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A Review on Courtyard Design Criteria in Different Climatic Zones

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Abstract

The application of courtyard in a building design can contribute meaningfully towards achieving a passive building with high energy efficiency, only when its design criteria are not ignored. It is on this note that this study examined the design criteria for courtyard in different climatic zones. The courtyard design criteria with respect to form and its effects on wind movement and lighting in different climatic zones is investigated based on literature review. Journals, Conference Papers and Books were used to generate information. The study showed that, courtyard buildings have almost the same design criteria in all the climatic zones but the appropriate form, dimensions and proportions are dependent on the climatic characteristics of each zone. These criteria include: form, size, area, orientation, shading devices, vegetation, ground ratio, the courtyard aspect ratio, shape factor, perimeter ratio and water pond. The appropriate application of the courtyard proportions and dimensions could effectively improve or mire its potentials for improved environmental performance. The study concluded that due to climatic condition variations, a detailed simulation study is required for the appropriate form, sizes and orientation for courtyard design in buildings in a particular geographical location.

Key words: Courtyard, Design, passives building, Sustainability

Introduction

According to the report of Intergovernmental Panel on Climate Change (IPCC), "Future Climate Changes, Risks and Impacts", preventive climate change would have need of significant and continuous reductions in conservatory gas emissions in other to reduce climate change threats. The report continued that, outside temperature is anticipated to move up over the 21st century under all assessed emission situations, the report goes on and on (IPCC, 2015). But the challenge is that if temperature will continue to rise, what then can the architect do in his architectural scheme? Should he continue in his usual design approach that depends on active means cooling due to the prolonged summer rise in temperature and thereby adding to the lingering challenge of greenhouse gas emissions, as use of electric generators remain the only sure source of power in Nigeria and in most underdeveloped countries in Africa and the world generally, or should a shift to passive strategy for architectural design be considered as an option?

Tablada et al., (2005) has asserted that passive and low energy architecture is a major strategy for mitigating cooling effects in buildings. Akande (2010) has also concurred in his studies on "Passive Design Strategies for Residential Buildings in a Hot Dry Climate in Nigeria". The aim of the study was to reduce overdependence on active means to energy use in residential buildings in Bauchi state of Nigeria. The study revealed that the hot dry climatic region of Nigeria is best described as a season of high degree of hotness and low relative humidity in the months of February, March, April and May. Most residents have experienced constant problem of thermal performance in buildings due to high indoor temperature conditions. He concluded that the use of passive design strategies such as good courtyard and building orientation, building materials, and natural ventilation can improve cooling naturally and bring to minimum the energy required for cooling in buildings. In a related case study to that of Akande, "the tropical climate of southern China", the courtyard was applied as a cooling strategy (Wener, 1985). Also, Rasdi (2000) has revealed that the Courtyards is generally considered as a "microclimate modifier" in the dwelling owing to their capability to moderate high temperatures, channel wind and regulate the amount of dampness. Thus, the fact that the courtyard is a good strategy for the attainment of Passive and Low Energy Architecture (PLEA) in building may be true.

But according to Tabesh and Sertyesilisik (2015), the courtyard as a passive design strategy evolved mainly in response to climatic requirements but inappropriate design may create challenges for controlling temperature, glare, and energy consumption in buildings. On this note, Ghaffarianhoseini et al., (2015) opined that, courtyard optimization through analysis of design variants could contributes in reducing the duration of hours of discomfort to the barest level in a building. Again it has been revealed in a study conducted by Almhafdy et al., (2013) on "Courtyard Design Variants and Microclimate Performance" that the possibilities of optimized courtyard for effective microclimate is realistic only when the key design variants are put into consideration. Also, Akande (2010) agreed that Courtyards can lessen the chilling energy needs of residential houses in a very substantial way particularly if cautiously designed. Therefore, for the courtyard to fulfil its three main climatic task in buildings such as cooling, lighting and ventilation and to provide efficient environmental performance, the space conceivers (the architects) most understand the basic courtyard design variants for effective optimization (Kharseh at el., 2014).

Therefore, this study examined the design criteria for courtyard in different climatic zones. The courtyard design criteria with respect to form and its effects on wind movement and lighting in different climatic zones is investigated based on literature review. Journals, Conference Papers and Books were used to generate information. The findings of this study is summarised in the conclusion of this paper and is beneficial to architects as design information and also to scholars for future studies. This paper is divided into six (6) main sections; the introduction, literature review on courtyard design variants, the study area, the courtyard form, ventilation in courtyard, lighting in courtyard and the conclusion.

Courtyard Design Variants

The courtyard is a universal design element which has been put into practice for hundreds of centuries of years globally, particularly in houses. Its design has become an area of interest in recent times. Scholars have conducted numerous studies and offered the basic courtyard design variants for its optimum environmental potentials. For instance, Kharseh et al., (2014) asserted that courtyard design criteria in terms of high thermal mass in the tropical climates are not very clear but Rempel et al., (2016) revealed that the factors that influences design of courtyard for optimum microclimate or its environmental performance include; the area, number of floors, its degree of exposure, types of wall, orientation, natural elements within it and many more. Almhafdy et al., (2013), developed a checklist for courtyard design in their studies on "Analysis of Courtyard Functions and its Design Variants in the Malaysian Hospital" as; Form, Shape, Area, Number of floors, Orientation, Shading device, Water ground ratio, Vegetation ground ratio and courtyard plan aspect ratio. Berkovic et al., (2012), also asserted that the geometry (shape, size, area) and material composition of the courtyard are the basic determinants in designing courtyard with optimum microclimate.

It is very obvious from the above findings that courtyards form, size, area, orientation, shading devices, vegetation and ground ratio and the courtyard plan aspect ratio; are the main design variants. The appropriate application of their proportions and dimensions could effectively improve their behaviour (Mehdi 2016). The appropriate proportion of the courtyards form is usually based on latitude, even though the proportion of the piece of land is significant to some degree (Givoni, 1976). Survey studies have shown that courtyard form are sufficiently narrow to keep a shaded area throughout summer, and sufficiently wide to accept solar energy throughout winter (Nadimi and Yaghoubzadeh, 2014). It can be concluded that courtyard form (CF) is directly proportional to its shading potential (SP) that is CFαSP provided that other criteria are not ignored.

On courtyard form typology, Zamani et al. (2012), in a study on “A Review of Courtyard House: History, Evolution, Form and Function”, revealed that courtyard has no definite shape, it is of rectangle, square and circle from ancient time. Sthapak & Bandyopadhyay (2014), also concurred that through history, the basic plan of the transitional building component (the courtyard) keep changing in order to satisfy basic site conditions such as topography, restrictions, orientation leading to new forms or shapes such as U, L, T and Y. Lenzholzer and Brown (2013) has confirmed this fact.

However, Ok et al., (2008) in a study on “Evaluation of the Effects of Courtyards Design Shapes on Solar Heat gain and Energy Efficiency according to Different Climatic Regions” said that the amount of energy consumed in a building is directly proportional to how long the courtyard is (it’s length), that the amount of solar heat gain in the courtyard will be minimal or maxima as its length is varied. Muhaisen and Gadi, (2006), also concord in his shading simulation of courtyard form in different climatic regions in order to find the effects of rectangular courtyard proportion on the shading and the exposure condition produced on the internal envelope form, that, the internal component of the courtyard is a function of the geometrical composition. Berkovic et al., (2012), continued that elongated east-west rectangular courtyard has the smallest portion of shade and consequently, not recommended for effective shading strategy for cooling. Nadimi and Yaghoubzadeh (2014), in a research work on “Courtyard Forms: An Approach to Improve the Illumination and Acoustical Environment” uses simulation to produce a model that depends on form procedures and asserted that courtyard envelope is the most fundamental factor in accessing the amount of light luminance in rectangular courtyard, and therefore employing its design criteria very important.

Still on the rectangular courtyard, Tablada et al., (2005) recommended the rectangular form of courtyard for protecting the building from excessive heat gain by solar radiation, only if orientation factor is not compromised. Muhaisen and Gadi, (2006), also studied the transitional rectangular form of courtyard and concluded that it has the most effective impact in both summer and winter seasons.

In the quest for a better understanding of courtyard environmental performance and behaviour based on its design variant, Mohaisen and Gadi (2006b), stressed in their polygonal model simulation studies that courtyard with high depth using any kind of geometry shape is the most preferred for good shading especially in the hottest season, while in winter shallow courtyard forms is more preferred for effective sunlit areas. Almhafdy et al., (2013a), in their own effort to contribute on the effects of the design variants such as aspect ratio and shading device on courtyard thermal behaviour used the popular computational fluid dynamics CFD simulation method and the predictive mean vote PMV for evaluation of thermal comfort. The degree of hotness or coldness in (in degree centigrade), air speed (in m/s) were the three environmental parameter measured. The study revealed that the aspect ratio and the cantilevered roof (shaded portion) are the key determinants of air speed and thereby, the thermal sensation. In their comparison, the U form transitional area with aspect ratio 1:2, that is, the rectangular courtyard has demonstrated a better thermal performance than the U form transitional courtyard with aspect ratio as 1:1, that is, the square form of courtyard. They concluded that increasing the shaded area of the courtyard will result in a more comfortable and excellent courtyard microclimate.

On this wheel of progress, Aldawoud (2008) conducted another research evaluating the ability of un-shaded courtyard with natural features within its envelope and building height ratio for providing thermally comfortable outdoor spaces according to different configurations and scenarios. By using the ENVI-met for simulation software, the predicted mean vote PMV and the Psychrometric effective temperature PET for further evaluation of thermal sensation. The study revealed that, the elevation of the building in terms of height ratio; availability of natural features such as trees, flowers, grasses, water body...in courtyard has the capability of improving its microclimate significantly. He said courtyard in the Malaysian climatic region can only provide conducive environment between the morning hours of 7:00am – 10:00am and 5:00pm in the evening, but that this duration can change for the better only if the courtyard is properly designed. He continued that seventy-five percent coverage of the entire floor area of the courtyard with green and natural features can alter the long critical duration of thermal unrest to 1:00pm – 2:00pm.

Furthermore, Kharseh et al., (2014) argued in his research on “Heat in Courtyards: A Validated and Calibrated Parametric Heat Mitigation Strategies for Urban

Courtyards Blocks"; he used simulation by changing the percentage of light reflective potentials of the courtyard wall enclosures, water body and greeneries (the three mitigation strategies for heating and cooling in courtyard). The research shows that increasing the wall enclosure potential for light reflection will lead to less radiant temperature within the courtyard, and the application of water body and greeneries has the effects of cool environmental sensation; and thereby, proving the fact that they are indeed the best mitigation strategies for cooling. He concluded that application of these strategies can mitigate courtyard microclimate efficiency. Other scholars such as: (Aldawood, 2008; Al-Masri and Abu-Hijleh, 2012); (Rasdi, 2000); (Chen, 2012) have contributed their own quotas on the effects and implications of designing courtyard based on its design variant, as: aspect ratio; height; area; degree of exposure and the wall composition.

More is on the impact of wall enclosures on courtyard microclimatic performance. According to Arch & Coates (2006), the phrase 'Courtyard Wall Enclosure" refers to the most important components of the courtyard interior such as: the walls, windows and doors (that is the fenestration). These elements defined the courtyard and the building envelope. The scholar insisted that all space conceiving professionals most adhere strictly to this important design variant even right from the design stage, the sketches and the implementation stage. Almhafdy et al., (2013a) also has investigated the different function of wall enclosure functions in his research in International Courtyard Ventilation and its Thermal Performance. The thermal performance effectiveness of the courtyard building during variant design conditions such as: glazing type and window to wall ratio was conducted by Aldawoud, (2008). In addition, Almhafdy et al., (2013c), continued in their research in colour, material, shading device and wall enclosure material composition and concluded that the courtyard wall ensured can contribute significantly to the courtyard environmental performance.

Courtyard orientation is also another design variant that seems to record very few literatures. However, scholars that have contributed in this regards include Almhafdy et al., (2013a); they studied the impact of courtyard orientation on its environmental performance by using both experimental and simulation methods and 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 nearby location to the courtyard. On orientation, the study revealed less significance on air temperature, but affects ventilation significantly as the enclose walls tend to block air free passage. Berkovic et al., (2012), continued that elongated east-west rectangular courtyard has the smallest portion of shade and consequently, not recommended for effective shading strategy for cooling.

The Courtyard Form

Numerous studies tried to discover the best size of geometric shape such as: round, polygon, quadrilateral and right-angled form of courtyard in diverse climates. Tabesh and Sertyesilisik (2015), indicated that altering the form's sizes in circular model expressively effects shading or exposure possibility of the courtyard interior and that shallow courtyards do well than the deeper ones, see fig.2. Again, Muhaisen and Gadi (2006a) used computer simulation studies to investigate the effect of solar heat gain on courtyard form with diverse sizes. They discovered that courtyards with deep forms need low energy for cooling in summer. In a study on polygonal courtyard form, Ahmed and Muhaisen (2006b) opined that courtyard with deeper forms with any kind of shape can be suggested for obtaining optimum internal shading in summer. But in winter, shallow forms were recommended for optimum sunlit areas, see fig.3. Muhaisen and Gadi (2005) conducted a modelling study to investigate the effect of rectangular courtyard sizes on the shading circumstances on the interior covering of the form in four different settings. The results displayed optimum courtyard elevation to obtain a good result in summer (see fig.4).

Ventilation in Courtyards

Natural ventilation is a passive phenomenon that can improve comfort and save energy, hence is a significant strategy for passive architecture. Haw et al., (2012), revealed that apart from wind towers, other architectural elements exist, for instance; atriums, courtyards, air walls, which have been used in architectural designs and proved to have positive effects on the indoor air movement. They concluded that courtyard can improve air movement in a building.

Ok et al., (2008) confirmed the effect of ventilation through fenestrations in courtyard buildings. It was revealed that the locations, dimensions, configuration and orientations of fenestrations affect air movement in a courtyard. Al-Masri and Abu-Hijleh, (2012) opined that courtyard is ideal in humid climates particularly when courtyard can bring ventilation because of stack effect.

According to Tran et al., (2015), all fenestrations should be accustomed to improve air movement and lighting. They discovered that courtyard building has a significant role on air movement into rooms facing the courtyard. Their examination also emphasised that courtyard facing windows are more important than street-facing windows. They continued that wind velocity in the courtyard house was independent from wind conditions at different points in the house, and concluded that ventilation, orientation, shape and shading strategies in Vietnamese climatic situations are better than earth cooling, thermal insulation and high thermal mass.

Daylight in Courtyard

Al-Masri and Abu-Hijleh (2012) in a simulation studied orthodox and courtyard houses to decide on the energy usage, energy savings potential and daylight levels, as shown in fig.5 The result revealed the improved courtyard model is 11.16% better than the conventional form building and for daylighting, the improved courtyard form shows more daylight without excessive glare.

Conclusion

Courtyard in buildings have almost the same design criteria in all the climatic zones but the appropriate form, dimensions and proportions are dependent on the climatic characteristics of each zone. Air movement and daylighting performances in the courtyard buildings are dependent on its design variants such as; form, size, area, orientation, shading devices, vegetation, ground ratio, the courtyard aspect ratio, shape factor, perimeter ratio and water pond. The courtyard form and size have a significant result on the shading conditions. This also has a major impact on the courtyard building cooling and heating loads. Finally, due to the differences in climatic requirements of climatic regions such as; hot-dry, hot-humid, cold, and temperate climates, detailed simulation studies are required for the appropriate form and size for a particular climatic zone.

Illustrations

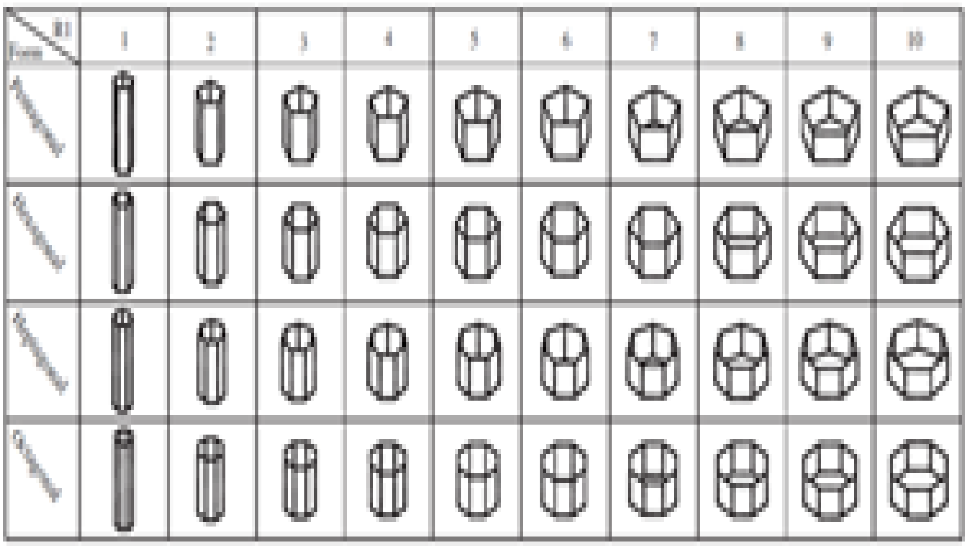
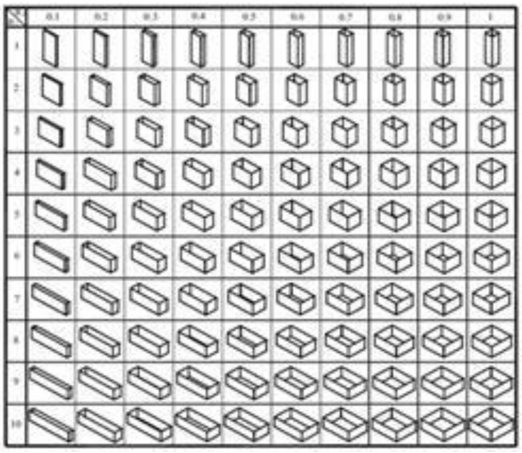


Fig 2: Polygon Form of Courtyard

Source: Tabesh & Sertyesilisik (2015)



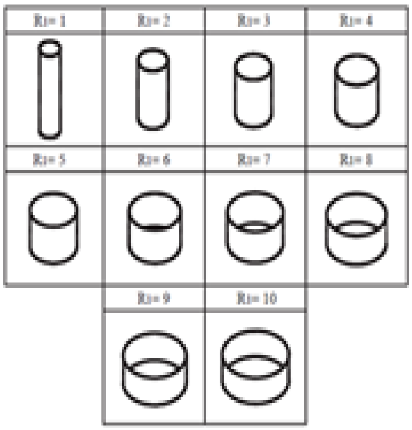


Fig 4: Rectangular Form of Courtyard **Fig 3**: Circular Form of Courtyard.

Source: Tabesh & Sertyesilisik (2015)

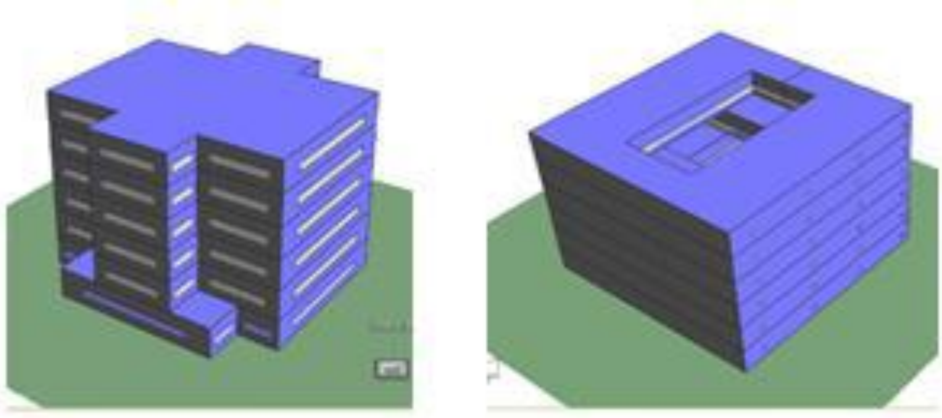


Fig 5: Courtyard Model **Source:** Tabesh & Sertyesilisik (2015)

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