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AN EVALUATION OF THERMAL COMFORT CONDITIONS IN AN URBAN ENTERTAINMENT CENTRE IN HOT-DRY CLIMATE OF NIGERIA.

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ABSTRACT: *The aim of this study was to evaluate the effects of environmental design parameters on thermal comfort conditions in an urban entertainment centre located in the hot-dry climate of Nigeria. Building designs in Nigeria now tend towards mix-use functions as in the case of an urban entertainment centre, therefore, making thermal comfort a necessity. Unfortunately in the hot-dry climatic regions of Nigeria, buildings fulfill this requirement through total dependence on mechanical means of cooling to solve for overheating. It was evident that some design parameters caused this undesirable situation. The study therefore focused on understanding and evaluating the effects of design-dependent elements such as materials of building envelop, thermal mass, the size and orientation of windows, shading and vegetation on thermal comfort conditions in the case study building. Data loggers were used to record temperature and humidity data in predetermined rooms. Data was collected during certain periods in April, May, and June 2013. Hypotheses were developed and statistically tested using ANOVA. The study showed that temperature based on ASHRAE standards 55-66 and OSAHS 1997 was above comfort range in all the spaces investigated. Further, the results showed that the effect of thermal mass was almost the same for most of the spaces, primarily due to the fact that most of the building had been constructed with thick concrete walls. In terms of thermal performance, the building materials used, number and orientation of the exterior walls, orientation and size of windows and also sun shading with surrounding vegetation were most effective design parameters for the spaces investigated.*

KEYWORDS: Thermal Comfort, Data Logger, Urban Entertainment Centre, Material of Building Envelope, Thermal Mass, Building Orientation.

INTRODUCTION

Thermal comfort is often related to the condition of an individual's mind which expresses satisfaction or dissatisfaction with the thermal environment. Man has, for the most part, strived to create a thermally comfortable environment. This is reflected in building traditions around the world - from ancient history to present day. A healthy and comfortable thermal environment of indoor workspace helps the users to improve their work efficiency by maintaining various comfort related parameters within the desired range, Shanu (2010). Today, creating a thermally comfortable environment is still one of the most important parameters to be considered when designing public buildings such as an urban entertainment centre. Due to the rapid growth in urban areas and global warming, the issue of thermal comfort conditions have gained great attention. Khaliq (2009) states the importance of the thermal comfort in a daily life cannot be denied, whether it is related to indoors such as an urban entertainment centre or outdoors such as recreational parks.

Jason (2005), states that an urban entertainment building which is usually family-oriented entertainment destinations, integrating entertainment with retail, dining, recreational and cultural facilities should be able to cater for both the physical and psychological needs of its users by creating a human thermal environment. Achieving thermal comfort in UECs has been a challenge especially in hot-dry regions of Nigeria. Builders and designers usually do not pay attention to the thermal performers of their buildings, Ahmed (2012).

In recent times, most building designs in Nigeria tend towards mix-use functions as in the case of an urban entertainment centre where shopping, entertainment and recreation fall under the same roof. This has made thermal comfort a necessity in the design of such buildings. In order for the human body to achieve thermal balance, it must be protected from the effects of severe outdoor conditions. On the other hand, most urban entertainment centres in hot-dry climate fulfil this requirement with the help of air conditioning and cooling units.

Consequently, since thermal comfort varies from one climatic zone to another, buildings having mix-use functions (i.e. urban entertainment centres) are expected to be designed in relation to the climatic zone. Unfortunately, there is great reluctance, especially in Nigeria, where builders and designers do not pay attention to the thermal performance of their buildings, despite existing knowledge regarding design solutions which provide thermal comfort conditions in a building. In view of these problems, architects should understand that they must design buildings which not only have minimum cooling loads but also provide thermal comfort for their occupants. Moreover, it will be a logical approach for architects to pay attention to local climatic conditions during the design process. To this end, the aim of the research was to analyse the effects of design-dependent elements on thermal comfort conditions in an urban entertainment centre in hot-dry climate of Nigeria. The first objective of the research was to investigate the thermal behaviour of the predetermined spaces in the urban entertainment centre in terms of temperature and relative humidity. The second objective was to determine which design-dependent variables were most effective on the thermal performance of the urban entertainment centre.

LITERATURE REVIEW

Thermal comfort is defined in the ISO 7730 (1994) and ASHRAE standards 55-66 as “the condition of the mind that which expresses satisfaction with the thermal environment”. Cheung (2003) states that, thermal comfort occurs when there is a thermal equilibrium in the absence of regulatory sweating and the heat exchange between the human body and the environment.

The most commonly used indicator of thermal comfort is air temperature because it is the most easy to use and people can rate it without any difficulty. Although it has vital importance, however, it is not the only parameter that can be used to define thermal comfort very accurately. According to Khaliq (2009), air temperature should always be considered in relation to other environmental and design factors. Temperature and relative humidity are the two local climatic factors that affect indoor comfort while building envelop, orientation, shading, glazing type and size, vegetation, thermal mass are the design dependent parameters that contribute to the thermal comfort condition in a mixed-used building such as an urban entertainment centre. Another set of factors affecting thermal comfort are known as the human thermo-regulatory factors. Although these factors are independent to each other, they have collectively a great impact. Thermo-regulatory factors are not considered further in this research, because it is outside the scope of the study.

There are many models developed by people to assess the thermal comfort indoor but for outdoor conditions their list is very short. The fundamental work by Fanger (1970); indicated that model is based on the heat balance conditions of the human body.

The predicted mean vote (PMV) is a thermal sensation scale. The mean opinion of a large group of individuals expressing a vote on their thermal feeling under different thermal circumstances has been used to provide an index to thermal comfort. A PMV value of zero provides the optimal thermal comfort conditions. Ahmed (2012) states that, a positive PMV value means that the temperature is higher than optimal, while a negative value means that it is lower. The comfort zone is generally regarded as stretching from a slight feeling of cold (termed 'fresh', when the PMV is -1) to a slight feeling of warmth (termed 'mild', when the PMV is +1).

The predicted percentage of dissatisfied (PPD) is an indication of the percentage of people susceptible to feeling too warm or too cold in a given thermal environment. It can be deduced from the PMV that if, for instance, the PMV is in the range -1 to +1, then the PPD index shows that 25% of the population will be dissatisfied. To reduce this figure to 10%, then the PMV has to be in the range -0.5 to +0.5, (Fanger 1970). Due to some limitations the ISO (Internal standards organization) standard 7730(ISO1984), "Moderate Thermal Environment-determination of the PMV and PPD indices and specification of the conditions for thermal comfort" used limits on PMV as an explicit definition of the comfort zone.

The adaptive approach is not based on the heat balance equilibrium between human body and environment but on observations. Depending upon the observations, there are ranges of actions which can be performed in order to achieve thermal comfort. In a human body, brain temperature is a sensor to regulate the temperature of the whole body. It acts as a control to maintain the thermal comfort conditions between the body and environment, (Shanu 2010). If changes occur in the environment or somewhere else, the brain equilibrium will deviate from the close limits of thermal comforts, and then action is taken to restore the brain to close limits, (Ahmed 2012).

Comfort zone

According to Çakir (2006), thermal comfort in an interior space can be considered as the sum-total of heat or cold sensations experienced by occupants. Further, if the interior space has neither excessive heat nor cold conditions, it is then considered to be thermally comfortable. This reveals that the space is within an occupant's comfort zone. Thus, the comfort zone may be defined as a thermal condition in which little or no effort is required by occupants to adjust their bodies to surrounding environmental conditions.

Notice that most people are comfortable at higher temperatures if there is lower humidity. As the temperature drops, higher humidity levels are still within the comfort zone. Occupational safety and health services (1997) OSAHS, provided a thermal comfort standard for sedentary occupations applicable in any climatic zone. According to the standard, most people will be thermally comfortable in the following conditions;

- Air temperature : heat periods (19ºC-24ºC) cold periods (18ºC-22ºC)
- Relative humidity : 40%RH-70%RH
- Air speed : 0.1-0.2 m/s, without creating draught
- Radiant heat : no direct exposure to radiant heat source

Other experiment happens to be science based, and so could not be part of this study. In this research the documentation of thermal comfort is not generalized as it's conducted in locations identified as the research area.

Hot-dry climate

As stated by the MNRE, (2010) the Ministry of New and Renewable Energy, hot-dry climatic region is characterized by very high radiation levels, ambient temperature and relatively average humidity. Countries that are found in such climates are Nigeria, Niger, Egypt, Syria, Malaysia, Saudi Arabia, and United Arab Emirates. According to community portal of Nigeria (2012), the climate of Abuja (capital city of Nigeria) is hot-dry for most periods of the year. The mean daytime temperature for most stations in the Federal Capital Territory (FCT) is about 38ºC. The highest temperature of about 40ºC is normally experienced between March and June while minimum of about 30ºC are recorded in December and January (Ahmed, 2012).

Historical development and trends in urban entertainment centres (UEC)

The development of the modern UEC is based on the crisis of the classical retail trade. Beginning in the 1960 and 1970, the trend therefore went for years to shopping centres where numerous different businesses were offered to the consumer under a roof. Classical forming out of shopping centres consists of a Mall in the Centre with one anchor tenant each at each side. This form is also called "dog bone". Shopping centres are usually closed buildings with numerous passenger car-parking bays, (Thomas, 2002).

According to Jason (2005), UEC have been developed everywhere with trends like theme parks, sport arenas, indoor leisure sites, centre parks, multiplex cinemas and or musical theatres. These centres, often dedicated to a special theme, combine different leisure functions with retail trade and entertainment. Because of their huge size, growing number and needful catchment areas, their spatial impacts are immense. Jason (2005) further noted that it is necessary for environmental professionals (architects, planners and engineers) and politicians to think about connected issues like the roles of UECs within the city structure, its influence on traffic and economic impacts to existing structures of retail trade and leisure functions. The environment format examined here is led by the provision of leisure and entertainment facilities and they are referred to as **'entertainment centres'**.

The shop tenants in these examples are restricted to specific types, which tend to be specialist shops that are recreationally focused, rather than comparison fashion retailers. The purchasing is generally impulse-driven, which is more dependent on the 'feel good' factor derived from experiencing the place or participating in the entertainment activities. Entertainment centres require a sufficiently sized attraction to guarantee a level of attention to the Centre (Haynes, Joel & salil 1997).

Urban entertainment centres are a partnership between retail and entertainment and created by variations of retail and entertainment combinations. They are generally compared to shopping malls in almost every respect, but scale. UECs are not the stereotypical indoor climate controlled centres like malls, but incorporate a variety of outdoor plazas, corridors, paths, trails, courtyards, and interior spaces. The crucial criterion for a UEC is the kind of the entertainment and complementary functions. This covers often a multiplex cinema, a musical/concert hall or open space, a gaming house, recreational facilities or indoor games (e.g. bowling, snooker) and are sometimes individualized components.

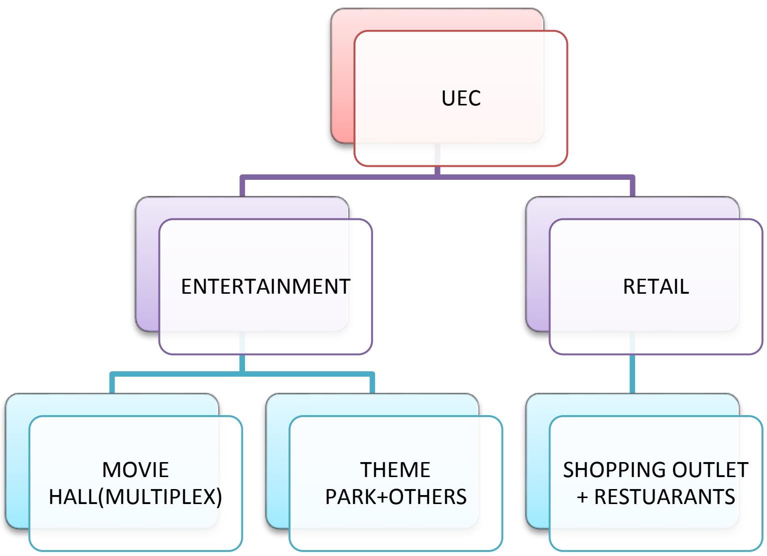

Figure 1. Basic components of UEC (Thomas, 2002)

CHALLENGES OF ACHIEVING THERMAL COMFORT IN URBAN ENTERTAINMENT CENTRES

In tropical countries such as Nigeria, according to the world summit held in Johannesburg, 2001, thermal comfort of a person in these regions lies between 19 ºC and 24 ºC. Providing thermal comfort in this range to occupants is a challenge for building designers especially if applied in mixed-use buildings such as a UEC. Most urban entertainment buildings use air-conditioning systems to achieve thermal comfort, which consume a lot of energy. The primary function of an urban entertainment building envelope is to protect the occupants of the building from the heat of the sun, rains, dust and provide a congenial environment for entertainment, work and leisure. To achieve this, it is necessary that the design measures adopted should result in the balance of natural ventilation, space conditioning, and lighting. The first step towards achieving thermal comfort in such a large scale building is to integrate suitable bio-climatic design principles with respect to the region while designing the macroclimate and microclimate of the site.

The climatic design varies from one climate zone to the other. Nigeria has six climatic zones representing varying climatic conditions, ranging from extreme cold conditions to extreme hot and dry conditions. Therefore an urban entertainment building designed for hot-dry climate should have features to reduce solar gain, like smaller window size, shaded walls, minimum exposure to west and east directions, use of external wall and roof insulation, or design elements like solar chimneys, wind towers, water-based features to aid in the cooling of spaces and so on to maximize ventilation, (Çakir 2006).

METHOD

This is basically a quantitative research. The objective of this research is focused on design-dependent elements and their possible effects on thermal performance of the urban entertainment centres in hot-dry climate of Nigeria. The study adopted the case study methodology, because this allows the researcher to explore and understand complex issues (Zaidah, 2007).

Sampling

Veal (2006) noted that case study selection was comparable to sampling in a quantitative research and that cases were usually purposely selected. This meant that cases were identified for study due to their inherent qualities which were in consonance with the phenomenon under investigation (Oluigbo, 2010).The sampling method used was a purposive sampling in which the building chosen typified the particular character.

Population of study

The population of study is with respect to the building and not its users', this is due to the nature of the variables and research method which is quantitative or objective. According to Zaidah (2007), a case study research could either be a single-case deign (in which the case typifies a particular character) or multiplex-case design depending on the nature of the research. This research adopted the single-case design due to the buildings representation as an urban entertainment Centre, time constraint, proximity, geographical location (hot-dry climate) and ease of collection of data. To this end, the galleria (silverbird), Abuja was purposely selected because it was extremely atypical or representative, information-rich, and its location being the only urban entertainment centre in the hot-dry region.

Survey instrument

The research is a Field study. Tiny-tag (see plate 1) data logger was used for the collection of temperature and relative humidity simultaneously which are the two local climatic parameters affecting indoor thermal comfort at 30 minutes intervals. Data loggers can be located only inside. Certain precautions have to be taken while using this sensitive tool; for example, interior data loggers should not be located close to walls or openings, in the path of direct sunlight and frequent air movements, near heat or moisture producing sources. These also should be kept away from heat/cool sources and moisture producing sources. Data loggers are launched and offloaded by the software called Gemini Data Logger Manager. The tabular data can be exported to spread sheet documents to develop the comparison graphs.

In order to exclude external microclimatic influences, the study had to be performed under possible uncooled and unoccupied conditions. This meant that no one was able to enter the selected spaces to perform any activity whatsoever. Therefore, suitable unoccupied spaces were selected to record humidity and temperature data during the months of (April, May, and June) 2013.

Plate 1. Tiny-tag data logger. (www.tinytag.info)

Case study building

The Silver-bird Galleria building was the case study building, which is situated in Abuja municipal area. This building is a High-rise structure, and was constructed in 2009. It includes 12 screen multiplex cinemas, 8 VIP lounges, game arcades, retail shops, stores and administrative offices. It's a six storey building having total site area of 35,000sqm, the area of theatre complex is 3,700sqm, office tower is 296sqm, generator is 186sqm, security is 195sqm, landscaped area is 17% and paved area is 57.5%. The building form is rectangular elongated on the north-south axis [see plate 2]. It has concrete curtain walls having 225 mm thickness with extensive use of steel and glass material. All the windows are made of tampered glass which is reflective and double glazed. The roof is partly decked and drained with pipes at the exterior, while other areas are covered with fiber-boards to serve as atriums and its interior floors are covered with decorative hardware tiling. [See figures 2, 3, and 4 showing floor plans, in which spaces investigated are also marked].

Plate 2. Aerial view of case study site [silverbird galleria, Abuja, Nigeria] (Google maps 2014)

Data collection

Table 1. shows the data sets collected for certain days in April, May, and June 2013. These datasets are listed in the first column, while dates for data recordings, Room numbers and data logger identity are given in the 2nd, 3rd and 4th columns respectively.

Table 1. Data sets collected in April, May, and June, 2013.

	DATE	ROOM/SPACE	DATA LOGGER
DATA SET 1	7th-14th April 2013	Shop 1 (conc. wall)	DL1
		Shop 2 (brick wall)	DL2
DATA SET 2	18th-24th May 2013	Shop 3 (conc. wall)	DL 1
		Shop 4 (brick wall)	DL 2
DATA SET 3	24th-27th June 2013	Cinema 2(conc. wall)	DL 1
		Cinema 7(conc. wall)	DL 2

Data analysis

According to Veal (2006), all forms of analysis are possible within the context of a case. Hypotheses were formulated and then tested by conducting Analysis of Variance (ANOVA) to show if there is a significant difference between the temperatures of the rooms; and their levels of humidity. If a significant difference was determined then the reasons behind this difference were investigated in terms of the design-dependent parameters influencing the thermal conditions within. In this context, the ANOVA at a 5 % level of significance was applied and the following [Null hypotheses] were tested for Data Sets 1; 2; and 3.
Ht01: There is no difference between the temperatures of the rooms, Ht02: There is no difference between the humidity of the rooms.

Limitation of study

The current study has several limitations. Ideally, the field measurements of the two thermal comfort parameters at the pre-determined spaces should be recorded simultaneously. However it should be noted that collecting data concurrently for the whole building was impossible due to shortage of data loggers. In course of the work, a data logger was taken by an unknown individual who at the beginning of the work was clearly stated by the management to be at owners' risk.

RESULTS

All three data sets are presented, for each selected spaces. In the temperature graphs the x-axis shows the date of recording period and the y-axis shows the temperature in degrees C. In humidity graphs, the x-axis shows the date of recording period and the y-axis shows the relative humidity as percentage.

Data set 1

This data set was recorded in shop1 and shop 2 concurrently. Shop 1 and shop 2 are located opposite to each other in the corridor to the north of the atrium. Room 1 (see figure 5) has south-facing windows and floor-to-ceiling glass sliding door overlooking the atrium. Room 2, on the other hand has north facing window and floor-to-ceiling glass sliding door to the exterior (see figure 6).

Data set 2

This data set was recorded in Room 3 and Room 4 concurrently. These rooms are located adjacent to each other. Room 3 (see figure 7) has west-facing windows and floor-to-ceiling glass sliding door facing atrium from interior. Room 4 (see figure 8), on the other hand has east facing windows and floor-to-ceiling glass sliding door also facing the atrium from interior.

Data set 3

This data set was recorded in Cinema 2 and 7 concurrently. These Cinemas are located opposite to each other. Cinema 2 (see Figure 9) located northward while Cinema 7 (see figure 10), on the other hand is located southwards both with no exterior window.

Hypothesis tested

Null hypotheses [Ht01 and Ht02] were tested with the help of ANOVA for the temperature and humidity data

Anova test for data set 1

Table 2. Anova for temperature data of shop1 and 2

Anova single factor						
SUMMARY						
groups	*count*	*sum*	*mean*	*variance*		
Shop 1; Dl 1	[235]	5866,6	20,6322415	0,252115		
Shop 2; Dl 2	[235]	5263,6	41,2256354	0,202162		
ANOVA	*SS*	*df*	*MS*	*F*	*P-value*	*F-crit*
Source of variation						
Between groups	[78,24561]	501	88,25361	365,1864	1,62E-55	4,524031
Within groups	[144,3654]	4	0,225687			
Total	195,325	508				

Ht01: There is no difference between the temperatures in Shop 1, and Shop 2 According to table 2, Ht01 is rejected (i.e. there is a significant difference between the temperatures in shop 1, and shop 2). As seen in table 2, there are strong temperature fluctuations in shop 2 as compared shop1. This fluctuation is probably due to the thermal mass effect in the building. Shop 1 has more stable temperature because its north-west orientation and choice of building material which is of a low density (brick). This prevents excessive warming in shop 1 and keeps the indoor temperature at a certain level. Another point is that, shop 2 is expected to be much hotter than the other two rooms because of the east-west orientation and choice of building material which is of high density (concrete). On the other hand, average temperature of this

room might have been affected from lack of overhangs and the cooling effect of outdoor vegetation.

Table 3. Anova for humidity data of shop1 and 2

Anova single factor						
SUMMARY						
groups	*count*	*sum*	*mean*	*variance*		
Shop 1; Dl 1	[210]	18005	2,5742	4,256382		
Shop 2; Dl 2	[285]	14114,5	37,5736	2,250042		
ANOVA	*SS*	*df*	*MS*	*F*	*P-value*	*F-crit*
Source of variation						
Between groups	[21002,36]	2	35462,36	5405,18	0	4,214031
Within groups	[2145,354]	502	3,124057			
Total	125,521	508				

Ht02: There is no difference between the humidity in shop1, and 2.
According to table 3, Ht02 is rejected (i.e. there is a significant difference between the humidity in shop 1, and shop 2). It is expected that shop 1 facing north-west orientation show larger Humidity values than the other two rooms. However, shop 2 had more humidity; this could be due to the broken sprinkler in shop 2 after which it was.

Anova test for data set 2

Table 4. Anova for temperature data of shop3 and 4

Anova single factor						
SUMMARY						
groups	*count*	*sum*	*mean*	*variance*		
Shop 3; Dl 1	[235]	7536,6	25,6325165	0,252245		
Shop 4; Dl 2	[235]	8263,6	36,2456354	0,252562		
ANOVA	*SS*	*df*	*MS*	*F*	*P-value*	*F-crit*
Source of variation						

Between groups	[88,25361]	502	88,25361	365,1864	1,62E-55	3,542654
Within groups	[125,3654]	4	0,225687			
Total	195,325	504				

Ht01: There is no difference between the temperatures in the two Shops (3 and 4).In table 4, Ht01 is rejected (i.e. there is a significant difference between the temperatures in shop 3 ad shop 4). Temperature values for these shops were close to each other although shop 3 faces north-west and shop 4 faces east. This situation may be explained by the fact that Shop 3 has floor-to-ceiling sliding door and small windows and on the other hand, shop 4 made use of burnt brick for walling and has larger windows which doesn’t create more thermal mass effect.

Table 5. Anova for humidity data of shop3 and 4

Anova single factor						
SUMMARY						
groups	*count*	*sum*	*mean*	*variance*		
Shop 3; Dl 1	[235]	14005	2,35602	3,256382		
Shop 4; Dl 2	[235]	12114,5	37,00236	1,250042		
ANOVA	*SS*	*df*	*MS*	*F*	*P-value*	*F-crit*
Source of variation						
Between groups	[13562,36]	2	13562,36	5235,18	0	3,542524
Within groups	[1358,354]	506	2,250057			
Total	144,325	504				

Ht02: There is no difference between the humidity in the two shops (3 and 4).

According to Table 5, Ht02 s rejected, there is a significant difference between the humidity in the two rooms. Shop 4 is cooler than shop 3 because of the orientation of its large windows facing the entrance foundation of 3.2m. Moreover this feature is known to retain humidity.

Anova test for data set 3

Table 6. Anova for temperature data of cinema 2 and 7

Anova single factor						
SUMMARY						
groups	*count*	*sum*	*mean*	*variance*		
Shop 3; Dl 1	[305]	7536,6	25,2225165	0,252220		
Shop 4; Dl 2	[305]	7263,6	25,2456054	0,252521		
ANOVA	*SS*	*df*	*MS*	*F*	*P-value*	*F-crit*
Source of variation						
Between groups	[812,2361]	653	98,25361	1365,164	1,6E-551	3,542014
Within groups	[502,3623]	4	0,225231			
Total	1435,322	654				

In Table 6, Ht01 is accepted because it shows that there is little or negligible difference between the temperatures in Cinema 2 and Cinema 7,this is excusable with the fact that it's a cinema hall, therefore its requires no windows for lighting and its completely sealed up to insulate sound. Although the excessive warming can be said to have resulted from the choice of building material this is of a high density (concrete)

Table 7. Anova for humidity data of Cinema 2 and Cinema 7

Anova single factor						
SUMMARY						
groups	*count*	*sum*	*mean*	*variance*		
Shop 3; Dl 1	[235]	12105	2,21402	3,224522		
Shop 4; Dl 2	[235]	1322,5	28,10216	1,100252		
ANOVA	*SS*	*df*	*MS*	*F*	*P-value*	*F-crit*
Source of variation						
Between groups	[13242,36]	2	13024,36	4821,13	0	2,210524
Within groups	[12452,354]	406	2,220157			
Total	125,328	407				

In Table 7, Ht02 is accepted because it shows that there is little or negligible difference between the Humidity in Cinema 2 and Cinema 7 and its at minimal range of 60%RH - 70%RH due to the walls being completely sealed up and insulated with no external openings (windows), the Cinemas experience less climatic influence, though the humidity values at specific time intervals are higher in Cinema 2 as compared with Cinema 7.

DISCUSSION

The following design parameters helped the author to evaluate the results obtained from field measurements; these influences are explained in more detail in the following paragraphs:

- Materials of building envelop.
- Thermal mass effect.
- Surrounding vegetation/water bodies.
- Shading or sun control devices.

This study showed that temperature and humidity data graphs, and ANOVA test results were [compatible with each other]. Findings about the effects of design dependent parameters on thermal conditions in the spaces were summarized as below:

Material of building envelop

- High temperature values of +30ºC is as a result of the use of concrete walls (e.g. shop 1, shop 2, shop 3, cinema 2 and cinema 7)
- Low temperature value of 27ºC is as a result of the use of brick walls (e.g. shop 4)

Thermal mass

- High thermal mass in the thick concrete walls and slabs caused stable temperature in the spaces facing East and West directions (e.g. in shop 4).
- Spaces with more thermal mass had higher temperature values. Cinema 2 and 7 for instance, had more interior wall surfaces than those in Shop 1, 2, 3 and 4.
- Thermal mass effect is more obvious in spaces with smaller or no windows (e.g. in Shop 1, Shop 2, Cinema 2 and Cinema 7).

Orientation and glazing size

- Spaces facing East, West or north-east were hotter than those facing south-west (e.g. Shop 4 have higher than that in Shop 1, 2 and 3).
- Large windows caused heat loss at night and also strong temperature fluctuations (e.g. in Shop 4).
- Rooms with no windows gained more heat by day, therefore they were hotter (e.g. Cinema 2 and Cinema 7).
- Size of the south and west facing windows should be smaller to control the amount of sunlight coming in, provided no sun shading or vegetation is to be used (e.g. Shops 1, 2 and 3).

Shading or sun control devices

- High temperature values in the spaces analysed is seen to be with regards the absence of shading devices, thereby leaving the building envelope exposed to direct solar radiation (e.g. shop 1, shop 2, shop 3 and shop 4).

Orientation and size of spaces

- Depending on the orientation of the spaces, average temperatures in spaces changed; those facing North-West orientation were cooler (e.g. Shop 1 and shop 3).
- Spaces facing North-East and South-West directions had almost the same temperature when the size of the one facing west had a larger volume (e.g. Shop 4 and shop).

Effects of surrounding vegetation and water body

- In the absence of trees etc. there was no cooling effect of surrounding vegetation.
- There was a cooling effect of surrounding water body at the buildings entrance (e.g. Shop 4).

CONCLUSION

This study revealed that the effect of thermal mass was almost the same for all the rooms investigated because most part of the building had been constructed with concrete. It was also seen that building materials such as burnt bricks with high thermal storage capacity could improve thermal performance of buildings in Hot-dry climatic conditions if appropriate glazing are provided. Furthermore, other design parameters had an influence on thermal performance of the case study building when the location of spaces and size and type of glazing, open courtyard system, vegetation, open sky atrium and shading or sun control devices are considered.

There are many design approaches to improve building thermal performance, such as, environmental design, climate responsive design, energy efficient design, passive solar design, passive and low energy architecture etc. All these design approaches aim to improve the occupant's thermal comfort and thermal performance of the buildings without using excessive energy. [The results of this research helped to highlight the energy efficient features of the case study building].

CONTRIBUTION TO KNOWLEDGE

The development of mixed-use buildings such as an urban entertainment centre in Nigeria today is regarded as "big ideas" of urban stratosphere. However, since the theoretical framework of this research (i.e effects of design dependent variables on thermal comfort) was expected to be responsible for the "technical details" as well as the Spaces, Forms and Surfaces (i.e. Aesthetics) of the case study building, its incorporation in the design of any facility in a hot dry climate would have contributed to additional knowledge which becomes a big innovations in the following way:

i. Create avenues for designers to acquaint themselves on the importance of incorporating design dependent variables (i.e material of building envelop, thermal mass, size and orientation of windows/glazing, orientation of spaces/building, sun control device or shading, and surrounding vegetation respectively) as objectives for conditioning indoor thermal comfort in hot dry climatic regions of Nigeria with less dependence on mechanical means of cooling as the case is presently.

ii. Expose and increase the competence of future design professionals in line with new design dependent strategies and possible construction techniques in tackling the issue of thermal comfort in hot dry climatic regions of Nigeria.

Hence, with the increasing global awareness of desert encroachment causing severe heat and draught in most hot dry climatic regions in Nigeria, the study revealed that key strategies for enhancing thermal comfort which are applicable to UECs in this regions are with regards the material of building envelop, thermal mass, size and type of glazing, orientation of building, sun control device or shading, and surrounding vegetation respectively.

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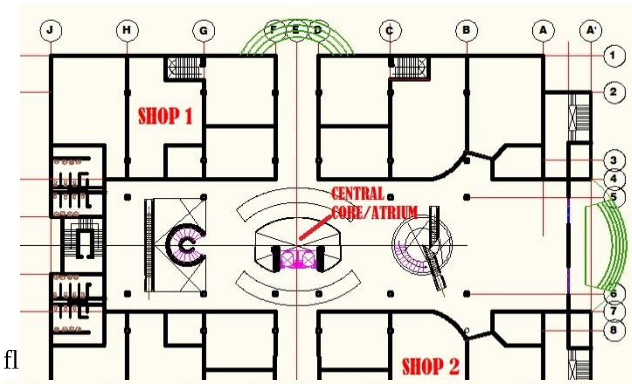

Figure 2. Ground fl ... a Abuja

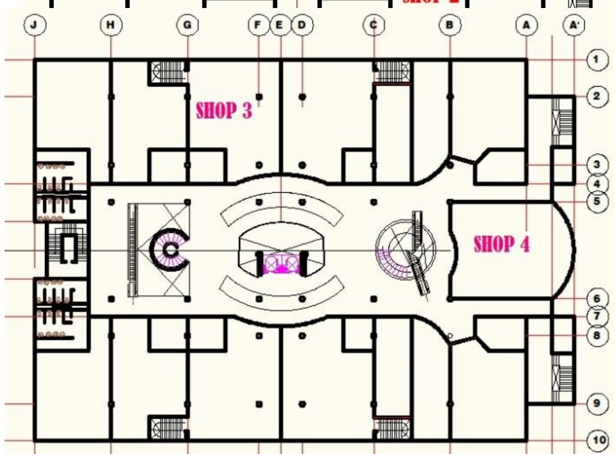

Figure 3. Second floor plan of the case-study building. SILVERBIRD galleria Abuja

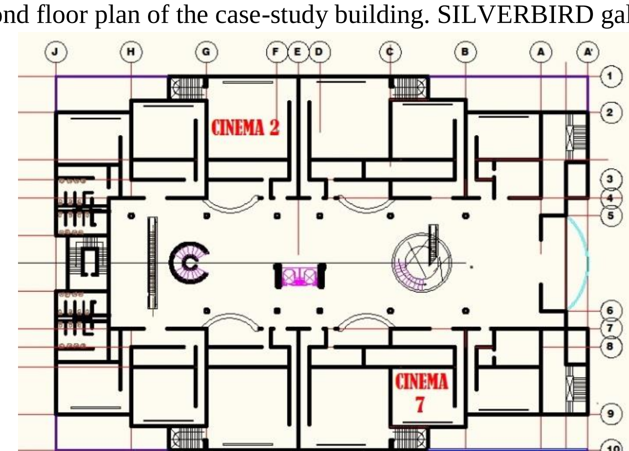

Figure 4. Fourth floor plan of the case-study building. SILVERBIRD galleria Abuja.

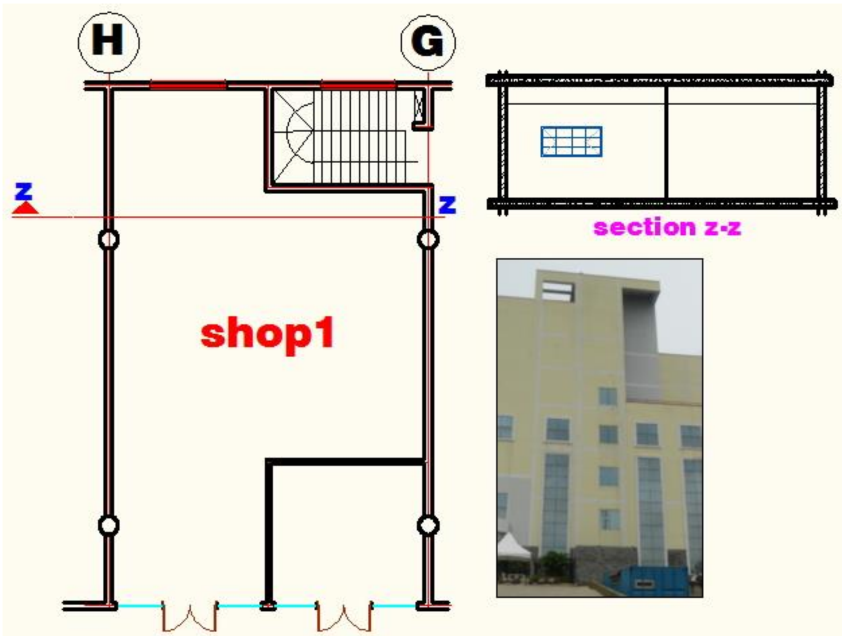

Figure 5. Floor plan, section ZZ and exterior view of Room 1. (Photo by the author.)

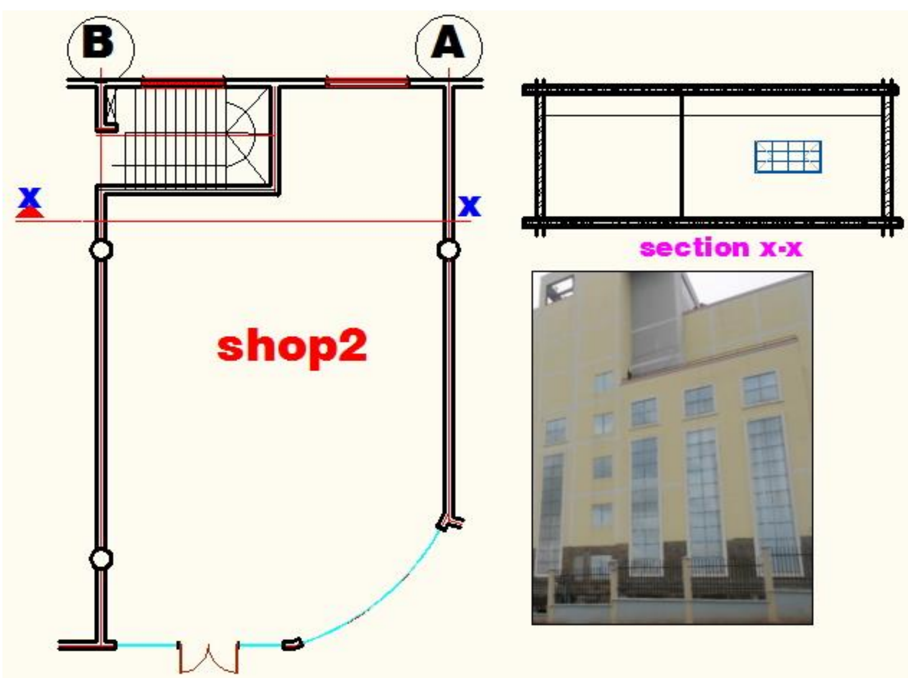

Figure 6. Floor plan, section XX, and exterior view of Room 2. (Photo by the author.)

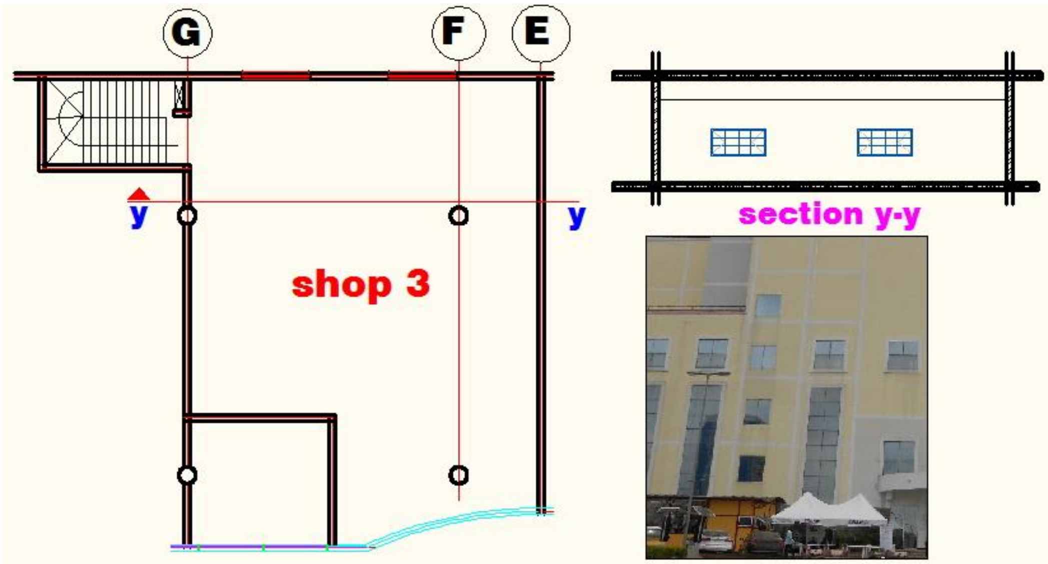

Figure 7. Floor plan, section YY and exterior view of Room 3. (Photo by the author.)

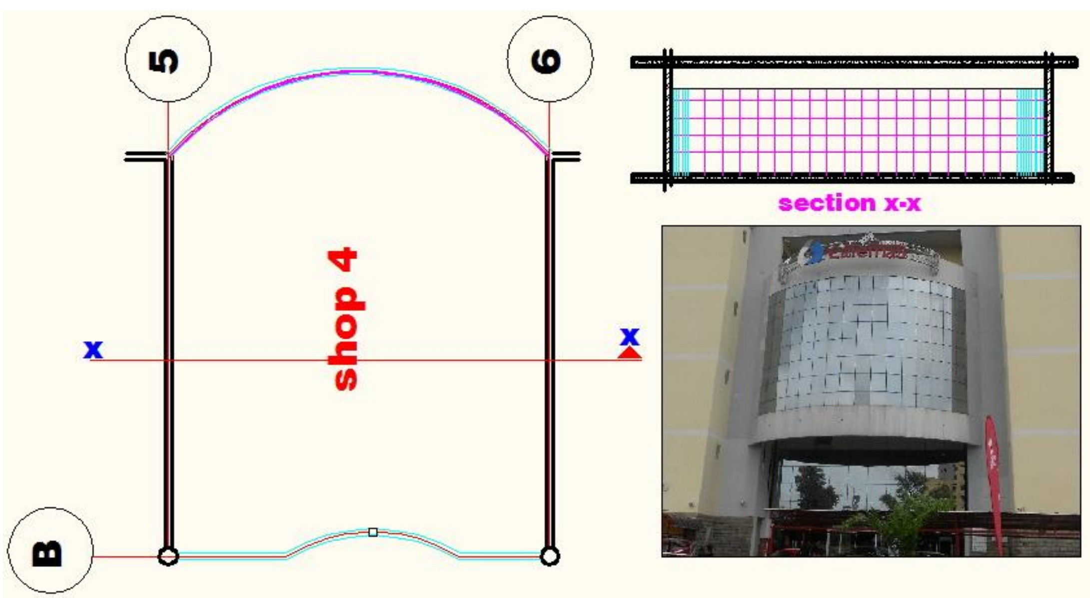

Figure 8. Floor plan, section XX and exterior view of Room 4. (Photo by the author)

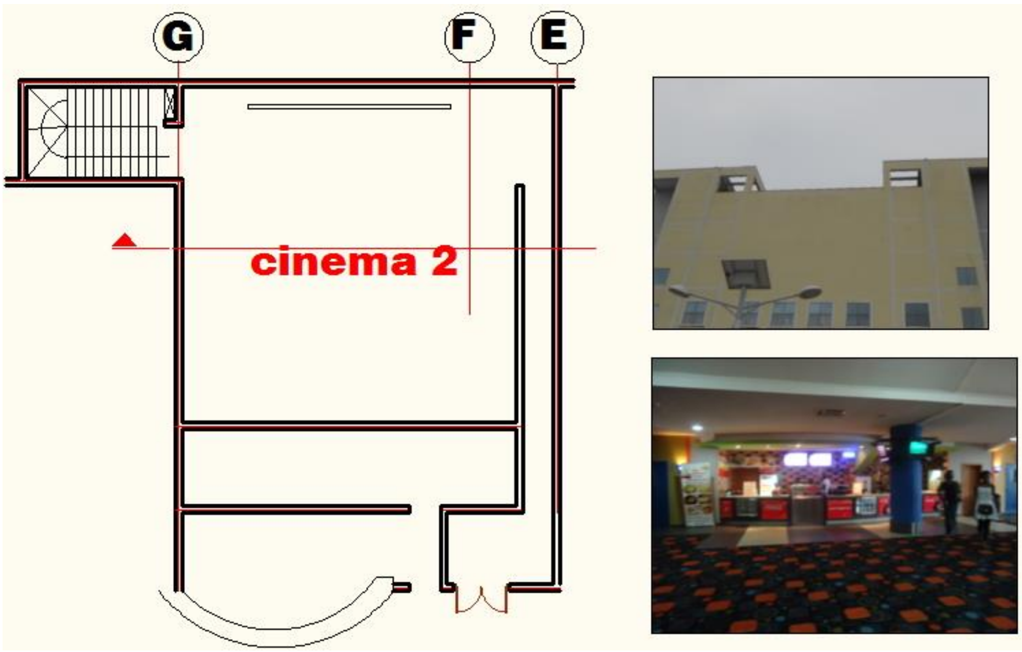

Figure 9. Floor plan and exterior view of Cinema 2. (Photo by the author)

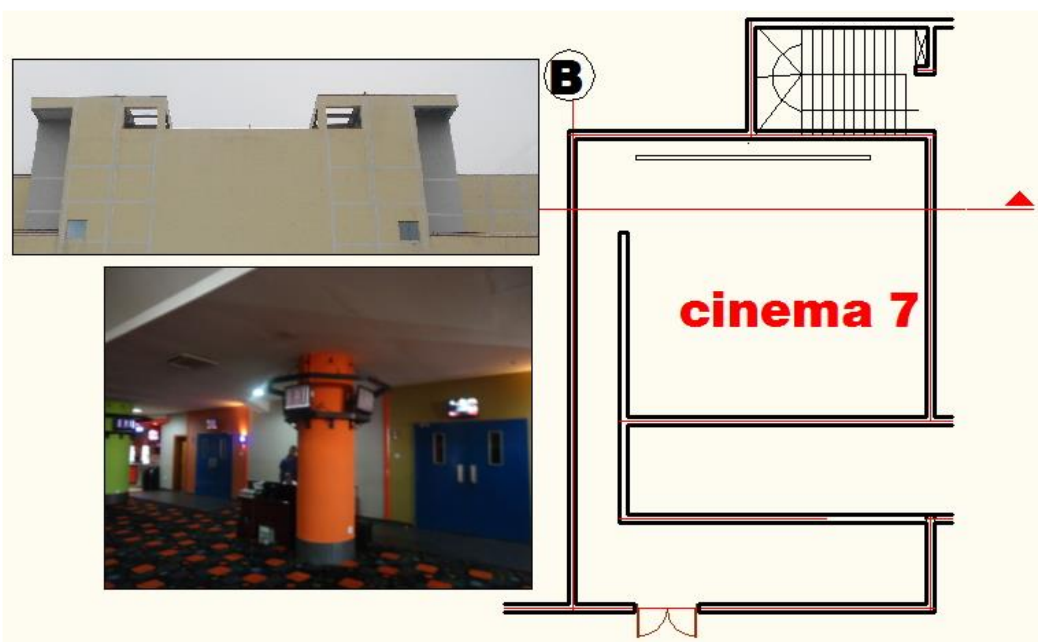

Figure 10. Floor plan and exterior view of Cinema 7. (Photo by the author)

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