ANALYSIS

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Discovery

Assessment of passive cooling techniques in all lecture theatres of Federal University of Technology Minna, Niger state

Kolo YW✉, Olagunju RE

The inadequacy of conventional energy sources couple with the ever increasing energy costs in the phase of global warming; it is therefore, imperative to reinvent natural means to attain optimal cooling for comfort in buildings. Effective learning environment (physical), stimulate better dissemination and assimilation of information in a conducive and comfortable indoor space. The need for thermal comfort in a learning environment such as lecture theatre plays tremendous benefits to human health; good ventilation/ air quality affects body metabolism rate, which thereafter affects the quality of learning. This study assessed passive cooling techniques adopted in the design of all the lecture theatres of Federal University of Technology, Minna which enhance the indoor spaces used for learning. To achieve the aim of the study, the various passive cooling techniques used in building designs in Federal University of Technology (FUT), Minna were identified and examined. The study employed both primary and secondary sources of data collections. Observation schedule was used based on the sample size. The study revealed that all lecture theatres in FUT Minna, adopted between 64% to 82% of heat gain control measures. While between 6% to 17% are the considerations for heat loss control measures utilized in the design of all the lecture theatres. The study recommends that, all passive cooling techniques should be careful analysed, and the most suitable should be applied in lecture theatres and building designs in general; in conjunction with the prevailing environmental challenges.

INTRODUCTION

Ferco (2017), define lecture theatre/ halls as a large room used for instruction, typically at a college or university. Lecture Theatres are large buildings with rows of seat which are arrange in an incline manner (pitched floor), that are used for lectures/ instructions, seminar and other functions and its capacity is measured in hundreds. Oxford Air Conditioning (2017) suggests that Atmospheric temperature above 37 degrees causes the brain to trigger a set of reflex reaction in order for the body to become cooler, such as sweating; due to the aforementioned brain activity, the brain ability to learn and retain new information becomes less. The need for optimal cooling in a learning environment such as lecture theatre is therefore very important, because of its tremendous benefits to human health; good ventilation/ air quality which affects body metabolism rate, thereafter affects the quality of learning. It is important for such buildings to be developed to meet up with today's realities in term of science and technology to withstand present day reality of climate change (excessive heating), deficiency of energy and high cost of maintaining power supply which is not sustainable.

Givoni in 2009 defines passive cooling as a process cooling of buildings without the use of any external cooling system. This implies the use of renewable sources of energy solutions to increase heat loss in buildings. The study of passive cooling system and it application is imperative in development of lecture theatres considering global warming and excessive heat, in conjunction with the high cost and inadequacies of energy supply. Therefore, to achieve conducive learning environment for students and their lectures' it is imperative that cost effective and sustainable design solutions which passive cooling is an option could be employed.

Since passive cooling is an approach of cooling an interior (indoor) space by means of non-mechanical system, which has long been in used since the onset of architecture but it is now seldomly practice in Nigeria, easier and more expedient means of cooling are the norm of this era. The increase in energy consumption has led to environmental pollution which consequences are the depletion of the Ozone layer and global warming. Environmental activist and experts are now clamouring for greener building and sustainable approaches to enhance and create comfortable, liveable and working environments. Passive cooling design is one of the sure ways of attaining building sustainability.

Considering the epileptic power supply in Nigeria, it is only expedient for professionals in the building industry to consider of passive design techniques such as building envelope and shading, natural ventilation and air cooling as means of cooling indoor spaces, other than just mechanical methods. Passive cooling in tropical climates such as Nigeria can be realized by intelligent environmental and design

Department of Architecture, Federal University of Technology, Minna, Niger State, Nigeria
✉*Corresponding Author:*
E-mail: kolo.williams@gmail.com

considerations. In tropical climates, it's important to keep the interior of a building cool and it is known as "passive cooling" because the reliance on "active" or mechanical means (air-conditioning) is kept to a minimum (Mehta, 2015). Nigeria happens to fall within the tropical climate region as such it experiences some degree of hot temperature (heat). There has been steadily increase in the demand for power supply which is fuelled by population explosion and the economy of Nigeria. Regardless of this increase, the use of active cooling system is still on the rise, giving prominent to non- sustainable design practice which will only increase the greenhouse gas emission.

LITERATURE REVIEW

The sun is the determinant factor to all aspect of passive cooling or heating, the designers of living space are trying to achieve. The temperature of a region therefore determines the type of passive solar design to be adopted. Solar energy is a radiant heat source that causes natural process upon which all life depends; this natural process can be used to attain and sustain thermal comfort in heating or cooling of a building, (Sustainable Sources, 2016). Cooling is energy transfer from a space or air to a space, to achieve lower temperature compare to the natural surrounding/ environment.

A 'passive' solar design is the use of natural processes for cooling or heating to achieve a conducive interior space conditions. The primary strategy for passive cooling is cooling a building without mechanical assistance in hot/ humid climate is to employ passive/ natural ventilation. The flow of energy in passive design is by natural means: radiation, conduction, or convection without using any electrical device. Passive cooling techniques are closely related to the thermal comfort of the occupants of an indoor space. Kumar, Garg and Kaushik in 2005, sees passive cooling techniques as not standardized as solar heating methods and are more or less applied independently in the building. According to Agboola (2011), maintaining a comfortable environment within a building in a hot climate relies on reducing the rate of heat gains into the building and encouraging the removal of excess heat from the building. Kamal in 2012 said, to prevent heat from entering into the building or to remove once it has entered is the underlying principle for accomplishing cooling in passive cooling concepts. Passive cooling can be more effective with mechanically assisted heat transfer techniques, which can improve the natural cooling processes. Such applications are called "hybrid "cooling systems. Energy consumption is maintained at very low levels, but the efficiency of the systems and their applicability is greatly improved.

Passive design is simply a design for climate; that is to say designing with appropriate considerations to all climatic condition of the site (location), geographical area and region in mind, to maximize natural energy in the environment. For a designer in the tropics/ hot climatic region, the goal is to reduce the rate of heat gains into the indoor living space and promote the removal of excess heat from the building, in order to maintain comfort within the building space.

For effective passive cooling both the building occupants and the building need to be cooled and temperature should not exceed comfortable temperature (20 - 25°) even in the face of harsh weather. Controlling heat gain is essentially the first step in any attempt to cool buildings naturally, through design itself (Holtz 1979). This is to attempt to make the external air as cool as possible. Within the built environment this involves enhancing the green and blue infrastructure of parks, trees, open spaces, open water and water features.

From earlier researches carried out, techniques and principles adopted for achieving passive cooling are in concordance with each other, showing that such techniques are right for the fulfillment of such goal. According to Holtz (1979), explorers have found out that most of the techniques that work have worked for centuries. These techniques shall be briefly highlighted, while a selected few of for the purpose of this work shall be discussed. These techniques are categorised into two groupings; 1) Heat gain control strategy, 2) Heat loss control strategy

Heat gain control strategy

Heat gain control has to do with measures for managing the amount of heat that the building is exposed to from the environment. Since heat transfer involves energy movement from one medium to another, it is only right that we take into cognisance the follow factors which serve as mediums for heat gain;

Building Envelope

This is the integration of building forms as well as materials, as the sum total system to attain optimum comfort and energy saving. A good building envelope and internal layout responds to climate and site conditions optimise thermal performance; thus, reducing the operation cost, improve comfort, life style and minimizing environmental impact.

Thermal Mass

This is storage properties of building materials for coolness or warmth in passive design. Climate responsive design is the placing and positioning of the right building materials to be exposed to appropriate level of passive cooling; since these materials tend to radiate heat well into the night when there is drop in the external temperature. Materials for wall, floor, ceiling and roof should be carefully selected to reduce cooling load. The colours of the materials should put into consideration also, because bright colours reflect solar radiation while dark colours tend to absorb sunlight and store heat.

Building Orientation

Proper orientation of building can protect the interior space from harsh environmental factors such as excessive solar radiation, glare (solar exposure) and wind direction (site wind pattern). Solar exposure and site wind pattern cannot be ignored in passive cooling drive for comfort and convenience in the indoor space.

Shading Devices

These are shading elements introduce to shield the building openings, windows and the exoskeleton of a building. Fins, trellises and other shading devices such pergolas, recesses, overhangs and projected eaves. They also serve as wind breakers and redirect air into the interior space.

Window Placement

Proper placement of window to maximize or minimize solar gain, day light design requirement considering solar exposure of the window openings. The use of suitable glazing materials for the windows is an effective way of controlling the level of sunlight into the interior space and the type shading install around the window or openings is also very important.

Vegetation

Vegetation improve the micro-climate through evapotranspiration of plant leaves, this regulate their foliage temperature releasing fresh air. The impact depends on their type, location and sizes. For example tall trees with large branches provide shading for buildings and also serve as

Table 1 Surveyed lecture theatres selected for the study

S/No	Name of Lecture Theatre	Location
1.	Bosso Campus Twin Lecture Theatre (Twin LT)	Bosso Campus
2.	Chemical Engineering Department Lecture Theatre (CED LT)	Gidan Kwano Campus
3.	School of Agriculture and Agriculture Technology Twin Lecture Theatre (SAAT LT)	Gidan Kwano Campus
4.	School of Engineering and Engineering Technology Lecture Theatre (SEET LT)	Gidan Kwano Campus
5.	School of Environmental Technology Twin Lecture Theatre. (SET LT)	Gidan Kwano Campus
6.	School of Information and Communication Technology Lecture Theatre (SICT LT)	Gidan Kwano Campus
7.	Federal University Technology Auditorium(FUT A)	Gidan Kwano Campus

Source: Author's fieldwork 2017

wind breakers. The nature of the terrain is also very important element to be considered.

Insulation Installations

Installation of insulation such as heat resistant material reduces the thermal mass of the building envelope by acting as a barrier for heat transfer and it also maintain indoor temperature. Earth coupling is the insulation of the building from earth temperature and also act as barrier for transmission of absorbed by the earth from being transferred into building from ground.

Heat loss control strategy

The second aspect of passive cooling is heat loss form a building. This is majorly through the conductive heat losses through the building walls, floor, ceiling, glass, or other surfaces, and the convective infiltration losses through cracks and openings, or heat required to warm outdoor air used for ventilation (Bhatia, 2015)

Air Movement

This is the most important element in passive cooling; it works by increasing evaporation and providing the required breeze to cool the interior space, as well as carrying heat out replacing it with cooler air. Vent, thermal turbine, solar chimney are some of the ways of expelling warm air or introducing warm air into the indoor spaces through convection process. Openings and pattern determine the air flow in and out of the indoor spaces while direction of prevailing wind and re-directed wind enable the free flow of air in and out, therefore achieving natural ventilation.

Cooling Breeze

Heat sink such as fountain, pool, waterfall and pond are very effective and efficient for passive cooling because water absorbs a lot of heat due to its low albedo, since it transfer only small heat to it surrounding during the day. The type and sizes of opening are also very important for solar gain control by allowing cool breeze in and out of the building. The evapotranspiration which occurs as a result of absorption of radiation by plant is very important to have robust vegetation.

Evaporation

As water from cooling pond, pool, fountains, waterfall and water features around the window evaporates it draws a large amount of heat from the surrounding air. This means of heat loss control is more effective in region were the relative humidity is lower than 70% or less of the water vapour; the rate of vapour increases with air movement. Courtyards can pro-cool air entering the interior space. A careful location of these water features can also create convective breeze.

Cool Night Air

This one of the most reliable cooling source in land areas were cooling breeze are limited. The hot air that radiates from the building thermal mass is replaced with cooler air drawn by internal to external temperature differential rather than the breeze itself. Fountain, land and sea breeze, pond, and waterfall can be used to achieve cool night air.

Adequacy of passive cooling

Most passive cooling studies tend to emphasize one passive cooling aspect. In a study by Kumar, Garg and Kaushik (2005), multi-passive cooling techniques are implemented and evaluated in residential buildings in three ways, viz. solar shading of building block, insulation of building components and ventilation. The application of solar shading combined with a proper insulation, landscaping and window infiltration rate reduces the indoor temperature of the building to a significant degree. This study geared towards assessment of adequacy of these two aspects of passive cooling techniques in lecture theatres of Federal University of Technology Minna, Niger State.

Conventional cooling and heating systems are not widely used in developing countries which Nigeria follow into that category; there is an opportunity to implement a different approach that would provide sufficient cooling at a fraction of the expense of conventional systems, while being respectful of the outdoor environment and socially acceptable. Passive cooling systems offer this opportunity. En *et al* (2014) indicated the need for cooling systems to be emphasized, especially when energy consumption is taken into consideration.

Passive cooling systems have lower initial and operating costs than air conditioners, which are expensive and out of reach of low income and even many middle income families in less developed countries. Even families and cooperate that can afford to buy air conditioners, sometimes cannot provide maintenance for them or even turn them on when they need to. Because of their simple design, passive cooling designs can be built at lower costs and using local labour and resources, generating income for local entrepreneurs that live in the community and contributes to local development at large.

RESEARCH METHODOLOGY

Descriptive survey was used in the study to obtain qualitative data on Lecture theatres in Federal University of Technology, Minna. Observation survey method was employed which is suitable due to the architectural nature of the research. Sampling technique was used stratify all the Lecture halls to identify all the lecture theatre with racks, which helps in the elementary selection process of the lecture theatres in the study area. The selected Lecture theatres are listed in Table 1. The study approach of this research paper is to evaluate passive cooling system employed in the design of all the Lecture Theatres of Federal University of Technology Minna, Niger state. Data for the study was obtained through the use of observation schedule that was structured to provide basic for the study analysis; the passive cooling techniques used were observed and identified to attain passive cooling features applied in all the buildings. The variables are categorised into two groups Heat gain control measures (Building Envelope, Thermal Mass, Building Orientation, Shading Devices, Window Placement, Vegetation and Insulation Installations) and Heat loss control measures (Air Movement, Cooling Breeze, Evaporation and Cool Night Air). Findings of this research were collated and analysed with the aid of SPSS, descriptive tools such as Frequency and cross-tabulation were used to analyse the data. For visual data aspect, pictures were used to elaborate the existing states of the buildings in question. The results and discussions are presented under explicit subheadings with suitable plates and tables. The aforementioned research methodology was employed to identify and distinguish the racked theatres from all other lecture halls and classrooms.

RESULTS AND DISCUSSION

The results of this study are discussed based on the findings observed and parameters of passives cooling techniques adopted in all the lecture theatres of Federal University of Technology, Minna.

Heat Gain Control Measures

Heat gain control has to do with measures for managing the amount of heat that the building is exposed to from the environment. Since heat transfer involves energy movement from one medium to another, it is only right that we take into cognisance the follow factors which serve as mediums for heat gain.

Building Envelope

This is the integration of building forms as well as materials, as the sum total system to attain optimum comfort and energy saving. In the words of Priyanka *et al.*, (2014), building envelope like walls and roofs plays an important role in heat transfer process between indoor and outdoor environment of the building; which implies that the building envelope should be able to regulate the indoor thermal environment. A good building envelope and internal layout responds to climate and site conditions optimise thermal performance; thus, reducing the operation cost, improve comfort, life style and minimizing environmental impact.The shape of the envelope and the choice of materials of every building are very critial for thermal performance.

The shape of envelope were observed to be properly considered in the building structures studiedalso all the envelope materials were adequately chosen in all the lecture theatres except those of CED LT and SAAT LT which were not as shown in table 2. The considerations for building envelope is 85.7% for all the Lecture theatres as it concern heat gain control in buildings. Figure 1 and 2, shows two of the lecture theatres, one with building envelope and the other without building envelope respectively.

Thermal Mass

This is storage properties of building materials for coolness or warmth in passive design. Climate responsive design is the placing and positioning of the right building materials to be exposed to appropriate level of passive cooling; since these materials tend to radiate heat well into the night when there is drop in the external temperature. Al-Azri *et al.*, (2013), sees thermal mass as very imperative considering the significant temperature differences between day and night. As such, materials for wall, floor, ceiling and roof should be carefully selected to reduce cooling load. The colours of the materials should put into consideration also, because bright colours reflect solar radiation while dark colours tend to absorb sunlight and store heat.

From table 3, it is observed that the thermal mass of the walls, floor and ceiling of all the lecture theatres were adequately utilized while the thermal mass of the roof wasn’t put into consideration in any of the building structured studied. The result effect of this is that the roof radiates a lot of heat at night. The thermal mass consideration is 75% in compliance with the requirements for heat gain control from all the structures studied. Figure 3 and 4, shows the application of thermal mass in two of the lecture theatres; all the buildings have same level of application of the aforementioned.

Building Orientation

In the view of Nedhal *et al.*, (2011), selection of the most optimal building orientation is one of the critical energy efficient design decision which impact on the building envelope energy performance as well limit solar radiation. Proper orientation of building can protect the interior space from harsh environmental factors such as excessive solar radiation, glare (solar exposure) and wind direction (site wind pattern). Solar exposure and site wind pattern cannot be ignored in passive cooling drive for comfort and convenience in the indoor space.

The building orientation were adequately taken care of in all the lecture theatres considering both solar exposure and site wind pattern as show in table 4. The application of building orientation consideration is 100%.

Shading Devices

These are shading elements introduce to shield the building openings, windows and the exoskeleton of a building. Fins, trellises and other shading devices such pergolas, recesses, overhangs and projected eaves. They also serve as wind breakers and redirect air into the interior space. In Mohammad (2010) opinion, a well-designed shading devices should either be part of the building or placed on the building façade; he also likened shading device as putting a hat on a building, which can dramatically reduce building peak heat gain and cooling requirement.

From the table 5, only 71.4% of all the lecture theatres have fins for shading and 42.9% of them have other shading devices. None of all the building structure has trellis for shading from solar radiation. This indicates that the application of shading device is 38.1% in all the lecture theatres, which is not that effective. Figure 5 and 6, captures the contrast of various shading devices applied in two out of seven Lecture theatres.

Window Placement

Proper placement of window to maximize or minimize solar gain, day light design requirement considering solar exposure of the window openings are essential for all building designs in respect to geographical location. The use of suitable glazing materials for the windows is an effective way of controlling the level of sunlight into the interior space and the type shading install around the window or openings is also very important.

From table 6, all the lecture theatres were proper window placement; day light design and suitable glazing for the windows. 71.4% of the entire windows have glass shading. This implies that the application of window placement is 92.9% in all the lecture theatres.

Vegetation

Vegetation improve the micro-climate through evapotranspiration of plant leaves, this regulate their foliage temperature releasing fresh air.

Figure 1 Building Envelope, School of Engineering Agriculture and Agriculture Technology Twin Lecture Theatre (SAAT LT); **Figure 2** Building Envelope, School of& Engineering Technology Lecture Theatre (SEET LT)
Source: researcher's fieldwork 2016

Table 2 Building Envelope

S/No	Lecture Theatre	Shape of Envelope	Envelope Material
1	Twin LT	✓	✓
2	CED LT	✓	x
3	SAAT LT	✓	x
4	SEET LT	✓	✓
5	SETLT	✓	✓
6	SICT LT	✓	✓
7	FUT A	✓	✓
	Total	**100%**	**71.4%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**

Figure 3 Thermal Mass, Chemical Engineering Technology Twin Lecture Theatre (SET LT); **Figure 4** Thermal Mass, School of Environmental Department Lecture Theatre (CED LT)
Source: researcher's fieldwork 2016

Table 3 Thermal Mass

S/No	Lecture Theatre	Wall	Floor	Ceiling	Roof
1	Twin LT	✓	✓	✓	x
2	CED LT	✓	✓	✓	x
3	SAAT LT	✓	✓	✓	x
4	SEET LT	✓	✓	✓	x

5	SETLT	✓	✓	✓	x
6	SICT LT	✓	✓	✓	x
7	FUT A	✓	✓	✓	x
	Total	**100%**	**100%**	**100%**	**0%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**

Table 4 Building Orientation

S/No	Lecture Theatre	Solar Exposure	Site Wind Pattern
1	Twin LT	✓	✓
2	CED LT	✓	✓
3	SAAT LT	✓	✓
4	SEET LT	✓	✓
5	SETLT	✓	✓
6	SICT LT	✓	✓
7	FUT A	✓	✓
	Total	**100%**	**100%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**

Figure 5 Shading devices, School of Engineering Information & Communication Technology Lecture Theatre (SICT LT); **Figure 6** Shading devices, School of Engineering Technology Lecture Theatre (SEET LT)
Source: researcher's fieldwork 2016

Table 5 Shading Devices

S/No	Lecture Theatre	Fins	Trellis	Other Shading Devices
1	Twin LT	✓	x	✓
2	CED LT	x	x	✓
3	SAAT LT	x	x	x
4	SEET LT	✓	x	x
5	SETLT	✓	x	x
6	SICT LT	✓	x	x
7	FUT A	✓	x	✓
	Total	**71.4%**	**0%**	**42.9%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**

Table 6 Window Placement

S/No	Lecture Theatre	Proper Window Placement	Window Shading For Glass	Day Light Design	Suitable Glazing for Window
1	Twin LT	✓	✓	✓	✓
2	CED LT	✓	x	✓	✓
3	SAAT LT	✓	x	✓	✓
4	SEET LT	✓	✓	✓	✓

5	SETLT	✓	✓	✓	✓
6	SICT LT	✓	✓	✓	✓
7	FUT A	✓	✓	✓	✓
	Total	**100%**	**71.4%**	**100%**	**100%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**


Figure 7 Vegetation, Bosso Campus Twin Lecture Information & Communication Technology Lecture Theatre (SICT LT); **Figure 8** Vegetation, School of Theatre (Twin LT)
Source: researcher's fieldwork 2016

Table 7 Vegetation

S/No	Lecture Theatre	Lawn	Shrubs	Trees
1	Twin LT	✓	✓	✓
2	CED LT	✓	✓	✓
3	SAAT LT	✓	✓	✓
4	SEET LT	✓	✓	✓
5	SETLT	✓	✓	✓
6	SICT LT	✓	x	✓
7	FUT A	✓	✓	✓
	Total	**100%**	**85.7%**	**100%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**

Table 8 Insulation Installations

S/No	Lecture theatre	Heat Resistance Installation	Earth coupling
1	Twin LT	x	x
2	CED LT	x	x
3	SAAT LT	x	x
4	SEET LT	x	x
5	SETLT	x	x
6	SICT LT	x	x
7	FUT A	x	x
	Total	**0%**	**0%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**

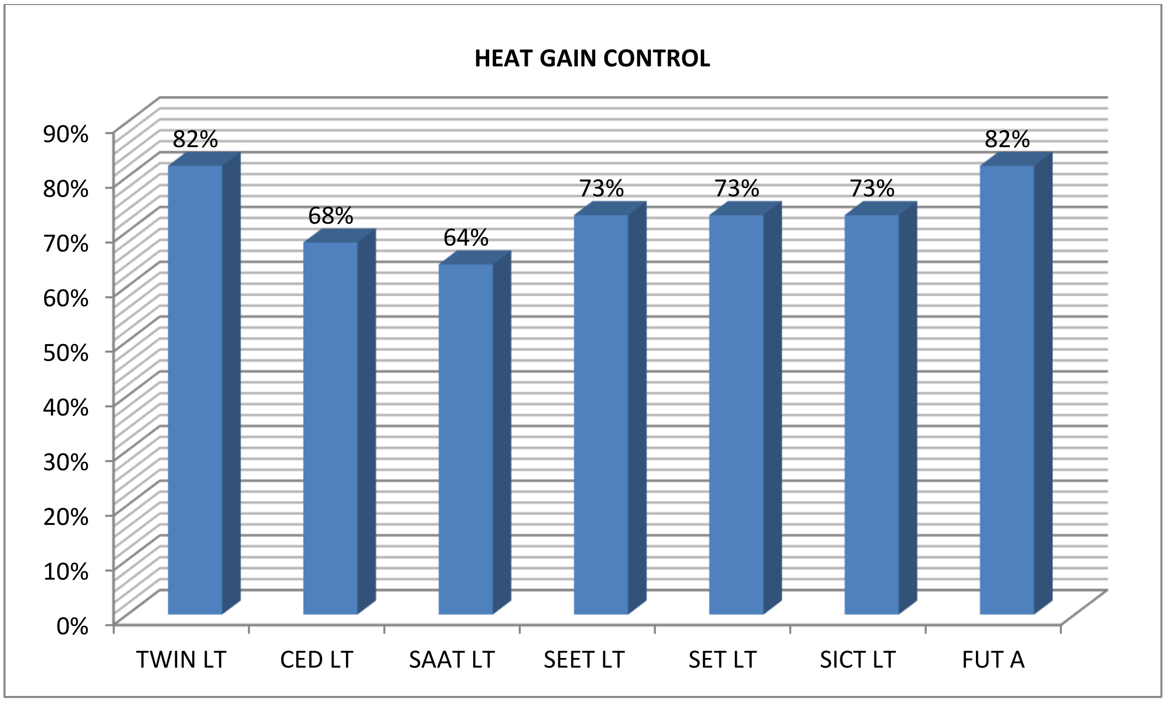

Figure 9 Heat gain control measures application in all the lecture theatres
Source: Author's Field survey, 2017

Table 9 Air Movement

S/No	Lecture Theatre	Vent	Thermal Turbine	Openings and pattern	Direction of Prevailing Wind	Re-directed Wind	Solar Chimney
1	Twin LT	x	x	x	✓	✓	x
2	CED LT	x	x	x	✓	✓	x
3	SAAT LT	x	x	x	✓	✓	x
4	SEET LT	x	x	x	x	✓	x
5	SETLT	✓	x	x	x	✓	x
6	SICT LT	✓	x	x	x	✓	x
7	FUT A	✓	x	x	✓	✓	x
	Total	**42.9%**	**0%**	**0%**	**57.1%**	**100%**	**0%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**

Table 10 Cooling Breeze

S/No	Lecture Theatre	Fountain	Pool	Waterfall	Pond
1	Twin LT	x	x	x	x
2	CED LT	x	x	x	x
3	SAAT LT	x	x	x	x
4	SEET LT	x	x	x	x
5	SETLT	x	x	x	x
6	SICT LT	x	x	x	x
7	FUT A	x	x	x	x
	Total	**0%**	**0%**	**0%**	**0%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**

Table 11 Evaporation

S/No	Lecture Theatre	Cooling Pond	Pool	Fountain	Courtyard
1	Twin LT	x	x	x	x
2	CED LT	x	x	x	x
3	SAAT LT	x	x	x	x

4	SEET LT	x	x	x	x
5	SETLT	x	x	x	x
6	SICT LT	x	x	x	✓
7	FUT A	x	x	x	x
	Total	**0%**	**0%**	**0%**	**14.3%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**

Table 12 Cool Night Air

S/No	Lecture Theatre	Fountain	Pond	Waterfall	Land and Sea Breeze
1	Twin LT	x	x	x	x
2	CED LT	x	x	x	x
3	SAAT LT	x	x	x	x
4	SEET LT	x	x	x	x
5	SETLT	x	x	x	x
6	SICT LT	x	x	x	x
7	FUT A	x	x	x	x
	Total	**0%**	**0%**	**0%**	**0%**

Source: Author's fieldwork 2017 **(Key - ✓ : Yes, X: No)**

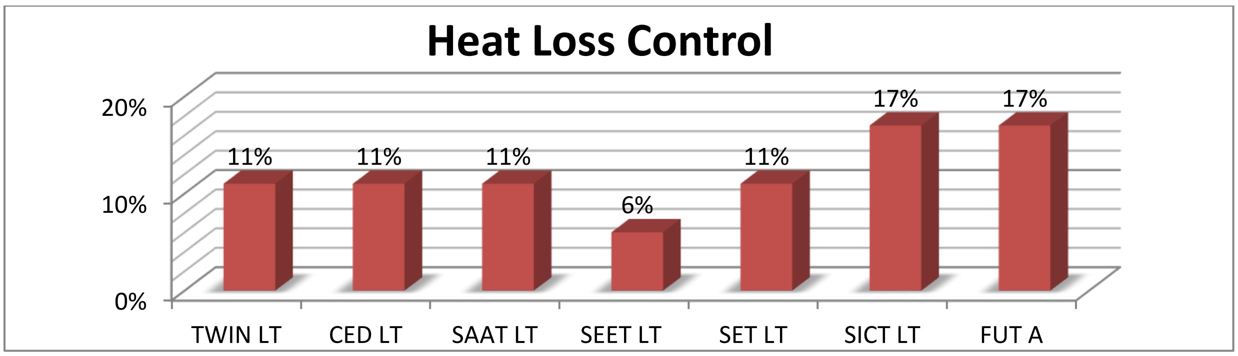

Figure 10 Heat Loss Control Measures Application in All the Lecture Theatres
Source: Author's Field survey, 2017

According to Geetha and Velraj (2012), "vegetation modifies the microclimate and the energy use of buildings by lowering the air and surface temperatures and increasing the relative humidity of the air". The impact depends on their type, location and sizes. For example tall trees with large branches provide shading for buildings and also serve as wind breakers. The nature of the terrain is also very important element to be considered.

All the building structures have adequate vegetative cover of lawns and trees. Only SICT LT has no shrubs as shown in the table 7. This suggests that the application of Vegetation is 95.2% in all the building structures. Figures 7 and 8, shows the nature of the vegetation of two the lecture theatres, from a well landscape to least landscaped theatre.

Insulation Installations

Installation of insulation such as heat resistant material reduces the thermal mass of the building envelope by acting as a barrier for heat transfer and it also maintain indoor temperature. Mohammad (2012) also sees insulation as a means of controlling temperature difference between interior and exterior as well as to control the interior mean radiant temperature by isolation of interior surfaces. Earth coupling is the insulation of the building from earth temperature and also act as barrier for transmission of absorbed by the earth from being transferred into building from ground.

From the table 8, the consideration for insulation installations is 0% for all the lecture theatres, which is very poor for heat gain control. There is no insulation of the buildings against solar exposure.

Drawing from Table 2 to 8 as analysed in Figure 9 which shows that TWIN LT and FUT A. adopted 82% of heat gain control methods in there design, these happens to be the buildings with the highest use of such technique, while SEET LT, SET LT AND SICT LT have used 73% of this same technique for passive cooling. CED LT utilized 68% and SAAT LT 64% application of heat gain control measures. These appear to be the level of application of heat gain control measures in all the lecture theatres, based on these data.

Heat Loss Control Measures

The second aspect of passive cooling is heat loss form a building. This is majorly through the conductive heat losses through the building walls, floor, ceiling, glass, or other surfaces, and the convective infiltration losses through cracks and openings, or heat required to warm outdoor air used for ventilation (Bhatia, 2015).

Air Movement

Al-Azri *et al*., in 2013, defines Air movement as an intuitive and essential passive cooling strategy. This implies that air movement is a very important element in passive cooling; which works by increasing evaporation and providing the required breeze to cool the interior space, as well as carrying heat out replacing it with cooler air. Vent, thermal turbine, solar chimney are some of the ways of expelling warm air or introducing warm air into the indoor spaces through convection process. Openings and pattern determine the air flow in and out of the indoor spaces while direction of prevailing wind and re-directed wind enable the free flow of air in and out, therefore achieving natural ventilation.

From table 9 the air movement consideration in all the lecture theatres was just 33.3% compliance with the requirement for the aforementioned. The vent, direction of prevailing wind and re-direction wind were majorly considered which are 42.9%, 57.1% and 100% respectively.

Cooling Breeze

Heat sink such as fountain, pool, waterfall and pond are very effective and efficient for passive cooling because water absorbs a lot of heat due to its low albedo, since it transfer only small heat to it surrounding during the day. The type and sizes of opening are also very important for solar gain control by allowing cool breeze in and out of the building. The evapotranspiration which occurs as a result of absorption of radiation by plant is very important to have robust vegetation.

Deducing from table 10 cooling breeze strategies of removal of heat within and outside of the building is 0% which insinuates it was not considered in any of the lecture theatres.

Evaporation

As water from cooling pond, pool, fountains, waterfall and water features around the window evaporates it draws a large amount of heat from the surrounding air. According to Michael J.Holtz (1979), evaporative cooling is a powerful cooling technique in climate with low relative humidity. This means of heat loss control is more effective in region were the relative humidity is lower than 70% or less of the water vapour; the rate of vapour increases with air movement. Courtyards can pro-cool air entering the interior space. A careful location of these water features can also create convective breeze.

From table 11 only 3.6% of the entire structures made consideration for evaporation as a means of heat loss control measures. The result suggest that only courtyard was seen as means of cooling which was only applied in 14.3% of the whole lecture theatres.

Cool Night Air

This one of the most reliable cooling source in land areas were cooling breeze are limited. The hot air that radiates from the building thermal mass is replaced with cooler air drawn by internal to external temperature differential rather than the breeze itself. According to Geetha and Velraj (2012), cool night air is efficient mainly on the relative difference between indoor and outdoor temperature during the night. In other words, the cool ambient air from Fountain, land and sea breeze, pond, and waterfall can be used to achieve cooling at night to reduce the indoor air temperature and the building structure temperature as well.

The application of cool night air as a means of heat loss within and around the building structure, 0% was the consideration for such in all the lecture theatres as shown in table 12. The result implies that heat loss control through this means was not considered at all. Deducing from all the tables 9 to 12 as explained in Figure 10 which shows that SICT LT and FUT A. adopted 17% of heat loss control methods in the design, these happens to be the buildings with the highest in use of such technique, while TWIN LT, CED LT, SAAT LT and SET LT utilized 11% and SEET LT 6% application of heat loss control measures. These appear to be the level of application of heat loss control measures in all the lecture theatres, based on these data.

CONCLUSION

Passive cooling is a very important consideration for architects, engineers and other professionals in the building industry because it can play a great role in reducing energy cost for heat or cooling of indoor spaces, as well as aesthetics. Natural ventilation can be used to achieve effective cooling of lecture theatre, if careful analysed and planned. This research observed that the passive cooling techniques employed in the lecture theatres are inadequate, although, more considerations was given to heat gain control measures with little on heat loss control measures and heat storage, to effectively deal with cooling of the building as well as the interior space. The landscaping is poorly managed and maintained; pedestrian ways were not well defined in most cases. From the data analysis carried out, this shows that the design of lecture theatres in Federal University of Technology Minna, this summation was derived from the data analysed. Drawing from the observation and deductions from the data analysed, insulating the building envelope will definitely reduce the thermal mass of the existing lecture theatres. And with a well landscaping and introduction of soft landscaping features, solar effects can be reduced as a result of an enriched micro-climate through vegetation. To achieve effective ventilation of interior spaces, Architects and Designers need to see the indoor spaces as 'living space' because it inhales (cool fresh air) and exhales (warm polluted air); fenestrations and vents should be properly planned.

Recommendations

Drawing from the data collected and analysed the passive cooling techniques employed in the lecture theatres of FUT Minna, Niger state are inadequate, ill planned or abandon, it is important to carefully pay attention to the adequacy of passive cooling techniques considerations in designing and constructing future ones. The paper recommend that only professional with sound knowledge of passive design application should be employed for all building designs and construction like lecture theatre were passive cooling is a major factor. Professional bodies in charge of construction must employ integrity, accountability, fairness, honesty, transparency in enforcement of government policy building development and project monitoring and control. In addition, design tailored toward sustainable development should the standard for future.

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