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INFLUENCE OF CENTRAL COURTYARD'S DAYLIGHTING ON VISUAL COMFORT AT TAMARIND SQUARE SELANGOR, MALAYSIA: A CASE STUDY

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Abstract

Current commercial buildings are designed in a compact and massive form leading to an unhealthy environment. Courtyard is an effective daylight passive design strategy implemented in a building that can contribute to a healthier environment. Moreover, courtyards can also act as a multi-functional space that can enhance social activities. These two potentials make courtyards relevant in solving the issues which arise in current commercial building's design. However, Malaysia is a tropical country with bright sky condition. To make use of the potential of daylight in courtyards in a tropical climate, a design strategy is needed to adapt with the over exposure of sunlight. To study the influence of daylight in courtyards and the strategies needed to counter the issues of visual discomfort, Tamarind Square was chosen as a case study, as the building is considered as one of the best design practices in Malaysia, based on the recognitions given by the Pertubuhan Akitek Malaysia (PAM) and other notable bodies. Daylight design strategies are examined to verify whether courtyards in Tamarind Square do meet the criteria for good visual comfort. Visual comfort is analysed based on visual comfort parameters that include: available amount of light, light uniformity, shading strategy, risk of glare, choice of material, access to view, and colours. There were three courtyards involved in this study: the North Court, the Centre Court and the South Court. Each of these courtyards has its own strategies in adapting to tropical climate and providing good visual comfort, while at the same time meeting its purpose as part of the commercial space in Tamarind Square.

Keywords: Courtyard, Daylighting, Commercial building, Visual comfort, Tropical climate region

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INTRODUCTION

Modern mall that is enclosed, air-conditioned, with all spaces fit inside the building like a box, was invented for temperate climates, particularly in America. As it is enclosed, it creates a negative impact to the environmental, psychological, health and well-being of the building users. In response to these design issues, introducing courtyards is one of the best potential solutions as deep building plan can be punched by courtyards and thus creates a meaningful functional place for public activities (Madihah et. al, 2022). Besides, a courtyard is also an effective space in a building that can control, regulate and homogenize the luminous environment. The trilogy areas surrounding a courtyard building include indoor spaces, outdoor spaces, and the courtyard itself, interacting in systemic ways to optimize the building's luminous performances. However, natural lighting sources in a tropical climate region might require certain strategies and adaptation in facing the hot and intense solar radiation which consequently causes over exposure, leading to visual discomfort issues. With this concern, this research paper attempts to investigate courtyard influences in a tropical climate architecture focusing on commercial buildings.

Tamarind Square is one of the commercial buildings in Malaysia which integrated courtyards into its building layout design, located in a 14.54-acre land in Cyberjaya. What makes Tamarind Square more special than other commercial buildings is the fact that it was built with the the intention to break away from the air-conditioned box malls, by reinventing the building approach that can adapt with tropical climates, particularly in Malaysia. Hence, the idea of a 'mall in the garden', a retail centre in the tropics, suited to the climate, culture and context, was born. Although the concept is relatively new in Malaysia, the developer believes it is a good idea to embark on commercial developments while helping to preserve a part of the country's green environment, combining both shopping and nature. Overall, Tamarind Square offers what is not found in a typical air-conditioned mall; a building that integrates nature and a community centre as part of meeting the purpose of a commercial centre. With this bold and new approach, where the past and the present were reinvented, Tamarind Square had won the PAM Pertubuhan Akitek Malaysia's Gold Award 2019 for Commercial Low-Rise category.

By selecting Tamarind Square as a case study, this research paper aims to investigate luminous environment of the existing courtyards at Tamarind Square in meeting the needs of the activities involved. These needs are examined by identifying the daylighting strategies in the Tamarind Square courtyard areas; whether the illuminance level provided is adequate or not to achieve visual comfort. The findings of this research is hoped to raise the value of the internal courtyard's role in architecture, in meeting the human needs for visual comfort

and increase the possibilities towards the development of internal courtyard in commercial buildings in the future.

LITERATURE REVIEW

Courtyards are outdoor spaces typically enclosed on three or four sides, functioned as a unique way to bring the outside in (Sara, 2020). In the early years of its existence, courtyards functioned as the primary meeting places for specific purposes including gardening, cooking, working, playing, sleeping, or even in some cases as places to keep animals (Edwards et al., 2006). The function later formed into a space that has social, cultural, religious, and environmental usage (Rong and Azizi, 2023). The application of courtyards 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). Besides, it also has an architectural design element that is adaptable to almost all building typologies in all the climatic zones due to its passive tendencies for low energy consumption in buildings (Markus, Malsiah and Lim, 2017). Other than architectural, social, climatic, cultural, and religious benefits, it also has potentials in creating economic benefits (Almhafdy et al., 2013).

Daylight is defined as direct daylight coming from sunlight. Indirect daylight diffuses or reflected (sunlight) in the atmosphere (Baker and Steamers, 2002). In this situation, direct sunlight produces heat and glare but is not suitable for task illumination as it creates visual problems for building users. Malaysia has the amount of daylight that is considered high with an average of 12 hours/day with the brightest hours for the west-coast between 0830 to 0930 hours and for east-cost between 0930 to 1030 hours (Fadzil and Sia, 2003), in which illuminance is about 80,000 lux, 70,000 lux and 60,000 lux respectively (Zain et al, 1999). Sky condition in Malaysia is predominantly intermediate sky as the sky is 0% clear sky, 85.6% intermediate sky and 14.0% overcast sky. Intermediate sky is defined as the sky that is neither clear nor overcast (Zain-Ahmed et al., 2002).

It is relatively easy to identify a comfortable environment. However, it becomes a challenge to describe a visually comfortable environment because the effect produced by ‘well-being’ and ‘satisfaction’ levels is not a single effect but a generic condition of well-being. If the space is well-lighted, then the subjects usually do not experience any significant visual discomfort (TERI, 2021. Guidelines for optimum visual comfort is derived from key performance parameters. Visual comfort is considered to be achieved once it meets its criteria. First, the criteria are to be able to fully describe light in terms of its source, its distribution, its tone and colour, and its intensity. Second, to be able to control light level. Both too little and too much light can cause visual discomfort. Third, to be absent in light sharp contrast. Sharp contrast or major changes in light levels

(which is perceived as glare) can cause stress and fatigue as the human eye is permanently adapting to light levels (The Saint Gobain Building Science Handbook, 2020).

METHODOLOGY

Inventory

Data collection of the study involved three courtyards located within Tamarind Square, Cyberjaya (2°55'10"N and 101°38'13"E) using an inventory and field measurement method. The three courtyards are the North court, the Centre Court and the South Court. An inventory was completed to investigate and study the courtyard criteria that have influence towards visual comfort.

Figure 1: Location of case study in Cyberjaya, Malaysia
(Source: Google Earth, retrieved on 5 February 2024)

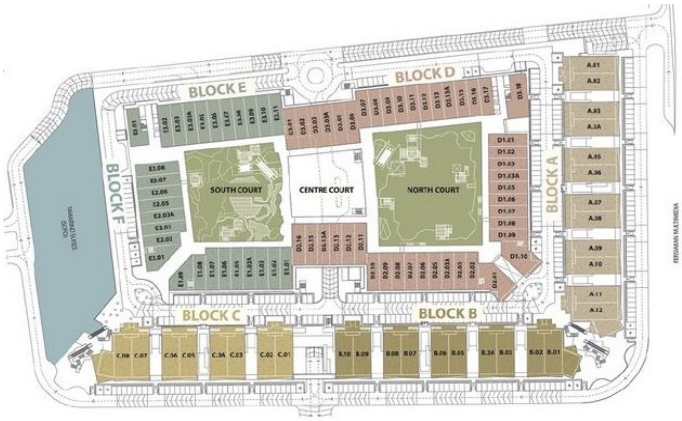

Figure 2: Location of North Court, Centre Court and South Court in Tamarind Square
(Source: tamarindsq.com)

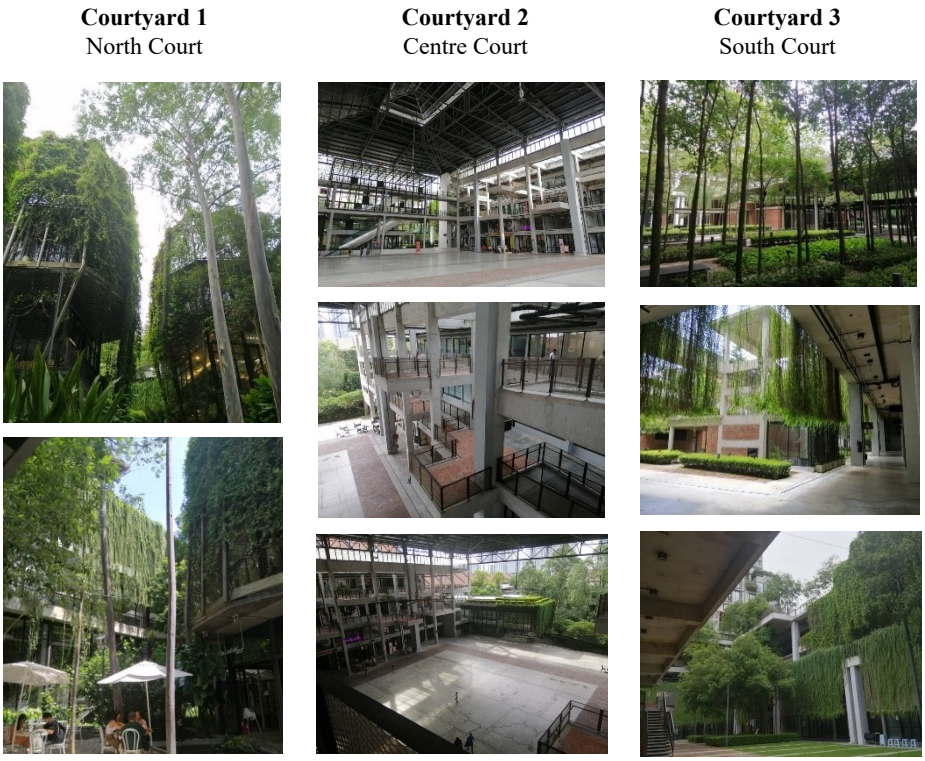

Figure 3: Courtyard's elements in three different court

Table 1: The parameters of courtyards case study at Tamarind Square

Item	Description	**Courtyard 1**	**Courtyard 2**	**Courtyard 3**
a.	Courtyard name	North Court	Centre Court	South Court
b.	Orientation	North	Center	South
c.	Courtyard size	52 m x 65 m	39 m x 39m	45.5 m x 65m
d.	Courtyard total area	3380 sqm	1521 sqm	2957.5 sqm
e.	Corridor Size	3.5 m	3.5 m	3.5 m
f.	Location	Center	Center	Center
Visual Comfort Parameter				
1.	Uniform distribution	X	√	X
2.	Optimal luminance	√	√	√
3.	Absence of glare	√	√	√
4.	Natural and artificial light	√	√	√
5.	Correct colours	√	X	√
6.	An access to views	√	X	√
7.	Adequate task lighting	√	√	√
	Assessment Score	6	5	6

Figure 4: North courtyard's sectional view and it's daylight design strategies

Figure 5: Centre courtyard's sectional view and it's daylight design strategies

Figure 6: South courtyard's sectional view and it's daylight design strategies

Field Measurement

Field measurement was conducted to collect illuminance levels data using a digital monitoring instrument, the lux meter. The instrument used for the field measurement study is a digital light meter known as SAUTER. This light meter is handheld with light-measuring levels ranging from 0.1 lux to 200,000 lux. The on-site measurements were intended to assess courtyard daylight strategies on

climate adaptation under local conditions. The important findings are related to the daylight strategies and the qualities of lluminous environments at the courtyard area.

The field measurement study was done by recording illuminance level of three different courtyards: the North Court, the Centre Court, and the South Court. Recording period was taken in 3 days on Sundays to get the average reading. Selections for time periods were based on the shops opening hours during daytime from 10 a.m. to 6 p.m. The timing is then divided into two period of time during daytime: Noon (Lunch) 01:00-2:00 and Evening (Tea) 5:00-6:00, as these two operational hours will have the negative affect of glare. P locations were positioned at the center of each grid as for along the East-West & North-south axis. P locations were arranged in linear formation perpendicularly to the grid. Sky illuminance according to the selected time period were captured at 100 000 lux – 90 000 lux (12 p.m. – 1 p.m.) and 30 000 lux to 10 000 lux (5 p.m. – 6 p.m.).

Figure 7: Digital light meter SAUTER

RESULT AND DISCUSSION

North Courtyard

Figure 8: Lux level at North courtyard at noon and evening

North courtyard has 97% of total reduction percentage of availability amount of light for noon and evening. According to MS 1525:2019, with reference to requirement of illuminance level, lux required is 750 lux for shops and 100 lux for corridor. Allowable illuminance level at the courtyard reached the highest reading at 3923 lux (more than required) and lowest illuminance level reading was 50 lux (less than required). This describes a fluctuation and inconsistency of illuminance level pattern at noon**.** Area shaded by trees has lower illuminance, while area exposed to the sun and unshaded have a rapid change in illuminance level. Meanwhile in the evening, illuminance level was stable and consistent as the sun already set to the west and has been filtered by the trees and shrubs. Most of the courtyard area was shaded by trees with different heights and random arrangement. Direct sunlight is filtered by trees creating a balance distribution of light. In the meantime, too many trees at certain area cause darkness.

The North courtyard used trees and shrubs as shading strategy. Creepers on tree house act as shading panel. This strategy allows the North courtyard to function as social activities area such as gathering place, photoshoot spot, resting area, and eating area. In terms of risk of glare, there is risk of glare but also risk of darkness in implementing trees as a shading strategy. Some areas become dark as the trees and shrubs blocked the sunlight. The North courtyard uses natural elements as choice of material. Pebble stones at walkway, steel at tree houses and concrete at floor and sittings areas are part of a strategy to reduce glare. In term of access to view, the North courtyard has access to view towards tree houses and greeneries. The colours that dominate the North courtyard are green colours as it is filled with greeneries.

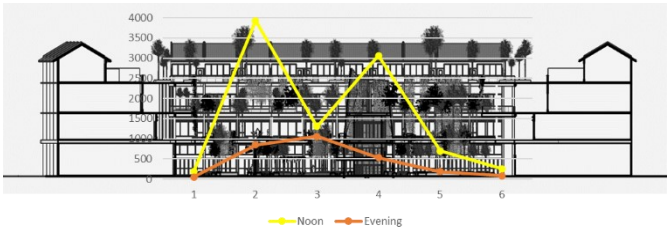

Figure 9: Comparison of average lux level noon and evening at North courtyard

Centre Courtyard

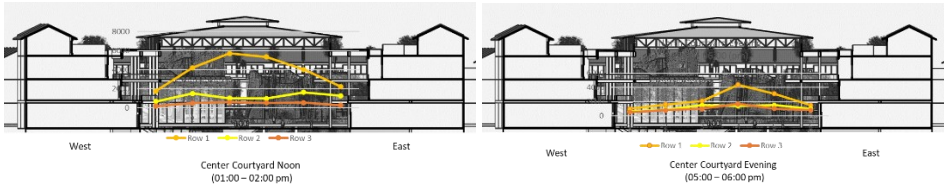

Figure 10: Lux level at Centre courtyard at noon and evening

The Centre courtyard has a total reduction percentage for noon and evening sun exposure of 98% - 93%, in terms of availability amount of light. According to MS 1525:2019 requirement of illuminance, maximum lux required is 750 lux for shops and minimum requirement of lux is 100 lux, that is applicable at the corridors. Allowable illuminance level at the courtyard recorded the highest reading at 2500 lux (more than required) and recorded lowest reading at 700 lux (more than required). This situation creates a stable and consistent uniformity of light at both noon and evening since the courtyard is covered by a roof and direct penetration of sunlight is thus controlled**.**

The Centre courtyard has a shading strategy by using a roof with side lit window at the roof tier. This allows the Centre courtyard to be utilized as an exhibition area, event space and recreational activities area. With this approach, it reduced the risk of glare from the sun. However, fully covered with cement floor with no trees planted around the courtyard area also cause some glare at the side area exposed to sunlight. Glare also happened at the open area exposed to sunlight in the evening as the sun is in a lower position than the roof. Neutral material is used as the chosen material at the Centre courtyard. The choice of material as in metal decking and steel roof structure, concrete with paint finish wall and column, and cement render floor do not help in reducing glare and providing a nice view at the courtyard. This approach also creates dull colours mood as in dominating colour effects.

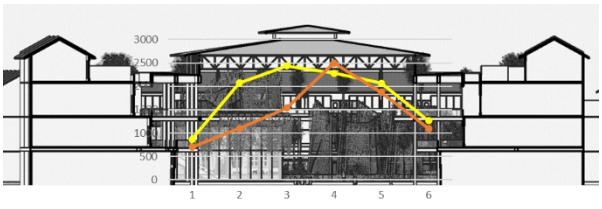

Figure 11: Comparison of average lux level noon and evening at Centre courtyard

South Court

Figure 12: Lux level at South courtyard at noon and evening

The South courtyard scores 90% - 78% of total reduction percentage of sun exposure for noon and evening. According to MS 1525:2019, illuminance requirement is 750 lux for shops and 100 lux for corridors. Allowable illuminance level at the South courtyard has the highest reading at 22500 lux (more than required) and the lowest reading at 473 lux (more than required). This pattern of readings affects the light uniformity at the South courtyard. At noon, the light uniformity pattern was fluctuated and inconsistent as the area shaded by trees has lower illuminance, while the area exposed to the sun and unshaded, has a rapid change in illuminance level. In the evening, the light uniformity pattern is more stable and consistent as the sun already set to the west and has been filtered by the trees and shrubs. Most of the South courtyard area is shaded by trees in a consistent height (5m) and in linear arrangement. Direct sunlight is filtered by trees which creates a balance distribution of light.

Shading strategy at the South courtyard are trees and shrubs. This strategy allows the center courtyard to function as social activities area such as gathering place, photoshoot spot and resting area. Choice of trees (vertical and monotonous in height) affect the glare control strategy as some areas are still exposed to glare. There is a risk of glare at areas exposed to sunlight. In terms of choice of material, exposed brick wall, and grass at ground level helps to reduce the risk of glare. The South courtyard has access to a view facing towards linear trees in the courtyard garden. The colour that dominates the South courtyard is green from the greeneries and earth colour from the walls.

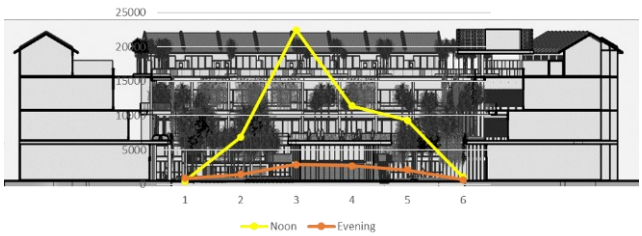

Figure 13: Comparison of average lux level noon and evening at South courtyard

Table 2: Comparison study on North, Centre and South courtyard in relation to visual comfort parameter

Visual Comfort Parameter	North Courtyard	Centre Courtyard	South Courtyard
Available amount of light	- Has appropriate brightness for performing task related to commercial building activities - Area that is too dense with greeneries causing darkness, need artificial light to help in achieving required illuminance.	- Has appropriate brightness for performing task related to commercial building activities.	- Has appropriate brightness for performing task related to commercial building activities.
Light uniformity	-A random planted of trees with a difference in height create an imbalance distribution of light around courtyard area.	-Covered with roof helps in creating a balance distribution of light especially during noon.	-Selection of trees higher than 5m in a linear arrangement create a more balance distribution of light around courtyard area.
Shading Strategy	- Good shading strategy - Sun exposure has been reduced up to 97%. - Selection of plants highly determined the effectiveness of the light filtered.	-Good shading strategy -Sun exposure has been reduced up to 98%.	-Good shading strategy. -Sun exposure has been reduced up to 90%. -Selection of plants highly determined the effectiveness of the light filtered.
Risk of glare	-Natural element absorbs light and reduce glare effect. -Leaf-green Reflection factor 20 - 25%, -Steel structure (black) Reflection factor – 0%, - Pebble stone – absorb light.	-Neutral colour of material absorbs light and reduces glare effect. -Bare concrete wall & column Reflection factor 30 - 35% -If painted white – Reflection factor - 100%, -Cement render flooring with glossy finish – produce glare.	-Natural element absorbs light and reduce glare effect -Leaf-green Reflection factor 20 - 25%
Choice of material	-Cooling environment effect	-Monochromatic environment effect	-Cooling environment effect

Visual Comfort Parameter	North Courtyard	Centre Courtyard	South Courtyard
Access to view	-Inward view all around courtyard -Create positive view -Heal visual fatigue	-Empty space with no view available -Create unpleasant view -No interesting visual experience	-Inward view all around courtyard -Create positive view -Heal visual fatigue
Colours	- Green – cooler colour -Relaxing to the eye -Psychological effect – Healing, calming, energizing -Cold colours help create the sensation that temperature is dropping.	-Bare concrete wall -- dull colour -Eye fatigue -Psychological effect - fatigue and boredom	-Green – cooler colour –Relaxing to the eye -Psychological effect – Healing, calming, energizing. -Cold colours help create the sensation that temperature is dropping.

CONCLUSION

To conclude whether the courtyard daylighting design strategy has the ability to provide good visual comfort or not is a challenge if it is justified according to the well-being of the users. Hence, this research paper decided to validate the visual comfort level through its parameters. Parameters are listed based on literature review that can specifically relate to courtyard criteria that influence daylight strategy in the courtyard areas. From the studies, it was found that the Tamarind's Square courtyards daylight strategy has two distinctive approaches. One is through greeneries, whereby multi-layered trees and shrubs are planted around the courtyard to reduce sun exposure and glare. This approach has been able to create a uniform distribution of light without having a direct exposure to the sun through the filtration from the tree leaves. The second one is through covered roof which is able to provide consistent shaded area at all times. However, this covered roof approach has limitations in terms of other aspects of visual comfort parameter as it only protects the courtyard from direct sun exposure.

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