FACTORS AFFECTING COMFORT LEVEL OF BUILDINGS IN LAGOS STATE

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DEDICATION

This write-up and project work is dedicated to Almighty ALLAH, the most Beneficent and the most Merciful for HIS protection and Guidance and also to my entire family.

APPROVAL PAGE

This project has been read and approved as meeting the requirement of school of Engineering and Engineering Technology, Federal University of Technology ,Akure for the award of Master of Engineering (M.Eng) in Mechanical Engineering.

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ABSTRACT

The problem of natural cooling of buildings in tropical climate has been considered in this research. Two locations Ebute Metta of Lagos Mainland and Ikorodu zones were chosen for the research where the ambient and room (indoor) temperatures of some selected buildings were taken.

The research showed that natural cooling of buildings could be achieved by:

- Building houses/rooms to face South or North.
- Using asbestos sheets as roofing Material
- Leaving spaces between buildings to allow for free airflow. etc.
- Limiting the number of people using a room.

Statistical methods were used in the analysis of the collected data which later showed that the both calculated and measured data are almost equal in every aspect.

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CHAPTER ONE

1.0 INTRODUCTION

Housing forms, by far, the most common building type throughout the world, with over half of all investment made in construction. Put in another way, over 15% of all savings in both developed and developing countries is invested in building (Evans, 1980). The objective of this massive investment is to provide shelter, security and comfortable living condition for the occupants (Marcus and Morris, 1980). However, buildings in hot climates bring inevitable the additional problems of inadequate cooling. Although, this can be catered for by mechanical means, it would be better for the designer (architect) to give serious considerations to the well –tried natural and traditional methods in siting and designing for tropical buildings, as this will enable occupants to be comfortable with minimum investment. This will be achieved when the architectural designer attempts to eliminate or reduce substantially the heat gain into a building through the three known mode of heat transfer- conduction, convection and thermal radiation.

Naturally cooled houses provide shelter for the overwhelming majority of the rural and urban population in tropical regions of the world, yet they have received very little attention. Most countries in the tropics have made genuine efforts at increasing the number of modern houses constructed with permanent building materials but this has benefited only a relatively small section of the community. This is evidenced by the fact that the larger parts of the population still rely on their own meager financial resources for housing materials and techniques (Friedrich, 1982).

A complete air-conditioning can be designed to provide the required internal environmental conditions. This however has the major disadvantage of high initial cost and subsequent running and maintenance expenses. In addition, most of the communities lack electricity, and where it is available, it is not in constant supply.

It is not practicable to plan a building exclusively on economic, functional or formal grounds and expect a few minor adjustments to give a good indoor climate. Climate conditions must be taken into consideration when deciding on the overall concept of a project; on the layout and orientation of building; on the shape and characteristics of structures; on the spaces to be enclosed and the spaces between buildings. In other words climate must be considered at the early design stage (Overseas Division of Building Research Establishment, (1980).

It is a known fact that buildings are to provide comfortable internal condition in an economic way. Thus, it is possible to prescribe and specify the limits of internal environment within which various human activities can take place. The thermal field knowledge required for this physiology and its application of thermal comfort. To specify the characteristics of a building, it is necessary to have a sound knowledge and clear picture of the climatic features of the area in which the building is located (Marcus and Morris, 1980)

The maintenance of thermal equilibrium between human body and the environment is one of the primary requirements for health, well-being and comfort. It involves keeping the temperature of the body within a narrow range, regardless of the relatively wide variations in the external environment.

The condition under which such balance is achieved and the state of the body when it reaches equilibrium with the environment depends largely on the combined efforts of many factors. Some of these are level of human activity, clothing type, air temperature, radiation, humidity and the air movement. In tropical climates, hardly can people live comfortably and work effectively without some form of winter heating and summer cooling (Givoni, 1969).

1.1 REMOVING BUILT-UP HEAT

Nothing feels better on a hot day than a cool breeze. Encouraging cool air to enter houses forces warm air out, keeping houses comfortably cool. However, this strategy only works when the inside temperature is higher than the outside temperature. (Akbari, et al; 1992).

Natural ventilation maintains indoor temperatures close to outdoor temperatures and helps remove heat from homes.

The climate one lives in determines the best ventilation strategy. In area with cool night and very hot days, allow the night air in to cool the house. A well-insulated house will gain only 0.6°C per hour if the outside temperature is 29°C to 32°C. By the time the interior heats up, the outside air should be cooler and can be allowed indoors. (Kriggers, 1991).

In climates with daytime breezes, open windows on the side from where the breeze is coming and on the opposite side of the house. Keep interior doors open to encourage whole house ventilation. If a location lacks consistent breeze, create them by opening windows at the lowest and highest points in the house. This natural "thermosiphoning" or Chimmey" effect can be taken a step further by adding a clerestory or a vented sky light to the buildings.

In hot, humid climates where temperature swings between day and night are small, ventilate when humidity is not excessive. Ventilating attic greatly reduces the amount of accumulated heat, which eventually works its way into the main part of the house. Ventilated attics are about 16°C cooler than unventilated attic. Properly sized and placed louvers and roof vents help prevent moisture buildup and overheating in the attic (Johnson, 1990).

1.2 HEAT TRANSFER IN BUILDING

Dull, dark-coloured home exterior absorb 70% to 90% of the radiant energy from the sun that strikes the home's surfaces. Some of this absorbed energy is then transferred into the home by way of conduction, resulting in heat gain. In contrast light-coloured surfaces effectively reflect most of the heat away from homes. (Kriggers, 1991)

About a third of the unwanted heat that builds up in homes comes in through the roof. This is hard to control with traditional roofing materials. For example, unlike most light-coloured surfaces, even white asphalt and fiberglass shingles absorb 70% of the solar radiation.

One good solution is to apply a reflective coating on existing roof. Two standard roofing coatings are available; they have both waterproof and reflective properties and are mainly used for mobile homes and recreational vehicles. (Kriggers, 1991)

One coating is white latex that can be applied over many common roofing materials, such as asphalt and fiberglass shingles, tarpaper and metal.

A second coaling is asphalt based and contains glass fibres and aluminum particles. It can be applied to most metal and asphalt roofs. Because it has a tacky surface, it attracts dust, which somewhat reduces its reflectivity. Another way to reflect heat is to install a radiant barrier on the underside of the roof. A radiant barrier is simply a sheet of aluminum foil with a paper backing, when installed correctly; a radiant barrier can reduce heat gains through the ceiling by about 25% (Kriggers, 1991)

WINDOWS AND DOORS

Roughly 40% of the unwanted heat that builds up in houses comes in through windows. Reflective windows coating are one way to reflect heat away from homes. These coatings are plastic sheets treated with dyes or thin layers of metal. Besides keeping homes cooler, these reflective coatings cut glare and reduce fading of furniture, draperies and carpeting.

Two main types of coatings include sun control films and combination films; sun-control films are best for warmer climates because they can reflect as much as 80% of the incoming sunlight. Many of these films are tinted, however, and tend to reduce light transmission as much as they reduce heat, thereby darkening the room.

Combination films allow some light into a room but they also let some heat in and prevent interior heat from escaping. These films are best for climates that have both hot and cold seasons. One has to investigate the different film options carefully to select the film that best meets one's needs. The coatings are applied to the interior surface of the window. When specifying doors, insulated metal or fiberglass doors are the best choice for energy performance. The glazing choice for the door should be evaluated in terms of the door's orientation and insulation, solar heating (or shading) and daylighting roles that the door may help fulfill. When evaluating doors and windows, U-value (heat transfer coefficient) must be considered as a whole, as some frames will conduct heat readily, as Aluminum Frames, for instance, conduct heat well, and should not be used in cold climates.

1.3 DEFINITION OF TROPICAL CLIMATE

Tropical climate is a region of the world climatic region with a solar inclination of about 23.5°C characterized by the following (Stoll and Evshtroctor, 1987): high ambient temperatures (about 25 – 35°C); high relative humidity (about 60%); high and fair evenly distributed rainfall; small diurnal and annual variation of temperature; little seasonal variations; light winds; long periods of still air.

1.4 DEFINITION OF COMFORT

Comfort is a subjective sensation. It is defined as "the state of mind which expresses satisfaction with the thermal environment" (Jones, 1985). There is no such thing as a perfect combination of conditions for comfort since it is not possible to satisfy everyone at the same time.

In order to feel comfortable, man must maintain the temperature inside his body within narrow limits. The metabolic processes that take place within the body produce heat and the body must lose this heat so as to maintain a stable internal temperature.

The metabolic rate depends on the level of activity such as rest, work or exercise.

Naturally, the higher the metabolic rate, the higher the heat transfer rate from the body to the environment to maintain an energy balance (Rohles & Nevins, 1977). Table 1.2.1which is taken from the ASHRAE Handbook lists approximate metabolic rates for various types of activities. The unit is in "Met". One met is equal to $58.2 W/m^2$ of surface area.

Table 1.2.1 METABOLIC RATE OF DIFFERENT TYPICAL ACTIVITIES

ACTIVITY	METABOLIC RATE
Reclining	0.8
Seated quietly	1.0
Sedentary activity (Office, dwelling, Lab., School)	1.2
Standing, relaxed	1.2
Light activity, standing (Shopping, lab, light industry	1.6
Medium activity, standing (Shop assistant, domestic work, machine work)	2.0
High activity (Heavy machine work, garage work)	3.0

Source: ASHRAE Handbook of Fundamentals, 1977.

The range of comfort parameters within which an acceptable value will lie for most people in the hot humid environments are as follows: - (ASHRAE, 1977)

(i) Air temperature: $20^{O}C - 27^{O}C$

(ii) Air Relative Humidity: 40% - 50%

(iii) Air Speed: 0.2m/s – 0.35m/s

(iv) Noise level: 45 decibels

(v) Odour level: Tolerable

There are a wide variety of mechanisms used to control body temperature.

Firstly, there are methods to control heat production and heat flow within the body. Then there are methods to increase or reduce the rate of heat loss from the body surface, from the skin or from the respiratory tract. These are mainly the physiological control mechanisms. Outside the body, heat loss can be controlled by clothing, posture, choice of location and activity. These are individual voluntary control mechanisms. Then, there is the adaptation of the surrounding thermal environment by the physical built environment. The different climatic zones of the world have thermal comfort that is widely common and acceptable to the majority of them, and for tropical climate, the comfort zone is within 23°C and 26 °C dry – bulb and approximately within 20 – 60% saturation (Jones, 1985).

1.5 DEFINITION OF THE PROBLEM

People have been living in buildings designed in various ways through the ages, the purpose of the designs being to provide for comfort as much as possible. The architect made use of the solar energy through passive architectural design techniques for heating purposes (Kreider and Kreith, 1981). However, with advances in technological development, the use of mechanical air-conditioning equipment had almost stopped the natural approach. But the cost of procurrent, installation and maintenance of this mechanical equipment is high. When it can be afforded, electricity supply is not regular, and fuel is not always available to run electricity generating plants .

Thus this project is seeking to address issues such as:

- Can comfort be achieved through natural approach? and if possible,
- How can it be achieved?

1.6 OBJECTIVES OF THE PROJECT

The main objective of the project is to:

1. Study the effect of building construction and orientation as they affect internal comfort in buildings in different locations in Nigeria.
2. To identify building designs and orientation that provide natural cooling.
3. To identify the best building materials that can perform adequately well in tropical climate and
4. To recommend efficient materials and building orientations to achieve comfort.

1.7 JUSTIFICATION OF THE PROJECT

Keeping cool indoors when it is hot is a problem. The sun beating down on our homes causes indoor temperatures to rise to uncomfortable levels. Air conditioning provides some relief, but the initial costs of installing an air conditioner and the electricity cost, where it is available in the tropics to run it can be high. In addition, conventional air conditioners use refrigerant made of chlorine compounds which are suspected contributors to the depletion of the ozone layers and global warming. But there are alternatives to air conditioning. This research work tries to provide some commonsense suggestions and low-cost retrofit options to help "keep our cool" – and save electricity. (Consumers Digest 1992).

The most effective method to cool home is to keep the heat from building up in the first place. The primary source of heat building (i.e heat gain) is sunlight absorbed by the house through the roof, walls and windows. Secondary sources are air leakage (Ewert, etal; 1998).

Indoor comfort depends largely on the control of air movement and radiant heat. Maximum air movement passing through the body must be encouraged to ensure rapid evaporation from the sun. Solar heat must be prevented from reaching the building occupants directly through doors and windows or indirectly by heating the structures and thereby re-radiating the heat to the occupants or warming the indoor air and the building must cool quickly after sun set to give maximum night-time comfort.

This requirement call for light, well-insulated construction of walls and roofs, reflective surfaces, correct shading and design for good breeze penetration.

Advantage can be taken of large temperature difference between day and night. Cool night air may be stored by closing doors and windows during the days and opening them at night. The passage of heat through walls and roofs can be slowed down so that it is out of phase with the daily heating and cooling of the outside environment.

All these can be achieved through the building design, thus proffering solution to the problems of energy crisis, high cost of procurement and maintenance of mechanical cooling equipment and the indoor comfort level of inhabitants improved.

CHAPTER TWO

2.0 LITERATURE REVIEW

The objective of building construction is to provide shelter, security and comfortable living conditions for occupants, but building in hot climate brings the additional problems of inadequate cooling being catered for by mechanical means. Ways of naturally controlling the climate in the tropics had been for centuries and has been highlighted by various authors.

The use of solar energy for cooling purposes was first documented in ancient Greece in the fifth century. Prior to the period, the Greeks have no means of cooling their house in the extreme heat of summer, nor did they have an adequate heating system for use in winter. They frequently use kitchen stoves fueled by wood for heating. With time, wood became scarce, and they then depend on expansive imports from Thrace, Mediterranean and Italy. Efforts to overcome these problems led them to the development of basic principles of solar architectural designs (Kreider and Kreith 1981).

As reported by Buth and John (1981), Aeschylus, Aristotle and Xenophon outlined the principle of using the sun's heat in winter. They pointed out that the main rooms of a house should face south, and the north side of the building should be sheltered from cold winds. To minimize solar heat gains in summer, caves on the south side should provide shacks to keep out the hot sun. An example of this design is the Olympian house in the ancient city of Greece. As a result, many other architectural designs of such followed. For example, Masion du trident in Delos and Maison de Maques were built higher on the north side than on the south side of the building. This spread to Rome in the first century A.D. and resulted into solar heated homes, Bath and Green house in Rome.

Cowan (1980) reported that passive solar energy include a number of building techniques, which has been employed for centuries. These techniques include the use of sun shading, natural ventilation, and thermal inertia without cost implication

The passive designs according to Fullerton (1978) have evolved in several early cultures that could rely on fossil fuels, mechanical equipment and automatic controls for their thermal comfort system. The use of natural comfort cooling was reportedly prominent in the countries of the Middle East where the climate is hot and arid. He stated that passive solar system are those that work with nature such as to provide heat for buildings in the winter and or cooling in summer without requiring an external energy to operate the system. This natural cooling system is not strictly a solar energy system, but to encourage heat losses from the building so as to counter the effect of solar gains (and other internal heat sources), which are generally minimized in the building design.

Discussing the development and application of the principles of designing naturally cooled buildings; Givoni (1962) listed the following points in support of the investigation at the Building Research Station of Israel. The body indicated the effectiveness of heavy weight insulation when used with certain specific design features to reduce the overall internal temperature.

- Suitable high heat capacity walls externally insulated with determined thickness according to outdoor and indoor temperature.
- Windows may be larger but should be protected by moveable insulated shelter.

- Layout of building and their individual structures should be to minimize surface radiation and outside hot air infiltration.
- Select suitable building orientation in hot dry area to reduce the internal daytime temperature and thus minimize solar heating and ensure building orientation to wind direction.
- Adequately cross ventilate the occupied area of a house with room provided with doors, windows at windward and Leeward.
- Orientation should be aimed at providing the best possible ventilation and therefore, the direction of prevailing wind must be studied.
- Large openings, doors and windows are of advantage in a warm, wet climate provided the effective protection against solar radiation, rain, thieves, and animals are considered.
- The most effective height of window for human comfort aspect is 0.5 – 1.5m above the floor of the occupied zones
- Shading devices should be provided but should not reduce air velocity within occupied zone.
- Large sliding walls that may be kept open most of the time may provide good control of conflicting requirement for maximum ventilation alternating with wind and rain protection during storm.
- Adjustable and retractable louvers and other shading devices maybe equally satisfactory if they can withstand wind force

Discussing building materials, Norton (1980) explained that rooms built with earth are usually well insulated. This he attributed to the thickness of most earth construction and the earth's low thermal conductivity value. Earth has a thermal conductivity value of

$0.62W/m^2k$ for mud brick, 1.21 W/m^2k for fired brick, $1.44W/m^2k$ for concrete and $1.53W/m^2k$ for limestone. According to him; the combined factors of low conductivity and thickness mean that it takes a long time for a peak outside temperature to be transmitted to the interior. Typical time lags are 1-6 hours for a 0.3m thick compressed brick wall. The insulating ability of this long time lag is particularly valuable in places where there is a large diurnal range of temperature. The effect maintains a balance between the extremes of nighttime cool and daytime heat.

On roofs, (Mulahtar, 1978) said that the performance of a building through careful designing, planning and selective use of materials for walls and openings can be negated by the poor design of the roof. The roof forms a considerable proportion of the external surface of the building, and is particularly exposed to the sun and the external climate. According to him, roof unlike other building components do not often receive adequate attention on their thermal performance at the design stage.

In the tropics, the roof receives the greatest proportion of the sun's radiation. This is because of its inclination with respect to solar altitude and its area as compacted with the external walls. The roof also loses the greatest amount of stored heat by long wave radiation to night sky for the same reason.

Apart from the requirements of structural safety and protection from the direct sun and rain, the roof construction plays a major role in the attainment of thermal comfort. He opined that the traditional form of roof construction, which is basically heavy with layers of materials offer a high degree of resistance and modification to the external climate and the diurnal variation in temperature. He concluded tha the thermal performance of roofs could be improved by any of the following methods, used singly or in combination:

(a) Applying coat white paint to external surface of the roof.

(b) Ventilating during the hours when external air temperature is lower than the corresponding internal air temperature.

(c) Allowing shaded roof construction to lose most of its gained heat to the cooled night atmosphere by folding or rolling away the shading devices during the nighttime.

Kindanger (1997) reported that roofs, everywhere in various climates and cultures have aesthetic values. A certain type of roofs, according to him is often a typical characteristic of a nature, a climate, a culture, local material, and construction techniques. He said that airflow inside buildings can be improved by increasing the avearge velocity coefficient which is induced by the shape and its orientation. The height of the roof is another factor that influence interior airflow.

This, for large wind angle $60^0 \leq ¢ \leq 90^0$ at the inlet acts to increase the exposed projected area on the windward side.

In 1997, (Albert and Steve) investigated traditional and contemporary housing thermal performance in atropical upland climate using Zambia as a case study.

They looked at a typical traditional house and a typical low-cost house and analyse their thermal response to the climate. They compared the results of the climate study with the results of the thermal comfort field survey carried out at the same time. This according to them served as a way of confirming whether the response of the people actually agreed with the results from the thermal performance analysis. They concluded that the traditional house is more discomfortable in the cool season than the contemporary house, and the outside way of life in the traditional village is more suited to the climate. A heavy weight fabric was found to be more appropriate for the cool season in the climate instead of the traditional solution of mud and pole walls roofs and the contemporary solution of concrete walls and asbestos cement roof.

2.1 DESIGN OF THE STUDY

2.1.1 DESIGN CONSIDERATION

Buildings have to satisfy the needs of the hot periods as well as those of the warm humid periods. Thus many factors must be put into consideration in designing building for all year round human comfort in tropical climates. These include site selection, building materials, sun-shading devices, insulation, infiltration, ventilation and building's orientation to sun's inclination.

2.1.1.1 SITE SELECTION

The first decision to be taken which will affect thermal comfort is the selection of the site. With new settlements or large housing development sited some distance from existing towns, and where terrain causes large differences in site climate over short distances, the climatic aspects of the site selection become more important; sometimes they are critical. Unfortunately it is very difficult to evaluate the benefit of climate against the cost of site development. The environmental aspects of site selection may therefore have a very low priority when the techniques such as cost benefit analysis are employed; despite the fact that environmental factors will have a continuous effect on the settlement for as long it continues to exist, while the capital cost is only incurred when the settlement is founded (Evans 1980)

In most cases, however, the designer has little choice in the location of dwelling. The client whether a housing authority, private developer, or individual will often have selected a site before the designer or architect is appointed. Even when this occurs, the designer should be able to recognize or predict the desirable and undesirable feature of the site climate.

Finally, the ground cover, slope, orientation, and the elevation of the site, as well as the nature of the terrain surrounding the site should affect site climate that is related to the area to be developed. For this project two locations, Lagos Mainland and Ikorodu are selected for study.

2.1.1.2**BUILDING MATERIALS**

Various materials have different heat capacities. As such, they absorb heat energy in the day, and discharge it when the environment is at a lower temperature. This implies that the heat generated into a space can be controlled by using materials of extremely low heat capacities. That is, the mass and thermal properties of the materials of a building are powerful tools for providing a suitable modified environment for a wide range of climatic condition. (Cowan 1980)

The thermal properties of building materials can influence the transmission of heat through walls, roofs, windows and doors. For natural heat flow, this will reduce heat absorption and hence its consequent transmission into building interiors. The thermal conductivities of the major building materials are as given in Table 2.1.1.2

Table 2.1.1.2. Thermal conductivity of some Building materials.

	MATERIAL	THERMAL CONDUCTIVITY W/M^2K
Wall	1. Mud	0.62
	2. Concrete	1.44
Roof	1. Iron Sheet	111.55
	2. Asbestos	0.166
Doors & Windows	1. Wood	0.1124
	2. Glass	0.76

Source: Cowan, 1980

2.1.1.3 BLOCKING THE HEAT

Two excellent methods to blocking heat are shading and insulation. Insulation helps keep home comfortable and saves money on mechanical cooling systems such as air conditioners and electric fans. Shading devices block the sunrays and absorb or reflect the solar heat. (Meier 1987)

(i) SHADING

Shading homes can reduce indoor temperatures by as much as 11°C. (Meier 1987) Effective shading can be provided by trees and other vegetation and exterior or interior shades.

LANDSCAPING

Landscaping is a natural and beautiful way to shade homes and block the sun. A well placed tree, bush or vine can deliver effective shading and add to the aesthetic value of the building. At the design stage of the landscaping, plants native to the area that will survive with minimal care should be chosen.(Meier, and Friesen, 1987).

Deciduous trees that lose their leaves in the dry season help cut cooling costs the most when selectively placed around a building, they provide excellent protection from the sun. The height, growth rate, branch spread, and shape are all factors to consider in choosing a tree.

Vines are a quick way to provide shading and cooling. Grown on trellises, vines can shade windows or the whole side of a house. Besides providing shade, trees and vines create a cool microclimate that dramatically reduces the temperature (by as much as 5°C) in the surrounding area. During photosynthesis, large amounts of water vapor escape through the leaves, cooling the passing air. And the generally dark and coarse leaves absorb solar radiation.

Low ground cover such as grass; small plants and bushes may also be considered. A grass-covered lawn is usually 6°C cooler than bare ground. (Meier, 1990).

(ii) SHADING DEVICES

Both exterior and interior shades control heatgain. Exterior shades are generally more effective then interior shades because they block sunlight before it enters windows.

Sun rays can be intercepted before reaching the building envelope. This is best achieved by the use of external sun shading devices. The first step here is to know the direction of sun to the house, and hence the period during which the devices would be employed, i.e. whether we will be willing to open and close the windows daily or just put them for the hot season. The devices cast a shadow of itself as it is interposed between the sun rays and the area being shaded. (Stoll and Evshtroctor, 1987).

Exterior shading device include awnings, louvers, shutters, rolling shutters and shades, and solar screens awnings are very effective because they block direct sunlight. They are usually made of fabric or metal and are attached above the window and extend down and out. A properly installed awning can reduce heat gain up to 65% on Southern windows and 77% on eastern windows. A light-colored awning does double duty by also reflecting sunlight.

East – and West – facing windows generally cause excessive heat gains in the dry season and heat - losses in the west season. (BTS Home; 2001)

Overhangs and other forms of protection from sun and rain are needed in the warm humid tropics, but are not so essential in hot dry climates since rainfall is low and sky glare and high levels of diffuse radiation are less frequent. External shading devices may still be needed in addition to shutters, if windows are poorly oriented or too large. The main elements, which may be found in a window opening, are listed in Table 2.1.1.3.

Table 2.1.1.3 Window Element and Their Functions

Element	Function	Typical Application
Thick curtain	Reduce heat loss (or Gain) Provide Privacy at night Reduce natural lighting	Night use rooms in cold season
Lace curtain	Reduce glare Diffuse light Provide privacy by day.	Day use rooms
Glass (closed)	Reduce heat loss Permit heat gain from solar radiation Prevent long wave radiation heat loss Allow a view out Allow daylight to enter Exclude dust, noise pollution, insects Rain, wind etc.	High % of fixed glass in cold climates
Glass (open)	Allow air movement (for 'body cooling') Allow ventilation (for hygiene) Allow ventilation (for structural cooling)	High proportion of opening glass in hot climates
Solid shutter of roller blinds	Exclude solar radiation Provide security Exclude rain Protect opening from heavy winds Prevent glare Reduce rate of heat transfer	Unsahded windows in hot sunny climates Area subject to heavy storms or hurricanes
Louvred shutters	Provide security Reduce light levels Allow air movement and ventilation Provide privacy Exclude direct solar radiation Allow reflect sunlight to enter	Climates requiring night ventilation Climates with strong reflected sun light
Fixed screen (security bars)	Provide security Reduce light levels Reduce glare Reduce radiation Increase privacy	Climates requiring ventilation
Mosquito screen	Prevent insects entering Provide privacy by day Reduce light levels Reduce glare Reduce radiant heat gain (reduce air movement)	Climates requiring night ventilation (with open windows and artificial lighting on)
External shading Device	Allow a view out Protect from rain Protect from direct solar radiation Protect from sky glare	Day use rooms facing the sun (simultaneous view, light and shade)

Source: Evans (1980)

2.1.1.4 THERMAL INSULATION

Insulation is a way of reducing the rate of heat loss or heat gain through a material. However, the properties of the insulating materials must be known so as to be able to apply the right type at the right time.

Among available insulating materials are glass fibre, rock wool, cellulose fibre, urea formaldehyde foam and reflective oil laminate. Thus, the choice of any of these depends on the thermal resistance, physical appearance, cost of procurement and fibre protection ability.(Carter, 1981)

2.1.1.5 INFILTRATION AND VENTILATION

Infiltration is the uncontrolled entry of unconditioned outside air into an enclosure or a building. While ventilation is air intentionally brought into an enclosure or a building.. Building design must allow for proper infiltration, which can best be achieved through cross-ventilation. The location of windows and doors in relation to the directions of wind flow will aid the two. Ventilation is the least expensive and most energy efficient way to cool buildings in some cases, natural ventilation will suffice, although it usually needs to be supplemented with fans or other forced ventilation. (http://www.eren.doe.gov/EE/buildings_space_heating.html)

- (1) last updated 25th Jan 2002.

However, storm and air containants are limiting factors.

2.1.1.6 BUILDING ORIENTATION AND SUN'S INCLINATION

The position of the sun in relation to the location of a building (latitude and longitude) plays an important role in heat gain into an enclosure. There are standard formats for estimating the total heat gain into a building in a particular location, and orientation to the inclination of the sun. (ASHRAE, 1985).

However, heat gain will be reduced if the receiving surfaces are vertical or horizontal. Thus, the building design must ensure that the possible heat gain into the building is minima.

Proper orientation and good daylighting can significantly reduce the electricity needed for lighting and cooling.

A building with a large south exposure and small east and west exposures has advantages in all seasons. The south-wall exposure maximizes the heating benefit of the winter sun, and minimal east and west exposures keeps the summer sun at bay. (http://www.eren.doe.gov/EE/buildings_space_heating.html)

- (1) last updated 25th Jan 2002.

West facing buildings invariably result in problems with glare and overheating that raises cooling loads and causes discomfort to the occupants.

(http://www.eren.doe.gov/EE/buildings_space_heating.html)

- (1) last updated 25th Jan 2002.

2.2 CLIMATIC CHARACTERISTICS AFFECTING HUMAN COMFORT

Some climatic characteristics affecting human comfort are here discussed.

2.2.1 AIR TEMEPRATURE

Extremes of either hot or cold weather are not comfortable for human beings. In hot weather, being comfortable involves dissipating excess heat to prevent the body temperature from rising. This is accomplished by a diversion of blood from internal organs to the body surface so that heat losses by conduction, radiation and evaporation can take place.

If the outdoor air temperature is so hot that heat losses from the body cannot equal the body's heat production, then body temperature rise. This will negate the natural effect of the air temperature being lower than the body temperature.

2.2.2 MOISTURE CONTROL

Humidity is the amount of evaporated water in the air. High humidity reduces evaporation rate, resulting in discomfort. Although, the human body is comfortable with a relative humidity of between 20% and 60% at a temperature of 20°C, the degree of humidity that can naturally be maintained indoors without objectionable condensation is dependent on the outdoor temperature, the types of amount of insulation, the moisture production in the house.

Other characteristic is the air movement that brings fresh air into contact with the sun. The speed needs not to be too low or too high, as an extreme will result in discomfort.

2.2.3 BUILDING LOCATION

The location of a building (longitude and Latitude) can also have positive or negative effect on cooling. However, standard values obtained through research and experiments have been formulated to determine the heat loss or heat gain through a building at different climatic zones of the world in relation to solar radiation (ASHRAE 1985)

2.2.4 REDUCING HEAT – GENERATING SOURCES

Often – overlooked sources of interior heat gain are light and household appliances, such as ovens, dishwashers and dryers.

Because most of the energy that incandescent lamps use is given off as heat, use them only when necessary. Take advantage of daylight to illuminate the house consideration must be given to switching to fluorescent lamps. These use about 75% less energy than incandescent lamps and emit 90% less heat for the same amount of light. (http://www.eren.doe.gov.erec/factsheet,/coolhome.html).

- (2) Many household appliances generate a lot of heat. When possible, use them in the morning or late evening when you can better tolerate the extra heat.

Consideration may be given to cooking on an outside barbecue grill or use a microwave oven, which does not generate as much heat and uses less energy than a gas or electric range.

Washer, dryers, dishwashers and water heaters also generate large amounts of heat and humidity. To gain the most benefit, seal off your laundry room and water heater from the rest of the house if any.

New, energy – efficient appliances generate less heat and use less energy. (As above).

2.2.5 HEAT ESTIMATION

Heat transmitted through a building is estimated when the following are put into consideration:

- Heat gain from the building walls, windows and roofs.
- Heat stored in the building structure.
- Heat released within the building.
- Heat gain or loss due to ventilation and infiltration.

Heat gain or loss through component is estimated from the relation: -

$$Q = UA\Delta T \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where Q = heat gain or loss (W)

U = overall thermal coefficient (W/m^{2}K

= 1/R_T (R_T =Total Thermal resistance) (m ^{2}K/W)

A = Area exposed to heat source (m^2)

T = Difference in temperature (k)

For glass, heat transmission depends on the characteristic of the surface; whether transparent or opaque.

For a transparent surface, the solar energy passing is given by;

$$Qsg = A(ASHGF)(SC)(CLF) \ldots\ldots\ldots\ldots (2)$$

Where Qsg = Solar heat gain or loss through glass

A = Area of exposed surface

SHGF = Solar heat gain factor (W/M^2)

SC = Shading coefficient

CLF = Cooling load factor

There are standard values for these, i.e. SHGF, SC, AND CLF are obtainable from tables and charts of ASHRAE.

Also, air temperature and humidity level between the outside and inside of the building contribute to the heat value either as sensible load or latent heat load. These are due to infiltration and ventilation differences due to air change in the building space.

For sensible heat:

$$Qs = 3000Q^o (t_o - t_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

And for latent:

$$Ql = 1.23Q^o (Wo - Wl)$$

where Qs = sensible heat (W)

Ql = latent change (W)

Q^o = air change (Lt/s)

t_i = inside air temperature (K)

t_o = outside air temperature (K)

ω_i = inside humidity

ω_o = outside humidity

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 DATA COLLECTION

Lagos is on latitude 7^0, and other data used were obtained through measurements and questionnaire. On building data, occupants of each of the buildings studies were questioned in addition to the questionnaire administered.

The temperatures were taken using mercury-in-glass thermometer on hourly basis for ten buildings in each of the two study locations; Lagos Mainland and Ikorodu. These two locations were chosen to study rural and urban settlement; as Mainland can be said to be urban and Ikorodu rural.

3.2 BUILDING DATA

For each building, the following information was obtained: type of house, wall material, roof material, building orientation, building location, ceiling material, room material, room size, window material and dimension, door material and dimension, and for a particular house in Lagos Mainland, these parameters were measured and recorded as below;

3- storey building (8 flats of 2 bedroom each)

Wall material: 228.6mm cement block

Roof material: Asbestos-roofing sheets

Building orientation: North facing

Building location: Lagos Mainland

Ceiling material: Asbestos...

Room size: Sitting rooms: 508.0 cm x 356.6cm x 233 cm

Living room: 308.8 cm x 254.0 cm

Window (Louvers): Each is 600mm x 150mm x 5mm

Door: Main Door: Glass sliding door: 1,800mm wide x 2,100mm high

INTERNAL HEAT SOURCES

1. Source of Electricity: NEPA
   - Fluorescent
   - Bulbs
   - Gas Lamp
   - Kerosene Lantern
2. People
3. Appliance- Electric Cooker
   - Electric Kettle
   - Air Conditioner
   - Sound System
   - Deep Freezer
   - Television Set
   - Fan
   - Washing Machine

For House I, the data is an average of what obtains in all flats for 5 consecutive days.

The collected data were coded as below for ease of recording. The given codes were used in presenting the data as shown in Tables 3.1 and 3.2.

Feature	**Code**
Wall Material	WM
Roofing Material	RM
Building Orientation	BO
Ceiling Material	CM

Room Size	RS
Window Material	WDM
Door Material	DM

<u>INTERNAL HEAT SOURCES</u>

	Code
Source of Electricity/Lighting	SE/L
- Fluorescent	F
- Bulbs	B
- Gas Lamp	GL
- Kerosene Lantern	KL
People	PL
Appliances	AP
- Fan	FN
- Electric Cooker	EC
- Refrigerator	RF
- Electric Kettle	EK
- Air Conditioner	AC
- Sound System	SS
- Deep Freezer	DF
- Television Set	TS
- Washing Machine	WM

The building data for ten (10) houses in each zone were taken. Using the codes listed, obtained values and information are presented in a tabular form

Table 3.1: Building Data for Lagos Mainland

	HOUSE1	HOUSE 2	HOUSE 3	HOUSE 4	HOUSE 5	HOUSE 6	HOUSE 7	HOUSE 8	HOUSE 9	HOUSE 10
WM	Cement Block' 22.8.6mm	Cement Block 228.6mm	Red Block And Cemented	Tescote Plastering Cement Block (228.6mm)	Concrete Block and Smooth Plastering (228.6mm)	Concrete Block Plastering (228.6mm)	Concrete Block (smooth plastering	MudBrick and Plastering	Mud Concrete Plastering	Concrete Block Plastering
RW	Asbestos Roofing Sheeting	Corrugated Iron sheets	Corrugated Iron sheets	Asbestos Sheets	Concrete Decking	Corrugated Iron sheets	Asbestos Roofing Sheets	Corrugated Iron sheets	Plank	Asbestos Sheets
BO	West facing	South Facing	South Facing	South Facing	South Facing	South Facing	West Facing	West Facing	West Facing	East Facing
CM	Asbestos	Asbestos	Cardboard	Concrete Decking	Concrete Decking	Asbestos	Asbestos	Cardboard	Cardboard	Asbestos
RS	SittingRoom (508mmx 356.6) x 233cm	RoomSize (254 x 254cm) x 236mm	Parlour (420 x 366cm) x 255cm	Sitting Room (474cm x 366cmx255	Room (366cm x 237cm) x 260cm	Sitting Room (366cm x 30.15cm) x 236	Parlour (366cm x 301.5cm) x 260cm	Room (301..5 x 301.5cm) x 262	Room (301.5 x 301.5cm) x 265cm	Room (366 x 301cm x255)
	Room(cm) (308.8 x 254 x 233)		Room(cm) 366 x 301.5x 255	Room(cm) 301.5 x 301.5x 255		Room(cm) 366 x 237 x236	Room(cm) (301.5 x 301.5x260			
WDM	Glass Louvers (600 x150 x5) mm	Glass Louvers (50.4 x 100.8) mm	Sliding Glass (118.5 x 118.5cm)	Glass Louvers (91.5 x 118.5)mm	Glass with Wood (183 x 118.5cm)	Louvers (118.5 x 183 cm	Louvers (118.5 x 183cm)	Louvers (118.5 x 183cm)	Panel Window (99 x 153.3cm)	Louvers (113 x 83.3cm) (8Blades)
DM	Glass Sliding Door 1,800 wide 2,100mm high	FlushPanel 203.5mm 73.3m wide	Flush Door	Glass Sliding Door (183mm x 212.63cm)	Wooden Door (183 x 84.65cm)	Wooden Door 265.8 84.65cm	Wooden Door 183 x 84.65cm	Plywood (flush) 210 x 83.3cm	Plywood (flush) 198.2 x 79.66cm	Plywood 198.2 x 83.3cm
SE/L	NEPA	NEPA	NEPA	NEPA	NEPA	NEPA	NEPA	NEPA	NEPA	NEPA
F	6	4	2	6	1	2	2	1	-	1
B	8	8	2	2	-	3	-	-	1	1
GL	1	1	-	-	-	-	-	-	-	-
KL	1	2	-	-	-	-	-	-	-	-
PL	8	16	6	6	4	8	2	3	4	5
APP	-	-	-	-	-	2	-	-	-	-
FN	4	4	3	-	-	-	-	-	-	-
C	1	-	-	-	-	-	-	-	-	-
RF	1	2	1	-	1	1	-	-	-	-
K	1	2	-	-	1	1	-	-	-	-
C	2	3	-	-	-	-	-	-	-	-
S	2	1	1	-	1	-	-	-	-	-
F	1	1	1	-	-	-	-	-	-	-
V	-	-	1	-	1	-	-	-	-	-

Table 3.2: Building Data for Ikorodu

	HOUSE 1	HOUSE2	HOUSE3	HOUSE4	HOUSE5	HOUSE6	HOUSE7	HOUSE8	HOUSE9	HOUSE10
WM	Concrete Block (Plastered) 22.8.6mm	Concrete Block (Plastered) 228.6mm0	Mud (Plastered inside)	Concrete Block Plastered)	Concrete Block Plastered)	Concrete Block Plastered)	Concrete Block (Texcote Smoothplaste inside	Concrete Block (Plastered)	Concrete Block (Plastered)	Concrete Block (Plastered)
RM	Concrete Decking	Corrugated Iron sheets	Iron sheets	Concrete Decking	Asbestos Roofing Sheets	Asbestos Sheets	Aluminum Sheets	Asbestos	Iron sheets	Iron sheets
BO	South Facing	North Facing	North Facing	South Facing	South Facing	West Facing	East Facing	East Facing	West Facing	North Facing
CM	Concrete Decking	Asbestos	Cardboard	Concrete Decking	Asbestos	Asbestos	Asbestos	Cardboard	Cardboard	Cardboard
RS	603 x 474cm x 255cm	366 x 301.5 cm x 260cm	301.5 x 237cm x 265cm	366 x 301.5 x 262cm	366 x 301.5cm x 275cm	366 x 301.5ccm 280 cm	Living Room 603x426cm x 265 Bedroom 366x301.5cm	366 x 301.5cm x 260	301.5 x 301.5cm x 252	301.5 x 301.5cm x 270
WDM	Sliding Glass 118.5 X118.5cm	Louvers (8blades) 50.4 x 100.8	Plank 91.5 X 118.5	Sliding Glass 118.5 x 118.5	Sliding Glass 118.5 x 118.5cm	Glass Louvers Blades	Sliding glass 118.5 x 118.5cm	Louvers 113 x 83cm	Louvers	Wood 91.5 X 118.5
DM	Sliding Glass Door 212.6 x 183	Flush Plywood 183 x 84.65cm	Plank 183 x 87cm	Sliding Glass door 212.6 x 183	Plywood 210 x83.3	Wooden Panel 205.8 x 84.65	Sliding 237 x 183cm	Panel Door 183 x 118.5cm	Wooden Door 183 X 84.65	Wooden Door (white wood) 198 x 91.5cm
SE/L	NEPA	NEPA	NEPA	NEPA	NEPA	NEPA	NEPA	NEPA	NEPA	NEPA
F	2	1	1	4	2	1	3	2	-	-
B	8	2	1	6	4	3	2	3	1	1
GL	-	-	-	-	1	-	1	-	-	-
KL	1	2	-	2	1	-	-	2	-	-
PL	4	6	16	6	8	12	5	18	14	14
FN	1	2	1	4	3	2	2	1	1	1
EC	-	-	-	1	-	1	-	-	-	-
RF	1	1	-	1	2	1	2	1	-	1
EK	-	-	-	-	-	-	1	-	-	-
AC	1	-	-	2	-	-	3	-	-	-
SS	2	1	1	1	2	2	2	1	1	1
DF	1	-	-	1	-	-	2	-	-	-
TV	2	1	1	2	2	1	3	1	-	1
WM	-	-	-	-	-	-	-	-	-	-

Source: Field Survey

3.3 METHOD OF DATA ANALYSIS

Statistical method would be employed in the analysis of collected data. This is to allow for thorough comparison of results. The expression used include those for mean temperature (T), Daily Range Temperature (DRT), Mean Deviation Temperature (MDT), Standard Deviation (SD), and Regression Analysis using the least squares method.

The expressions are as defined below:

1. Mean Temperature; (T)

$$T = \frac{\Sigma\, n\, T_0}{n}$$

where,

T = Mean Temperature ($^\circ C$)

T_o = Outside Temperature of Room ($^\circ C$)

n = Number of days

2. Daily Range Temperature (D.R.T)

DRT = Maximum Temperature - Minimum Temperature

= Tmax – Tmin

3. Mean Deviation Temperature (M.D.T)

$$M.D.T. = \frac{\Sigma (T - T_o)}{n}$$

4. Standard Deviation (SD)

$$S.D. = \sqrt{\frac{\Sigma (T - T_0)^2}{n}}$$

5. Regression analysis

The regression of the room temperature on the outside temperature using the least square method is given by:

$$T = a + b\,T_o$$

Where

T = Room Temperature

T_o = Outside Temperature

a = Constant

b = Slope of regression

$$a = \frac{\Sigma T - b\Sigma To}{n}$$

and

$$b = \frac{n\Sigma\,T\,To - \Sigma\,T\ \ To\Delta\,To}{n\,\Sigma\,To^2 - (\Sigma To)^2}$$

The Correlation Coefficient 'r' of the technique is found using the relation.

$$r = \frac{1 - \Sigma\,(T - To)^2}{\Sigma\left(T - \Sigma\,\frac{nTo}{n}\right)}$$

A statistical method of percentage frequency ratio is employed in analyzing responses to the administered questionnaire.

The percentage is calculated using a ratio of the number of respondents to a particular item to that of the total number of respondents expressed as a percentage using the relation below:

$$R\% = \frac{FD}{N} \times 100$$

Where

R	=	Response percentage
FD	=	Frequency distribution
T	=	Total number of respondents

50 questionnaires were given out and 42 responses obtained. The analysis will be based on the number of responses, and will strictly address two questions on the possibility of cooling naturally,

The questions are:

1. Can comfort be achieved through natural approach?
2. If possible, how can it be achieved?

Questions 9 to 13 of the questionnaire are related to the first question for the possibility of achieving comfort naturally while questions 14 to 16 addressed the means of achieving natural cooling.

The verbal interview deals with people of three categories;

- High Class – people living in duplex
- Middle Class – people occupying flats
- Low Class – people in single rooms or room houses

The responses are discussed under results and discussion.

CHAPTER FOUR

4.0 RESULTS AND DISCUSION

4.1 RESULTS

The results obtained during the period of research are in two folds; one is the result of measured parameters of the two locations, and the second one is the verbal response of the people interviewed.

The measured temperatures for both day and night for Lagos Mainland is represented as Appendix I, while that for Ikorodu is presented as appendix II

The statistical analysis obtained is as presented in Tables 4.1(a & b) while Tables 4.2 (a & b) represent the results of regression analysis. The regression analysis was done for individual houses in the two locations, and average temperature values for each house was calculated. This is presented as Appendix. III

Table 4.1 (a) STATISTICAL RESULTS FOR MAINLAND

HOUSES / RESULTS	1	2	3	4	5	6	7	8	9	10
Mean Outdoor Temperature, To(°C)	32.2	32.8	30.3	32.5	34.2	34.2	31.0	34.8	34.5	32.6
Mean Indoor Temperature Ti (°C)	28.1	30.9	27.8	28.1	30.1	30.1	27.4	29.6	31.1	29.0
Average Daily Range, Tr (°C)	10.5	7.0	13.0	12.0	14.5	14.5	15.0	18.0	14.0	16.0
Standard deviation, SD (°C)	3.36	0.72	1.25	3.87	3.36	3.36	2.59	5.41	2.31	2.59
Intercept of regression Line (a)	6.45	-13.98	82.34	24.29	8.62	8.62	13.11	-4.98	21.32	24.29
Slope of regression line (b)	0.69	1.53	3.95	0.16	0.66	0.66	053	1.02	0.32	0.16
Correlation Coefficient	0.573	0.798	0.501	0.834	0.928	0.928	0.915	0.834	0.967	0.834
Regression Equation	0.578	0.798	0.501	0.834	0.928	0.928	0.915	0.834	0.967	0.834
Regression Equation	T_1 =6.45 +0.69To	T_2 = -13.98 +1.53To	T_3 = -82.34 +3.95To	T_4 = 24.29+ 0.16To	T_5 = 24.29+ 0.66 To	T_6 = 8.62+ 0.66 To	T_7 = 13.11 + 0.53 To	T_8= -4.98 +1.02To	T_9 = 21.32+ 0.32To	$T1_{10}$= 24.29 + 0.16 To
Building Orientation	West	South	South	South	South	South	West	West	West	East
Wall Material	Cement Block	Cement Block	Red Block	Texcote Cement Block	Concrete Block	Concrete Block	Concrete Block	Mud Bricks	Mud Blocks	Concrete Block
Roof Material	Asbestos Sheets	Iron Sheets	Iron Sheets	Asbestos Sheets	Concrete Decking	Iron Sheets	Asbestos Sheets	Iron Sheets	Plank	Asbestos Sheets
Ceiling Material	Asbestos	Asbestos	Card Board	Concrete Decking	Concrete Decking	Asbestos	Asbestos	Card Board	Card Board	Asbestos

SOURCE: DATA ANALYSIS

Table 4.1 (b) STATISTICAL RESULTS FOR IKORODU

HOUSES / RESULTS	1	2	3	4	5	6	7	8	9	10
Mean Outdoor Temperature, Tl (°C)	28.2	30.5	33.5	32.2	29.8	30.8	31.9	32.4	32.3	32.3
Mean Indoor Temperature, Ti (°C)	28.0	28.6	28.2	28.6	26.6	28.0	27.4	28.3	28.2	28.2
Average Daily Range, Tr (°C)	16.0	16.0	14.0	16.0	9.0	10.0	10.0	13.0	15.0	15.0
Standard Deviation, SD (°C)	0.00	0.72	5.62	2.59	2.05	1.57	4.05	3.36	3.36	3.36
Intercept of Regression line (a)	2.62	3.91	16.29	6.88	20.62	15.83	19.88	22.52	12.02	12.02
Slope of Regression line (b)	0.83	0.82	0.27	0.68	0.14	0.37	0.26	0.17	0.50	0.50
Correlation Coefficient	0.971	0.905	0.250	0.958	0.250	0.740	0.880	0.372	0.941	0.941
Regression Equation	T_1 = 2.62=0.83 To	T_2 = 3.91 = 0.82 To	T_3 = 16.29+ 0.27To	T_4 = 6.88+ 0.68 To	T_5 = 20.62 + 0.14 To	T_6 = 15.83 + 0.37 To	T_7 = 19.88 + 0.26 To	T_8 = 22.52+ 0.17To	T_9 = 12.02 + 0.50 To	T_{10} = 12.02 + 0.50 To
Building Orientation	South	North	North	South	South	West	East	East	West	North
Wall Material	Concrete Block	Concrete Block	Mud	Concrete Block	Concrete Block	Concrete Block	Concrete Block	Concrete Block	Concrete Block	Concrete Block
Roofing Material	Concrete Decking	Iron Sheets	Iron Sheets	Concrete Decking	Asbestos Sheets	Asbestos Sheets	Aluminium sheets	Asbestos Sheets	Iron Sheets	Iron Sheets
Ceiling Material	Concrete Decking	Asbestos	Card Board	Concrete Decking	Asbestos	Asbestos	Asbestos	Card Board	Card Board	Card Board

SOURCE: DATA ANALYSIS

Table 4.2 (a) REGRESSION ANALYSIS RESULT FOR LAGOS MAINLAND

T House	T_{in} (° C)	T_{ic} (° C)
1	28.1	28.6
2	30.9	36.2
3	27.8	27.5
4	28.1	28.8
5	30.1	28.5
6	30.1	28.5
7	27.4	27.6
8	29.6	25.2
S9	31.1	31.3
10	29.0	28.9

T_{in} = Measured Indoor Temperature
T_{ic} = Calculated Indoor Temperature

Table 4.2(b) REGRESSION ANALYSIS RESULT FOR IKORODU

T House	T_{in} (° C)	T_{ic} (° C)
1	28.0	26.0
2	28.6	27.4
3	28.2	23.9*
4	28.6	26.3
5	26.6	24.3*
6	28.0	26.2
7	27.0	27.0
8	28.3	27.3
9	28.2	26.1
10	28.2	26.1

T_{in} = Measured Indoor Temperature
T_{ic} = Calculated Indoor Temperature
* = Rainy and Cloudy Days

4.2 **DISCUSSION OF THE RESULTS**

4.2.1 .1 VERBAL/INTERVIEW

Three groups of people were interviewed. The grouping is as below:

- High Class: This consists of people living in duplex.
- Middle Class: People living in flats
- Low Class: People living in room – room houses.

Although the high class group believe in natural cooling, they do not show much interest as they have the money to procure generating sets to operate their mechanical cooling systems when there is electricity outage. 30% of them, however, still believe that natural cooling is the best, but that they cannot wait for long hours it would take their rooms to cool naturally.

The middle class group supported natural cooling as the best way out with 72% responses in favour. Responding to a question on how best this could be achieved, they said that the rooms should be left opened. However, most of them said that the natural cooling has to be supported by mechanical means, thus, as much as they have preferred natural cooling, the fear of armed robbers would not allow them.

People in the low class group all agreed to natural cooling as the best, and perhaps the only way out. They said that even with the constant supply of electricity, there is little or nothing the mechanical cooling systems could achieve. Of those interviewed, 85.71% in this class agreed that comfort can be achieved naturally.

On how natural comfort can be achieved, they said it has a lot to do with house design and orientation. Though most of them are not knowledgeable in solar heating, but based on 'rule of thumb, they said building orientation should have living rooms facing North or South, and that roofing material is also very important.

On building materials, people agreed that materials have a role to play in comfort, but that most often, people make do with what their money can buy them rather than what they should use.

4.2.1.2 **GRAPHS**

The recorded data were used to plot graphs of Temperature (outdoor and indoor) versus Local Time. These are presented as Figs. 1 to 20.

On a general note, the indoor temperature always falls below the outdoor temperature especially during the day. And in the night, there are times when equilibrium is reached, and at some other times, the indoor temperature is higher.

This trend can be explained based on the principle of heat transfer. The building walls absorb heat during the day only to radiate same in the night, when the outdoor temperature is now lower, equilibrium would be reached and if the outdoor is still at lower temperature, the indoor temperature goes higher.

MAINLAND ZONE

House 1: Figure 1 shows the graphs of temperature against time on 17^{th} day of August 2000. It can be seen that the trend follows the basic principle of outdoor temperature being higher than the indoor temperature during the day. In the night however, the indoor temperature becomes higher. This

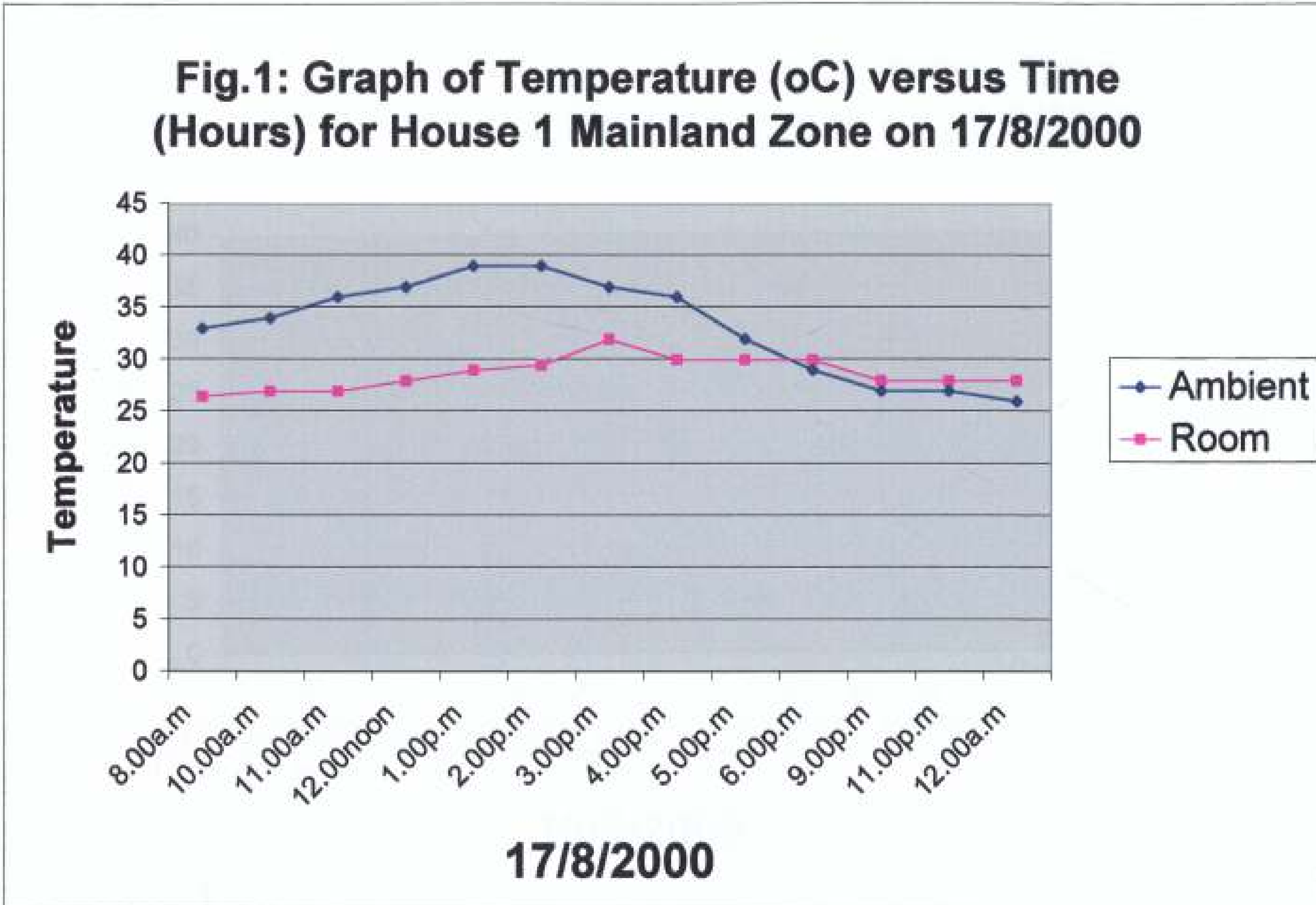
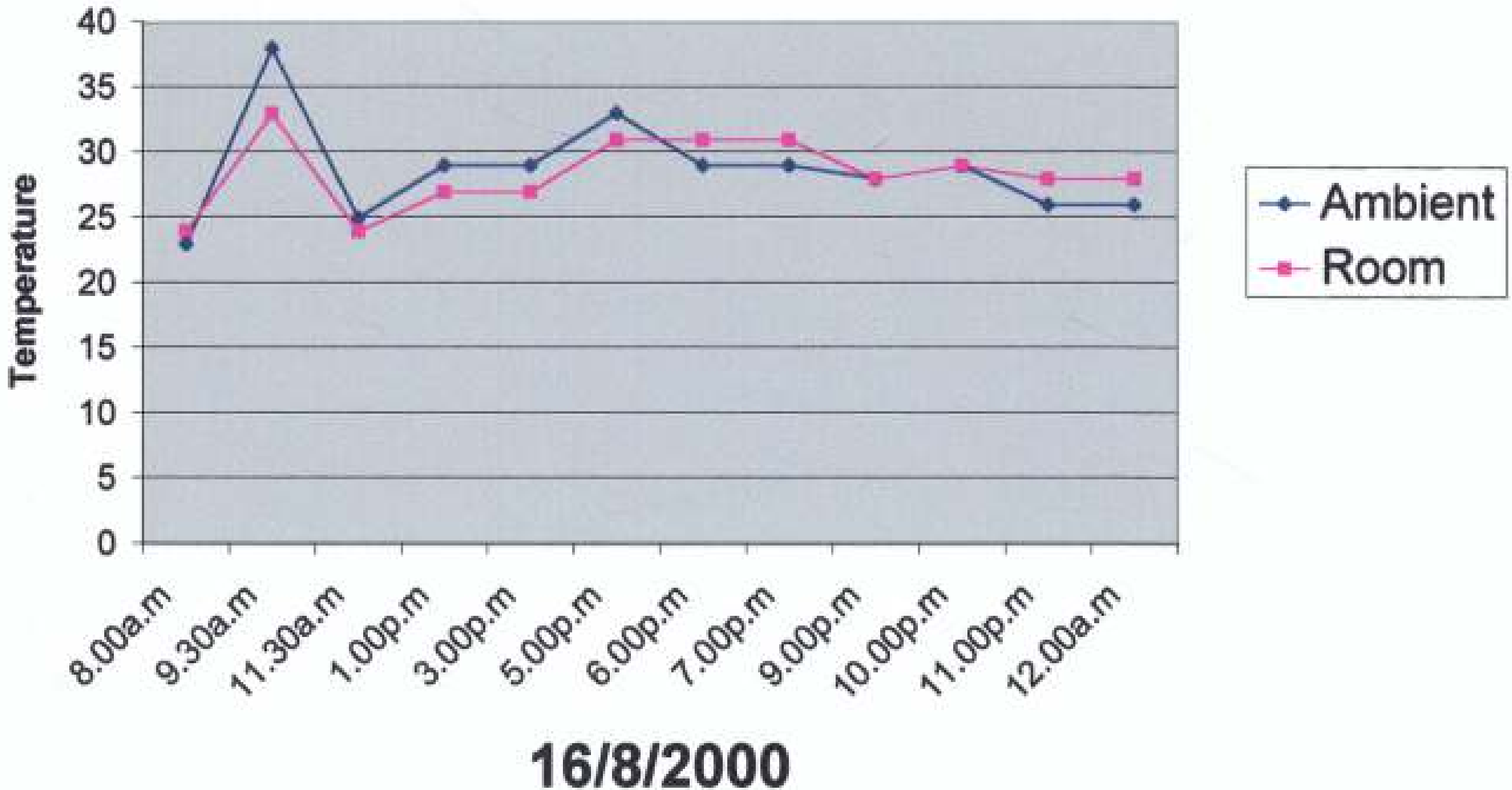


Fig.1: Graph of Temperature (oC) versus Time (Hours) for House 1 Mainland Zone on 17/8/2000
45
40
35
30
25
20
15
10
5
0
Temperature
8.00a.m
10.00a.m
11.00a.m
12.00noon
1.00p.m
2.00p.m
3.00p.m
4.00p.m
5.00p.m
6.00p.m
9.00p.m
11.00p.m
12.00a.m
17/8/2000
Ambient
Room

Fig.2: Graph of Temperature (oC) versus Time (Hours) for House 2 Mainland Zone on 16/8/2000



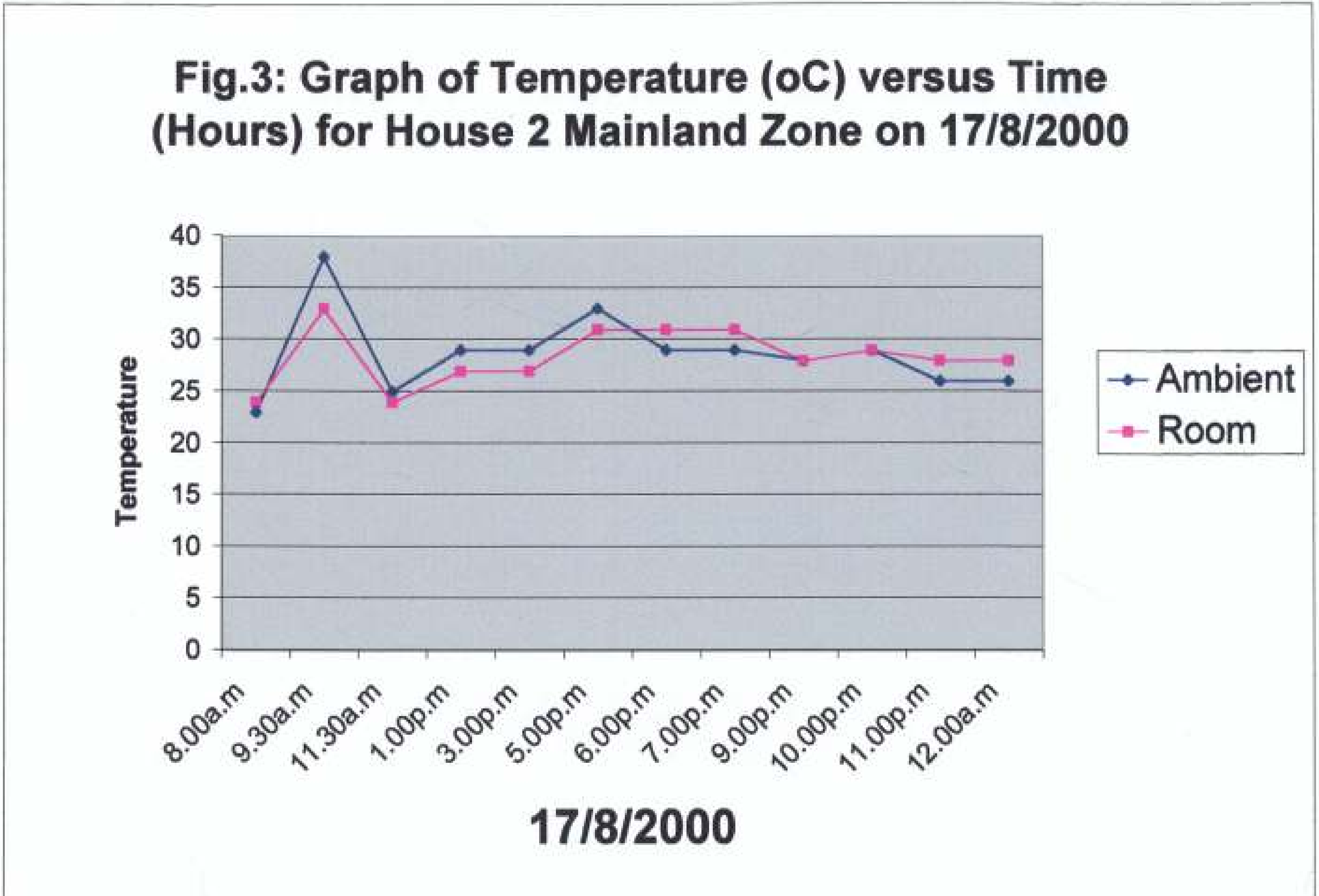


Fig.3: Graph of Temperature (oC) versus Time (Hours) for House 2 Mainland Zone on 17/8/2000
40
35
30
25
20
15
10
5
0
Temperature
Ambient
Room
8.00a.m
9.30a.m
11.30a.m
1.00p.m
3.00p.m
5.00p.m
6.00p.m
7.00p.m
9.00p.m
10.00p.m
11.00p.m
12.00a.m
17/8/2000

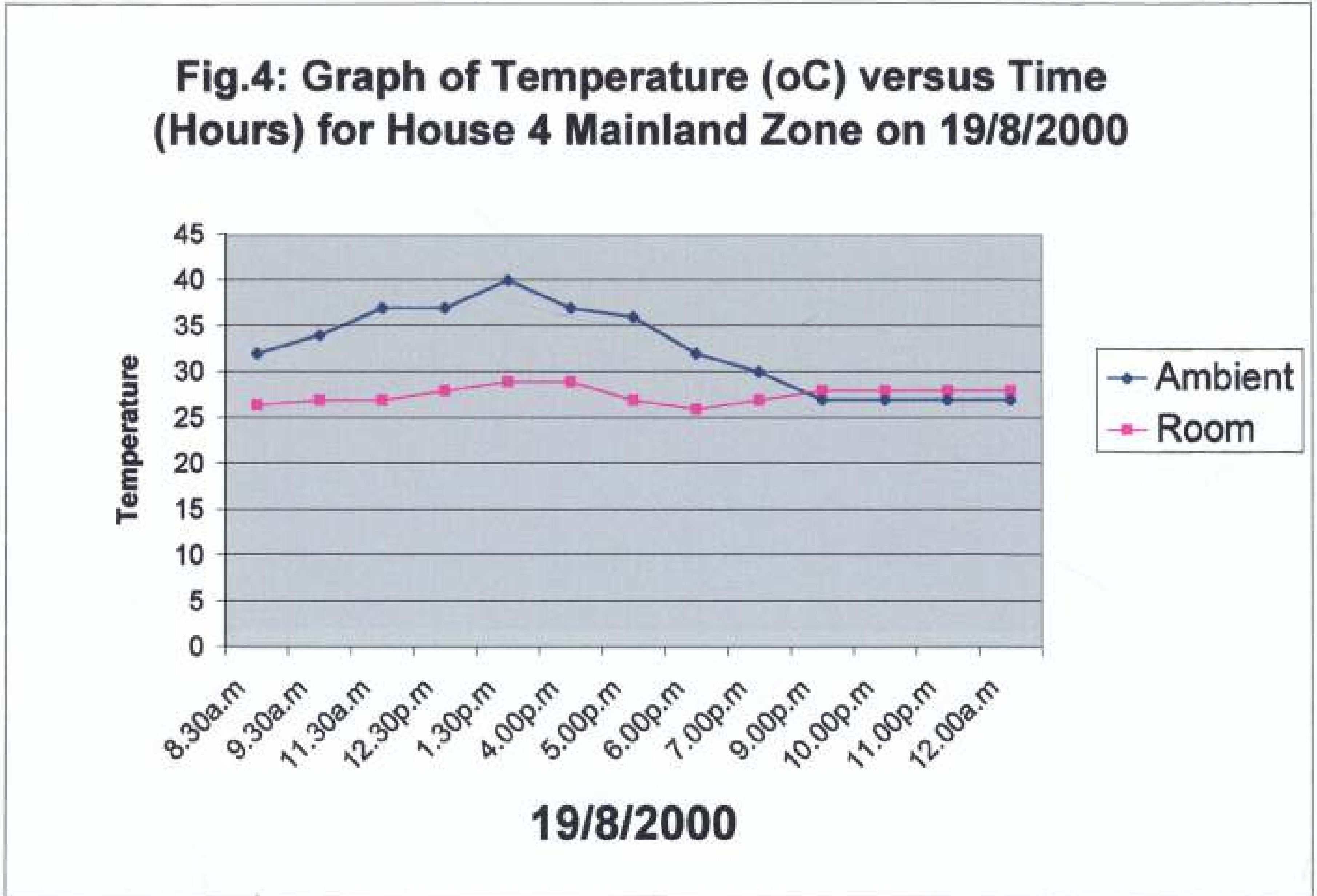


Fig.4: Graph of Temperature (oC) versus Time (Hours) for House 4 Mainland Zone on 19/8/2000
45
40
35
30
25
20
15
10
5
0
Temperature
8.30a.m
9.30a.m
11.30a.m
12.30p.m
1.30p.m
4.00p.m
5.00p.m
6.00p.m
7.00p.m
9.00p.m
10.00p.m
11.00p.m
12.00a.m
19/8/2000
Ambient
Room

Fig.5: Graph of Temperature (oC) versus Time (Hours) for House 5 Mainland Zone on 20/8/2000

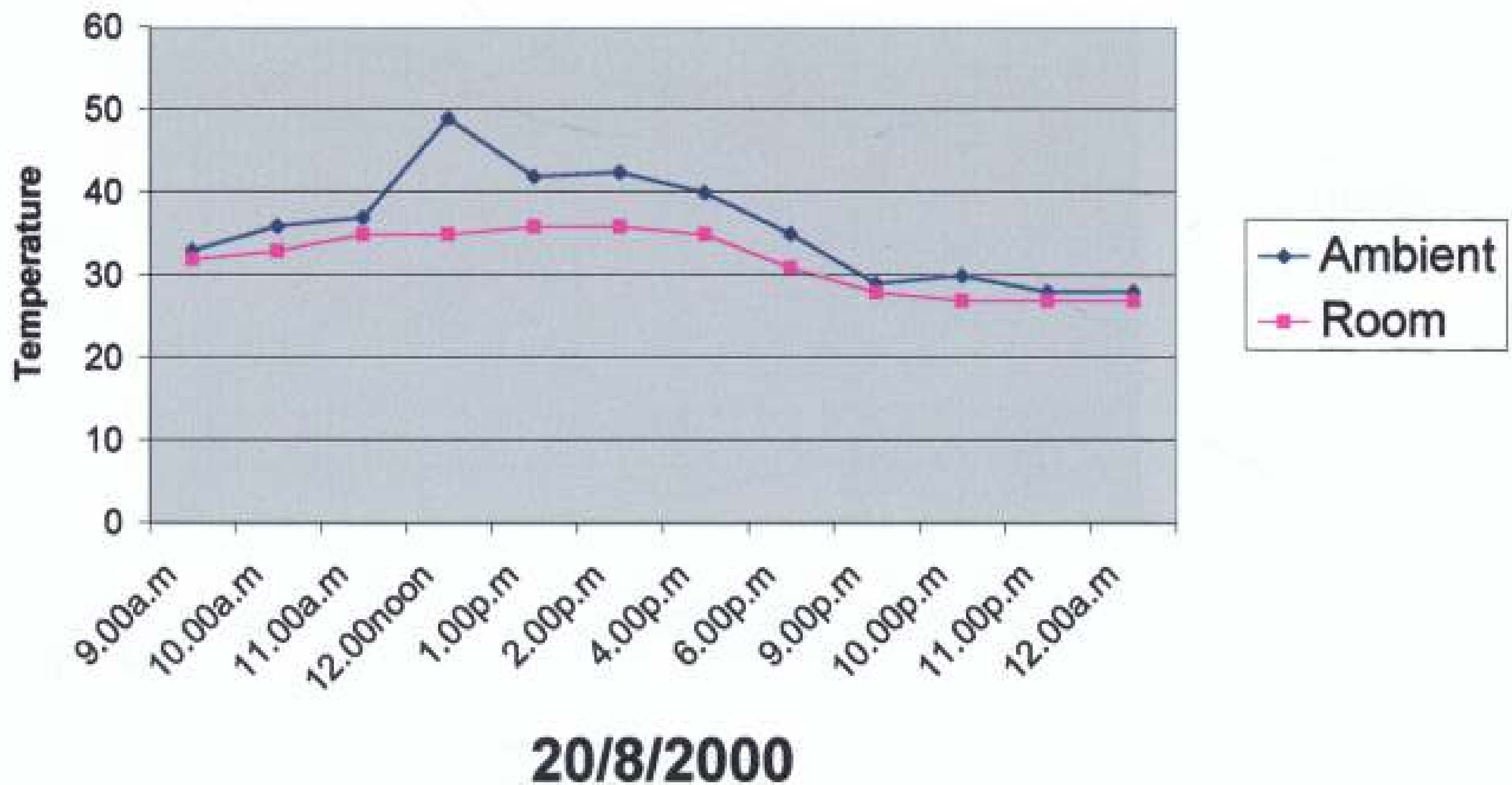


Fig.6: Graph of Temperature (oC) versus Time (Hours) for House 6 Mainland Zone on 21/8/2000

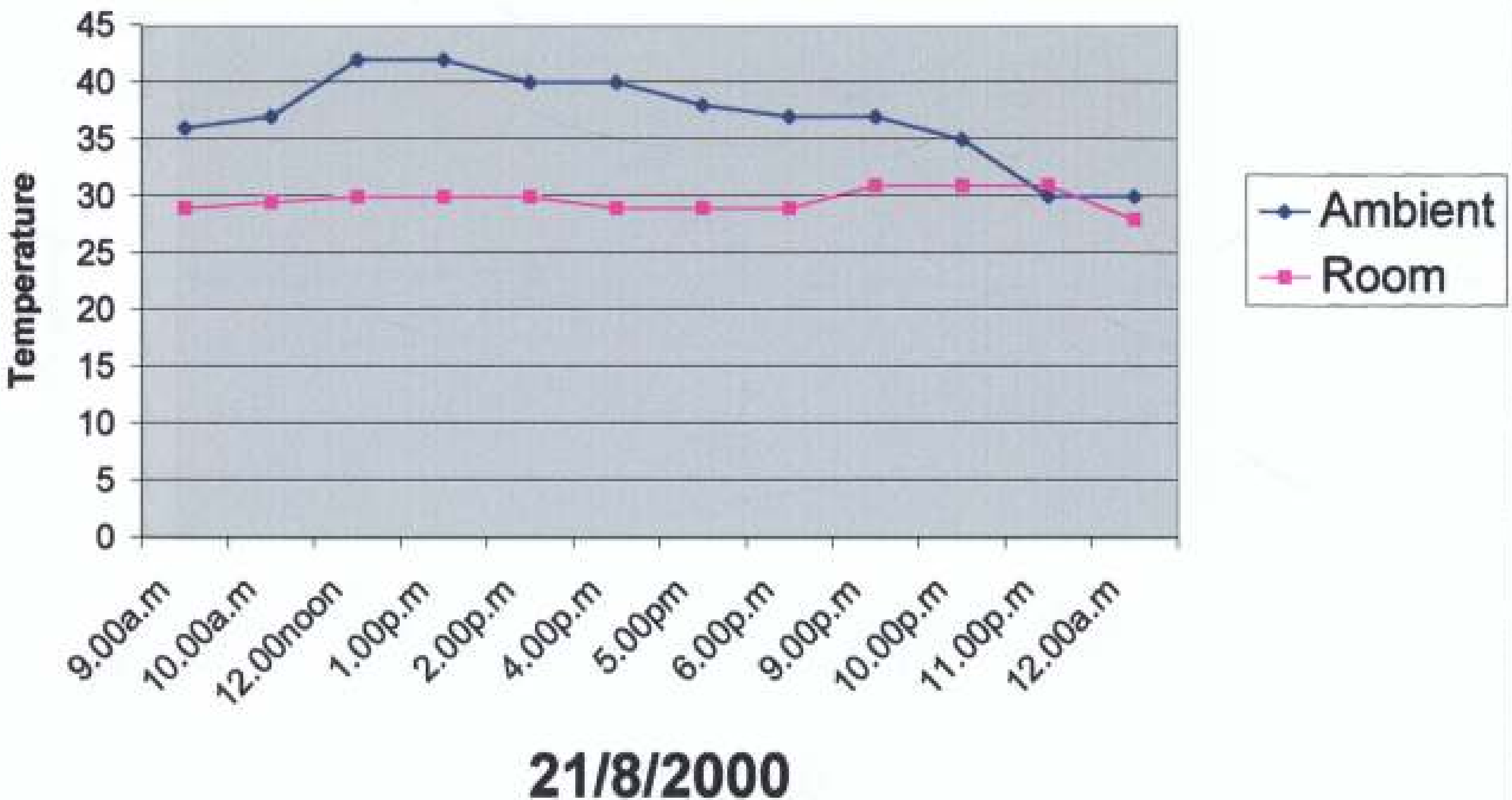


Fig.7: Graph of Temperature (oC) versus Time (Hours) for House 7 Mainland Zone on 18/8/2000

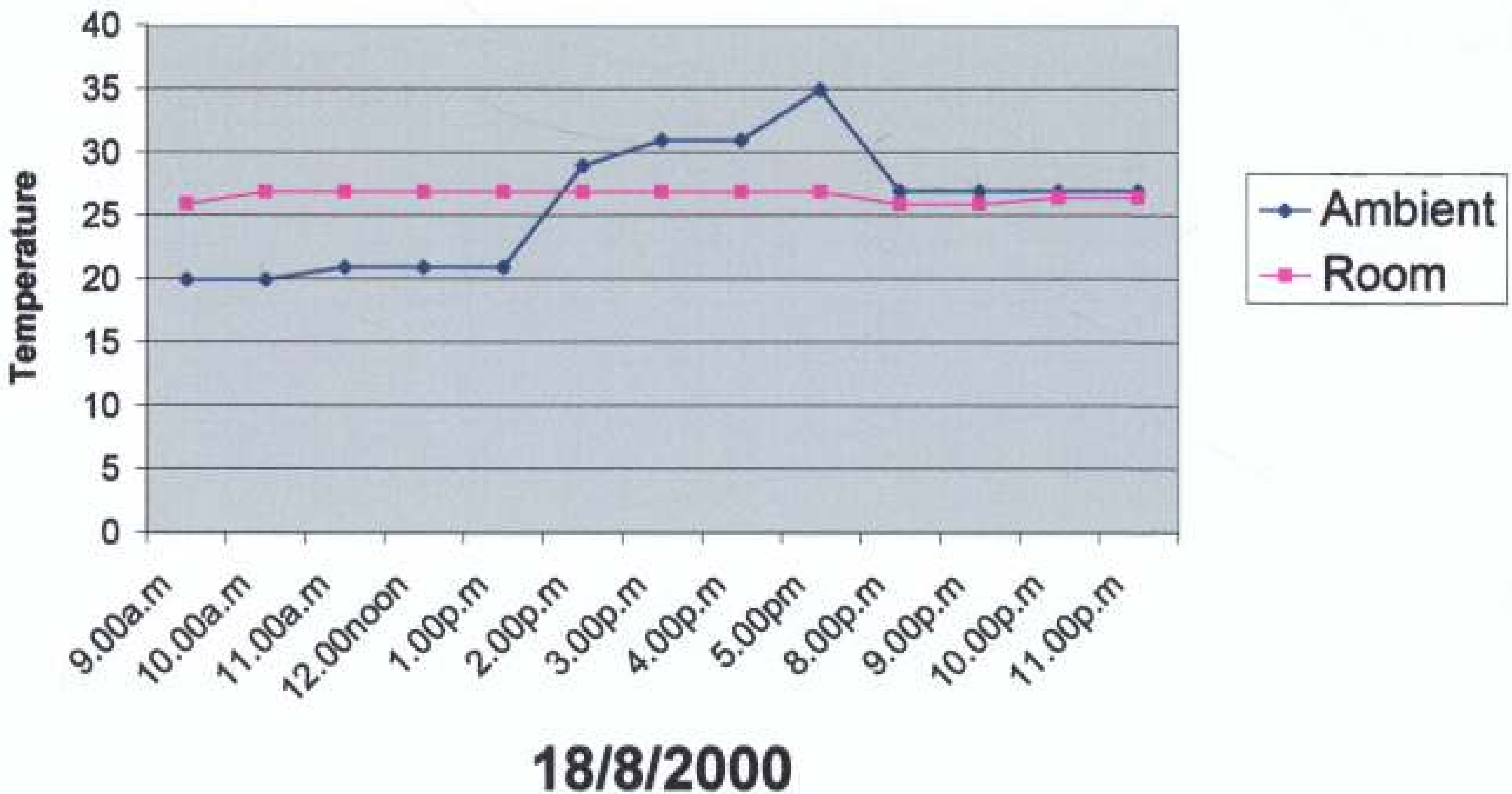
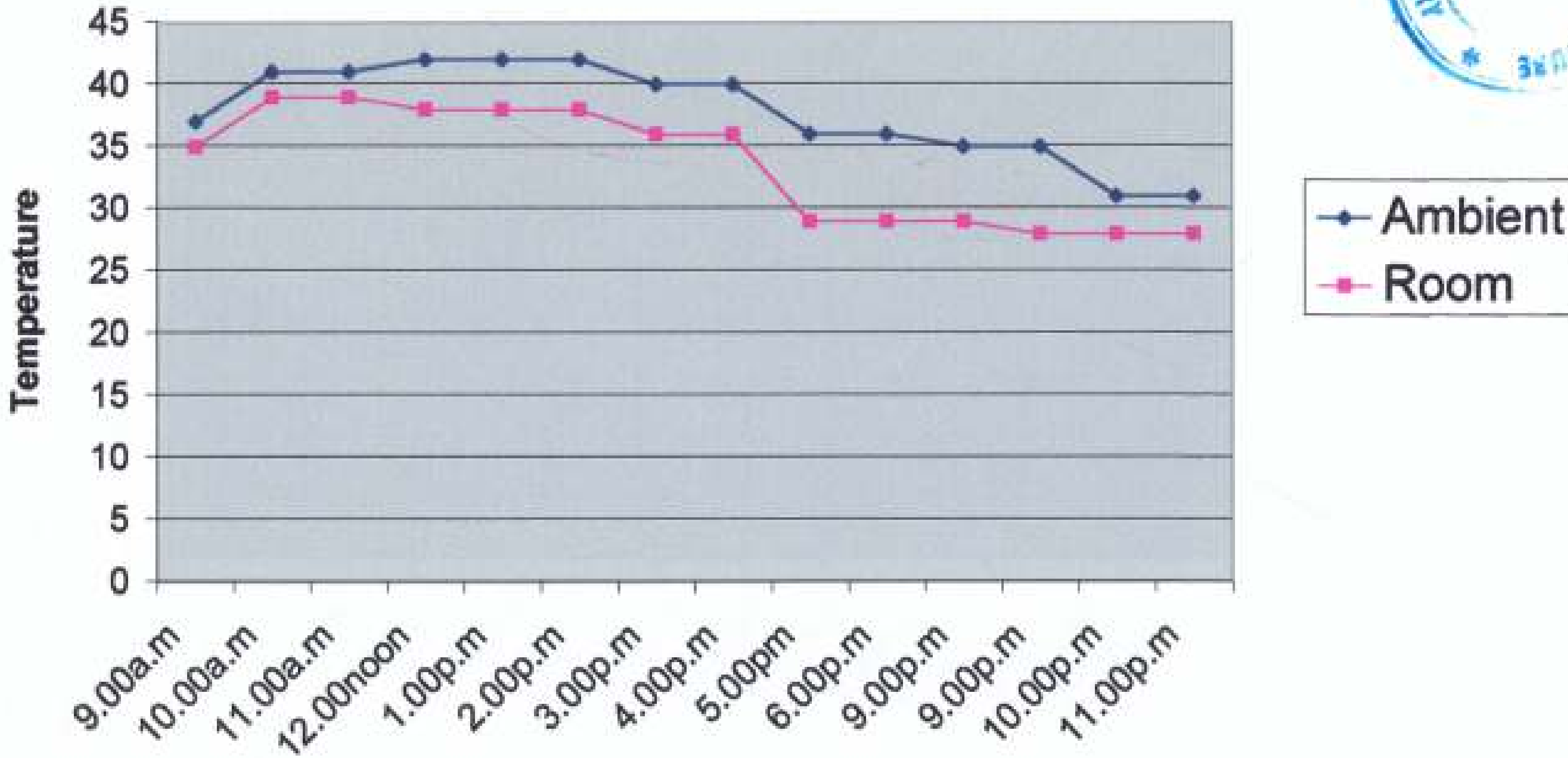


Fig.8: Graph of Temperature (oC) versus Time (Hours) for House 8 Mainland Zone on 21/8/2000



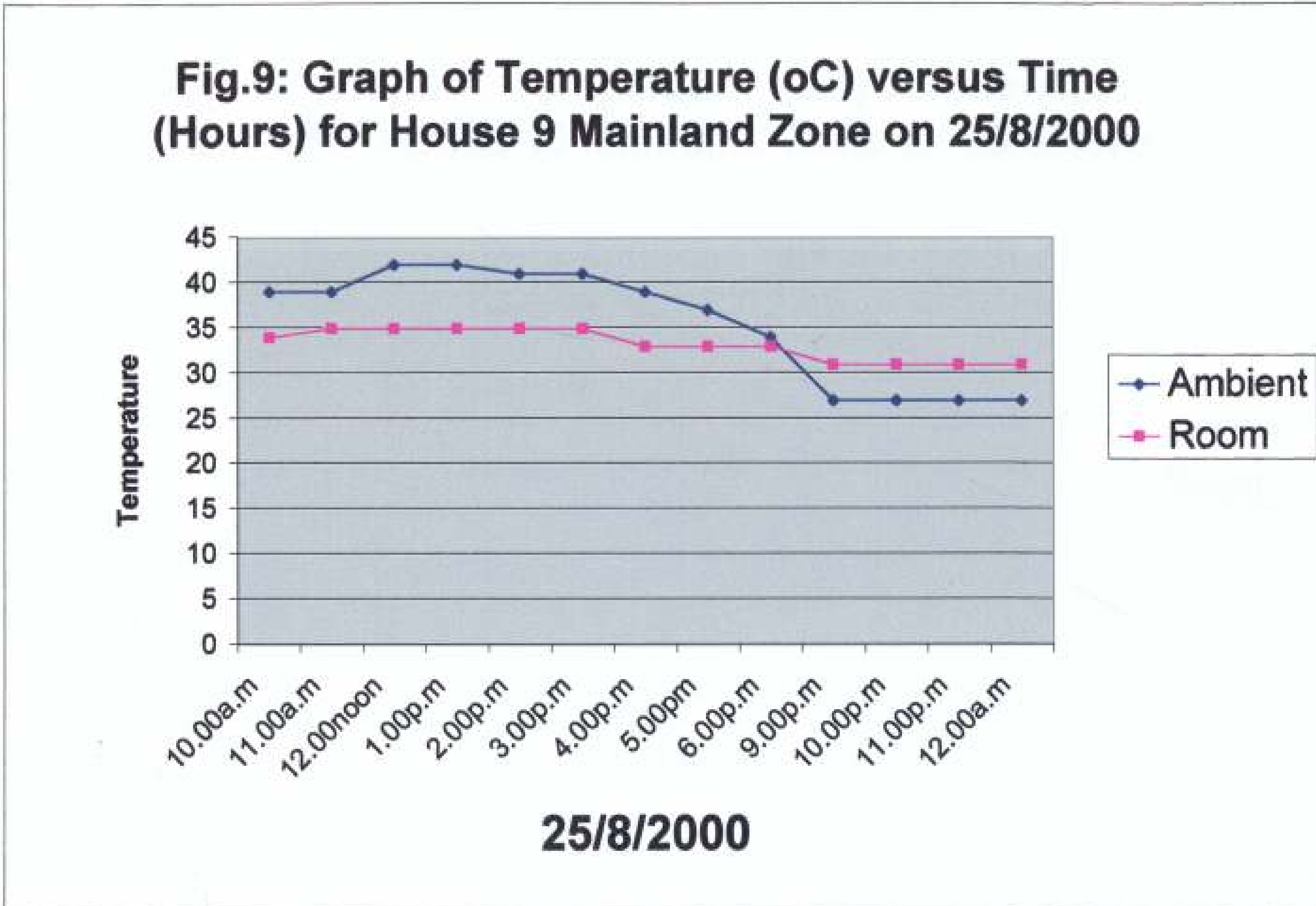
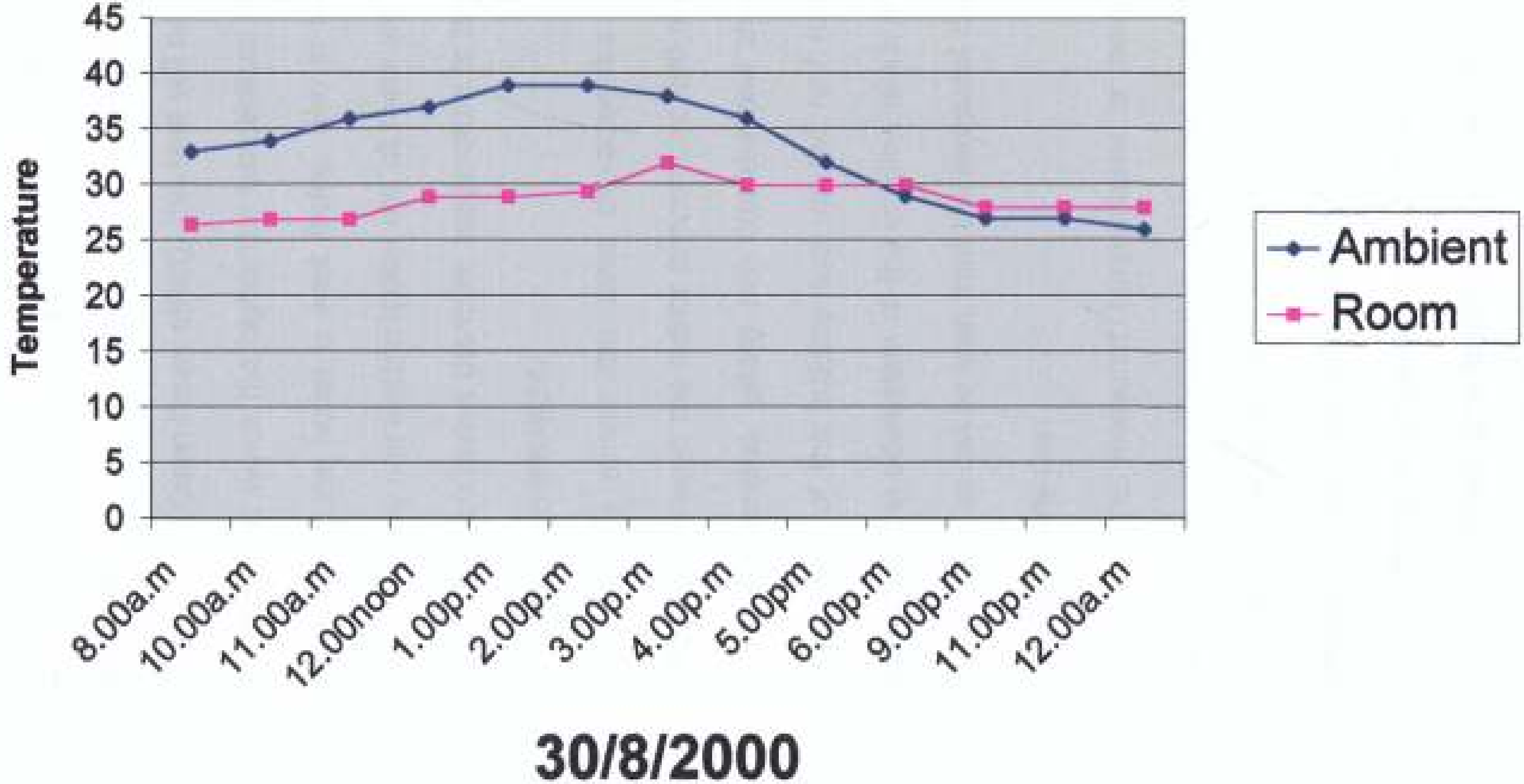


Fig.9: Graph of Temperature (oC) versus Time (Hours) for House 9 Mainland Zone on 25/8/2000
Temperature
45
40
35
30
25
20
15
10
5
0
10.00a.m
11.00a.m
12.00noon
1.00p.m
2.00p.m
3.00p.m
4.00p.m
5.00pm
6.00p.m
9.00p.m
10.00p.m
11.00p.m
12.00a.m
25/8/2000
Ambient
Room

Fig.10: Graph of Temperature (oC) versus Time (Hours) for House 10 Mainland Zone on 30/8/2000



could be attributed to the materials used in building the houses. The roof material used is asbestos and ceiling material used is asbestos.

The door material is glass; just as the window materials are louver blades. Thus, heat is greatly transmitted into the building during the day, but will not be released, (Green house effect), this heat will be circulating in the room in the room and hence the higher the temperature readings at night, despite the fact that the house is west facing. Also in the house there are eight bulbs, six fans, one electric cooker etc, all these are contributing their heat in the night which makes the room temperature to be higher than the ambient temperature in the night.

House 2 has almost the same characteristics as house one, but the difference between the indoor temperature and outdoor temperature is not much as expected, taking into consideration the materials used for the construction of the building such as the roof material is corrugated Iron sheets and the orientation of the building which is south-facing. This could be attributed as can be seen from the measured data that the readings were done on a rainy day.

Comparing the measured temperatures of houses one and two for a particular day, (17/08/2000), it can be seen that the difference between the ambient temperatures around both house is smaller than the difference between the room temperatures of both houses.

The difference in ambient temperature can be attributed to the fact that house one is built on a spacious compound with few houses compound with few houses surrounded by trees acting as shades preventing direct sunlight from penetrating into building through the windows/glass. There is also cross-ventilation in the building from the Table 4.3(a) it is also seen that there is a high volume – Temperature ratio in house one which, indicates that there is more cool air in the building and there are also only eight people living in the whole building, whereas in house two there is no feasible space between the surrounding buildings which makes the ambient temperature have to be a little higher. A lot of people (16) are living in rooms considered in house two.

The living room is being heated by direct sunlight, which makes the room direct sunlight, which makes the room temperature to be high, the volume-temperature ratio is very small, which means the cool air available is so small.

However, the trend changed in house 3, as the indoor temperature was higher almost throughout, though with just a difference of between 1°C and 2 °C. From its building data, house 3 is built with red block and has wooden flush door. It has corrugated iron sheets on the roof and the ceiling is made of cardboard, the building is also southfacing.

With the materials used, more heat is gained into the house; through the room volume- indoor temperature ratio is high.

For house 4, two cases were considered, from the measured data obtained on 17th August, when it was raining. The data showed that the temperature readings were close (both outdoor and indoor), while, Fig. 4 shows the plot of data obtained on 19th August, a sunny day, the outdoor temperature was higher throughout the day.

From its building data, house 4 is built with cement block, has a concrete decking, glass louvers window blades, glass sliding door and the building is south –facing.

Much heat will be transmitted into the building during the day but this heat will not be easily released, which will make the building indoor temperature to be high.

The above trend continues for all the remaining houses as can be seen from their respective graphs and the measured data.

While, house 10 is east facing, with asbestos roofing, asbestos ceiling and wooden door, this makes heat being absorbed into the house to be minima.

IKORODU ZONE

Figures 11 – 20 show the graphs of Temperature against Time for the various houses in the zone.

They still follow the same trend of the outdoor temperatures being greater than the indoor temperatures during the day and in the night however, an equilibrium would be reached between the outdoor and indoor temperatures since the building walls would have absorbed heat during the day and only to radiate same in the night, thereby bringing about lower temperature inside than the outdoor temperatures.

House 6,7,8 and 9 which are facing either east or west direction have lower indoor temperature range than other houses which are either facing north or south direction, this is because the rooms are heated by the day sunlight either in the morning or when the sun is going to set on the west orientation.

Fig.11: Graph of Temperature (oC) versus Time (Hours) for House 1 Ikorodu Zone on 30/8/2000

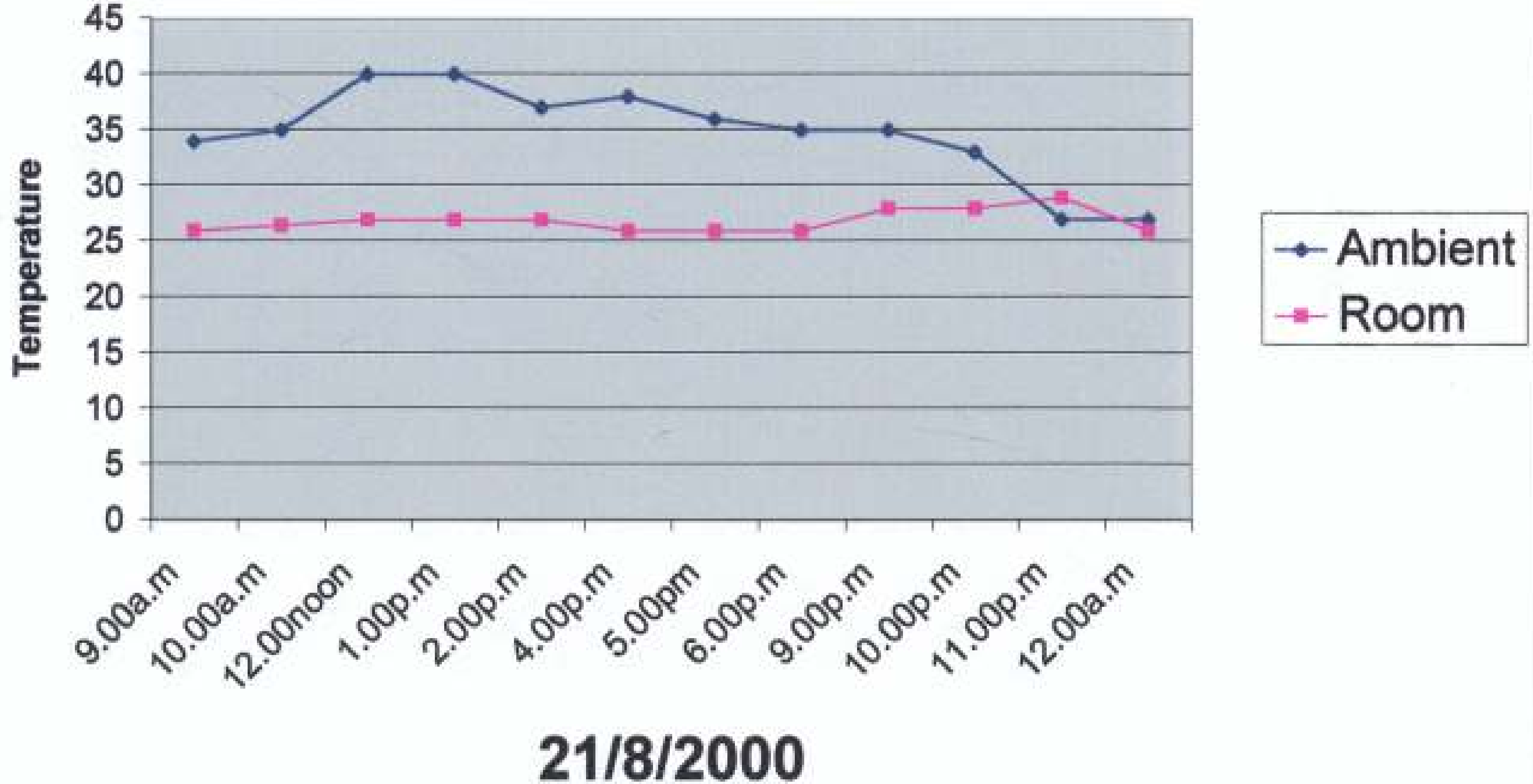


Fig.12: Graph of Temperature (oC) versus Time (Hours) for House 2 Ikorodu Zone on 30/8/2000

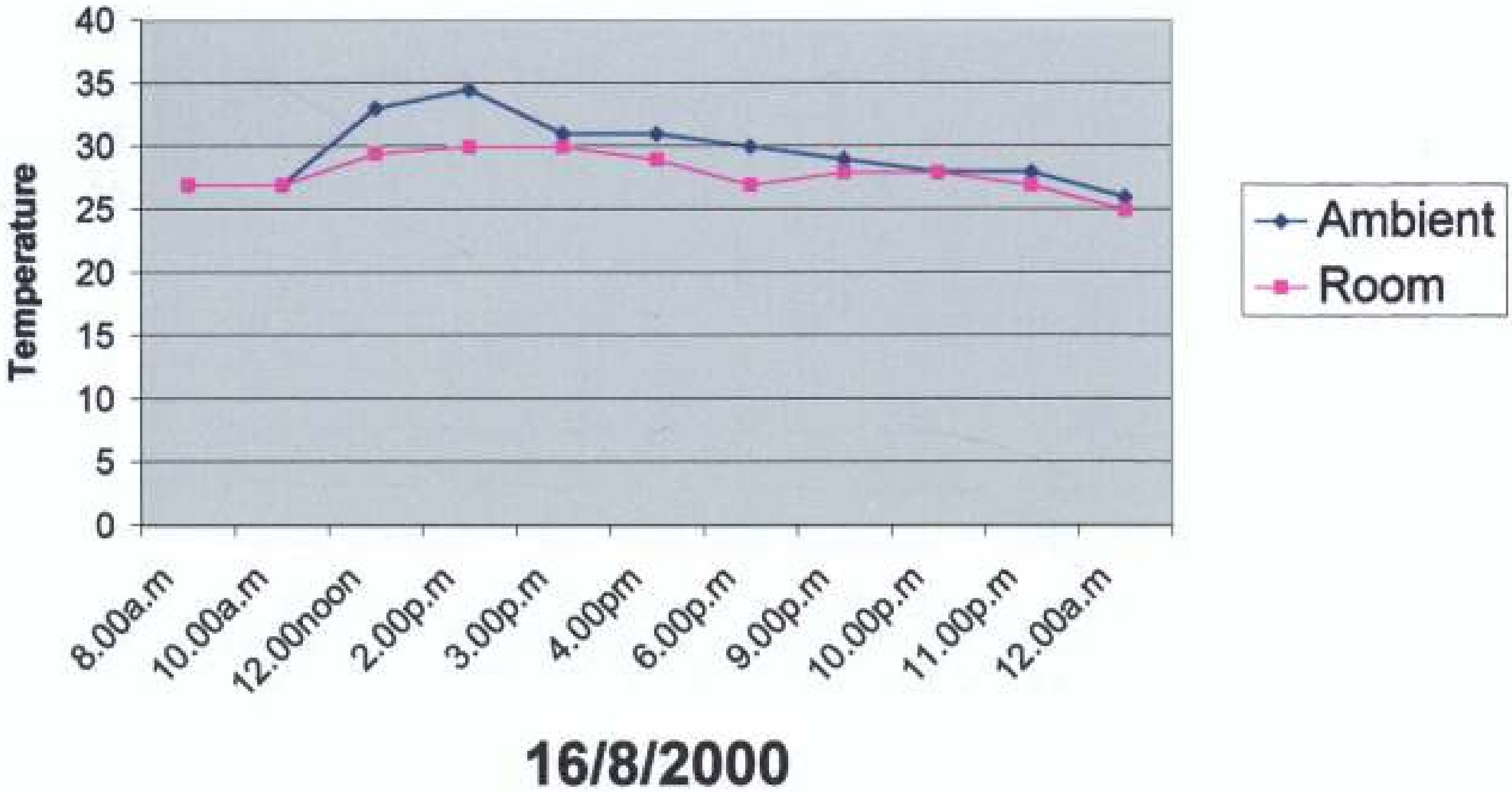
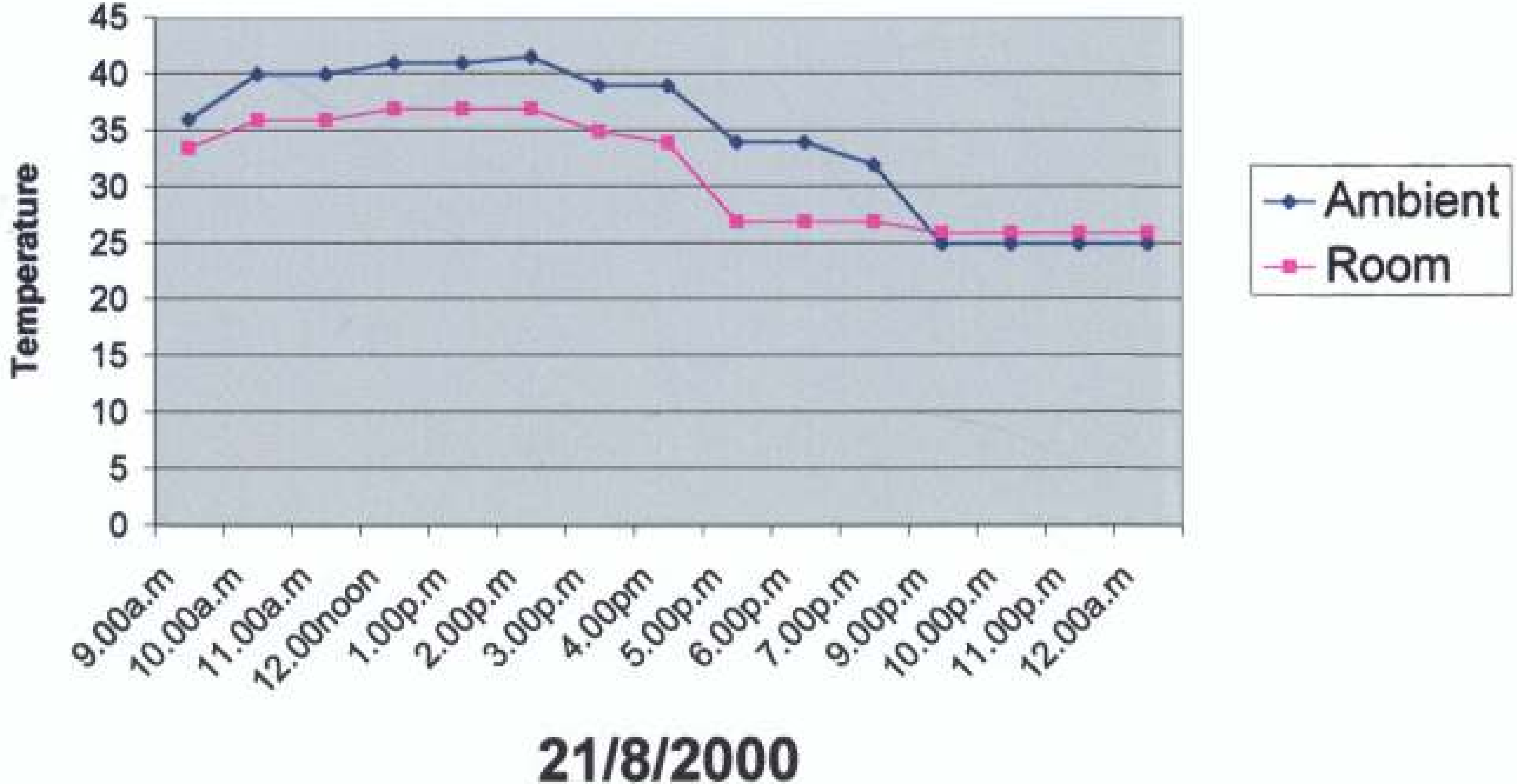


Fig.13: Graph of Temperature (oC) versus Time (Hours) for House 3 Ikorodu Zone on 21/8/2000



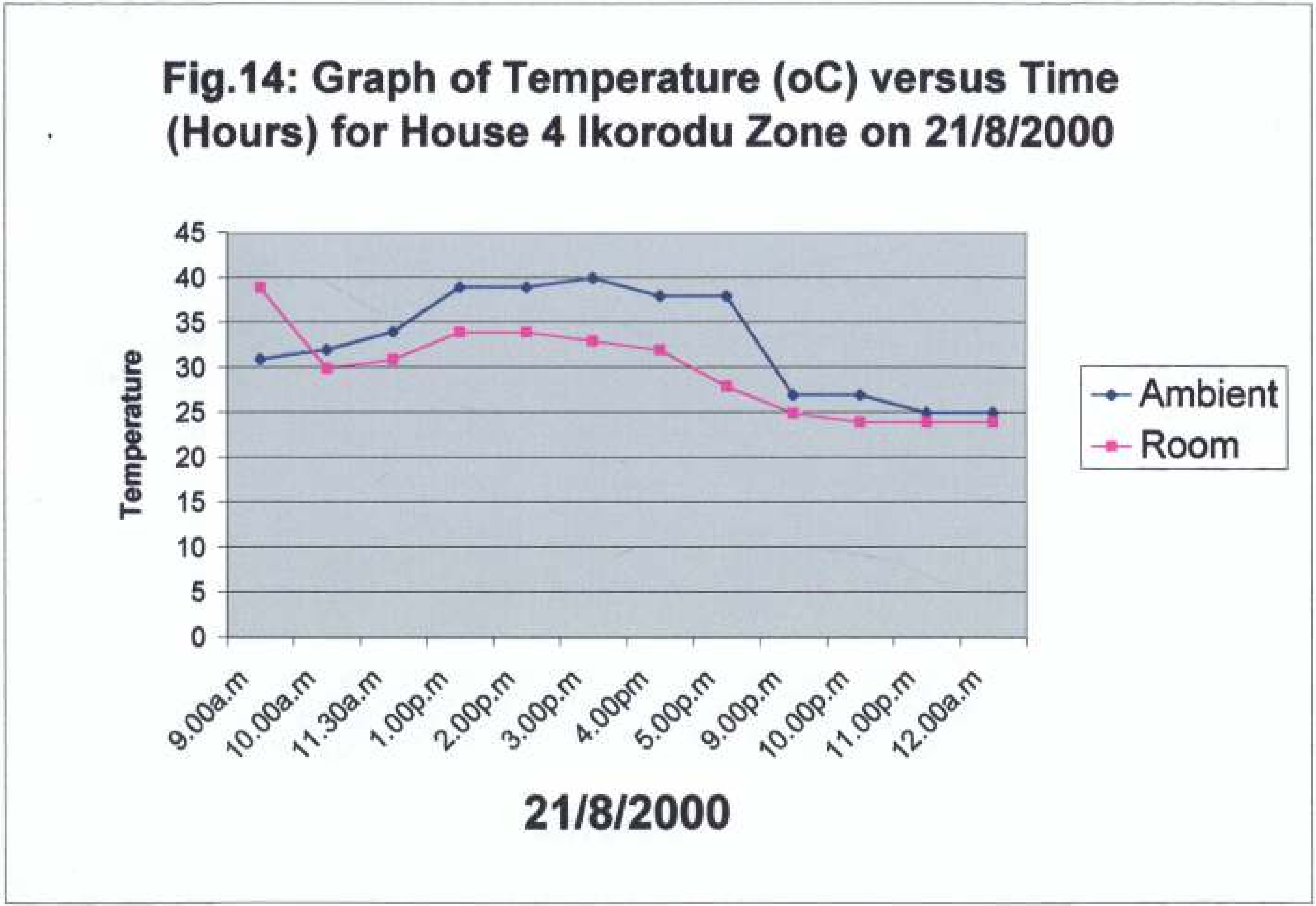


Fig.14: Graph of Temperature (oC) versus Time (Hours) for House 4 Ikorodu Zone on 21/8/2000
Temperature
45
40
35
30
25
20
15
10
5
0
9.00a.m
10.00a.m
11.30a.m
1.00p.m
2.00p.m
3.00p.m
4.00pm
5.00p.m
9.00p.m
10.00p.m
11.00p.m
12.00a.m
21/8/2000
Ambient
Room

Fig.15: Graph of Temperature (oC) versus Time (Hours) for House 5 Ikorodu Zone on 25/8/2000

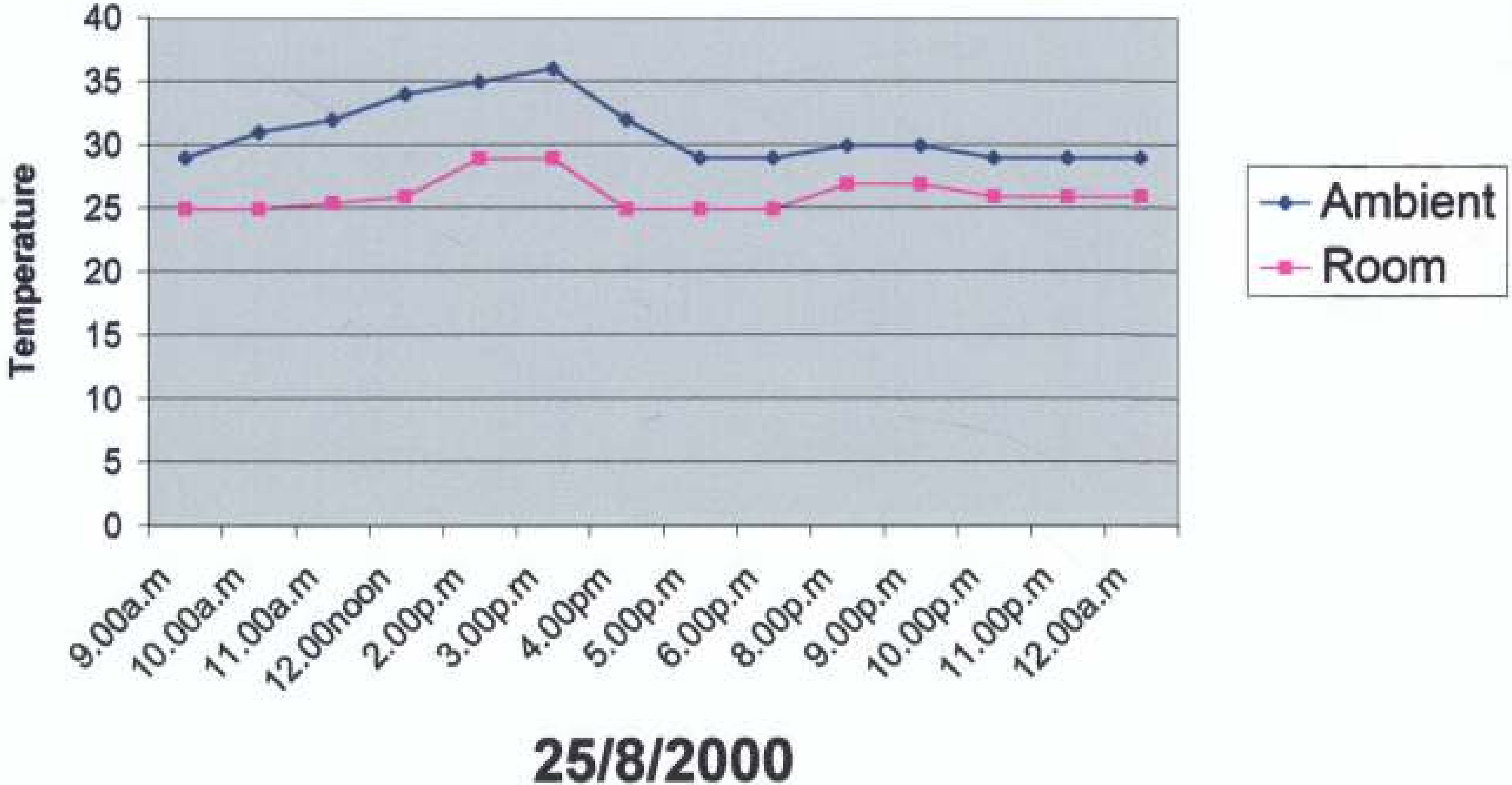
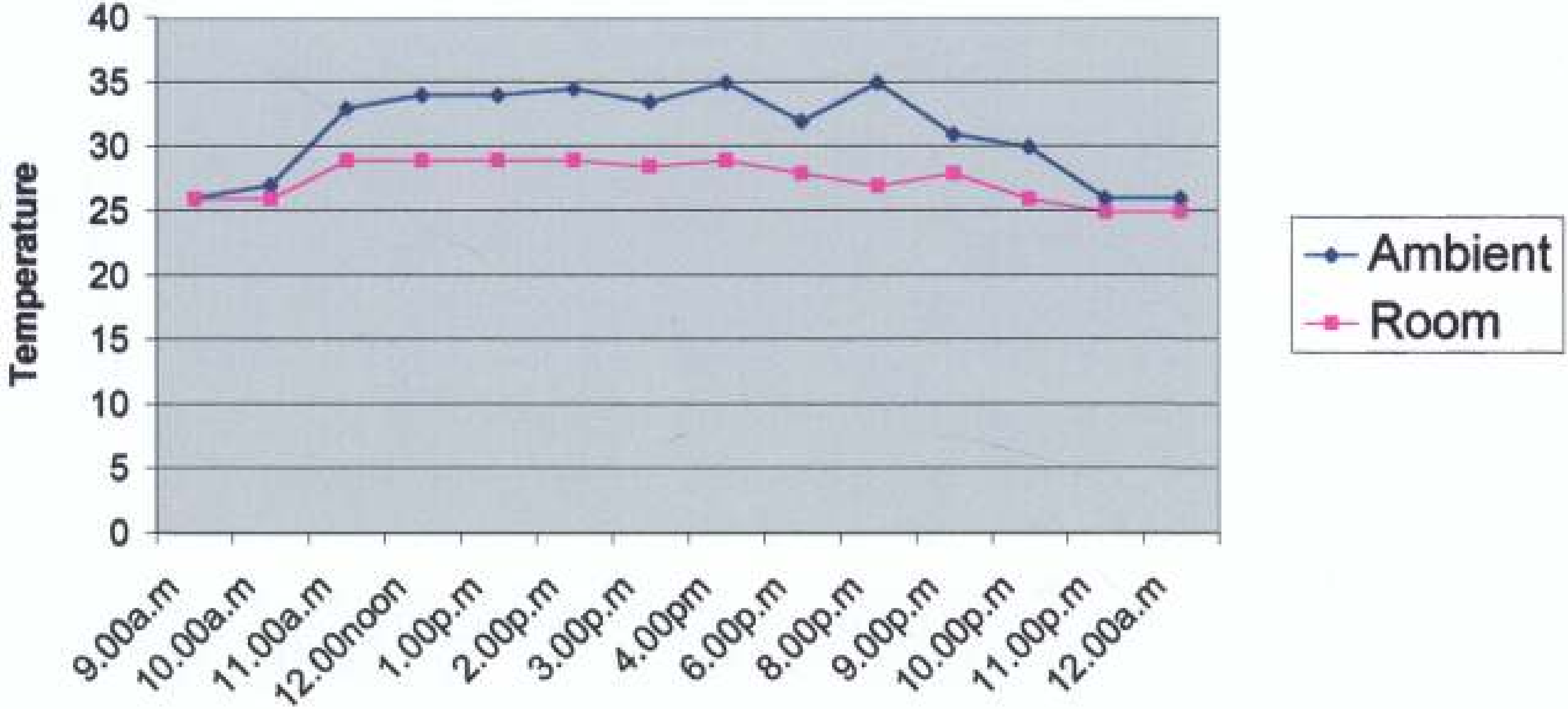


Fig.16: Graph of Temperature (oC) versus Time (Hours) for House 6 Ikorodu Zone on 16/8/2000



25/8/2000

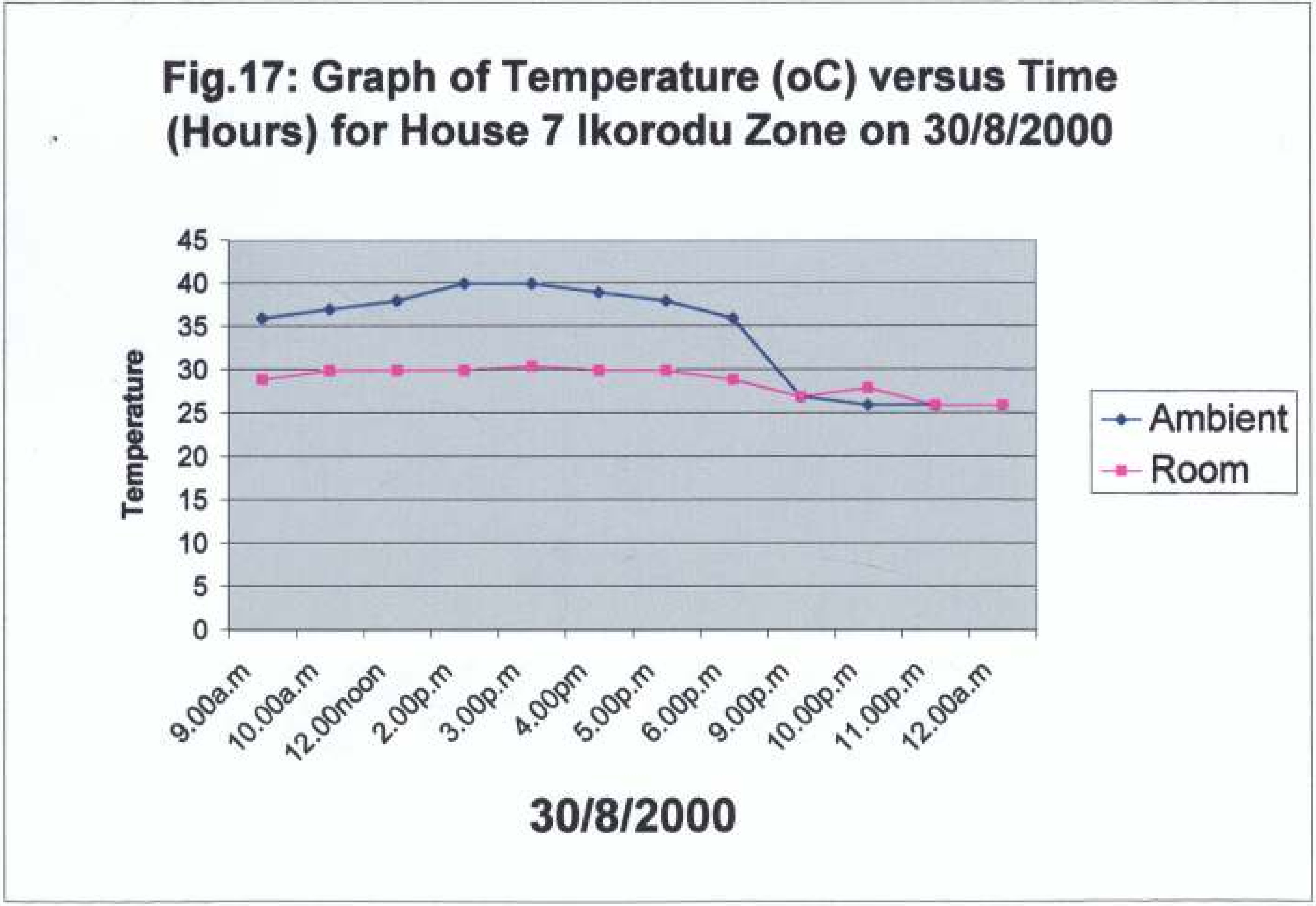


Fig.17: Graph of Temperature (oC) versus Time (Hours) for House 7 Ikorodu Zone on 30/8/2000
45
40
35
30
25
20
15
10
5
0
Temperature
9.00a.m
10.00a.m
12.00noon
2.00p.m
3.00p.m
4.00pm
5.00p.m
6.00p.m
9.00p.m
10.00p.m
11.00p.m
12.00a.m
30/8/2000
Ambient
Room

Fig.18: Graph of Temperature (oC) versus Time (Hours) for House 8 Ikorodu Zone on 5/9/2000

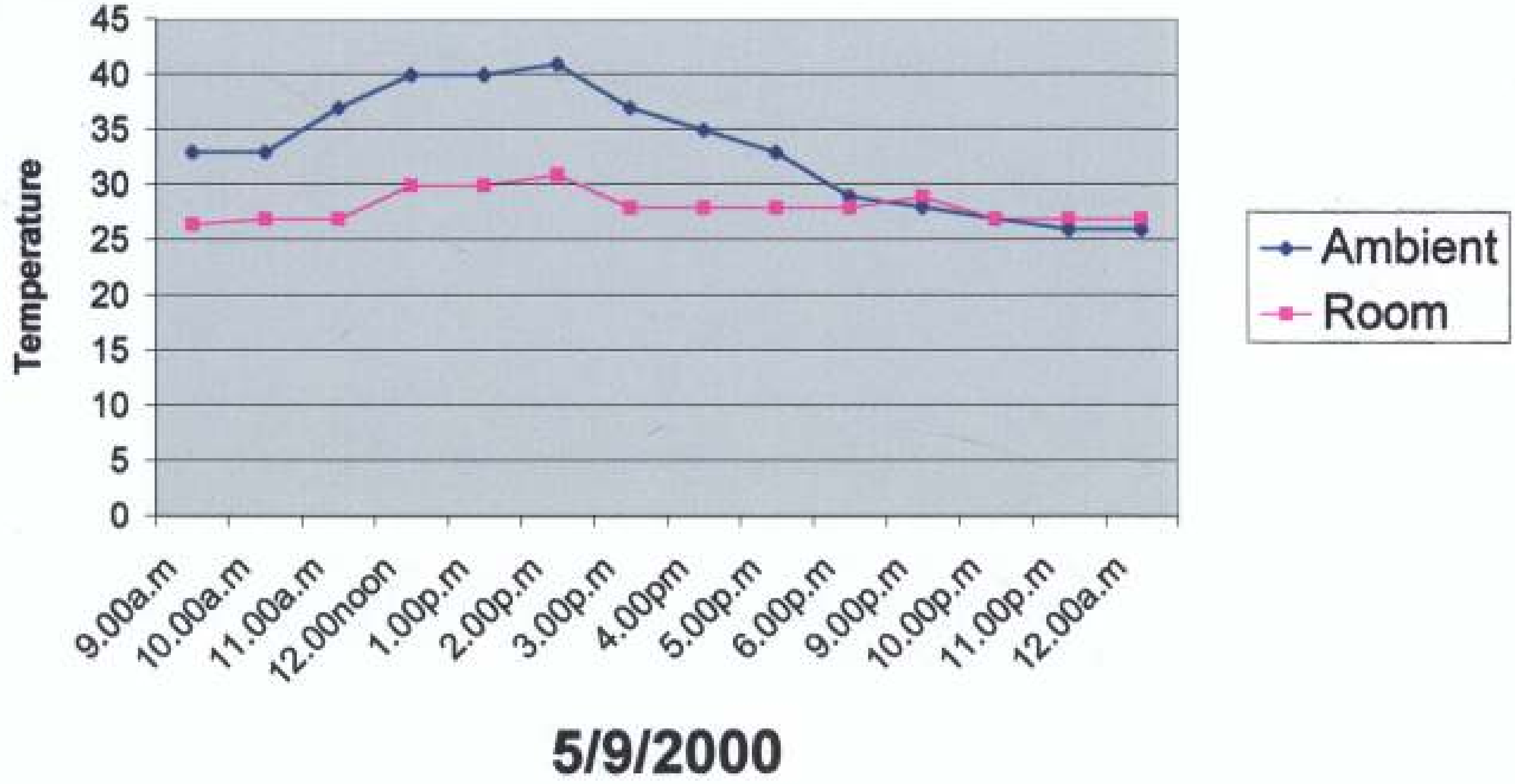


Fig.19: Graph of Temperature (oC) versus Time (Hours) for House 9 Ikorodu Zone on 3/9/2000

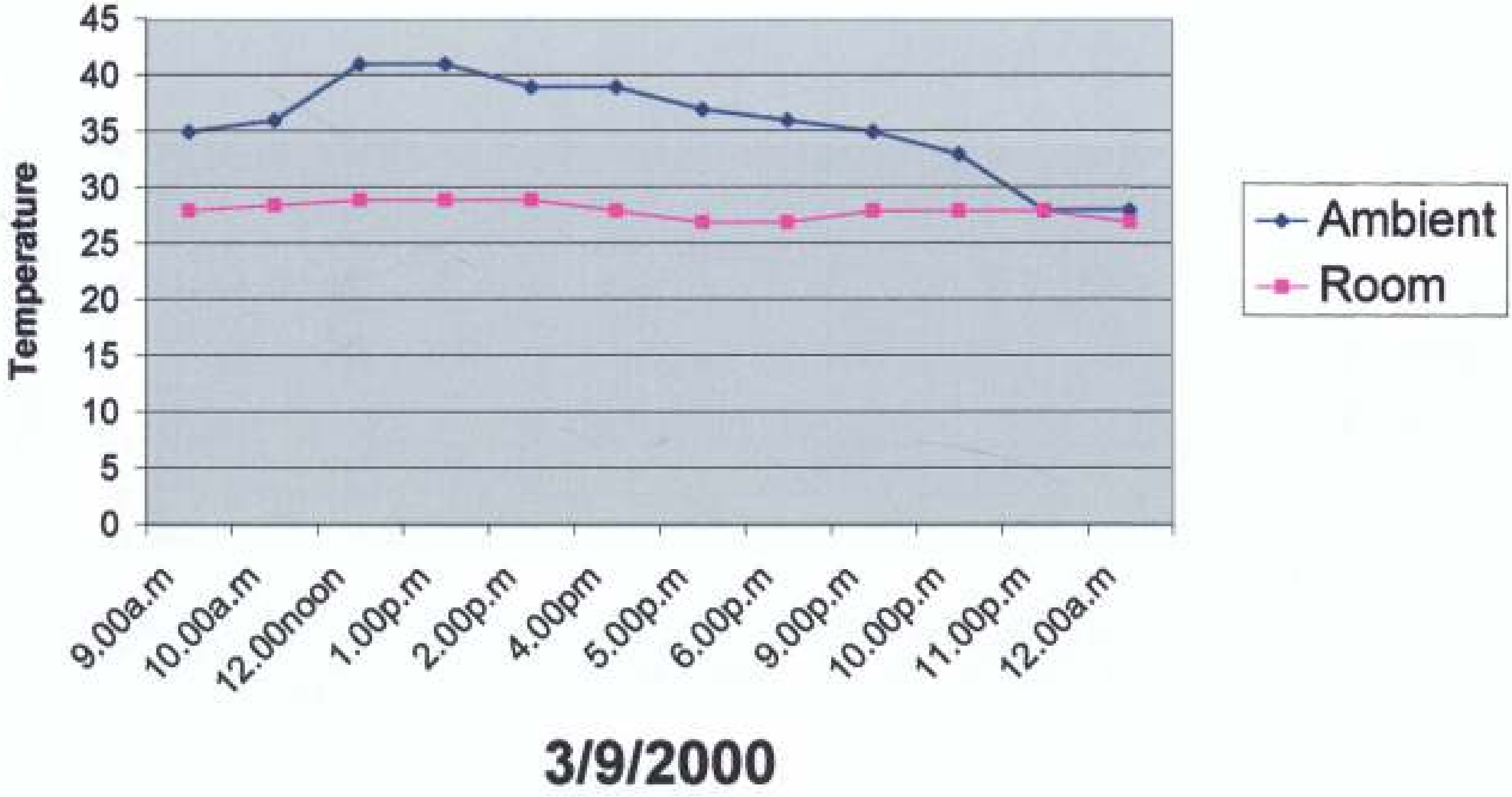
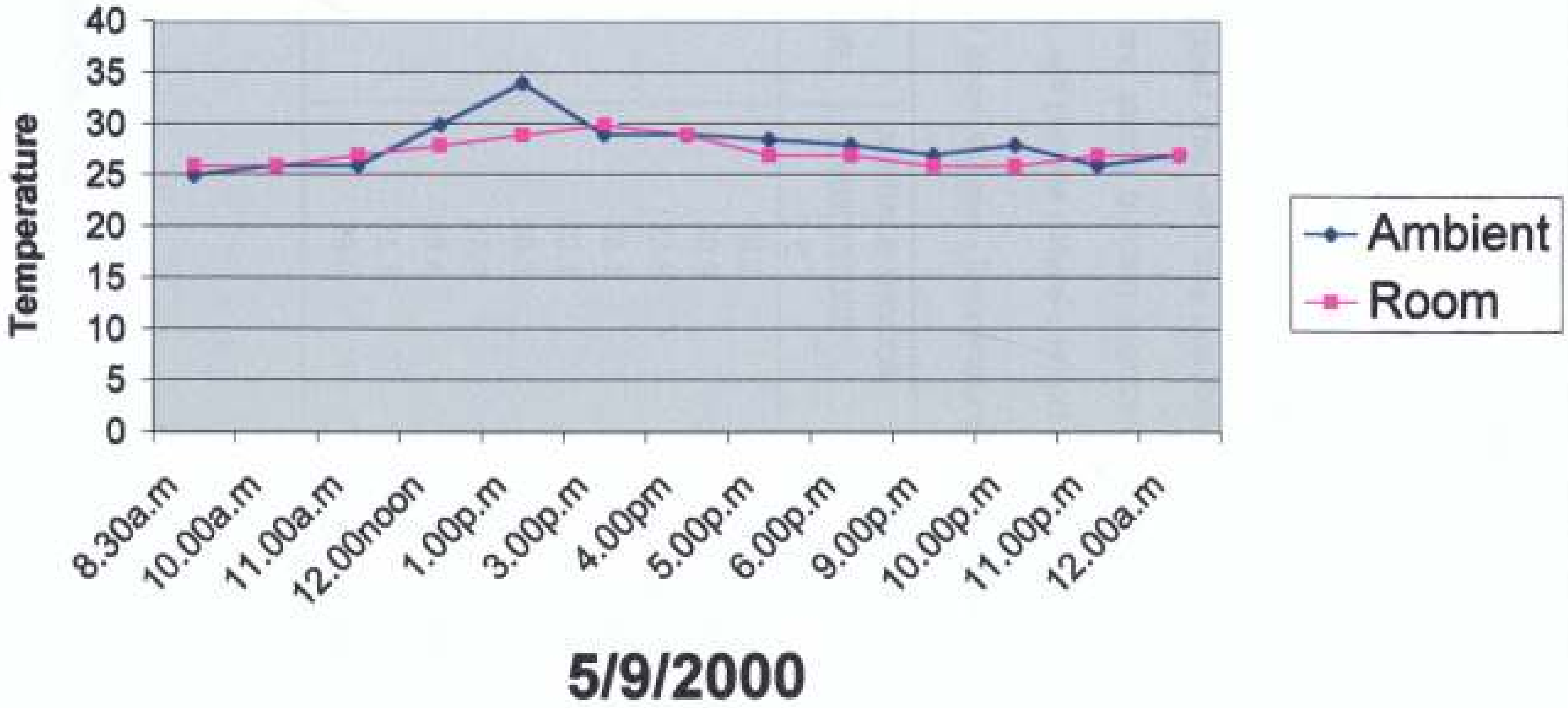


Fig.20: Graph of Temperature (oC) versus Time (Hours) for House 10 Ikorodu Zone on 5/9/2000



One other factor that contributed to lower temperatures both for indoor and outdoor temperatures is that Ikorodu zone is less populated than the mainland zone and there is still some abundant natural vegetation in the zone, which in the mainland zone, there is no vegetation of any sort.

Also, comparing the values of ratio of room volume to indoor temps, it is seen that more houses in Ikorodu zone have values that are above 1 which readily shows that Ikorodu zone is more habitable than mainland zone, which means to suggest that with less population in an area, more spaces between buildings and taking building orientation into consideration when constructing houses, will provide natural comfort for habitants.

Table 4.3 (a) Indoor Room Volume -Temperature Data For Mainland Zone

HOUSE	ROOM VOLUME (M^3)	AVERAGE INDOOR TEMPERATURE °C	RATIO (VOL/T° C)
1	42.26	28.1	1.504
2	15.23	30.9	0.493
3	39.20	27.8	1.410
4	44.24	28.1	1.574
5	22.55	30.1	0.749
6	28.25	30.1	0.939
7	28.69	27.4	1.047
8	23.82	29.6	0.805
9	24.09	31.1	0.775
10	28.09	29.0	0.969

SOURCE: DATA ANALYSIS

Table 4.3(b) Indoors Room Volume -Temperature Data For Ikorodu Zone

HOUSE	ROOM VOLUME (m^3)	AVERAGE INDOOR TEMPERATURE °C	RATIO (VOL/T)
1	72.88	28.0	2.602
2	28.69	28.6	1.003
3	18.94	28.2	0.672
4	28.91	28.6	1.010
5	30.35	26.6	1.141
6	30.90	28.0	1.104
7	68.07	27.0	2.521
8	28.69	28.3	1.014
9	22.91	28.2	0.812
10	24.54	28.2	0.870

SOURCE: DATA ANALYSIS

4.2.2 QUESTIONNAIRE ANALYSIS

Here, the research questions are put to test and percentage of responses analysed.

4.2.2.1 <u>Question 1</u>

Can comfort be achieved through natural approach?

CLASS	NO OF RESPONDENTS	YES	%	NO	%
HIGH	10	8	19.05	2	4.76
MIDDLE	14	10	23.80	4	9.52
LOW	18	18	42.86	-	-
TOTAL	42	36	85.71	6	14.28

SOURCE: FIELD SURVEY

The percentage of yes is 85.71%. Thus, it can be accepted that comfort is possible through natural means.

4.2.2.2 Question 2

If possible, how can it be achieved?

CLASS	NO OF RESPONDENTS	YES	%	NO	%
HIGH	10	7	16.67	3	7.14
MIDDLE	14	8	19.05	6	14.29
LOW	18	18	42.86	-	-
TOTAL	42	33	78.58	9	21.43

SOURCE: FIELD SURVEY

The Yes answer has 78.58% as against 21.43% NO. Therefore, the various means of natural cooling are accepted.

From the respondent's answers, it was gathered that means of achieving comfort include proper selection of good building materials, selecting appropriate orientation for the building from the planning stage, and provide good shade/ good lanscapings for buildings are some of the factors that will provide natural comfort in homes

4.2.3 DATA ANALYSIS

The research has provided some information relating to the thermal behavior of building designs, depending on wall materials, roof materials and building orientation. Two locations; Lagos Mainland and Ikorodu were studied with ten houses considered in each location.

The analysis showed that the response of each room temperature to indoor temperature depends largely on what are contained in the affected room as well as the level of activity in it.

4.2.3.1 LAGOS MAINLAND

Highest Temperature of 30.9^{0}C is attained in House No 2. Although it is South Facing, it has a roof of corrugated Iron sheets and the smallest room size of 254cm x 254 cm x 236 cm. Also it uses 8 incandescent bulbs against 4 fluorescent tubes for lighting. It has the highest number of occupants (16) in the region. All these appear to overpower the four (4) fans in the building, which is thus inadequate ventilated and cooled, resulting in the high indoor temperature.

The Lowest temperature of 27.4^{0}C is attained in House number 7. This apartment has a concrete wall with smooth plastering, asbestos ceiling materials, although it is west facing.

The parlour is very big (366 cm x 301.5 cm x 260 cm) and it has the biggest room size (301. 5 cm x 301. 5 cm x 260 cm) in the location. Furthermore, it is illuminated with only 2 fluorescent tubes and occupied by only 2 people.

Houses 5 & 6 have the same high temperature of 30.1^{0}C. They are both South facing, with concrete block & smooth plastered walls.

House 5 has concrete decking while 6 has corrugated iron sheets.

House 5 is occupied with 4 people while House 6 has 8 people. House 6 also has 3 incandescent bulbs and 2 fluorescent tubes, while House 5 has one fluorescent tube.

The two houses have an average of 4 people per room; House 5 in single room while 6 in two room apartment. Neither of these two apartments has any means of forced ventilation, while they both have an electric kettle and a refrigerator each.

All these factors interplay to produce the high indoor temperature. The average indoor temperature for the zone is 29.22^0C

4.2.3.1 IKORODU

The average indoor temperature for this zone is 27.97^0C. Highest temperature is 28.6^0C. This is attained in House 2 and House 4.

House 2 has a roof of corrugated iron sheets, although it is North facing. It uses two incandescent bulbs and one fluorescent tube for lighting. It has one electric cooker and electric kettle.

Although north facing, the factors enumerated above seem to have created this locally high temperature in this building. House 4 has a concrete decking top, and it has 4 fluorescents tubes and 6 incandescent bulbs. It has two kerosene Lanterns, 2 Electric kettles and 2 deep Freezers. Hence, although south facing the above factors seem to have annulled the effects of the building orientation to result in the locally high temperature.

LOWEST TEMPERATURE

The lowest temperature of 26.6^0C is attained in House 5. However, since this was attained on cloudy days, we take House 7 with 27^0C. House 7 has Aluminum sheet roofing, which is more reflecting than corrugated iron sheets. It uses 3 florescent tubes against 2 incandescent bulbs for lighting. Although it has 2 Electric cookers, 3 electric kettles 2 Air conditioners and 3 Deep Freezers and it is also East facing, the fact that it is painted and has aluminum roofing sheet with fluorescent tube lighting seems to have combined to produce the lowest temperature in the region.

For example, in the Mainland zone, house 2 has 16 occupants with room volume being 15.23cm^3 while house 7 has 2 occupants with the room volume being 28.69 cm^3. Their indoor temperature values were 30.9° C and 27.4 $^\circ$C respectively. From Tables 4.3a & b, it can be seen that houses with almost the same characteristics in the two zones i.e house 3 in the Mainland zone and house 5 in the Ikorodu zone, the two houses are south facing, the room volume – indoor temperature ratio is almost the same, 1.410 and 1.141 respectively, the material for house 3 Mainland zone is corrugated iron sheet while house 5 in the Ikorodu zone is asbestos roofing sheets which tends to have more cooling effect in the afternoon than the roofing sheet which absorbs more heat in the afternoon and radiate same immediately.

It can also be noted that while houses 5 in Ikorodu zone has 8 occupants living in there, only 6 occupants live in house 3 in the Mainland zone. The same room volume – indoor temperature ratio in the two houses being compared could be attributed to natural vegetation which abound more in the Ikorodu zone then in the Mainland zone and also the buildings in the zone are well-spaced then what obtains in the mainland zone which is a typical urban city because of the building compactness and vegetation deprivation.

Generally, the temperature values at Ikorodu are lower with an overall average of 28^{0}C as against 30.2^0 C recorded in the Mainland zone.

In summary if appears that the type of roofing sheet materials plays a dominant role on the natural cooling in these two regions.

Also the effect of urbanization is to increase the average temperature in an area, considering the fact that the average in Mainland is slighting more (29.22^{0}C) than that in Ikorodu 27.97^{0}C.

4.2.4 **REGRESSION ANALYSIS**

From correlation coefficient, and from Lagos Mainland zone, the highest correlation coefficient obtained was 0.967 or 96.7%. This was obtained for a West – facing building built with mud bricks, while the least was 0.5.01 0r 50.1% obtained for a South –facing building built red blocks.

The analysed result showed good correlation between the measured temperature values and the calculated values (Table 4.1a)

Also, for the Ikorodu zone, the highest correlation coefficient obtained was 0.971 or 97.1%. This was obtained for a South – facing building built with concrete blocks.

However, the roof is also concrete, hence, its ability to store heat. The least value here was 0.372 or 37.2% for an East – facing building also built with concrete blocks, but the roof was made of asbestos sheets. The very low values of 0.25 or 25% were obtained on rainy days.

The results also showed good correlation between the measured and calculated values (Table 4.1b)

Also from the result of regression analysis, tables (4.2 a&b) for both zones, the calculated indoor temperatures are very close to the measured indoor temperatures in all the houses except in few cases and areas where there drastic climatic changes i.e. rainy and cloudy days.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The objectives of identifying building materials, building design and orientation suitable for natural cooling in tropical climates have been carried out.

The results of the study confirm that thermal behavior of buildings is a direct function of the building material, the building orientation and the roofing materials. Although, building and roofing material have to do with money, orientation goes a long way in aiding natural cooling. The level of activity and the number of people involved were also identified as factors affecting comfort, like in the mainland zone from Table 4.3(a), the room volume indoor temperature ratio shows that house 7 with two occupants has a value of 1.047 compared to that of house 2 which has 0.493 which shows that the lower the number of occupant in a house, the better the comfort occupants can get.

The study also showed that cooling can be achieved naturally, and that natural cooling is superior to mechanical means of cooling, apart from the cost. In tropical climate therefore, the best natural cooling design can be achieved by;

- Building houses/rooms to face South or North.
- Using asbestos sheets as roofing material.
- Leaving spaces between buildings to allow for free airflow.
- Limiting the number of people using a room.

5.2 RECOMMENDATIONS

The following are recommended for natural comfort in tropical climate.

- Houses must not just be built, but first designed to take comfort into consideration, via orientation and building materials.
- Mud bricks are best suitable for tropical climate, but are not readily available for use in urban cities. It is therefore recommended that efforts be made at making them available everywhere.
- In the alternative the concrete blocks should be made of higher thickness than what obtains now.
- On further studies, it is recommended that such a study be carried out in rural settings where electricity supply has become a rare priviledge.

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APPENDIX I

LAGOS MAINLAND ZONE

HOUSE 1

DAY TEMPERATURES

		Ambient	Room
15/8/2000	2.30p.m	42 °C	38 °C
	3.30p.m	40 °C	36 °C
	4.30p.m	40 °C	30.5 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 °C	29 °C
10.00p.m	26 °C	29 °C
11.00p.m	26 °C	28 °C
12.00p.m	25.5° C	26 °C

DAY TEMPERATURES

		Ambient	Room
16/8/2000	6.30a.m	26 °C	28 °C
	8.00a.m	26.5 °C	26.5 °C
	10.00a.m	27 °C	26.5 °C
	12.00noon	35 °C	27 °C
	1.00p.m	35 °C	30 °C
	2.00p.m	35.5 °C	30 °C
	3.00p.m	34.5 °C	29.5 °C
	4.30p.m	37 °C	29 °C
	6.30pm	33 °C	28 °C

NIGHT TEMPERATURES

	Ambient	Room
8.00p.m	35 °C	28 °C
9.00p.m	31 °C	28 °C
10.00p.m	30 °C	28 °C
11.00p.m	26 °C	27 °C
12.00p.m	26 °C	27 °C

DAY TEMPERATURES

		Ambient	Room
17/8/2000	8.00a.m	33 °C	26.5 °C
	10.00a.m	34 °C	27 °C
	11.00a.m	36 °C	27 °C
	12.00noon	37 °C	28 °C
	1.00p.m	39 °C	29 °C
	2.00p.m	39 °C	29.5 °C
	3.00p.m	37 °C	32 °C
	4.00p.m	36 °C	30 °C
	5.00p.m	32 °C	30 °C
	6.00p.m	29 °C	30 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 °C	28 °C
11.00p.m	27 °C	28 °C
12.00p.m	26 °C	28 °C

HOUSE 2

DAY TEMPERATURES

		Ambient	Room
15/8/2000	8.30a.m	37 °C	39 °C
	10.00a.m	39 °C	39 °C
	11.00a.m	40 °C	39 °C
	12.00noon	41 °C	39 °C
	2.00p.m	43 °C	39 °C
	4.00p.m	41 °C	37 °C
	5.00p.m	40 °C	36 °C
	6.00p.m	40 °C	35 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	29° C	29 ° C
10.00p.m	28 ° C	27 ° C
11.00p.m	28 ° C	27 ° C

DAY TEMPERATURES

		Ambient	Room
16/8/2000	8.00a.m	28° C	29° C
Rainy	10.00a.m	29° C	29° C
	12.00noon	35° C	32° C
	2.00p.m	36.5° C	32.5° C
	4.00p.m	34° C	32° C
	5.00p.m	34° C	31° C
	7.00p.m	33° C	29° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	31° C	30° C
10.00p.m	30° C	30° C
11.00p.m	30° C	29° C
12.00p.m	28° C	27° C

DAY TEMPERATURES

		Ambient	Room
17/8/2000	8.00a.m	36° C	32.5° C
	9.00a.m	38° C	33° C
	11.00a.m	40° C	34° C
	1.00p.m	41° C	34° C
	3.00p.m	34° C	27° C
	40.00p.m	36° C	27° C
	5.00p.m	32° C	30° C
	6.00p.m	32° C	30° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	30° C	30.5° C
10.00p.m	30° C	30.5° C
11.00a.m	28° C	29° C
12.00p.m	28° C	29° C

DAY TEMPERATURES

		Ambient	Room
18/8/2000	8.00a.m	23° C	24° C
	9.30 a.m	38° C	33° C
	11.30a.m	25° C	24° C
	1.00p.m	29° C	27° C

	3.00p.m	29° C	27° C
	5.00p.m	33° C	31° C
	6.00p.m	29° C	31° C
	7.00p.m	29° C	31° C

NIGHT TEMPERATURES

		Ambient	Room
18/8/2000	9.00p.m	28° C	28° C
Rainy	10.00p.m	29° C	29° C
	11.00p.m	26° C	28° C
	12.00p.m	26° C	28° C

DAY TEMPERATURES

		Ambient	Room
18/8/2000	7.30a.m	30° C	33° C
	9.30a.m	36° C	33° C
	10.30a.m	38° C	35° C
	11.30a.m	40° C	35° C
	1.00p.m	42° C	35° C
	2.00p.m	41° C	35° C
	3.00p.m	41° C	35° C
	4.00p.m	39° C	33° C
	6.00p.m	30° C	31° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	29° C	28° C
10.00p.m	29° C	28° C
11.00p.m	28° C	27° C
12.30a.m	27° C	26° C

HOUSE 3

DAY TEMPERATURES

		Ambient	Room
17/8/2000	8.00a.m	25° C	26° C
Rainy	9.00a.m	25° C	26° C
	11.00a.m	26° C	26.5° C
	1.00p.m	26° C	27° C
	3.30p.m	29° C	29° C
	4.30p.m	30° C	30° C
	5.30p.m	29° C	30° C
	6.30p.m	29° C	30° C
	7.30p.m	29° C	30° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	31° C	30° C
10.00p.m	30° C	30° C
11.00p.m	30° C	29° C
12.00p.m	29° C	28° C

DAY TEMPERATURES

		Ambient	Room
18/8/2000	8.00a.m	32° C	30° C
	9.00a.m	32° C	30° C
	10.00a.m	36° C	35° C
	1.00p.m	36° C	35° C
	2.00p.m	35° C	27° C
	3.00p.m	35° C	27° C
	4.00p.m	32° C	30° C
	5.00p.m	32° C	31° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	30° C	29° C
10.00p.m	30° C	28° C
11.00p.m	28° C	28° C
12.00p.m	28° C	29° C

DAY TEMPERATURES

		Ambient	Room
20/8/2000	8.00a.m	33° C	29° C
	9.00a.m	34° C	29° C
	10.00a.m	36° C	29° C
	11.30a.m	39° C	29° C
	1.00p.m	39° C	30° C
	2.00p.m	38° C	30° C
	3.00p.m	36° C	30.5° C
	4.30p.m	33° C	30.5° C
	5.30p.m	29° C	29° C
	6.30p.m	29° C	29° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27.5° C	28° C
10.00p.m	27.5° C	28° C
11.00p.m	26° C	28° C
12.00p.m	26° C	28° C

HOUSE 4

DAY TEMPERATURES

		Ambient	Room
16/8/2000	9.00a.m	38° C	30° C
	10.00a.m	39° C	30° C
	12.00noon	40° C	30.5° C
	2.00p.m	42° C	31° C
	3.00p.m	42° C	31° C
	4.00p.m	39° C	31° C
	5.00p.m	40° C	31° C
	6.00p.m	40° C	30° C

NIGHT TEMPERATURES

	Ambient	Room
9.00a.m	27° C	29° C
10.00p.m	26° C	29° C
11.00p.m	26° C	28° C
12.00p.m	26° C	28° C

DAY TEMPERATURES

		Ambient	Room
17/8/2000	8.00a.m	25° C	25° C
	9.00a.m	25° C	24° C
	10.00a.m	25° C	24° C
	1.00p.m	28° C	26° C
	3.00p.m	28° C	26° C
	5.00p.m	29° C	26.5° C
	7.00p.m	29° C	27° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	31° C	30.5° C
10.00p.m	30° C	30.5° C
11.00p.m	30° C	30° C
12.00p.m	29° C	28° C

DAY TEMPERATURES

		Ambient	Room
19/8/2000	8.30a.m	32° C	26.5° C
Sunny	9.30a.m	34° C	27° C
	11.30a.m	37° C	27° C
	12.30p.m	37° C	28° C
	1.30p.m	40° C	29° C
	4.00p.m	37° C	29° C
	5.00p.m	36° C	27° C
	6.00p.m	32° C	26° C
	7.00p.m	30° C	27° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27° C	28° C
10.00p.m	27° C	28° C
11.00p.m	27° C	28° C
12.00p.m	27° C	28° C

DAY TEMPERATURES

		Ambient	Room
20/8/2000	8.00a.m	30° C	27° C
	11.00a.m	39° C	27° C
	12.00noon	42° C	28° C
	2.00noon	41° C	28° C
	4.00p.m	39° C	29° C
	5.00p.m	37° C	29° C
	6.00p.m	34° C	27° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27° C	28° C
10.00p.m	27° C	28° C
11.00p.m	27° C	28° C
12.00p.m	27° C	28° C

HOUSES 5 & 6

DAY TEMPERATURES

		Ambient	Room
20/8/2000	9.00a.m	33° C	32° C
	10.00a.m	36° C	33° C
	11.00a.m	37° C	35° C
	12.00noon	49° C	35° C
	1.00p.m	42° C	36° C
	2.00p.m	42.5° C	36° C
	4.00p.m	40° C	35° C
	6.00p.m	35° C	31° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	29° C	28° C
10.00p.m	30° C	27° C
11.00p.m	28° C	27° C
12.00p.m	28° C	27° C

DAY TEMPERATURES

		Ambient	Room
21/8/2000	9.00a.m	36 ° C	29 ° C
	10.00a.m	37 ° C	29.5 ° C
	12.00noon	42 ° C	30 ° C
	1.00p.m	42 ° C	30 ° C
	2.00p.m	40 ° C	30 ° C
	4.00p.m	40 ° C	29 ° C
	5.00p.m	38 ° C	29 ° C
	6.00p.m	37 ° C	29 ° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	37 ° C	31 ° C
10.00p.m	35 ° C	31 ° C
11.00p.m	30 ° C	31 ° C
12.00p.m	30 ° C	28 ° C

DAY TEMPERTURES

		Ambient	Room
24/8/2000	8.30a.m	25 ° C	26 ° C
	10.00a.m	26 ° C	27 ° C
	11.00a.m	26 ° C	27 ° C
	12.00noon	31 ° C	29 ° C
	1.00p.m	35 ° C	29 ° C
	3.00p.m	31 ° C	29 ° C
	4.00p.m	31 ° C	28 ° C
	5.00p.m	29.5 ° C	29 ° C
	6.00p.m	29 ° C	29 ° C

HOUSE 7

DAY TEMPERATURES

		Ambient	Room
16/8/2000	9.00a.m	25 ° C	24.5 ° C
Rainy	10.00a.m	26 ° C	25 ° C
	11.00a.m	26.5 ° C	25 ° C
	12.00noon	31 ° C	26 ° C
	1.00p.m	33 ° C	26.5 ° C
	3.00p.m	35 ° C	27 ° C
	4.00p.m	33 ° C	26 ° C

NIGHT TEMPERATURES

	Ambient	Room
8.30p.m	27° C	26° C
10.00p.m	27° C	26° C
11.00p.m	27° C	26° C
12.00p.m	27° C	26° C

DAY TEMPERATURES

		Ambient	Room	
18/8/2000	9.00a.m	20° Cs		26° C
Rainy	10.00a.m	20° C	27° C	
	11.00a.m	21° C	27° C	
	12.00noon	21° C	27° C	
	1.00p.m	21° C	27° C	
	2.00p.m	29° C	27° C	
	3.00p.m	31° C	27° C	
	4.00p.m	31° C	27° C	
	5.00p.m	35° C	27° C	

NIGHT TEMPERATURES

	Ambient	Room
8.00p.m	27° C	26° C
9.00p.m	27° C	26° C
10.00p.m	27° C	26.5° C
11.00p.m	27° C	26.5° C

DAY TEMPERATURES

		Ambient	Room
19/8/2000	9.00a.m	30° C	27° C
	10.00a.m	32° C	27° C
	11.00a.m	33° C	27.5° C
	12.00noon	35° C	28° C
	1.00p.m	35° C	28° C
	2.00p.m	35° C	28° C
	3.00p.m	37° C	28° C
	4.00p.m	33° C	27° C
	5.00p.m	30° C	27° C
	6.00p.m	30° C	27° C
	7.00p.m	30° C	27° C

NIGHT TEMPERATURES

	Ambient	Room
8.00p.m	31° C	27° C
9.00p.m	31° C	27° C
10.00p.m	30° C	27° C
11.00p.m	29° C	27° C
12.00p.m	29° C	27° C

DAY TEMPERATURES

		Ambient	Room
21/8/2000	9.00a.m	32° C	27° C
	10.00a.m	39° C	27.5° C
	11.00a.m	39° C	28° C
	12.00noon	40° C	28° C
	1.00p.m	40° C	28° C
	2.00p.m	38° C	27.5° C
	3.00p.m	38° C	27.5° C
	4.00p.m	36° C	27° C
	5.00p.m	32° C	27° C
	6.00p.m	30° C	27° C
	7.00p.m	29° C	27° C

NIGHT TEMPERATURES

	Ambient	Room
8.00p.m	29° C	30° C
9.00p.m	29° C	31° C
10.00p.m	29° C	30° C
11.00p.m	29° C	30° C
12.00p.m	29° C	30° C

DAY TEMPERATURES

		Ambient	Room
18/8/2000	8.00a.m	33° C	27° C
	10.00a.m	34° C	27.5° C
	11.00a.m	34° C	27.5° C
	1.00p.m	37.5° C	28° C
	2.00p.m	36° C	32° C

NIGHT TEMPERATURES

	Ambient	Room
8.00p.m	34° C	28° C
10.00p.m	34° C	27° C
12.00p.m	32° C	26° C

DAY TEMPERATURES

		Ambient	Room
21/8/2000	8.00a.m	25° C	26.5° C
Rainy	10.00a.m	24° C	25° C
	12.00noon	26.5° C	27° C
	1.00p.m	31° C	29° C
	2.00p.m	31° C	29° C
	3.00p.m	31° C	32° C
	5.00p.m	35° C	32° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27° C	28° C
10.00p.m	27° C	28° C
11.00p.m	26° C	28° C

HOUSE 8

DAY TEMPERATURES

		Ambient	Room
21/8/2000	9.00a.m	37° C	35° C
	10.00a.m	41° C	39° C
	11.00a.m	41° C	39° C
	12.00noon	42° C	38° C
	1.00p.m	42° C	38° C
	2.00p.m	42° C	38° C
	3.00p.m	40° C	36° C
	4.00p.m	40° C	36° C
	5.00p.m	36° C	29° C
	6.00p.m	36° C	29° C
	7.00p.m	35° C	29° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	35° C	28° C
10.00p.m	31° C	28° C
11.00p.m	31° C	28° C
12.00p.m	30° C	28° C

DAY TEMPERATURES

		Ambient	Room
22/8/2000	9.00a.m	37° C	29° C
	10.00a.m	40° C	29° C
	11.00a.m	41° C	29° C
	12.00noon	41° C	29° C
	1.00p.m	42° C	30° C
	2.00p.m	40° C	30° C
	3.00p.m	40° C	29° C
	4.00p.m	38° C	29° C
	5.00p.m	36° C	28° C
	6.00p.m	34° C	28° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27° C	28° C
10.00p.m	27° C	28° C
11.00p.m	27° C	28° C
12.00p.m	27° C	28° C

DAY TEMPERATURES

		Ambient	Room
24/8/2000	9.00a.m	34° C	28° C
Rainy	10.00a.m	35° C	29° C
	11.00a.m	42° C	30° C
	12.00.noon	42° C	30° C
	1.00p.m	42° C	30° C
	2.00p.m	30° C	30° C
	3.00p.m	27° C	22° C
	4.00p.m	27° C	22° C
	5.00p.m	27° C	22° C
	6.00p.m	30° C	24° C
	7.00p.m	30° C	24° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27° C	28° C
10.00p.m	27° C	28° C
11.00p.m	27° C	28° C
12.00p.m	27° C	28° C

HOUSE 9

DAY TEMPERATURES

		Ambient	Room
24/8/2000	9.00a.m	34° C	32° C
	10.00a.m	35° C	32° C
	11.00a.m	42° C	35° C
	12.00noon	42° C	35° C
	1.00p.m	42° C	35° C
	2.00p.m	30° C	32° C
	4.00p.m	27° C	30° C
	5.00p.m	27° C	30° C
	6.00p.m	27° C	30° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27° C	30° C
10.00p.m	27° C	30° C
11.00p.m	27° C	30° C

DAY TEMPERATURES

		Ambient	Room
25/8/2000	10.00a.m	39° C	34° C
	11.00a.m	39° C	35° C
	12.00noon	42° C	35° C
	1.00p.m	42° C	35° C
	2.00p.m	41° C	35° C
	3.00p.m	41° C	35° C
	4.00p.m	39° C	33° C
	5.00p.m	37° C	33° C
	6.00p.m	34° C	33° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 ° C	31 ° C
10.00p.m	27 ° C	31 ° C
11.00p.m	27 ° C	31 ° C
12.00p.m	27 ° C	31 ° C

DAY TEMPERATURES

		Ambient	Room
28/8/2000	9.00a.m	35 ° C	28 ° C
	10.00a.m	37 ° C	28 ° C
	11.00a.m	39 ° C	29 ° C
	12.00noon	42 ° C	29 ° C
	1.00p.m	42 ° C	30 ° C
	2.00p.m	41 ° C	30 ° C
	3.00p.m	40 ° C	30 ° C
	4.00p.m	39 ° C	29 ° C
	5.00p.m	37 ° C	29 ° C
	6.00p.m	34 ° C	26 ° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 ° C	28 ° C
10.00p.m	30 ° C	28 ° C
11.00p.m	27 ° C	28 ° C
12.00p.m	27 ° C	28 ° C

HOUSE 10

DAY TEMPERATURES

		Ambient	Room
28/8/2000	2.00p.m	42 ° C	38 ° C
	3.00p.m	42 ° C	36 ° C
	4.00p.m	40 ° C	33 ° C
	5.00p.m	37 ° C	30 ° C
	6.00p.m	35 ° C	30 ° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27° C	29° C
10.00p.m	26° C	29° C
11.00p.m	26° Cs	28° C
12.00p.m	25.5° C	26° C

DAY TEMPERATURES

		Ambient	Room
29/8/2000	6.20a.m	26° C	28° C
	8.00a.m	26.5° C	26.5° C
	10.00a.m	27° C	27° C
	12.00noon	35° C	29° C
	1.00p.m	35° C	30° C
	2.00p.m	35.5° C	30° C
	3.00p.m	34.5° C	29.5° C
	4.30p.m	37° C	29° C
	6.30p.m	33° C	28° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	33° C	28° C
10.00p.m	31° C	28° C
11.00p.m	28° C	27° C
12.00p.m	26° C	27° C

DAY TEMPERATURES

		Ambient	Room
30/8/2000	8.00a.m	33° C	26.5° C
	10.00a.m	34° C	27° C
	11.00a.m	36° C	27° C
	12.00noon	37° C	29° C
	1.00p.m	39° C	29° C
	2.00p.m	39° C	29.5° C
	3.00p.m	38° C	32° C
	4.00p.m	36° C	30° C
	5.00p.m	32° C	30° C
	6.00p.m	29° C	30° C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27° C	28° C
11.00p.m	27° C	28° C
12.00p.m	26° C	28° C

DAY TEMPERATURES

		Ambient	Room
31/8/2000	8.00a.m	33° C	27° C
	10.00a.m	34° C	27.5° C
	11.00a.m	34° C	28° C
	1.00p.m	39° C	28° C
	2.00p.m	40° C	32° C

NIGHT TEMPERATURES

	Ambient	Room
8.00p.m	28° C	28° C
10.00p.m	27° C	28° C
12.00p.m	26° C	27° C

APPENDIX II
IKORODU ZONE
HOUSE 1

DAY TEMPERATURES

		Ambient	Room
20/8/2000	9.00a.m	31°C	29°C
	10.00a.m	34°C	30°C
	11.00a.m	35°C	32°C
	12.00noon	38°C	32°C
	1.00p.m	40°C	33°C
	2.00p.m	40.5°C	33°C
	4.00p.m	38°C	32°C
	6.00p.m	33°C	28°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27°C	25°C
10.00p.m	27°C	25°C
11.00p.m	25°C	24°C
12.00p.m	25°C	24°C

DAY TEMPERATURES

		Ambient	Room
21/8/2000	9.00a.m	34°C	26°C
	10.00a.m	35°C	26.5°C
	12.00noon	40°C	27°C
	1.00p.m	40°C	27°C
	2.00p.m	37°C	27°C
	4.00p.m	38°C	26°C
	5.00p.m	36°C	26°C
	6.00p.m	35°C	26°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	35°C	28°C
10.00p.m	33°C	28°C
11.00p.m	27°C	29°C
12.00p.m	27°C	26°C

DAY TEMPERATURES

		Ambient	Room
22/8/2000	9.00a.m	33°C	30°C
	10.00a.m	36°C	33°C
	11.00a.m	38°C	34°C
	12.00noon	36°C	32°C
	1.00p.m	28°C	25°C
	2.00p.m	27°C	24°C
	3.00p.m	27°C	245°C
	4.00p.m	34°C	31°C
	5.00p.m	34°C	31°C
	6.00p.m	34°C	31°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27°C	25°C
10.00p.m	27°C	26°C
11.00p.m	25°C	24°C
12.00p.m	25°C	24°C

DAY TEMPERATURES

		Ambient	Room
24/8/2000	8.00a.m	24°C	24.5°C
	10.00a.m	24°C	25°C
	11.00a.m	24°C	25°C
	12.00noon	29°C	25°C
	1.00p.m	33°C	27°C
	3.00p.m	28°C	27°C
	4.00p.m	28°C	27°C
	5.00p.m	27.5°C	26°C
	6.00p.m	27°C	26°C

NIGH T TEMPERATURES

	Ambient	Room
9.00p.m	25°C	26°C
10.00p.m	25°Cs	26°C
11.00p.m	25°C	26°C
12.00p.m	24°C	26°C

DAY TEMPERATURES

		Ambient	Room
20/8/2000	9.00a.m	33 °C	30 °C
	10.00a.m	36 °C	33 °C
	11.00a.m	37 °C	35 °C
	12.00noon	40 °C	35 °C
	1.00p.m	42 °C	36 °C
	2.00p.m	42.5 °C	36 °C
	3.00p.m	41 °C	35 °C
	4.00p.m	40 °C	35 °C
	6.00p.m	35 °C	31 °C
	7.00p.m	33 °C	29 °C

HOUSE 2

DAY TEMPERATURES

		Ambient	Room
16/8/2000	8.00a.m	27 °C	27 °C
Rain	10.00a.m	27 °C	27 °C
	12.00noon	33 °C	29.5 °C
	2.00p.m	34.5 °C	30 °C
	3.00p.m	31 °C	30 °C
	4.00p.m	31 °C	29 °C
	6.00p.m	30 °C	27 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	29 °C	28 °C
10.00p.m	28 °C	28 °C
11.00p.m	28 °C	27 °C
12.00p.m	26 °C	25 °C

DAY TEMPERATURES

		Ambient	Room
18/8/2000	8.00a.m	22 °C	23 °C
	9.30a.m	22 °C	23 °C
	11.30a.m	24 °C	23 °C
	1.00p.m	27 °C	25 °C
	3.00p.m	27 °C	25 °C
	5.00p.m	29 °C	27 °C

	6.00p.m	27°C	27°C
	7.00p.m	27°C	27°C

NIGHT TEMPERATURES

		Ambient	Room
	9.00p.m	26°C	26°C
	10.00p.m	26°C	26°C
	11.00p.m	25°C	25°C
	12.00p.m	25°C	26°C

DAY TEMPERATURES

		Ambient	Room
19/8/2000	8.00a.m	35°C	36°C
	10.00a.m	37°C	36°C
	11.00a.m	38°C	36°C
	12.00noon	39°C	36°C
	2.00p.m	41°C	36°C
	4.00p.m	38°C	34°C
	5.00p.m	37°C	33°C
	6.00p.m	37°C	33°C

NIGHT TEMPERATURES

		Ambient	Room
	9.00p.m	27°C	27°C
	10.00p.m	26°C	25°C
	12.00p.m	25°C	23°C

DAY TEMPERATURES

		Ambient	Room
20/8/2000	8.00a.m	29°C	31°C
	9.00a.m	34°C	31°C
	10.30a.m	36°C	33°C
	11.30a.m	38°C	33°C
	1.00p.m	40°C	33°C
	2.00p.m	39°C	33°C
	3.00p.m	39°C	33°C
	4.00p.m	37°C	31°C
	6.00p.m	28°C	29°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 °C	25 °C
10.00p.m	27 °C	25 °C
11.00p.m	26 °C	24 °C
12.00p.m	25 °C	23 °C

HOUSE 3

DAY TEMPERATURES

		Ambient	Room
21/8/2000	9.00a.m	36 °C	33.5 °C
	10.00a.m	40 °C	36 °C
	11.00a.m	40 °C	36 °C
	12.00noon	41 °C	37 °C
	1.00p.m	41 °C	37 °C
	2.00p.m	41.5 °C	37 °C03
	3.00p.m	39 °C	35 °C
	4.00p.m	39 °C	34 °C
	5.00p.m	34 °C	27 °C
	6.00p.m	34 °C	27 °C
	7.00p.m	32 °C	27 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	25 °C	26 °C
10.00p.m	25 °C	26 °C
11.00p.m	25 °C	26 °C
12.00p.m	25 °C	26 °C

DAY TEMPERATURES

		Ambient	Room
23/8/2000	9.00a.m	35 °C	26 °C
	10.00a.m	38 °C	26 °C
	11.00a.m	39 °C	26 °C
	12.00p.m	39 °C	27 °C
	1.00p.m	40 °C	28 °C
	2.00p.m	38 °C	28 °C
	3.00p.m	28 °C	27 °C

	4.00p.m	38 °C	27 °C
	5.00p.m	34 °C	26 °C
	6.00p.m	32 °C	26 °C

NIGHT TEMPERATURES

		Ambient	Room
	9.00p.m	25 °C	26 °C
Rain	10.00p.m	25 °C	26 °C
	11.00.m	25 °C	26 °C
	12.00p.m	25 °C	26 °C

DAY TEMPERATURES

			Ambient	Room
24/8/2000		9.00a.m	32 °C	26 °C
		10.00a.m	33 °C	27 °C
		11.00a.m	40 °C	27 °C
		12.00noon	40 °C	27 °C
		2.00p.m	28 °C	20 °C
	Rain	3.00p.m	25 °C	20 °C
		4.00p.m	25 °C	20 °C
		5.00p.m	25 °C	20 °C
		6.00p.m	28 °C	23 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	25 °C	26 °C
10.00p.m	25 °C	26 °C
11.00p.m	25 °C	26 °C
12.00p.m	25 °C	26 °C

HOUSE 4

DAY TEMPERATURES

		Ambient	Room
21/8/2000	9.00a.m	31 °C	29 °C
	10.00a.m	32 °C	30 °C
	11.30a.m	34 °C	31 °C
	1.00p.m	39 °C	34 °C
	2.00p.m	39 °C	34 °C
	3.00p.m	40 °C	33 °C
	4.00p.m	38 °C	32 °C
	5.00p.m	38 °C	28 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 °C	25 °C
10.00p.m	27 °C	24 °C
11.00p.m	25 °C	24 °C
12.00p.m	25 °C	24 °C

DAY TEMPERATURES

		Ambient	Room
22/8/2000	9.00a.m	34 °C	29 °C
	10.00a.m	35 °C	29 °C
	11.00a.m	37 °C	28 °C
	12.00noon	40 °C	29 °C
	1.00p.m	40 °C	29 °C
	2.00p.m	37 °C	29 °C
	3.00p.m	36 °C	29 °C
	4.00p.m	36 °C	29 °C
	5.00p.m	36 °C	29 °C
	6.00p.m	36 °C	29 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	35 °C	28 °C
10.00p.m	33 °C	27 °C
11.00p.m	27 °C	27 °C
12.00p.m	27 °C	26 °C

DAY TEMPERATURES

		Ambient	Room
24/8/2000	9.00a.m	24 °C	24.5 °C
	10.00a.m	24 °C	25 °C
	11.00a.m	24 °C	25 °C
	12.00p.m	27 °C	26 °C
	1.00p.m	33 °C	28 °C
	2.00p.m	29 °C	28 °C
	3.00p.m	38 °C	27 °C
	4.00p.m	38 °C	27 °C
	5.00p.m	27.5 °C	26 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	25°C	26°C
10.00p.m	25°C	26°C
11.00p.m	25°C	26°C
12.00p.m	24°C	26°C

DAY TEMPERATURES

		Ambient	Room
25/8/2000	9.00a.m	33°C	31°C
	10.00a.m	35°C	32°C
	11.00a.m	36°C	33°C
	12.00a.m	39°C	34°C
	1.00p.m	41°C	35°C
	2.00p.m	42°C	36°C
	3.00p.m	41°C	35°C
	4.00p.m	40°C	35°C
	5.00p.m	35°C	31°C
	6.00p.m	33°C	31°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27°C	25°C
10.00p.m	27°C	24°C
11.00p.m	25°C	24°C
12.00p.m	25°C	24°C

HOUSE 5

DAY TEMPERATURES

		Ambient	Room
23/8/2000	9.00a.m	24°C	23.5°C
Cloudy	10.00a.m	24°C	25°C
Morning	11.00a.m	25.5°C	25°C
	12.00p.m	29°C	24°C
	1.00p.m	31°C	25°C
	2.00p.m	31°C	25°C
	3.00p.m	33°C	25°C
	4.00p.m	33°C	26°C

NIGHT TEMPERAUTRES

	Ambient	Room
9.00p.m	26 °C	25 °C
10.00p.m	26 °C	24 °C
11.00p.m	26 °C	24 °C
12.00p.m	26 °C	23 °C

DAY TEMPERAUTRES

		Ambient	Room
25/8/2000	9.00a.m	29 °C	25 °C
	10.00a.m	31 °C	25 °C
	11.00a.m	32 °C	25.5 °C
	12.00noon	34 °C	26 °C
	2.00p.m	35 °C	29 °C
	3.00p.m	36 °C	29 °C
	4.00p.m	32 °C	25 °C
	5.00p.m	29 °C	25 °C
	6.00p.m	29 °C	25 °C

NIGHT TEMPERATURES

	Ambient	Room
8.00p.m	30 °C	27 °C
9.00p.m	30 °C	27 °C
10.00p.m	29 °C	26 °C
11.00p.m	29 °C	26 °C
12.00p.m	29 °C	26 °C

DAY TEMPERATURES

		Ambient	Room
26/8/2000	9.00a.m	20 °C	26 °C
Rainy	10.00a.m	20 °C	27 °C
Morning	11.00a.m	21 °C	27 °C
	12.00p.m	20 °C	27 °C
	1.00p.m	21 °C	27 °C
	2.00p.m	29 °C	28 °C
	3.00p.m	30 °C	28 °C
	4.00p.m	33 °C	28 °C
	5.00p.m	33 °C	28 °C

NIGHT TEMPERATURES

	Ambient	Room
8.00p.m	27°C	26°C
9.00p.m	27°C	26°C
10.00p.m	27°C	26°C
11.00p.m	27°C	26.5°C
12.00p.m	26°C	26°C

HOUSE 6

DAY TEMPERATURES

		Ambient	Room
16/8/2000	9.00a.m	26°C	26°C
	10.00a.m	27°C	26°C
	11.00a.m	33°C	29°C
	12.00noon	34°C	29°C
	1.00p.m	34°C	29°C
	2.00p.m	34.5°C	29°C
	3.00p.m	33.5°C	28.5°C
	4.00p.m	35°C	29°C
	6.00p.m	32°C	28°C

NIGHT TEMPERATURES

	Ambient	Room
8.00p.m	35°C	27°C
9.00p.m	31°C	28°C
10.00p.m	30°C	26°C
11.00p.m	26°C	25°C
12.00p.m	26°C	25°C

DAY TEMPERATURES

		Ambient	Room
17/8/2000	8.00a.m	32°C	25.5°C
	10.00a.m	33°C	26°C
	11.00a.m	36°C	26°C
	12.00p.m	37°C	27°C
	1.00p.m	38°C	27°C
	2.00p.m	38°C	28°C
	3.00p.m	36°C	30°C
	4.00p.m	34°C	29°C
	5.00p.m	32°C	29°C
	6.00p.m	28°C	29°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	26 °C	27 °C
10.00p.m	26 °C	27 °C
11.00p.m	26 °C	27 °C
12.00p.m	26 °C	27 °C

DAY TEMPERAUTRES

		Ambient	Room
18/8/2000	8.00a.m	32 °C	27 °C
	10.00a.m	33 °C	26.5 °C
	11.00a.m	33 °C	26.5 °C
	1.00p.m	36.5 °C	28 °C
	2.00p.m	25 °C	30 °C

NIGHT TEMPERAUTRES

	Ambient	Room
8.00p.m	26 °C	28 °C
10.00p.m	26 °C	27 °C
12.00p.m	26 °C	27 °C

DAY TEMPERAUTRES

		Ambient	Room
21/8/2000	8.00a.m	25 °C	26.5 °C
	10.00a.m	24 °C	25 °C
	12.00p.m	26.5 °C	27 °C
	1.00p.m	31 °C	29 °C
	2.00p.m	31 °C	29 °C
	3.00p.m	35 °C	32 °C
	5.000p.m	25 °C	32 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 °C	28 °C
11.00p.m	27 °C	28 °C
12.00p.m	26 °C	28 °C

HOUSE 7

DAY TEMPERAUTRES

		Ambient	Room
30/8/2000	9.00a.m	36°C	29°C
	10.00a.m	37°C	30°C
	12.00noon	38°C	30°C
	2.00p.m	40°C	30°C
	3.00p.m	40°C	30.5°C
	4.00p.m	39°C	30°C
	5.00p.m	38°C	30°C
	6.00p.m	36°C	29°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27°C	27°C
10.00p.m	26°C	28°C
11.00p.m	26°C	26°C
12.00p.m	26°C	26°C

DAY TEMPERATURES

		Ambient	Room
31/8/2000	8.00a.m	24°C	23°C
	9.00a.m	24°C	22°C
Rainy	10.00a.m	24°C	22°C
	1.00p.m	28°C	26°C
	3.00p.m	28°C	26°C
	5.00p.m	29°C	26.5°C
	7.00p.m	20°C	27.0°C

NIGHT TEMPERAUTRES

	Ambient	Room
9.00p.m	30°C	29.5°C
10.00p.m	29°C	29.5°C
11.00p.m	29°C	29°C
12.00p.m	28°C	27°C

DAY TEMPERATURES

		Ambient	Room
1/9/2000	9.00a.m	34 °C	27 °C
	11.00a.m	36 °C	26 °C
	12.00noon	37 °C	27 °C
	1.00p.m	39 °C	28 °C
	3.00p.m	39.5 °C	28 °C
	4.00p.m	36 °C	27 °C
	5.00p.m	35 °C	26 °C
	6.00p.m	32 °C	25 °C

NIGHT TEMPERAUTRES

	Ambient	Room
9.00p.m	27 °C	28 °C
10.00p.m	27 °C	28 °C
11.00p.m	27 °C	28 °C
12.00p.m	27 °C	28 °C

DAY TEMPERATURES

		Ambient	Room
21/9/2000	8.00a.m	29 °C	26 °C
	11.00a.m	38 °C	29 °C
	12.00p.m	41 °C	28 °C
	2.00p.m	40 °C	28 °C
	4.00p.m	38 °C	28 °C
	5.00p.m	36 °C	27 °C
	6.00p.m	33 °C	27 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	26 °C	27 °C
10.00p.m	26 °C	27 °C
11.00p.m	26 °C	27 °C
12.00p.m	26 °C	27 °C

HOUSE 8

DAY TEMPERATURES

		Ambient	Room
1/9/2000	9.00a.m	33°C	26.5°C
	10.00a.m	35°C	27°C
	11.00a.m	36°C	27°C
	12.00p.m	37°C	29°C
	1.00p.m	39°C	29°C
	2.00p.m	39°C	29.5°C
	3.00p.m	38°C	32°C
	4.00p.m	36°C	30°C
	5.00p.m	32°C	30°C
	6.00p.m	29°C	30°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27°C	28°C
10.00p.m	27°C	27°C
11.00p.m	26°C	27°C
12.00p.m	26°C	27°C

DAY TEMPERATURES

		Ambient	Room
2/9/2000	8.00a.m	25°C	26°C
	9.00a.m	25°C	26°C
	10.00a.m	26°C	26°C
	11.00a.m	34°C	29°C
	1.00p.m	34°C	30°C
	2.00p.m	34.5°C	29.5°C
	3.00p.m	33.5°C	29°C
	5.00p.m	36°C	29°C
	6.00p.m	33°C	28°C

NIGHT TEMPERAUTRES

	Ambient	Room
9.00p.m	31°C	28°C
10.00p.m	30°C	28°C
11.00p.m	28°C	27°C
12.00p.m	26°C	27°C

DAY TEMPERATURES

		Ambient	Room
3/9/2000	9.00a.m	33 °C	26.5 °C
	10.00a.m	35 °C	27 °C
	11.00a.m	36 °C	27 °C
	12.00p.m	37 °C	29 °C
	1.00p.m	39 °C	29 °C
	2.00p.m	39 °C	29.5 °C
	3.00p.m	39 °C	32 °C
	4.00p.m	36 °C	30 °C
	5.00p.m	32 °C	30 °C
	6.00p.m	29 °C	30 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 °C	28 °C
10.00p.m	27 °C	27 °C
11.00p.m	26 °C	27 °C
12.00p.m	26 °C	27 °C

DAY TEMPERAUTRES

		Ambient	Room
5/9/2000	9.00a.m	33 °C	26.5 °C
	10.00a.m	33 °C	27 °C
	11.00a.m	37 °C	27 °C
	12.00p.m	40 °C	30 °C
	1.00p.m	40 °C	30 °C
	2.00p.m	41 °C	31 °C
	3.00p.m	37 °C	28 °C
	4.00p.m	35 °C	28 °C
	5.00p.m	33 °C	28 °C
	6.00p.m	29 °C	28 °C

NIGHT TEMPERATURE:

	Ambient	Room
9.00p.m	28°C	29°C
10.00p.m	27°C	27°C
11.00p.m	26°C	27°C
12.00p.m	26°C	27°C

HOUSE 9

DAY TEMPERAUTRES

		Ambient	Room
2/9/2000	9.00a.m	31°C	29°C
	10.00a.m	34°C	30°C
	12.00noon	38°C	33°C
	2.00p.m	40°C	34°C
	4.00p.m	38°C	32°C
	6.00p.m	34°C	29°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27°C	26°C
10.00p.m	28°C	28.5°C
11.00p.m	26°C	25°C
12.00p.m	26°C	25°C

DAY TEMPERATURES

		Ambient	Room
3/9/2000	9.00a.m	35°C	28°C
	10.00a.m	36°C	28.5°C
	12.00p.m	41°C	29°C
	1.00p.m	41v	29°C
	2.00p.m	39°C	29°C
	4.00p.m	39°C	28°C

5.00p.m	37 °C	27 °C
6.00p.m	36 °C	27 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	35 °C	28 °C
10.00p.m	33 °C	28 °C
11.00p.m	28 °C	28 °C
12.00p.m	28 °C	27 °C

DAY TEMPERATURES

		Ambient	Room
4/8/2000	9.00a.m	31 °C	29 °C
	10.00a.m	34 °C	30 °C
	1.00p.m	39 °C	32 °C
	2.00p.m	41 °C	32 °C
	3.00p.m	40 °C	32 °C
	4.00p.m	40 °C	32 °C
	5.00p.m	36 °C	30 °C
	6.00p.m	34 °C	29 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 °C	26 °C
10.00p.m	28 °C	25 °C
11.00p.m	26 °C	25 °C
12.00p.m	27 °C	25 °C

DAY TEMPERATURES

		Ambient	Room
5/9/2000	8.30a.m	25 °C	26 °C
	10.00a.m	26 °C	26 °C
	11.00a.m	26 °C	27 °C

12.00noon	30 °C	28 °C
1.00p.m	34 °C	29 °C
3.00p.m	29 °C	30 °C
4.00p.m	29 °C	29 °C
5.00p.m	28.5 °C	27 °C
6.00p.m	28 °C	27 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 °C	26 °C
10.00p.m	28 °C	26 °C
11.00p.m	26 °C	27 °C
12.00p.m	27 °C	27 °C

HOUSE 10

DAY TEMPERATURES

		Ambient	Room
4/9/2000	9.00a.m	31 °C	29 °C
	10.00a.m	34 °C	30 °C
	12.00p.m	38 °C	33 °C
	2.00noon	40 °C	34 °C
	4.00p.m	38 °C	32 °C
	6.00p.m	34 °C	29 °C

NIGHT TEMPERAUTRES

	Ambient	Room
9.00p.m	27 °C	26 °C
10.00p.m	28 °C	25 °C
11.00p.m	26 °C	25 °C
12.00p.m	26 °C	25 °C

DAY TEMPERATURE:

		Ambient	Room
5/9/2000	9.00a.m	35°C	28°C
	10.00a.m	36°C	28.5°C
	12.00a.m	41°C	29°C
	1.00p.m	41°C	29°C
	2.00p.m	39°C	29°C
	4.00p.m	39°C	28°C
	5.00p.m	37°C	27°C
	6.00p.m	36°C	27°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	35°C	28°C
10.00p.m	33°C	28°C
11.00p.m	28°C	28°C
12.00p.m	28°C	27°C

DAY TEMPERATURES

		Ambient	Room
7/9/2000	8.30a.m	25°C	26°C
	10.00a.m	26°C	26°C
	11.00a.m	26°C	27°C
	12.00noon	30°C	28°C
	1.00p.m	34°C	28°C
	3.00p.m	29°C	30°C
	4.00p.m	29°C	29°C
	5.00p.m	28.5°C	27°C
	6.00p.m	28°C	27°C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 °C	26 °C
10.00p.m	28 °C	27 °C
11.00p.m	26 °C	27 °C
12.00p.m	27 °C	27 °C

DAY TEMPERATURES

		Ambient	Room
9/9/2000	9.00a.m	31 °C	29 °C
	10.00a.m	34 °C	30 °C
	1.00p.m	39 °C	32 °C
	2.00p.m	41 °C	32 °C
	3.00p.m	40 °C	32 °C
	4.00p.m	40 °C	32 °C
	5.00p.m	36 °C	30 °C
	6.00p.m	34 °C	29 °C

NIGHT TEMPERATURES

	Ambient	Room
9.00p.m	27 °C	26 °C
10.00p.m	28 °C	25 °C
11.00p.m	26 °C	25 °C
12.00p.m	27 °C	25 °C

APPENDIX II

AVERAGE TEMPERATURE VALUES

(1) Lagos Mainland Zone

HOUSE	OUTDOOR TEMPERATURE (To °C)	INDOOR TEMPERATURE Ti °C
1	32.2	28.1
2	32.5	30.9
3	30.3	27.8
4	32.5	28.1
5	34.2	30.1
6	34.2	30.1
7	31.0	27.4
8	34.8	39.6
9	34.5	31.1
10	32.6	29.0
Average	**32.9**	**30.2**

AVERAGE TEMPERATURE VALUES

(2) Ikorodu Zone

HOUSE	OUTDOOR TEMPERATURE (To °C)	INDOOR TEMPERATURE (Ti °C)
1	28.2	28.0
2	30.5	28.8
3	33.5	28.2
4	32.2	26.6
5	29.8	28.0
6	30.8	28.0
7	31.9	27.4
8	32.4	28.3
9	32.3	28.2
10	32.3	28.2
Average	**31.4**	**28.0**

APPENDIX IV

Department of Mechanical
Engineering, Federal
University Technology,
P.M.B. 704,
Akure, Ondo State,

August 2000

Dear Sir/Ma,

I am a postgraduate student of above-named School, conducting a research on BUILDING CONSTRUCTION IN TROPICAL CLIMATE: A NATURAL COOLING APPROACH.

The attached questionnaire is designed to assist me obtain relevant information in line with the project title. All information generated will be treated in absolute confidence and statically analysed for academic purposes only.

Thanks for your co-operation

OLOKO, G.A.

QUESTIONNAIRE

Please fill the blank space provided or mark 'X' in the box that most appropriately represent your response to the questions.

1 Name ....

2. Marital Status: Married [ ] Single [ ]

3. Number of Children (if married) ....

4. Residential Area: ....

5(a) Type of Building: Downstairs [ ] One story [ ]

Others [ ] Please specify ....

(b) Building Orientation i.e. which direction is the building facing? ....

....

6(a) No of rooms occupied: ....

(b) Which direction are your windows facing? ....

(c) Which materials are the windows made of? Glass [ ] [ ]

Casement

Sliding Windows [ ] Louvers [ ] Others [ ]

7. Types of Roofing materials: Alumin [ ] Corrugated iron sheet [ ]

Asbestos Sheet [ ] Others [ ] specify others ....

8(a) Is the house ceiled? Yes [ ] No [ ]

(b) Named type of ceiling Materials used? ....

9. How do you cope with climatic condition here? ....

Naturally [ ] Mechanical [ ] Combination of the two [ ]

10. Please briefly explain your response to 9 ....

....

....

11. Sir/Madam, During the hot season and cold season, do you feel the same interms of comfort in your room(s)

Yes ☐ No ☐

12. Explain ....

....

Is/are the mechanical means enough especially during the hot season?

Yes ☐ No ☐

13. How do you get natural air into your room? ....

....

14. Which of the two (Mechanical Cooling or Natural Cooling) would you recommend?

Mechanical ☐ Natural ☐

15. Why? ....

....

16. What is your general view regarding building and comfort in this area?

....

....

....

....