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Courtyard as a Passive Cooling Strategy in Buildings

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ABSTRACT

One of the most significant current discussions in the built environment, architectural practice, theory, and procedures is "Passive Design". It is becoming very difficult to ignore the issues of passive architectural design strategies in buildings. Recent studies emphasized the need for passive architectural design strategies and the application of the courtyard as a passive design strategy for cooling in buildings. Also, that the courtyard is very suitable in almost all building typologies in all the climatic zones due to its passive tendencies for cooling. Its cooling potentials can be achieved only when design requirements are not ignored. The courtyard has social, cultural, religious, and environmental benefits. Despite its abundant advantages, research effort towards courtyard design requirements is very scarce. Therefore, the main objective of this study is to investigate the design of central courtyard as a passive cooling strategy for improving indoor thermal comfort in Universiti Teknologi Malaysia (UTM) Buildings. Courtyard design requirement such as the courtyard configurations, orientation, and natural features in courtyard buildings in UTM were investigated. Besides the design variants, courtyard usage in such buildings was also examined. The methodology of this study involved the developing of a checklist based on literature for the field survey. Forty-six (46) courtyards in thirty-two (32) buildings in UTM were surveyed, and the statistical description method was used to interpret and analyzed the data. The Results of this quantitative study shows that UTM central courtyards buildings were designed based on a cautious consideration to orientation and configurations to enhance their effective passive cooling potentials, however, only two courtyards had water pools. The study concluded that courtyards in UTM buildings are creatively designed but future experimental studies to appraise their thermal performances is required, and future simulation studies can predict a better design requirement for optimum performance. Therefore, further simulation studies are recommended.

1. Introduction

One of the most significant current discussions in the built environment, architectural practice, theory, and procedures is "Passive Design". It is becoming increasingly difficult to ignore the issues of passive architectural design strategies in buildings. According to the Intergovernmental Panel on Climate Change (IPCC) (2015), atmospheric temperature is anticipated to move up over the 21st century under all assessed emission situations. But the concern is that if the temperature will continue to rise, what then can the architect do in his architectural scheme? Should he continue in his design of buildings that depends on active means of reducing the effect of rise in temperature and continue to add to the lingering challenge of greenhouse gas emissions as use of electric generators remain the only sure source of power in most of the underdeveloped countries in the world, most especially in African nations such as Nigeria, or, should a shift to passive strategy for architectural design of buildings be considered as an alternative?

Recent studies in passive architectural design have emphasized the need for passive architectural design strategies as the best option for mitigating temperature-rise in buildings. Therefore, the application of courtyard as a passive design strategy in architectural vocabulary may be one among the most suitable approaches to the attainment of passive buildings. Tablada *et al*., (2005) asserted that passive design is a major strategy for mitigating cooling effects in buildings and recommended the application of the courtyard. Akande (2010), also concurred in his studies on Passive Design Strategies. He concludes that the use of certain passive design strategies such as; good courtyard and building orientation can improve cooling naturally and bring to a minimum the energy required for cooling in buildings.

The application of the courtyard as an architectural design element in buildings is not uncommon to architects. The courtyard is a universal design element which has been put into practice long ago. In particular, contemporary buildings in UTM have this concept and it has become an area of interest in recent times to scholars. This is perhaps due to the numerous benefits of the courtyard. According to Edwards *et al.* (2006), the use of the courtyard in buildings was originally initiated in the hot and dry climatic regions of the world. Thus, its application is most suitable in the tropical regions. However, it is also applicable to all climatic regions. Abass *et al*. (2016) defined courtyard as a covered outside space but open to the element at its apex. Mishra & Ramgopal (2013) also defined the courtyard as a room that is open to the heavens, a square or rectangular in form and bordered by a group of buildings or the most important rooms. The definitions can go on and on.

The courtyard configuration is a very vital requirement for the courtyard optimum performance and the appropriate form supposed to vary from one climatic region to the other, even its location in the building. For instance, having a courtyard in the middle of the architectural design may not do better in all climatic situations (Ghaffarianhoseini *et al*., 2015). Thus, adopting the courtyard form from the western states into the tropical region; the hot-dry climatic region or the hot humid climatic region in particular, rather than the using the original indigenous concept which is adaptable to the cultural, climatic and religious requirement of the people may lead to a more thermal distress in buildings. More so, many primordial courtyards in the Arab nations have elucidated a clear picture of a courtyard designed based on the social, cultural and climatic requirements. The courtyard design parameters for instance; aspect ratio, height, orientation, exposure to the sky, nature of the courtyard wall components and much other physical factors were evolved in other to obtained an effective courtyard that responds to the human requirement for comfort in buildings (Berkovic *et al.,* 2012).

The use of the courtyard as an architectural design element is adaptable to almost all building typologies in all the climatic zones due to its passive tendencies for low energy consumption in buildings. It has social, cultural, religious, and environmental usage. Despite its abundant advantages, research effort towards courtyard design requirements is very scarce. Therefore, the main objective of this study is to investigate the design of central courtyard as a passive cooling strategy for improving indoor thermal comfort in Universiti Teknologi Malaysia Buildings (UTM). Courtyard design requirement such as; the courtyard configurations, orientation, and natural features in courtyard buildings in UTM were investigated. Besides the design variants, courtyard usage in such buildings was also examined. The methodology of this study involved the developing of a checklist based on literature on courtyard studies for the field survey. Forty-six (46) courtyard in thirty-two (32) buildings in UTM were surveyed, and the statistical description method was used to interpret and analyzed the data. This paper is divided into five (5) parts; the introduction, study background, methodology, findings and discussion, and the conclusion. This study is important not only to architects but even to scholars as it has provided a background for future allied studies.

1.1. Courtyard Functions

In architectural design, the courtyard has been put into use for many years particularly in housing design. Its application is justified due to its numerous benefits. In recent times, scholars have opined the benefits of the courtyard in order to elucidate its relevance in a building. These benefits include; architectural benefits, social benefits, climatic benefits, cultural benefits, economic benefits, and the religious benefits (Almhafdy *et al.*, 2013a).

The courtyards were frequently used as meeting area for specific functions such as gardening, cooking, working, playing, sleeping, or even in some cases as places to keep animals (Edwards *et al.*, 2006). The courtyard suitability for diverse functions may not be far from its location in the house layout (which varies from one group of culture to another). According to Antonio & Carvalho (2015), the importance of such a space was by their being located in central sites within the urban fabric or building. Surrounded by arcades and colonnades, paved, landscaped with water bodies, various plants, shade, and light, they all played an important role in our social and working life. In terms of its contribution to good health, Antonio & Carvalho (2015) continued that the courtyard can be used as a place for facilitating the healing process due to its natural healing environment. The courtyard also contributes in a major way by modifying the climatic setting and thereby inducing mental and physiological sensation of its end users.

1.2 Courtyard Configuration

The rectangular and square forms are the most commonly adopted for courtyard in buildings even though, there is no any particular form that is considered as the most suitable (Almhafdy et al., 2013b). In residential design, the courtyard is in rectangular or square form, but circular, curvilinear and other forms may evolve. The courtyard form can be adapted to by using the numerous eco-friendly aspects such as scenery, site limitations, and building orientation, to generate new shapes such as; U, L, T or Y (Das, 2006; Reynolds, 2002). Also, the courtyard form can be fully enclosed, semi-enclosed or in some cases even two sided (Berkovic *et al*., 2012). Again, the application of these forms is not limited to residential buildings alone but even in non-residential and multi-purpose buildings.

Scholars have conducted studies on courtyard design concepts. The studies made it clear that the form can be manipulated to act as a microclimate modifier to the built environment. For instance, the courtyard form was found to be a key design requirement in a study on the archetypal rectangular courtyard form and its impact on the eco-friendly performance in the tropical region by (Aldawoud, 2008). Tablada *et al.* (2005) studied and suggested that the courtyard form and its entire envelope needed to be protected against extreme solar radiant heat and the penetration of dusty air as well as air movement which has a severe consequence on thermal stress. Also, Ganem *et al.* (2014) conducted a study on "the effect of three-sided courtyard on the microclimate behavior in a building". The result revealed that the courtyard generated improved microclimatic condition; mostly when some design requirements for instance orientation, depth of courtyard and ventilation strategies are not ignored. Again, Muhaisen (2006) researched on 'The Effect of a Rectangular Courtyard Proportions at Four Different Climatic Locations' using the simulation method, the impact of courtyard form and orientation on shading effect was investigated. The appropriate courtyard elevation to obtain a good shading effect in summertime and wintertime was discovered to be at least nine (9) meters in hot-humid region, six (6) meters in hot-dry region and three (3) meters in cold and temperate region. This suggests that higher elevations should be used for courtyards in warmer climatic regions while low elevation should be applicable for courtyards in the cooler climatic region. Furthermore, Huang *et al*. (2014) revealed that the deeper form generates more shadow within the courtyard in summertime whereas narrow courtyard form behaves well in wintertime. They suggested an annual calculating ratio. But, for the daylight, this recommendation is not applicable. The courtyard potential to act as a passive cooling element can be compared with a building composition in terms of airflow rate and pattern.

Enes and Ok (2014), studied the effect of courtyard geometry in terms of energy effectiveness or thermal comfort. The main objective of the study was to propose a model for optimum courtyard form and comfort based on the variety of climatic and meteorological conditions for three different climatic regions such as the hot dry, hot humid and the cold region. In the study, all thermal factors were kept constant except temperature. The building energy simulation tool used was the

Computational Fluid Dynamics (CFD). The study revealed that the more the courtyard is exposed to solar radiation, the more cooling is needed during summer and equitably less heating is needed during winter. The best courtyard ratio was defined as that which permits least radiant heat gain during summer and high radiant heat gain during winter. The study concludes with "H" (6000mm x 9000mm x 6000mm) option as the best courtyard form for all the three regions in terms of thermal gain and the criteria of comfort in Turkey.

Mohsen (1979) in his study on "Solar Radiation and Courtyard House Form -A Mathematical Model" proposed a mathematical model that simulates the relation between the courtyard geometry and the thermal performance. The study concludes that solar radiation is the main determinant of discomfort in the hot dry climate region and the optimum courtyard form should be calculated at the pre-design stage. Olgyay (1963) in a study on courtyard optimum ratio recommended an inverse relationship between the thermal impact and the form. In a separate document prepared by The United Nations Department of Economics and Social Affairs titled "Design of Low-Cost Housing Communities Facilities, Climate and Housing Design 1" the concept of the courtyard is recommended based on the fact that the courtyard shape factor that is, its plan should not exceed its height. Also, in another similar document on climatic design in Islamadad (1966), four typologies of courtyards were studied, it was revealed that the courtyard height is the most significant factor that influences solar radiation and shading: increase in a story height resulted in two to three hours of reduction of radiant heat penetration. The conclusion was the recommendation of overhead shading devices for a courtyard with an area greater than $18m^2$.

Muhaisen and Gadi (2006a) in a study entitled "Shading Performance of Polygonal Courtyard forms", study the shading behavior of five-sided courtyard, six-sided courtyard, seven sided courtyard and eight-sided courtyard forms. They produced a computer package that could calculate the shaded and unshaded areas produced by all the studied courtyard geometries. The study revealed that the courtyard geometry has a substantial impact on the shading behavior of courtyard forms. For a reasonable performance throughout the whole year courtyards with R1 equal to or greater than 5 are recommended. They ensure a significant amount of internal shadows in summer, as well as a considerable sunlit area in winter.

In another study on "Shading Simulation of The Courtyard Form in Different Climatic Regions," Muhaisen (2006b) aimed at the effect of quadrilateral courtyard sizes on the shading and degree of exposure created the form in four different sites. The sites include Kuala Lumpur, Cairo, Rome, and Stockholm. They represent the climatic zones of hot humid, hot dry, temperate and cold climates, respectively. The study reveals that it is difficult to achieve the optimum courtyard ratio, as the optimum ratio for effective performance in summer was found to be the opposite in winter. However, the optimum courtyard height for a sensible performance in summer and winter was revealed to be nine meters (9m) in hot humid climates, six meters (6m) in hot dry and temperate climates, and three meters (3m) in a cold climate.

In a computational analysis study on "A Ventilated Courtyard as a Passive Cooling Strategy in the Warm Humid Tropics" conducted by Rajapaksha *et al.,* (2003), examined the possibility of a courtyard for passive cooling in a building of three meters (3m) height in Colombo, Sri Lanka a warm humid climate. The objective is to propose some design principle for courtyard in buildings. A better performance in terms of air temperature reduction is observed when heat exchange between the courtyard indoor air and ambient air temperature is allowed. But, this performance is influenced by the courtyard dimensions and proportion. With the used of k-e two equation turbulence model for simulation, a good thermal adjustment is observed when the courtyard acts as an air funnel discharging indoor air into the sky, then the courtyard form is configured to acts as a suction zone encouraging air movement from its sky opening into the courtyard and back to the atmosphere.

1.3. Orientation

Courtyard orientation is also another design variant that seems to record very few literature. However, scholars that have contributed in this regards include Antonio & Carvalho (2015), he studied the impact of courtyard orientation on its environmental performance by using both experimental and simulation methods. He 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 a nearby location to the courtyard. On orientation, the study reveals 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. Almhafdy *et al*. (2013a), asserted that there is no evident record on verification of the most suitable courtyard orientation for its optimum environmental performance, although, there is a general assumption that courtyard orientation with the elongated side facing the north to south direction is the best option.

According to Meir, *et al.* (1995), accurate orientation of courtyard can increase their thermal well-being, but orienting it irrespective of solar angles and wind course may create thermal distress. But the setting of a building is considered in most cases by the orientation. The factors with direct impact on courtyard microclimatic behavior include; location of the sun, direction of the wind, shading effect and radiant heat (Bagneid, 2006). All these factors are key to Courtyard orientation. Finally, these copious discoveries only seem to establish the fact that building orientation and courtyard relationship is a key strategy for mitigating the courtyard cooling effects, and by and large, the building. However, due to the difference in geographical location two different latitudinal and longitudinal locations are bound to have different orientation requirement. Thus, according to Almhafdy *et al*., (2013b), there is no evident record on verification of the most suitable courtyard and building orientation for optimum cooling performance for two different locations, although, there is a general assumption that orientation of buildings with the elongated side facing the north/south direction is the best option. Therefore, understanding the most suitable orientation for a single story residential courtyard building in Nigerian hot-dry climate will be a very important objective of this study.

1.4. Wall Enclosure

Courtyards enclosing walls varied from one region to the other. The variations are caused by the social, cultural, economic and eco-friendly conditions. Even though the design remains analogous, the requirements of the design are determined by usage and location (Meir *et al.,* 2000). Wall enclosure can be defined as the summation of the courtyard components within the building. These components include walls, doors and windows. They play a significant role in the microclimate performance of the courtyard through natural ventilation strategies. They can also be influenced by opening or closing of the openings and by altering the wall to window ratio. According to Al-hemiddi & Al-saud (2001), insignificant cooling is observed when all windows are closed. But, opened windows and doors improve natural ventilation in the courtyard. Other scholars such as: (Muhaisen, A. 2006; Bagnied, A. 2006) agreed that other preferences to look into when optimizing courtyard are the choice of the component material, color and specifications.

Application of natural elements in a courtyard would yield eco-friendly benefits. Muhaisen (2006), revealed that vegetation (as garden elements) in a courtyard can meaningfully impact the thermal performance of a courtyard as they provide shade and increase humidity level in hot-dry regions. Al-Hemiddi & Megren (2001) revealed in a study on the impact of applying a water pond in a courtyard that the interior courtyard with a pool during sunny hours delivered substantial cooling impact within the internal courtyard envelope.

2. Methodology

Information were derived from literatures on courtyard functions, courtyard design variants and their effect on environmental behavior and used to generate a checklist. This methodology was adopted from Almhafdy et al., (2013), a study on "Analysis of the Courtyard Functions and its Design Variants in the Malaysian Hospitals", even though few modifications were effected. The checklist was used in examining all the surveyed courtyards.

2.1. The Checklist

Table 1 illustrates the checklist that was used for the site survey. The checklist was derived according to the study background as presented in the literature of this study. Furthermore, roof shading device was added.

2.2. Sites Visit and Observation

A total of forty-six (46) courtyards in thirty-two (32) buildings in UTM were surveyed. Figure 2 is a sample of some of the courtyards. The specification list was used for data collection as mentioned. Due to the favorable response from the Physical Unit of Universiti Teknologi Malaysia, the whole exercise lasted for two (2) weeks only as there were not major issues encountered. A comprehensive observation was carried out for each of the courtyards. On the courtyard usage, the observation was based on people activity inside the courtyards. The nature of the courtyard design conditions was investigated

3. Results and Discussions

The survey documented true data such as the courtyard functions, form and shape, aspect ratio, height, orientation, vegetation, water body and roof/shading devices inside the courtyard. It was revealed that the use of courtyard is conversant in Kaduna-Nigeria commercial centers (shopping complex).

3.1. Courtyard Function

In architectural design, the courtyard has been put into use for many years particularly in housing design. Its application is justified due to its numerous benefits. In recent times, scholars have opined the benefits of the courtyard in order to elucidate its relevance in a building. These benefits include architectural benefits, social benefits, climatic benefits, cultural benefits, economic benefits, and the religious benefits. However, in UTM courtyards buildings satisfy four (4) important function. As shown in figure 3, its functions include playing ground,

Table 1 *Specification List of Courtyard Design Variants*

				YES	NO
Courtyard Configuration	Form	Square			
		Rectangular			
		Triangular			
		Irregular			
	Shape	Fully enclose	**O**-Shape		
		3 Sided enclose	**U**-Shape		
		2 Sided enclose	**L**-Shape		
		Others	**I**-Shape		
Orientation	North/South				
	East/West				
	North-east/South-west				
	North-west/South-east				
Shading Device	Cantilever Roof				
	Overhangs				
Natural Features	Vegetation				
	Water body				
Usage	Lighting				
	Playing				
	Ventilation				
	Car parking				
	Recreational				

Figure 2 *Samples of some of the courtyards surveyed in UTM*

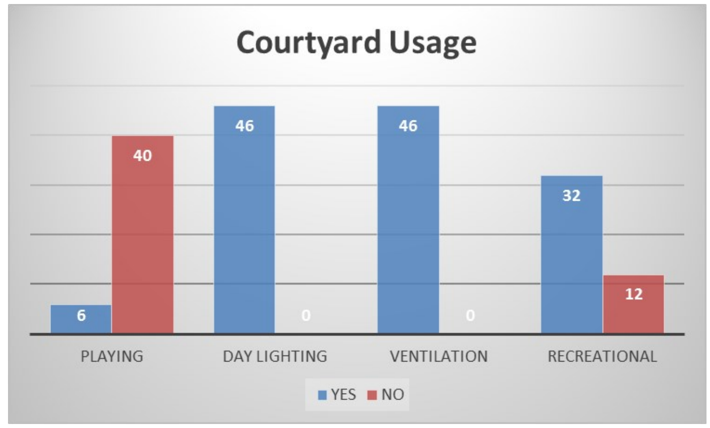

Figure 3 *Distribution of Courtyards Usage in UTM Buildings*

ventilation, lighting, and recreational activities. The study shows that out of the forty-six (46) courtyard surveyed, only six (6) are used for playing, thirty two (32) for recreational functions. All the surveyed courtyards fulfil the architectural requirement for lighting and ventilation. This suggests that Almhafdy et al., (2013a) assertion that the courtyard has numerous functions; such as; architectural, social and climatic benefits is true. However, 12 courtyards did not fulfil the recreational function.

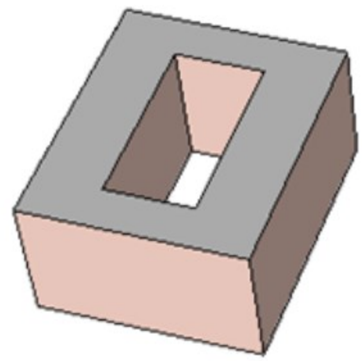

Figure 4 *Showing a fully enclosed courtyard*

3.2. Courtyard Shape in UTM Buildings

In residential design, the courtyards are in rectangular or square form, but circular, curvilinear and other forms may evolve. The courtyard form can be adapted to by using the numerous eco-friendly aspects such as scenery, site limitations, and building orientation, to generate new shapes such as U, L, T or Y (Das, 2006; Reynolds, 2002). Also, the courtyard form can be fully enclosed, semi-enclosed or in some cases even two sided (Berkovic *et al*., 2012). Again, the application of these forms is not limited to residential buildings alone but even in non-residential and multi-purpose buildings. This study has revealed that the application of courtyard in UTM is comparable to other Asian countries, for instance in Iran, where the courtyard has been designed and shaped to modify the courtyard microclimate (Almhafdy et al. 2013a). As illustrated in figures 4 and 5, the courtyard shape can be categorized as fully enclosed, and semi-enclosed. The fully enclosed courtyards typology are bounded on all the sides (4 sides), while the

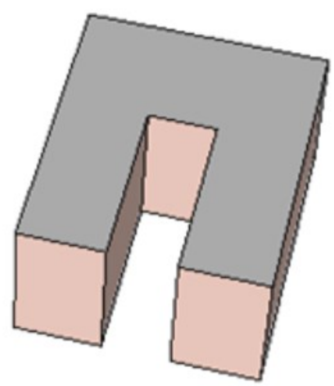

Figure 5 *Showing a semi-enclosed courtyard*

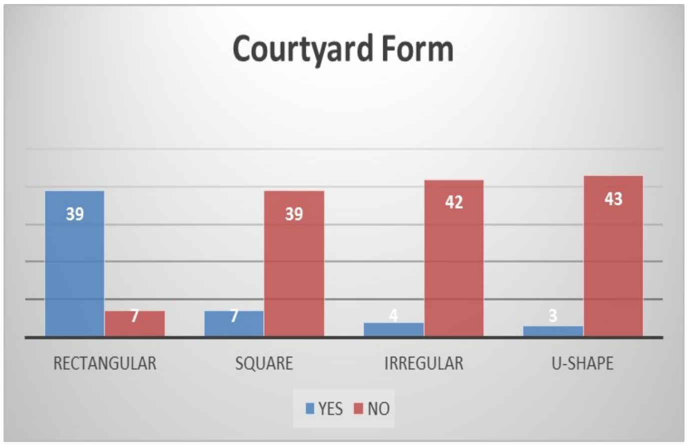

Figure 6 *Distribution of Courtyard Form in UTM Buildings*

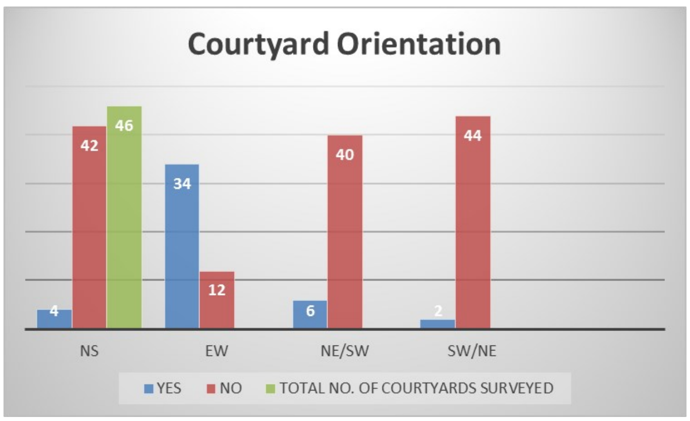

Figure 7 *Orientation of Courtyards in UTM Buildings*

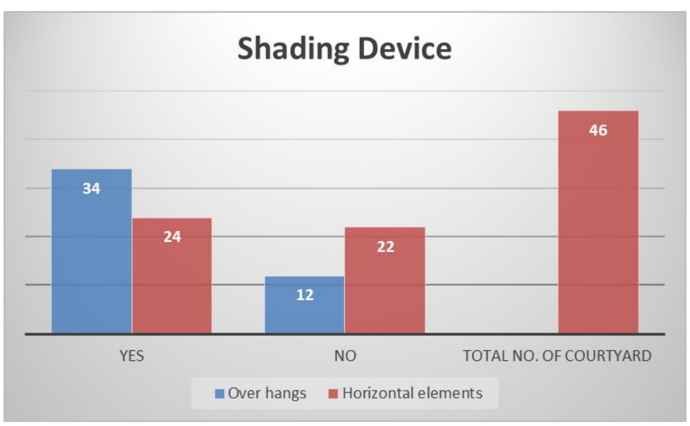

Figure 8 *Shading Devices in UTM Courtyard Buildings*

semi-enclosed typology are defined by courtyard exposure to the atmosphere through its walling components.

Among the surveyed courtyards, 38 are fully enclosed, while 8 are semi-enclosed. It signifies that about 82% of the surveyed courtyards are fully enclosed. This has agreed with Meir (1995) assertion that fully enclosed courtyard have better microclimatic modifying capability than the semi-enclose typology, hence, it can be deduced that the good number of courtyards in UTM buildings have the most preferred courtyard shape for optimum climatic performances.

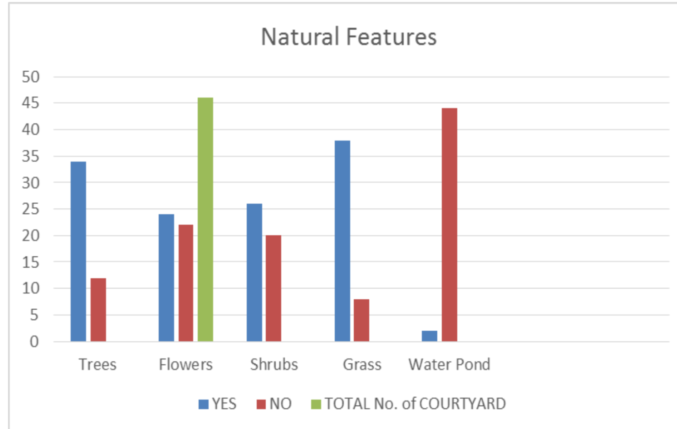

Figure 9: Natural Features of Building Courtyards in UTM

3.3 Courtyard Form in UTM Buildings

The studies made it clear that the form can be manipulated to act as a microclimate modifier to the built environment. For instance, the courtyard form was found to be a key design requirement in a study on the archetypal rectangular courtyard form and its impact on the eco-friendly performance in the tropical region by (Aldawoud, 2008).

As shown in figures 4 and 5, the courtyard shapes as revealed are: fully enclosed and semi-enclosed courtyards. However, they are in the square, rectangle, irregular and U-shape forms. Figure 6 revealed that out of the 46 surveyed courtyards, 39 are in a rectangular form, 7 square, 4 has an irregular form, and 3 U-shape. The Most popular form is the rectangular, followed by the square, irregular and the u-shape. This revelation has concurred with Almhafdy et al. (2013b) assertion that rectangular and square courtyard form are the most used in buildings. Thus it means that about eighty (80%) of the surveyed courtyard buildings in UTM are rectangular in form, and constitute an excellent grade.

3.4. Orientation

Courtyard orientation is also another design variant that seems to record very few literature. However, scholars that have contributed in this regards include Antonio & Carvalho (2015), he studied the impact of courtyard orientation on its environmental performance by using both experimental and simulation methods. He discovered that increased height of courtyard walls will cause a reduction in the degree of air temperature in the courtyard as well as the rooms in a nearby location to the courtyard. On orientation, the study reveals less significance on air temperature but affects ventilation significantly as the enclose walls tend to block air free passage. Courtyard orientation is another significant design variant. Although past studies have not shown the best courtyard orientation, the common assumption is that courtyard orientation with its longest axis facing north-south will improve thermal performance (Almhafdy et al. 2013a). In figure 7, the study revealed that four (4) courtyards are oriented in the North-South direction, six (6) in the North-East/South-West direction, thirty-four (34) in the East-West and two (2) in the South-West/North-East direction respectively. It is obvious that about ninety-four (94%) percent of the courtyards has large portions under shade, as these courtyard are oriented in the East-West direction and are rectangular in form configuration as illustrated in figure 5.

3.5. Shading Devices

The literature has shown that shading strategies is a key factor for cooling in the courtyard (Berkovic et al., 2012). Figure 8 reveals that thirty-eight (38) courtyards have overhangs while twenty -four (24) has horizontal shading elements. This connotes that about 72% and 60% of the surveyed courtyard has overhangs and horizontal shading elements respectively. This result suggests that a very good percentage of the courtyard buildings in UTM are well shaded.

3.6. Natural Features

Natural features such as vegetation; trees, flowers, shrubs, grass and water ponds has been revealed as very effective in courtyard thermal performance (Edward *et al.* 2006). Figure 9 reveals thirty-four (34) courtyards had trees, twenty-four (24) had flowers, twenty-six (26) had shrubs, thirty-eight (38) had grasses and only two had water pool. This result signifies that about 75% of the courtyard studied has a satisfactory percentage of natural features, hence, their thermal performances is expected to be excellent (Muhaisen 2006). Also, the fact that only two courtyards had water pools is a very good result due to the fact that humid regions like Malaysia will not require a water pool because it lead to increase in humidity level, but rather recommended in a hot dry climatic region as a water pond can improve courtyard humidity level and thereby influencing positively the hot-dry atmospheric conditions (Meir 2000).

4. Conclusions

Courtyard design requirement such as the courtyard configurations, orientation, and natural features in courtyard buildings in UTM were investigated. Besides the design variants, courtyard usage in such buildings was also examined. The methodology of this study involved the developing of a checklist based on literature for the field survey. Forty-six (46) central courtyards in thirty-two (32) buildings in UTM were surveyed, and the statistical description method was used to interpret and analyzed the data. The results of this quantitative study show that UTM central courtyards buildings were designed based on a cautious consideration to orientation and configurations to enhance their effective passive cooling potentials, however, only two courtyards had water pools. Also, this study explains a research work that adds in the direction of understanding the characteristics of courtyards in UTM buildings. The finding reveals that courtyards are common architectural elements used in UTM buildings. They are categorized into fully enclosed and semi-enclosed shapes. The most regular courtyard form is the fully-enclosed rectangular courtyard. About 72% and 60% of the surveyed courtyard has overhangs and horizontal shading elements respectively; 75% of the courtyard studied has a satisfactory percentage of natural features, hence, their thermal performance is expected to be excellent. On orientation, thirty-four (34) courtyard buildings are in the East-West direction. All the courtyards contributed to ventilation, lighting, and recreational functions while only six were suitable for playing. The study concludes that courtyards in UTM buildings are creatively designed but future experimental studies to appraise their thermal performances is required, and future simulation studies can predict a better design requirement for optimum performance. Therefore, simulation studies are recommended.

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