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Exploratory Survey of Recessed Window Façade Shading in Johor Bahru Malaysia

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The built environment is a major source of global energy consumption and greenhouse gas (GHG) emissions potentially exacerbating the threats of climate change. With global rising temperatures, the energy requirements for cooling and ventilating buildings in tropical nations like Malaysia will soar geometrically. Scientists around the globe are exploring several technologies to address the challenges posed by building emissions and energy consumption. One of the main methods is the application of passive design strategies such as external façade shading or self-shading. Studies indicate one of the most practical self-shading technique is recessed window facades (RWF) which can easily integrate without reducing natural light and obscuring views. However, studies on the RWF are limited in literature particularly in Malaysia. This research aimed at carrying out an exploratory survey of recessed window façade (RWF) shading in selected buildings in Johor Bahru Malaysia. The RWF buildings characteristics namely; Window-Wall Ratio (WWR), Recessed Depth (RCD), Shading Ability (SHA), Solar Heat Gain Coefficient (SHGC) and Shading Coefficient (SC) will be examined. The results indicated that the values for solar heat gain and shading coefficient are within acceptable limits. Furthermore, the high shading ability of the buildings indicated that RWF might be responsible. Further studies are required to ascertain empirical correlations between the examined characteristics. This further study will potentially improve the design of more energy efficient, low emission and thermally comfortable buildings for the future.

1. Introduction

The built environment is a major contributor to greenhouse gas (GHG) emissions, global warming, and climate change. It is estimated that over 24 % of global carbon dioxide (CO_2) emissions originate from energy consumption in buildings (Gillott and Spataru, 2010). This consumption is largely due to the energy needed for cooling, heating, ventilation, and lighting (Široký et al., 2011) to create effective spaces for occupants' thermal comfort (Ma et al., 2012). In the warm and humid tropical climate of Malaysia, extreme solar heat gain (Lim et al., 2013) accounts for high energy demand for cooling and ventilation systems (Saadatian et al., 2013). The operational energy consumption in buildings exceeds their embodied energy consumption resulting in increased GHG emissions (Gillott and Spataru, 2010). There is an urgent need to address these challenges and safeguard the future of the planet.

The integration of energy efficient design, renewable energy technologies (Chow, 2010) and low carbon building materials are potential solutions (Dodo et al., 2015). Sustainable design strategies such as retrofitting, natural ventilation and daylighting can also reduce energy consumption and improve energy efficiency in buildings (Gillott and Spataru, 2010). Babatunde and Ogunsote (2011) observed that good façade shading design (FSD) is one of the most effective strategies for minimising solar transmission into buildings. The study revealed that FSD could ensure desirable daylighting and passive heating in buildings; thereby reducing energy consumption without compromising the thermal comfort of occupants.

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The heat gained by the ESD is diverted from the window by radiation (Jagersma, 2012) and airborne convection currents (Aljoaba, 2013). ESDs face serious challenges such as strong anchorage against wind load resistance, distorting building aesthetics, and thermal bridging issues (Totten et al., 2008.). The most practical solution is to design self-shaded buildings. The form of the building can be designed to act as an external shading device (ESD). Shading devices can considerably reduce energy consumption in buildings by 23 – 89 % depending on the type of shading device, building orientation and climatic conditions (Dubois, 1997). Shading devices should be integrated to a building's facade at an early design stage to ensure effective energy savings. This can be achieved by traditional design tools like solar path diagrams and shading masks or purposed design computer programs (Noble and Kensek, 1998) that automatically "generate" the optimum shading device geometry as a function of a set of input parameters (Szokolay, 2014).

One of the most practical self-shading alternatives is the use of deeply recessed window facades (RWF). Such designs can reportedly minimise solar heat gains by creating an ESD from the entire wall around the opening of windows in buildings. RWFs can be efficiently integrated into buildings without reducing natural light (Hensley and Aguilar, 2012) and obscuring views (Wood and Salib, 2013). Another important sustainable passive design (SPD) consideration for energy efficiency, daylighting and emissions reduction is the orientation of the building. The requirements for shading depend mainly on building orientation and climate (McGee, 2013).

Figure 1 presents an example of provision of shade using mixed shading, inclusive of recessed wall façade for optimum shading to cool buildings. The deployment and integration of the outlined sustainable design practices can potentially reduce the energy demand for cooling and ventilation in Malaysian buildings. There is limited research on recess window facades (RWF), their applications and effects on cooling and ventilation on energy in Malaysian buildings. The study will present the results of an exploratory survey of recessed window shading facade in selected buildings in Johor Bahru, Malaysia. The findings of the study will assist architects, engineers and policy makers in the design of more energy efficient, low emission and thermally comfortable buildings for the future.

Figure 1: Mixed exterior shading strategies

2. Methodology

The study was carried out in Johor Bahru, the capital of Johor Darul Takzim (JDT) in Malaysia located on Latitude 1.4927° N (1° 28' 0" N) and Longitude 103.7414°E (103° 45' 0" E). The procedure involved physical surveying to observe the characteristics of Recess Wall and Window Façades (RWF) of the selected buildings in Johor Bahru. The selected buildings are; Jay Hotel, Hong Leong Bank, KTC City Centre, Wisma Rakyat, Citrus Hotel, Wisma KWSP, and Wisma TMT and S. The selection was made base on the characteristics exhibited by the buildings among others, as enumerated in Tables 1 - 3. The selected buildings were photographed using a lens compact camera (Model: Sony-12.1 Mega Pixel, 4× Optical Zoom intelligent auto (26 mm wide angle lens) for analysis and comparison with similar buildings in literature. This method is adopted because of the constraint of direct contact with the buildings. The observation was made from the photographs and parameters observed were recorded. The comparative analysis of the recess window façades (RWF) buildings was evaluated based on several parameters, Tables 1 - 3. These include Window to Wall Ratio (WWR), Recess Depth (RCD), Shading Ability (SDA), and Solar Heat Gain Coefficient (SHGC) Shading Coefficient (SC) among others from the buildings based on the checklist derived from the previous studies in Table 1. The SC can be calculated from the SHGC using the relation – (SC = SHGC/0.87). A SHGC of 0.50 is equal to SC of 0.50/0.87 = 0.57, Table 3. SHGC was predicted considering the measured and observed WWR, WGZ, BOT and RCD.

Table 1: Checklist Guidelines for RWF Survey Analysis.

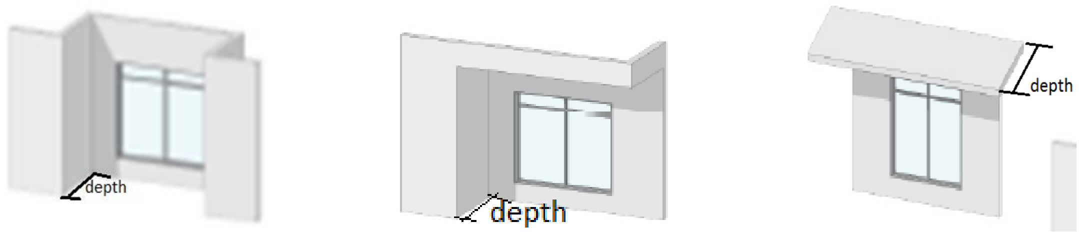
Property	Abbr.	Shading Ability and Thermal Performance			
		Low	Moderate	High	Reference
Window to Wall Ratio	WWR	75 – 100%	50 – 74%	0 – 49%	(Krüger, 2010)
Window Glazing	WGZ	Clear Glass	Tinted	Reflective	(Selim, 2008)
Solar Heat Gain Coefficient	SHGC	1.0 – 0.7	0.6 – 0.4	0.3 – 0.0	
Recessed Depth	RCD	0.0 – 0.3 m	0.4 – 0.6 m	≥ 0.7 m	(McGee, 2013)
Building Orientation	BOT	North	South	East-West	(Krüger, 2010)

Based on the outlined criteria, the properties of the RWFs will be evaluated to deduce valuable data for the design and deployment of future energy efficient and low emission buildings in Johor DT, Malaysia.

2.1 SHGC and Shading Ability (SDA)

The SHGC is the ratio of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. SHGC expressed as a number ranges between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits and the higher the shading ability (Efficient Windows Collaborative, 2016).

Figure 2 illustrate depths of recessed façade and horizontal overhang. This parameter affects the shading ability of the shading strategy. Higher depth increases the shading ability and lower the value of solar heat gain coefficient thereby enhances the performance of the shading devices.



(a) Composite vertical recessed (b) Composite right + horizontal (c) Single horizontal overhang

Figure 2: Recessed façade window and horizontal overhang depths

2.2 Building orientation of hot and humid climate

Orientation for passive cooling in hot and humid climate is about blocking the sun as a source of free home heating by reducing the direct solar radiation penetration through the window. This strategy is done by setting the building’s fenestration out of the direct rising and setting of the sun.

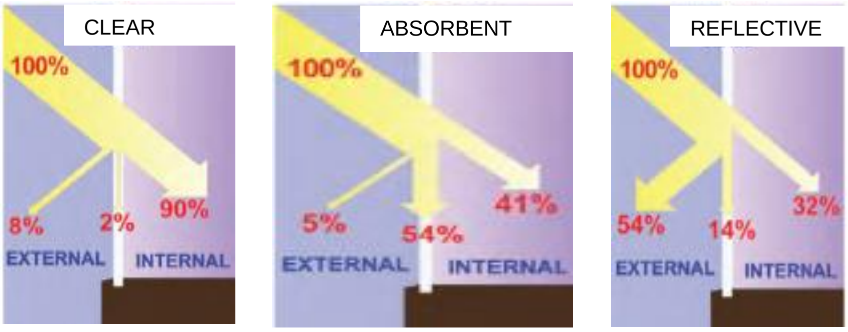
3. Result and discussion

The characteristic properties; Building Orientation, Window Glazing, and Window Framing, of the selected RWF shaded buildings, are presented in Table 2. As can be observed, the buildings comprise of aluminium framed windows. The choice of aluminium is primarily due to its importance as an insulation material with good reflective and mechanical support as well as high solar reflect index (50 - 56). It is a relatively cheap window framing material with low emittance (0.03 – 0.04), low infrared emittance (0.25) and a solar reflectance (0.06) (McGee, 2013). The outlined properties may account for the choice of aluminium as window framing in the selected buildings investigated.

Table 2: Characteristics of RWF Buildings in Johor Bahru Malaysia.

SN	Selected Building	Orientation	Window Glazing	Window Framing
1	Jay Hotel	East	Black Tint	Aluminium
2	Hong Leong Bank	East	Blue Tint	Aluminium
3	Wisma Rakyat	East	Clear Glass	Aluminium
4	Citrus Hotel	East	Reflective Glass	Aluminium
5	Wisma KWSP	South	Blue Tint	Aluminium
6	Wisma TMT and S	South	Reflective Glass	Aluminium
7	KTC Building	South	Black Tint	Aluminium

The window glazing used in the buildings ranged from clear to reflective glass to tints. The most commonly used window glazing were clear glass which empirical evidence submits leads to excess solar heat. Excessive glazing on façades must be avoided in building design to prevent solar heat gain particularly in tropical countries like Malaysia. In general, the type, design, and glazing of windows in buildings influence energy performance. The orientation of buildings is a crucial parameter in assessing the potential energy requirements for heating, cooling, and ventilation. Building orientation and window glazing colour affect the amount of light entering the building, thereby influencing energy consumption as illustrated in Figure 3. According to the US Department of Energy study on High-performance commercial buildings, the southern geographical orientation is the most ideal.



(a) Clear glazing (b) Tinted/absorbent glazing (c) Reflective glazing

Figure 3: The thermal performance of various glazing type

As observed in Table 2, three of the selected buildings are oriented to the south. The architect's design may have opted this orientation to shade the Sun at South solstice and reduce unwanted solar gain. In effect, this will help capture adequate daylight to decrease lighting energy load of the building. Conversely, the RWF of the remaining four buildings is inclined to the east which according to the US DoE makes it harder to control sun angles, glare and solar heat gain (US Energy Information Administration, 2015). Figure 4 presents photos of the RWF of the selected buildings in Johor Bahru, Malaysia. Figure 4 clearly illustrates the degrees of thermal performance of each glazing type in buildings. The reflecting glazing shows the greater rejection of heat penetration compares to other two glazing types by blocking 68 % of solar transmission into the building. The absorbent or tinted glazing performed moderately by shielding the building from the effect of solar radiation by 59 %; although there is a likelihood of rerelease of some absorbed one into the interior, despite that, clear glazing performed very poorly by intercepting solar radiation by only 10 %. This performance shows the weak nature of the clear glazing in building design for passive cooling. Conversely, clear glazing is recommended in passive heating and can also be used in the north side orientation.

Figure 4: Photographic comparison of RWF buildings in Johor Bahru Malaysia

Based on the photographs, observation, and on-site measurements the characteristics of the selected RWF buildings were computed as presented in Table 3. The terms WWR, RCD, SDA, SHGC, and SC, denote Window to Wall Ratio, Recessed Depth, Shading Ability, Solar Heat Gain Coefficient and Shading Coefficient respectively.

Table 3: Characteristics of RWF Buildings in Johor Bahru Malaysia

SN	Selected Building	WWR (%)	RCD (cm)	SDA (%)	SHGC	SC
1	Jay Hotel Building	50.00	45.00	50.00	0.50	0.57
2	Hong Leong Bank	25.00	22.50	45.00	0.45	0.52
3	Wisma Rakyat Building	65.00	22.50	75.00	0.25	0.29
4	Citrus Hotel	65.00	15.00	55.00	0.45	0.52
5	Wisma KWSP	25.00	22.50	45.00	0.55	0.63
6	Wisma TMT and S	50.00	15.00	55.00	0.35	0.40
7	KTC Building	50.00	45.00	55.00	0.35	0.40

As observed in Table 3, the Window to Wall Ratio (WWR) of the RWF buildings ranged from 25 – 65 with an average of 47.14. The WWR is defined as the ratio of the window area to the gross exterior wall area (Krüger et al., 2010). It is typically determined by the ratio of the total glazed area to the external wall area of the building (Ferdous and Gorgolewski, 2014). In general, it is an important variable that also influences the energy performance of buildings, particularly regarding daylight and ventilation.

The Recessed Depth (RCD) of the RWF buildings ranged from 15 – 45 cm with an average value of 26.80. Similarly, the shading ability (SDA) ranged from 45 – 75 % with an average of 54.30 %. This range indicates that buildings were shaded adequately from solar heat gain. The Solar Heat Gain Coefficient (SHGC) for the RWF buildings ranged from 0.25 – 0.55 with an average of 0.40. The Shading Coefficient (SC) ranged from 0.29 – 0.63 with an average value of 0.48. The SHGC and SC (Selim, 2008) were observable within the limits of 0.0 - 1.0 for materials (Chen et al., 2012)

4. Conclusion

The paper presented results from the exploratory survey of recessed window façade (RWF) shading in selected buildings in Johor Bahru, Malaysia. The RWF buildings characteristics namely; Window to Wall Ratio (WWR), Recessed Depth (RCD), Shading Ability (SHA), Solar Heat Gain Coefficient (SHGC) and Shading Coefficient (SC) were examined. The results indicate that the values for solar heat gain and shading coefficient are within acceptable limits. The shading ability of the buildings was high indicating that RWF may be responsible. Further studies are required to ascertain empirical correlations between the examined characteristics. This correlation will potentially improve the design of more energy efficient, low emission and thermally comfortable buildings for the future.

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