OPTIMISING MICROCLIMATE DESIGN STRATEGIES IN HOT DRY CLIMATE TO ENHANCE THERMAL COMFORT FOR A PROPOSED POSTGRADUATE RESIDENCE, FEDERAL UNIVERSITY DUTSE

By

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Declaration

I declare that the work in this Thesis entitled 'OPTIMISING MICROCLIMATE DESIGN STRATEGIES IN HOT DRY CLIMATE TO ENHANCE THERMAL COMFORT FOR A PROPOSED POSTGRADUATE RESIDENCE, FEDERAL UNIVERSITY DUTSE' has been carried out by me in the Department of Architecture. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this Thesis was previously presented for another degree or diploma at this or any other institution.

Kani Fatima Aminu		
P14EVAT8025	Signature	Date

Certification

This Thesis entitled 'OPTIMISING MICROCLIMATE DESIGN STRATEGIES IN HOT DRY CLIMATE TO ENHANCE THERMAL COMFORT FOR A PROPOSED POSTGRADUATE RESIDENCE, FEDERAL UNIVERSITY DUTSE' by Fatima Aminu KANI meets the regulations governing the award of the degree of Master of Science in Architecture of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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Dedication

This research project is dedicated to Allah (S.W.T), my parents, my husband and entire my family.

Abstract

Climatically responsive building design principles are considered to be effective in obtaining comfortable, healthier and sustainable living spaces. Due to rapid urbanization, urban and highly developed areas are often characterised by large number of surfaces that absorb solar radiation giving rise to higher surface and ambient temperatures. In order to mitigate urban heat island in an area, implementing microclimate design strategies can serve as an effective tool. This study aimed at exploring microclimate design strategies as a passive technique in improving thermal comfort in hot dry climates. Mixed methodology research approach was used in carrying out this research which is descriptive and experimental in nature. It was carried out through local case studies and computer simulations to determine the extent to which parameters affecting the microclimate were considered are further carried out using ENVI-met software to conduct a microclimatic analysis by altering dependent variables to observe its effect on thermal comfort. The results show that surface materials and vegetation are virtuous strategies in improving the microclimate of an area. Therefore, using high albedo surface materials and a range of small to large trees incorporated with green areas can improve the ambient temperature within a building of a site by 12-18% in the hot dry climate of Nigeria. This research further concludes through a demonstration of the appraisal in the design of Postgraduate Residence Dutse applying the strategies studied such as cool roofing systems and shading devices that depict the cultural character of the area of Dutse.

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1.0 INTRODUCTION

1.1 Background of Study

Thermal comfort is one of the basic physical and biological needs of humans. A good thermal condition is required to attain a comfortable (without heat stress or thermal strain for the occupants) and healthy environment to sustain occupants' living quality. It is important to keep thermal conditions in buildings within acceptable limits in maintaining maximum human productivity and performance (Jamaludin, Khamidi, Abdul Wahab, & Klufallah, 2014). Thermal comfort is considerably affected by environmental factors such as air temperature, air movement, humidity and radiation. In recent times, occupants tend to make use of air conditioners in achieving a comfortable indoor environment, and as such, due to the reliance on mechanical systems for health and comfort levels has a major increase in the energy consumption buildings (Uno, Hokoi, Ekasiwi, Hanita, & Majid, 2012.). The ideal thermal condition can be defined as the situation in which the least extra effort is required to maintain the human body's thermal balance. The greater the effort that is required, the less comfortable the climate is felt to be. However, it is the aim of the designer to provide an indoor climate close to an optimum, within a certain range in which thermal comfort can be experienced (Gut & Ackerknecht, 1993).

Climate has a major effect on the performance of the building which helps to create a comfortable setting and impact on reducing its energy consumption (Behbood, Taleghani, & Heidari, 2013). As cited in (Behbood, Taleghani, & Heidari, 2013), (Hui, 2000) enlightens that by logically applying design principles that capture natural breezes and the sun's energy, comfortable healthier and sustainable living spaces can be obtained through a climatically responsive sustainable building design. The climate of hot-dry zones in general is characterized by high temperatures (of about 30-45°C during the summer), with sharp variations in both diurnal (day / night) and seasonal (summer-/

winter) temperatures; and precipitation (rainfall) is low, irregular and unreliable. Cold winds and dust/sandstorms prevail in winter (Gut & Ackerknecht, 1993). Researches have shown that man's physical strength and mental activities are at their best within a given range of climatic conditions, outside this range efficiency lessens, while possibility of diseases increases.

A microclimate is the term used to describe the localised climate parameters based on the characteristics of a specific place or region where the climate differs from the encircling area (Hootman, 2012). A simple and effective example of designing for microclimate at the site is to implement strategies that reduce the urban heat island effect. Urban and highly developed areas are often characterised by large number of surfaces that absorb solar radiation, such as asphalt roads, asphalt parking lots and dark coloured roofs. These stores of solar radiation raise air temperatures in urbanised areas and should therefore be considered in the analysis of a site. Incorporating high albedo paving, landscaping, shade trees, green roofs and cool roofs prevents solar radiation absorption and the temperature rise caused by the urban heat island effect. Microclimate design for a site involves a thoughtful and effective integration of architecture, landscape architecture and urban design. It creates opportunities for free energy and can greatly enhance the passive thermal comfort of a site and building (Hootman, 2012). The Earth's major source of heat and light; the sun, also creates the secondary climatic elements of wind and humidity that affect physiological comfort. These are caused by the configuration and nature of the local surface, such as the mountains, plains, oceans, deserts, and forests. Microclimates can be created at a variety of scales and in several configurations, from open sites such as streets and gardens to enclosed courtyards and even against the exterior envelopes of buildings (Fathy, 1986; Hootman, 2012). Also, building orientations and arrangements create a specific microclimate for each site. The building materials, surface textures and

colours of exposed surfaces of the buildings should be taken into consideration (Fathy, 1986).

Education has been defined as a complex of social processes of acquiring knowledge and experience, formally or otherwise. Educational Pathways International, 2010 describes University education as more than the next level in the learning process; it is a crucial component of human development worldwide. An educated populace is vital in today's world, with convergent impacts of globalisation, the increasing importance of knowledge as a main driver of growth and the information and communication revolution. Knowledge accumulation and application have become major factors in economic development and are increasingly at the core of a country's competitive advantage in a global community.

The increasing role of universities in improving the quality of human resources can hardly be overstated due to the focus in strengthening infrastructure in the university and college system by way of campus accommodations (University Grants Commission, 2008). The main aim of providing residences on university campus is to provide quality living and sleeping environments for its occupants (Abiodun, 2014). Sekhar & Goh, (2011) reported that a quality night sleep allows adequate daytime functioning: concentration, attention and comprehension as well as learning level. Bad thermal conditions and lack of quality sleep can result in health symptoms such as fatigue, headaches, stress, tiredness, undesired physiological stress on the body and aggressiveness faced by occupants (Abiodun, 2014).

The Postgraduate Residence (PGR) supports the Federal University, Dutse, all its post graduate students, post-doctoral researchers and visiting lecturers by operating a thoroughly professional, high quality, and responsive organization. The goal of

Postgraduate Residence is to provide a variety of safe and comfortable housing options for the university with a living environment that offers support and assistance that maximise their educational opportunities. The convenience of living on campus provides the occupants with easy access to numerous campus resources and opportunity to interact with the university community outside the classroom by participating in a variety of campus-wide and residence hall programmes (Kent State University, 2015).

1.2 Problem Statement

Generally, in most universities, buildings have been observed to have high energy consumption when it comes to thermal and visual comfort (Kumar, 2014). This is especially true in the hot dry climate where high temperatures, very little rainfall, humidity, vegetation cover and ineffective ventilation systems within buildings make the occupants less comfortable with their environment inhibiting the day time functions of its residents. Furthermore, this uncomfortable thermal condition affects both academic performance and capabilities of residents. As such, buildings are required to be designed with adequate consideration for the climatic and environmental factors, not just for aesthetic purpose.

Due to rapid urbanization, urban and highly developed areas are often characterised by large number of surfaces that absorb solar radiation giving rise to higher surface and ambient temperatures. The term “urban heat island” refers to increased surface temperatures in some parts of a city, caused by an ever changing microclimate. Urban and highly developed areas are often characterised by large number of surfaces that absorb solar radiation, such as asphalt roads, asphalt parking lots and dark coloured roofs.

1.3 Aim and Objectives

The aim of this research is to optimise the microclimate as a passive technique in enhancing thermal comfort in a Post Graduate Residence design in hot dry climate, Federal University Dutse (FUD), Jigawa state.

The aim of this work would be achieved through the following objectives:

1. To explore microclimate design strategies that augment passive thermal comfort.
2. To establish in postgraduate residential buildings within the hot dry climate, the extent to which parameters affecting the microclimate were considered.
3. To analyse using ENVI-met software to carry out a microclimatic analysis by altering dependent variables to observe its effect on thermal comfort.
4. To demonstrate through design, the influence of microclimate design in a Post Graduate Residence.

1.4 Research Questions

The main research questions of this research are:

1. How can passive thermal comfort be improved through microclimate design in a hot dry climate of Nigeria?
2. To what extent have these strategies been applied in the hot dry climate of Nigeria?
3. What is the optimum achievable level suitable of passive thermal comfort in a Post Graduate Residence for hot dry climate?

1.5 Scope of The Study

The scope of this research will be limited to studying methods where the microclimate is being utilised as a passive cooling technique for improving thermal comfort in Post

Graduate Residences. The results at the end of this research will further be used to develop the design of climate responsive buildings for the university housing that will provide an adequate indoor thermal environment for its users.

1.6 Justification

The Federal Government of Nigeria in 2010 took the decision to establish nine additional universities nationwide to address the twin challenges of qualitative access to tertiary education and equitable educational development of states in the Federation. The Federal University, Dutse is one of the nine universities approved for immediate take-off under this initiative.

As part of the take-off process, a physical masterplan has been prepared to give direction to the university to plan its growth from inception to maturity. The space projection on the physical masterplan of FUD identifies key zones for development among which includes the residential zone (Amosun & Associates, 2013).

Currently, there is a rising number of population of postgraduate students with a wide age range. This is due to the challenges of the current times as a first degree is no longer efficient to get a job with a good income that will cater for basic needs of a typical educated and civilized Nigerian. It is now a common trend that young Nigerians are enrolling for their second degrees. For older youths to keep up with this trend and survive well in the labour market, they are also going back to universities for their postgraduate studies.

2.0 LITERATURE REVIEW

2.1 University

Oxford Dictionaries, (2010) defines a university as a high-level educational institution in which students' study for degrees and academic research is done.

The Collins Dictionary, (2016) outlines a university as an institution of higher education having authority to award bachelors' and higher degrees, usually having research facilities it also defines it as the buildings, members, staff, or campus of a university.

2.2 Post Graduate Residence (PGR)

(Merriam-Webster Dictionaries Inc., 2016) defines a residence as the place where one actually lives as distinguished from one's domicile or a place of temporary sojourn. The same source also defines it as the act or fact of living or regularly staying at or in some place for the discharge of a duty or the enjoyment of a benefit.

A Post Graduate Residence is small residential community on campus that serves as an environment that fosters academic, cultural, intellectual, personal, and social development of students in support of one another (University of Michigan, 2016). PGR aims to provide a variety of safe and comfortable housing options for university post graduate students, post-doctoral researchers and visiting lecturers with a living environment that offers support and assistance that maximise their educational opportunities (Kent State University, 2015).

2.2.1 Residence halls

The Free Dictionary, Farlex Inc., (2012) defines a residence hall as a college or university building containing living quarters for students. It is also described as a place where students live at a college or university (Merriam-Webster Dictionaries Inc., 2016)

2.2.2 Visiting/post-doctoral researchers' quarters

This consists of houses used as a temporary residence for lecturers on sabbatical ranging on an average period of one year. A postdoctoral researcher is a person who has received a doctoral degree and who is pursuing additional research, training, or teaching in order to have better skills to pursue a career in academia, research, or any other fields (Cornell University Office of Postdoctoral Studies, 2016).

2.2.3 Transient quarters (Guests)

"Transient lodging" means a room or suite of rooms which is occupied not as a principal residence by persons for periods of less than 30 consecutive days (OregonLaws.org, 2007).

2.3 International Case Studies

2.3.1 The University of Texas at Dallas(UTD) - University Village, United States

University Village apartments include a variety of floor plans and amenities, available to sophomores through seniors and graduate students. Its offers apartments with floor plans that can feature a balcony, washer/dryer, refrigerator/freezer, stove/oven and dishwasher. Amenities include a swimming pool, volleyball court and outdoor grills. Billiards, ping-pong tables and a student centre are located in the clubhouse. Student housing offers affordable on-campus living communities for those who appreciate the ease and convenience of being able to live onsite and quickly walk to classes, campus dining, event venues and athletic facilities. The approach view of the University Village can be seen in Plate I below.



Plate I University of Texas' University Village, Source: (The University of Texas at Dallas, 2017)

2.3.1.1 Summer Guest Housing

Residential Camps & Conference Services offers housing to summer camps, conferences, corporate interns, and non-UTD student summer researchers. Fig 2.1 below shows the University village masterplan.

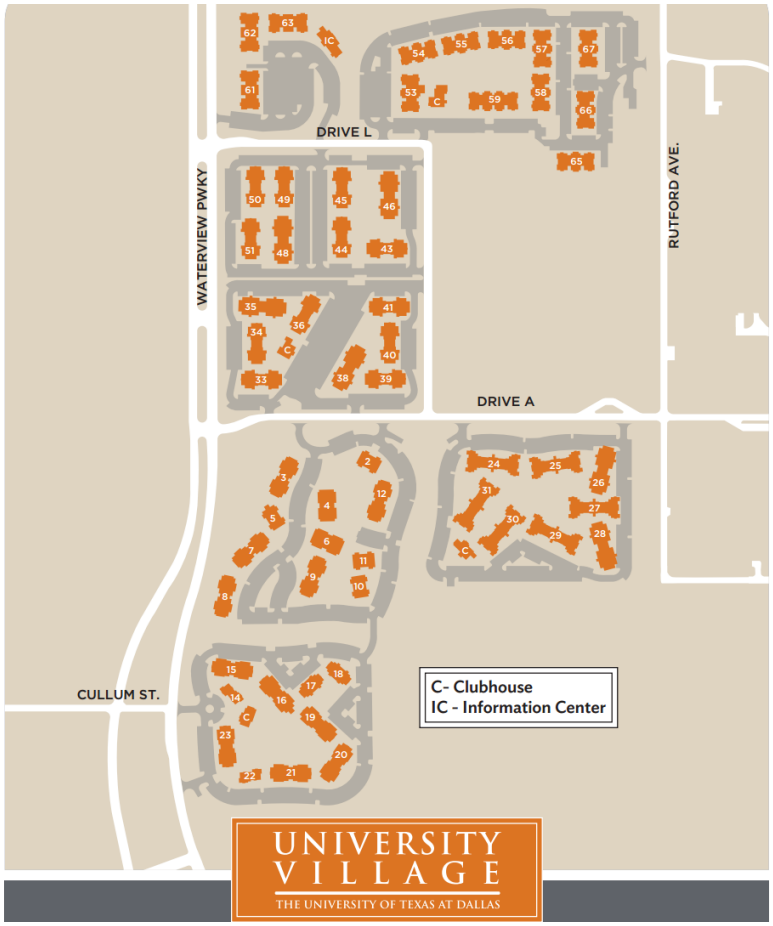


Figure 2.1 University Village Master Plan, Source: (The University of Texas at Dallas, 2017)

2.3.1.2 University Village Features

The university villages feature the following in their residences; refrigerator/freezer with ice maker, dishwasher, electric stove/oven, garbage disposal, cable, internet jacks in each unit, plush carpeting, mini blinds, washer/dryer and microwave (in selected units), central heat/air conditioning and vinyl flooring in the kitchens and bathrooms.

2.3.1.3 Community Amenities

University village provides the following amenities: peer advisors, study centres, meeting rooms and lounges, outdoor grills, swimming pools, sand volleyball court, outdoor basketball and tennis courts, billiards and ping-pong tables, landscaped and maintained grounds, picnic areas, bicycle racks and repair stands, on-site maintenance staff, mailbox stations, 24-hour campus police patrol, 24-hour lockout service, emergency call stations, shuttle service to central campus.

2.3.1.4 Units and Floor Plans

Size information of floor plan is average for typical apartment. Exact dimensions, square footage and layouts vary. Table 2.1 below shows the sizes and prices of the various apartments in the University Village. The Floor plans of this various apartments are shown in Fig. 2.2- Fig. 2.10 respectively.

Table 2.1 shows the sizes and prices of the various apartments in the University Village

Floor Plan[1]	**Bed/Bath**	**Square Feet 1**	**$ Price Per Bed, Per Month [2]**
Efficiency	Efficiency/1	350	720
1x1 A	1/1	440	780
1x1 B	1/1	630	865
1x1 C	1/1	530	875
1x1 D	1/1	650	905
2x2 A	2/2	870	680
2x2 B	2/2	975	760
4x2	4/2	1120	

Source: (The University of Texas at Dallas, 2017)

1. Efficiency apartment: This apartment features a living room, bedroom closet, kitchenette and closet spaces



Figure 2.2 Floor plan of a typical Efficiency apartment, Source: (The University of Texas at Dallas, 2017)

2. One Bedroom, one bath (1x1 A apartment): This apartment features a bigger living room, bedroom, a kitchen and closet spaces than the Efficiency apartment.



Figure 2.3 Floor plan of a typical 1x1 A apartment, Source: (The University of Texas at Dallas, 2017)

3. One Bedroom, one bath (1x1 B apartment): This features two apartment options with bigger living rooms, bedrooms, kitchens and closet spaces than the 1x1 A apartment.



Figure 2.4 Floor plans of two 1x1 B apartment options, Source: (The University of Texas at Dallas, 2017)

4. One Bedroom, one bath (1x1 C apartment): This apartment features a bigger living room, bedroom closet, a kitchen and closet spaces than the 1x1 B apartment.

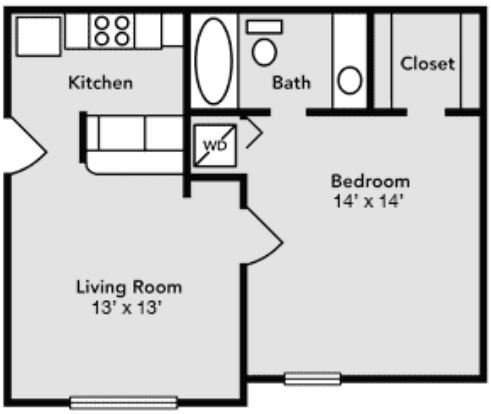


Figure 2.5 Floor plan of a typical 1x1 C apartment, Source: (The University of Texas at Dallas, 2017)

5. One Bedroom, one bath (1x1 D apartment): This apartment features a living room, dining room, bedroom, a kitchen and closet space.

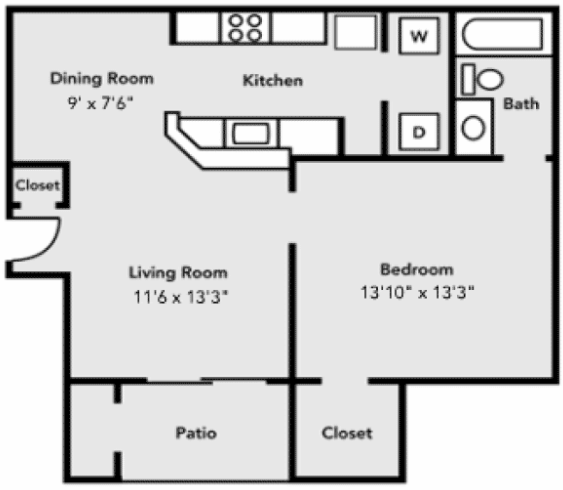


Figure 2.6 Floor plan of a typical 1x1 D apartment, Source: (The University of Texas at Dallas, 2017)

6. Two Bedroom, Two Bath (2x2 A apartment): This apartment type offers two options which feature 2 bedrooms, 2 bathrooms both en suite, living room, dining and kitchen.

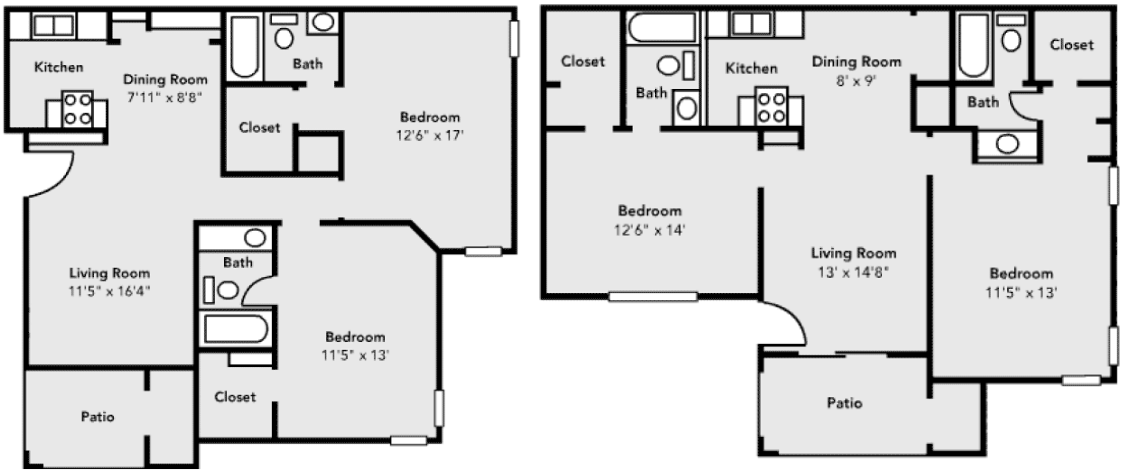


Figure 2.7 Two floor plans of the 2x2 A apartments, Source: (The University of Texas at Dallas, 2017)

7. Two Bedroom, Two Bath (2x2 B apartment): This apartment features two bedrooms, 2 bathrooms both en suite, living room, dining and kitchen larger than 2x2 A apartment.

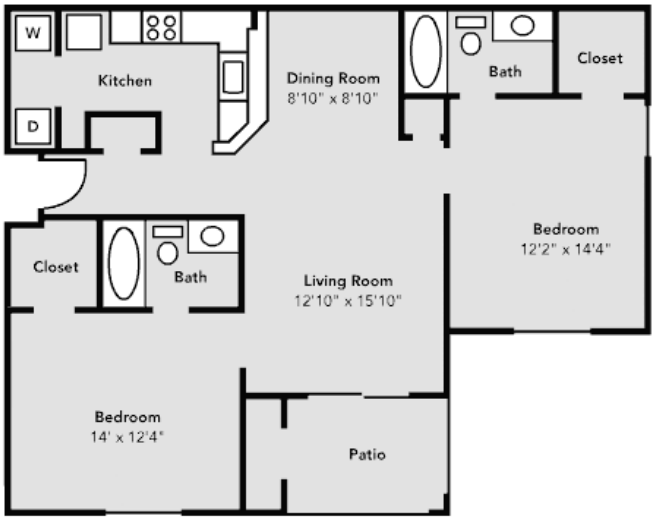


Figure 2.8 Typical 2x2 B apartment, Source: (The University of Texas at Dallas, 2017)

8. Four Bedroom, Two Bath (4x2 apartment): This apartment type offers four different floor plans with features of four bedrooms, two bathrooms, living room or a common area, a kitchen, patio, storage space with no dining and kitchen.



Figure 2.9 Two of the four floor plans of the 4x2 apartment type, Source: (The University of Texas at Dallas, 2017)



Figure 2.10 Other two floor plans of 4x2 apartment type, Source: (The University of Texas at Dallas, 2017)

2.3.2 University of Warwick, United Kingdom

2.3.2.1 Benefactors Hall

Benefactors is a newly renovated and refurbished hall situated at the heart of central campus. The building offers a high level of style for postgraduate students. Ideally situated at the heart of Central Campus, only a couple of minutes' walk away from University facilities including the Students' Union and grocery store and only a 10-minute walk to Gibbet Hill campus. It offers modern, comfortable living in either single en-suite rooms or self-contained duplex studios. There is also a ground floor communal lounge for all residents to enjoy. Plate II shows a view of this hall.



Plate II View of the Benefactors Hall, Source: (University of Warwick, 2016)

This hall features one block, postgraduate students only hall with 23 standard singles rooms and 14 studio duplex rooms for single occupation. The rooms are self-catered, all en suite including toilet, washbasin and shower.

1. Single en suite rooms: Single en suite bedrooms located on the first floor with shared kitchen facilities for single occupancy, three quarter double bed (120cm x 190cm), average bedroom (including en suite) size 4.5m x 3m, 11-12 number of students per kitchen. All rooms include a double wardrobe, desk, desk chair, storage unit, full length mirror, glass blackboard with pen, television, bed linen, duvet and pillows. Each shared kitchen includes cupboards, cooker(s), microwave(s), fridge(s), freezer(s), dishwasher, toaster(s), kettle(s).
2. Duplex studios: These are duplex (split level) en suite studio flats for single occupancy. A duplex studio is spread across 2 floors and include narrow steep open stairs (11 steps approx 55cm wide), the bedroom and bathroom are located on the lower level of the duplex studio. The kitchen, dining and living/study area including a dining table and 2 chairs are located on the next level accessed by the stairs within the duplex studio. Features double bed (135cm x 190cm), average size of both levels (including en suite) size 2.9m x 6.2m. All studios include a triple wardrobe, chest of 3 drawers, desk, desk chair, easy chair, full length mirror, television, blackboard with pen, bed linen, duvet and pillows. Kitchen includes cupboards, hob, oven, microwave, fridge freezer, toaster, kettle.

Other facilities in the benefactors hall include residential staff, launderette located on first floor, wi-Fi in hall, communal lounge and network port in all bedrooms. Campus accommodation fees include heating, electricity, gas, water, insurance, TV licence and internet connection

2.3.2.2 Claycroft Hall

Eight students live together in flats within three block of Claycroft. The hall is set within pleasant surroundings of ponds and wooded areas. It is only a 5-minute walk to the centrally located campus facilities and to the Cannon Park shopping centre as well as the centrally located campus facilities such as the library and the sports centre. The hall has three blocks with a total of 679 self-catered single rooms. One block is assigned to the postgraduate students. Plate III below shows a view of this hall.



Plate III View of the Claycroft Hall, Source: (University of Warwick, 2016)

Bedroom and bathrooms: Shared bathroom between two students includes toilet, washbasin and bath with overhead shower, two students of the same gender share a bathroom. Some rooms include level access bathrooms with network port in all bedrooms. All bedrooms include wardrobe, desk, chair, bookshelf, wastepaper bin, bed linen, duvet and pillow. Standard single bed (UK single, 190cm x 91cm) and average bedroom size 4.0m x 2.5m.

Kitchen: Number of students per kitchen 8, each kitchen includes cupboards, cooker(s), microwave(s), fridge(s), freezer(s), toaster(s), kettle(s) and an ironing board

Other facilities: Other facilities include residential Staff, launderette, Wi-Fi in hall, communal telephone. Campus accommodation fees include heating, electricity, gas, water, insurance and internet connection.

2.3.2.3 Heronbank

Heronbank is only a short 10-minute walk to some of the campus facilities such as the library and learning grid. The hall features three blocks with 701 single rooms and en suite bathroom facilities. Plate IV shows the view of the Heronbank Hall.



Plate IV View of the Heronbank Hall, Source: (University of Warwick, 2016)

2.3.2.4 Lakeside

Lakeside is divided into flats of eight and only takes a short 10-minute walk to some of the campus facilities such as the library and learning grid. Lakeside as its name suggests sits beside a tranquil lake. The hall is divided into flats of eight and each block is built around an attractive courtyard. It will only take a short 10-minute walk to some of the campus facilities such as the library and learning grid. Plate V show a view of the Lakeside Hall below.



Plate V View of the Lakeside Hall, Source: (University of Warwick, 2016)

Hall features: First year undergraduates (one block), final year undergraduates (one block) and postgraduates (two blocks), four blocks, 596 en suite single rooms all self-catered

Bedrooms and bathrooms: En suite bathroom including toilet, washbasin and bath with overhead shower. Some rooms include level access bathrooms with network port in all bedrooms. All bedrooms include wardrobe, desk, chair, bookshelf, wastepaper bin, bed linen, duvet and pillow with a standard single bed (UK single, 190cm x 91cm) and average bedroom (including bathroom) size 4.3m x 3.8m.

Kitchens: 8 number of students per kitchen, each kitchen includes cupboards, cooker(s), microwave(s), fridge(s), freezer(s), toaster(s), kettle(s) and an ironing board.

Other facilities: include residential staff, launderette, Wi-Fi in hall, communal telephone, quiet room available for study (located in block 1). Campus accommodation fees include heating, electricity, gas, water, insurance and internet connection.

2.3.2.5 Tocil Hall

Tocil is situated next to the campus sports centre and is only a short walk to Cannon Park Shopping Centre, the library and the Warwick Arts Centre. Tocil is situated next to the campus sports centre with gym, climbing wall and indoor sports halls among the facilities. It is only a short walk to Cannon Park Shopping Centre, the library and the Warwick Arts Centre so this hall is ideally located. Tocil offers individual flats for 6 to 12 persons, self-contained spaces, each with their own front door. Plate VI shows a view of the Tocil Hall below.



Plate VI Approach view of Tocil Hall, Source: (University of Warwick, 2016)

Hall features: First year undergraduates (approx. 3 blocks), final year undergraduates (approx. 5 blocks) and postgraduates (approx. 2 blocks). There are ten blocks, 574 single rooms all self-catered.

Bedrooms and bathrooms: Shared bathrooms including toilets, washbasins, showers and bath. Approximately four students per bathroom with network port in all bedrooms. All bedrooms include wardrobe, desk, chair, bookshelf, wastepaper bin, bed linen, duvet and pillow, a standard single bed (UK single, 190cm x 91cm) and average bedroom (including bathroom) size 3.4m x 2.5m.

Kitchens: Number of 6-12 students per kitchen, each kitchen includes cupboards, cooker(s), microwave(s), fridge(s), freezer(s), toaster(s), kettle(s) and an ironing board.

Other facilities: include residential Staff, launderette, Wi-Fi in hall, communal telephone. Campus accommodation fees include heating, electricity, gas, water, insurance and internet connection.

2.3.2.6 Westwood Hall

Westwood has spacious rooms within corridor style living is located next to the Westwood sports facilities and only a 10-minute walk to the Learning Grid. Westwood has spacious rooms and is divided into eight blocks of corridor style accommodation

which offers both kitchen dining areas and common rooms so you will have plenty of opportunities to socialise as well as study. The hall is a 10 minute walk to the Learning Grid and only a couple of minutes away from the University running track, astro pitches and Tennis Centre. Plate VII shows a view of the Westwood Hall below.



Plate VII View of the Westwood Hall, Source: (University of Warwick, 2016)

Hall features: Postgraduates and first year undergraduate hall, eight blocks, one block for postgraduates all self-catered.

Bedrooms and bathrooms: Shared bathrooms including toilets, washbasins and showers, six students per bathroom, washbasin in bedroom with network port in all bedrooms. All bedrooms include wardrobe, desk, chair, bookshelf, wastepaper bin, bed linen, duvet and pillows. Standard single bed (UK single, 190cm x 91cm) and average bedroom size 4.2m x 3.2m

Kitchens: Number of students per kitchen 12-17, each kitchen includes cupboards, cooker(s), microwave(s), fridge(s), freezer(s), toaster(s), kettle(s) and an ironing board.

Other facilities: include residential staff, launderette, Wi-Fi in hall, communal telephone. Campus accommodation fees include heating, electricity, gas, water and internet connection.

2.3.3 University of Wisconsin-Madison – University Apartments, United States

The University Apartments community is known for its diversity with dozens of nationalities and languages spoken throughout the neighbourhoods. It serves UW-Madison graduate students, students with families, postdoctoral researchers, academic staff, and faculty. It comprises of the three neighbourhoods, some residents are here short-term, and some stay with us for many years.

Eagle Heights and University Houses are situated just a half-mile northwest of UW-Madison's western campus and is a community of apartment buildings nestled in 83 acres of green space on the shoreline of Lake Mendota. These neighbourhoods primarily serve families, and boasts numerous picnic and playground areas, a central community centre and one of the oldest community gardens in the United States. Harvey Street Apartments serves single graduate students and is located south of University Avenue, just west of campus. This quiet street is close to shops, restaurants, and the UW campus.

Students can apply to one or more of these neighbourhoods, depending on your eligibility for each area. Priority is given to families in the University Houses and Eagle Heights neighbourhoods. Table 2.2 below shows the three neighbourhood, building style apartment types and their rates.

Table 2.2 shows the three neighbourhood, building style apartment types and their rates.

Neighbourhood	University Houses	Eagle Heights	Harvey Street
Building Style	Town Houses	Apartment	Apartment
1 Bedroom	Yes	Yes	Yes
2 Bedroom	Yes	Yes	Yes
3 Bedroom	Yes	Yes	No
Number of Apartments	144	1,044	47
Rates	$986-1236	$775-1157	$700-900
Nearby services/attractions	Community Centre Lake Mendota Biking/running trails UW Hospital	Community Centre Lake Mendota Biking/running trails UW Hospital	Hillsdale Mall Quarry Park University Avenue
Bus lines	Route 80	Route 80	There are several on University Avenue that pick-up by Bagels Forever

Source: (University of Wisconsin—Madison, 2016)

2.3.3.1 Types of Apartments

University Apartment has different options of apartments in our neighbourhoods at different rates. Table 2.3 below shows the apartment types in each neighbourhood and students eligible for them.

Table 2.3 shows the University Apartment neighbourhoods, apartments and students eligible.

Apartment Type	Eagle Heights	Harvey Street	University Houses
1 Bedroom/ 1 Bathroom	Couples without children Families of 3 or less Singles without a roommate	Singles without a roommate	Couples without children Families of 3 or less Singles without a roommate
2 Bedroom/ 1 Bathroom	Families with children Couples without children Families of 5 or less Singles with or without a roommate	Singles with or without a roommate	Families with children Couples without children Families of 6 or less Singles with or without a roommate
3 Bedroom/ 1 Bathroom Townhouse and 2 Flats	Families with two or more children Families of 7 or less	N/A	Families with two or more children Families of 8 or less
Large 3 Bedroom/ 1 or 1 1/2 Bathroom(s) Apartments and Townhouses	Families with two or more children Families of 8 or less	N/A	N/A

Source: (University of Wisconsin—Madison, 2016)

Eagle Heights neighbourhood: This consists of 1,044 unfurnished apartments, 284 one-bedrooms, 716 two-bedrooms and 44 three-bedrooms. It is situated on the northwest edge of UW-Madison's campus, it is a community of apartment buildings surrounded by woods and just minutes from Lake Mendota. It boasts numerous picnic and playground areas, a central community centre and one of the oldest community gardens in the United States.

Eagle Heights serves students with families, graduate students, postdoctoral researchers, academic staff, and UW-Madison faculty. All apartments include a standard-sized refrigerator, combination stove/oven, garbage disposal, and energy-efficient windows with window coverings (pull-down shades). Plate VII shows a view of the Eagle Heights Neighboorhood.



Plate VIII View of the apartment buildings in eagle heights neighbourhood, Source: (University of Wisconsin—Madison, 2016)

Apartment types available in Eagle heights include one bedroom with one bath apartment, two bedrooms with one bath apartment, three bedrooms with one bath, three bedrooms with one and half bathroom.

Harvey Street neighbourhood: This consists of 47 furnished apartments, 23 one-bedrooms and 24 two-bedrooms. It is located a half mile west of UW-Madison's west campus, the Harvey Street apartment buildings are located just south of University Avenue, a main

thoroughfare for the city of Madison, Wisconsin. It is close to shops, restaurants and a beautiful 16-acre wooded area just across the street. The community offers space for small gatherings and grills for cooking outdoors, as well as easy access to Madison Metro buses through the Associated Students of Madison's (ASM) free campus bus pass program. Harvey Street serves single UW-Madison graduate students with furnished apartments.

All apartments include a standard-sized refrigerator, combination stove/oven, garbage disposal, kitchen table with two chairs, couch, lounge chair, two small bookcases, end table, two lamps, long twin bed (one per bedroom), end table with drawers, desk and chair per bedroom, closet space, and small bedroom bookcase. In-Unit Laundry No. All units have access to on-site laundry facilities. Personally owned washers and dryers are not permitted in units.

Apartment types available in Harvey Street neighbourhood include one bedroom one bath apartment and two bedrooms one bath.

University Houses neighbourhood: this neighbourhood consists of 144 unfurnished apartments, 43 one-bedrooms, 87 two-bedrooms and 10 three-bedrooms. The University Houses community is nestled between the woods of the Lakeshore Nature Preserve to the west and east, Eagle Heights to the north, and the village of Shorewood Hills to the south. Like Eagle Heights, the 20-acre apartment community offers easy bike or bus access to UW-Madison's campus, numerous picnic and playground areas, a central community centre in Eagle Heights, and one of the oldest community gardens in the United States.



Plate IX View of the University Houses neighbourhood, Source: (University of Wisconsin—Madison, 2016)

University Houses serves students with families, graduate students, postdoctoral researchers, academic staff, and UW-Madison faculty. All apartments include a standard-sized refrigerator, combination stove/oven, and energy-efficient windows with window coverings (pull-down shades). Plate IX above shows a few of the University House neighbourhood.

Apartment types include one bedroom with one bath apartment, two bedrooms two bath apartment and three bedrooms one bath apartments.

2.4 Microclimate

Climate is the average of the atmospheric conditions over an extended time over a large region. Small-scale patterns of climate, resulting from the influence of topography, soil structure, ground and urban forms, are known as microclimates (Geetha & Velraj, 2012). Generally, the climate in cities is characterized by ambient temperatures, reduced relative humidity, reduced wind speed and precipitation. Sharma, 2016 futher explains that the conditions for transfer of energy through the building fabric and for determining the thermal response of people are local and site-specific. These conditions are generally grouped under the term of "microclimate". As explained by Sharma, 2016 in his study, a microclimate of a site is affected by the following factors: landform, vegetation, water bodies, street width and orientation, open spaces and built form. A good understanding

of these factors helps in the preparation of the site layout plan. For example, in a hot and dry climate, the building needs to be located close to a water body. The waterbody helps in increasing the humidity and lowering the temperature by evaporative cooling((Sharma, 2016).

Giridharan conducted extensive field measurements in order to identify the key urban design variables that influence the urban climate conditions in Hong Kong (Giridharan, Lau, Ganesan, & Givoni, 2007). Their research relates that variables such as sky view factor, surface albedo, altitude, vegetation and the average height-to-floor area ratio are crucial for mitigating the urban climate.

Ragheb, El-Darwish, & Ahmed, (2016) and Tumini, García, & Rada, (2016) in their study focused on the use of vegetation as a form of improving microclimatic control in public spaces. Urban green structures can cool hot air by combining shade and evapotranspiration effects, which result in a reduction in the radiant temperature and greater control over wind velocity and direction (Picot, 2004).

The climate of cities differs from the climate of the surrounding rural areas, due mainly to the structure of cities and the heat released by vehicles. This is as a result of rapid urbanization and industrialization. The term "urban heat island" refers to increased surface temperatures in some parts of a city, caused by an ever changing microclimate (Sharma, 2016). Microclimates can be created at a variety of scales and in several configurations, from open sites such as streets, parks and gardens to enclosed courtyards and even against the exterior envelopes of buildings (Fathy, 1986; Hootman, 2012). Also, building orientations and arrangements create a specific microclimate for each site. The building materials, surface textures and colours of exposed surfaces of the buildings should be taken into consideration (Fathy, 1986).

2.4.1 Vegetation and soft landscaping

Vegetation modifies the microclimate and the energy use of buildings by lowering the air and surface temperatures and increasing the relative humidity of the air. Furthermore, plants can control air pollution, filter the dust and reduce the level of nuisance from noise sources. Vegetation also creates different air flow patterns by causing minor pressure differences and can be used to direct or divert the prevailing wind condition (Sharma, 2016). Landscaping combines elements of art and science to create a functional and aesthetically pleasing extension of indoor living to the outdoors. A purpose of landscape design is to blend man's technology (house or building) into the natural surroundings. Landscape plants can be used as air conditioners, heat modifiers to alter the environment for maximum human comfort. Vegetation plays an important role in changing the climate of a place. It is also effective in controlling the microclimate as seen in Fig. 2.11.

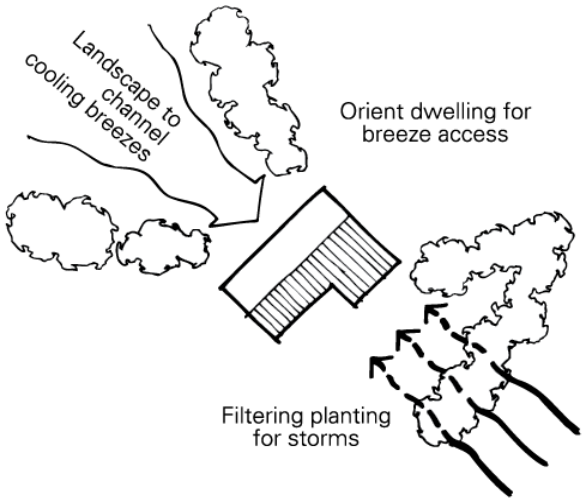


Figure 2.11 Landscape for channelling cool breezes and filtering storms, Source: *(Reardon & Clarke, 2013)*

Soft landscaping elements refer to vegetation, these include: Trees and shrubs, lawns, Pools and ponds, mulches, trellis and climbers.

2.4.1.1 Trees and shrubs

Trees and shrubs are the most significant in the provision of shade, the control of relative humidity and air movement. They contribute more to the attainment of thermal comfort than any other element. Ventilation is affected by plant materials. The air crossing through hard, reflective or absorptive surfaces like parking lots and sidewalks is usually warm while air passing through trees and plants is usually cool (Ogunsote & Prucnal-Ogusote, 2002). Shrubs and trees cool the environment when they absorb radiation for photosynthesis. They are useful in shading a particular part of the structure and ground for reducing the heat gain and reflected radiation. By releasing moisture, they help raise the humidity level. Based on the requirement of a climate, an appropriate type of tree can be selected. Planting deciduous trees to shade east and west walls would prove beneficial in hot and dry zones. In summer, they provide shade from intense morning and evening sun, reduce glare, as well as cut off hot breezes. On the other hand, deciduous trees shed their leaves in winter and allow solar radiation to heat the building. The cooling effect of vegetation in hot and dry climates comes predominantly from evaporation. Trees can be used as windbreaks to protect both buildings and outer areas such as lawns and patios from both hot and cold winds. The velocity reduction behind the windbreak depends on their height, density, cross-sectional shape, width, and length with the first two being the most important factors (Sharma, 2016). To avoid the western and eastern solar radiation in 'hot and dry' climatic zones during the hot season, long oval shaped trees as shown in Fig. 2.12 having the spread half of the height and foliage in oval shape are useful because the lower sun rays cast long shadow on the pedestrians' path and wall surface. The shaded walls areas generally admit only diffuse solar radiation and in turn the sol-air temperature on exposed wall surface with respect to the external heat transfer coefficient of the material can decrease the indoor air temperature by 3ºC to 4ºC (Ramesh , 2016).

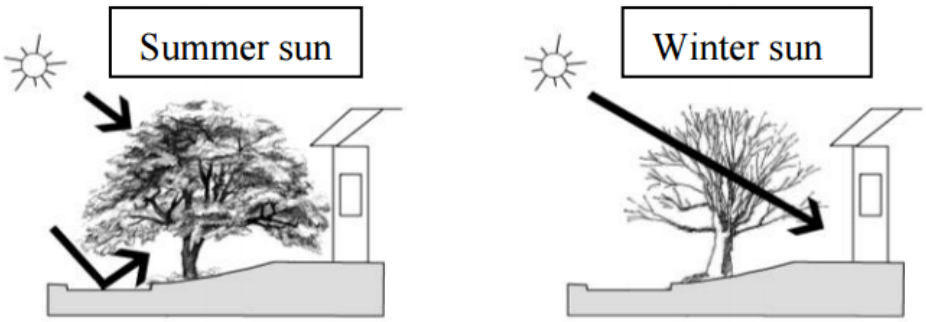


Figure 2.12 Deciduous trees shading the south façade, Source: *(Ramesh , 2016)*

2.4.1.2 Lawns

Lawns and flowerbeds are used to reduce ground temperature and to prevent glare. Lawns also cool the environment when they absorb radiation for photosynthesis. The ground covering such as grass is an important surface element as it reduces the incidence of heat and the glare as illustrated in Fig. 2.13. Grass preserves moisture in root system and reduces heat transfer (Ramesh , 2016). Vegetation generally improves air freshness and fragrance.

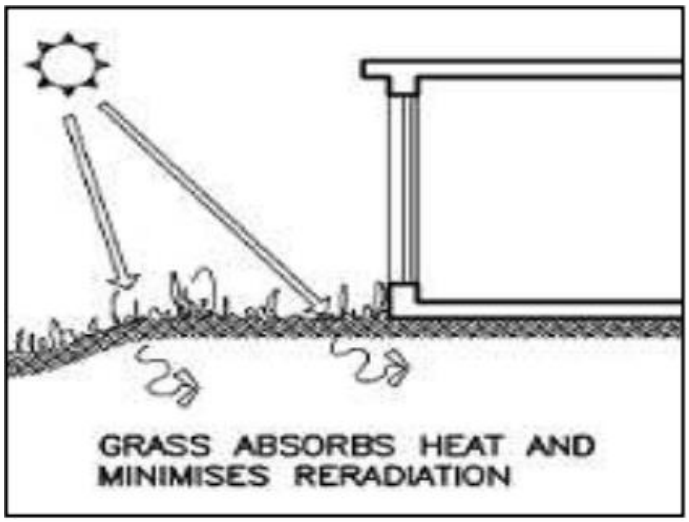


Figure 2.13 Lawns helping to improve thermal comfort, Source:
http://www.mirarestudio.com

2.4.1.3 Mulches

Mulch is a protective covering over the roots of trees and bushes to retain moisture and kill weeds. Mulches include straw, fallen leaves or plastic sheeting. Others are gravel,

wood chipping, rotting leaves and grass as seen in Plate X below. Mulches can be used to reduce surface and air temperatures by reducing the heat absorbed by the ground (Ogunsote & Prucnal-Ogusote, 2002).



Plate X Mulches covering the roots of a tree, Source: www.totallandscapecare.com

2.4.1.4 Trellis and climbers

A trellis is a light framework of crossing strips of wood, plastic, et cetera used to support climbing plants and it is often fastened to a wall. This can be used to provide shade on western walls (Ogunsote & Prucnal-Ogusote, 2002). This is illustrated in Plate IX below.



Plate XI A climbing plant growing on a trellis, Source:www.themicrogardener.com

2.4.2 Hard landscaping elements

Hard landscaping elements are all other elements used for landscaping apart from vegetation which include: Steps and paving, walls and fences, slopes and barriers, stones and boulders.

2.4.2.1 Steps and paving

The choice of the surface finishing, material and construction of steps and paving can play a significant role in the reduction of ground temperature. The use of asphalt in parking lots without any form of shade is a primary source of discomfort. Plate XII illustrates steps and paving.



Plate XII Steps and Paving, Source: http://www.allisonpaving.co.uk/patios/patio-steps/

2.4.2.2 Walls and fences

Walls are used to deflect the wind, and they can be used to channel the wind. Walls are usually solid, while fences are made from stakes, rails, wire, netting, et cetera. Fences thus allow some wind to flow through them, even when they have climbers. Plate XIII below shows a fence.



Plate XIII Walls and Fences, Source: www.pinterest.com

2.4.2.3 Slopes and barriers

The use of slopes and barriers as seen in Plate XIV below to direct airflow can be very effective on sites with significant variations in the topography.



Plate XIV Slopes and Barrier, Source: www.lowes.com

2.4.2.4 Stones and boulders

Stones and boulders can be arranged to direct airflow and to provide shade. This is illustrated in Plate XV below.



Plate XV Stones and boulders,

Source: https://www.pinterest.com/pin/474848354431078389/

2.4.3 Water Surfaces

These water bodies are used for humidification and evaporative cooling. Water bodies can be in the form of sea, lake, river, pond or fountains (Ogunsote & Prucnal-Ogusote, 2002). Since water has a relatively high latent heat of vaporisation, it absorbs a large amount of heat from the surrounding air for evaporation. The cooled air can then be introduced in the building. Evaporation of water also raises the humidity level. This is particularly useful in hot and dry climates. Large water bodies tend to reduce the difference between day and night temperatures because they act as heat sinks (Sharma, 2016).

Water surfaces modify the microclimate of the surrounding area, reducing the ambient air temperature, either by evaporation, or by the contact of the hot air with the cooler water surface. Fountains, ponds, streams, waterfalls or mist sprays may be used as cooling sources, for lowering the temperature of the outdoor air and of the air entering the building. The asphalt and concrete used in urban environments is typically too dense to allow water permeability, and therefore, drastically limits the latent heat exchange. The water and air passage allows latent heat exchange, and therefore decreases the

temperature of the pavement. This, in turn, assists trees and other landscape root systems to better access air and nutrients, providing cooler root zones which result in larger and denser shading landscape materials (Geetha & Velraj, 2012). Plate XVI below shows a typical pond for landscaping.



Plate XVI A typical pond for landscaping, Source: www.landscapingnetwork.com

2.5 Thermal Comfort

Thermal comfort is that condition of mind that expresses satisfaction with the thermal environment (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2010). Agboola (2011) in his paper describes comfort as the maintenance of thermal balance between human body and the environment. Ogunsote (1993) explains that knowledge of nature of comfort is essential in design with climate with the aim of maintaining comfort within buildings. Thermal comfort is basically affected by: air temperature, air velocity, mean radiant temperature, relative humidity, clothing and metabolic rate. It has been determined that other contributing parameters include climate change with time as well as occupants' perception. Due to biological variance beyond occupants and psychological phenomena, neither perfect conditions nor well defined comfort boundary settings exist, but rather a comfort zones with a band of operative temperatures that satisfy higher percentage of occupants (Nicol & Humphreys, 2007).

Jamaludin, Khamidi, Abdul Wahab, & Klufallah, (2014) states the human body temperature needs to be maintained at a constant 37°C (±5) regardless of the prevailing ambient condition. It is important to keep thermal conditions in buildings within acceptable limits in maintaining maximum human productivity and performance.

The ideal standard for TC can be defined in terms of a range of operative temperatures that provides acceptable comfort thermal environmental conditions or in terms of the combinations of air temperature and mean radiant temperature that provide acceptable comfort people find thermally acceptable (ANSI/ASHRAE Standard 55, 2010).

Humidity can increase wetness on different areas of the body, leading to a perception of discomfort. The metabolism rate fluctuates when a person performs certain activity, or under certain environmental conditions. The other personal variable that affects thermal satisfaction is the type and amount of clothing that a person is wearing. ASHRAE Standard 55 (2004) gives the conditions for an acceptable thermal environment.

2.6 Thermal Comfort Parameters and Comfort Limits

The six primary factors affecting thermal comfort are both environmental and personal. These factors may be independent of each other, but together contribute to an occupant's thermal comfort (Health and Safety Executive, 2004). The six primary factors must be addressed when defining conditions for thermal comfort. A number of other, secondary factors affect comfort in some circumstances (ANSI/ASHRAE Standard 55, 2010).

The six primary factors are: Metabolic rate, Clothing insulation, Air temperature, Radiant temperature, Air speed and Humidity. The major factors that determine thermal comfort combine to create the sensation of comfort. Discomfort occurs not when one or more factors are outside the comfort limits, but when the combination of all the factors causes a shift outside the comfort limits. When all the other factors are within the comfort limits

however, a shift outside the comfort limits of one factor will result in discomfort. The comfort limits for each of the four environmental factors that determine comfort are discussed below, with the assumption in each case that all the other factors are within comfort limits.

2.6.1 Environmental Factors:

i. Air temperature

ii. Radiant temperature

iii. Air velocity

iv. Humidity

2.6.1.1 Air temperature

Health and Safety Executive, (2004) defines it as the temperature of the air surrounding the body. It is usually given in degrees Celsius (°C). Comfort can approximately be achieved between 16^0C and 28^0C. The highest air temperature is normally in April (Agboola, 2011).

2.6.1.2 Radiant temperature

Mean Radiant temperature is defined as the temperature of a uniform, black enclosure that exchanges the same amount of thermal radiation with the occupant as the actual enclosure (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2003). Thermal radiation is the heat that radiates from a warm object. Radiant heat may be present if there are heat sources in an environment. Radiant temperature has a greater influence than air temperature on how an occupant loses or gains heat to the environment (HSE, 2004). Comfort can be achieved if the globe temperature is between 16^0C and 28^0C and if the differences between the mean radiant temperature and the dry bulb temperature are less than 5^0C (Ogunsote & Prucnal-Ogusote, 2002).

2.6.1.3 Air velocity

Air speed is the average speed of the air to which the body is exposed (ASHRAE, 2003). Air velocity of up to 0.1 meter per second may lead to a feeling of stuffiness indoors. Air velocities of up to 0.1 to 1.0m/s are comfortable indoors when air movement is required but above this level there is discomfort. Outdoor wind speeds of up to 2.0m/s lead to considerable discomfort (Ogunsote & Prucnal-Ogusote, 2002).

2.6.1.4 Humidity

Humidity is the percentage of water vapour in the air (Autodesk Inc., 2013). Relative humidity can also be defined as the ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature (HSE, 2004). In the North during January to April mean values are close to 20% or 25%. Thermal comfort can be achieved when the relative humidity is between 20% and 90% (Ogunsote & Prucnal-Ogusote, 2002).

2.6.2 Personal Factors:

i. Clothing insulation (clo)

ii. Metabolic heat

2.6.2.1 Clothing insulation (clo)

The amount of thermal insulation the person is wearing (Autodesk Inc., 2013). ANSI/ASHRAE Standard 55, (2010) defines it as the resistance to sensible heat transfer provided by a clothing ensemble, expressed in clo units (I_{cl}). Note: The definition of clothing insulation relates to heat transfer from the whole body and, thus, also includes the uncovered parts of the body, such as head and hands (ANSI/ASHRAE Standard 55, 2010). The range of intrinsic clothing for thermal comfort is taken to be from 0.5 to 1.0 clo (Agboola, 2011).

2.6.2.2 Metabolic heat

This is the rate of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism, usually expressed in terms of unit area of the total body surface, it is expressed in met units (ANSI/ASHRAE Standard 55, 2010). The higher the activity, the more heat is produced by the metabolic rate. Comfort can be maintained with metabolic rates from about 0.7 to 2.5 met (Agboola, 2011).

2.7 Hot Dry Climate

Agboola, (2011) in his paper described this climate to be characterized by a long dry season associated with cold and dry harmattan wind, high temperature ranges and intense sunlight. The research stated that the main common characteristics of hot dry regions affecting human comfort as well as building design is the combination of low humidity and high summer daytime temperature.

The climate of Jigawa state is semi-arid, characterised by a long dry season and a short wet season. The climatic variables vary considerably over the year and are erratic. The mean annual temperature is about 25^0C but the mean monthly values ranges between 21^0C in the coolest month and 31^0C in the hottest month. However, the mean daily temperature could be as low as 20^0C during the months of December and January when the cold dry harmattan wind blows from the Sahara Desert. Evapotranspiration is very high and relative humidity is the highest in August (up to 80%) and low in January through March (at about 23-30%) when it is moderated by the harmattan. The year is characterised by well-marked dry and wet seasons. Wet season is roughly four months (June to September) and dry season is seven to eight months (October to May). The total annual rainfall ranges from 600mm in the north to 1000mm in the southern parts of the state. Great variations occur in the in annual total rainfall and may result in severe and

prolonged droughts, which cause crop failures, death of livestock and overall human sorrow (Jigawa State, 2003).

2.8 Design Considerations for Hot Dry Climate

The main goal of climatic design, on a macro (settlement) and micro (building) level, is hence to reduce uncomfortable conditions created by extremes of heat and dryness. Buildings must be adapted to their climatic changes to achieve a well-balanced indoor climate (Gut & Ackerknecht, 1993).

2.8.1 Building design

i. Building Orientation
ii. Shape and volume
iii. Type and form
iv. Room arrangements
v. Courtyard

2.8.1.1 Building orientation

Orientation of building in this climatic zone should be such that non-habitat rooms can be located on outer faces to act as thermal barrier. Longer walls of building should face North & South so that the building gets minimum solar exposure. The building should be properly oriented to take advantage of solar radiation and prevailing wind. The longer axis of the building should lie along east-west direction for minimum solar heat gain by the building envelope. The cooling load for a residential building can be reduced to 8% - 11% by following this orientation (Akande, 2010;Wong & Li, 2007;Gut & Ackerknecht, 1993).

2.8.1.2 Shape and volume

The shape and volume of buildings should be compact, yet somewhat elongated along the east-west axis because large, compact building volumes gain less heat. In general, the optimum shape is that which has a minimum heat gain in the hot season and the maximum heat gain in the cold season. A compact "patio" house type is preferable. Adjoining houses, row houses, and group arrangements (all continuous along the east-west axis), which tend to create a volumetric effect, are advantageous, as well as high massive buildings (Gut & Ackerknecht, 1993).

2.8.1.3 Type and form

Dense settlement patterns require a particular type of building consisting of compact structures and forms. In hot climates, external and internal living spaces are required to be protected against solar radiation, glare and hot dusty winds. Compactness can be achieved by "carpet-planning" layouts with courtyard houses or cluster settlements of high buildings to create suitable patterns. Heat gain and storage in the cool season is desirable.

2.8.1.4 Room arrangements

The arrangement of rooms depends on their function and according to the time of the day they are in use. The rooms should be planned taking into consideration solar orientation and prevailing wind direction. Cross ventilation can be used to enable faster cooling and better ventilation. Bedrooms can be located on the east side where it is coolest in the evening. Rooms which are in use for most times of the day, such as living rooms should be located on the northern side. Stores and other auxiliary spaces should be located on the disadvantaged side, mainly on the western sides. Provided the kitchen is used during morning and midday hours, it can be located on the west side as well. Rooms with high

internal heat load, such as kitchens, should be detached from the main rooms (Akande, 2010).

2.8.1.5 Courtyard

Another common natural ventilation and cooling technique is the use of atria and courtyards. Courtyards can reduce the cooling energy needs of residential buildings in a very significant way especially if carefully designed (Akande, 2010). Due to the incident solar radiation in the courtyard, the air in the courtyard becomes warmer and rises up as a result of stack effect (Sharma, 2016). This is illustrated in Fig. 2.14 below.

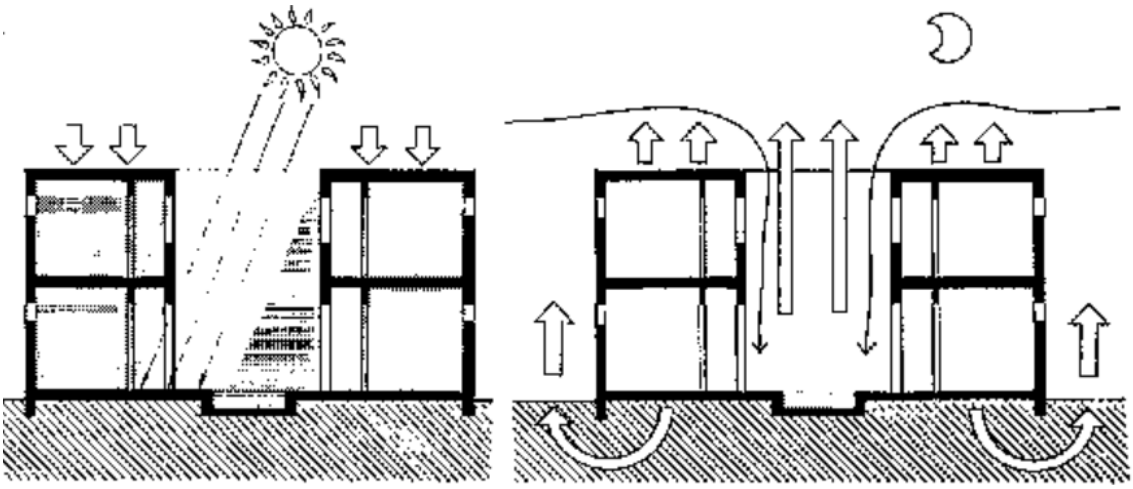


Figure 2.14Courtyard house with covered galleries and an internal pool for evaporation, day and night situation, Source: *(Gut & Ackerknecht, 1993)*

2.8.2 Building components

i. Foundations, basements and floors

ii. Walls

iii. Openings and windows

iv. Roofs

2.8.2.1 Foundations basements and floors

The ground is a valuable means of heat absorption; therefore, the building should have maximum contact with the ground. Flooring materials should be of high thermal conductance. The ground near the building should be shaded during the day, but fully exposed to the night sky, so that the emission of radiant heat is not obstructed.

2.8.2.2 Walls

During the hot season, walls of daytime living areas should be made of heat-storing materials; walls of rooms for night time use should have a light heat capacity. East and west walls should preferably be shaded. High reflective qualities are desirable for both thermal and solar radiation.

2.8.2.3 Openings and windows

Openings and windows are necessary for natural lighting and ventilation, but heat gain during hot seasons should be minimal. Main openings should face north and south, but the latter should be shaded either by shading devices, roof overhangs or by deciduous trees. During the daytime, little or no openings would be desirable on the west side in order to shield from direct radiation and should be located high on the walls to protect from ground radiation. At night, the openings should be large enough to provide adequate ventilation for the dissipation of heat emitted by the walls and the roof. Hence larger

openings should be closed during the day with insulated shutters and opened at night. Such systems are not always reliable because they require the attendance and readiness of the inhabitants. Other considerations such as desired privacy and safety may prevent the correct use of a system with shutters. The depth of rooms and the size of windows have to be coordinated. Glare from direct natural lighting can also be avoided by the use of internally reflected light. This is illustrated in Fig. 2.15 below.

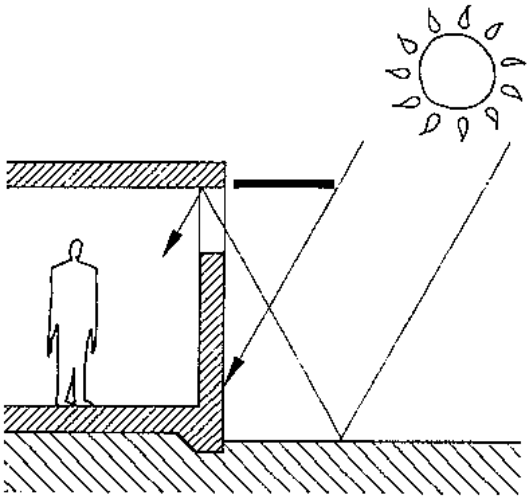


Figure 2.15 Indirect natural light, Source: *(Gut & Ackerknecht, 1993)*

Generally, single glazing is sufficient. Tight closing joints and window profiles are important to prevent the penetration of hot air, sand, dust and insects. Windows and other openings must be placed in suitable positions in relation to the prevailing (cool) breeze to allow a natural airflow through the building. This is done to achieve air movement across the body for evaporative cooling and air changes for driving out excess heat. An internal draft (cross-ventilation) can be channelled by louvres set in an upward position towards the ceiling or in a horizontal position towards the human body. Outlet openings should be located at a high level where hot air accumulates. High openings vent the hot air collecting near the ceiling and are most useful for convective cooling. For comfort, ventilation openings should be at the level of the occupants.

2.8.2.4 Roofs

Different forms of roofs are possible or can be traditionally applied, the latter mainly determined by local materials and technical means. The roof is the most critical part which should have high solar reflectivity and emissivity for long-wave radiation as well as thermal insulation and adequate time lag. The flat roof is practical in areas where it seldom rains. It is also a good reflector and re-radiates heat efficiently, especially if it consists of a solid, white painted material. Roofs (slopes) should be orientated towards the prevailing breeze and any obstructions which would prevent the airflow next to the roof surfaces should be avoided. Sloped roofs could also provide cold airflow towards a courtyard. A membrane covering a courtyard in the daytime allows retention of cool air and provides shade, but needs attendance by the inhabitants.

2.8.3 Building materials

The comfort of people inside the buildings depends largely on the thermal properties of the outer and inner walls and the roof. Depending on the function of the building components, specific insulating and/or thermal storage qualities are required. The different building components require adequate design and material properties to act as a balanced system. These include:

1. Thermal insulation
2. Time lag
3. External and internal colours

1. ***Thermal insulation***: is important to suppress surface temperature variations, but it is only applicable in connection with adequate inner ventilation and cooling means or in combination with light structures. Insulation can also reduce

necessary heat loss at night. Roof insulation is especially important in decreasing temperatures in hot seasons. The outside application of insulation is preferable because the structure and the construction materials are less exposed to thermal stress, and the storage capacity of a heavy structure material helps to balance the inner temperature. The additional needed skin for the building or roof must protect the insulation against damage by physical, mechanical forces, and should be of a hard material. The required insulation value depends on the sun exposure.

2. ***Time lag properties***: building parts and its materials should be used for energy storage and temperature exchange between day and night. Necessary time lags for internal heat balance are: Walls, east: 0 hours; south: 10 hours.; west: 10-hours.; north: 10 hours or no lag; roof: 12 hours.

3. ***External colours***: are required as a combination of high reflectivity of solar radiation and high emissivity of infrared radiation to the cool sky at night. white, non-shiny surfaces are desirable because it has a high reflection ratio on sun exposed surfaces while all dark absorptive colours surfaces are usable where reflection towards the interior should be avoided such as under eaves. Fig. 2.16 shows the absorptivity of some colours.

Colour	Absorptivity (%)
Perfectly black	100
Ordinary black	85%
Dark green	70
Dark grey	70
Light green	40
Light grey	40
White oil paint	20
New whitewash	12
White emulsion paint	12 – 20

Figure 2.16 The absorptivity of colours,

Source: *(Building Research Establishment, 1974)*

4. ***Internal colours:*** such as “cool” and bright colours can be used psychologically as a cooling contrast to intense outdoor heat and to distribute natural light for deep room arrangements.

2.8.4 Shading devices

It is essential to shade the surroundings against direct solar radiation and its reflection. Shading can be provided by different means, such as placing buildings closely together, the shape of the building itself like overhangs, vegetation such as deciduous trees or attached special shading devices. In some hot regions, the traditional “mashrabiyas” or “rowshans” are common. These projecting, screened windows or non-projecting screened windows consist mainly of wooden and shading screens over large openings and allow cross-ventilation as well as the passage of daylight.

2.8.5 Natural ventilation

Ventilation is the replacement of used inside air by outside air and it has three major functions: supply of fresh air, body cooling and structural cooling (Ogunsote O. , 1993). It is important for the building structure to have effective ventilation and an internal temperature below the outdoor level. Natural ventilation keeps the air moving within the indoor environment and keeps the inhabitants cool. It has been concluded based on research that natural ventilation is an attractive alternative to reduce the associated problems with air-conditioned buildings because natural ventilation has potential benefits such as reduced operation costs, improved indoor air quality and satisfactory thermal comfort. Some passive means in enhancing natural ventilation include:

1. Wind catcher
2. Solar chimney

2.8.5.1 Wind catcher

A device, especially found in hot regions of the Middle East, that ventilates a house by the use of wind. A small tower on the roof contains an opening that faces the prevailing wind, which is at a cooler temperature than the interior of the house. The wind velocity at this opening is greater than it is at the lower windows of the house, as a result air in the shaft of the tower is forced down the shaft to cool the house (McGraw-Hill Companies, Inc., 2003). Fig. 2.17 and Plate XVII illustrate the operation of a windcatcher.

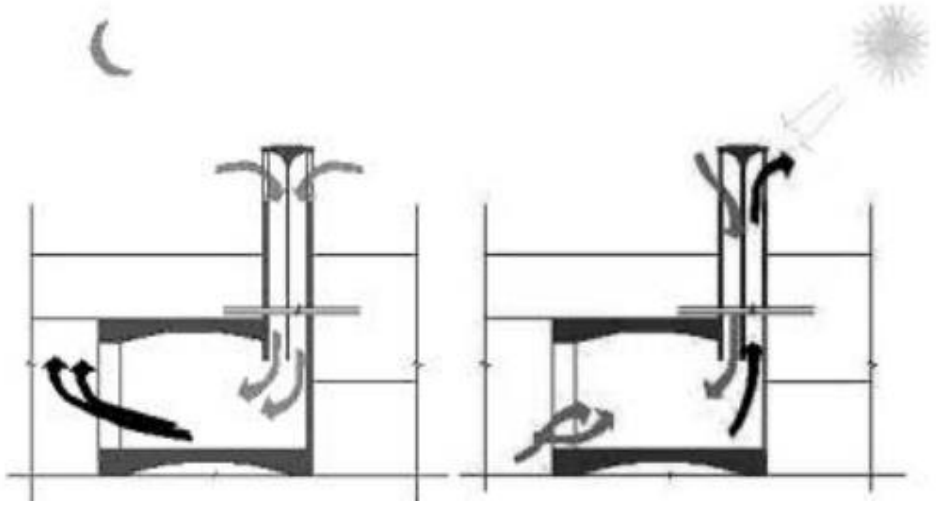


Figure 2.17 Day and night time operation of a wind catcher, Source: *(Azami, 2005)*

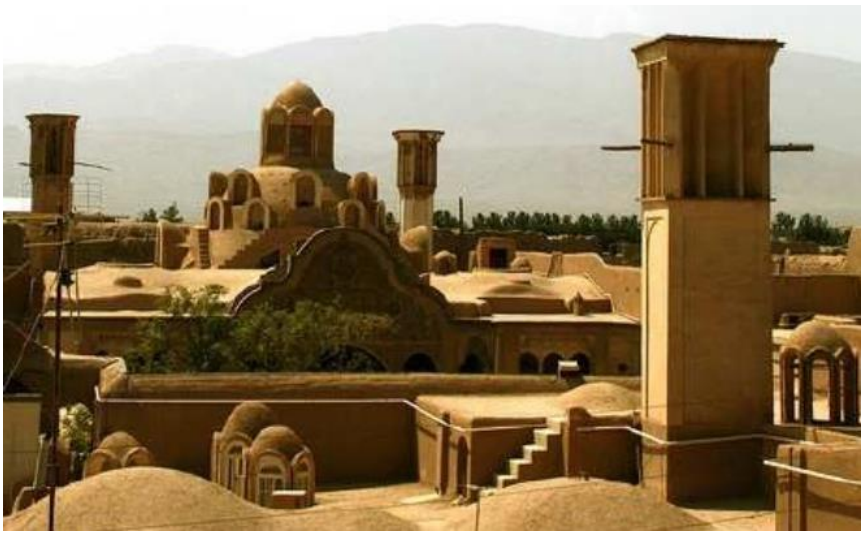


Plate XVII Wind catcher used in Boroojerdi- ha house in Kashan, Iran, Source: *(Sinclair, 2014)*

2.8.5.2 Solar chimney

Solar chimneys enhance stack ventilation by providing additional height and well-designed air passages that increase the air pressure differential. Warmed by solar radiation, chimneys heat the rising air and increase the difference in temperature between incoming and out-flowing air (see Fig. 2.18). The increase in natural convection from these measures enhances the draw of air through the building (Reardon & Clarke, 2013).

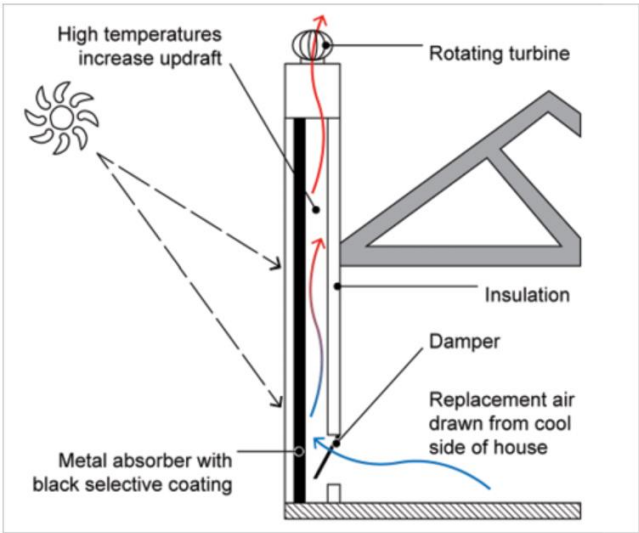


Figure 2.18 Solar chimney expelling heat from a residential building, Source: *(Reardon & Clarke, 2013)*

2.8.6 Evaporative/external cooling

Evaporative cooling of buildings may be either direct or indirect. It employs the latent heat of evaporation of water for cooling. The wind force is used to produce natural air flow through moist elements installed in windows and openings. The air is humidified while the dry bulb temperature falls, thus causing evaporative cooling (see Plate XVIII and Fig.2.19) (Ogunsote, Prucnal-Ogunsote, & Adegbie, Optimizing Passive Cooling Systems in Residential Buildings: A Case Study of Akure, Nigeria, 2011). If the inlet air is taken from the side of the building facing away from the sun, and is drawn over a cooling pond or spray of mist or through large areas of vegetation, it can end up several degrees cooler than outside air temperature by the time it enters occupied spaces

(Autodesk Inc., 2015a). Such cooling involves a change in both the water-vapour content and air temperature. When unsaturated air comes in contact with water, some water is evaporated, thus lowering the temperature of the air and increasing its water-vapour content (Sharma, 2016).



Plate XVIII A courtyard fountain in the Alhambra cools air before it enters the building, Source: *(Autodesk Inc., 2015a)*

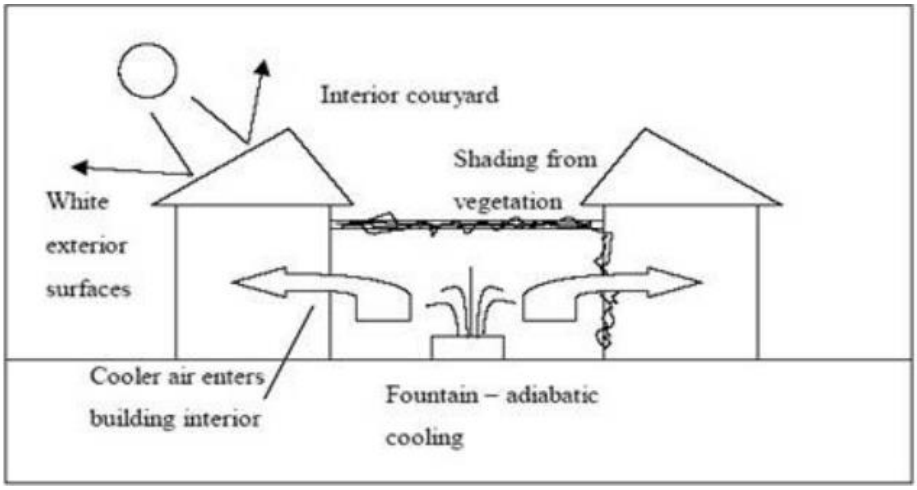


Figure 2.19 Evaporative cooling through the application of fountains between buildings, Source: *(Akande, 2010)*

2.8.7 Landscaping, vegetation and greenery

Vegetation grows rapidly around and can be used as an architectonic element either vertically or horizontally in the shape of pergolas, screens, vegetated atriums, patios, flower pots, and others, in order to create microclimates and to favour architectural

design. Internal and external vegetation could be considered as a potential design element. The use of vegetation provides shade and freshness almost the whole year. When the buildings in hot climates are surrounded with vegetated screens, a natural freshness that isolates the building from sun rays is achieved. The plantation of trees can result in energy saving, reduction of noise and pollution, modification of temperatures and relative humidity and psychological benefits on humans. Adequate space should be provided and left open either as a setback area or as designated green space within the residential environment (Akande, 2010).

2.9 Summary

Buildings will cause thermal discomfort if an effective strategy is not adopted to reduce the extra heat going into it. Out of the numerous passive design strategies that have been adopted by others in different climates, only those strategies discussed in this study have been chosen to meet the purpose of this study and can be applied in the context of hot dry climate of Nigeria. By adopting the above mentioned design strategies, this will limit the energy demand for cooling the climatic environment and will also result in comfortable, healthier and sustainable living spaces as well encourage innovative design solutions for building professionals in hot-dry climate.

3.0 RESEARCH METHODOLOGY

3.1 Introduction

Research methodology is a systematic way to solve a problem. It is a science of studying how research is to be carried out. Essentially, the procedures by which researchers go about their work of describing, explaining and predicting phenomena are called research methodology. It is also defined as the study of methods by which knowledge is gained (Rajasekar, Philominathan, & Chinnathambi, 2013). Its aim is to give the work plan of research. The Oxford Advanced Learner's Dictionary of Current English, (2010) defines research as "a careful investigation or inquiry specially through search for new facts in any branch of knowledge." Research refers to the systematic method consisting of enunciating the problem, formulating a hypothesis, collecting the facts or data, analysing the facts and reaching certain conclusions in the form of solutions towards the concerned problem or in certain generalisations for some theoretical formulation (Kothari, 2011).

The essence of this chapter is to present the research design, empirical methods and techniques to be used in the research including sampling, population, establishing rigour during and after data collection, ethical considerations and data analysis. This research is aimed to explore ways in which indoor thermal conditions can be enhanced through the application of building orientation and the use of landscape elements in a proposed University Residential design in the hot dry climate of Jigawa State.

3.2 Research Design

The research design refers to the overall strategy that a researcher chooses to integrate in the different components of the study in a coherent and logical way, thereby, ensuring the researcher will effectively address the research problem; it constitutes the blueprint for the collection, measurement, and analysis of data (De Vaus, 2001;Trochim, 2006).

This research is descriptive and experimental in nature and will be carried out through case studies and computer simulations using a mixed methodology research approach.

3.2.1 Case studies

Case study is an "empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009). This research is based on determining appropriate orientation patterns and landscape for optimising thermal comfort in residential buildings within a university setting. Case studies allow presentation of data collected from multiple methods (i.e., surveys, interviews, document review, and observation) to provide a comprehensive record of the buildings under consideration.

3.2.2 Computer simulations

Computer simulation is the discipline of designing a model of an actual or theoretical physical system, executing the model on a digital computer, and analysing the execution output (Fishwick, 1995). ENVI-met is a Computational Fluid Dynamics (CFD) numerical model that is capable of simulating a complete built environment surface-air-plant thermal interactions based on the fluid dynamics and heat transfer fundamentals (Tariq, 2014). The three-dimensional microclimate model ENVI-met is used in the different fields of urban climatology ranging from general urban planning over urban architecture down to individual building design (Huttner, Bruse, & Dostal, 2016). Several scholars have used ENVI-met to simulate the urban climate on the microscale. The software was developed by Michael Bruse at the University of Mainz, Germany to simulate the interaction between surfaces, plants and air in an urban environment. The tool has been further developed to allow the analysis of the effect of small-scale changes in urban design (pattern, vegetation, building morphology, etc.) on the microclimate

under mesoscale conditions defined at the beginning of the simulation (city climate, meteorological data, etc.) (Tumini, García, & Rada, 2016).

3.2.3 Research approach

This research data will be collected and analysed using the Mixed Methodology, which includes both quantitative and qualitative research approaches. Quantitative research is based on the measurement of quantity or amount, it applies statistics or mathematics and uses numbers (Kothari, 2011). A quantitative research approach has a few of the following characteristics: It is numerical, non-descriptive, the results are often presented in tables and graphs, it is conclusive and it investigates the what, where and when of decision making (Rajasekar, Philominathan, & Chinnathambi, 2013). Qualitative research, on the other hand, is concerned with qualitative phenomenon, i.e., phenomena relating to or involving quality or kind, it applies reasoning and uses words (Kothari, 2011). Some of the characteristics of qualitative research/method are: It is non-numerical, descriptive, exploratory, aims to get the meaning, feeling and describe the situation and investigates the why and how of decision making (Rajasekar, Philominathan, & Chinnathambi, 2013).

3.3 Instruments for Data Analysis

The investigation will be carried out through visual surveys and observation.

1. **Visual survey:** to enhance precision when discussing a region's built or natural environment with the aid of set of photographs generally taking from within the community or images from other areas depicting the data if it cannot be conveniently found in the survey area (Oluigbo, 2010).
2. **Observation:** This research will be analysed through critical study which makes use of the following instruments such as photographs and sketches.

3.4 Population

Population is the total number of cases likely to be considered. These cases share some common set of characteristics and comprise the entire purpose of the research problem. In this study the population considered will be PGR buildings in tertiary education campuses within the hot dry climate. This includes:

i. Ahmadu Bello University, Zaria.
ii. Bayero University, Kano.
iii. Kano University of Science and Technology, Wudil.
iv. University of Maiduguri, Borno.
v. Abubakar Tafawa Balewa University, Bauchi.
vi. Umaru Musa Yar'adua University, Katsina.
vii. Usman Danfodio University, Sokoto.

3.5 Case Study Selection Criteria

The criteria considered for selecting the cases included:

1. Identical climatic context similar to the proposed PGR.
2. Comparable design considerations in proposed typology.
3. Oldest and largest existing tertiary universities.

3.6 Sampling and Sampling Techniques

Sampling may be described as taking any portion of a population to represent that population. Purposive sampling technique will be used in this study. Purposive sampling is a sampling technique whereby all members of a population have an equal and independent chance of being included in the sample. Sample size is a portion or limited number of piece of a population that is selected to represent the whole demographic and statistical population. Samples are intended to assist in understanding and quantifying

mathematical probabilities, trends, or relationship within a population. The samples for this research include:

i. Ahmadu Bello University, Zaria.
ii. Bayero University, Kano.
iii. Kano University of Science and Technology, Wudil.

3.7 Research Variables

A Variable is defined as anything that has a quantity or quality that varies. The Dependent Variable is the variable the researcher is interested in while an Independent Variable is a variable believed to affect the dependent variable (Kowalczyk, 2012).

3.8 Methods of Data Presentation

The data gathered from the field survey would be collated and analysed. Also climatic data from the meteorological centre will be collected and imputed in the simulation software then analysed and represented in different forms which include:

3.8.1 Descriptions

This will entail the summary and conclusion, showing the how orientation has affected thermal comfort of the indoor spaces after the case study analysis was done and also the extent to which the landscaping was optimized for thermal comfort at the design stage.

3.8.2 Tables

It will involve the documentation and presentation of data collected from case studies on assessment tables.

3.8.3 Figures and plates

Data collected during the case studies in form of drawings and sketches will also be documented using Figures and plates.

4.0 RESULTS, ANALYSIS AND DICUSSION

4.1 Introduction

This chapter presents in detail how the collected data were analysed. This research aims to optimise microclimate and site design to enhance passive thermal comfort in a Post Graduate Residential design in hot dry climate. The analysis was carried out in line with the research questions and it was conducted through case study analysis and computer simulations. Various local cases were studied to establish the extent to which parameters affecting the microclimate were considered. A case study was used as a model to experiment by altering the dependent variables forming different case scenarios to carry out a microclimatic analysis to observe its effect on thermal comfort. All data collected and analysed in this chapter are presented

in form of tables and graphs.

4.2 Case Studies

Postgraduate residences were studied in three different university campuses within the hot dry climatic zone, namely;

i. Ahmadu Bello University, Zaria
ii. Bayero University, Kano
iii. Kano State University of Science and Technology, Wudil

The results focus on the variables as described in the methodology of this study. The variables of the study were developed from the review of relevant literature and similar studies that were done before presented in this research.

4.3 Case Study One: Akenzua Hall, Ahmadu Bello University

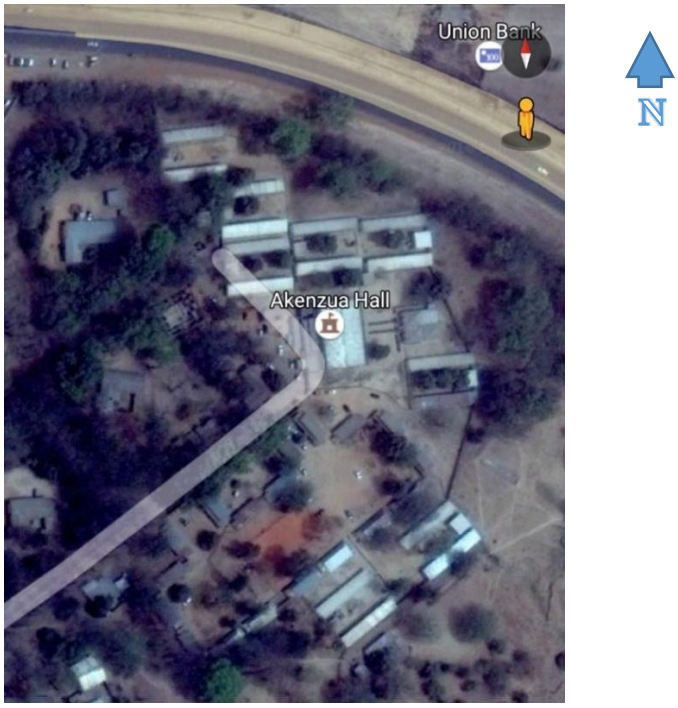


Plate XIX Aerial view showing Akenzua Hall, Source: (Google Earth, October 2016)

4.3.1 Background information

The main campus of Ahmadu Bello University is located in Samaru, a suburb of Zaria in Kaduna State. Ahmadu Bello University began full operation in 1962. Akenzua Hall is the largest Postgraduate hostel in the university campus of Ahmadu Bello University. Plate XIX above shows the aerial view of Akenzua hall. This hostel was formerly a female undergraduate hostel converted to a male postgraduate hostel. It is located within the residential zone of the campus alongside the university staff quarters, Area A. This hostel comprises of two block types, which will be referred to as prototype A and B in this chapter. There are 8 pairs of prototype A with a total of 16 blocks and 18 blocks of prototype B making 34 blocks all together. The front view of a typical prototype B block is shown in Plate XX below.



Plate XX Front view of a typical prototype B block, Source: (Researcher's field work, October 2016)

4.3.2 Building form

The hostel contains two different block prototypes as described earlier. Both prototypes A and B are rectangular in shape as shown in Plate XXI below. Prototype A blocks are arranged in pairs with one block facing another and enclosed by a fence.



Plate XXI Aerial view of the prototypes showing their building form and orientation (a)Prototype A (b)Prototype B, Source: (Google Earth, October 2016)

4.3.3 Building orientation

Prototype A has 6 pairs of blocks oriented with their longer sides along the east and west axis with a slight tilt towards the north-east and south-west axis avoiding insolent solar

radiation from the east and west it may be considered adequate. The other 2 pairs of prototype A are oriented at an angle along the north-east and south-west axis, this orientation is not adequate for both solar and wind orientation as it does not capture wind breezes neither does it protect the building form solar radiation. 10 blocks of prototype B are also oriented along the north-east and south-west axis and the other 8 blocks along the north-west and south-east angles, this orientation may be adequate for wind orientation but poor for solar radiation.

4.3.4 Building envelope

I. **Roof:** Prototype A used a shed roof structure that is made up of grey coloured long span aluminium roofing sheet. Prototype B also made use of a shed roof structure, made up of grey coloured long span asbestos roofing sheet. Both prototypes have overhangs of 450mm towards the back and 1000mm towards the front of the rooms serving as a veranda.

II. **Window and Door Openings:** Windows in prototype A are single glazed top hung casement windows, 600x1200mm in size and grey wooden flush doors 750x2100mm in size. Prototype B has side hung single glazed casement windows 1500mmx1200mm in size and blue wooden flush doors 750x2100mm in size.

III. **Walls:** Sandscrete hollow blocks, 230x450mm were used for the walls. Prototype A is painted milk and prototype B is grey in colour. This colours are llight and are considered to have low heat absorptivity and high reflectivity properties.

IV. **Floors:** Floors are made of 150mm oversite reinforce concrete with grey coloured terrazzo floor screed.

These components can be seen in Plate XXII below.



Plate XXII Front view of typical Prototype A block, within the courtyard, Source: (Researcher's field work, October 2016)

4.3.5 Landscape

The is poorly landscaped with few defined walkways and little shrub plants. Medium trees are positioned within the courtyard of Prototype A to enhance shading while smaller trees are positioned between the buildings of Prototype B. A few large trees are positioned randomly around the site which favour a few buildings by providing shade as seen in Plate XXIII below. There are no water features on or around the site.



Plate XXIII Rear view of a typical Prototype A block, showing a large tree which aids in shading, Source: (Researcher's field work, October 2016)

4.3.6 Topography

The site has relatively flat terrain composed of sandy laterite soil. The site has very gentle low slopes in some areas as represented in the elevation and cross sectional cut through the site shown in Plate XXIV and Fig. 4.1 below.



Plate XXIV: Approach view of a typical prototype A block from the gate entrance of the hostel showing the relatively flat terrain of the hostel, Source: (Researcher's field work, October 2016)



Figure 4.1 Sectional cut through of Akenzua Hall site showing the elevation profile of its terrain, Source: (Google Earth, October 2016)

4.3.7 Natural ventilation

The rooms in prototype A have two windows on one wall and one large window in prototype B with both prototypes having a door on the opposite wall of the rooms. A vent is positioned above the door for lighting in both prototypes to aid stack effect. Cross ventilation is inadequate in both.

4.4 Case Study Two: New Female Postgraduate Hostel, Bayero University Kano



Figure 4.2 Aerial viewing showing Bayero University Kano, Source: (Google Earth, October 2016)

4.4.1 Background information

Bayero University Kano (BUK) is a university situated in Kano, Kano State, Nigeria. It was founded in 1977, when it was renamed from Bayero University College and upgraded from university college to university. Fig. 4.2 above shows the aerial view of Bayero Univeristy. The hostel studied is the newly constructed female postgraduate hostel within the old campus of the university. This hostel is an independent structure. It is a two-storey building having 10 rooms on each floor. The building has a courtyard which is enclosed within the adjoining rooms. All rooms are self-contained rooms comprising of a toilet, kitchen and balcony each. The approach elevation of this hostel can be seen in Plate XXV below.



Plate XXV Approach elevation of the female postgraduate hostel (BUK) showing the main entrance to building, Source: (Researcher's field work, October 2016)

4.4.2 Building form

The building has a square form tilted at a 45^{o} angle to the true north as seen in Plate XXVI. The building comprises of 4 rectangular blocks arranged perpendicular to each other forming a square shaped building with a courtyard enclosed at the centre. The space within the courtyard is reduced due to the presence of staircases. It has balcony protrusions on all sides of the building.



Plate XXVI Aerial view of the postgraduate hostel (BUK) showing the building form and few site features, Source: (Google Earth, October 2016)

4.4.3 Building orientation

The building is oriented at a 45^{o} angle to the true north. This building has poor orientation as its walls are facing the east and west exposing them to insolent solar radiation. This

building has the advantage of capturing wind breezes from the walls that are oriented on the north-east and south-west axis.

4.4.4 Building envelope

I. **Roof:** The building uses a flat hipped roof structure covered with light brown coloured long span aluminium roofing sheet enclosed in parapet walls.

II. **Window and Door Openings:** Windows used are single glazed top hung casement windows, 600x600mm in size for the toilets and 1200x1200mm (600x600mm x 4) for one of the exterior room windows. Single glazed sliding windows 900x900mm brown are used for the kitchens. Single glazed sliding windows 1200x600 and 1200x1200mm in size are used for the other 2 windows in the bedroom. The doors used are wooden flush doors 750x2100mm in size for the kitchens and rooms. Metal doors 900x1200mm in size are used for the balcony and bedroom entrance doors.

III. **Walls:** Sandscrete hollow blocks, 230x450mm were used for the walls. The walls are light brown and cream in colour. White ceramic wall tiles were used for the toilet and kitchen wall finishing.

IV. **Floors:** Floors are made of 150mm oversite reinforce concrete with ceramic tile finishing.

These components can be seen in Plate XXVII below.



Plate XXVII Side view of the hostel showing the south facing wall and balcony protrusion, Source: (Researcher's field work, October 2016)

4.4.5 Landscape

The landscape is the site is characterised by few trees of medium size and lots of weed grasses around the site. The site has a paved walkway that goes round the side of the building on the south side from the front entrance of the building to the rear entrance. The courtyard is positioned at the centre of the building with a concrete paved ground cover and defined shrub planting beds.

4.4.6 Topography

The terrain of this site is relatively flat composed of sandy laterite soil. This is shown in the cross sectional cut through of the site in Fig. 4.3 below.





Figure 4.3 Sectional cut through of the hostel site showing the elevational profile of its terrain, Source: (Google Earth, October 2016)

4.4.7 Natural ventilation

The rooms are adequately cross ventilated with 2 windows on the exterior wall and one on the opposite wall. This aids both lighting and natural ventilation. This building has a courtyard but it was not fully utilised to enhance natural ventilation through soft landscaping.

4.5 Case Study Three: Girls' Postgraduate Hostel, Kano State University of Science and Technology



Plate XXVIII Aerial viewing showing Kano University of Science and Technology, Source: (Google Earth, October 2016)

4.5.1 Background information

Kano University of Science and Technology, Wudil (KUST) was created as "Kano University of Technology"" (KUT) in 2000. It is located in Wudil, a Local Government in Kano State Nigeria. Plate XXVIII shows the aerial view of KUST campus. The hostel studied here is the girls postgraduate hostel located within the university campus which was formerly an undergraduate hostel. Plate XXIX shows the approach elevation of the hostel.



Plate XXIX Approach elevation of the female postgraduate hostel (KUST) showing the main entrance to building, Source: (Researcher's field work, October 2016)

4.5.2 Building form

The building of the girl's hostel takes the shape of a rectangle with hollow spaces at its centre forming courtyard spaces as seen in Plate XXX. The building has a total height of about 8 metres.



Plate XXX: Aerial view of the postgraduate hostel (KUST) showing the building form and few site features, Source: (Researcher's field work, October 2016)

4.5.3 Building orientation

The building is oriented along the east and west axis with a slight tilt towards the north-east and south-west axis. The building has its longer axis aligned to the east and west axis avoiding exposure to east and west insolent solar radiation.

4.5.4 Building envelope

1. **Roof:** The building uses hipped roof structure that is covered with blue coloured long span aluminium roofing sheet.
2. **Window and Door Openings:** Windows used are single glazed side hung casement windows, 600x1200mm in size and grey wooden flush doors 750x2100mm in size.
3. **Walls:** Sandscrete hollow blocks, 230x450mm were used for the walls. The walls are finished with dull pink coloured paint.
4. **Floors:** Floors are made of 150mm oversite reinforced concrete finished with grey coloured terrazzo floor screed.

   These components can be seen in Plate XXXI below.



Plate XXXI A view of the inside of the girl's postgraduate hostel, Source: (Researcher's field work October 2016)

4.5.5 Landscape

This site is poorly landscaped with a tree on the eastern side of the building and very few weed grasses. The site's ground cover is mainly sand soil all-round the building. The courtyard provided within the building is completely paved with interlocking tiles and little provision was made for planting shrubs in the future.

4.5.6 Topography

This site has a flat terrain composed of sandy laterite soil. The whole site is mainly flat and relatively flat towards the west side of the site. A sectional cut through of site showing the elevation of the terrain is shown in Fig. 4.4 below.



Figure 4.4: Sectional cut through of the hostel site showing the elevation profile of its terrain, Source: (Researcher's field work, October 2016)

4.5.7 Natural ventilation

The rooms have two windows on one wall and a door on the opposite wall with sliding window openings above the door to aid stack effect and to enhance lighting. Presence of courtyard but was not fully utilised to enhance natural ventilation. This is shown in Plate XXXII.



Plate XXXII Views showing the paved courtyard of the hostel, Source: **(**Researcher's field work, October 2016)

4.6 Case Study Four: White House Block-Amina Hall, Ahmadu Bello University

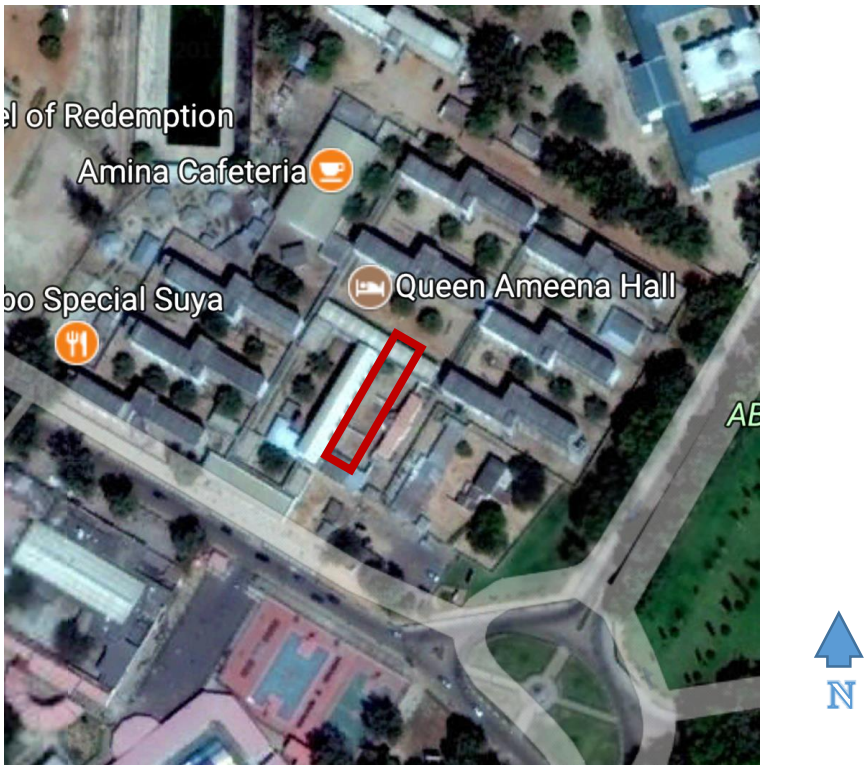


Plate XXXIII Aerial view showing Amina Hall- White House Block, Source: **(**Google Earth, January 2017)

4.6.1 Background information

The main campus of Ahmadu Bello University is located in Samaru, a suburb of Zaria in Kaduna State. Ahmadu Bello University began full operation in 1962. Amina Hall is one of undergraduate girl's hostel on the university campus of Ahmadu Bello University. It is located close to the university main gate, alongside the A. B. U. Garden and opposite

the students social centre. Plate XXXIII shows the aerial view of Amina hall. This hostel comprises of three block types, the White House block, the Links Block and the general prototype provided mainly for the hostel accommodation. The White House and one block of the general porotype called Block 9 are assigned to the postgraduate students. The White House Block and the Links block are located together at the centre positioned perpendicular to each other. This case study focuses on the White House block as it was purposely designed for the postgraduate students. Front view of the white house block is shown in Plate XXXIV and XXXV below.



Plate XXXIV: Front view of White House Block, Source: (Researcher's field work, January 2017)



Plate XXXV Front view of White House block and the courtyard, Source: (Researcher's field work, January 2017)

4.6.2 Building form

The White House Block takes the shape of a rectangle with an open space in front and behind it. The building is connected perpendicularly with the links block forming a T shape as seen in Plate XXXVI. The building is two stories tall with an approximate height of 9 meters.



Plate XXXVI Aerial view showing the building form of the White House and orientation, Source: (Google Earth, January 2017)

4.6.3 Building orientation

The building is oriented 60º along the east and west axis. The building has its longer axis almost aligned to the north and south axis exposing the longer side of the building to the east and west insolent solar radiation. Prototype A has 6 pairs of blocks oriented with their longer sides along the east and west axis with a slight tilt towards the north-east and south-west axis avoiding insolent solar radiation from the east and west it may be considered adequate. The other 2 pairs of prototype A are oriented at an angle along the north-east and south-west axis, this orientation is not adequate for both solar and wind orientation as it does not capture wind breezes neither does it protect the building form solar radiation. 10 blocks of prototype B are also oriented along the north-east and south-west axis and the other 8 blocks along the north-west and south-east angles, this orientation may be adequate for wind orientation but poor for solar radiation.

4.6.4 Building envelope

1. **Roof:** The buildings make use of a parapet roofing system with a flat roof structure that is made up of white coloured long span aluminium roofing sheet.
2. **Window and Door Openings:** Windows are single glazed side hung casement windows, 1200x1200mm in size and grey wooden flush doors 750x2100mm in size.
3. **Walls:** Sandscrete hollow blocks, 230x450mm were used for the walls. They are painted milk and white. This colours are light and are considered to have low heat absorptivity and high reflectivity properties.
4. **Floors:** Floors are made of 150mm oversite reinforce concrete with grey coloured terrazzo floor screed.

4.6.5 Landscape

The immediate landscape around the White House building is characterised by a small courtyard with shrubs arranged at the front of the building and also the front of the Links block. The courtyard is unpaved and has sand as the ground cover. Behind the White House block is another courtyard like area, partly paved with concrete and a small tree behind it.



Plate XXXVII Front view of the White House block and the Links block from the courtyard. Source: (Researcher's field work, January 2017)



Plate XXXVIII Rear view of the White House block from the partially paved courtyard, Source: (Researcher's field work, January 2017)

4.6.6 Topography

The site has relatively flat terrain composed of sandy laterite soil. The site has very gentle low slopes in some areas as represented in the cross sectional cut through of the site in Fig 4.5 below.



Figure 4.5 Sectional cut through of Amina Hall site showing the elevation profile of its terrain, Source: (Google Earth, January 2017)

4.6.7 Natural ventilation

The rooms in the building have windows on one wall and a door on the opposite wall of the rooms as seen in Plate XXXIX. Two small hollow spaces are positioned above the doors in each room to aid stack effect. Cross ventilation is not adequate.



Plate XXXIX The window, the door and hollow spaces in a typical room, Source: (Researcher's field work, January 2017)

4.7 Case Study Five: Postgraduate Hostel- Phase II, Ahmadu Bello University

4.7.1 Background information

This postgraduate hostel is newly constructed hostel still under construction in the upcoming ABU Phase II in the university Samaru campus of Ahmadu Bello University. This hostel comprises of ten buildings of the same prototype. This hostel is a sponsored project by Aliko Dangote. The hostel comprises of 36 rooms per block to accommodate 2 students per room. It provides wardrobe space for each student, a group of toilets at the end of the block on one side and a laundry.



Plate XL Front view of some of the hostel blocks undergoing construction, Source: (Researcher's field work, October 2017)

4.7.2 Building form

The buildings are rectangular in shape with courtyard spaces at the centre of the buildings The building is connected perpendicularly with the links block forming a T shape. The buildings are one story tall with an approximate height of 6.5 meters.



Plate XLI Side view of a typical hostel block, Source: (Researcher's field work, October 2017)

4.7.3 Building orientation

The buildings are oriented having their longer axis aligned to the east and west axis avoiding insolent solar radiation.

4.7.4 Building envelope

5. **Roof:** The buildings make use of a parapet roofing system with a flat roof structure.
6. **Window and Door Openings:** Windows are 1200x1200mm in size and doors 750x2100mm in size.
7. **Walls:** Sandscrete hollow blocks, 230x450mm were used for the walls.
8. **Floors:** Floors are made of 150mm oversite reinforce concrete.

4.7.5 Landscape

The landscape around the site is yet to be defined.

4.7.6 Topography

The site has relatively flat terrain composed of sandy laterite soil. The site has very gentle low slopes in some areas.

4.7.7 Natural ventilation

The rooms in the building have two windows on one wall and a door on the opposite wall of the rooms. A fixed light is placed above doors to aid lighting. Cross ventilation and stack effect are not adequate.

4.8 Summary of Findings from case studies

i. Case studies 1 and 3 are not purposed based design postgraduate hostels. The building typologies were converted from previously being undergraduate hostels to postgraduate hostels. Case study 2, 4 and 5 are purposed based designed postgraduate hostels.

ii. Case study 1 (proptotype A) and 4 have a demerit of improper orientation exposing vital parts of the building to solar radiation and they do not capture wind breezes.

iii. All buildings studied in the case studies did not take advantage of evaporative cooling through use of water surfaces.

iv. Poorly landscaped areas based on ground cover on all case studies except case study 5 that is yet to be defined.

v. Absence of hedges, large trees and the green areas is a demerit for improving the site microclimate and passive cooling in case study 2 and 3. Case study 4 has a few shrub trees in the courtyard.

vi. Case studies 1, 3 and 4 have a merit of providing natural ventilation through stack effect while otherwise in the others.

vii. Case study 2 has a merit of providing natural ventilation through cross ventilation in the rooms.

viii. Courtyard design was provided in case study 2 and 3 but were all unfortunately not optimised to enhance natural ventilation.

4.9 Simulation software

ENVI-met is a CFD numerical model that is capable of simulating a complete built environment surface-air-plant thermal interactions based on the fluid dynamics and heat transfer fundamentals (Tariq, 2014). The three-dimensional microclimate model ENVI-met is used in the different fields of urban climatology ranging from general urban planning over urban architecture down to individual building design (Huttner, Bruse, & Dostal, 2016). Several scholars have used ENVI-met to simulate the urban climate on the microscale. The software was developed by Michael Bruse at the University of Mainz, Germany to simulate the interaction between surfaces, plants and air in an urban environment. The tool has been further developed to allow the analysis of the effect of small-scale changes in urban design (pattern, vegetation, building morphology, etc.) on the microclimate under mesoscale conditions defined at the beginning of the simulation

(city climate, meteorological data, etc.) (Tumini, García, & Rada, 2016). Figure 4.6 shows the simulation process using the various interfaces of ENVI-met 4.0, Figure 4.7 shows the interface of the spaces aspect of the software displaying a 2D representation of the modelling process and Figure 4.8 displays the 3D representation.

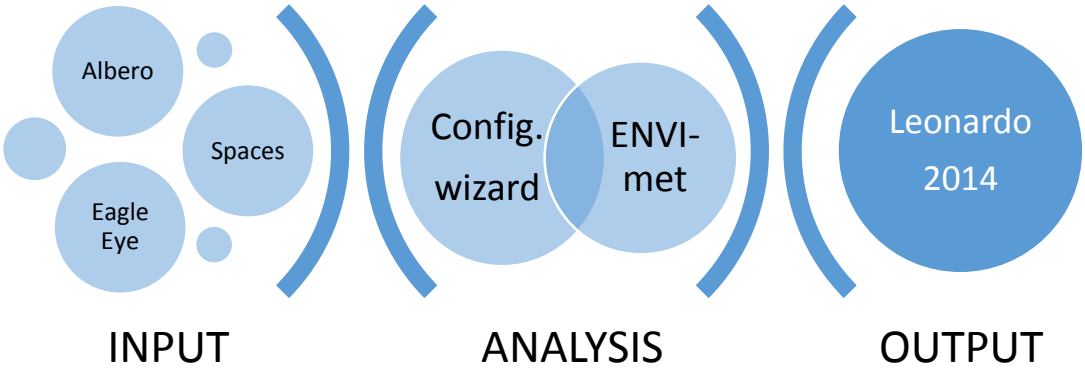


Figure 4.6: Simulation process using the various interfaces of ENVI-met 4.0, Source, (Researcher, October 2016)

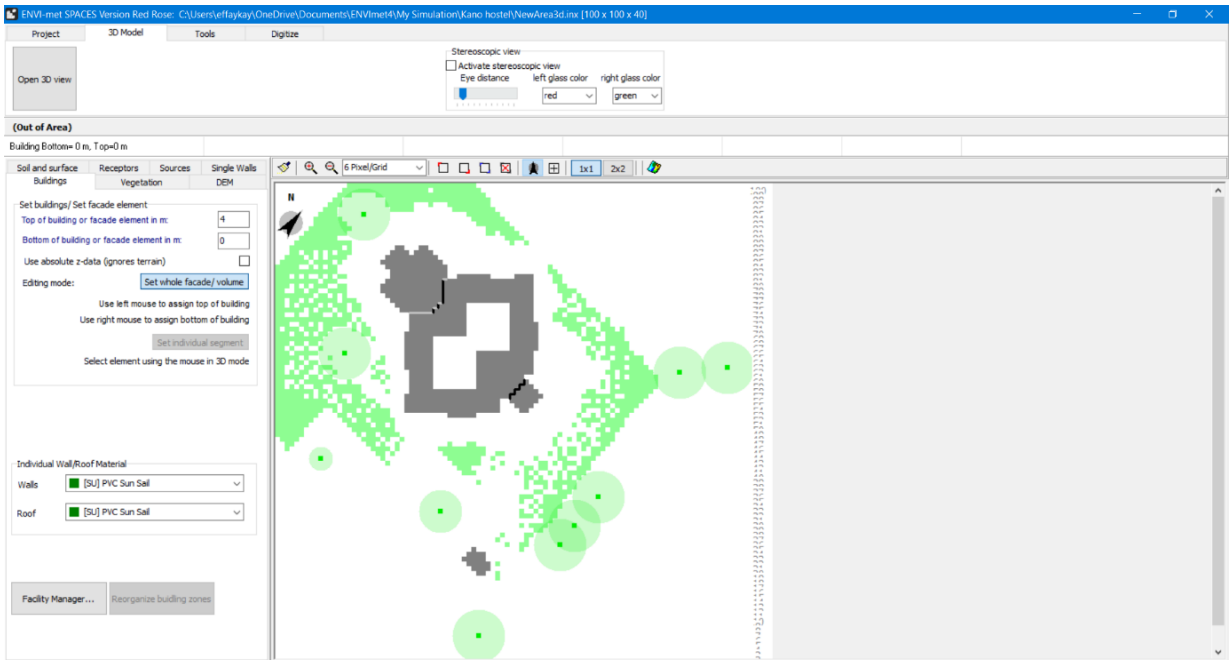


Figure 4.7 Interface of the spaces aspect of the software show a 2D representation of the process, Source: (Researcher, October 2016)

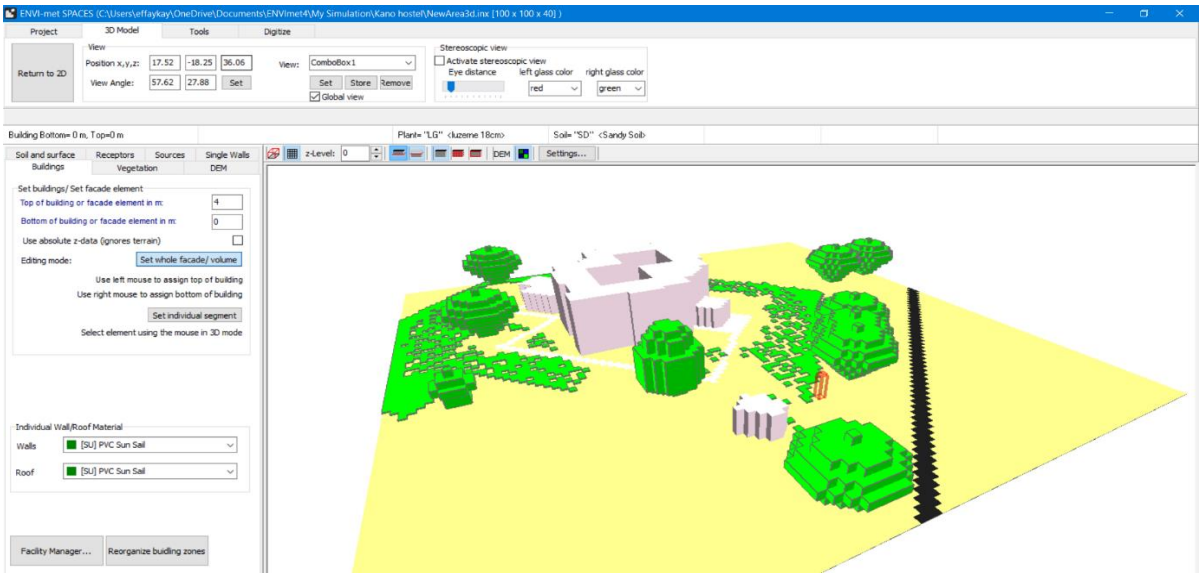


Figure 4.8 Interface of the spaces aspect of the software show a 3D representation of the process, Source: (Researcher, October 2016)

4.10 Simulation process

An experimental simulation was carried out using case study 2. The postgraduate hostel in Bayero University Kano. The work is based on real case studies of different scenarios for testing the effects of the modification of urban design elements on microclimates and thermal comfort. The numerical thermal behaviour of each scenario is simulated using ENVI-met, and the results are compared in terms of thermal comfort performance using the Universal thermal UTCI. Therefore, this research project is restricted to the open spaces around the building, where surface materials can be changed, green areas can be created, and shading systems can be established. For this reason, the analysis is limited to the comparison between two main strategies: a) the modification of green areas in terms of height and diameter of foliage and b) the placement of currently most used paving materials to establish their effect. Table 4.1 below shows description of Site design values for the reference sites along the study area.

Table 4.1 Description of Site design values for the reference sites along the study area.

Site	Current Site
Location	Kano
Climate region	Hot Dry
Building types	Residential
Total area	Area = 134214.8080, perimeter = 1649.5269
Buildings footprint (º)	
Ground cover (º)	
Greens (º)	
Water surfaces (º)	0%

The parameters of the temperature and wind velocity as seen in Table 4.2 are simulated using ENVI-met software in May, which had the highest temperature recording of the year.

Table 4.2 The primary input parameters used in the ENVI-met simulation.

Type	Parameter	Value
Air temperature	Initial temperature atmosphere (k, ^{o})	305.15, 32^{o}
Wind	Wind speed in 10 m ab. Ground (m/s)	3.0556
	Wind direction (^{o})	45
	Roughness length at reference point	0.010*
Humidity	Specific humidity in 2500 m (g water/kg air)	7*
	Relative humidity in 2 m (%)	29
Location	Location	Kano
	Latitude (N,S°)	11.9
	Longitude (E,W°)	8.6
Wall	Thermal resistance ([m2k]/w)	0.8*
	Albedo	0.4*
Roof	Thermal resistance ([m k]/w)	1.0*
	Albedo	0.3*

*Default ENVI-met value used.

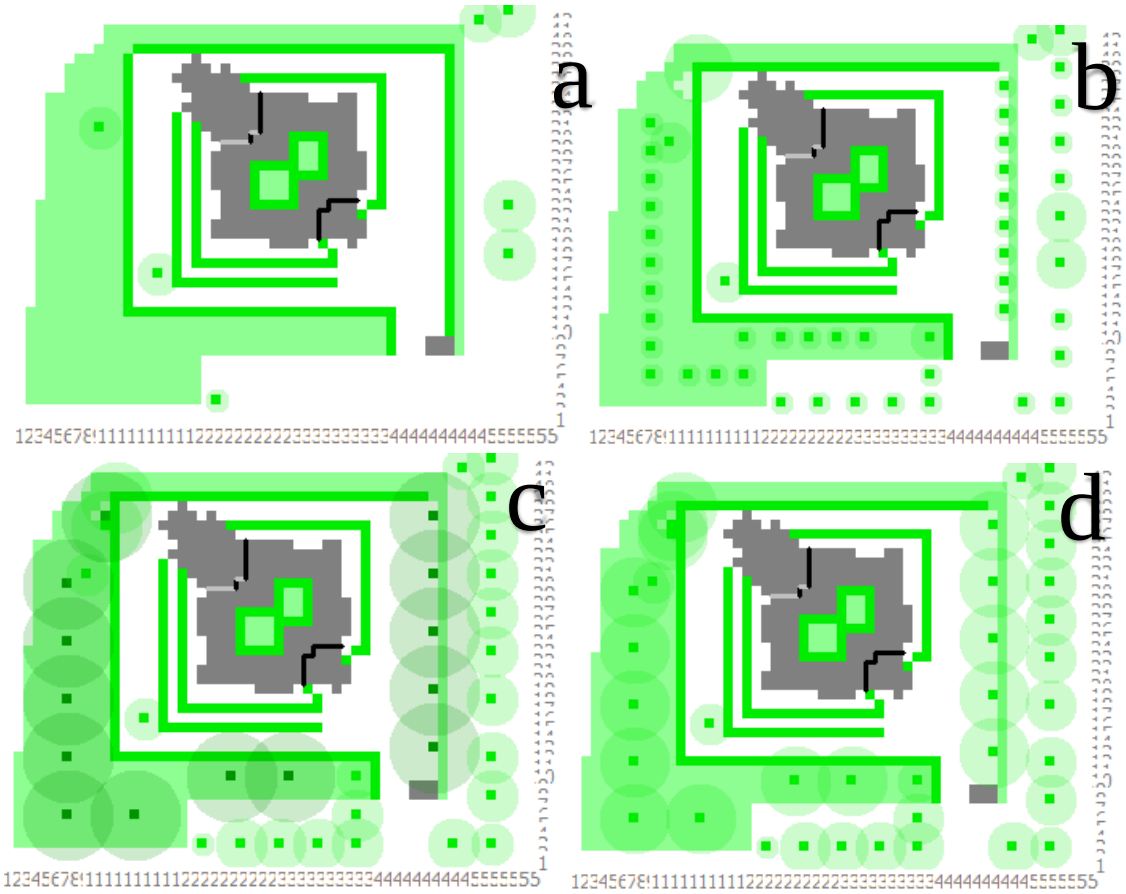


Figure 4.9 The scenarios (a)green areas with shrubs, (b) green areas with small trees, (c) green areas with medium trees and (d) green areas with large trees, Source: (Researcher, October 2016)

Tables 4.3 and 4.4 below show the results from the simulations for each surface material and the scenarios considered. The scenarios as shown in Figure 4.9 include (a)green areas with shrubs, (b) green areas with small trees, (c) green areas with medium trees and (d) green areas with large trees. These results are represented in table 4.3 and 4.4 below and also in charts in Fig. 4.10 for Grey concrete pavements, Fig. 4.11 for asphalt pavements and Figure 4.12 shows the comparison of all scenarios using each of the materials

Table 4.3 Results showing change in temperature and percentage change in temperature using grey concrete pavement

Simulation Scenarios	Air Temperature (Ta) using grey concrete pavement (°C)	Difference in temperature (°C) [*Base temperature=30.91°C*]	Percentage difference in temperature (%)
Scenario A	27.04	3.87	12.5%
Scenario B	26.60	4.31	16.20%
Scenario C	25.53	5.38	17.4%
Scenario D	25.27	5.64	18.25

Source: (Researcher, 2016)

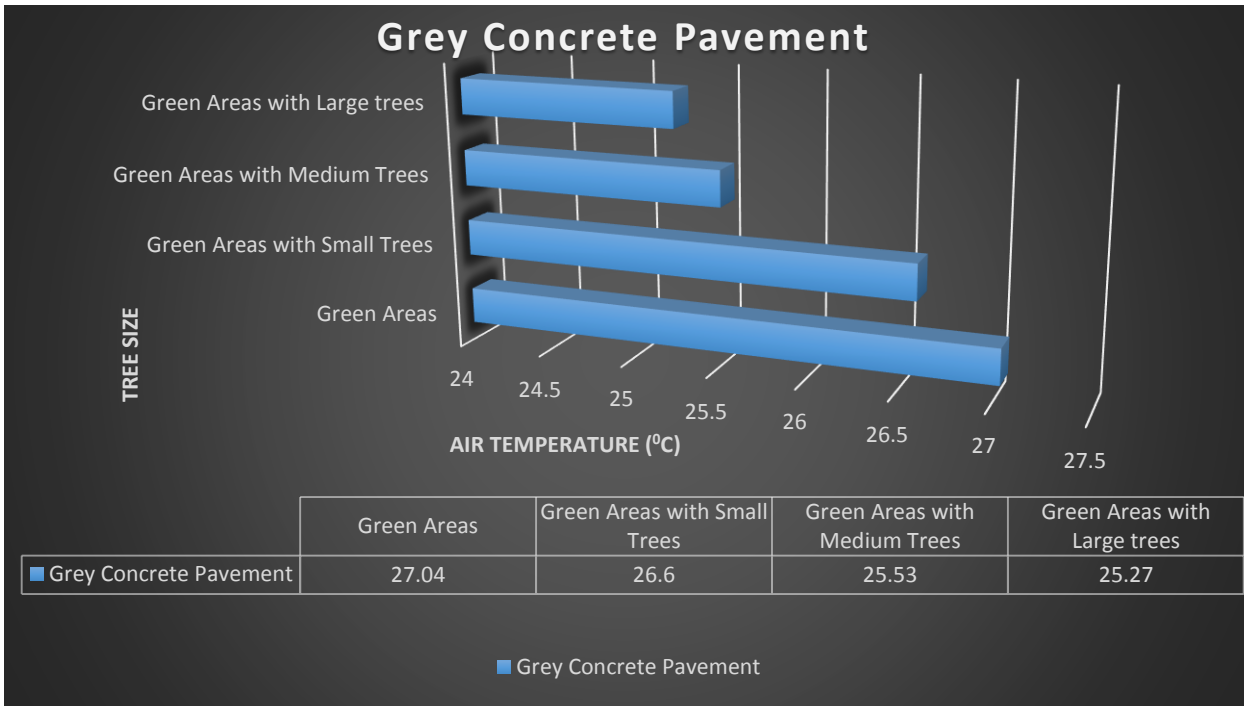


Figure 4.10 Change in temperature from the different simulated scenarios using concrete pavement, Source: (Researcher, October 2016)

Table 4.4 Results showing change in temperature and percentage change in temperature using asphalt pavement

Simulation Scenarios	Air Temperature (Ta) using asphalt pavement (°C)	Difference in temperature (°C) [*Base temperature=30.91°C*]	Percentage difference in temperature (%)
Scenario A	31.38	-0.47	-1.52%
Scenario B	30.19	0.72	2.38%
Scenario C	25.52	5.37	17.43%
Scenario D	25.33	5.58	18.05%

Source: (Researcher, 2016)

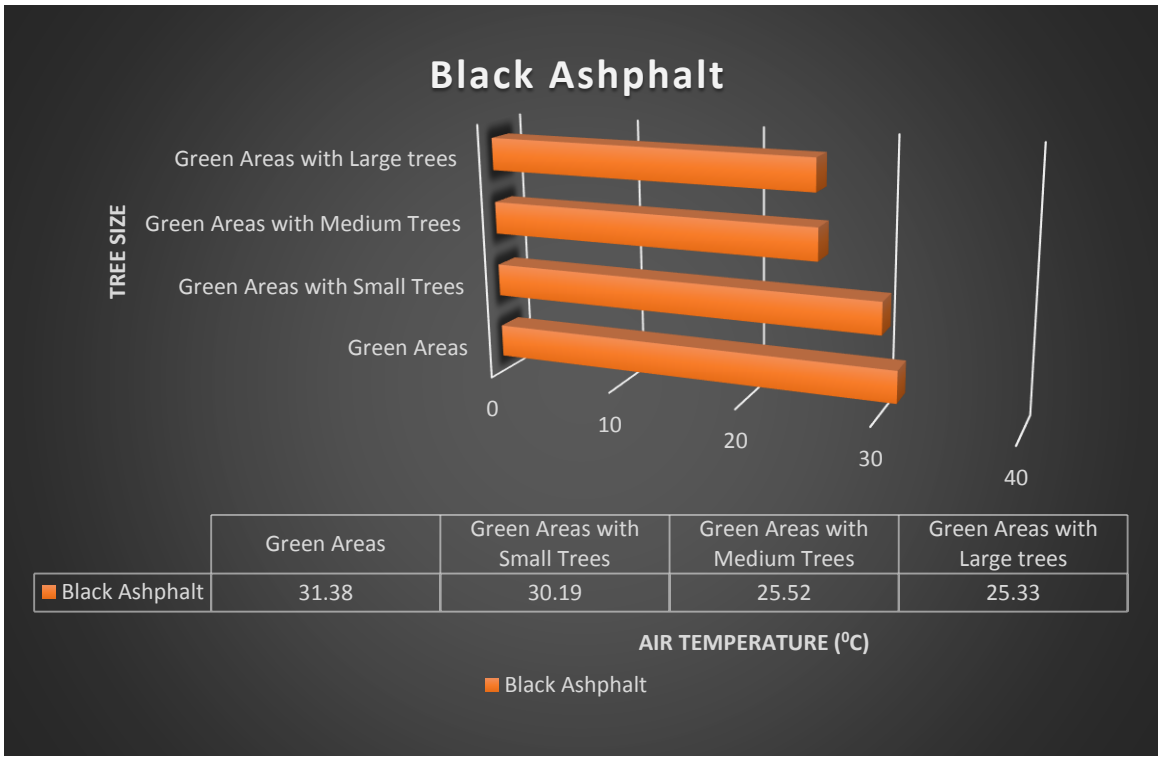


Figure 4.11 Change in temperature from the different simulated scenarios using asphalt pavement, Source: (Researcher, October 2016)



	Green Areas	Green Areas with Small Trees	Green Areas with Medium Trees	Green Areas with Large trees
Black Ashphalt	31.38	30.19	25.52	25.33
Grey Concrete Pavement	27.04	26.6	25.53	25.27

Black Ashphalt Grey Concrete Pavement

Figure 4.12 Comparison of all scenarios using each of the materials, Source: (Researcher, October 2016)

The chart above in Fig. XII shows the comparison between the change in temperatures of each scenario with the different surface materials.

4.11 Summary of Simulation results

The simulation results in this study shows that the longer side of a building positioned at 90° orientation to the true north (along the east and west axis) of as rectangular building is ideal for improving the microclimate. It could also be seen that scenario D using grey concrete pavement which has a high surface albedo has the best results with an optimum ambient temperature of 25.27°C and a difference of 5.64°C degrees from the base temperature of 30.91°C. This shows that the microclimate of an area can be improved by the use of low albedo surface materials and a range of small to large trees incorporated with green areas with a 12-18% decrease in temperature, proving that optimising the microclimate can augment thermal comfort.

5.0 THE SITE

5.1 Study Area (Profile)

5.1.1 Geography

The site for the Federal University Dutse was granted by the Jigawa state government who has acquired a piece of and located along Ibrahim Aliyu Bye pass township road Dutse, the capital town of Jigawa State. The site is located in a suburban environment that is ideal for learning teaching and research. The town of Dutse where the proposed University campus is to be sited is about 92 kilometres from Kano. The fourth largest city in Jigawa state with an estimated population of 17697 is located on Longitude of 920'3.012''E, Latitude of 11446'39.000''N and altitude 408m. The campus site which is approximately 500 hectares is trapezoidal shaped land, located around a central coordinate of 10º03'31.17'' North and 07º23'15.48 East with average elevation of 440 meters. Essentially the site is an open undulating landscape of low relative relief without prominent geomorphological features. It consists of a slightly tilted undulating plain with relatively moderate slopes. The site's cross section shows that north is relatively on higher grounds having elevation of about 450m above sea level, while the lowest end with an elevation of 430m (above sea level) is to the central area of the site. The campus has internal relief of 20m. land slopes on plain range mostly from 2%-10% covering over 95% of the site. Figure 5.1 illustrate the map of Nigeria showing Jigawa State.



Figure 5.1 Map of Nigeria showing Jigawa State, Source: (Google.com, 2016)

5.1.2 General Climatic Data

The climate of Jigawa state is semi-arid, characterised by a long dry season and a short wet season. The climatic variables vary considerably over the year and are erratic. The mean annual temperature is about 25^0C but the mean monthly values ranges between 21^0C in the coolest month and 31^0C in the hottest month. However, the mean daily temperature could be as low as 20^0C during the months of December and January when the cold dry harmattan wind blows from the Sahara Desert. Evapotranspiration is very

high and relative humidity is the highest in August (up to 80%) and low in January through March (at about 23-30%) when it is moderated by the harmattan. The year is characterised by well-marked dry and wet seasons. Wet season is roughly four months (June to September) and dry season is seven to eight months (October to May). The total annual rainfall ranges from 600mm in the north to 1000mm in the southern parts of the state. Great variations occur in the in annual total rainfall and may result in severe and prolonged droughts, which cause crop failures, death of livestock and overall human sorrow (Jigawa State, 2003).

5.2 Site Location

The university campus site is located along Ibrahim Aliyu Bye-pass, Township road, Dutse, Jigawa State. The site is located in a suburban environment about 90 kilometres away from Kano. The campus site which is approximately 500 hectares is a trapezoidal shaped land at a central coordinate of 10º03’31.7” North and 07º23’15.48 East with an average elevation of 440 meters. The various sites allocated for students’ accommodation on the university campus are generally within 250m of the academic core. The academic core is largely in one area while other zones such as the residential zone is split and laid out bearing in mind convenience, aesthetics, associated or interrelated activities e.t.c.

5.3 Site Selection Criteria

The Federal University Dutse’s draft of the physical master plan outlines the determination of the development potentials of the different segments (including the residential segment) of the campus site which were based on criteria such as:

i. Availability of developable contiguous expanse of land
ii. Presence of or level of exposure to environmental constraints
iii. Accessibility or remoteness from major transportation routes

iv. Relationship with existing infrastructure and services

v. Compatibility of the site to adjoining developments

vi. Proximity of site to a natural landscape element

vii. Land-use compliance

viii. Proximity to basic amenities

ix. Size of site, possibility for expansion, suitability and availability. The site should be large enough to accommodate the design

x. Soil on site should be fertile and able to support plant life for the landscape. It should also have a good load bearing capacity

xi. Site should have drainage and waste disposal possibilities

5.4 Site Analysis

The physical, climatic, and general features of the site were analysed in order to identify the possible opportunities that will be utilised for a better design and also to take note of the threats and to take possible measures that will reduce their effect to the building. The following are features that were noted during analysis of the site.

5.4.1 Climate

5.4.1.1 Rainfall (Percipitation)

Monthly precipitations above 150mm are mostly wet, below 30mm mostly dry. Dutse has highest precipitation in August which measures slightly greater than 100mm and mostly dry from November to February with little or no rainfall in March. This is shown graphically in Fig. 5.2 and 5.3 below.

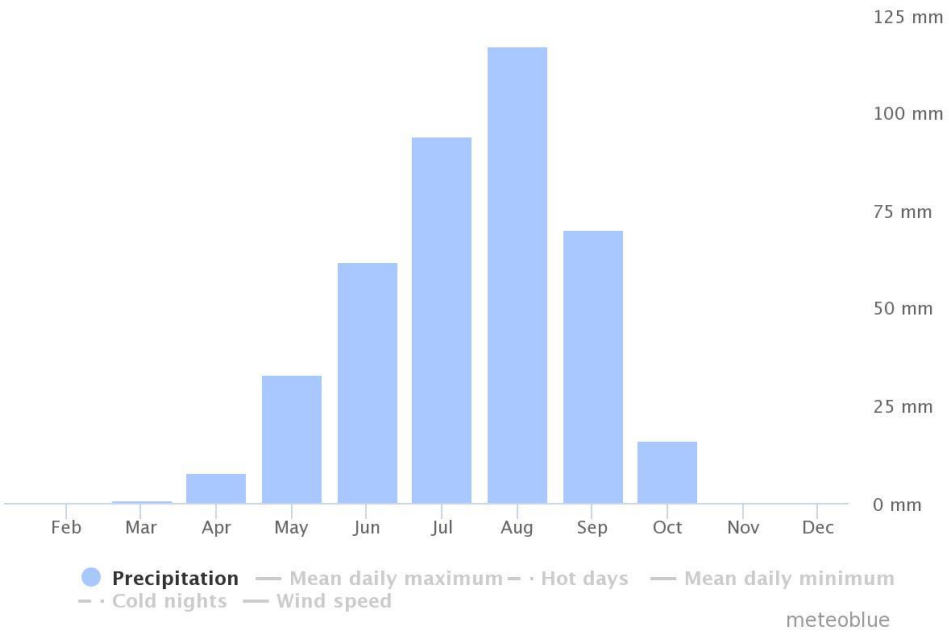


Figure 5.2 Percipitation diagram for Dutse showing rainfall levels, Source: (Meteoblue, 2016)

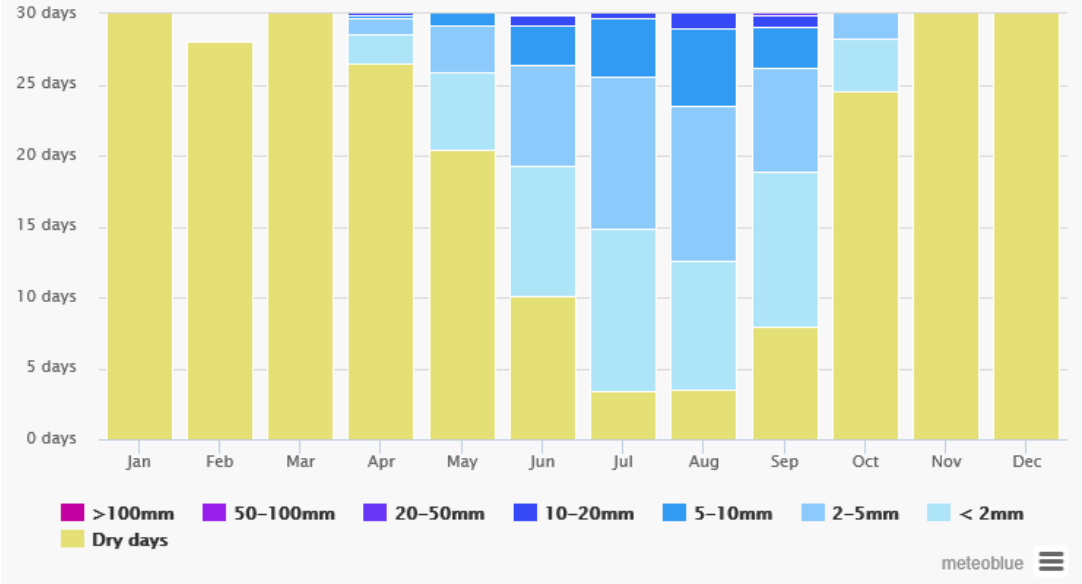


Figure 5.3 The precipitation diagram for Dutse shows on how many days per month, certain precipitation amounts are reached, Source: (Meteoblue, 2016).

5.4.1.2 Temperature

The "mean daily maximum" (solid red line) shows the maximum temperature of an average day for every month for Dutse. Likewise, "mean daily minimum" (solid blue line) shows the average minimum temperature. Hot days and cold nights (dashed red and blue lines) show the average of the hottest day and coldest night of each month of the last 30 years.

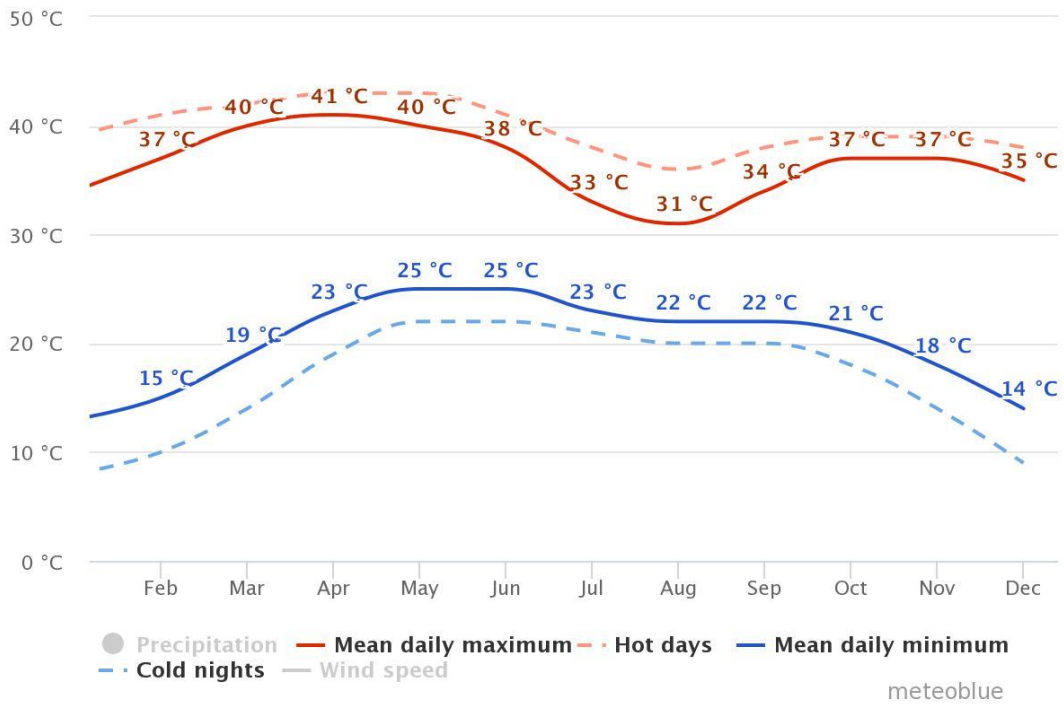


Figure 5.4 Average hot and cold temperatures of Dutse, Source: (Meteoblue, 2016).

The maximum temperature diagram for Dutse below displays how many days per month reach certain temperatures. Dutse has most of the hottest days in April with temperatures above 40°C. It also shows the cooler days with temperatures below 25°C. This is illustrated in Fig. 5.4 and 5.5.

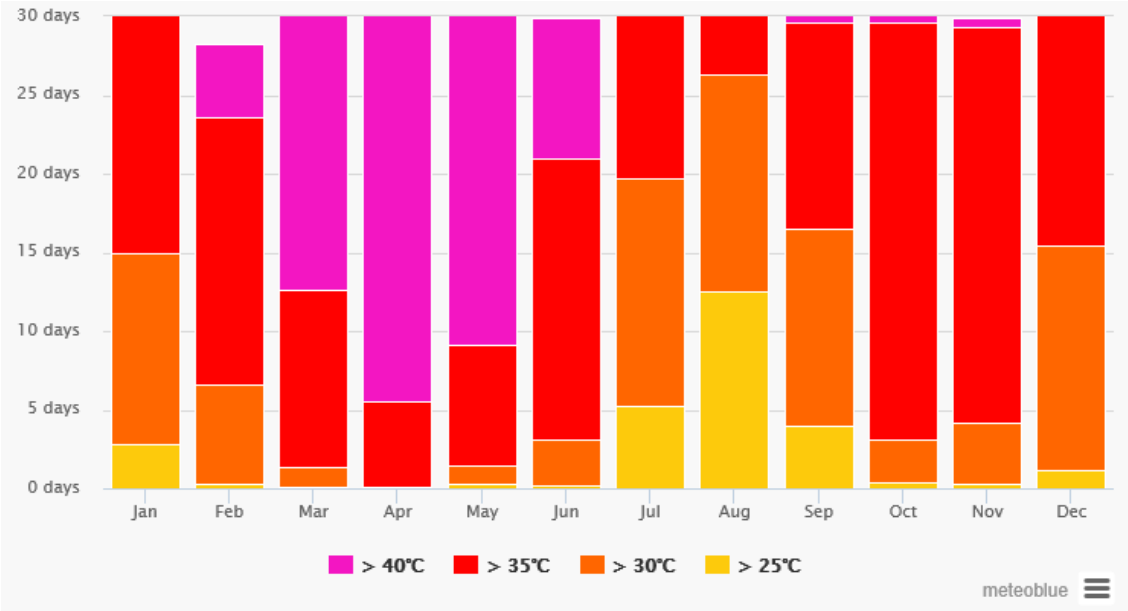


Figure 5.5 The maximum temperature diagram for Dutse below displays how many days per month reach certain temperatures, **Source**: (Meteoblue, 2016).

5.4.1.3 Sunshine and Cloud cover

The graph shows the monthly number of sunny, partly cloudy, overcast and precipitation days. Days with less than 20% cloud cover are considered as sunny, with 20-80% cloud cover as partly cloudy and with more than 80% as overcast. This is illustrated in Fig. 5.6.

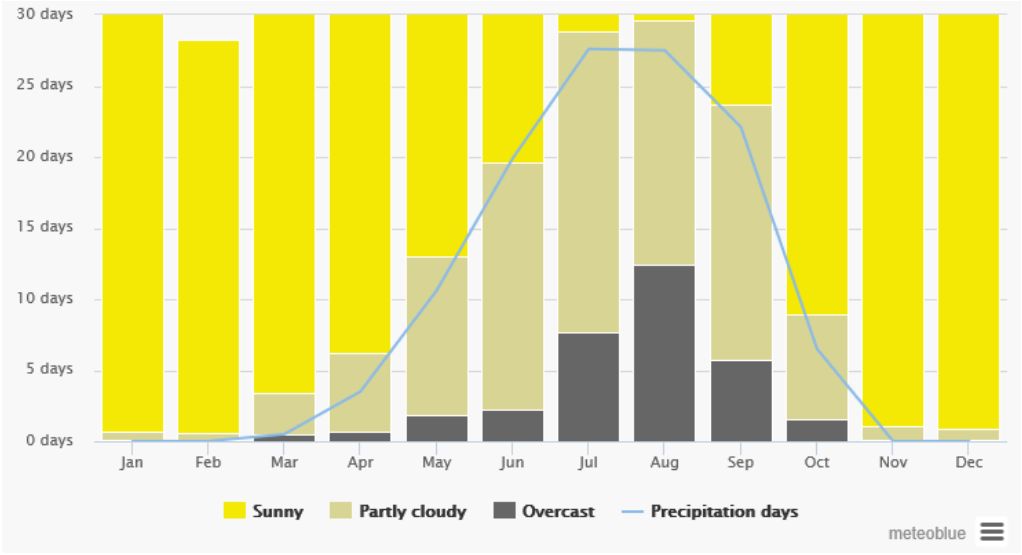


Figure 5.6 The monthly number of sunny, partly cloudy, overcast and precipitation days, **Source**: (Meteoblue, 2016).

5.4.1.4 Wind

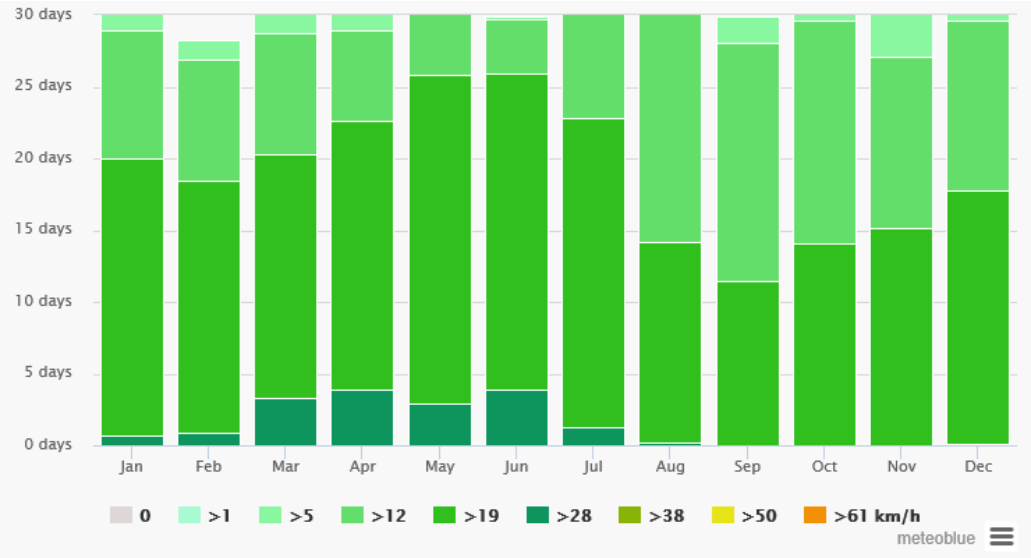


Figure 5.7 The diagram for Dutse shows how many days within one month can be expected to reach certain wind speeds, Source: (Meteoblue, 2016).

The wind rose for Dutse in Fig 5.8 shows how many hours per year the wind blows from the indicated direction. Example SW: Wind is blowing from South-West (SW) to North-East (NE).

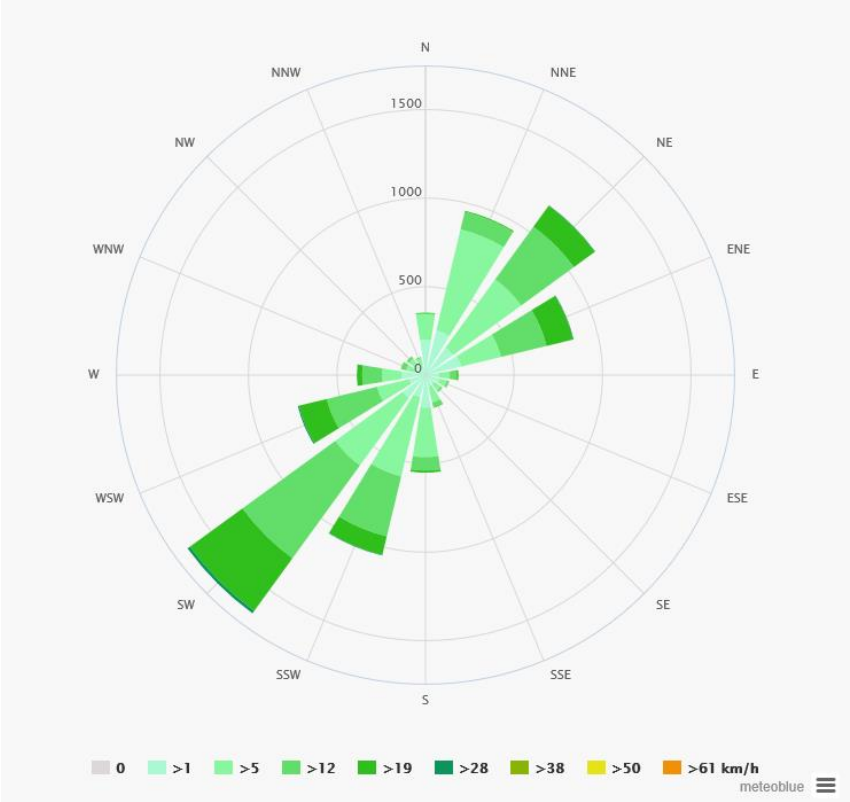


Figure 5.8 Wind rose for Dutse, Source: (Meteoblue, 2016)

5.4.2 Topography

The topography of the site relatively flat and has a Low lying strip of land with 0.5% gradient sloping towards the north-west end of the site. Site drainage would take this direction in order to use the concept of natural gravity. While the water supply should come from south-eastern direction in order to also use the principle of natural gravity.

5.4.3 Vegetation

Vegetation of the site is characterised by crop plants temporarily farmed on the site. Presence of medium trees.

5.4.4 Site Features

There are no special site features on the site except for the plants, grasses and few trees on site, service lines and access roads.

5.4.5 Services

Services like electricity power lines, water supply lines, telephone services, access roads and drainages are all available on site. The site is accessed from access road 3a and 3b (see Fig.5.9).

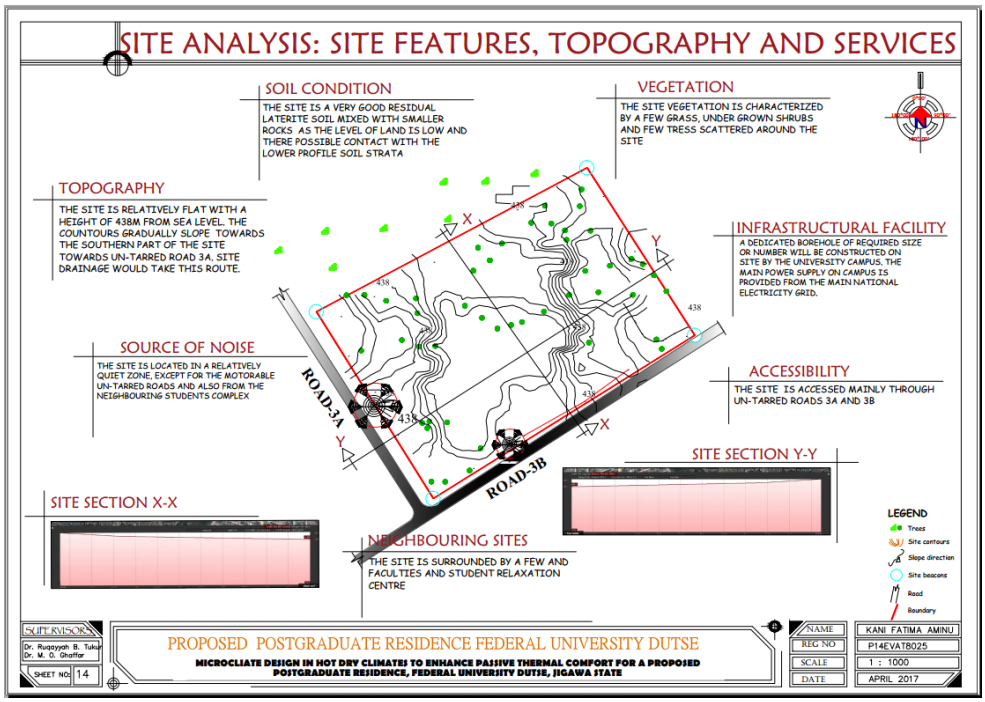


Figure 5.9 Site analysis showing site features topography services and vegetation of the proposed site, Source: (Researcher, 2017)

6.0 DESIGN DEVELOPMENT

6.1 Brief Development

CLIENT: Federal University Dutse, Jigawa State.

The Federal Government of Nigeria in 2010 took the decision to establish 9 additional universities nationwide, to address the twin challenges of qualitative access and equitable educational development of states in the Federation. The Federal University Dutse is one of the 9 universities approved nationwide for immediate take-off under this initiative.

33%- 40% of a school population is the acceptable student population to be accommodated on a university campus by the National University Commission (NUC). A total of 10,000 students is projected by the university in which 19% of the population will be postgraduate students. The total number of postgraduate students estimated is 1,900 making the acceptable number (40%of 1,900) of postgraduate students to be accommodated on campus to be 760 postgraduate students.

PGR, Federal University Dutse aims at providing a variety of safe and comfortable housing options for its postgraduate students, postgraduate students with families, post-doctoral researchers and visiting lecturers with a living environment that offers support and assistance that maximise their educational opportunities. All postgraduate students are to be accommodated in single rooms with adequate provision for toilet and bath in student hostels. PGR is to provide separate students hostel for males and females, common student facilities such as halls as part of strategy to promote healthy relationships and interpersonal skills and activities.

6.2 Concept Development

The concept idea adopted for the development of the proposed Postgraduate Residence (PGR), Federal University Dutse is the cluster development.

The cluster development is a site planning approach which practices low impact developments that groups residential properties in proposed subdivisions in order to utilise the rest of the land for open space, recreation or agriculture. The purpose of the cluster developments is to:

i. Primarily to create more area for open space, recreation and more social interaction.
ii. Promote integrated site design that is considerate to the natural features and topography.
iii. Protect environmentally sensitive areas of the development site, as well as permanently preserve important natural features, prime agricultural land and open space.
iv. Minimise non-point source pollution through reducing the area of impervious surfaces on site.
v. Encourage saving costs on infrastructure and maintenance through practices such as decreasing the area that needs to be paved and decreasing the distance that utilities need to be run.

The landscaping of the site takes the form of a “Triquetra”. This is a symbol with three interlocked loops created by the intersection of three circles, there is no beginning and there is no end to the knot work (see Fig. 6.1 and 6.2). This Triquetra in this design symbolises the three forces of nature; Earth, Air and Water. A circle is drawn in the triquetra to mean protection as well as symbolise spiritual unity.

The idea of the "Veins of a leaf" were also adopted. The veins serve as the support system of the leaf that provides it with water and nutrients. This was adopted in the design to provide primary road network on the site as well connecting walk ways between the interlocking circles.

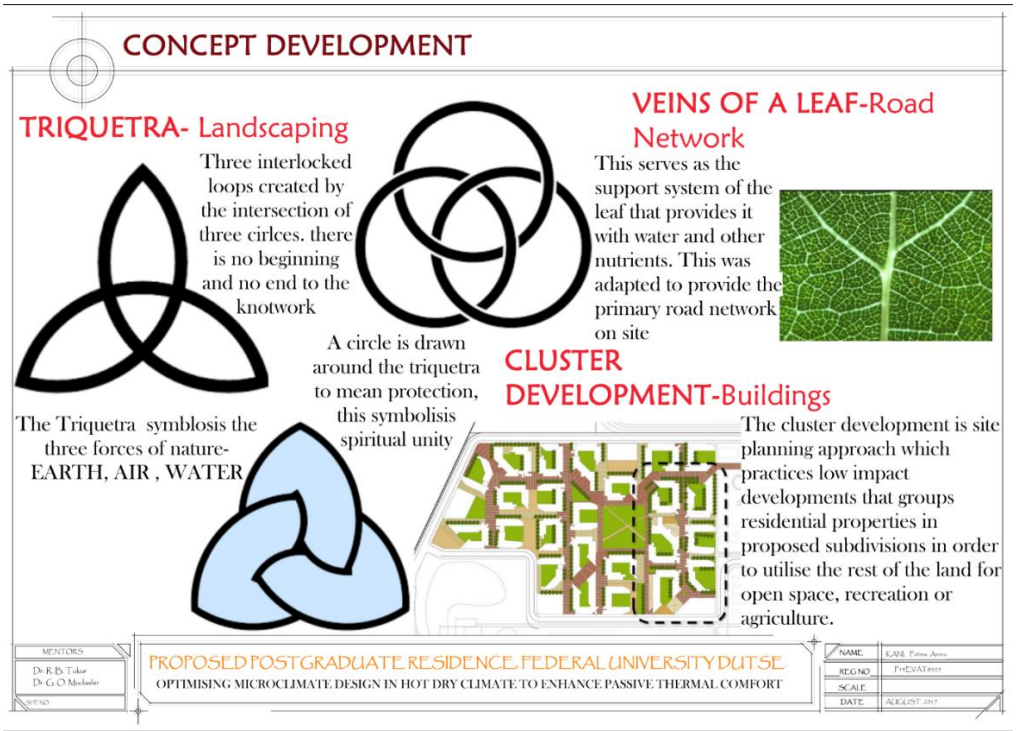


Figure 6.1 Concept development sheet, Source: (Researcher, 2017)

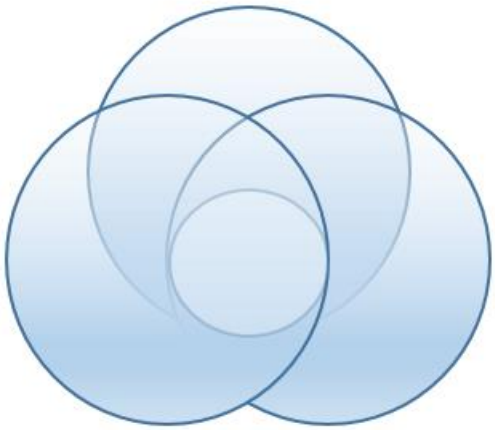


Figure 6.2 A Triquetra symbol, Source: (Google, 2017)

6.3 Architectural Philosophy

The overriding philosophy is to create a functional parkland university century community that:

i. Attracts all positive social elements, including spatial correlation, an effective interplay of the indoor and outdoor, a sense of well-being which actively draws strength from diversity and inclusiveness.

ii. Recognises the social and academic dimensions of campus life and sets out to interlink them unequivocally.

iii. Accords priority to concept of sustainability and embeds the goal of clean carbon-neutral environment. There is therefore great focus on energy efficiency.

iv. Infrastructure development will emphasise on renewable energy and a privately operated recycling plant is part of the campus's early development.

v. Maximally deploys ICT as an integral part of overall strategy of sustainability, allowing instructions to be delivered on-line.

vi. Anticipates the ecological evolution of the green field site by modelling the impact of development on the flora and fauna.

vii. Creates a haven for research and learning.

The architectural details also reflect this philosophy, especially in making maximum use of daylight in buildings thus lowering energy demand, rolling the indoor and outdoor into a continuum for spatial efficiency and ease of maintenance, simulates the natural human activity flow so that redundancies are minimised and works the landscape to achieve a symbiotic interaction with nature.

6.4 Design Descriptions

6.4.1 Site Zoning and development

The proposed site was zoned based on Noise into three zones. Quite zones, semi-quiet zone and noisy zone. This is illustrated in Fig. 6.3. this site zoning was further used in creating the site development plan. The site development plan was created in order to aid in positioning the facilities of the site in accordance with the site zoning. This is illustrated in Fig. 6.4.

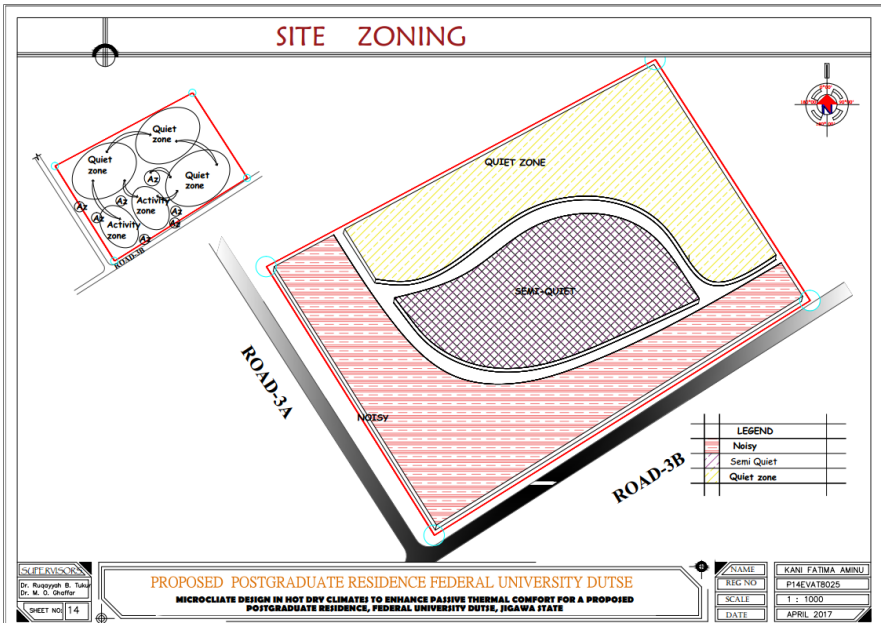


Figure 6.3 Site Zoning based on Noise, Source: (Researcher, 2017)

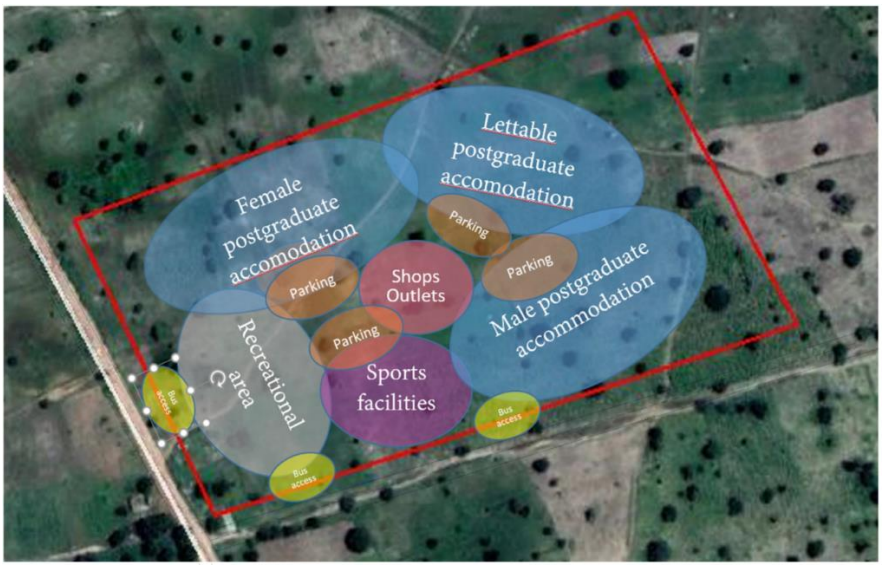


Figure 6.4 Site development plan of the proposed site, Source: (Researcher, 2017)

6.4.2 Site Planning

The Postgraduate Residence site design provides facilities such as the student residential accommodation in three categories; separate male and female residences and a transient quarters, residence facilities, recreational areas and gathering areas, a shopping outlet, sports facilities and parking areas. A triquetra in this site design is used in grouping each residence category as a macro cluster (See Fig. 6.5). The site can be accessed through the primary road from access road 3A.

A lot of consideration was taken based on the landscaping of the site. Large trees with and average height of 15m are positioned around the perimeter of the site to serve as noise buffers as well as screens for privacy. Large trees were also used by the primary road to aid in shading the road in order to reduce the amount of solar radiation that reaches the road thus limiting its heat absorption. The site provides central parking spaces for both administrative staff and students facing the administrative blocks. Extra parking spaces are provided for the students behind each macro cluster. Walkways are positioned and well defined on site to aid pedestrian movement on site.



Figure 6.5 Site Plan of the proposed PGR, Source: (Researcher, 2017)

6.4.3 Studio Bedrooms (Cluster Type A)

These are one-bedroom spaces with an en suite bathroom, balcony, wardrobe space and a kitchenette. This prototype houses twelve (12) of each studio bedroom unit, a laundry and a maintenance/storage room on every floor with a well-designed general courtyard See Fig. 6.6). It has four (4) floors with a total of forty-eight (48) rooms in a cluster. This cluster type is eight (8) in number each in the male and female residence macro clusters. There are a total of three hundred and eighty-four (384) studio bedroom units in each macro cluster.



Figure 6.6 Floor Plan of a typical Studio flat Cluster (Cluster type A), Source: (Researcher, 2017)

6.4.4 Studio flats (Cluster Type B)

These are open floor plan bedroom and living spaces (room divider provided for privacy) with en suite bathroom, balcony, wardrobe space and kitchenette. The difference between the studio bedroom and the studio flat is the presence of a living space in the studio flat. This prototype houses ten (10) of each studio flat unit, a laundry and a maintenance/storage room on every floor with a well-designed general courtyard (see Fig.

6.7). It has three (3) floors with a total of thirty (30) rooms in a cluster. This cluster type is two (2) in number each with a total of sixty (60) units in the male and female residence macro clusters. There are four (4) of this cluster type in the transient quarters with a total of one hundred and twenty (120) units.



Figure 6.7 Floor Plan of a typical Studio Flat Cluster (Cluster type B), Source: (Researcher, 2017)

6.4.5 2 Bedroom Apartments (Cluster Type C)

This cluster type is only provided in the Transient Quarters macro cluster. A transient quarters is mainly a place that consists of rooms and flats used as a temporary residence for visiting lecturers and post-doctoral researchers on sabbatical ranging on an average period of one year. This Quarters also supports students with families. The two-bedroom prototype provides an open floor plan living and kitchenette space with two bedrooms each having an en suite bathroom and wardrobe spaces with a well-designed general courtyard (See Fig. 6.8). The living area has a balcony so also the two rooms share a common balcony. The cluster is in two (2) parts with six (6) units on each part. There are 12 units on the ground floor and this cluster type has 3 floors providing a total of thirty-

six (36) units in each cluster. This cluster type is two (2) in number in this macro cluster providing a total of seventy-two (72) units.



Figure 6.8 Floor Plan of a typical 2 Bedroom Apartment Cluster (Cluster type C), Source: (Researcher, 2017)

6.4.6 Residence facilities

The PGR has facilities such as managements offices, kiosks, cafeteria with kitchen, common room, parking lots. The common room provides area for viewing and gaming.

6.4.6.1 Administrative Block

The administrative block houses offices of the Hall Administrator, Assistant hall admin., maintenance office, porters' offices, shops/kiosks, staff toilets, crèche facilities and a cafeteria designed with an outdoor eating area provided with kitchen facilities having an outdoor cooking area (See Fig. 6.9).



Figure 6.9 Floor Plan of Administrative Block, Source: (Researcher, 2017)

6.4.6.2 Common Room

The common room is a hall area provided as part of strategy to promote healthy relationships and interpersonal skills and activities between the residents. This hall provides a viewing area with an indoor gaming area, indoor games deck on the mezzanine floor with toilets accessible from the exterior of the building and storage area under the staircase (see Fig. 6.10).

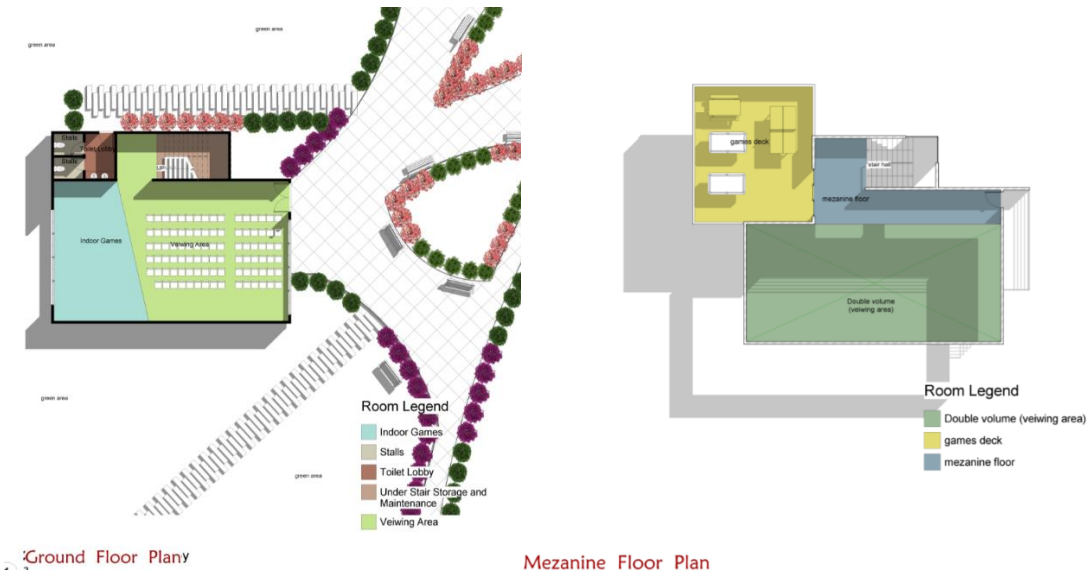


Figure 6.10 Floor plan of the Common room, Source: (Researcher, 2017)

6.4.6.3 Courtyards

Every cluster prototype has been designed with courtyards. The courtyards have been well landscaped with shrub trees with pebble beds, pervious concrete pavements for walkways, sit-outs, water fountains for evaporative cooling and medium sized trees with an average height of 9 meters for shading in the courtyard. Courtyards are essential because as a result of incident solar radiation in the courtyard, the air in the courtyard becomes warmer and rises up as a result of stack effect.

6.4.6.4 Laundry

The cluster prototypes in the general PGR have laundry rooms provided on every floor for easy use by the occupants.

6.4.7 Recreational and public areas

The PGR has a park area which is essential for recreation. A shop complex space is provided for which make available shop outlets, computer kiosks, eateries and a gymnasium. A sports area is also provided for sports with facilities such as basketball, football, volley ball, hand ball, badminton and lawn tennis.

6.5 Microclimate design strategies applied in design

6.5.1 Open spaces

i. Use of cluster housing development to create more area for open space, recreation and more social interaction.

ii. Provision of outdoor spaces such as reading gardens, green areas and recreational areas.

6.5.2 Water surfaces

Water surfaces positioned in courtyards and open spaces as evaporative cooling employs the latent heat of evaporation of water for cooling as the air is humidified through water fountains.

6.5.3 Landscape

Well defined landscaped areas with designated pedestrian walkways, roads and parking areas.

6.5.4 Building type and form

Building type and form are cluster settlements of high low rise buildings were implemented to achieve compactness which aids in mutual shading.

6.5.5 Vegetation

Medium trees are placed between clusters to aid shading and serve as a screening element.

Large trees were used to shade the main access road of the site and small trees to shade parking spaces.

6.5.6 Paved Areas

Reducing the amount of paved areas to be provided by providing general parking lots in each macro cluster.

6.5.7 Reflective surfaces

i. Reflective surfaces were provided using materials with high albedo and porous surfaces such as pervious concrete pavers in the sit out gardens and grasscrete for parking areas.
ii. Use of light colours on areas to provide reflective surfaces such as walls with cream, white and light brown emulsion paints as they have less heat absorptivity properties

6.5.8 Cool roofing

Use of cool roofing system through the application of a highly reflective coating on the roof surfaces to reflect heat and reduce surface absorptivity.

6.6 Hot Dry Climate Design Considerations applied in design

6.6.1 Building type and form

Building type and form are cluster settlements of high low rise buildings were implemented to achieve compactness as living spaces are required to be protected against solar radiation, glare and dusty winds.

6.6.2 Building shape

Building shape is compact, yet somewhat elongated along the east-west axis because large, compact building volumes gain less heat. Application of group arrangements of rooms (all continuous along the east-west axis) to create a volumetric effect.

6.6.3 Building orientation

All the buildings are positioned with their longer sides facing the north south axis, so that the rooms and buildings get minimum solar exposure.

6.6.4 Roofing

Roofing makes use of mono pitched and hipped flat roofs as they have less roof surface area for heat absorptions.

6.6.5 Natural ventilation

Natural ventilation is provided in the rooms as they are all adequately cross ventilated. Natural ventilation keeps the air moving within the indoor environment for improved indoor air quality. A courtyard is provided to aid natural ventilation.

6.6.6 Courtyards

Use of well landscaped courtyards. Due to the incident solar radiation in the courtyard, the air in the courtyard becomes warmer and rises up as a result of stack effect

6.6.7 Evaporative cooling

Water fountains positioned in courtyards and open spaces as evaporative cooling employs the latent heat of evaporation of water for cooling as the air is humidified.

6.6.8 Shading

Balconies, vertical shading devices, screen walls and trees used for shading in the buildings and surroundings against direct solar radiation and its reflection.

6.7 Building Services

6.7.1 Service vents

Service vents are provided for ease of plumbing maintenance in the buildings.

6.7.2 Water supply

A dedicated borehole of required size or number will be constructed on site by the university campus as most sites and building either have dedicated or shared boreholes.

6.7.3 Power supply

The main power supply on campus is provided from the main national electricity grid. The campus plans to provide an independent power plant (IPP) on campus in the nearest future which will serve as a backup up power supply. So also, every cluster will be equipped with solar powered inverter systems.

7.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 Summary

Chapter one provides a background study of the research. It describes thermal comfort, the climate, climatically responsive buildings and university accommodation. This chapter further outlines the aim and objectives of the research. The scope of the research, research questions and justification of the researched are also outlined in this chapter.

Chapter two of this research explains thermal comfort, parameters that affect it and comfort limits. This chapter also discusses the university, Postgraduate residence and its facilities as well as microclimate design strategies. This was achieved through in-depth literature review of works related to this field.

The methodology of this research is explained in chapter three. Based on established selection criteria of postgraduate hostels in hot dry climates, case studies were carried out to determine the extent at which microclimate strategies were applied in each. One of the case studies was selected and simulated on for the purpose of a microclimate analysis.

Chapter four is a report of results and findings from the field work and simulation process. It covers a report of the case studies and results from the microclimate analysis. The research questions were answered in which most of the case studies poorly applied the microclimate strategies and results from the simulations gave about 12%-18% decrease in temperature after altering the dependent variables.

Chapter five discusses the choice for the selection of the proposed site and a thorough analysis of the site and its surrounding features.

Chapter six contains the design report. It discusses the proposed design form, the concept development, architectural philosophy, prototypes, organisational layout and

development. The application of the findings is clearly shown in the proposed design and have clearly been discussed in chapter six.

7.2 Conclusion

It is important to keep thermal conditions in buildings within acceptable limits in maintaining maximum human productivity and performance. Comfortable, healthier and sustainable living spaces can be obtained through a climatically responsive sustainable building design. This research aimed at optimising the microclimate of hot dry climates in order to improve the thermal environment. Cases were studies and were observed based on their level of application of the microclimate strategies and it was observed that most of this strategies were either absent or not properly applied. Based on the simulation findings, applying microclimate design strategies improve thermal comfort of a place up to 18% decrease in temperature. The buildings were designed based on the application of other thermal comfort principles to achieve thermally comfortable environment. Both microclimate and bioclimatic design principles were applied.

7.3 Recommendation

I. With the current urban heat island effect, it is recommended that sustainable methods such as microclimatic design strategies will important for the future climate. Therefore, building professionals should work together in an integrated approach focusing on how to improve the thermal performance of buildings; enforcing environmental and efficiency policies and encourage the development of the future environment.

II. Sufficient account must be taken in the micro-climate of Dutse especially to the building's form and configuration as the solar radiation is the most important parameter in this climate.

III. Sites should have well landscaped and defined to aid are purification, modification of air temperatures, provide shade and reduce solar absorption.

IV. Courtyard spaces should be adopted and well designed in order to optimise natural ventilation in buildings.

V. Evaporative cooling should be adopted in the hot dry climates of Nigeria as it aids in improving humidification of an environment.

7.4 Contributions to Knowledge

i. This study contributes by generating an appraisal of microclimate design as a passive technique for thermal comfort in postgraduate campus accommodations in the Nigerian Hot Dry climate.

ii. It contributes by demonstrating the assessment through a proposed design of a Postgraduate Residence with a conducive microclimate design in the Hot Dry climate of Nigeria.

iii. The assessment shows a range in 12-18% decrease in ambient temperature through the incorporation of high albedo surface materials and a range of tree sizes in the Hot dry climate of Nigeria.

iv. Shading devices and screen walls with Islamic mosaic patterns were introduced in the facades to depict the predominant culture of the area of Dutse.

v. It illustrates the application cool roofing systems through the use of highly reflective coating on roof surfaces to reflect heat and reduce surface absorptivity.

7.5 Areas of Further Research

This research was conducted in a Hot dry climate of Jigawa State using Students residential buildings. Further research can be carried out in other climatic regions within the country and other building typologies such as institutional and industrial buildings. Research on other passive cooling techniques can also be carried out for the same climatic

region or same state using the same typology. The challenge for this dissertation has been to create a conducive microclimate that will provide a passive thermal comfort in a postgraduate residence in hot dry climate of Dutse Jigawa. So further research can be;

i. This study is restricted to the micro-climate of Dutse, Jigawa State, further research can be done in other cities and climatic regions of Nigeria.
ii. There is need to replicate this research on other building typologies in order to ascertain the impact of the microclimate design strategies in such buildings.

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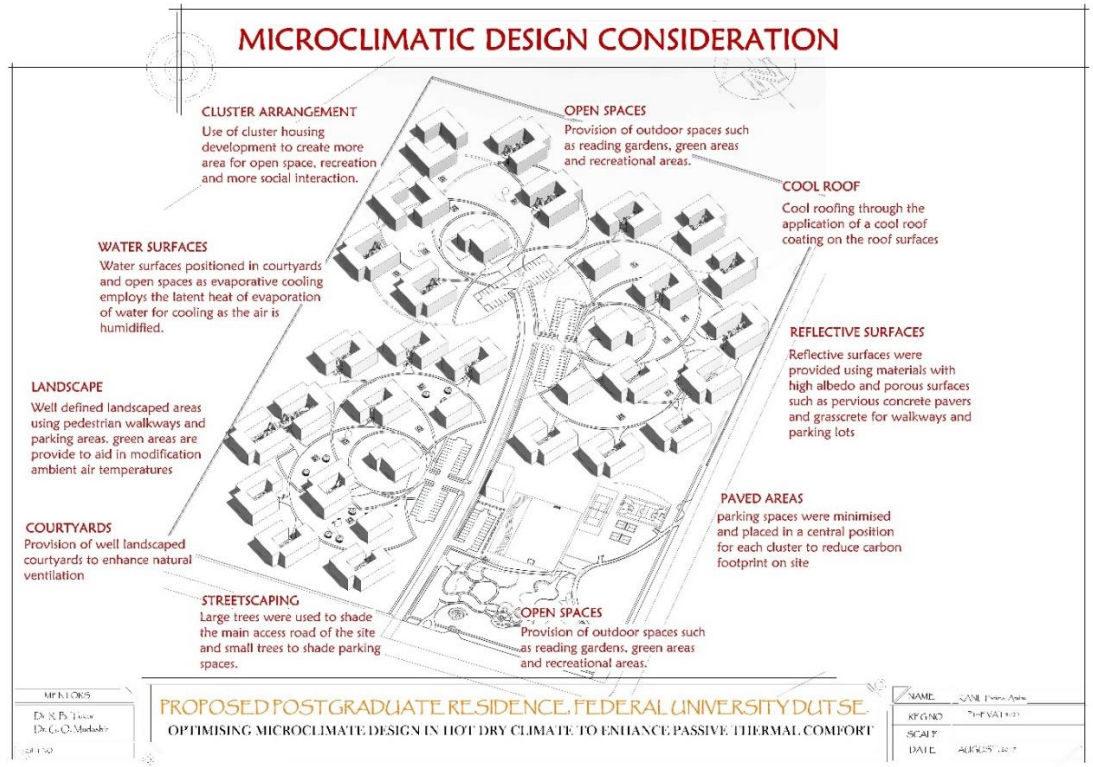
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APPENDICES

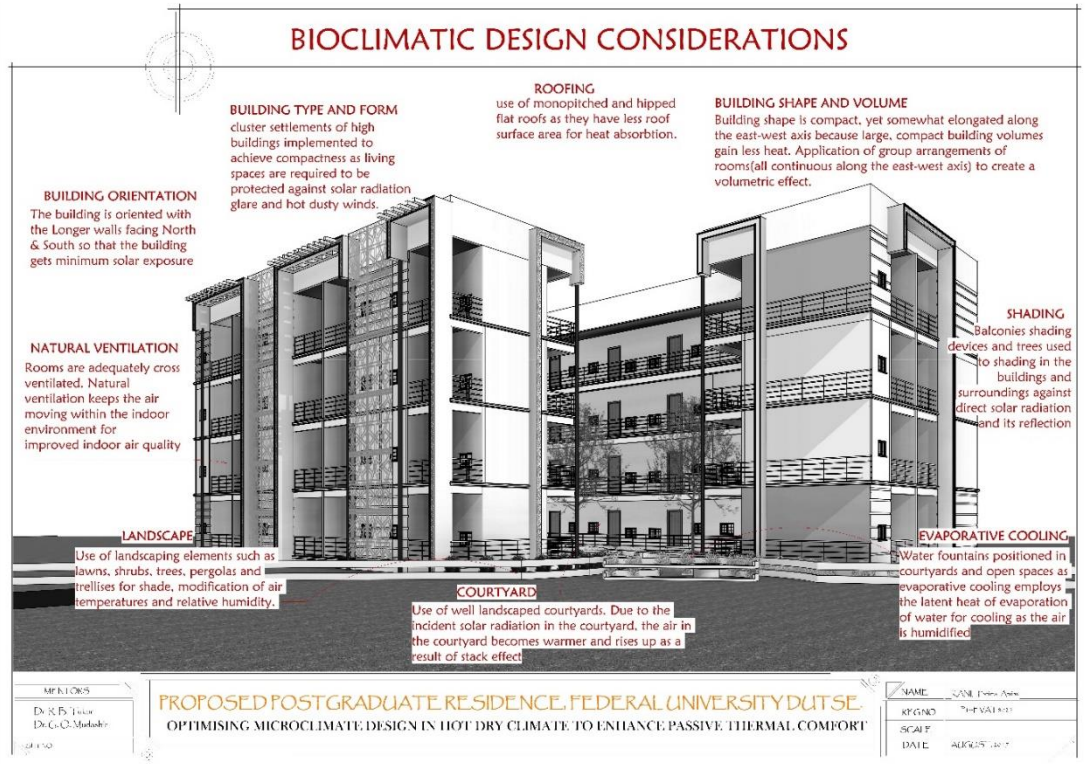
Appendix I

Microclimate Design Strategies applied in the design



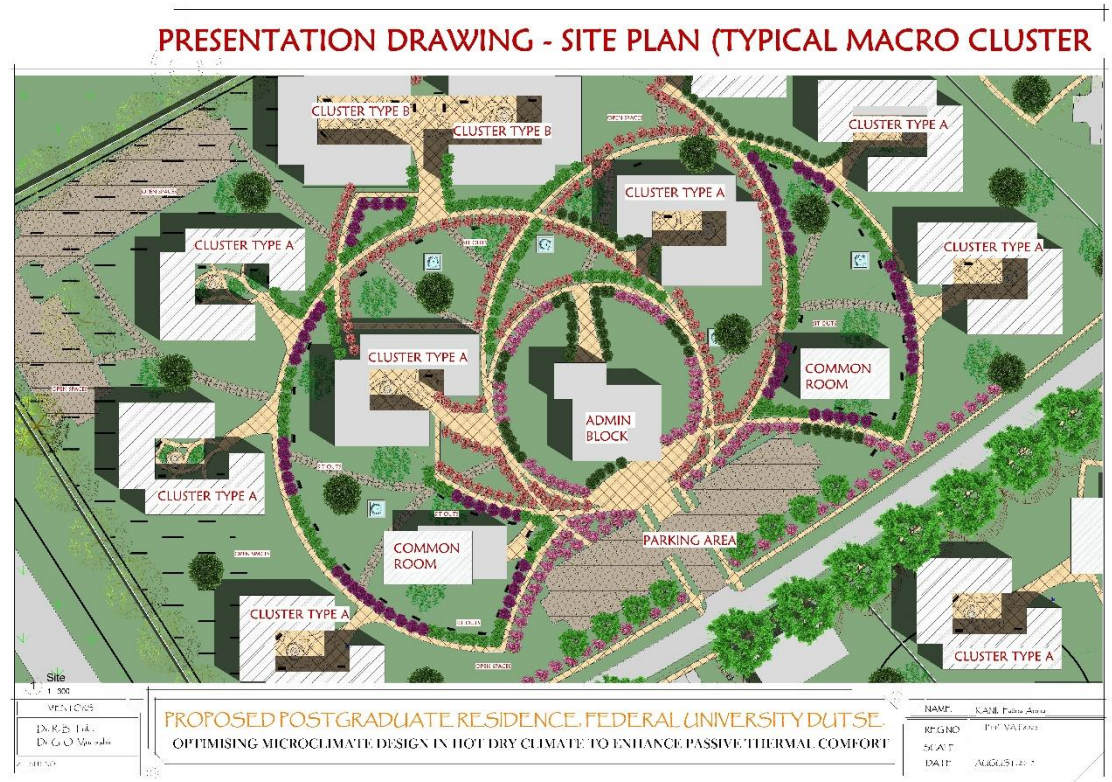
Appendix II

Bioclimatic principles applied in the design



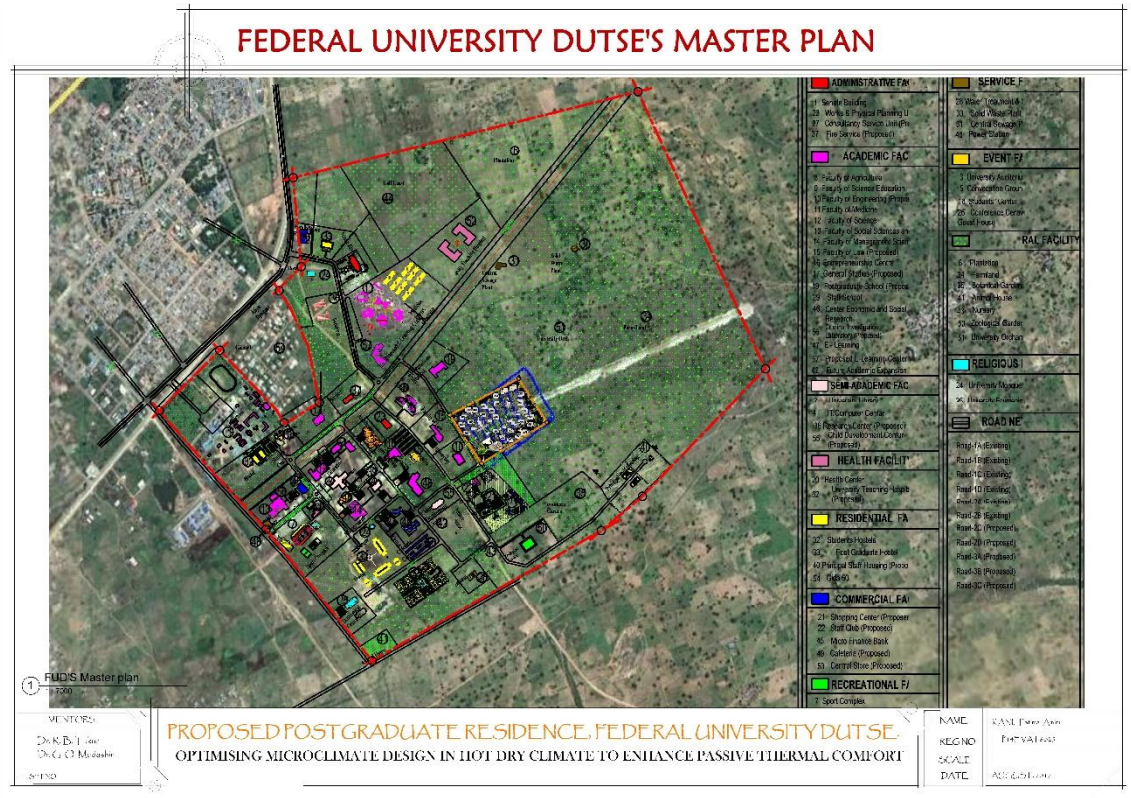
Appendix III

Site Plan of a typical Macro cluster of the proposed Postgraduate Residence, FUD



Appendix IV

Masterplan of the FUD showing the proposed site



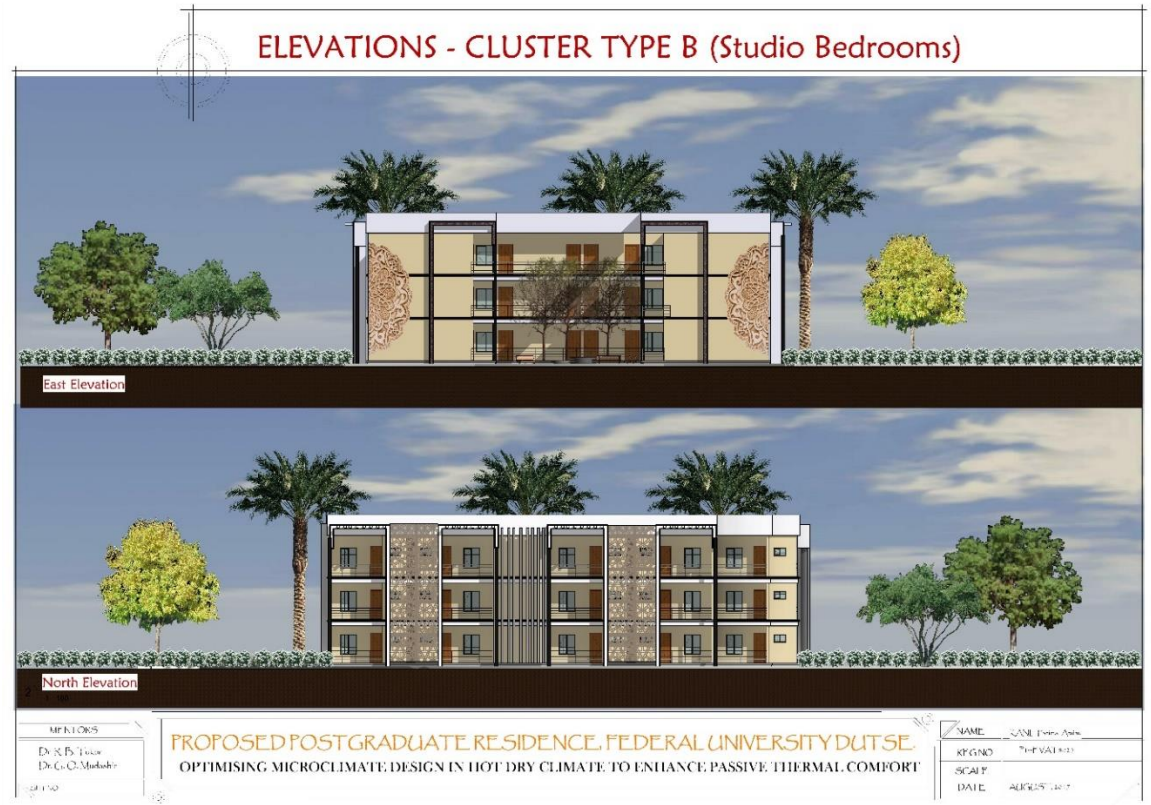
Appendix V

East and North elevations on cluster type A (Studio bedrooms)



Appendix VI

East and North Elevations of cluster type B (Studio flats)



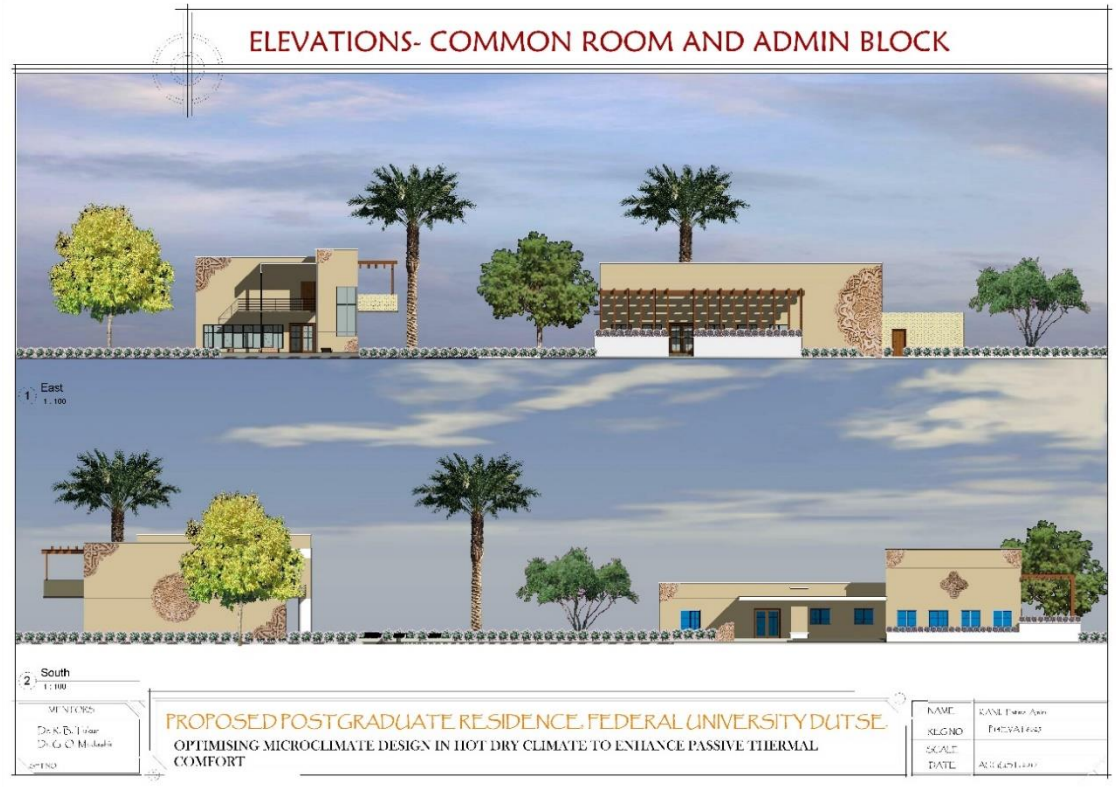
Appendix VII

East and South elevations of cluster type C



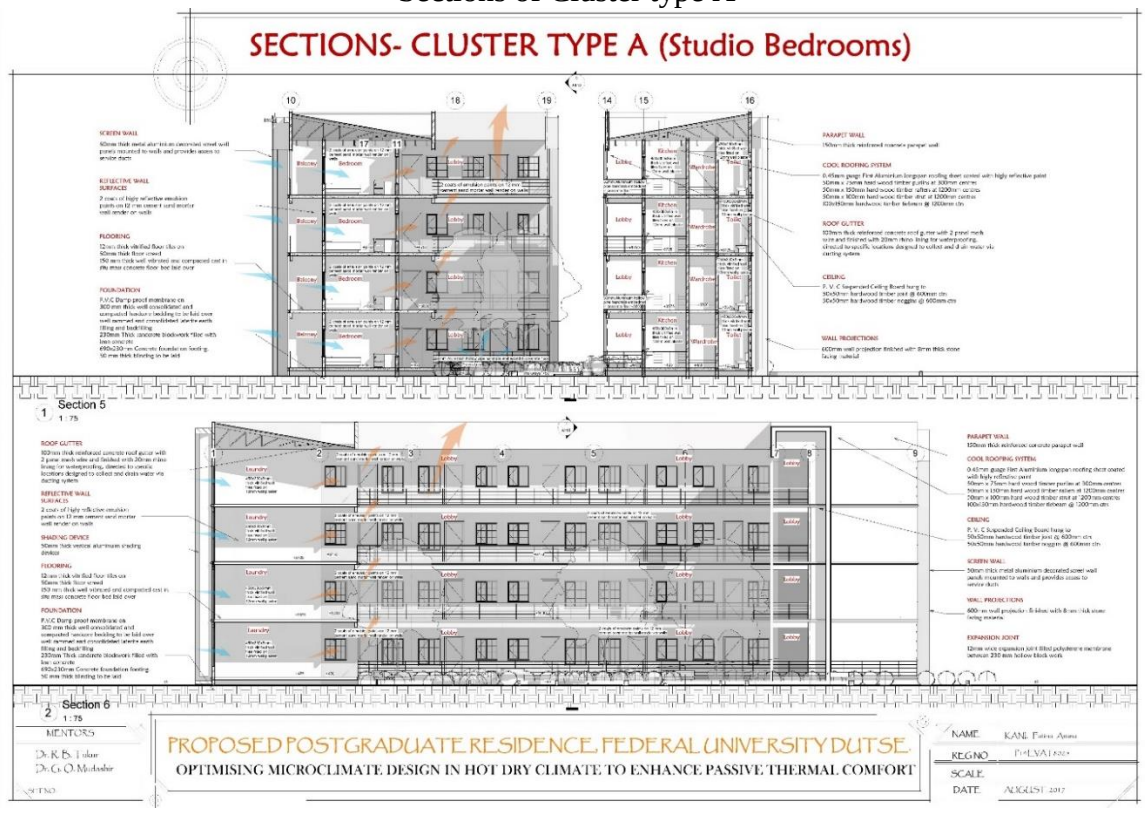
Appendix VIII

East and South Elevations of the Common Room and Administrative block



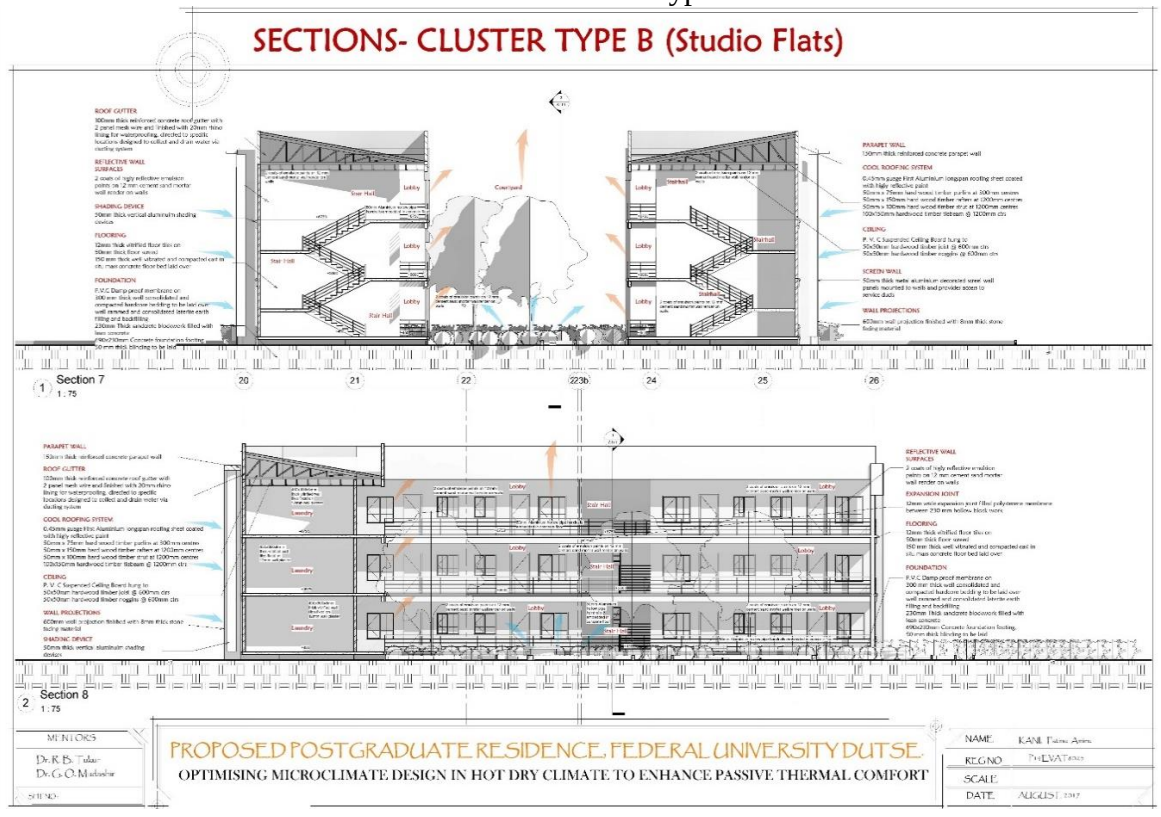
Appendix IX

Sections of Cluster type A



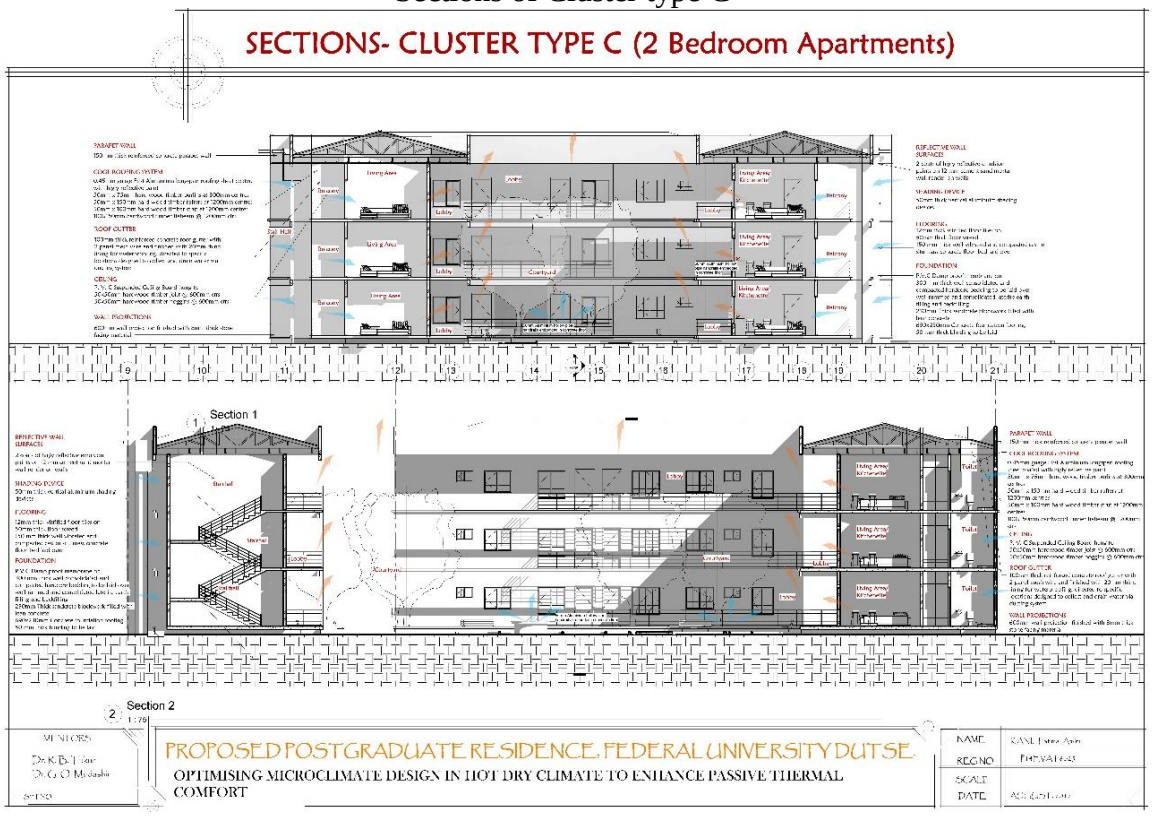
Appendix X

Sections of Cluster Type B



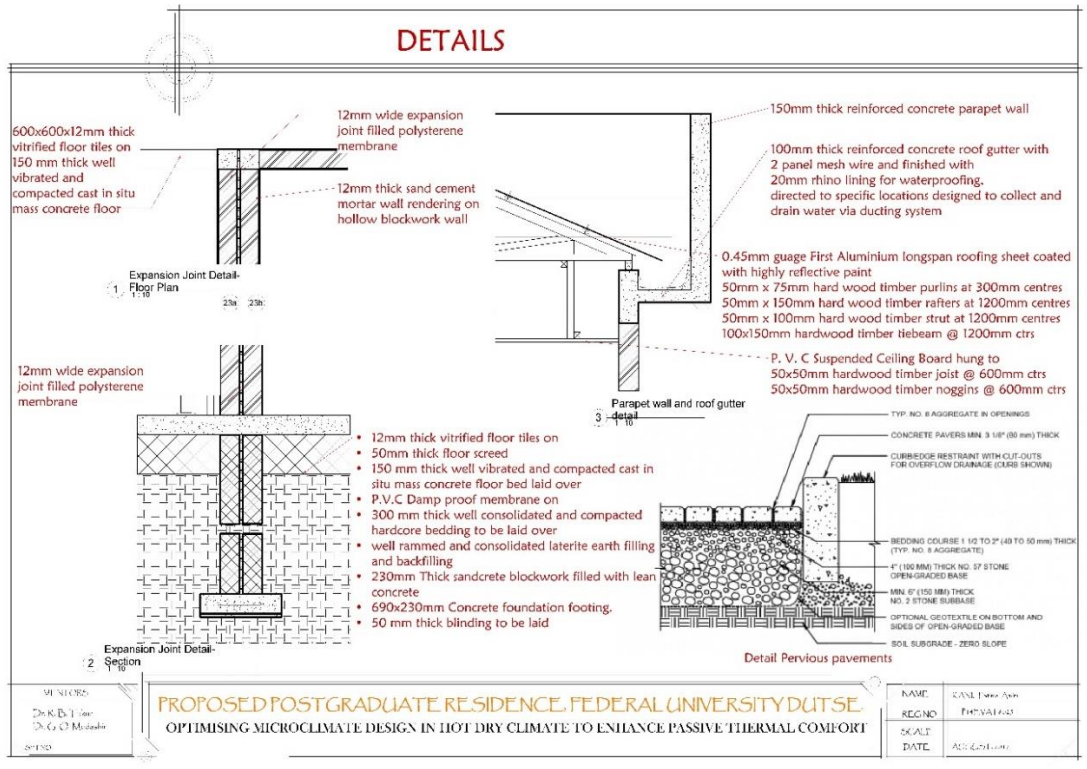
Appendix XI

Sections of Cluster type C



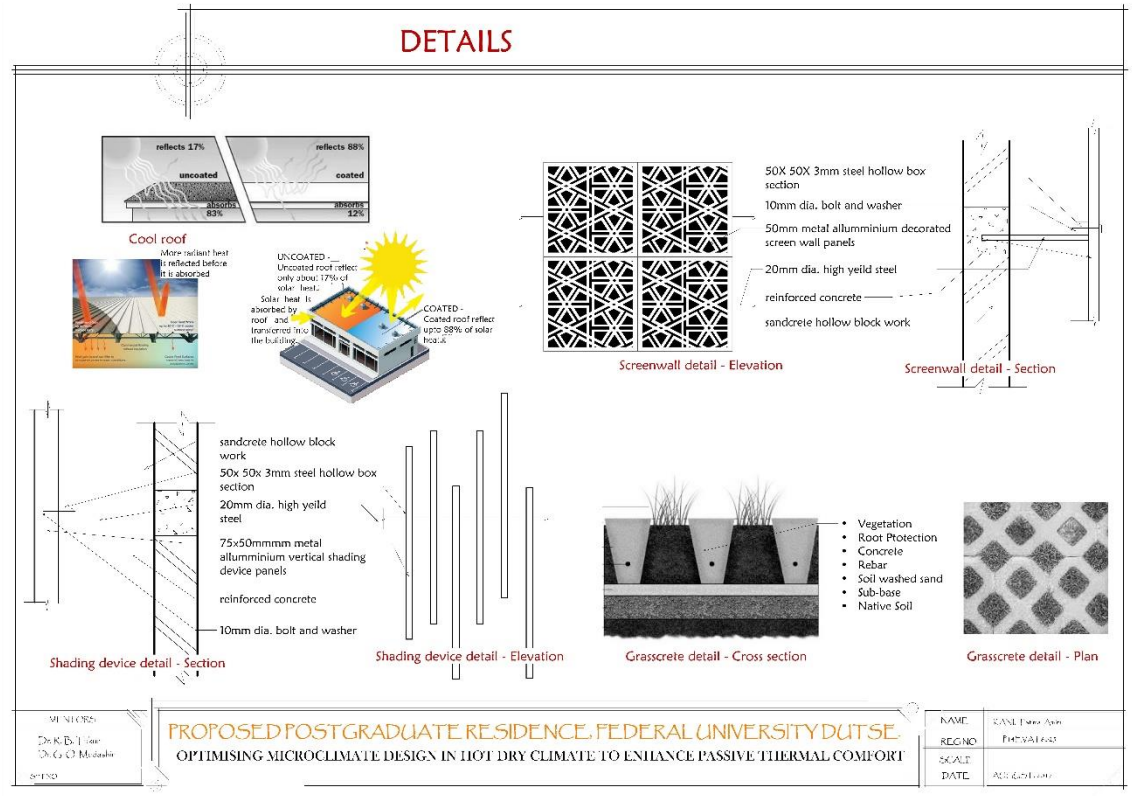
Appendix XII

Details of expansion joints, parapet roof and pervious pavements



Appendix XIII

Details of cool roof system, screen wall, vertical shading device and grasscrete paving



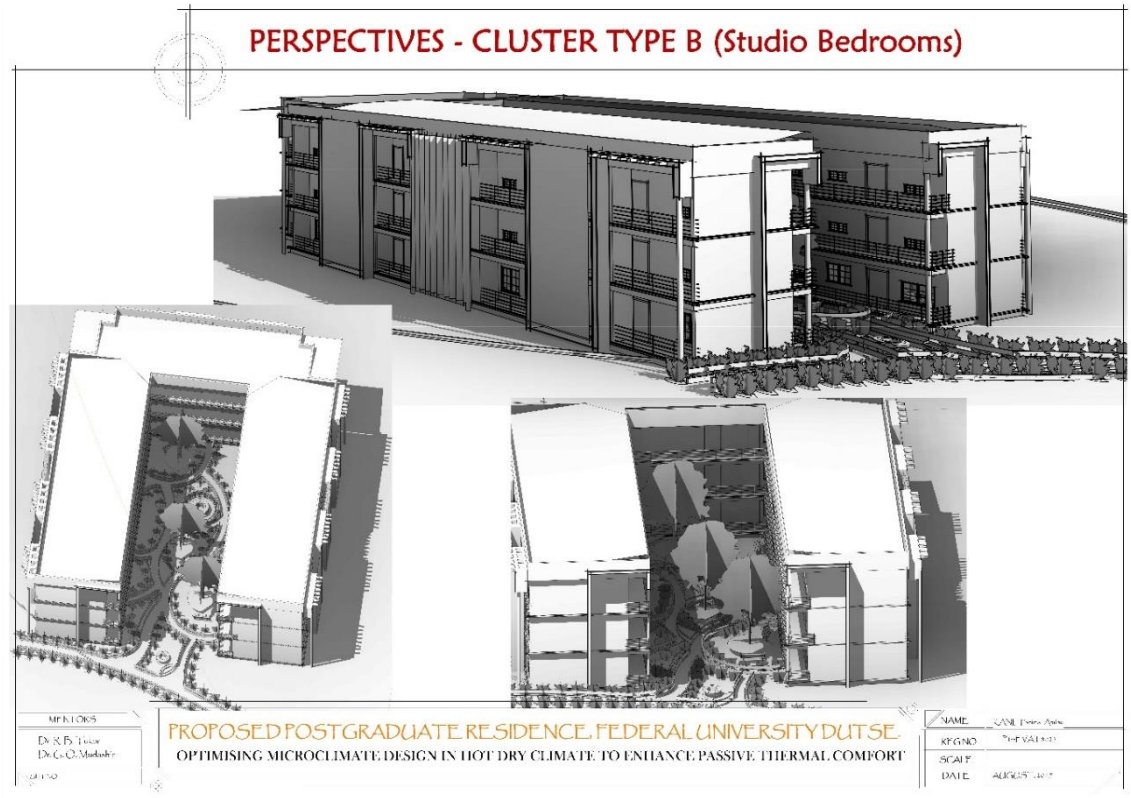
Appendix XIV

Perspective View of cluster type A



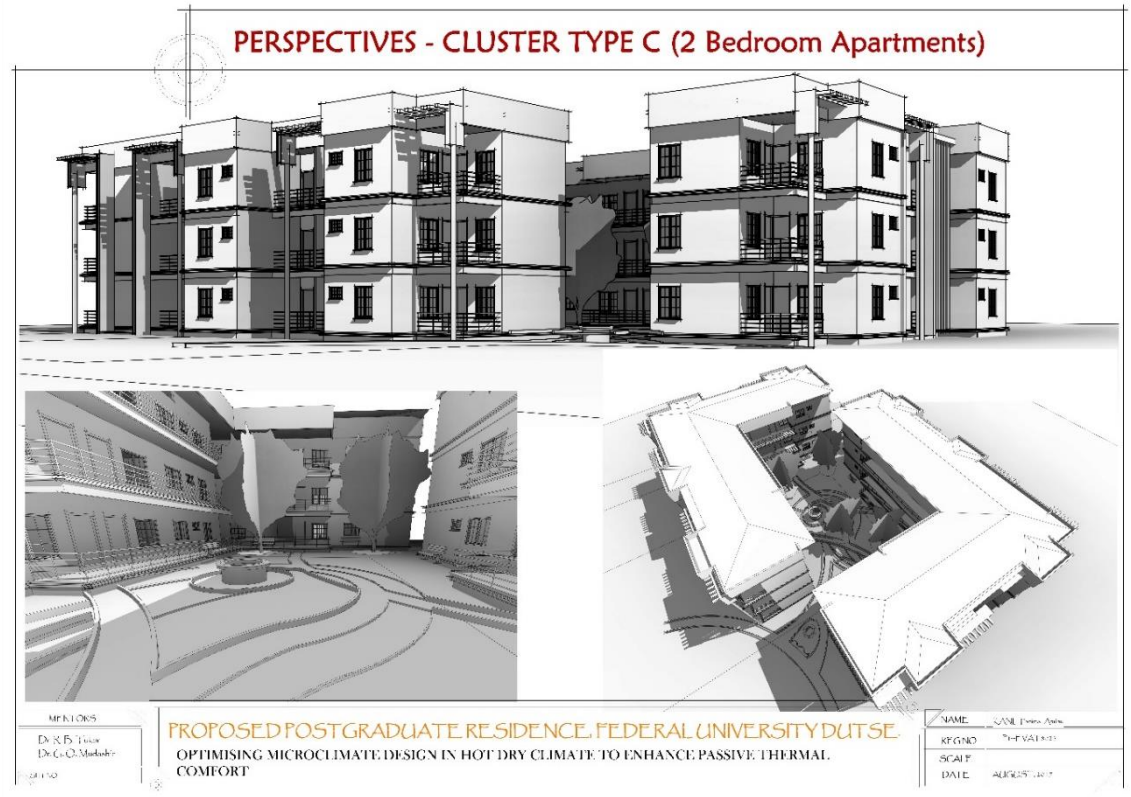
Appendix XV

Perspective View of cluster type B



Appendix XVI

Perspective view of cluster type C



Appendix XVII

Aerial view of the PGR from the site's primary road



Appendix XVIII

Aerial view of the proposed PGR, FUD



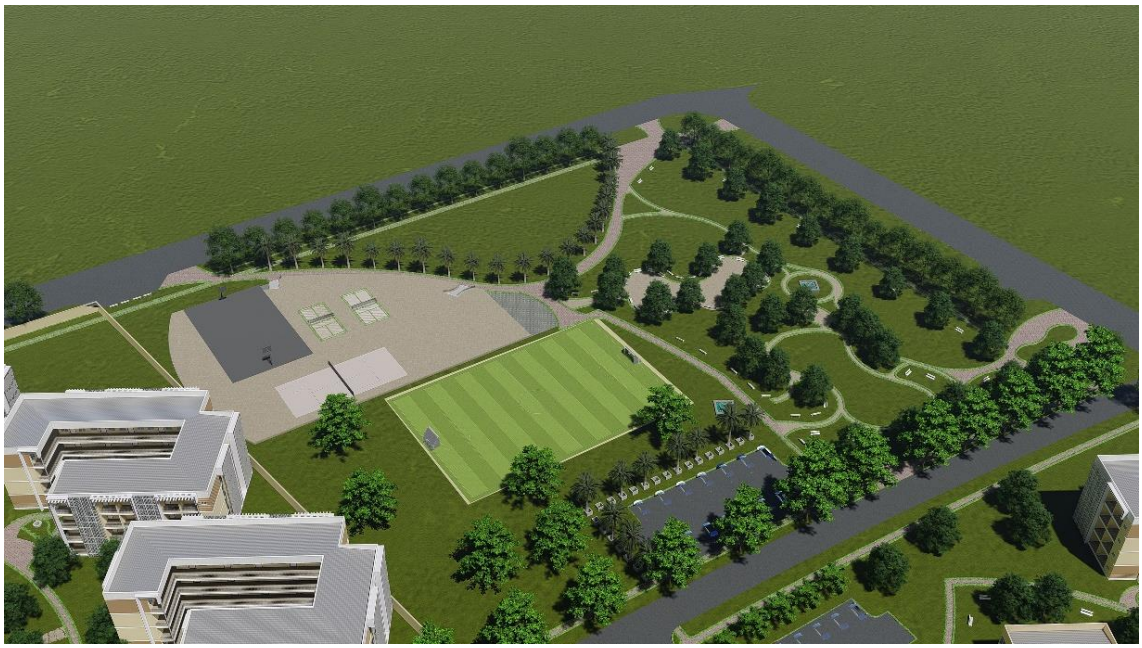
Appendix XIX

Aerial view showing all macro clusters, sports facilities and recreational area



Appendix XX

Aerial view showing the sports facilities and recreational area



Appendix XXI

Aerial view showing administrative block, common room, cluster type A and B and parking area of a typical macro cluster



Appendix XXII

3D view of Cluster Type A (Studio bedrooms) with a view of the courtyard



Appendix XXIII

Approach 3D view of Cluster Type A



Appendix XXIV

Rear 3D view of Cluster Type A



Appendix XXV Approach 3D view of Cluster type B

Appendix XXVI

Approach 3D view of Cluster Type B



Appendix XXVII

Aerial view of Cluster Type B



Appendix XXVIII 3D view of Cluster type C

Appendix XXIX

3D view of Cluster Type C



Appendix XXX

Aerial view of cluster type C



Appendix XXXI

3D of the rear view of the common room



Appendix XXXII

Aerial view of a macro cluster capturing Admin block and cluster types A



Appendix XXXIII

View of common room and admin block with cluster types A in the background



Appendix XXXIV

Interior views of a studio bedroom (Cluster type A)



Appendix XXXV

Interior views of Studio flats (Cluster type B)



Appendix XXXVI

Interior view 2 bedroom flats (Cluster type C)

