods in a shop by a buyer or consumer. This can be in different shopping areas including the department store,

market, super markets, shopping streets shopping centers or complexes. Shopping activities also includes the following:

Short term shopping

This refers to the shopping activity that is usual done frequently for example, the purchase of food items, vegetables and toiletries. Long term shopping. This refers to shopping done occasionally for example, purchase of textiles, and electronics among others.

Formal and informal shopping activities

It is the sales and purchase of goods and services in shops whose activities and locations have been approve by the authority and are usually within a confined shop or space. The informal activities refer to hawkers along streets, with no confined shopping space.

2.10.2 Shopping centers

Shopping centers are set up to ensure convenience to their users by the provision of parking, open spaces and good sanitary conditions. They are classifying into the neighborhood, community and CBD/regional shopping centers depending on volume and types of goods sold, location, size and relative trade area. They also serve as recreational and social centers. They are mostly without planning problems and privately owned. The modern shopping centers are located away from but linked to major thoroughfares of the city to reduce traffic problems.

In developing countries, the shopping scene plays a secondary role in the city's retail trade and is yet to have any significant impact. What obtains is the occurrence of shopping complex scattered in the city and shopping districts or streets adjacent to markets. The latter ads to the congestion around the parking area and chaotic problems in the market area.

It can be concluding that in both the developed and developing countries shopping centers have suburban location except for shops existing in the cities of the developing countries.

2.10.3 The Patterns of Shopping Activities

The characteristics of urban shopping activities and other commercial activities were discussed in the various theories of urban structure. These theories are expressed in two important characteristics of commercial activities. They are highly dependent on location. This is why commerce is ready to pay the highest price for a given location on the basis of location, two important attributes of the site are Inter-dependent i.e. accessible and cost for rent or land. A highly accessible site is likely to attract a higher cost than poorly accessible site. For the reason explained above commerce is also consumer orienteer that it tends to follow it consumers which determines location, accessibility and cost.

The theories explained reasons why commerce also occupies the most accessible parts of a settlement or city that accessibility determines land or rent values which are mostly very high in commercial zone, based on these factors Glenn (1978) suggested that "commercial land uses form the skeletal of urban organization about which other uses are arranged according to their ability to pay"

The central place theory by Chris taller was one of the earliest geographic theories that developed a model, on the distribution of market places and towns in regions. Since the 1950s, the planned shopping center in Europe gradually increased in function. From a purely commercial center to a recreational and social center.

2.11 Shopping Standards

The use of different indices to establish various authors based on volume of activities at different hierarchies, types that could be provide and the socioeconomic characteristics of the population have proposed shopping standards. Wegener (1966) observed that the responsibility of the decision has shifted from market forces to the shoulders of the planning authorities. He further observed that there is uncertainty in the ideal figure in view of the complexity of the problem, and if there is an optimum size measured in terms

of population served, it will be different for different trades and will be affect by economic scale and competition. The main distinction lies between shopping goods, trades and between trades that represent a high degree of specialization possible in centers or communities. Examples are super markets, small-scale stores among others at the neighborhood centers. His observations imply that the shopping standards will be of different towns and cities as well as in different areas within the urban spatial structure. They will also be affect by the socio-economic characteristics of the city population. The impact of socio-economic characteristics of the population on the development of urban shopping activities are further analyzed by Linera (1970) and Gonzalez (1970). Gonzalez (1970) observed that social factors such as increased number of working women, the accelerated pace of life, the pressure of press and television, have catalyzed the demand for more efficient methods of retailing, which will in turn affect the types and locations of retail outlets shopping areas in the town. Linera (1970) also postulated that types of shopping areas to develop the facilities to be provided and their locations must be preceded by a market research as well as shopping surveys to ensure their successful implementation and operation. These proposals express the significance of socio-economic factors, in the development and emergence of urban shopping activities. These factors will consequently determine the types, patterns and distribution of shopping activities in the urban area. This implies that combination of population size and the socio-economic characteristics of the city's population are very important factors in determining the characteristics of shopping activities in the urban area. These could provide explanations for the various proposals made by the different authors.

2.11.1 Shopping facilities

Although different types of recreational services and facilities are necessary on many commercial areas, the best long-term interest of both the public and the concessionaire

will be serve by recreation activities to ensure the primary values of such areas. While the financial solvency of those who provide necessary commercial services must be consider by the administration, concessionaires and most also recognize that the existence of their enterprises depends on the maintenance of any alterations of an area.

2.12 Facilities required in the shopping mall

These include all facilities that make the shopping experience less stressful and enhance comfort and easy circulation within the shopping mall. They include,

a. Security: The security office should be located close to the shopping area for effective services.

b. Tiny Taxis: Free tiny taxis are facilities made available to customers purchasing large amount of good, hence walkways should be wide to prevent its interference with pedestrian movement within the mall.

c. Lifts and Escalators Public lifts should be conveniently located at the central atrium or side to assist movement between all floor levels. These lifts should preferably be of panoramic type to enhance the effect of vision while in use.

d. Meeting/Waiting Areas: should be provide at the reception near the main entrance, to ease the location of lost children and inquiry.

2.12.1 Categories of shops

Department Stores: These are shops, which come in different sizes and offer various services to the public, to ensure financial stability of a shopping mall. Departmental stores should be located in a way that they complement themselves and thus imposing minimal stress on the users.

Health stores: Personalized health, vitamins & supplements, diet and nutrition, sports nutrition, healthy and pharmacy should be providing.

Beauty & Personal Care stores: Women’s skin care and makeup accessories, men's skin Care and hairdressing.

Jewelry & Fragrances stores: Jewelry accessories, bracelets and watches, earrings, necklaces and chokers, rings, fashion accessories.

Home care store: Laundry and apparel care, wipes and cleaners, house wares, bedding and bath, air and water, home furnishings and fabrics.

Apparel store: Men's, women's, children's, shoes. Bridal wear, menswear, maternity wear, children wear, women wear.

Sport & Outdoor Leisure: Bowling alley, table tennis, and other indoor games.

Audio/Visual/Photographic: Passport, photographs, recording studio, video clubs, music rooms.

Specialist Shops and Services: Travel agents, opticians, fixed wireless service providers, cards and gifts shop.

Entertainment, Toys and Games shops: Game arcade, children play room, aquarium among others.

Financial stores: Bureau de change and atm.

News/Stationery and Books: Bookshops, newspaper stands and book clubs.

Food and Beverages stores: Bars, beverages, breakfast foods, condiments, fasy meals restaurants, cafés and fast food shops and stores.

Anchor Stores: These are typical examples of larger departmental shops that helps to draw as much traffic as possible, thus resulting in the patronage of other stores around them. These larger departmental stores could also be referring to as draw tenant. In physical configuration, anchor stores are normally located as far from each other as possible to maximize the amount of traffic from one anchor to another.

Food court: A shopping mall food court consists of food vendors offering a selection of food at a typical food court; food is ordered at one of the vendors and then consumed at a seating area. Other types of anchor stores induce, galleries, cinemas, bowling hall, aquariums, showrooms among others, which is normally surrounded by the counters of the multiple food vendors.

Table 2.3: Standard Schedule of Accommodation.Source: (Neufert, 1995) .

Space definition	Basic.	Desirable.
Entrance hall	20msq	30msq
Offices	12msq	15msq
Shops	12msq	15msq
Parking space	1 parking	per 75msq per floor
Toilet	1.2m	1.5m
Staircase	Riser 150mm	Riser 175
	Thread 270	Thread 300mm
Conference/meeting room	0.65msq/person	.85msq/person
Cafeteria/restaurants	0.65msq/person	0.6

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

After identified the scope and objectives of the investigation, it is necessary to follow an appropriate research methodology, which refers to a set of methods. In this investigation, quantitative research methods are choosing to suit the different aspects of the research. This Chapter provides information on how the research was conduct in order to achieve the research aim and objectives presented section 3.2. It covers the research strategy, design and method adopted for this dissertation thereby contextualizing the methodology and justifying their use as compared to alternative ones.

Other issues discussed in this chapter Include reliability, explicability, validity, ethical issues, limitations and a reflection on how the negative effect of these are minimize on the research process. Figure 3-1 shows the overall research methodology adopted for the dissertation. It shows the context, research aim, research strategy, research design, research methods and analysis adopted for the study.

Different methods have different strengths and weakness; however, using a range of methods can produce a more complete picture (Leech, 2000 & Gillham, 2008).

Further, a multi-method approach has the potential of enriching, as well as cross-validating, research findings. The research methods, which have been practice in this study, are explain below.

CONTEXT

•Energy crisis

Cost of space cooling

Need for sustainability

RESEARCH AIM & OBJECTIVES:

The current investigation assesses how effective orientation, window-wall ratio and types of windows as a parameter for the reduction of annual cooling energy demand and the annual total energy consumption in commercial buildings.

RESEARCH STRATEGY

Literature review, Observation and case study.

RESEARCH DESIGN

Experimental (computer simulation)

RESEARCH METHODS

Quantitative

ANALYSIS

•Descriptive statistics, degree-days and parametric analysis using computer simulations

Figure 3-1: Overall research methodology

3.2 Dependent and independent variables

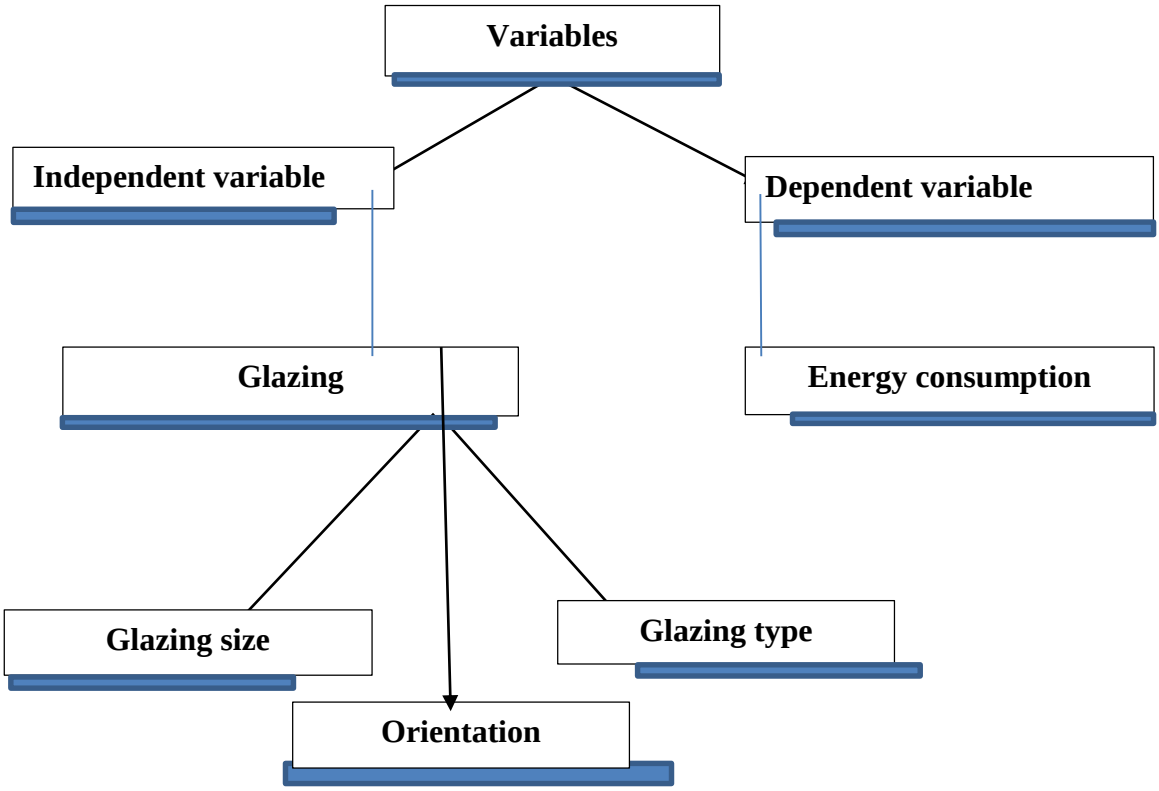


Figure 3-2: Dependent and independent variables

3.3 Research method

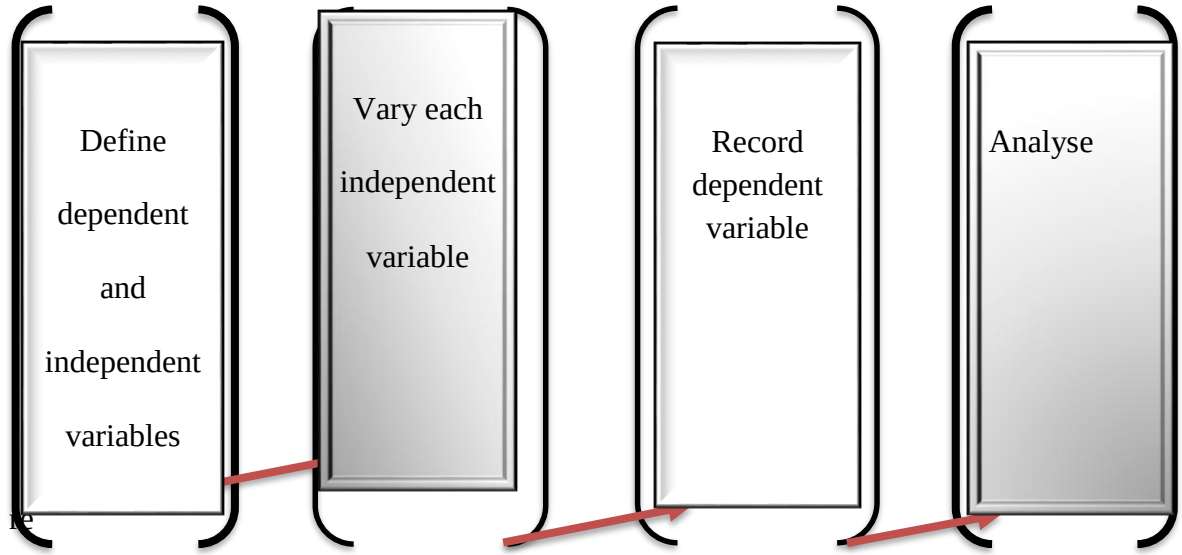


Figure 3-3: parametric analysis procedure

CHAPTER FOUR

4.0 RESULTS AND DATA PRESENTATION

4.1 Introduction

This chapter presents in detail how the collected data were analyses. The investigation was conduct in four-stage process as shown in Figure 4-1below,

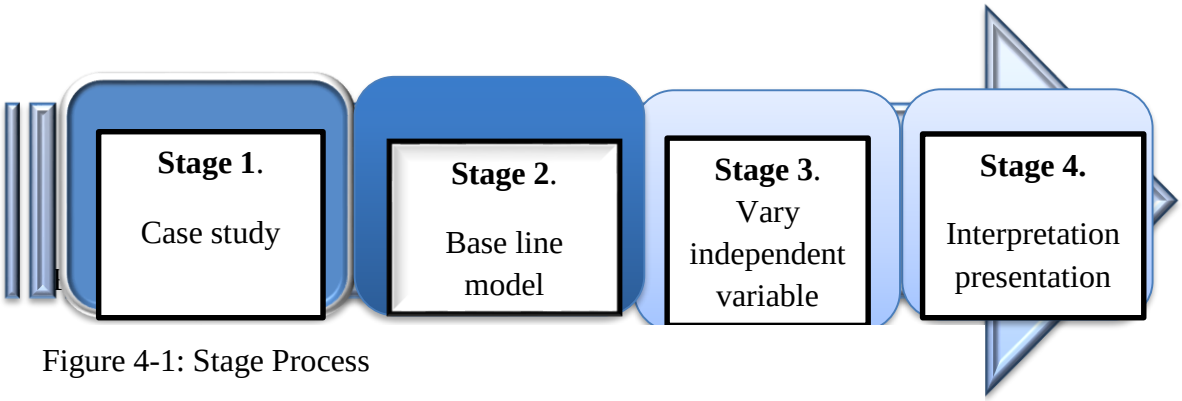


Figure 4-1: Stage Process

The information recovered from first stage will serve as data input for the generation of the base-case model on which to simulate alternative energy conservation mechanisms with different glazed area and orientation. As established, a massive growth in new shopping malls construction trend is coming up having front façade completely glazed in Nigeria. This necessitated the fieldwork exercise to enable data collection through a case study. A case study of a shopping mall building conducted using tools. As shown in figure 4-2 Below;

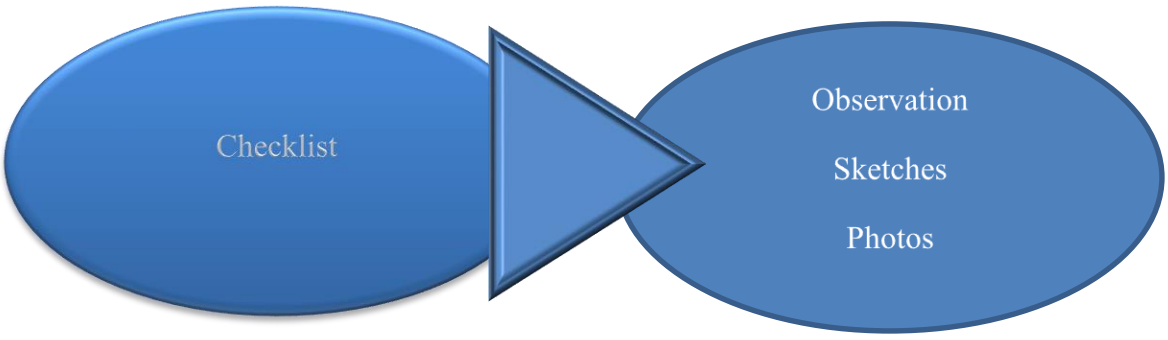


Figure 4-3: Data Collection Instrument for Case Study.

The objective is to create a base case model for assessing the proportion at which the energy consumption increases with the glazed area and their optimum orientation from cooling point.

Another objective is to recorded energy consumption against weather profile of the location where the building is located.

4.2 Results

The following sections present the data recorded in the case studies. The results presented here is for three buildings studies. The results are classifying into building descriptions.

4.2.1 Physical building characteristics

The building is made of the same wall construction method most common in Nigeria of hollow sand Crete blocks with standard mix proportion of 1:6 cement-sand ratios. The size of the block used is 225 x 225 x 450 mm for external walls and 225 x 225 x 150 mm for internal walls with one-third of the volume as cavity (Baiden and Tuuli, 2003; Baiden and Asante, 2004 cited in Batagarawa, 2013). These are heavyweight-walling units made from coarse natural sand or crushed stone dust mixed with cement and water and pressed to shape. The blocks are produced hollow having a much more obvious cavity right through the block. The total volume of the cavity is, however, restricted to 50% of the gross volume of the block. Sand Crete blocks are for single leaf wall construction; the blocks are in stretcher course in which the units of successive courses overlap half their length. Joints in between the blocks are fill with cement, sand mortar of mix 1:4. The wall construction considered in the heavyweight category with a calculated U-value of 1.4 W/m2K based on the CIBSE calculation method (CIBSE, 2007).

4.2.2 Building descriptions

These results, described in Table 4-1 are record during the case study stage of the investigation. The case study enabled observation of physical building characteristics as construction, glazing and working scheduled.

Table 4.1: Case study building description used to create base case model.

Climate Zone	Hot /dry	Hot /dry	Hot /dry	Hot/dry
Building	Umar Shopping Mall, Katsina.	Country mall, Kano	Jifatu Shopping Mall, Kano.	Base case Model
Weekday work hour/yr.	8am-10pm (5460hrs)	8am-10pm (5460hrs)	8am-10pm (5460hrs)	8am-10pm (5460hrs)
Gross Floor Area (m^2)	646	3450	4956	646
Wall /window ratio ($^0/_0$)	83	67	90	90
All single panel glazing	Tinted blinds	Tinted internal blinds	Tinted internal blinds	Clear
Orientation	EW	SW	SN	ACTUAL+

(Source: Author's field work, 2016.)



Plate II: Single glazed, bronze tinted, aluminium framed glazing.

(Source: Author's field work, 2016.)



Plate III: Single glazed tinted, aluminium framed glazing.

(Source: Author's field work, 2016.)



Plate IV: Single glazed, bronze tinted, aluminium framed door and windows.

(Source: Author's field work, 2016.)

4.3 Modelling The Base Case

4.3.1 Weather profile;

Weather data include monthly mean hourly values of global solar radiation, diffuse solar radiation, relative humidity, and ambient temperature has been procuring from Katsina. This measured data conforms to the international standards for measurement of surface climate data.

4.3.2 Building envelop

I. Wall;

A well-insulated commercial building with dimensions of 25 m × 26 m × 8m has been investigate. Based on the CIBSE calculation method (CIBSE, 2007). U-values of its walls

and roof are 0.352 W/m^2K and 0.409 W/m^2K, respectively. Walls constructed with 225 mm of brick with 13 mm of cement plaster on both sides.

II. Roof;

0.12mm thick, long span aluminium corrugated roofing sheet with dark brown coat.

III. Working schedule

Working schedule assumed from 8 am to 10 pm, including Sunday and Saturdays. Internal gains from occupants, lighting, and appliances during working hours taken are person 65 W; computer with monitor 140 W; lighting density 10.8 W/m^2. The temperature has been control at 20°C in winter and 27°C in summer during working periods. The ventilation rate considered is 1 ACH (air changes per hour) during the working hours.

IV. Glazed Surfaces;

Glazed Surfaces leading source of heat gain, accounting for nearly 50% of the heat that enters a building. Heat gain through glazing may also depend on climate, surface size, glazing type where different types are available around the world from double aerogel glazed, single to multiple layers with or without e-low glazed materials, however, in third world countries such as Nigeria single type is the most used one, which revealed the highest solar heat transferred type. In this investigation, different types of glazed surface, size and orientation are simulating to access the level of optimization that can be achieve using each type of this glazed surface including double glazed with aerogel material. As shown in Table 4-2, there are five types of glazing used in ECOTECT simulation, which applied on the Baseline Model (case study) presenting in different glazing types, area and their optimum orientation, from cooling point of view.

Table 4.2: Different kinds of glazed surface used in this study. The values of both U and g have been analysed with Autodesk Ecotect Analysis (2011).

Glazing type	Description	Identity	U (W/m^2K)	SHGC (g-value)
Single glazed, Clear G1.	6 mm clear glass + 12 mm air space + 6 mm clear glass	Clear-clear	5.85	0.86
Double glazed, clear G2.	6 mm low-e glass + 12 mm air space + 6 mm clear glass	Clear -clear	2.95	0.73
Double glazed, low-e G3.	6 mm low-e glass + 12 mm air space + 6 mm clear glass	Low-e-clear	1.72	0.36
Double glazed, aerogel G5.	70 mm + Cabot's Lumia® + air (>90%)	aerogel	0.05	0.04
Solar control glazed (reflective) G6.	6 mm solar control (reflective) glass + 12 mm air space + 6 mm clear glass	Solar control-reflective	1.95	0.10

This study is for climatic conditions of Katsina, hot and dry (12°59N, 7°36'E); the climatic data of this location is show in methodology chapter. It includes monthly mean values of global radiation on horizontal surface, ambient air temperature, relative humidity, and wind speed. Winter is mild and exists for two months only (December and January) and mild heating is required. For air-conditioned buildings, cooling is required for about 8 /months, March to October. Therefore, this study is mainly from cooling point of view. The emphasis is on the selection of glazing area, types and their optimum orientation, from cooling point of view.

4.3.3 Effect of glazed area on annual cooling load (kwh/m^2 yr.)

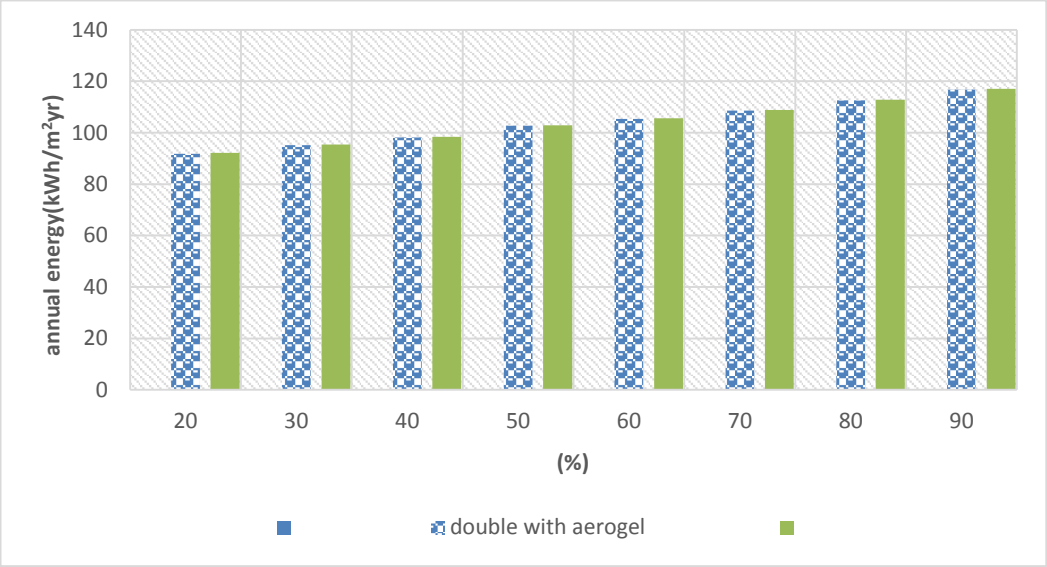


Figure 4-4: Effect of glazed area on building energy consumption. (SOUTH)

4.3.4 Effect of glazed area on annual cooling load (kwh/m^2 yr.).

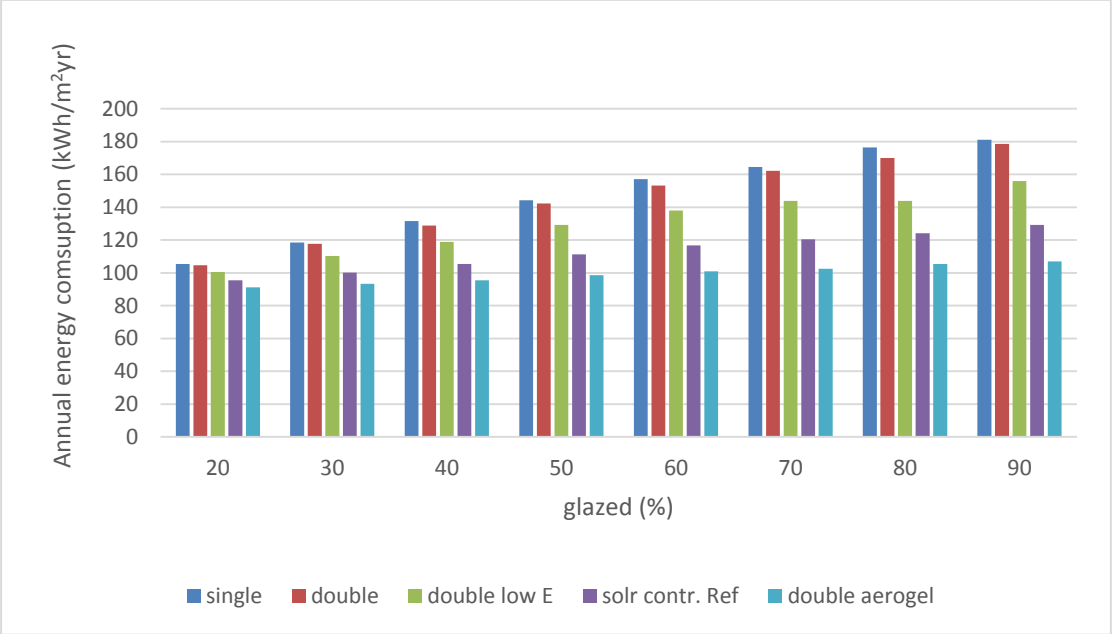


Figure 4-5: Effect of area on comparison with different glazed surface in reference case.

Shows that as glazed area increases, the energy consumption also increases, and this is already a well-known fact. In what proportion the energy consumption increases with the glazed area depends upon, selection of glazing types, and their optimum orientation, from cooling point of view. This is the subject matter of the present investigation. For this climate, the results are show in graphical form in Figure 4-5. This figure shows that annual energy consumption varies almost linearly with the glazed area. For 90% increment in glazed area, the corresponding increase in energy consumption is 13.3 kWh/m^{2}yr for single-clear, 11.1 kWh/m^{2}yr for double clear, 8.7 kWh/m^{2}yr for double low-e-clear, 5.3 kWh/m^{2}yr for solar control (reflective), and for 2.3 kWh/m^{2}yr double aerogel glazing. The highest increment in energy consumption is for single-clear glazing, and the lowest increment is for double-glazed with aerogel filled.

Table 4.3: Effect of different glazed area on building energy consumption. (North)

Glazed area (%)	Single clear			Double			Double low-e			Solr.control-ref			Double aerogel		
	Heating load	Cooling load	Total load	Heating load	Cooling load	Total Load	Heating load	Cooling load	Total load	Heating load	Cooling load	Total load	Heating load	Cooling load	Total load
							North								
20	0.2	105.3	105.5	0.2	104.5	104.7	0.3	100.3	100.6	0.5	95.1	95.6	0.5	90.7	91.2
30	0.2	118.3	118.5	0.2	117.6	117.8	0.2	110.1	110.3	0.7	99.5	100.2	0.6	92.8	93.4
40	0.3	131.3	131.6	0.2	128.7	128.9	0.2	118.8	119	0.9	104.6	105.5	0.8	94.8	95.6
50	0.3	143.6	144.2	0.1	142.3	142.4	0.2	129.1	129.3	1	110.4	111.4	0.8	97.8	98.6
60	0.3	156.8	157.1	0.1	153.2	153.3	0.2	137.8	138	1.3	115.5	116.8	1	99.9	100.9
70	0.4	164.2	164.6	0.1	162.1	162.2	0.2	143.6	143.8	1.4	119	120.4	1.1	101.5	102.6
80	0.4	172.5	176.5	0.1	170	170.1	0.2	149.6	143.8	1.4	123	124.1	1.1	104.4	105.5
90	0.4	180.8	181.2	0.1	178.5	178.6	0.2	155.8	156	1.4	127.8	129.2	1.1	106	107.1

Table 4.4: Effect of different glazed area on building energy consumption. (South and East)

20	0	118.9	118.9	0	116.8	116.8	0	109	109.1	0.2	97.9	98.1	0.3	91.8	92.1
30	0	146.3	146.3	0	143	143	0	128.3	128.3	0.1	106.5	106.6	0.3	95.1	95.4
40	0	173.3	173.3	0	168.9	168.9	0	147.6	147.6	0.1	114.3	114.4	0.3	98.1	98.4
50	0	200.1	200.1	0	196.6	196.6	0	168	168	0	124.9	124.9	0.2	102.7	102.9
60	0	225	225	0	222.1	222.1	0	187.5	187.5	0	134	134	0.2	105.4	105.6
70	0	242.7	242.7	0	239.8	239.8	0	200.8	200.8	0	140.6	140.6	0.2	108.6	108.8
80	0	259.4	259.4	0	257.4	257.4	0	213	213	0	147	147	0.2	112.6	112.8
90	0	276.8	276.8	0	274.8	274.8	0	216.8	216.8	0	148.8	148.8	0.2	116.8	117
							East								
20	0	108.8	108.8	0.1	106.7	106.8	0.1	102.2	102.3	0.3	94.7	95	0.4	90.1	90.5
30	0	124.9	124.9	0	122.4	122.4	0	113.7	113.8	0.3	100.2	100.5	0.4	92.5	92.9
40	0	141.2	141.2	0	138.1	138.1	0	125.5	125.6	0.2	105.4	105.6	0.4	94.8	95.2
50	0	158.1	158.1	0	154.1	154.1	0	138	138	0.2	111.4	111.6	0.4	97.1	97.5
60	0	175.9	175.9	0	172.2	172.2	0	151.2	151.2	0.2	118.3	118.3	0.4	100.2	100.6
70	0	185.3	185.3	0	181.9	181.9	0	158.4	158.4	0.2	121.2	121.4	0.4	101.3	101.7
80	0	195.3	195.3	0	191.9	191.9	0	165.5	165.5	0.2	124.8	125	0.4	102.8	103.2
90	0	205.5	205.5	0	202	202	0	173	173	0.2	128	129	0.4	104	104.4

Table 4.5: Effect of different glazed area on building energy consumption. (West)

20	0.1	108.2	108.44	0.2	106.6	106.8	0.2	102.2	102.4	0.4	95.5	95.9	0.5	90.4	90.9
30	0	125.1	125.1	0.1	122.3	122.4	0.2	113.9	114.1	0.4	100.1	100.5	0.5	92.9	93.4
40	0	141	141.1	0.1	137.8	137.9	0.1	126.2	126.3	0.5	105.3	105.8	0.6	95.9	96.5
50	0	158.9	159	0	155	155	0.1	138	138.1	0.5	111.7	112.2	0.6	98.3	98.9
60	0	176.1	176.1	0	171.6	171.6	0.1	150.9	151	0.5	118.8	119.3	0.6	101.4	102
70	0	186.4	186.4	0	181.7	181.7	0.1	160.3	160.4	0.5	122.5	123	0.7	102.2	102.9
80	0	196	196	0	191	191	0.1	171	171.1	0.5	126.5	127	0.7	103.5	104.2
90	0	206.8	206.8	0	201.1	201.1	0.1	181.5	181.6	0.5	131.5	132	0.7	104.8	105.5

Effect of orientation on glazed surfaces for annual energy consumption is show in table 4.5. South orientation corresponds to maximum annual cooling load and it is minimum for north orientation. This fact-finding holds good. Annual energy consumption load for east and west orientation are almost equal (within 2% variation) for all types of glazed surfaces. In addition, energy consumption in east and west axis is a little more (around 2-3%) than north orientation. Radiation on east or west glazing is important and has almost equal value, while it is almost nil on north glazed surface.

CHAPTER FIVE

5.0 DISCUSSION OF FINDINGS

A case study of selected building was analysed with parametric analysis and a simulation with Ecotect as the computer software applied. The results predict annual cooling load for energy demand is 164.6kWh/m²yr; a reduction of 20.7kWh/m²yr when optimum glazed ratio is used. Again, results show that the total energy consumption increased when the window-wall ratio is also increased, in terms of annual cooling loads per unit floor areas, 60:70% window-wall ratio performed better.

In addition, energy consumption in South orientation corresponds to maximum annual cooling load and it is minimum for north orientation. This fact-finding holds good. Annual energy consumption load for east and west orientation are almost equal (within 2% variation) for all types of glazed surfaces. In addition, energy consumption in east and west axis is a little more (around 2-3%) than north orientation. Radiation on east or west glazing is important and has almost equal value, while it is almost nil on north glazed surface.

For this climate, annual energy consumption varies almost linearly with the glazed area. For 90% increment in glazed area, the corresponding increase in energy consumption is 13.3 kWh/m^2yr for single-clear, 11.1 kWh/m^2yr for double clear, 8.7 kWh/m^2yr for double low-e-clear, 5.3 kWh/m^2yr for solar control reflective, and for 2.3 kWh/m^2yr double aerogel glazing. The highest increment in energy consumption is for single-clear glazing, and the lowest increment is for double-glazed aerogel with. This indicates that if attention to orientation and aspect ratio as parameters during the design of a shopping malls, it would go a long way in ensuring that the design save cost to user'.

CHAPTER SIX

6.0 SITE REPORT

6.1 Site Selection Criteria

For effective selection of site for the proposed ultra-modern shopping mall, the following criteria were considered:

I. Land use – Compliance with the existing or proposed land use.

II. Accessibility- It should be easily accessible by both pedestrian and vehicles means.

III. Relationship with other buildings- The relationship with existing buildings in the immediate neighborhoods with regard to general environment.

IV. Views - Visual and aesthetic potential.

V. Services - Availability of basic building services.

VI. Geographical zoning- The site should be located in a remote and silent part of the city.

VII. Expansion potential- The site should be large enough for expansion.

It must be stated that the task of choosing a site for the mall in order to fulfill its assigned role is one which may not necessarily satisfy all the above criteria but helps to create a shopping mall based on the energy efficiency design, resulting in a structure that will reduce cooling load and save cost to building user's.

6.1.1 Site selection

SITE A

The site is located at kaita road near Katsina state house of assembly, western parts of Katsina capital city.

SITE B

The site is located along the state road close to new government house Katsina,

Southern parts of Katsina capital city.

Table 6.1: Site Comparison.

CRITERION	SITE A	SITE B	REMARKS
Land use compliance	3	5	
Accessibility	5	3	
Relationship with other Buildings	3	4	
Views	3	4	
Services	5	3	
Geographical zoning	4	3	
Expansion potential	28	25	

Weighing scale: Excellent 5, Very good 4, Good 3, Fair 2, Poor 1, Very poor 0.

Source: (Author's Field Work 2016)

Site A is considered premium based on the total weight scored.

6.2 The Project Site

The site for the proposed ultra-modern shopping mall is located in the western part of Katsina metropolis; along kaita road near Katsina state house of assembly, western part of Katsina capital city. It has a latitude of (11°04'10"N) and Longitude (7°42'14"W). The time zone is GMT+1hour with an altitude of about 400m above sea level. The site contains many features that make it a perfect location for this facility. The site has a good topography. The landscape orientation is spread from east to west.



Figure 6-1: Site Diagram

(Source: Author's field work, 2016.)

6.3 Site Analysis

The site contains a number of features that needed to be taking into consideration when approaching it from a design perspective. As shown in the existing conditions model below figure 6.2 there are distinct contour lines that pass east to west through the site.

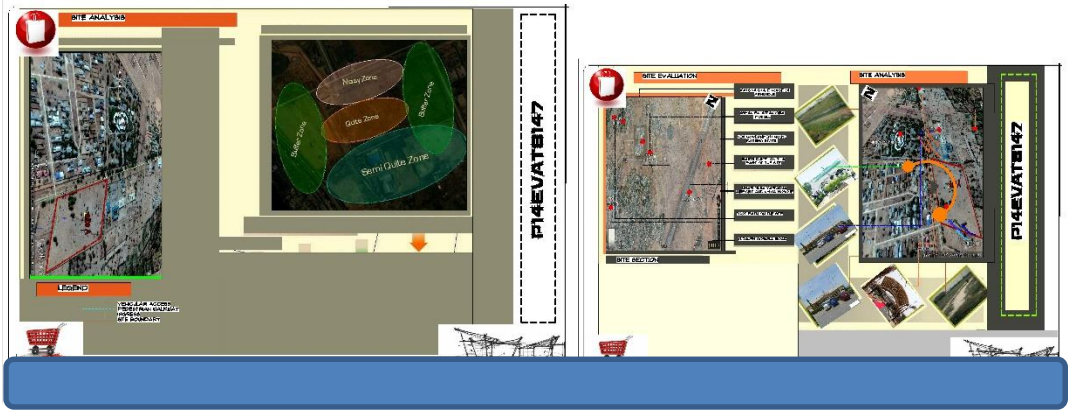


Figure 6-2: Site Analysis

(Source: Author's field work, 2016.)

These natural circulation paths are used by people and other animals that inhabit the site as they provide the smoothest transition up and down the site. The site contains mature trees with tall canopies that allow for a circulation underneath them. It will be beneficial to preserve these two areas to create shaded outdoor natural green spaces that act as a buffer between the access road and the shopping mall. Also these existing circulation trails help to inform the easiest areas to navigate throughout the site and will be taken into consideration for basing circulation methods off the natural process that occur on the site.

6.3.1 Site analysis; climate

For the purpose of this study, it is necessary to make a general study of the environment, thus outlining the climatological influence that effect the design within the locality of the site. Generally, environment could be regard as the sum total of influence which modify and determine the development of life and/ or character. A good study demands that the environment will be analysed in relation to the climate of the area in question as this will invariably influence the final design. A proper study of the climatic factors that effects an area will equip the designer and enable him adopt new conventional solutions to the prevailing climatic conditions and problems. Most of the data were retrieved from internet and compared with that from the department of Metrology, Umaru Musa Yar'adu University Katsina. The climate of Katsina city is typical of the guinea savannah. Two different types of air masses pass through Katsina, one from the north mostly dry and dusty (continental in origin) blowing from the Sahara Desert called the north-east trade winds and the other from the Atlantic in the south, brings rainfall, mostly cool and desirable for human comfort.

1. Temperature: Fluctuations in daily November temperature are from 23 ºC to 35 ºC clear skies, visibility becomes poor and the sun's rays do not reach the surface. This lowers the minimum temperature to 18ºC in January. Nights and mornings are cool but temperature

increases 18ºC to 35º C giving a variation of 16 ºC which is the highest during the year. Maximum temperature occurs in April which reaches 42 ºC but generally does not last more than two to three months.

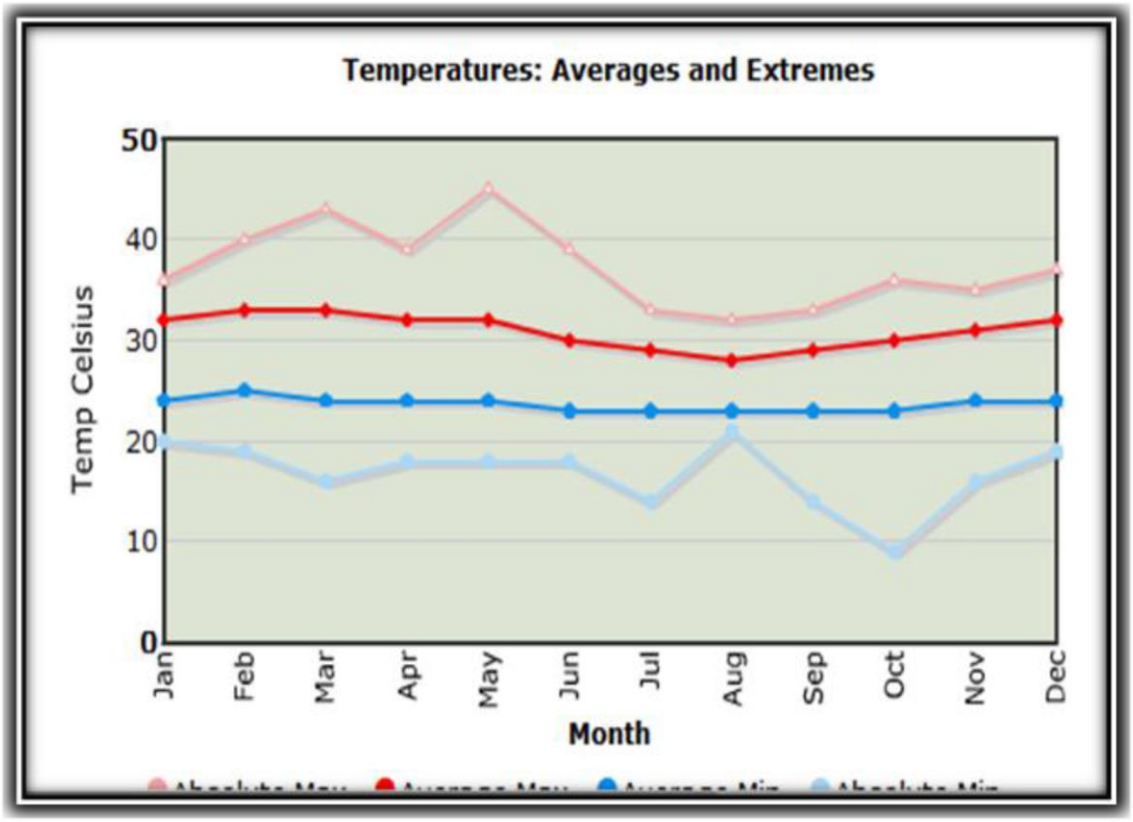


Figure 6-3: Katsina Temperature.

Source: Myweather2.co.uk.

2. Relative Humidity: At the start of the dry season, relative humidity falls from 68% in October to 36% in November with the stabilization of the easterly winds. It further falls to 35% in January and 20% in February. Mean relative humidity reaches its maximum value of 80% in the month of August.

3. Sunshine: Katsina being in the northern part of Nigeria has its sun movement from east through north to the south. The sun rises from the east and gently warms up to its maximum heat intensity in the afternoon. As the sun moves over to west its intensity witnesses a reduction till it is finally sets.

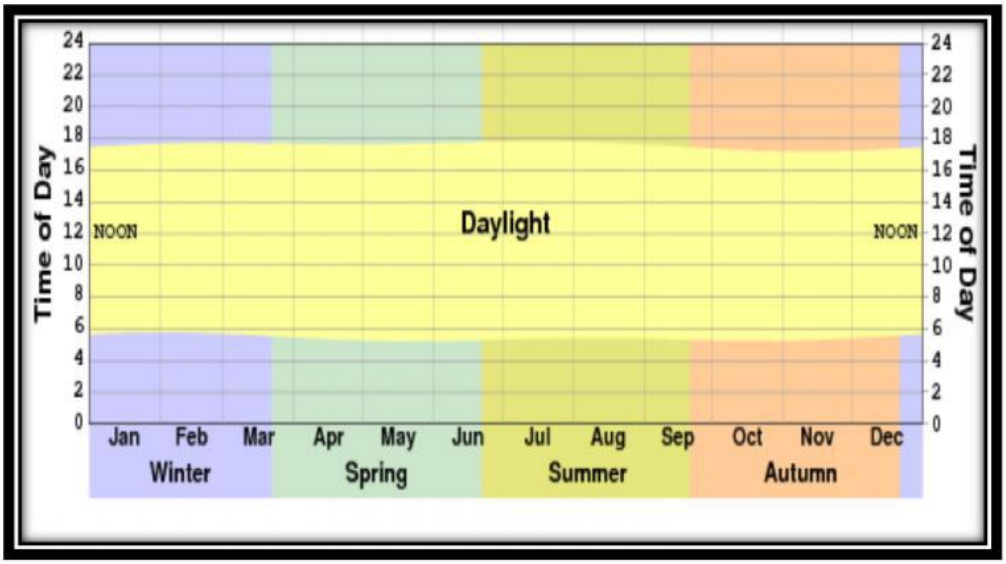


Figure 6-4: Sunshine: Katsina.

Source: Gaisma.com.

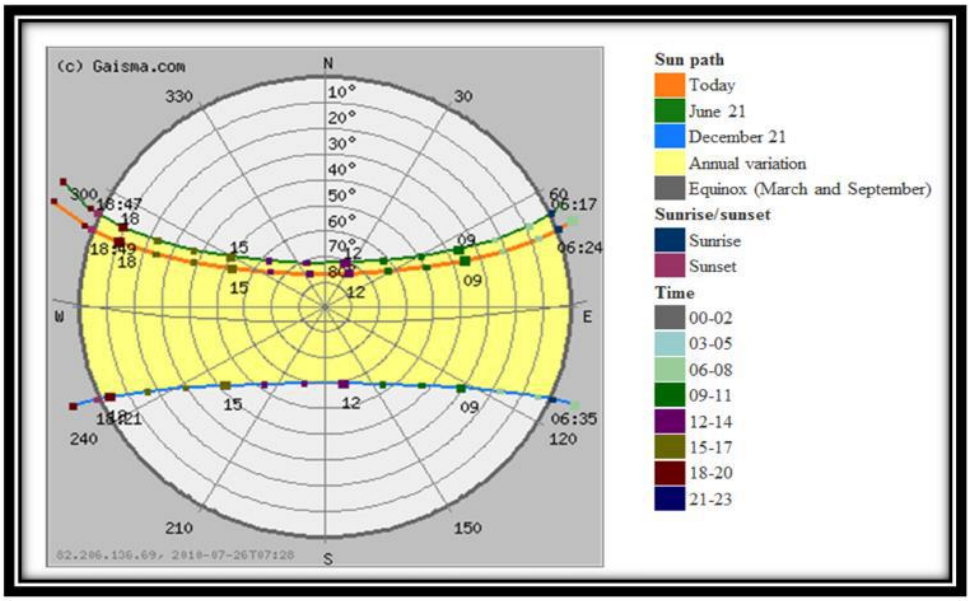


Figure 6-5: Sun Path Diagram

Source: Gaisma.com.

The yellow section shows when the sun is up, and how this changes over the year. The time of- day scales, on the left and right, and the month scale on the top and bottom, shows approximately when sunrise and sunset occur.

4 Rainfall: Rainfall starts in April and increases from 161.5mm in June to 281.6mm in August to its maximum throughout the year. Annual total rainfall lies within a range of 960mm to 1150mm.

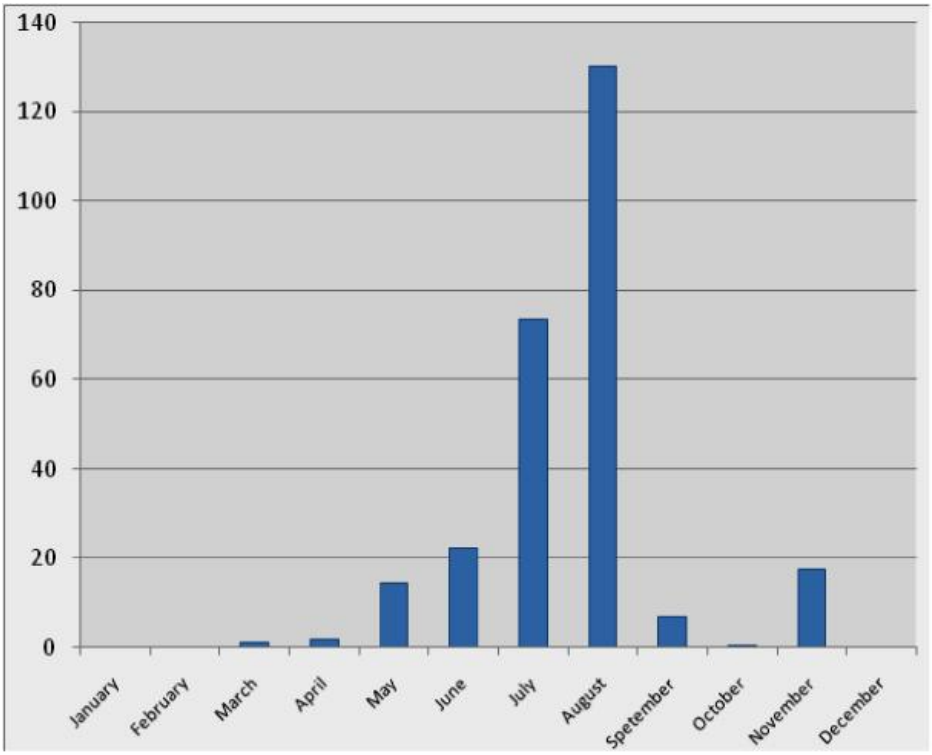


Figure 6-6: Number of Rain Days in Month: Katsina.

Source: Myweather2.co.uk.

5 Wind Pressure: In Nigeria there are two types of wind which prevails: Tropical Continental Air Mass and Tropical Maritime Air Mass. The tropical continental air mass (Harmattan wind) carries little or no moisture with it and therefore dries. This wind blows from northeast and predominantly prevails during the dry season. Its impact is more on the northern region of the country. The tropical Maritime air blows from southwest across the country and carries with it moisture (rainfall) which reduces from southern to northern region. This wind predominantly prevails during the wet season. The speed of both winds in Katsina ranges from 93kph for month of March to 43kph for month of December. Higher

speeds are sometimes recorded during harmattan period. Micro winds are occasionally generated by local air currents.

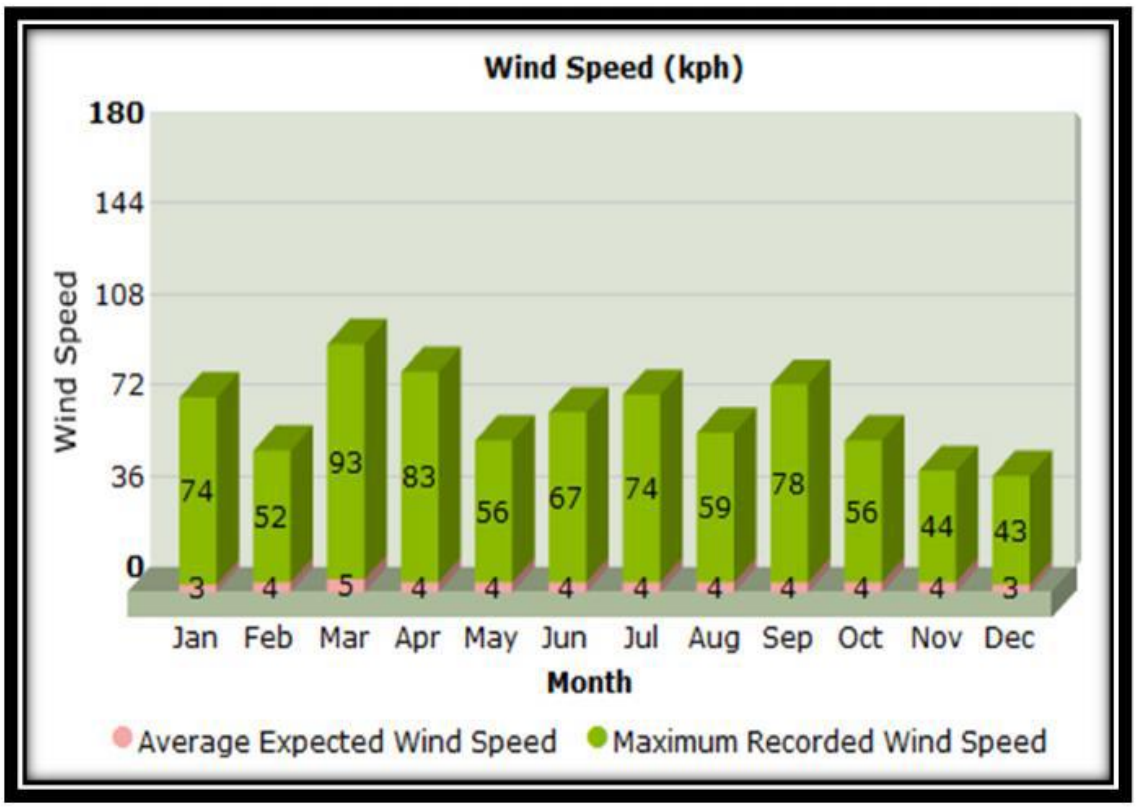


Figure 6-7: Wind Speed.

Source: Myweather2.co.uk.

6.3.2 Site analysis; (views and noise)

The major origin of noise is from the neighboring community, and from moving vehicles on the main road. Trees are to be planted close to these sources to buffer this effect. In planning, distance should be created between the facilities and this region with proper site zoning analysis. The best view of the site is at the north of the site, with Katsina state house of assembly, while the west side of the site is occupied by the civil service office and the adjacent view to the east and south of the site is a large expanse of land for future expansion of the mall with abundant trees and grasses.

6.3.3 Site analysis (soil and vegetation)

Eucalyptus and Mango trees are the predominant types of trees in the region, economically viable and shelter providing. They are to be maintained and planted where necessary but absent. Shrubs are scattered randomly across the site, and are to be maintained unless where it obstructs access, or development. The soil type on site is loamy in nature, with clayed deposits at the lower point of the site. It supports all forms of vegetation, and retains water. It should therefore be utilized for plantings and water collection schemes.

6.4 The Effects of Environmental and Climatic Factors On Building Design.

Natural climatic factors such as climate, geology and vegetation influence the lifestyle of the occupants and the design of a building landscape. For example, the two prominent trade winds influence orientation and design of buildings. The long span of buildings is oriented in a north and south direction. This is to reduce the effect of intense solar radiation from the east and west directions where sun rises and sets respectively. The cropping season begins in May at the commencement of the rains. The porous nature of the soil condition dictates special consideration for foundation design and landscape design that considers conservation of natural features on site. To achieve energy efficient design considerations on;

I. Temperature

Design should be such that;

- Shading devices or mechanism should be employ- canopies, covered walkways, wide veranda and balcony, and pergolas.
- Water bodies like pool and fountain around and within the building should be provided for.
- Healing, shading and absorption of radiation.
- Shaded windows and openings to encourage good natural ventilation.

- Minimum use of dark colored materials outside and inside building to reduces absorption of heat and radiation.
- Good orientation of building to take advantage of prevailing condition.

II. Humidity

- Due to the absence of dam in the design site, there will be a relatively low humidity in the area; there is need for effective ventilation to help the body lose heat is less. For close up and huge walls, air conditioning is inevitable.
- The ground floor slab of the building should be damp proofed.

III. Rainfall

- Roof form should encourage effective discharge of rain water.
- Provision should be made for adequate drainage channel to avoid flooding.
- Planting and paving should be used to discourage erosion on site.
- Canopies, eaves, window hoods and veranda should be employed to prevent driving rain from entering into the building through external windows and openings.
- Building materials used should withstand moist and wet environment.

IV. Wind Pressure

- Proper bracing and rigidity of the building structure to withstand strong wind is necessary.
- Trees should be planted in the site to reduce devastating effects of wind on the building.
- Good orientation of the building in relation to wind flow is necessary.
- Windows and openings should be of appropriate sizes, operable and should not be placed directly to the wind direction.

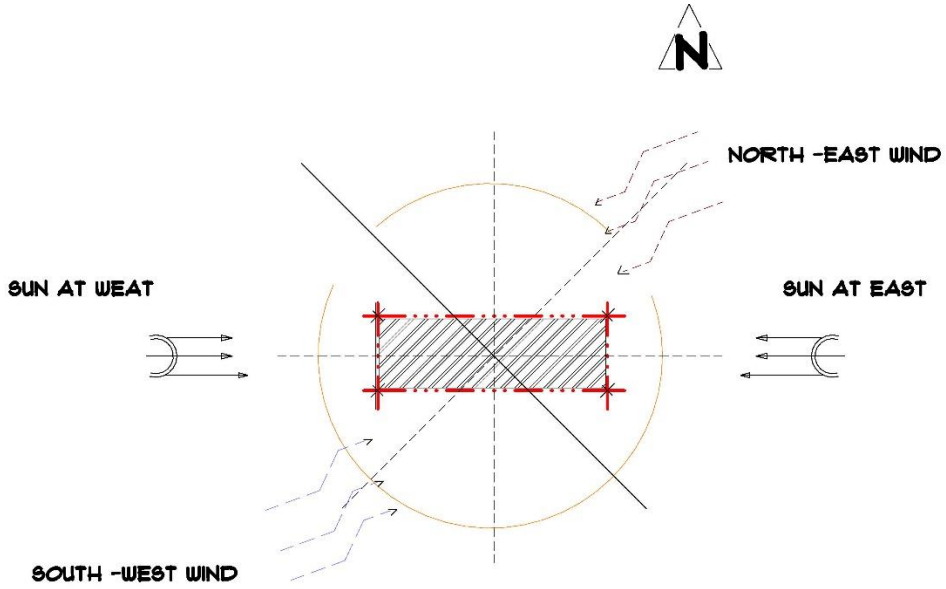


Figure 6-8: Orientation Consideration More Wind Than Sunlight.

(Source: Author's field work, 2016.)

V. Solar Radiation

- Good landscaping is necessary to reduce radiation of sun at the outdoor environment

- The use of sun shades and sun breakers is necessary in the building design.

- Good orientation of the building on site and spaces in the building is important to take advantages of the sun radiation.

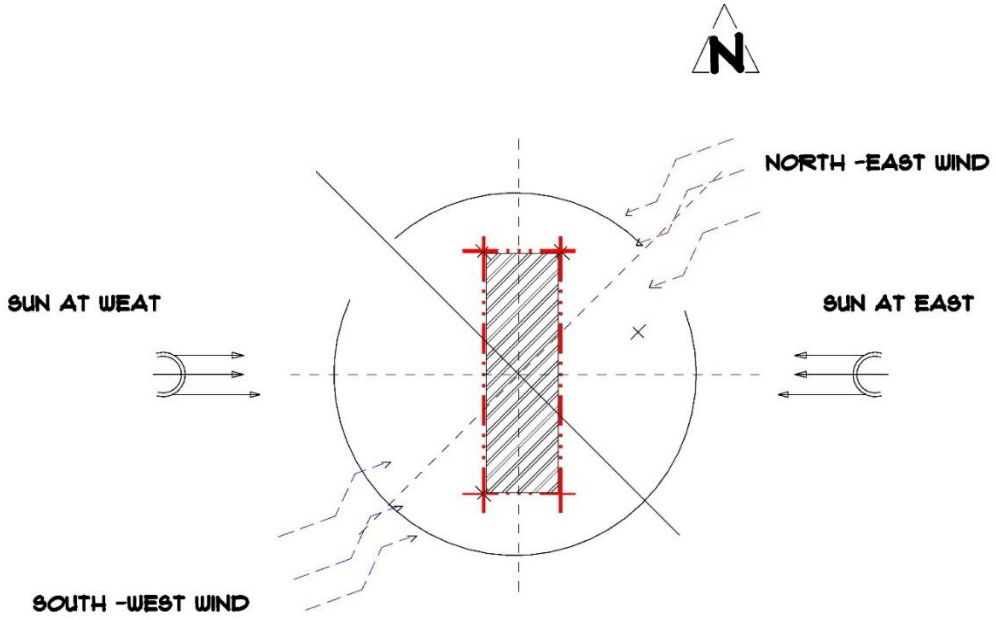


Figure 6-9: Orientation Consideration: More sunlight than wind.

(Source: Author's field work, 2016.)

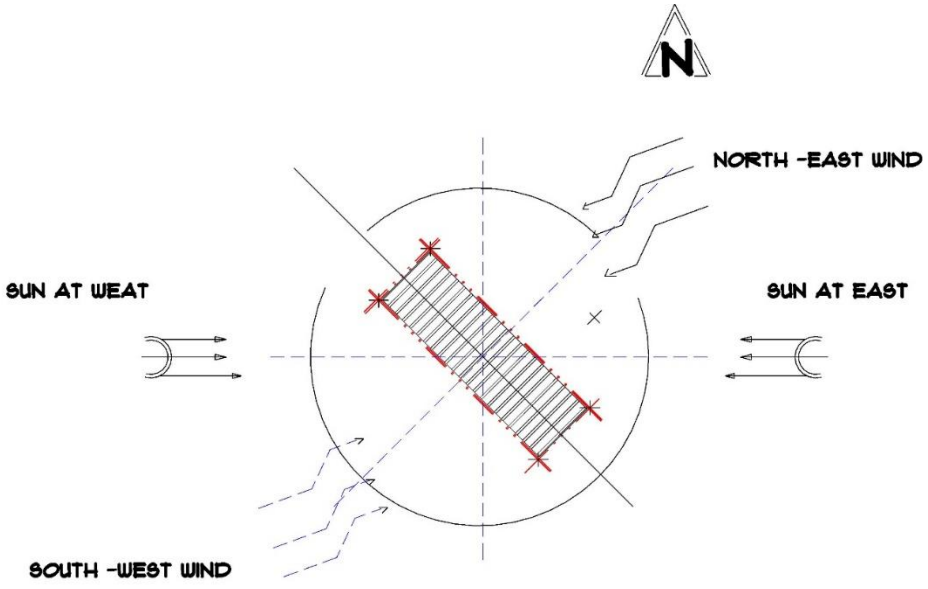


Figure 41: Orientation Consideration: Both sunlight and wind

(Source: Author's field work, 2016.)

CHAPTER SEVEN

7.0 DESIGN REPORT

7.1 Introduction

This chapter brings all data previously analysed into an articulated design philosophy which will form the basis for the formulation of design concept. All design solutions shall be attributed to the design concept.

7.2 Energy Efficient Design

Energy efficient building are designed in a way that ensures that energy is used at a reduced cost, and in a sustainable and conserved manner. The objective was to propose a design of an energy efficient ultra-modern shopping mall by applying most suitable glazed surfaces area with best orientation for hot-dry climate of Katsina. The primary and most visible notion was expressed in the overall structural and cladding members.

This system was influenced by the geometry of a wheel cart and simulating a structure that provides a structure that will save cost to building user's. By analyzing the forms, the main structural components were derived and implemented in the atrium space and in various transition spaces throughout the shopping mall.

7.3 Form Concept Development

The overall building form was designed based on several key attributes of the site and the surrounding context that would enhance the energy efficiency for shopping mall. The primary factor that drove much of the buildings form dealt with the views that could be experienced from the site.

The form derived from the wheel cart are manipulated in a three dimensional sense to accommodate the necessary pragmatic spaces. By merging the differing layers of site driven

forms together, in combination with an appropriate organizational method allowed the mall to take shape. Using the sites challenges, the mall is able to be nestled right into the slope and the prevailing winds, providing good thermal qualities for its performance factors, while also preserving the views from all points across the site. The shopping mall layout is organized in a fashion that would have the best possible view from the building, to further connect with nature and help to enhance energy efficiency.

7.3.1 Site planning concept

The site concept is based on the zones of a shopping mall into three parts: independent retail stores, services and parking area. These spaces were formulated under the shape of a wheel cart, as wheel cart is used for conveying good. As such, wheel cart is used as the main concept of this design.

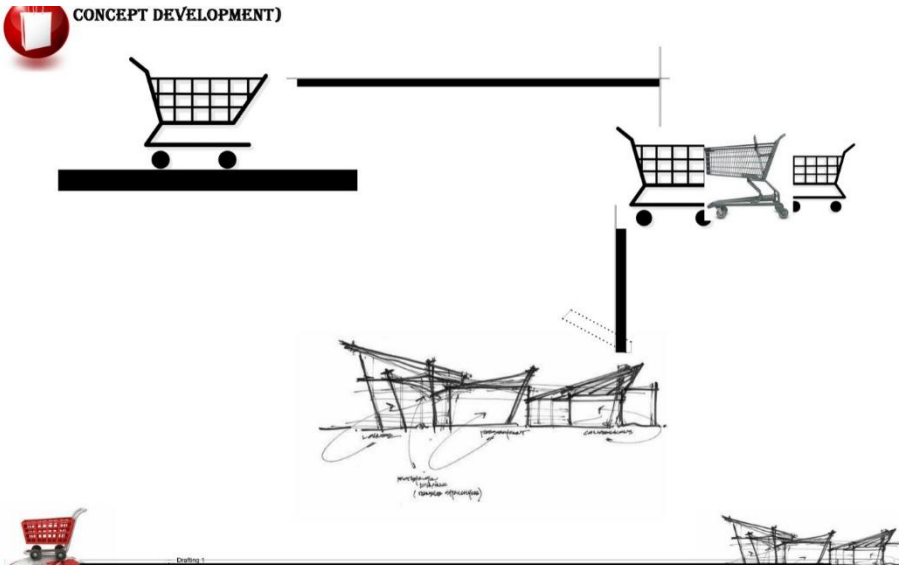


Figure 7-1: Concept: Form and Site Plan.

(Source: Author's field work, 2016.)

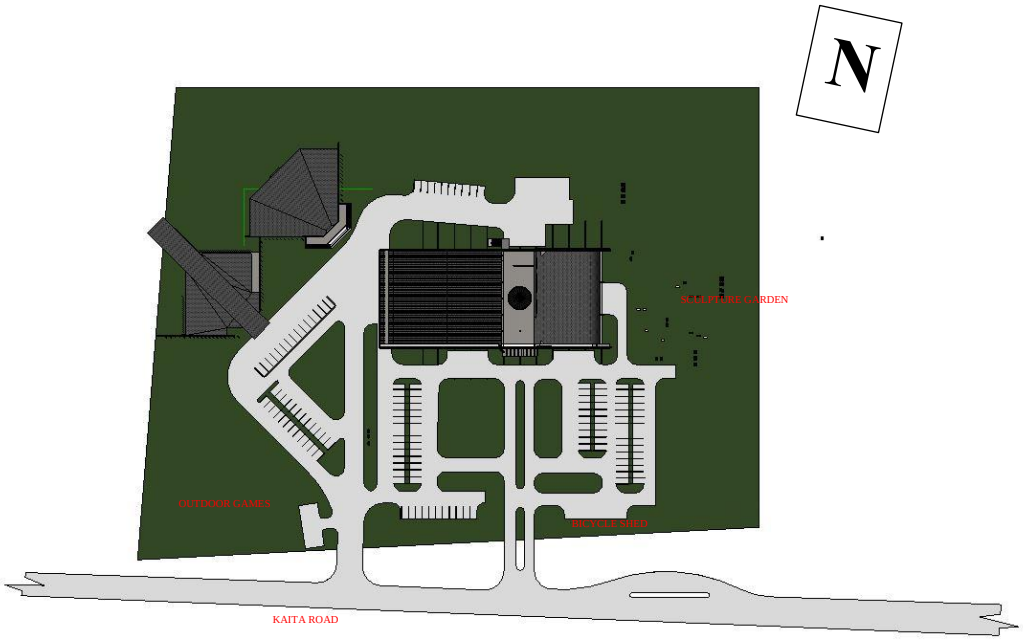


Figure 7-2: Proposed Site Plan.

(Source: Author's field work, 2016.)

The site concept was based on the following criteria:

I. Safety - The need to give much consideration to the pedestrian circulation. Hence a design that provides a free pedestrian environment. This will increase the shopping mall value.

II. Site configuration - The site is relatively sloping towards the access road and all data relating to the site analysis were concerned, i.e. point of penetration, natural features and site contours etc.

III. Circulation -The concept of circulation used within the site is pedestrian's free access, devoid of interference of pedestrian and vehicular circulation. Hence, the pedestrian circulation is totally and consciously separated to enhance safety and shopping value.

IV. Activity - Diversity in terms of activity in the mall to create the much needed excitement, pleasure associated with shopping facility.

V. Design with nature - Consideration of activity period of function as regard to zoning of functions in relation to local and micro climate.

7.3.2 Ventilation and lighting concept.

The whole mall is design to follow the pattern of the contour lines existing on the site. This gives room to optimal utilization of natural lighting and ventilation since the contour lines run from east to west of the site.

The shopping mall building is design with enough open planned functions and well landscaped to filters the light (creating “natural" protection from the sun’s rays) and allows in-depth views around the mall. These plantings also protect against the wind while, at the same time, allowing the passage of natural light that helps illuminate the interior.

Cross ventilation method is used in the ventilation of the building. This ventilation technique has been found to be effective in this type of building structure. Thus artificial ventilation lighting is optional. Except in the movie theatres and banking institute were special lighting is needed for display.

7.3.3 Landscaping

Tree canopy shaded driveways, hedges are put in place to enhance the micro climate, environmental features and refuge within the mall. The planning of the landscape follows from fractal principles of scaling, self-similarity and infinity. Stone paving as used for the walkways, in order to emphasis the use of natural materials. Gardens were introduced in the interior to enhance experience and to avoid creating a drastic difference between the interior space and exterior space.

7.3.4 Plan concept

The plan concept was synthesized from the two component of this research: energy efficiency and shopping mall.



Figure 7-3: Proposed Ground Floor Plan

(Source: Author's field work, 2016.)

7.4 Building Structure

7.4.1 Form

The building form is purely based on functionality and aesthetics which embodies the articulation of various architectural forms in three dimensions to achieve harmonious relationship, maintaining balance aesthetically. The massing of the building shows the unity of architectural forms and good visual perception. The building in its simplest form is an interdependent network of open areas with few internal non load bearing walls. The supports of the ceilings and upper floors are mainly provided by columns.

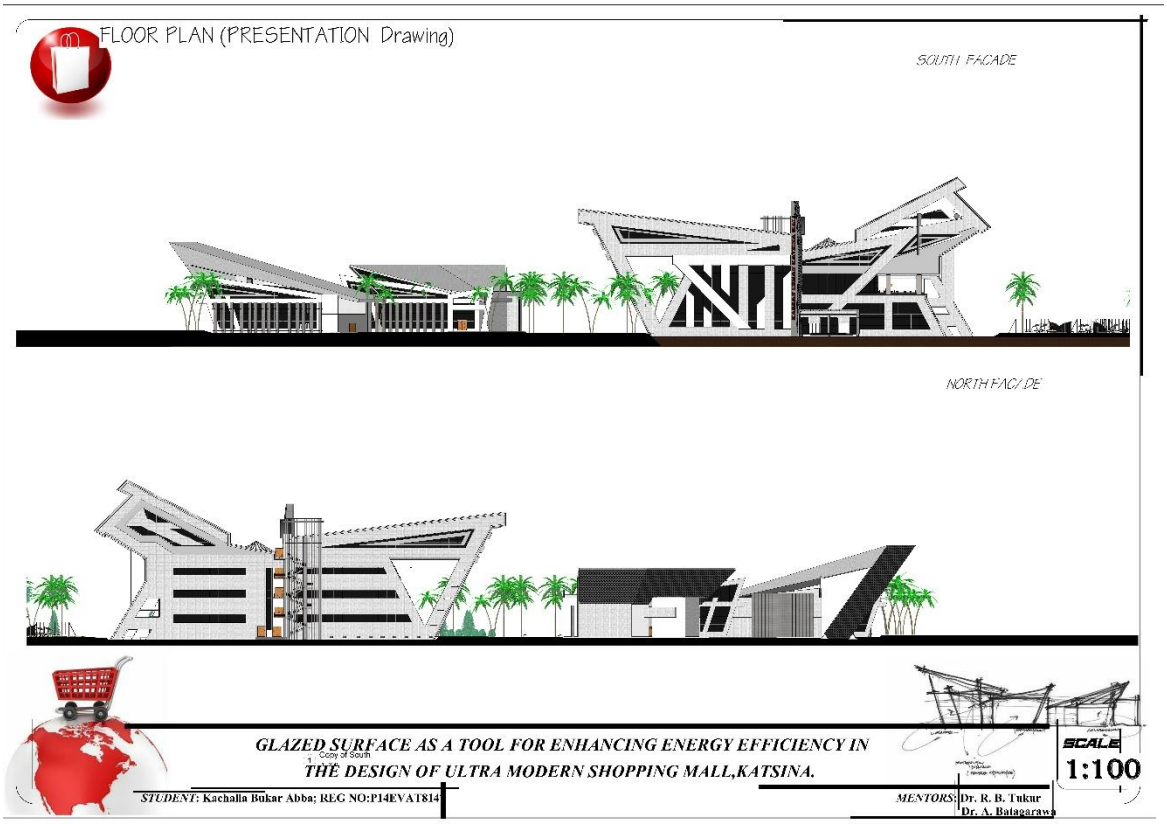


Figure 7-4: Proposed Facade

(Source: Author's field work, 2016.)

7.4.2 Floor loading

The activities that will add much live loads and dynamic loads to the floors are located on the ground floor level. Hence there is decrease in floor loading with increase in floor levels. Service equipment were also located at the ground level.

7.4.3 Foundation

Based on the analysis of existing buildings, the foundation should be of pad foundation, otherwise specified by structural engineer, with sufficient depth.

7.5 Design Consideration

The site is located along kaita road city of Katsina area of north-western Nigeria and design and construction will adhere to the North-western Building Code Congress International

guidelines as well as the Nigerians with Disabilities Act guidelines; therefore, a good skill in designing the flow of activities must be exercised so that a balance is struck. All the following factors were considered.

7.5.1 Sustainability

There is the opportunity to use the mall to encourage approaches to sustainability, by designing for minimum energy use and water use, choosing locally sourced, or other low environmental impact materials.

7.5.2 Space organization

The building must be easy for the staff to manage. Layout and circulation routes should be clear, and ample storage space is needed. Consideration for noise, type of activity, likely timing of activities and age groups when locating facilities. A reception area or office at or near the entrance will assist in the monitoring of activities and provide a focal point for information and organization.

7.5.3 Circulation

Economic planning is necessary to keep costs down, so all opportunities should be taken to minimize corridors, and make spaces useable for more than one function. Central circulation space doubling up as a café/informal meeting area is a typical solution. Circulation space must be easily monitored and have robust and hard-wearing surface finishes. Vertical circulation should be visible.

7.5.4 Accessibility

The building will need to cater for all age ranges, from children in prams and push chairs to ambulant disabled adults and wheelchair users. Citing of entrances, walking distances from

different functions, provision of disabled parking all need to be considered, as should colour and contrast in the interior design scheme.

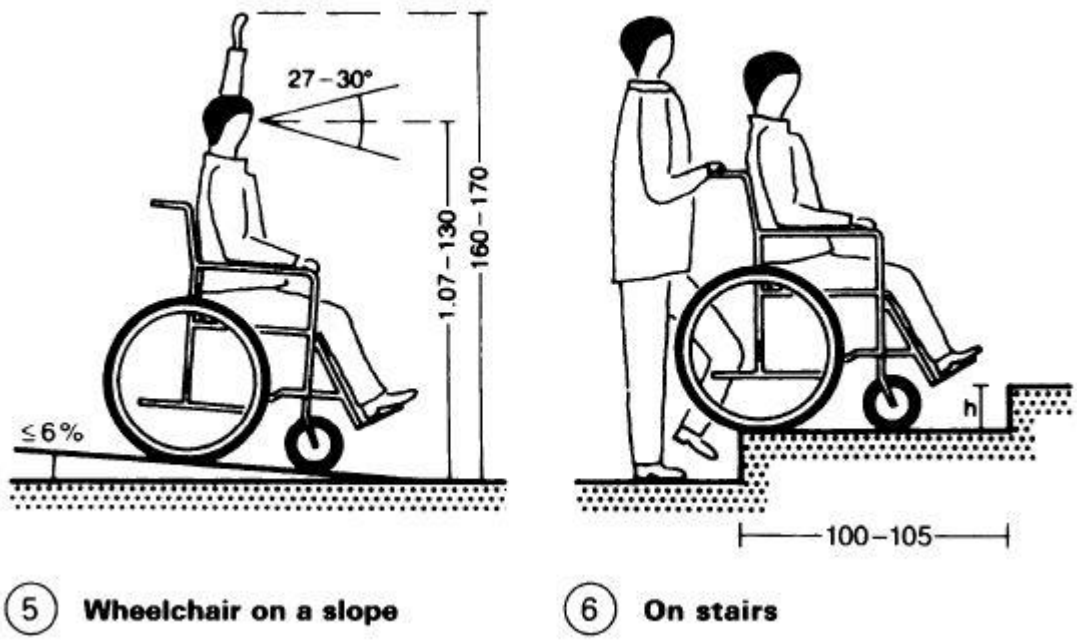


Figure 7-5: Design for the physically challenged.

Source: Neufert, 1995.

The implications of sloping sites, changes of level and designs with more than one floor level need careful consideration at the outset. Lifts and chair lifts are expensive to install and maintain, and prone to abuse. Opening hours and management policies of the building also need to be considered from the earliest stage and can often be subject to planning restrictions to avoid disruption of immediate neighbors.

7.5.5 Maintenance

There should be careful consideration of maintenance implications of all specifications to help to minimize running costs and ensure long-term viability of the mall. Specify robust high-quality materials and products wherever possible and avoid unusual fixtures and fittings (such as taps, toilets, boilers and shutters) that may cause maintenance difficulties for the management group through cost, availability of spares etc.

7.5.6 Flexibility

The building design must allow for maximum flexibility of use, which will need to be considered both in the short term to cater for current requirements, and in the longer term, as needs will change with time. For short-term change, moveable walls or partitions to divide spaces may have some applications but there are problems with the poor acoustic performance of some screens and the operational complexity of large systems. Design solutions that give flexibility through planning and space organization as well as the provision of a range of different sized spaces are to be preferred. For longer term change, designs that can easily accommodate internal reorganization through appropriate initial structural design and by allowing space for future extension are desirable.

7.5.7 Means of escape

Care in planning and signposting the means of escape in case of fire is especially important. Provision of escape staircase in case of fire is necessary.

7.6 Services

7.6.1 Water supply

The mall will be equipped with water supply from the new Katsina State Water Board plant that is presently under construction and a borehole water supply is also proposed for the mall as an alternative source.

7.6.2 Power supply

Power shall be tapped from the Power Holding Company of Nigeria (PHCN)'s national grid. However, the design shall also cater for its own power needs. There is provision for a power substation, with power generating sets and synchronization panel, to cater for power failure.

7.6.3 Refuse disposal

Waste bin should be provided in every room and along circulation route. Small incinerator should be provided at a remote part of the site, waste treatment plant, to cope with all refuse generated on site.

7.6.4 Waste water and sewage disposal

Waste water from water closets should be drain through the central sewer line to the sewage treatment plant for treatment and subsequently disposed by Katsina State Environmental Protection Agency.

7.6.5 Firefighting system

Fire hydrants for easy water collection by fire fighters, fire extinguisher and smoke detectors should be provided in the mall, but competent professional should be involved in determining the number and location of the firefighting systems.

7.6.6 Storm water drainage

The slope of the site being relatively steep will encourage natural drainage of storm water off the site. But drainage channels should be provided to take care of water run-off from roof.

7.7 Materials

To allow ease of construction, without the over-dependence of foreign expertise, the design of the facilities has been simplified to appreciable state. A combination of Stabilized Earth Bricks, steel and concrete has been used; for the available construction technology in Nigeria. Reinforced Concrete, Steel, steel and glass shall be the dominant building materials used for the construction of the facility.

7.7.1 Stabilized earth blocks

These blocks are made using compacted soil, cement serving as stabilizer. They are about 2-3 times better than conventional brick or concrete masonry in terms of thermal quality, strength, water absorption and they provide good finish.

7.7.2 Reinforced concrete

The high structural strength of concrete (especially when reinforced with steel) makes it the 'perfect' material for the structural. The fluidity of reinforced concrete makes it a good construction material for curved, slanted walls.

7.7.3 Steel

Steel offers many advantages, primarily high strength and ductility. It is also durable if protected from corrosion. Relatively, the higher yield stress of steel allows for smaller sections and its lower weight reduces foundation requirement.

7.8 Building Finishes

Shopping mall is a complex building with different commercial activities taking place. For each separate function, the materials used for the internal finishing will be based on; initial and long term cost, durability, maintenance, quietness, comfort, safety (no slippery), thermal conductivity, reflectance (shine) and appearance.

7.9 Construction Methods

Framing system should be used during the construction of the mall. All the building component should be produced insitu. Except for some materials like blocks, steel channels, roofing sheets and other components which production practicality on site will be difficult should be produce in factory. Due to the nature of the site soil, earthwork support should be

used at the foundation trench to hold the earth against collapse. All wiring and piping should be by conduit.

CHAPTER EIGHT

8.0 CONCLUSION

8.1 Conclusion

This chapter, provides conclusions to the entire report and gives a summary into the work carried out while also identifying the missing gaps and offering possible suggestions to into areas of further study that can be carryout. The basis of this study originates from a personal experience of heavily glazed façade construction trend coming up in Nigerian cities, Katsina is not exception. In response, energy conservation and efficiency practices and technologies are required to ensure rationalized consumption of energy in the country (Sambo, 2008). Investigation done, provides a base for clients to calculate energy and cost savings that can be achieved by optimum glazed surface area and their optimum orientation in commercial building within Katsina climate. The study discussed the annual cooling energy demand, and the total annual energy consumption at different conditions including different orientations, window-wall ratio, and types of windows in northeast Nigeria city of Katsina.

Moreover, the impact of window-wall ratio and window material types on the air conditioning energy consumption is analysed. The study shows the following:

i. Windows facing the east and west contribute to the greater effect on the energy consumption. Windows facing east or west should be avoided or the window-wall ratio of them should be limited, and external windows with suitable shading coefficient should be applied or movable sun-shading for the windows should be set up. In consideration of the building energy efficiency design, the windows should be on the north façade or the south and ventilation and natural lighting need to be considered.

ii. Reducing the window-wall ratios of in northwest Nigeria would provide significant energy saving benefits. The energy efficiency performance would be significantly increased by reducing the window-wall ratio for external windows of single glass compared to when it is double glass-aerogel filled.

8.1.1 Performance of the glazed surfaces.

A case study of selected building was analysed with parametric analysis and a simulation with Ecotect as the computer software applied. The results predict annual cooling load for the energy demand is 164.6kWh/m²yr; a reduction of 20.7kWh/m²yr when optimum glazed ratio is used. Again, in terms of annual cooling loads per unit floor areas, 60:70% glazed area performed better.

In addition, energy consumption in South orientation corresponds to maximum annual cooling load and it is minimum for north orientation. This fact-finding holds good. Annual energy consumption load for east and west orientation are almost equal (within 2% variation) for all types of glazed surfaces. In addition, energy consumption in east and west axis is a little more (around 2-3%) than north orientation. Radiation on east or west glazing is important and has almost equal value, while it is almost nil on north glazed surface.

For this climate, annual energy consumption varies almost linearly with the glazed area. Result predict from figure 60%-70% wall to window ratio performed better.

For 60% increment in glazed area, the corresponding increase in energy consumption is 13.3 kWh/m^2yr for single-clear, 11.1 kWh/m^2yr for double clear, 8.7 kWh/m^2yr for double low-e-clear, 5.3 kWh/m^2yr for solar control reflective, and for 2.3 kWh/m^2yr double (aerogel) glazing. The highest increment in energy consumption is for single-clear glazing, and the lowest increment is for double-glazed with aerogel filled.

8.1.2 Contribution to knowledge

- Using building energy simulation this work done has shown that it is possible to reduce cooling energy load for a heavily glazed façade commercial building in north west Nigeria. Results show that the total energy consumption increased when the window-wall ratio is also increased, in terms of annual cooling loads per unit floor areas, 60:70% window-wall ratio performed better.
- For 90% increment in glazed area, the corresponding increase in energy consumption is 13.3 kWh/m^2yr for single-clear, 11.1 kWh/m^2yr for double clear, 8.7 kWh/m^2yr for double low-e-clear, 5.3 kWh/m^2yr for solar control reflective, and for 2.3 kWh/m^2yr double glazed with aerogel filled.
- Umar shopping mall, the results predict annual cooling load for the energy demand is 164.6kWh/m^2yr; a reduction of 20.7kWh/m^2yr when optimum orientation is used. In addition, energy consumption in east and west axis is a little more (around 2-3%) than north orientation. In addition, energy consumption in South orientation corresponds to maximum annual cooling load and it is minimum for north orientation. This fact-finding holds good. Annual energy consumption load for east and west orientation are almost equal (within 1% variation) for all types of glazed surfaces.

8.1.3 Further work

- ✓ Cost effectiveness of using optimum glazed ratio, Glazed surface ratio in composite climate and in other cities within the hot-dry and Replicate this work on another building typology.

REFERENCES

Adebamowo, M. A., and Akande, O. K., (2010). *Indoor Thermal Comfort for Residential Buildings in Hot-Dry Climate of Nigeria, pdf,* Accessed: 15/08/2016 from http://nceub.org.uk.

Adebamowo, M. A., and Akande, O. K., (2010). Indoor Thermal Comfort for Residential Buildings in Hot-Dry Climate of Nigeria, pdf, Accessed: 15/11/2012 from http://nceub.org.uk.

Adeleke, L. G. and Ugursal, V. I. (2010) 'Modelling of end-use energy consumption in the residential sector: A review of modelling techniques', Renewable and Sustainable.

Adenikinju, A. (2005). *Analysis of the cost of infrastructure failures in a developing economy: The case of the electricity sector in Nigeria. Nairobi*: AERC

Akinlo, A.E. (2009) 'Electricity consumption and economic growth in Nigeria: Evidence from cointegration and co-feature analyses, Journal of Policy Modelling, 31(5), pp. 681-693.

Al-Najem, A.A. (2010). *The Effects of Orientation, Ventilation and Varied WWR on the Thermal Performance of Residential Rooms in the Tropics*. Accessed 9/08/2016 from http://www.ccsenet.org /journal/index.php/jsd/article.

Al-Tamimi, N. A. M., and Syed-Fadzil, S. F., (2011). *Thermal Performance Analysis for Ventilated and Unventilated Glazed Rooms in Malaysia (Comparing Simulated and Field Data). Indoor Built Environ*, (20) 5; pp. 534–542.

Alvarez, G., Flores, J. J., & Estrada, C. A. (1998). The thermal response of laminated glass with solar control coating. Journal of Physics D: Applied Physics, 31(21), 3057.

Arasteh, D. (1994). Advances in window technology: 1973-1993. Advances in solar energy, an annual review of research and development, 9, 339-382.

Arasteh, D., Apte, J., & Huang, Y. (2003). Future advanced windows for zero-energy homes. ASHRAE Transactions, 109(2), 871-882.

Arasteh, D., Reilly, M. S., & Rubin, M. D. (1989). A versatile procedure for calculating heat transfer through windows. Lawrence Berkeley Laboratory.

Arasteh, D., Selkowitz, S. and Apte, T., (2006). Zero Energy Windows. LBNL- 60049. Lawrence Berkeley National Laboratory.

Arasteh, D., Selkowitz, S. and Apte, T., (2006). Zero Energy Windows. LBNL- 60049. Lawrence Berkeley National Laboratory.

Asif, M., et al. (2005) "Sustainability analysis of window frames." Building Services.

Baiden, B.K. and Asante, C.K.O. (2004) *'Effects of orientation and compaction methods of manufacture on strength properties of sandcrete blocks', Construction and Building Materials,* 18(10), pp. 717-725.

Baiden, B.K. and Tuuli, M.M. (2003) 'Impact of Quality Control Practices in Sandcrete Blocks Production', Journal of Architectural Engineering 10(2).

Balcomb, J. D. (Ed.). (1992). Passive solar buildings (Vol. 7). MIT Press.

Batagarawa, A. (2013). *Assessing the thermal performance of Phase Change Materials in composite hot humid/hot dry climates: An examination of office buildings in Abuja-Nigeria*. (Doctoral dissertation, Newcastle University).

Beck, F. A., & Arasteh, D. (1992). Improving The Thermal Performance Df Vinyl-Framed Windows.

Ben-Nakhi, A. E. (2002). Minimizing thermal bridging through window systems in buildings of hot regions. Applied thermal engineering, 22(9), 989-998.

Berning, P. H. (1983). Principles of design of architectural coatings. Applied optics, 22(24), 4127-4141

Binamu, A. H. (2002). *Integrating Building Design Properties" air Tightness" and Ventilation Heat Recovery for Minimum Heating Energy Consumption in Cold Climates.* Tampereen Teknillinen Korkeakoulu.

Binarti, F., (2009). Energy-Efficient Window for Classroom in Warm Tropical Area. Eleventh International IBPSA Conference Glasgow, Scotland, July 27-30, 2009; pp 1655-1662.

Bouchlaghem, N. (2013). Optimising the Design of Buiklding Envelopes for Thermal Performance. Automation in Construction, Vol. 10, pp: 101-112.

Bouchlaghem, N. M., (1996). A Computer Model for the Design of Window Shading Devices. Building Research and Information, 24: (2), pp 104–107 http.dx.doi.org/10.1080/09613219608727509

Bube, R. (1983), Fundamentals of solar cells: photovoltaic solar energy conversion. Elsevier.

Bulow-Hube, H. (2001). Energy Efficient Window Systems. Effects on Energy Use and Daylight in Buildings (Doctoral dissertation, Lund University).

Burberry, P. (1997). Environment and services. Harlow: Longman.

Bureau for Public Enterprises (2009) About Nigeria. Available at: http://www.bpeng.org/Electric_Power/Pages/default.aspx. Accessed: 30-06-16.

Byars, N., & Arasteh, D. (1992). Design options for low-conductivity window frames. Solar energy materials and solar cells, 25(1), 143-148.

Byrne, S. J., & Ritschard., R. L. (1985). A Parametric Analysis of Thermal Mass in Residential Buildings, ASHRAE/DOE/BTECC Conference: Thermal Performance of the Exterior Envelopes of Buildings, (pp. 1225–1240). Clearwater Beach.

Center for Sustainable Building Research (CSBR). Efficient Windows Collaborative Tools for Schools (2011). College of Design, University of Minnesota. Available at www.csbr.umn.edu. Accessed on 4th June, 2016.

Christian K., David Nyame-T., Jimmy Nkrumah (2016). Towards the Reduction of Cooling Loads in Ghanaian Glazed Office Buildings: Orientation as a Recommendation by the Ghana Green Building Council (GHGBC), Accessed: 15/11/2016 from http://nceub.org.uk.

CIBSE (2004) Energy efficiency in buildings. London: The Chartered Institution of Building Services Engineers.

CIBSE (2007) Guide A. Norfolk: Chartered Institute of building service engineers.

Duer, K., Svendsen, S., Moller Mogensen, M., & Birck Laustsen, J. (2002). Energy labelling of glazings and windows in Denmark: calculated and measured values. Solar Energy, 73(1), 23-31.

Ecotect (2011) Ecotect Architectural Reference. Available at: http://www.designbuilder.co.uk/helpv2/.

Ecotect (2011) Weather data file uploads. Available at: http://tech.groups.yahoo.com/group/Ecotect_Support/files/Meteonorm_Weather_Files/Africa/Nigeria%20%28NGA%29/.

Emeka, E.E. (2010) 'Causality analysis of Nigerian electricity consumption and economic growth', Journal of Economics and Engineering, 2078-0346(4), p. 5. Engineering Research and Technology, v. 26, n. 1, p. 72.

Flavell, R., & Smale, C. (1974). Studio glassmaking. Van Nostrand Reinhold.

Gardon, R. (1961). A review of radiant heat transfers in glass. Journal of the American Ceramic Society, 44(7), 305-312.

Givoni. (1981). Man, Climate and Architecture. London, UK.: Applied Science Publishers Ltd,

Glenn, D., Johnson, H., Dannenberg, R., Sieck, P. A., & Countrywood, J. (2009). U.S. Patent Application 12/394,119.

Gliner, J.A., Morgan, G.A. and Leech, N.L. (2000) Research Methods in Applied Settings. An Integrated Approach to Design and Analysis. Hoboken: Taylor & Francis.

Grynning, S., Gustavsen, A., Time, B., & Jelle, B. P. (2013). Windows in the buildings of tomorrow: Energy losers or energy gainers? Energy and buildings, 61, 185-192.

Gustavsen, A. (2001). Heat transfer in window frames with internal cavities (Doctoral dissertation, Norwegian University of Science and Technology).

Gustavsen, A., Arasteh, D., Jelle, B. P., Curcija, C., & Kohler, C. (2008). Developing low-conductance window frames: Capabilities and limitations of current window heat transfer design tools—State-of-the-art review. Journal of Building Physics, 32(2), 131-153.

Gustavsen, A., Arasteh, D., Kohler, C., & Curcija, D. (2005). Two-dimensional conduction and CFD simulations of heat transfer in horizontal window frame cavities. ASHRAE transactions, 111(1), 587-598.

Gustavsen, A., Grynning, S., Arasteh, D., Jelle, B. P., & Goudey, H. (2011). Key elements of and material performance targets for highly insulating window frames. Energy and Buildings, 43(10), 2583-2594.

Haase, M. and Amato, A. (2006) the 23rd Conference on Passive and Low Energy Architecture. Geneva, Switzerland. Passive and Low Energy Architecture.

Handbook, A. F. (1997). American society of heating, refrigerating and air-conditioning engineers. Atlanta, GA.

Hardy, A. C., & Perrin, F. H. (1932). The principles of optics. The principles of optics, by Hardy, Arthur Cobb; Perrin, Fred Hiram. New York, London, McGraw-Hill book company, inc., 1932. International series in physics, 1.

Hass, G., & Waylonis, J. E. (1961). Optical constants and reflectance and transmittance of evaporated aluminium in the visible and ultraviolet. JOSA, 51(7), 719-722.

Henderson, S., & Roscoe, D. (2010). Solar Home Design Manual for Cool Climates. Routledge.

Ibitoye, F.I. and Adenikinju, A. (2007) 'Future demand for electricity in Nigeria', Applied Energy, 84(5), pp. 492-504.

Ismail, K. A., Salinas, C. T., & Henriquez, J. R. (2008). Comparison between PCM filled glass windows and absorbing gas filled windows. Energy and Buildings, 40(5), 710-719.

Jamaludin, N., Khamidi, M. F., Wahab, S.N.A., Klufallah, M.M.A., (2014*). Indoor Thermal Environment in Tropical Climate Residential Building. E3S Web of Conferences 3*, 01026. DOI: 10. 1051/e3sconf/20140301026. Accessed on 18-05-2016 at www. e3s conferences.org

Jelle, B. P. (2013). *Solar radiation glazing factors for window panes, glass structures and electrochromic windows in buildings—Measurement and calculation. Solar Energy Materials and Solar Cells*, 116, 291-323.

Jelle, B. P., Gustavsen, A., Nilsen, T. N., & Jacobsen, T. (2007). *Solar material protection factor (SMPF) and solar skin protection factor (SSPF) for window panes and other glass structures in buildings. Solar energy materials and solar cells*, 91(4), 342-354.

Johnson, T. E. (1991). Low-e glazing design guide. Boston: Butterworth Architecture.

Inanici, M. N., & Demirbilek, F. N. (2000). *Thermal performance optimization of building aspect ratio and south window size in five cities having different climatic characteristics of Turkey. Building and Environment*, 35(1), 41-52.

Kalamees, T. (2007). Air tightness and air leakages of new lightweight single-family detached houses in Estonia. Building and environment, 42(6), 2369-2377.

Kaplan, M. and Caner, P. (1992) Guidelines for Energy Simulation of Commercial Buildings
Karlsson, J. (2001). Windows: optical performance and energy efficiency.

Karlsson, J., & Roos, A. (2000). Modelling the angular behaviour of the total solar energy transmittance of windows. Solar energy, 69(4), 321-329.

Koenigsberger, Otto H., T G Ingersoll, A. Mayhew, and S.V Szokolay. (1974) *Manual of Tropical Housing and Building: Climatic Design Pt. 1*. Longman.

Lam, J.C., Wan, K.K.W. and Yang, L. (2008) 'Sensitivity analysis and energy conservation measures implications', Energy Conversion and Management, 49(11), pp. 3170-3177.

Lam, J.C., Wan, K.K.W., Yang, L., (2008). Solar radiation modelling using ANNs for different climates in China. Energy Conversion and Management. (49): pp 1080–1090.

Lampert, C. M. (1981). Heat mirror coatings for energy conserving windows. Solar Energy Materials, 6(1), 1-41.

Lauber, W., (2005). Tropical Architecture: Sustainable and humane building in Africa, Latin America and South-East Asia. New York: Prestel Publishing.

Lee, E. S., Selkowitz, S. E., Clear, R. D., DiBartolomeo, D. L., Klems, J. H., Fernandes, L. L.& Yazdanian, M. (2006). Advancement of electrochromic windows. Lawrence Berkeley National Laboratory.

Linera. C & Gonzalez. C (2011). Energy Efficient Windows (Master of Science, thesis in master's program, Gothenburg University).

Markus, T. A. (1994). Domestic energy and affordable warmth. London: published on behalf of the Watt Committee on Energy by Spon.

Meteonorm 6.x (2014) Weather data files. Available at: http://meteonorm.com/home/.
myweather2. (2015, june 26). Retrieved from http://www.myweather2.com/City-Town/Nigeria/Katsina/climate-profile.aspx

Nilsson, A. M., & Roos, A. (2009). Evaluation of optical and thermal properties of coatings for energy efficient windows. Thin Solid Films, 517(10), 3173-3177.

Nwofe, P. (2014). Need for Energy Efficient Buildings in Nigeria. International Journal of Energy and Environmental Research.

Ochoa, C.E. and Capeluto, I.G. (2008) *'Strategic decision-making for intelligent buildings: Comparative impact of passive design strategies and active features in a hot climate', Building and Environment*, 43(11), pp. 1829-1839.

Ogunsote, O.O. (1991) *Introduction to building climatology: A basic course for architecture students. Zaria*: Ahmadu Bello University Press.

Oluigbo. S. N. (2010). *Context and Applications of Case Studies in Architectural Research*, ABU Zaria.

Oluwafemi, J. C., Wan, K. K. W. and Yang, L. (2015) *'Sensitivity analysis and energy conservation measures implications', Energy Conversion and Management*, 49, (11), pp. 3170-3177.

Ossen, D. R., Abdulmajid, R., and Ahmad, M. H. B., (2008). *Tropical Building Design Principles for Comfortable Indoor Environment. Master's thesis. Faculty of Built Environment*, University Technology Malaysia.

Persson, M. L., Roos, A., & Wall, M. (2006). Influence of window size on the energy balance of low energy houses. Energy and Buildings, 38(3), 181-188.

Pfrommer, P., Lomas, K. J., Seale, C., & Kupke, C. (1995). The radiation transfers through coated and tinted glazing. Solar Energy, 54(5), 287-299.

Pino, A., Waldo, B. W., Escobar, R., Pino, F.E., (2012). Thermal and Lighting Behaviour of Office Buildings in Santiago of Chile. Accessed 25/10/2016 from www.elsevier.com/locate/enbuild.

Rathi, P., (2012). *Optimization of Energy Efficient Windows in Office Buildings for Different Climate Zones of the United States. Master's thesis, Kent State University*. U.S.A.

Relander, T. O., Kvande, T., & Thue, J. V. (2010). *The influence of lightweight aggregate concrete element chimneys on the airtightness of wood-frame houses. Energy and Buildings*, 42(5), 684-694.

Robinson, P. D., & G Hutchins, M. (1994). *Advanced glazing technology for low energy buildings in the UK. Renewable energy*, 5(1), 298-309.

Roos, A., & Karlsson, B. (1994). *Optical and thermal characterization of multiple glazed windows with low U-values. Solar Energy*, 52(4), 315-325.

Rubin, M. (1982). *Calculating heat transfer through windows. International Journal of Energy Research*, 6(4), 341-349.

Salmon, C., (1999). *Architectural Design for Tropical Regions*, First Edition, John Wiley & Sons, Inc., New York, pp. 124 - 125.

Sambo, A.S. (2008) *NAEE/IAEE Conference. Istanbul*, Turkey. International Association for Energy Economics.

Sambo, A.S. (2009) 'The challenges of sustainable energy development in Nigeria', Nigerian Society of Engineers Forum. Abuja. Nigerian Society of Engineers.

Selkowitz, S., Lee, E., Arasteh, D., & Willmert, T. (2004). *Window systems for high-performance buildings*. New York: Norton.

Seok-Hyun, K., Sun-Sook, K., Kwang-Woo, K.,Young-Hum, C., (2013). *A Study on the Proposes of Energy Analysis Indicator by the Window Elements of Office Buildings in Korea. Accepted Manuscript. Journal of energy and buildings.* Accessed on 20/05/2016 from DOI: http://dx.doi.org/doi:10.1016 /j.enbuild.2013.12.061.

Smith, G. B., Dligatch, S., Sullivan, R., & Hutchins, M. G. (1998). Thin film angular selective glazing. Solar Energy, 62(3), 229-244.

Song, S. Y., Jo, J. H., Yeo, M. S., Kim, Y. D., & Song, K. D. (2007). Evaluation of inside surface condensation in double glazing window system with insulation spacer: A case study of residential complex. Building and environment, 42(2), 940-950.

Su, X., & Zhang, X. (2010). Environmental performance optimization of window–wall ratio for different window type in hot summer and cold winter zone in China based on life cycle assessment. Energy and buildings, 42(2), 198-202.

Szczyrbowski, J., Dietrich, A., & Hartig, K. (1989). Bendable silver-based low emissivity coating on glass. Solar Energy Materials, 19(1), 43-53

Szokolay, S., (2004). Introduction to Architectural Science: The Basis of Sustainable Design, First Edition, Architectural Press, Oxford, UK.

Szokolay, S., (2004). Introduction to Architectural Science: The Basis of Sustainable Design, First Edition, Architectural Press, Oxford, UK

URL 5: Aluminium spacers with high thermal conductivity (left side); warm edge spacer with low thermal conductivity (right side), 2014 http://www.weatherproof windows.co.uk/glazing.php

URL 6: Solar Radiation of four wavelengths in spectrum, (2014) http://www.jc solarhomes.com/css/understanding-sunlight.html

URL 7: Heat Transfer Mechanism through Glazing, (2014) www.homepower.com

URL1: Sun path in north hemisphere, 2014(http://www.nachi.org/buildingorientation optimum-energy.htm)

URL2: Clear Ordinary Glasses with Highest Solar Transmission, 2014(http://www.commercialwindows.org/shgc.php)

URL3: Solar heat and Visible Transmittance in Low-E Coated Glass, 2014 http://www.replacementwindowsnj.org/a-synopsis-of-low-e-glass-with-argon why-its-so-energy-efficient/)

URL4: Low-E coating function in different surface based on different climate, 2014 (http://myimageglass.com/wp-content/uploads/2011/12/innerglass-low-e illustrati.jpg)

Van Den Bergh, S., Hart, R., Jelle, B. P., & Gustavsen, A. (2013). Window spacers and edge seals in insulating glass units: A state-of-the-art review and future perspectives. Energy and Buildings, 58, 263-280.

Wall, M. (1997). Distribution of solar radiation in glazed spaces and adjacent buildings. A comparison of simulation programs. Energy and Buildings, 26(2), 129-135.

Wegener, E. J. (1997). Large volume coated glass production for architectural markets in North America. Journal of non-crystalline solids, 218, 7-11.

Weir, G., & Muneer, T. (1998). Energy and environmental impact analysis of double-glazed windows. Energy Conversion and Management, 39(3), 243-256.

Wilson, C. F., Simko, T. M., & Collins, R. E. (1998). Heat conduction through the support pillars in vacuum glazing. Solar Energy, 63(6), 393-406.

Wright, J. L. (1998). Calculating center-glass performance indices of windows. 104, 1230-1244.

Zerwick, C., Errett, R. F., & Williams, N. L. (1980). A short history of glass. Corning Museum of Glass.

APPENDICES

Appendices A

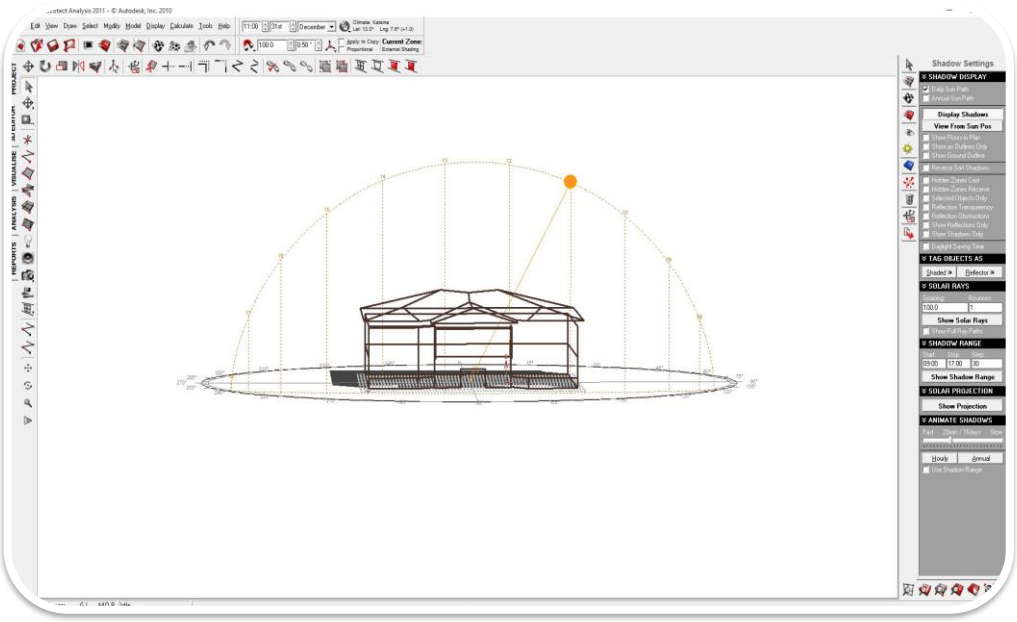
Sample of the checklist of the case study variables,
Building Description Used to Create Base Case Model.

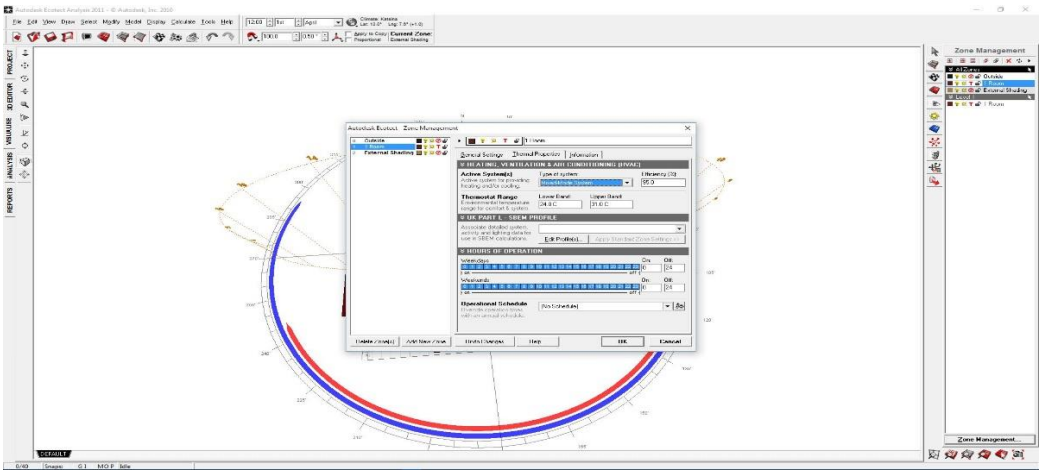
Climate Zone	Hot /dry	Hot /dry	Hot /dry	Hot/dry
Building				
Weekday work hour/yr.				
Gross Floor Area (m^2)				
Wall /window ratio ($^0/_0$)				
All single panel glazing				
Orientation				

Appendices B

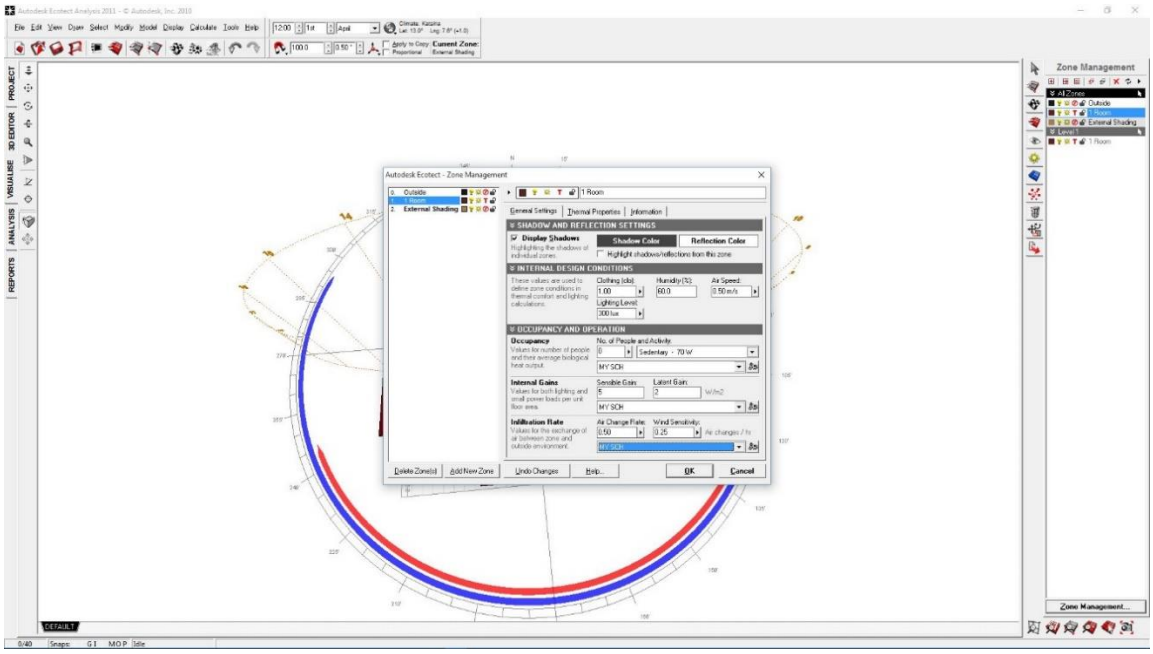
The data fed to Ecotect Analysis to obtain results for the selected case are as follows: The initial data input for Base model is shown below, and second data input, on the next page.

Data input 1 for base model (Ecotect 2011)

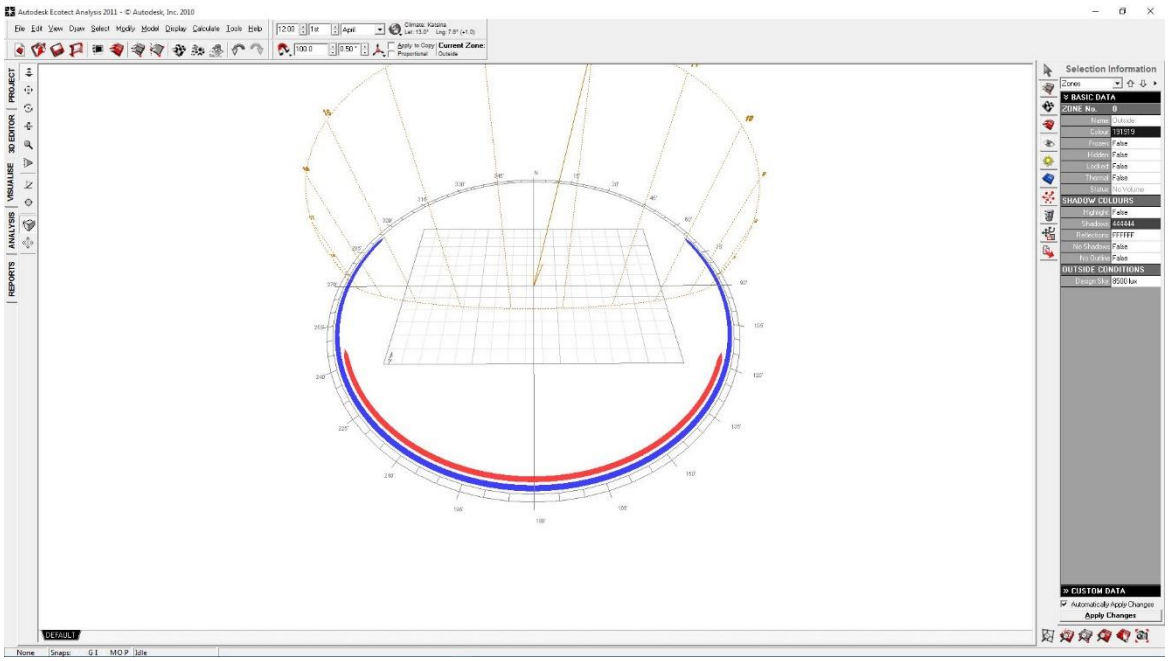




Appendices C



Data input 2 for base model (Ecotect 2011)



(Ecotect 2011) Environment.