

ASSESSMENT OF ASPECT RATIO AND CONFIGURATION EFFECTS IN CORPORATE OFFICE BUILDINGS COURTYARD, IN ABUJA, NIGERIA

Ofiedane J.M and Eze J. C

Department of Architecture, Federal University of Technology Minna

Abstract

The courtyard is known as a micro-climate modifier and has been used in many houses over centuries in several countries. The corporate office which incorporates many administrative functions, consumes lots of energy due to lighting and cooling, as thus measures of self-sustainability should be integrated. The aim of this research is to identify aspect ratio and configuration effect as it affect airflow, shading and thermal mass of the building in-order to promote natural lighting and ventilation in the building. The scope of the research covers government secretariat buildings situated in Abuja municipal area council (AMAC), Abuja. Descriptive research approach was utilised in carrying out the research using observation method, data was collected by means of observation schedule from field work. Stratified random sampling technique was used to study office buildings in Abuja, the primary data obtained was analysed using SPSS software, version 19 and bar charts were used to show the results. The result revealed that, 75% of the 8 sample size assessed, had aspect ratio moderate and above, 75% made use of the semi- enclosed courtyard. 25% of the buildings had aspect ratio to be low. 25% of the courtyard configuration were fully enclosed. It is therefore recommended that, Courtyard should be designed with high aspect ratio in consideration especially in office buildings, to reduce cost of artificial lighting. The semi- enclosed courtyard configuration should be continually encouraged, as this has been identified by many researchers to be the most effective.

Keywords: *Aspect Ratio, Courtyard, Configuration, Energy, Office*

8INTRODUCTION

According to Younis (2016), Courtyard should be introduced into office buildings in tropical climate regions, in order to provide indoor thermal comfort and a cut in energy consumption. The courtyard is defined as an open space within a housing unit without roof , it can also be an open space as a result of arrangement of individual building units to form an open space within the compound (Eze, 2018). The corporate office building is the main base of operation of an organization, clerical duties are majorly carried out in these buildings. The aim of this research is to identify aspect ratio and configuration effect as it affect airflow, shading and thermal mass of the building in-order to promote natural lighting and ventilation in the building. Heat gained by buildings should be minimised, this is an important concept in building design, as this has great implications on both the economy and cost of operating such buildings. Many authors have demonstrated that the air temperature within the courtyard is usually lower than the air temperature at the inside of the building, thus the courtyard serve as heat exchange point between itself and servant spaces thereby providing cooling in the building (Rajapaksha and Hyde, 2005).

The significance of the paper reflects the possible comfort conditions that can be achieved through the use of courtyard in office building. The positive implication it will have on the health of users of such building, besides lowering down on the cost of operating such buildings thereby helping to improve the power supply capacity of the country. The research would be a yardstick guide for safety and effectiveness within the office space while promoting courtyard

Correspondence Mail: Jonathanofiedane@gmail.com

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usage, even as temperature within the country keep increasing and rainfall keep decreasing due to climate changes as a result of ozone layer depletion.

Scope and Study Area

The scope of the paper would cover some selected government secretariat office buildings in Abuja municipal area council (AMAC) Abuja, which use courtyard or atrium in the building, to save time and cost while carrying out the research. The choice of AMAC is because, the bulk of corporate office buildings are situated in this region, with only a pocket of offices outside this region. Abuja has six area council: Abaji, Abuja municipal (AMAC), Gwagwalada, Kuje, Bwari and Kwali area council. Of the six area council, Abuja municipal area council (AMAC), is the largest, most developed and constitutes of the bulk of the built area in the FCT. AMAC is situated between Latitude 8°40' and 9°20' north of the equator and longitude 6°40' and 7°40' east of the Greenwich meridian. It constitutes of six main districts, namely Asokoro, Maitama, Garki, Central area , Utako and Wuse with some developing districts such as Apo, Gaduwa, Gudu, Lokugoma, Kaura, Durumi, Katampe, Gwarinpa, Guzape and Kado

THEORETICAL FRAMEWORK

Design Considerations for Courtyard

According to Almhafdy, Ibrahim, Ahmed and Josmin, (2013) and Bulus (2016) in every study of courtyard the following are variants that are constants: functions, configuration, orientation, wall enclosure and natural elements within the courtyard. Courtyard functions in various ways, which ranges from being used as a meeting place, gardening, cooking, working, playing, and sleeping to keeping of animals. Invariable this various functions can be categorised as, social, leisure and micro-climate (Edwards, 2006). In order for the courtyard to receive sufficient sunshine, the aspect ratio (AR) must be put into consideration and it is defined as the degree of openness to the sky (Sthapak and Abir, 2014). Therefore the greater the aspect ratio the more exposed the courtyard will be to the sky and can be calculated using the formula:

$$\text{Aspect ratio} = \frac{\text{Width of the courtyard floor}}{\text{Average height of the surrounding wall}}$$

Therefore in the instance in which more sunlight is required into the building, the courtyard is wide and shallow (high aspect ratio) but when less sunlight is required, it should be made narrow and deep (low aspect ratio) in order to serve as a sunlight protector. Aspect ratio when moderate is 1 but should be greater than 1, in-order to optimise its thermal cooling effects (Rodriguez, Tablada, Mabel, Guillermo, and Andreas, 2018). It is worthy of note that, courtyard configuration could be fully enclosed, semi enclosed, and semi open. The courtyard create micro-climatic conditions particularly when some variables are taken into consideration such as the orientation, volume and ventilation. A study was carried-out on polygonal courtyard forms (non-typical form) and it's shading performance to develop a shading calculation tool for courtyards (Ahmed and Mohamed, 2006).

The study concluded that courtyard geometry and proportions have a significant influence on the shading produced on the internal surface. The orientation of courtyard usually depends on the building layout and it affects the ventilation effect or wind speed. It has been argued that the right orientation of a courtyard can improve thermal comfort within the building, as the building should be oriented with respect of solar angles and wind direction (Antonio and carvalho, 2015). There is a general believe that courtyard orientation should be such that the elongated side is best to face north south direction (Bulus, 2016). It has been discovered that increased height of courtyard walls will cause reduction in the degree of air temperature in the

courtyard as well as the rooms in the nearby location to the courtyard. The design variants of courtyard wall enclosure include, its shape, size and details of the enclosing wall of the courtyard. Courtyard wall enclosure components such as walls, doors and windows need to be considered during the design stage. Wall enclosure can play a very important role in the micro-climate conditions of the courtyard through natural ventilation techniques. Placing natural elements in a courtyard produce some environmental benefits, as plants such as: trees, shrubs and flower within a courtyard can significantly affect the thermal comfort as they provide shade and oxygen in the courtyard (Almhafdy, *et al.*, 2013). It has been found that water body (pool) and water spray within the courtyard produces some thermal effect, the courtyard with pool, tent and water spray during sunny hours provided significant cooling effect within the internal surroundings of the courtyard.

Outdoor spaces in office building

According to a study, the courtyard acts as an interaction point for users of the building. It encourage them to act as a group, promotes visual privacy when the court is visually secluded by screening or walled entrances. It serves as a relaxation spot especially when the climate is conducive to out-door activity and it promotes acoustical privacy, enclosure elements work as a noise barrier between the courthouse and the outside area (Sthapak and Abir, 2014).

The courtyard can play a role in promotion of sound health, simply by the architect adding courtyard features such as shade, water, trees and flowers, wind tower, pavement and colours which could all provide a positive effect towards the five senses of the human body (Rust, 2010). The courtyard is generally referred to as a microclimate changer due to its ability to reduce high temperatures, channel breezes and adjust the degree of humidity.

The courtyard can bring about some environmental benefits if the space and the surrounding servant spaces maintain favourable environmental conditions for thermal comfort. The airflow, thermal mass and passive solar all regulate heat transfer between the courtyard, its adjacent servant spaces and the out-door environment. In the tropics, the courtyard can be exposed to overheat and transfer solar heat to adjacent occupied servant spaces, in order to avoid this issue, airflow effect, shading and thermal mass must be promoted (Rajapaksha and Hyde, 2005).

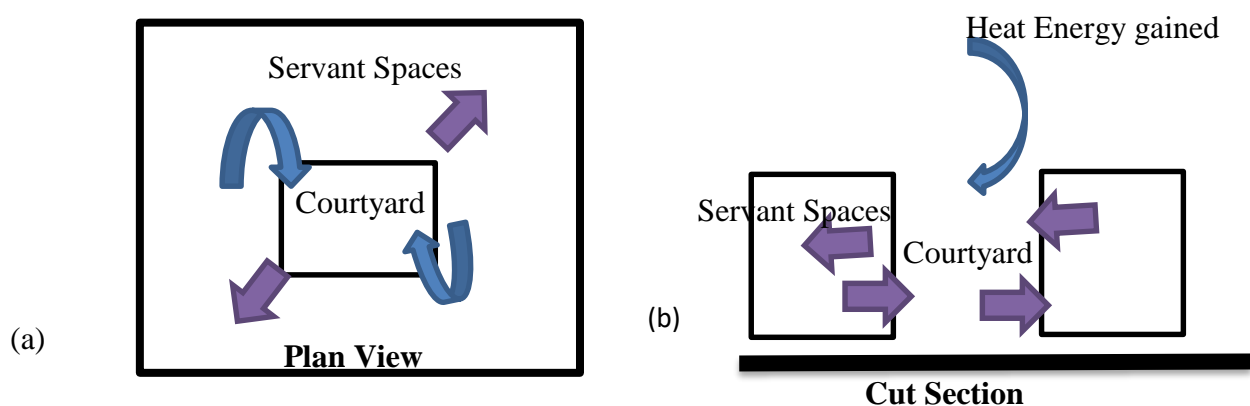


Figure 2.5: Heat transfer in a typical fully enclosed courtyard building
Source: Researcher 2018

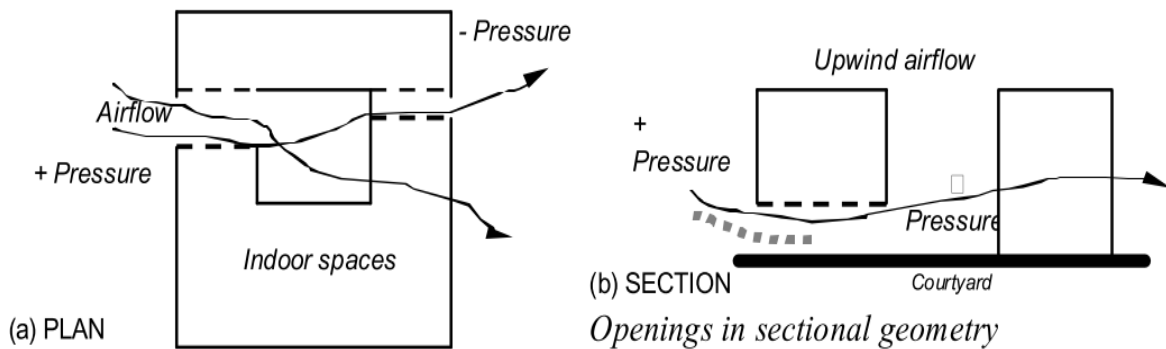


Figure 2.6: Semi enclosed courtyard acting as an air funnel, wind permeability of plan
Source: (Rajapaksha and Hyde, 2005)

Airflow is the major effect which dictates the thermal environment inside the courtyard as shown in figure 2.5 and 2.6, this effect is what causes comfort cooling for occupants, structural cooling, controlling of excess heat and the removal of heat from interior spaces. Airflow effect is caused due to wind pressure effect or stack effect which can be regulated either by wind permeability of the geometry or wind permeability of the enclosure as shown in figure 2.6. It is worthy of note that air flow effect is much more felt in a semi enclosed courtyard, such courtyard promotes cross ventilation through the courtyard and attached servant spaces. The wind that moves across the building increases the pressure fields around the building, creating high pressure zones at the openings in the enclosed envelop.

METHODOLOGY

Data was collected from field exercise using observation schedule as also used by Almhafdy, et al., (2013) and Bulus (2016) to carry out similar research. The data was then analysed using IBM statistical package for social science software (SPSS). The descriptive analysis from SPSS were interpreted using Microsoft excel spread sheet program by generating charts and distribution frequencies. Descriptive method was adopted by this research, Stratified random sampling technique was used to sample data, and a total of eight (8) buildings out of 20 were studied. Four sample each, from two unit subset of government system representing federal and state level secretariat. This represented 40% of sample size of 20 from a population of 21 buildings as obtained from 1970 Morgan's table of determining sample size from a given population.

Result and Discussion

Table 1: Variable Measurement for Aspect Ratio in Eight Selected Government Secretariat Buildings in Abuja, Nigeria

S/N	Building	High	Moderate	Low	Aspect Ratio
1	Federal Ministry of Environment	0	0	1	0.84
2	Federal Ministry of Agriculture	0	1	0	1.14
3	Head of service of the federation	0	1	0	1.25
4	Department of education	1	0	0	3.24
5	Abuja municipal area council	0	1	0	1.33
6	Abuja metropolitan management council (AMMC)	0	0	1	0.43
7	Abuja geographic information system (AGIS)	1	0	0	5.81
8	Ministry of works power and housing	1	0	0	3.41

S/N	Building	High	Moderate	Low	Aspect Ratio
	Total number of buildings	3	3	2	8
	Total percentage of buildings	37.5%	37.5%	25%	

Scale factor: yes =1, No= 0

Source: Field Work, 2018

As observed in table 1, 37.5% of the courtyard has aspect ratio to be high, 37.5% has it to be moderate while 25% of the courtyard aspect ratio was low. Aspect ratio less than 1 is considered low, aspect ratio in the range of 1 is considered moderate whereas aspect ratio above 1 is considered high as stated by Rodriguez, et al., (2018). Courtyard with high aspect ratio allowed greater permeability of sunlight, with less shading and good air flow. Courtyard that were observed low had low sunshine permeability with shading in portions of the courtyard.

Table 2: Variable Measurement for Courtyard Configuration

S/N	Building	Fully enclosed	Semi enclosed	Semi open
1	Federal Ministry of Environment	0	1	0
2	Federal Ministry of Agriculture	0	1	0
3	Head of service of the federation	1	1	0
4	Department of education	0	1	0
5	Abuja municipal area council	0	1	0
6	Abuja metropolitan management council	1	0	0
7	Abuja geographic information system	0	0	1
8	Ministry of works power and housing	0	1	0
	Total number of buildings	2	6	1
	Total percentage of buildings	25%	75%	12.5%

Scale factor: yes =1, No= 0

Source: Field Work, 2018

Assessment of table 2, was based on observation of the various configuration type utilised. The fully enclosed courtyard is completely rectangular or square in shape, the semi enclosed courtyard is U-shape or semi rectangular whereas the semi open configuration is L-shaped

Courtyard Configuration

It is an established fact by researchers that the best form of courtyard configuration is the semi-enclosed courtyard due to reasons stated in the framework of study. It was observed that 75% of the buildings surveyed made use of the semi- enclosed courtyard as shown in figure 1, in these courtyard good air pressure was observed, but some of the buildings had poor internal partitioning.

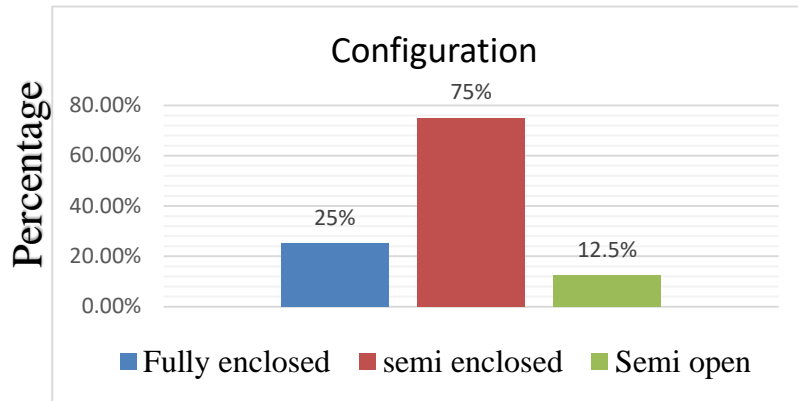


Figure 1: Shows the most dominating of the configuration
Source: Field Work, 2018

Courtyard Aspect Ratio

Aspect ratio can be defined as the degree of exposure of the courtyard to sunlight. From the data set in figure 2, it is observed that the courtyard luminous light varies, from low to high. The highly luminous courtyard is most effective for lighting purpose, one cardinal need of office buildings is lighting. Poor lighting is the resultant effect of artificial lighting which sustainability seeks to address.

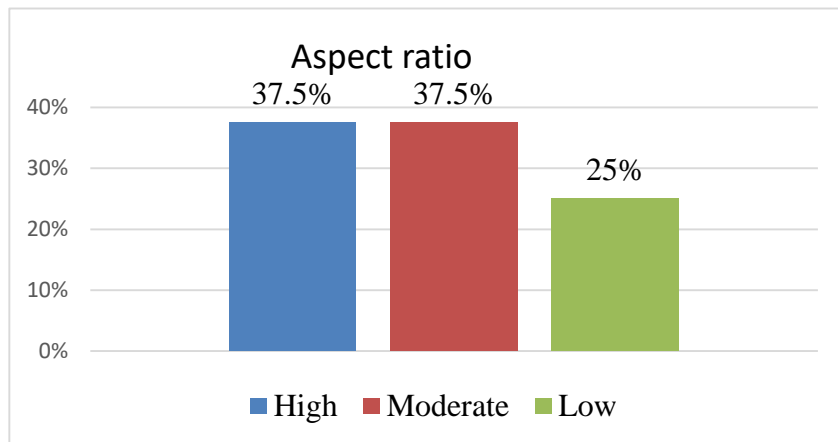


Figure 2: Shows the most dominating of the aspect ratio
Source: Field Work, 2018

CONCLUSION

This paper basically assesses the aspect ratio and configuration effect of office buildings in AMAC region of Abuja, Nigeria. From the findings in this paper, high aspect ratio is not given due consideration in office buildings, this could be due to the scarcity of land in the location. Low aspect ratio is one of the cardinal reasons behind courtyard shading. The semi- enclosed courtyard is the most dominating of the courtyard configuration types that was surveyed, this allows for good air flow which aid cross ventilation when there is proper positioning of openings in the building. Some of the buildings were observed not to be well partitioned internally. Even when aspect ratio was discovered to be high in this places, lighting conditions was still poor internally due to one directional lighting source.

This study clearly explains in details how adequate lighting and cross ventilation can best be achieved through courtyard system in corporate office building. The study creates awareness of courtyard shading due to inadequate aspect ratio and poor air flow condition due to the use of wrong courtyard configuration. As much as courtyard are spaces in buildings with opening to the sky, without due consideration for aspect ratio and configuration type, the efficiency of the courtyard will be under-achieved

RECOMMENDATION

1. Courtyard should be designed with high aspect ratio in consideration especially in office buildings, to reduce cost of artificial lighting. Greenery, in form of trees, shrubs and grasses should constitute the courtyard to compensate for over-exposure.
2. The semi- enclosed courtyard configuration should be continually encouraged, as this has been identified by many researchers to be the most effective. This promote good air pressure difference in the courtyard.
3. Government should enact policies that will mandate courtyard placement and effectiveness within the office space, to serve for natural ventilation and lighting

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