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# Assessing the Role of Shading Devices in Improving Visual Comfort on Lecture Theatres in Modibbo Adama University Yola, Nigeria

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**ABSTRACT**

External shading devices can be utilized to block the solar radiation before it reaches the indoorenvironment, and are hence more effective than internal shading devices. However, external shading devices can affect daylighting and natural ventilation performance of the building. Therefore, the research aimed at investigating and proving the importance of external shading devices in institutional buildings and also to determine specific external shading devices relevant for use in Modibbo Adama University, Yola.The research attempted to answer questions such as; to what extents do external shading devices in institutional buildings have effect on visual comfort on users?To what extents do users' needs are met in the institutional buildings for visual comfort?How do problems encountered towards external shading devices in institutional buildings for visual comforts is accessed. For the purpose of answering the research questions a comparative analysis will be done to ascertain the effect of applying therapeutic architecture in the psychiatric hospital Yola. Hence, this research is descriptive and analytical in nature, descriptive because according Kothari (2004) it includes surveys and fact-finding enquiries of different kinds in order to describe the state of affairs as it exists at present where the researcher has no control over the variables; he can only report what has happened or what is happening. However, it is analytical because the researcher has to use facts or information already available, and analyse these to make a critical evaluation of the case under study (Kothari, 2004). Hence, it is non-experimental in approach taking the form of a survey through the use of checklist and field observation facilitated by the use of checklist (Kothari, 2004). According John (2014) Survey research in particular provides a quantitative or numeric description of trends, attitudes or opinion of a population by studying a sample of that population. Fowler (2008) also stated that this type of research includes cross-sectional and longitudinal studies using questionnaires or structured interviews for data collection- with the intent of generalizing from a sample to a population.

**Keywords:** Shading devices, Visual comfort,

## I. INTRODUCTION

Buildings in the world require large amounts of energy for cooling and heating, while the cost of electrical energy is continuously increasing. (Liddament, et al,2000)The amount of energy required for providing comfortable living conditions inside the buildings in a particular region depends on the weather conditions prevalent in that region (Anand, et al., 2013). An architectural element such as a shading device could be an important tool for reducing the energy consumption of a building, especially in hot climates. There are different types of shading devices which improve the energy performance of buildings, such as external shadings (Tzempelikos and Athienitis, 2007) internal shadings (Florides and Kalogirou 2000), overhangs (Lee and Tavil, 2007), venetian blinds (Hans and Binder, 2008) and canopies (Kenneth, et al., 2010) External shading devices, such as eaves, awnings, and verandahs, play a critical role in reducing unwanted solar heat gain, especially in cooling-dominant climates and during summer in temperate climates. Shading devices work firstly by restricting unwanted direct solar radiation through windows, they assist by reducing the direct heating of walls. External shading devices are the most effective way to

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control solar heat gain. Passive heating in heating-dominant (temperate and alpine) climate zones relies on maximizing solar heat gain from north-facing windows in winter. However sufficient shading must exist on the north, east, and west facades to block out unwanted heat in summer (Anand, et al., 2013).

The use of external shades in building façades is known to contribute to a decrease in a building's energy consumption and to improve users' visual comfort. This is achieved by controlling the level of sun radiation and daylighting on a building's exterior walls and within the building's interior. Recent advances in control, design and fabrication tools allow architects and engineers to design and build unprecedentedly complex static and kinetic external shading systems. Parallel to the advances in design tools, numerous integrative models for the simulation and optimization of the influence of external shading devices on the building performance have been developed. However, these models are not currently being employed widely by designers during the design process. This can be explained by the complexity of the simulation models; the lack of time and relevant knowledge on the part of architects; and the fact that these tools often stand alone and are not integrated into the architectural design environment. (Yasha, et al., 2016).The use of daylight inside a building has a strong impact on important visual aspects. Depending on each room's destination, different illuminance levels are required. Using the free sun light can significantly reduce the energy consumption for lighting at the building level. On the other hand, too much uncontrolled daylight can have a negative impact on the worker's ability to concentrate during certain parts of the day, due to the fact that high illuminance levels can lead to screen images (Liu et al., 2017). Thus, different types of devices are used to reduce and control the daylight that enters a room. Daylight systems have the role of redirecting the sun light in order to prevent glare, but as a side effect they can cause the overheating of the interior environment. However, louvers have evolved in time becoming more and more effective. (Zomorodian and Tahsildoost, 2017).

It is important to lower these values energy consumption by using more of the free visual energy coming from the sun and at the same time prevent high values of illuminance levels entering the interior space, if possible, at the window level. (Lavin and Fiorito, 2016). A survey on multiple tall buildings with large glazed façades in Malaysia showed that most of them are not equipped with external shading devices, leading to a non-uniform distribution of daylight and serious glare problems for the occupants. As a response to the problem the tenants of these buildings installed internal blinds and curtains and are using only artificial lighting (Lim and Heng, 2016) According to the European Standard 12464–1, the visual requirements of a room should be accomplished without wasting energy and, at the same time, visual comfort should be achieved regardless of the energy consumption. Studies showed that during the times when the sky is partially cloudy, the reflective louvers do not present results that are better than in the late afternoon, when external light has a lower value, resulting in a drop of the illuminance levels deep inside the room. (Leung and Fuller 2013). Daylight control becomes very important in climates with clear sunny skies, like the regions from the south of Europe. In these areas, users should have the possibility to adjust the slat angle of the blinds for a higher thermal and visual comfort (Gomes et al., 2014). In 2016 Gosh proposed to change the 1m2 glazing of south-facing wall from a double-glazed window to a 30% transparent suspended particle device (SPD) glazing. The results showed the fact that in a room without glazed surfaces the power needed to maintain the daylight factor at 4% is 0.7 kWh, but when using the suspended particle device glazing it is only 0.0048 kWh. (Ghosh et al., 2016).

The transformable shading systems are aesthetically attractive while providing improved insulation across a window or other types of openings due to their modular construction. The design emphasis on various building structures has maintained pressure on the industry to continue creating unique aesthetically attractive coverings for architectural openings.Previous studies revealed that different design methods towards efficient daylighting are one of the most important approaches employed in high performance contemporary buildings (Panopoulos and Papadopoulos, 2017). To maximize the benefit of daylight for individuals, it is necessary that indoor design for daylight harvesting ensures occupants' visual comfort (Garretón, et al., 2015). The natural light reduces the use of energy for artificial lighting, and that visual comfort is typically prioritized by users over concerns about energy efficiency for heating and cooling. Therefore, they will adjust shading devices based on their visual comfort sensation. In this regard, building fenestrations are responsible for daylight availability of indoor spaces, where designing a proper façade can enhance physiological and

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psychological needs. (Banihashemi, et al., 2017: Banihashemi, et al., 2012).

## II. VISUAL COMFORT CRITERIA

There are numerous parameters in human psychology that influence the perception of lighting quality. Such parameters include, amongst others, mood, access to a direct view to the outdoors and the occupants' need for privacy, and cannot be objectively measured Some authors argue that, besides enabling visual comfort, "lighting quality" requirements should also comprise proper conditions for task performance and energy-efficiency considerations. (Boyce and Eklund 1995) There also seems to be a general agreement that the most basic visual comfort requirements relate to levels of illuminance and to how light is distributed in the visual field (Dubois, 2003). This chapter presents a bibliographic review of the main physically measurable parameters that drive visual comfort, based on illuminance and luminance distributions.

Illuminance is the quantity underlying visual comfort requirements that is the most often referred to in lighting literature.According to a research by Pedro Correia da Silva, Vítor Leal, and Marilyne Andersen on the Influence of shading control patterns on the energy assessment of Lecture Hall spaces (2012), For Lecture Hall buildings, the recommendations for the minimum horizontal illuminance at the work plane vary from 200 to 600 lux for typical writing, typing and reading Lecture Hall tasks. For computer based tasks, however, the recommendations range is between 100 and 300 laces, significantly lower than for paper-based work. He also presents recommendations for maximum illuminance levels on the work plane ranging between 1280 and 1800 lux, implying that above those levels glare is likely to occur. In addition, the research indicates recommendations for the ratio between minimum and maximum work plane illuminance, which should be kept higher than 0.7, and ratios between horizontal illuminance of the task immediate surrounding areas and illuminance of the task between 0.2 and 0.8 meaning that illuminance of the task shall be higher than the task surroundings. The type of tasks (computer-based or paper-based) and the source of recommendation (8 different ones) lead to variations for reference work plane illuminance of a factor of 3. Consequently, the considered reference for building design and operation will significantly impact the building energy consumption – directly for the electric lighting and indirectly for the space heating and cooling.

## III. LUMINANCE DISTRIBUTION

The luminance distribution affects task visibility, comfort and perception of brightness of a space. (Rea 2000). According to Pedro Correia da Silva, recommendations that consider the average luminance of the visual field, wall luminance, ceiling luminance and work plane luminance were all found with highly varying recommended ranges. According to these recommendations, walls and work plane would have to have significantly lower luminance than the ceiling. The recommendations for luminance ratios take into consideration the ratios of paper or VDT luminance and surrounding area luminance, with recommended ratios of at most 1:3 between the task and the immediate surrounding area luminance.

## IV. DYNAMIC EXTERNAL SHADING

Dynamic external shading has the potential to improve the performance of the shading device by adjusting its position or dimensions to current light conditions. Numerous such kinetic façade cladding systems have been developed over the last 50 years. (Loonen et al., 2013) presented a review of research, design and development efforts in the field of climate adaptive building shells (CABS). The review, which highlighted the motivations for using CABS and the enabling technologies and characteristic features of CABS, found 44 CABS concepts. The research suggested that this field cannot be considered mature due to the lack of information regarding monitored operational performance and post-occupancy evaluations.

## V. BUILDING ORIENTATION

Studying the sun's behavior and rotation definitely helps in deciding the best orientation for a building on its site and an appropriate building orientation generally offers two climatic functions. The first function is to minimize the amount of sunlight received by the building's façade. The second function is to avoid reflections from the surrounding buildings, like glazed or shiny façades, that can reflect sunlight and glare onto other buildings. Glazed façades have to be protected from direct sunlight during the hottest period of the day. The maximum amount of solar radiation is usually received by horizontal roofs, followed by the south façade east and west façades, while the minimum solar radiation is received by the north façade. So, it is most appropriate to have a large glazed area on the north wall of the building and small openings on the east or west walls to protect the building from undesired sunlight. It has been

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argued that the most significant heat gain occurs between 6:30 h and 10:00 h on the east wall and between 14:00 h and 17:30 h on the west wall when the sun is lower in the sky. The east and west windows are the sources of the greatest solar gains and should therefore either be eliminated or reduced in size. It is also advisable to place unconditioned spaces (garages, closets and other buffer spaces) on the east and west sides. Efficient building orientation should maximize solar exposure in winter (the heating season) and minimize it in summer (the cooling season). Most of the summer heat gain occurs through the east, west, south-east and south-west orientations. Several studies have noted that, in summer, south facing windows are less exposed to solar radiation due to the high angle of the sun.

## VI. SHADING BY NEIGHBOURING BUILDINGS

The design of the site layout can be very effective in shading the building through the distance between the building and the building's height so they are spaced to shade each other. The efficiency of the shade depends on the type of building group or cluster. Bansal (1994) classified such clusters into three basic types: pavilions, streets and courts.Pavilions are lone buildings, erected singly or in groups; these are surrounded by large open spaces. In street formations, buildings are arranged as blocks in parallel rows separated by the streets themselves while courts are open spaces surrounded by buildings on all sides. To compare the performance of these types of building cluster, it is necessary to refer to building volume and floor area.

## VII. SHADING BY TREES AND VEGETATION

In hot climates, vegetation can be used to shade the buildings. The strategic location of trees can be very effective in shading and therefore saving energy. Low trees or shrubs are suitable when the sun is at a low angle in the morning and evening as they will then cast long shadows against the façades. The only limitation in gaining shade by using vegetation is that this is only suitable for use with low buildings due to their physical height and the amount of shade they cast. Shade from vegetation is not suitable for high-rise buildings although some architects use vegetation and trees on balconies, in open courts, on terraces, plant boxes and windows of some high-rise buildings to act as shading elements for Lecture Hall spaces. The method of achieving shading and cooling by using vegetation can be effective because the trees' leaves absorb solar radiation for photosynthesis and achieve heat loss by evaporation. Usually, east and west oriented windows and walls receive about 50% more sunshine than north and south oriented windows. The best location for trees for shading is next to those windows that admit the most sunshine during peak hours so trees should be planted in positions determined by lines drawn from the centres of windows on the west and east façades toward the position of the sun at the selected hour and date.

## VIII. SHADING DESIGN TOOLS

A number of methods exist for evaluating the performance of shading devices. One method is to determine the solar penetration through a fenestration by using solar geometry and the position of the sun through solar altitude and azimuth angle equations (Olgyay & Olgyay, 1957).

### i. The efficiency of shading devices

Solar shading has many important impacts on a building's energy consumption, the comfort of occupants, and the view out. Shading is also important in the reduction of overheating and glare from the window. Usually, all shading devices will reduce heat gain to some extent but external shading is nearly always better than internal shading. External shading, like overhangs, fixed external shading louvers, and also moveable shading, can be appropriate for many buildings. During the time of peak solar gain, such shading can cut down cooling loads and overheating while the interface of solar radiation by the building is the source of maximum heat gain inside the space. (Little fair, 1999).

The natural way to cool a building, therefore, is to minimize the incident solar heat. This can be achieved efficiently by proper orientation of the building, an appropriate layout with respect to other buildings, and by using proper shading devices to help control the incident solar radiation on a building. Efficient shading systems can save up to 10% - 20% of the energy used for cooling the building. Properly designed roof overhangs can provide adequate sun protection, especially for south facing surfaces, while vertical shading devices, such as trees, trellises, shutters, shading screens, awnings and exterior roll blinds, are also effective. These options are recommended for east-facing and west-facing windows and walls. (Hassan Fathy, 1988) illustrated that shading devices could contribute to reducing the solar heat gain on buildings by a third. If the ambient temperatures are higher than the room temperature, heat enters the building by convection due to undesirable ventilation; this needs to be reduced to the minimum possible level. Adequate wind shelter and the sealing of windows reduces the infiltration of the air and this requires proper planning and landscaping. An evaluation of the expected performance of a designed shading device and its geometrical characteristics, subsequent to actual construction, is essential for the satisfactory thermal performance of a building.

Shading devices can be designed if the position of the sun relative to the building face is known. Allowing privacy is another function of shading devices as adjustable shading devices, such as curtains and movable blinds, allow the occupants to have the degree of privacy they want at any time. Windows are architectural elements that can be very effective in terms of energy performance in the building when shading systems are used with them. High energy performance of windows can be achieved by using external shading devices which can be considered as a part of the window system itself or as part of the wall or roof systems. Moreover, roof overhangs, louvered sunscreens, blinds or awnings can effectively accomplish efficient shading. Such shading devices can offer secondary energy settlement in addition to their primary function. For example, an external sun screen (fixed or movable), in addition to providing shade in summer, can reduce the heat transfer coefficient at the external surface of the window glass. Consequently, there will be less exposure to wind speed and sky conditions, and reduced winter heat losses. The principal advantage of external shades of all types is that the solar heat absorbed by them dissipates in the open air.

Interior shading devices, like curtains, Venetian blinds or fabric blinds have some advantages over external devices. These interior devices are protected from the weather and are easy to control and maintain. Interior devices reduce heat gain and heat loss through windows and they can shield the occupants of the space from radiant solar heat. However, they are generally less effective than exterior shading devices in minimizing solar heat gains because the amount of heat they absorb is released into the room. The shading device has to trap the air between itself and the window to reduce the heat loss effectively if the insulation value is to be at a maximum. Devices should be installed properly to provide a sealed enclosure. Materials should also be selected with properefficient solar properties so interior devices can improve the energy performance of a window.

In hot humid climates where airflow is desirable, internal devices can seriously impede ventilation. In this case, opaque or translucent blinds could be considered as a means to increase the ventilation rate. Furthermore, in composite climatic conditions, such devices block the undesirable solar radiation very effectively during the summer. Although lightcoloured blinds are preferable, dark-coloured blinds absorb solar radiation and transmit it into the room in the form of long wave heat radiation. Overhangs on south oriented windows provide efficient shading from the high sun altitude. Even an extended roof, shading the entire north or south wall, will give effective protection from the noon sun. (Richard, 2000).

**ii. Natural lighting**

Throughout the history of architecture, natural light has been considered as the main source of light and so, through studying the availability of natural light, builders and architects have built their dwellings with an appropriate response to this factor. (Al-Shareef, 1996) observed that windows and openings in regions with high levels of availability of natural lighting should be medium in size and fitted with grilles and translucent or tinted glass for protection against undesired solar radiation. Al-Shareef also mentioned that the availability of natural light in a climatic region depends mainly on the amount of solar radiation available in that zone. Moreover, the rotation of the earth about its axis and its revolution about the sun affect natural light availability. Due to the extremely high temperatures, the massive availability of natural light, and the intensive solar radiation in Saudi Arabia, traditional houses, especially in the western region (Hidjaz), are constructed with Rowshans (wooden windows to filter the solar radiation). This traditional element allows a reasonable amount of daylight to penetrate inside the space. Other strategies to use natural lighting, such as sky light domes, can be found in the traditional houses of Jeddah like those found in Bit Nasef, one of the largest traditional houses in old Jeddah. Some these skylight domes are made of coloured glass to add an aesthetic element to the house. Maghrabi (2000) noted that Khan 1986, indicated that the use of Rowshans reflected the elegance of the house owner.

**iv. Glazing**

In a recent study by Al-Saffar to evaluate passive cooling strategies in greening existing residential buildings in the Kingdome of Bahrain as a case study of a hot arid area, it has been shown that most heat gain or losses come from windows and openings in buildings. Therefore, the use of doubleglazed windows achieved dramatic changes in energy reduction in the indoor environment. Moreover, single glazing is less efficient than double glazing having 12 mm cavity containing Argon gas for better insulation. (May Al-Saffar. (2015)

Although many passive cooling techniques have been proposed in literature, it has been demonstrated that solar shading of buildings especially in developing countries is of great interest due to their efficiency, easy implementation and low cost (Furlan, R., & Sipe, N. 2017). In hot arid areas in rural India and developing countries in the Middle East region, masonry houses roof tend to make the indoor temperature very high around 41°C due to high roof top temperature of around 65°C in these regions. Solar shading with locally available materials like terracotta tiles, hay, inverted earthen pots, date palm branches etc. can reduce this temperature significantly. Another easy cheap method for solar shading is the use of trees which reduces ambient temperature near outer wall by 2oC to 2.5oC. In addition, the design of effective shading devices such as the overhangs, louvers and awnings is very effective at shading south-facing windows in the summer when sun angles are high.

### 2.3.4 Shading devices

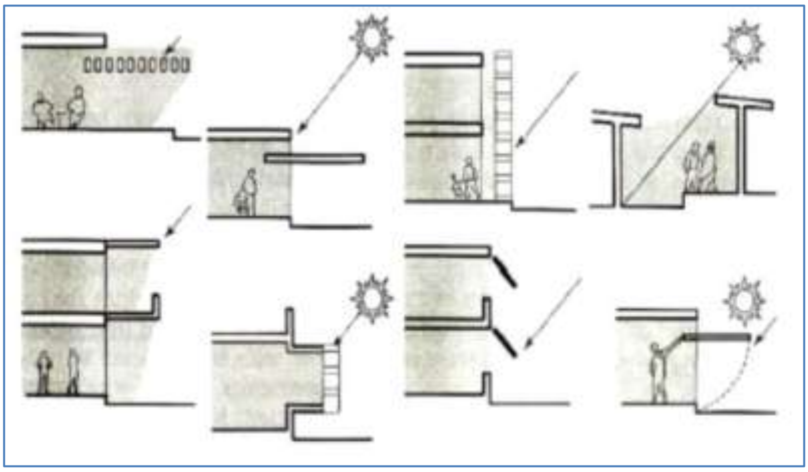

Figure 1 different types of shading devices

**v.Shading by Use of Overhangs, Louvers and Awning Etc.**

Shading device and sun control devices that are perfectly designed to integrate either as part of the building or separately placed from a building façade; can decrease heat gain in the building, its cooling demand as well as enhance the quality of natural lighting in the interiors of the building. Solar orientation of a particular building façade affects the design and type of shading device to be integrated for effective shading.

## IX. RESULT AND DISCUSSION

Fowler (2008) also stated that this type of research includes cross-sectional and longitudinal studies using questionnaires or structured interviews for data collection- with the intent of generalizing from a sample to a population. The results discussed showed that the adoption of the selected shading solutions can significantly reduce the energy needs for space cooling in summer, both in the entrance hall and in the Lecture Hall. Moreover, they allow reducing overheating in case the air conditioning system is not used, thus improving indoor thermal comfort.However, a possible side effect of the shading devices is an excessive reduction in the daylight availability. This can occur especially if the shading device has a too low visible transmittance, or when the occupants cannot lift it in the event of cloudy sky conditions. This might be the case of the solar control film.Still looking at the Lecture Hall, it is also interesting to observe that the maximum illuminance value close to the glazed surface keeps below 2000 lux, which suggests the absence of glare. Of course, further analyses should be conducted to evaluate glare occurrence in terms of luminance.

As concerns the entrance hall, higher illuminance values are observed, thanks to the presence of a glazed surface on two sides of the room: in this case, the minimum illuminance is

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around 1000 lux, and the Uniformity Ratio ranges between 0.76 and 0.79. Hence, the hall is very well daylit, which enhances its fruition and provides a sense of connexion to the outdoors. Moreover, once again glare is not likely to occur, since the maximum illuminance keeps slightly below 2000 lux. On the contrary, internal light venetian blinds do not seem as effective as the other shading devices. Indeed, the illuminance on about half the working plane keeps above 2000 lux, both in the Lecture Hall and in the hall. Furthermore, the Uniformity Ratio decreases, and in the Lecture Hall it now gets slightly lowers than 0.4. These results suggest that internal venetian blinds, even when shut, provide a non-uniform daylight distribution within the Lecture Halls, with highly likely risk of glare in the half of the room closer to the glazed façade.

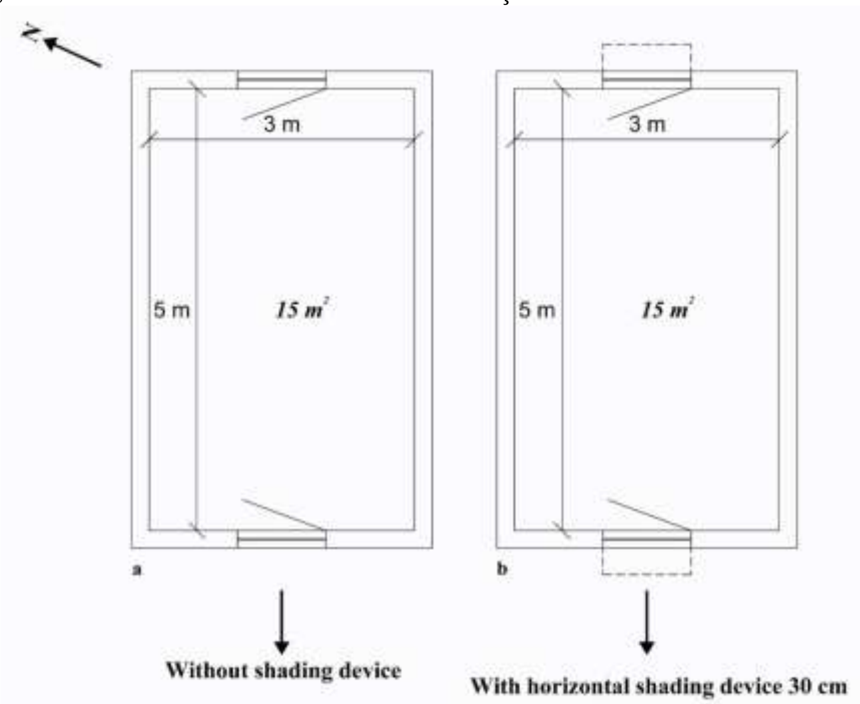


Figure 4.1: thermal sensation scale of naturally ventilated institutional building.

Table 4.6: Facade Detail at Modibbo Adama University Yola LT1 and LT2, LT 3 and LT and 4 LT 5 and LT6 BuildingCurtain wall system

| | |
|---|---|
| Type Shading Device Used (V or H) | Horizontal |
| Thickness of Shading Device | 9inches |
| Orientation of the Device | South Façade |
| Material of Shading Device | Steel rods |
| Inclination | 0 degree |
| Geometry | Rectangle terracotta blades |

The shading assembly's horizontal terracotta louvers are distributed in a non-repeating pattern, creating interplay between the blades and the negative spaces between them.

Table 4.7 Modibbo Adama University Yola LT1 and LT2, LT 3 and LT and 4 LT Detail

| | |
|---|---|
| Floor Area | 62,000 sqft. |
| Average Ceiling Height | 14 ft |
| Space Usage | Classrooms and Lecture Hall |

Table 4.8 Modibbo Adama University Yola LT1 and LT2, LT 3 and LT and 4 LT Gallery Shading Detail
Façade Features

Curtain wall system

| | |
|---|---|
| Window Height | 8ft. operable |
| Type Shading Device Used (V or H) | Horizontal |
| Thickness of Shading Device | 5” |
| Orientation of the Device | South, East |
| Material of Shading Device | Cedar wood |
| Inclination | 15̊ |

## X. SUMMARY AND CONCLUSION

The results discussed show that the adoption of suitable shading devices in highly-glazed Lecture Hall buildings is of the uttermost importance, as it allows to significantly reduce the energy needs for space cooling and to improve thermal comfort while limiting indoor overheating. Moreover, the indoor daylight illuminance keeps suitable levels to allow visual tasks; illuminance distribution is improved and glare risk is considerably reduced.However, not all the shading devices show the same effectiveness. First, internal blinds should be avoided, since their benefit in terms of comfort is much lower than for external blinds. Then, the results suggest that outer solar control films perform well on all the orientations; on the other hand, external (roller) blinds are very effective on south-facing glazed façades, whereas their performance is worse than solar control films in west-facing glazed façades.

This inquiry has been concluded to these days the subject of thermal and visual comfort for buildings has great value to investigate according to international standards such as heating, cooling, lighting and so on.Four basic factors which influence human thermal environmentally are radiation temperature, air temperature, air movement and humidity. As already it is mentioned, the more natural sources are used, the more cooling and heading will be cheaper and more efficient.Lately architects have paid too much consideration on the association between both architecture and climate to deliver inhabitants' comfortable situation. By accomplishment of several stratagems like Lecture Hall coordination, wind in hot and humid climates can be appealed.In any case, it is not easy to draw general conclusions. Such analyses must not disregard the difference between indoor air temperature and operative temperature, the latter being considerably higher than the former, due to the indoor surface heating induced by the large incoming direct solar radiation. Control logics for space cooling systems should account for this issue, and should not simply operate on fixed set-points on the indoor air temperature.

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