JOURNAL OF ARCHITECTURE, PLANNING & CONSTRUCTION MANAGEMENT
Volume 14 Issue 1, 2024 E-ISSN: 2462-2222 ISSN: 2231-9514

COURTYARD VISUAL COMFORT ISSUES IN COMMERCIAL BUILDING IN TROPICAL CLIMATE MALAYSIA

Received: 05th June 2024 | Accepted: 28th June 2024 | Available Online: 07th July 2024

DOI: 10.31436/japcm.v14i1.882

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ABSTRACT

Courtyards, while effective as multifunctional open spaces and passive daylight strategies in buildings, face challenges in tropical climates such as visual discomfort due to intense solar radiation. Visual discomfort impacts outdoor activities, affecting the efficiency of courtyards. To understand this issue, Setia Walk Puchong has been selected as a case study. Observation, fieldwork measurement, and simulation are methods used in investigating visual comfort performance. The main issues identified include uneven light distribution, glare, and insufficient shading, suggesting the need for effective design solutions. Given the context of tropical climates, the study aims to explore architectural strategies that can enhance visual comfort and ensure courtyards remain functional and usable spaces. This involves adapting designs to mitigate issues such as uneven lighting, glare, inadequate shading, and other factors that impact comfort in courtyards. Optimal configurations like small, deep, and decentralised courtyards are among the strategies to provide shade effectively. Choosing elements such as layered greenery and independent structures that can help mitigate glare and manage illuminance levels are other strategies for ensuring courtyards are functional and inviting spaces in tropical climates.

Keywords: Courtyard, commercial building, tropical climate, visual comfort.

1.0 INTRODUCTION

Courtyards are outdoor spaces typically enclosed on three or four side, functioned as a unique way to bring the outside in (Sara, 2020). Courtyard originated from hot and dry regions has evolved in architecture for many centuries, since 10th millennium B.C. until today in a modern world expanding from both Eastern and Western country. In 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 to a space that has social, cultural, religious, and environmental usage. Starting from small scale courtyard house, then later developed to a bigger scale building such as commercial and institutional buildings (Tablada et al., 2005).

Courtyard was found to be applied in Malaysian terrace house as a solution to adapt with the elongated configuration (Hazwan, 2016). Meanwhile, courtyard is applied in commercial building as to solve the issue of massive and deep plan layout. Compact design of commercial building creates environmental and social issue. By introducing courtyard into the building, a

healthier environment can be created and contributed as an element that can motivate the customer to visit the building (Mee, 2021). It is believed that courtyard carries potentials to solve many problems for a very dense urban development (Edwards et al., 2006). In tropical region, a courtyard is an architecture design strategy that widely used to improve daylight in buildings. Besides, courtyard also offer social activity and pleasant view by connecting the indoor and outdoor spaces. According to Mee (2021), commercial building is not only served for shopping purpose, but also a place for people to gather and socialize. Hence integrating courtyard into commercial building could serve the needs in solving the issue of environmental and social aspects. Courtyard's potential and benefits can be efficiently applied in commercial buildings as it involves a bigger crowd and more relatable to public functions. All of these benefits can be an attraction and character for the commercial building itself.

Despite of the courtyard's potentials and advantages, having it applied in tropical countries seems to face some climatic constraint. Tropical countries received the amount of daylight with average of 12 hours per day which is considered high (Fadzil and Sia, 2003). In general, the brightest period of the year in Malaysia occurs from February to March, June and December, in which illuminance is about 80,000 lux, 70,000 lux and 60,000 lux respectively (Mee, 2021). This tropical climate condition allowed a space to be over exposed to sunlight that can lead to the problem such as inconsistent light distribution, inappropriate illuminance levels, and glare. Those problems create visual discomfort to the user especially in outdoor space like courtyard. Visual comfort is generally represented as a subjective reaction to the quantity and quality of light within any given space at a given time. If the space is well-lighted, then the subjects usually do not experience any significant visual discomfort (TERI, 2021). However, when light source is too little or too much, both situations can lead to visual discomfort issue in courtyard (The Saint Gobain Building Science Handbook, 2020). Besides the climatic constraints, courtyard design that neglect the issue of visual comfort can leads to dysfunctional and unmaintained courtyard. A visually discomfort courtyard environment will cause the courtyard to be left empty.

In order to examined and analysed visual discomfort issues at courtyard, observation to commercial building with courtyard around Kuala Lumpur and Selangor was conducted. The commercial building chosen are The Linc, Bangi Gateway, Tamarind Square and Setia Walk. All courtyards were analysed in terms of visual comfort performance. The Linc has an approach of small and deep courtyard. This approach creates a better control of illuminance level in the courtyard with the help of the existing trees as a shade element. Tamarind Square has a same approach with The Linc which used greeneries as shade element but with a bigger size of courtyard. However, too dense of greeneries planted create dark spot areas around courtyard especially around courtyard perimeter area. This situation caused visual discomfort as too little light is available. While Bangi Gateway courtyard was covered by roof, but the courtyard is fully paved. Though the courtyard is shaded, the absence of element like water elements and vegetation makes the courtyard dull and uninviting. Last but not least, Setia Walk was found to be the most exposed courtyard as the courtyard is wide and big. From the studies, it is to found out that Setia Walk courtyard has the most discomfort issues compared to others. To examine this issues, Setia Walk has been selected as a case study to represent a commercial building with wide and big courtyard, that is believed will consequently causes over exposure and visual discomfort.

This research objective is to identify visual comfort issues at courtyard focusing in commercial building. Once visual comfort issues are identified, courtyard characteristics that influenced visual comfort will be examined. Besides, when courtyard is chosen to be part of building design, it has to be adaptable to tropical climate constraints. Thus, all of these objectives lead to the research aim to explore architectural strategies that can help to improve visual discomfort that will makes the courtyard functional and usable space.

2.0 LITERATURE REVIEW

2.1 Visual comfort and discomfort

Visual comfort can be defined as the level of light transmission and glare in a building. These elements should be optimized for well-being and comfort, including the quantity and quality of light. Visual comfort is considered achieve once it meets its criteria. First criteria, is to be able to fully describe light in terms of its source, its distribution, its tone and colour and its intensity. Second criteria, is to be able to control light level and the third criteria, is to be absent in light sharp contrast (The Saint Gobain Building Science Handbook, 2020). Good daylighting design requires understanding a building's local climate, the location, placement, usage, shading strategy and skylights relative to their solar orientation. When designing for daylight, design teams should consider measures to control potential overheating and balance daylighting with various factors such as building form, building orientation, end user and use of space. (Lighting and Visual Comfort 2.0, 2020).

Meanwhile, poorly designed daylighting can create visual discomfort and glare issues. Poor daylighting design can introduce undesirable solar heat gain, causing discomfort and increase energy use (Lighting and Visual Comfort 2.0, 2020). According to The Saint Gobain Building Science Handbook (2020), both too little and too much light can cause visual discomfort. Important changes in light levels or sharp contrast, which is perceived as glare, can cause stress and fatigue as the human eye is permanently adapting to light levels.

In order to ensure a space achieved required level of visual comfort, it involves the measurement with the light intensity and illuminance level. In other words, the quantity of light received by a surface (Wienold, 2009). The required illuminance level needed for a certain task and activities can be referred to Malaysian Standard 1525:2019. Glare is hard to measure because how light is perceived is subjective and depends on several factors (including the age of the person). However, the baseline metric used for assessing glare is luminance within a person's field of view measured at a specific vantage point (cd/m^2). This is the amount of light reflecting off of a surface into a viewer's eye. Other rules of thumb include by avoiding an absolute illuminance value of 2,000 lux or greater (Wienold, 2009).

2.2 Courtyard Characteristics

Courtyard originated from the hot and dry regions has evolved in architecture for many centuries, since 10^{th} millennium B.C. until today in a modern world expanding from both Eastern and Western country. Starting from small scale courtyard house, then later developed to a bigger scale building such as universities and institutional buildings (Edwards et al., 2006). Though it is evolved in terms of its functions, courtyard characteristic and criteria shared similarities through all regions. The criteria of courtyard consist of form, orientation,

layout, ratios, elements, wall treatment, material, and colours. Based on its significant effects, only these criteria are selected: form, orientation, layout, and ratios.

Courtyard Form

In term of courtyard form, it comes in two categories, which the first category is based on forms (square, rectangular, circular, curvilinear, etc.) and the second category is based on shape (O, U, L, T, Y, etc.) (Ranjit, 2019). 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., 2013).

Courtyard Orientation

In terms of orientation, one of the most important factors that affects the duration of sunlight in buildings design is site layout. There are two main issues affecting site layout: orientation and overshadowing (Paul, 2011). The factors with direct impact on courtyard micro-climatic behaviour include; location of the sun, direction of the wind, shading effect and radiant heat (Bagneid, 2006).

Courtyard Layout

Meanwhile, for the layout criteria, the spatial layout of the courtyards can be divided into four categories according to their different compositions: centralized layout, decentralized layout, serial layout, and combined layout. In centralized layout, the courtyard space is at the core and becomes a central point of design. Decentralized layout is where the courtyard is surrounded by buildings, structures, and plants, with the buildings being scattered in the courtyard and connected by corridors. Serial layout is derived from the layout by organizing spaces through a series of courtyards with a strong spatial sequence. Combined layout merges the first three layouts, with a courtyard system not only visible in the overall layout but also in its different sections (Sun et al., 2019).

Courtyard Ratio

A geometrical descriptor has been developed to have a better understanding on courtyard's geometrical influences through several ratios descriptor that are: R_1 as the ratio of perimeter to height (P/H), R_2 as the ratio of width to length (W/L), and R_3 as the ratio of the area of the top opening to the area of the ground (At/Ag). Besides, Reynolds (2002) also has described the courtyard descriptors as AR is equal to ratio of width to height (W/H) that called as Aspect Ratio (Mee,2021).

Elements

Placing natural elements within a courtyard would produce environmental benefits. For instance, Safarzadeh & Bahadori (2005) found that trees, shrubs and flower plants as a garden element within a courtyard can significantly affect towards visual comfort as they provide shaded area with the wall of the courtyard. Al-Hemiddi & Megren (2001) studied the effect of using water body (pond) and water spray within the courtyard. It was found that the internal courtyard with a pool, tent and water spray during sunny hours provided significant cooling effect for the internal spaces surrounding the courtyard. 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 visual comfort performance of a courtyard as they provide shade.

Wall Treatment

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, 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 daylighting performance of the courtyard. They can also be influenced by opening or closing of the openings and by altering the wall to window ratio. Other scholars such as Muhaisen (2006) agreed that other preferences to look into when optimizing courtyard are the choice of the component material, colour and specifications.

Material

Courtyard character can be highlighted and strengthen by the selection of building material like roofs, column, walls, and floors. According to Khushboo (2014), courtyard in Baghdad and Cardova are characterized by using stone, marble and mosaic. While greenish brick, grey tiles, masonry panels are preferred material to be used at courtyard in China. Meanwhile Greek courtyard used mud brick or stone Most of the material used are a material that is locally available and adaptable to the local climate conditions.

Colour

Selecting a suitable colour for a site contributes a great deal to the general wellbeing of the user. In the same way, the finish of the surfaces contributes to creating pleasant visual conditions and pleasant work environment. Colour can be classified into three categories that are warm appearance, intermediate appearance and cold appearance. The colour used in a given space are among others key factors that influence the sensations a person feels. For instance, warm colour excites the nervous system, while cold colours have a calming effect (ILO Encyclopedia, 2011).

2.3 Relationship between visual comfort and courtyard characteristic

In designing a space to achieved visual comfort, the parameter that can affect and put into consideration are many. There are ten parameters that affect visual comfort. There are: (1) Glare control, (2) Shading strategy, (3) Uniform distribution of daylighting, (4) Adequate task lighting, (5) Optimal illuminance, (6) Good combination of natural and artificial light, (7) Window design, (8) Access to views, (9) Correct colours and (10) Choice of material (The Saint Gobain Building Science Handbook, 2020). To choose the parameter of visual comfort in order to provide the conditions necessary for visual comfort at courtyard, diagram as shown below are analysed. Table 1 shows the relationship between courtyard characters that influence visual comfort. Courtyard configuration; form, orientation, layout and ratio and elements have a close relation to visual comfort parameter.

From the literature studies, it can be concluded that, there are three visual comfort parameter that influenced the most towards courtyard design. The three parameters are; glare control, shading strategy and uniformly distribution of daylighting. These three parameters will be examined and analysed further in confirming how does courtyard characteristics can contribute in improving visual discomfort at courtyard.

Table 1: Visual comfort parameter relationship with courtyard characteristics

		Courtyard Characteristics							
No.	**Visual Comfort Parameter**	**Form**	**Orientation**	**Layout**	**Ratio**	**Wall treatment**	**Elements**	**Material**	**Colours**
1	Glare control	•	•	•	•	•	•	•	•
2	Shading strategy	•	•	•	•	•	•		
3	Uniform distribution of daylighting	•	•	•	•	•	•		
4	Adequate task lighting			•	•	•			
5	Optimal illuminance			•	•	•			
6	Good combination of natural and artificial light			•	•	•			
7	Window design			•	•	•			
8	Access to views					•	•	•	•
9	Correct colours					•	•	•	•
10	Choice of material					•	•	•	•

3.0 METHODOLOGY

There are three methods chosen for this research, which are; observation, fieldwork measurement and simulation. Observation was conducted to gather data by investigating people behaviours, activities, events, and notifying courtyard physical characteristics that contribute towards visual comfort or discomfort. Fieldwork measurement was used to collect data of illuminance level in examining courtyard's visual comfort through quantitative method. Meanwhile, 3D simulation model was conducted to analyse the shade effect as the implication of building configuration and orientation.

3.1 Background Study

In order to proceed of which building to be chosen as the case study in examining courtyard visual comfort issues in commercial building, studies to all commercial buildings with courtyard around Kuala Lumpur and Selangor was conducted. From the studies, four commercial buildings that apply courtyard as part of the development layout has been shortlisted. Those buildings are, The Linc Kuala Lumpur, Tamarind Square Cyberjaya, Bangi Gateway Bangi, and Setia Walk Puchong. These four building was finalized based on the courtyard criteria fulfilled by those buildings. However, among those four buildings, Setia Walk

courtyard was found to be fully exposed. Thus, it was chosen to be studied further and examine if there are issues arise at the courtyard area.

Setia Walk located in Puchong (3°N 101°E) is a mixed development consisting of retail blocks, offices, an entertainment complex and serviced apartments. It was completed in the year of 2014 and developed by the SP Setia's group, considered to be a hybrid development between shop offices and shopping malls. With an approach of open layout designed in a 20.8-acre site, it contains 506 lot number of stores, at 6 storey building height.

3.2 Observation

The development was designed around a central courtyard, with courtyard perimeter surrounded by terrace and corridor. Meanwhile, the centre courtyard was designed with greeneries, water features, and decking with sittings as shown in Figure 1. Water features act as the main element of courtyard as its cover almost most of the courtyard area. Water element that is represented as a reflecting pool in a random design form, following through the site shape throughout the centre of the courtyard act as cooling elements and climate modifier.

Legend

1. Entrance
2. Drop off area
3. Water Columns
4. Stainless Steel Water Feature
5. Reflecting Pool
6. Performing Stage
7. Timber Deck
8. Plaza
9. Water Jets
10. Play Sculpture
11. Water Play Element
12. Jets Platform
13. Lawn
14. Fun Pool
15. Climbing Web
16. Sand Pit
17. Feature Fountain
18. Rocks with Mist jets
19. Outdoor Dining/Plaza
20. Amphitheatre Seating
21. Cascading Water Feature
22. Performance stage
23. Lighting Globe

Fig. 1: Setia Walk Puchong Mix-development plan layout around centre courtyard
(Source: https://www.stxla.com/page_media/setia-walk)

To make the water is approachable by the user, wide decking is introduced. This wide decking allows a platform for many activities such as recreation, dining, and retail plaza. However, the existence of the reflecting pool and decking that dominate most of the courtyard area, effect the location of greeneries, in which most of the greeneries are planted around courtyard perimeter. The greeneries at the perimeter of courtyard create a shade area right next to the restaurant and shops, so that the user can have an outdoor time out and rest area after dine and shopping.

A checklist was prepared and observed during visits to Setia Walk Puchong. The visits were conducted by 3 visits during weekends on Sunday. The checklist is as per Table 2 and Table 3. Table 2 is to examine a checklist on courtyard criteria of Setia Walk Puchong. Table 3 is to identify what kind of activities happened at the commercial building (Setia Walk Puchong) and how does the courtyard is functioned in order to fulfilled those activities. Commercial opening hours are from 10 a.m. to 10 p.m. However, observation timing set up was only from 10 a.m. to 5 p.m. which is during the courtyard is exposed to daylight.

3.3 Fieldwork measurements

Field measurement have been conducted to collect illuminance levels data using a digital monitoring instrument lux meter. The instrument used for the field measurement study is a digital light meter SAUTER (Figure 2). This light meter is a handheld with light-measuring levels ranging from 0.1 lux to 200,000 lux. The on-site measurements intend to assess courtyard daylight illuminance level on tropical climate condition. The findings are related to the qualities of luminous environments at the courtyard area. Field measurement study was conducted by recorded illuminance level at ten different courtyard points. Recording period was taken in 3 days on Sunday from 10 a.m. to 5 p.m. to get the average reading. Sky illuminance according to the selected time period are 100 000 lux – 90 000 lux (12 p.m. – 1 p.m.) which at this time is considered as the brightest hour of the day.

Fig. 2: Digital light meter SAUTER

3.4 Computer Simulation

Sketch up Pro 2021 is a convenient 3D modelling tool, ease the complicated modelling process and minimized time consumption to build up the model effectively (Mee, 2021). With these advantages, Sketchup Pro 2021 has been used to generate preliminary building massing for Setia Walk Puchong plan layout to indicate the check point for illuminance study as per Figure 3 and Table 3. The preliminary building massing is also used to study the shadow pattern at Setia Walk Puchong with the time period of commercial operational hour during daytime that is from 10 a.m. to 5 p.m. as shown in Figure 10. The height of the model is following the height of Setia Walk building that is 6 storey height with 4 m height for each floor. Thus, the total building height for the building massing is 24 m.

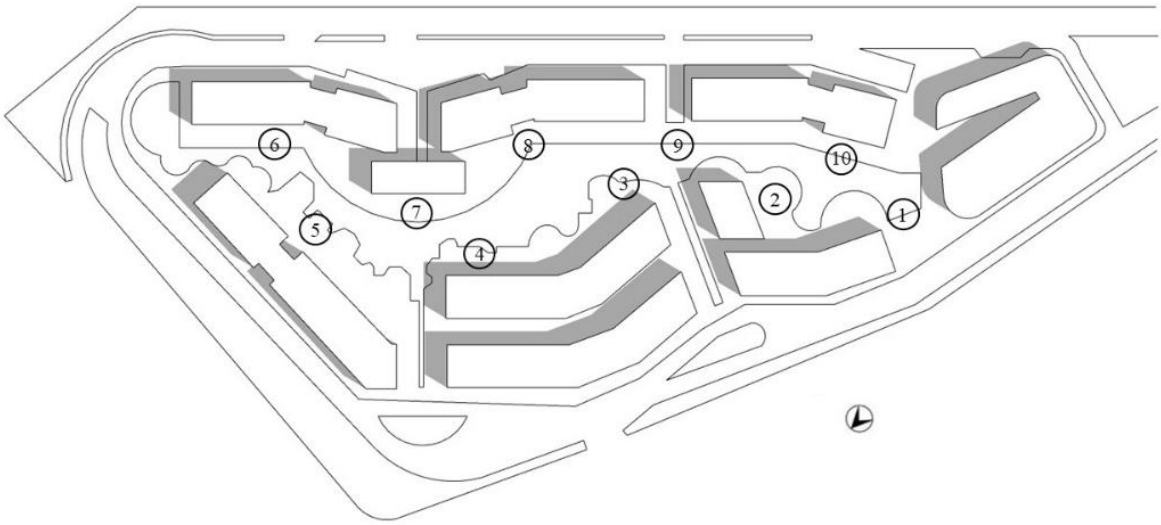

Fig. 3: The location of check point from 1 to 10, for the study of illuminance level at Setia Walk Puchong

4.0 RESULTS

The research main objective is to identify visual comfort issues at courtyard in commercial building. From the literature study, three visual comfort parameters have been shortlisted in relation to courtyard characteristic. Through observation, the checklist was confirmed on site. The inventory list was checked and analysed based on the visit conducted at Setia Walk Puchong. The results of the observation during visit to Setia Walk Puchong are as per Table 2.

Table 2: Setia Walk Puchong courtyard characteristics

Courtyard Characteristics			Visual Comfort	Visual Discomfort	Remarks
1	Courtyard Form	Irregular and enclosed at all side		√	Uncontrolled illuminance
2	Courtyard Orientation	North East		√	Less shade
3	Courtyard Layout	Centralized layout		√	Uncontrolled Illuminance Unshaded Glare
4	Courtyard Ratio	Wide and big		√	Uncontrolled Illuminance Unshaded Glare
5	Elements	Water features		√	Glare
		Greens	√	√	Shade/Unshaded
		Decking	√		Shade

Courtyard Characteristics			Visual Comfort	Visual Discomfort	Remarks
6	Wall Treatment	Perimeter corridor	√		Shade
		Brick wall	√		Absorb glare
		Aluminium framed tinted glass window	√		Absorb glare
7	Material	Plaster and paint finished brick wall	√		Absorb glare
		Timber decking	√		Absorb glare
8	Colours	White	√		Cool colour
		Green	√		Cool colour
		Yellow	√		Cool colour

From Table 3, it is to observe that most main activities were happened indoor, such as dining, meeting place, recreational, lounging, and shopping. This is due to indoor is shaded and protected from sun. Some seating is provided at outdoor area for dining, at the same time act as meeting place. Since the decking is wide, the user can walk through and experience the courtyard and the pool easily. The greeneries and the pool that act as main attraction elements create and provide nice view towards the courtyard, thus can also became a photoshoot spot for the visitors. The existence of greens and water as part of natural elements also act as climate modifier and at the same time also act as healing space.

Table 3: Commercial functions and activities at Setia Walk Puchong

No.	Functions & Activities	Indoor	Decking	Green area	Pool
1	Dining	•	•		
2	Walking		•	•	
3	Meeting place	•	•		
4	Photoshoot spot		•	•	•
5	Recreational	•			
6	Lounging	•			
7	Park			•	
8	Shopping	•			
9	Climate modifier				•
10	Healing space			•	•
11	View			•	•
12	Shades	•			

Thus, from these two observation checklists, it is to conclude that, Setia Walk Puchong courtyard faced visual discomfort issues. The issues are uncontrolled illuminance, glare, and lack of shaded area.

4.1 Uncontrolled illuminance

Visual discomfort issues identified at courtyard includes inconsistent distribution of light. Inappropriate illuminance whether too little or too much light can give negative affect to visual performance of the user to do a certain task (The Saint Gobain Building Science Handbook, 2020). Due to the inconsistency of distribution of light, it leads to uncontrolled illuminance level at the courtyard area.

The use of the courtyard in buildings was originally initiated in the hot and dry climatic regions of the world. However, in the tropic, the concept of courtyard imported from the western countries rather than adapting and applying the concepts into tropical courtyards (Edwards et al., 2006). Inappropriate design of courtyard in the tropic, can lead to poor daylight quality due to the unpredictable changes in daylight availability (Lim & Hamdan, 2010). This happened in the cause of the sky condition in Malaysia is variant due to the inconsistent cloud formation (Ahmad, 1996).

(1) 2200 lux (4) 35410 lux

(6) 7700 lux (9) 10750 lux

Fig. 4: Setia Walk Puchong different courtyard location at point (1), (4), (6), and (9) with inconsistent distribution of light.

Table 4: Setia Walk Puchong illuminance levels at courtyard area and its adjacent space

Illuminance levels- Lux			
Check-point	1st 3-meter (Corridor)	2nd 3-meter (Decking)	Centre Courtyard
1	20	16000	22000
2	75	20000	24500
3	350	21000	23000
4	105	21500	35410
5	3300	18200	21500
6	500	7700	27100
7	105	13500	32000
8	450	11450	28750
9	290	10750	49500
10	550	50600	52100

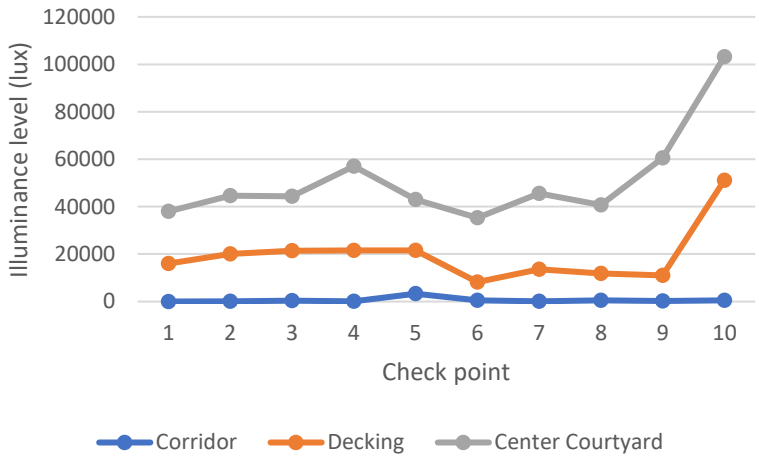

Fig. 5: Analysis of Setia Walk Puchong inconsistent illuminance levels at courtyard area and its adjacent space

From the data collected and examined as per Table 4 and Figure 5, the illuminance level at corridor is at the range of 20 lux to 3300 lux. The average lux reading at corridor are 575 lux. According to MS Standard 1525:2019, the minimum lux required for walkway is 100 lux. This mean the corridor is well lighted. It was the daylight from the courtyard that lighted the space during daytime. For the decking area that is exposed and open, the range of illuminance level are from 7700 lux to 50600 lux. Since it is open to the sky, the illuminance level fluctuates drastically at a certain point and show inconsistency for the overall reading. Meanwhile, the illuminance level at the centre courtyard fluctuates even more drastic and inconsistent at most of the check points at the range of 21500 lux to 52100 lux, with the difference of 30600 lux from the lowest and the highest reading. The needs for the activities such as eating for these two open areas, according to MS Standard 1525:2019, only 200 lux is required. While the illuminance available at courtyard way too high at the extra of 31386 lux. These fluctuate illuminance level is due to inconsistency condition of cloud which affect visually discomfort for the outdoor activities. Activities like eating and shopping are preferred at indoor space and

if are provided outdoor, only a limited period of time can be fully used especially during shaded period like early in the morning or late evening.

4.2 Glare

The other issue is glare. Courtyard is an open space exposed to direct sun exposure. Difficulty of doing various activities in an open space due to sun exposure and glare led to increase the needs to specialized indoor space for other activities independently such as hall etc. Courtyard that offers an abundant space for social and public activities can be abandoned caused by excessive sun exposure (Fekry, 2015).

Glare is one aspect of lighting that can cause discomfort to the occupants of a space. Glare happened when there is an excessive amount of light coming directly from a source. The human eye can function quite well over a wide range of luminous environments, but it cannot function well if extreme levels of brightness are present. Thus, it is necessary to ensure glare is kept under control (Ander,1995). Careful design of the shape and orientation of a courtyard can be used to reduce glare (Zuraini, 2004). If the courtyards are not designed properly according to the site orientation and sun path, they can easily block the benefits of natural lighting and replace them with glare (Tulisha, 2022). Glare is hard to measure because how light is perceived is subjective and depends on several factors. One of the methods to diminish glare is to avoid an absolute illuminance value of 2,000 lux or greater.

(5) 21500 lux (10) 52100 lux

Fig. 6: Setia Walk Puchong over exposure courtyard area at point (5) and (10) leads to glare and dysfunctional during noon

From the observation conducted during the fieldwork study, the size of the courtyard that is too wide and shallow, allow too much sun exposure to the courtyard area as shown in Figure 3. Meanwhile, the existence of the reflecting pool along the courtyard increases the risk of glare as the daylight also has possibility to be reflected on the pool surface. Although the water from the pool can act as a cooling effect, high illuminance level during noon that can reach up to 52100 lux does not help in providing good visual comfort environment by minimizing the absence of glare. These two factors, size of the courtyard that is wide and shallow, and existence of reflecting pool at most of the courtyard area, are the main contributing factor that cause glare to the courtyard. From the data collected and examined

as per Figure 7 shows that, all the check point illuminance level reach way too high above 2000 lux. This show that most of the courtyard area are prone to the risk of glare. With the reading range from 21500 lux to 52100 lux, extreme levels of brightness are present, and glare was not kept under control.

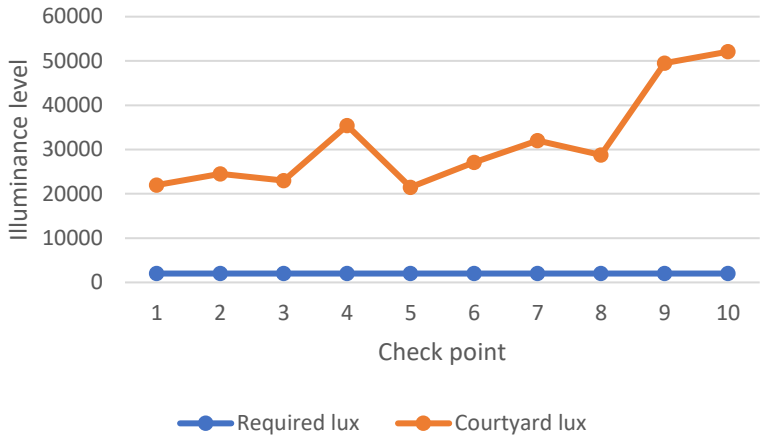

Fig. 7: Setia Walk Puchong courtyard illuminance reading over 2000 lux that caused glare

4.3 Lack of shaded Area

Issues of lack of shaded area also part of the constraint that effect by the tropical climate. Courtyard open space with lack of shades always left empty or treated with minimal architectural and landscape elements leads to courtyard dysfunctional, defeating the purpose of its existence at the first place. While courtyard can offer a lot of social and psychological effect to the user, as it left empty due to lack of shaded area leads to decreasing of its functionality.

(6) 770 lux (8) 11450 lux (10) 550 lux

Fig. 8: Limited Setia Walk Puchong shaded courtyard area covered by trees and corridors at point (6), (8) and (10)

As per shown from the pictures from Figure 8 shows that, at Setia Walk Puchong, the trees were planted around the courtyard but was not in the consideration to provide enough shades. Most of the trees selected are on the purpose of aesthetics. The canopy of the tress is not wide enough to cover and blocked the open courtyard area with shades. The location of the trees is mostly planted at the perimeter of the courtyard area defeat the purpose of the trees, as it can block light to the adjacent space but does not cover the exposed area at the centre of the courtyard that need to be shaded the most.

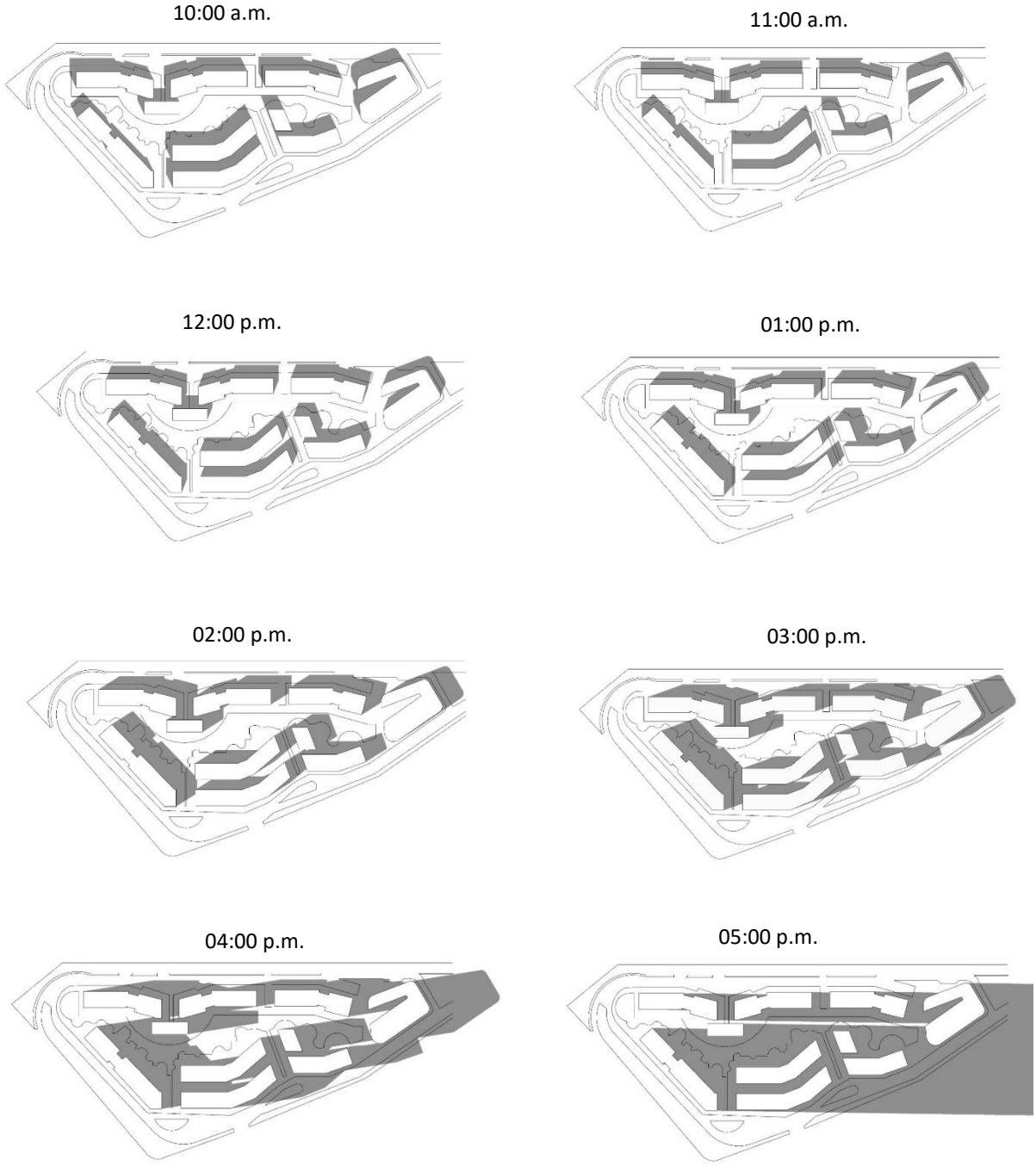

Fig. 9: Shadow simulation at Setia Walk Puchong during daytime operational hour from 10 a.m. to 5 p.m. in March

Meanwhile, as per Figure 9, simulation was done in March, that is considered the brightest month of the year, shows that the building mass cannot give enough shade for the courtyard. The courtyard was almost exposed to sun at most of the time from 10 a.m. to 3 p.m. The building mass only can help in providing shades at courtyard towards evening period of time from 4 p.m. to 5 p.m.

5.0 DISCUSSIONS

Uncontrolled illuminance affected by the courtyard form and ratio. Irregular form with wide and big courtyard size allows too much sun exposure in the central courtyard area. As the layout is centralized, open area is focused at one space and have a maximum opening size. Thus, illuminance levels were hard to control and stabilized. According to MS 1525:2019, most of activities in commercial building that can be extended to the courtyard area such as dining, recreational, healing and social activities only required minimum of 100 to 200 lux and maximum of 750 lux for shopping. Lux level at centre courtyard reach from the range of 21 500 lux to 52 100 lux. The deference of average lux reading with the minimum required lux is 36 050 lux. This reading definitely will not be inviting the user to facilitate and used the courtyard though there are a lot of attraction provided.

Meanwhile, glare occurred due to inefficiency in prioritizing courtyard elements and courtyard size. Water element that has more risk towards glare was dominating the courtyard compared to greeneries that can provide shade. Water is considered as reflective surface. When light hits the water surface, it will cause glare. Choosing water element as the main element and place it at the centre courtyard will not help to improve visual comfort but just will make it worst especially during noon. The reflective effects can cause visual discomfort not just to the user eye but will also cause them preferably to stay indoors. Besides, centralized courtyard design approach is not a good design strategy in this big site area. Though courtyard supposed to bring natural lights inside a building by punch the deep plan layout, but having it centralized without considering its proportion to the perimeter space can cause over exposure that leads to visual discomfort issues.

The two factors that effects glare, that are courtyard ratio and placements of greeneries, also a contributing factor that leads to lack of shaded area. From the simulation results, the courtyard was almost fully shaded only in 1 hour from the total of 7 hours during daytime operational period. The enclosed buildings that were within the perimeter of courtyard are considered low in height in comparison to the length and the width of the courtyard area. This configuration creates a wide and big open courtyard. Thought the buildings are around its perimeter, but it is not enough in height to cast a deeper shades area. Besides, although existence of the reflecting pool in the middle of the courtyard can act as a cooling element, but this approach can lead to limited and minimum area allowed for greeneries. While most of the greeneries are planted around its perimeter, the shade coming from the buildings and the greeneries are redundant. This approach may allow an immediate shaded area for the user to relax after shopping and dining, and invite them to be closer to the courtyard. However, it is only limited to the perimeter where it was planted but the rest of the area is exposed. A visually comfort area may be provided by the shade of the greeneries, but to the exposed area, will definitely cause visual discomfort.

6.0 CONCLUSION

In adapting to tropical climate, it is important to identified the climatic constraint to make the courtyard functional and efficiently used. As the original origin of courtyard coming from hot and dry climatic region, the application of courtyard in tropical climate does needs special consideration. The availability of sun throughout the year with the brightest period at noon leads to the problem of uncontrolled illuminance, glare and lack of shadowed area at courtyard. These leads to visual discomfort issues, that can make courtyard always left empty and dysfunctional. From the studies and research conducted, it is to conclude that, in achieving visual comfort, the strategies need to be considered in designing tropical courtyard are:

1) Uncontrolled illuminance:

- A good approach for courtyard design in tropical climate is small and deep as it provides cool shades instead of wide and big courtyard.
- Decentralized courtyard (pocket courtyard) is preferred compared to centralized courtyard to have a better control of lights and illuminance level.
- Courtyard proportion should be in small courtyard size (length and width) and proper ratio (height more than length and width) in order to control sun exposure.

2) Glare:

- Elements that should be prioritized in designing courtyard in tropical climate are elements that can reduce glare.
- Water features need to be minimized in tropical courtyard design as the reflection of water is one of the main sources of glare.
- Courtyard design layout need to have elements that can filter glare, such as multi layered height of greeneries or independent structure with shading devices.

3) Lack of shaded area

- A courtyard layout design that prioritizes greeneries over water features and decking to act as shade elements.
- More scattered greeneries at the centre of the courtyard instead of around its perimeter to provide more shade as the area are more exposed to sun.
- Building height should be high enough in order to provide more shade.
- Building height is considered as the most efficient approach towards creating shade at courtyard as the shadow casted will be provided at most of the time during daytime and can covered a wide range of shade at courtyard area.

Commercial building is one of the most potential building typologies that can implement courtyard as part of the building layout as it is a public building and courtyard is an interesting public open space. This kind of style can induce strong character, create a healthier building with an open space that promotes positive environmental and social connection. By understanding the constraints of tropical climate condition at courtyard through the research conducted, architectural approaches that can help to improve visual comfort are found to be highly affected by its configuration and elements. Small, deep, and decentralized courtyard is a good configuration for optimal shade. Selection of elements that can provide shade, filter high illuminance and avoid glare such as multi layered height of greeneries and independent structure will leads to create a more functional and usable courtyard space.

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