Passive Design Approach to Improve Energy Efficiency for Office Building

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Abstract

This research aimed to investigate the impact of passive design techniques on building envelope design. Whereas assessment of the heat transfer rate through building envelopes is frequently done using the OTTV standards worldwide. The research includes two parameters for measuring the thermal performance of the building facade. The first measurement uses a methodical approach to calculate the wall's thermal transmittance (U-values) and then moves on to calculate the OTTV. The OTTV of the case study was computed using the OTTV formula given by the Malaysian Standard. At the same time, building specifications were determined via a site examination. After that, the OTTV was compared with a recommended standard value for the local climate. New building materials and specifications are proposed when the OTTV value exceeds the standard range. The results indicated that the present OTTV value is 55.31 W/sq.m, more significant than the proposed value for a standard commercial building. It recommended considering 6 mm single glazing low e-glass for all windows on the East, West, South, and North elevations. As a result, the OTTV was lowered to 45.34 W/sq.m. Since air conditioning consumes most of the energy in an office building, lowering the OTTV will result in a slightly reduced air-conditioning cooling load.

Keywords
Green Building, Building Facade, Thermal Transmittance, Tropical Climate, Energy Efficiency

1. Introduction
The effect of greenhouse gas emissions has been acknowledged worldwide, and there is an urgent need to advocate for efforts to regulate primary energy usage around the globe (Sheng et al. 2020). According to studies (Min et al. 2022; Zhang et al.2022), buildings currently account for up to one-third of all worldwide greenhouse gas emissions, mainly due to the use of fossil fuels during the construction phase. The building industry uses up to 40% of all energy and produces up to 30% of the world's annual greenhouse gas emissions (Lakhiar et al. 2021). A substantial portion of the overall energy demand for buildings is accounted for by the electricity necessary to maintain inhabitants' thermal comfort level. In the United States, heating, ventilation, and air-conditioning systems account for 37% of the total

energy used in the construction industry (Santamouris 2016); in Japan and Hong Kong, commercial buildings consume 25% to 30% of the total energy in the construction industry for heating and cooling (Natephra et al. 2018). In addition, air conditioning in large office buildings consumes a significant amount of power in Thailand, especially during the summer (Natephra et al. 2018). In the same situation in Malaysia, air conditioning devices in office and residential buildings require tremendous amounts of electrical power, mostly on hot days. Building designers encountered several obstacles when maintaining a comfortable environment using less energy (F Abass et al. 2020). One way to encourage GHG reduction is to consume less energy. As one of the biggest power consumers, buildings may significantly improve energy efficiency and GHG elimination via innovative building design (Chan & Chow 2013). In order to reduce the usage of energy, architects who "play a vital role" in building design must create energy-efficient structures. They must create buildings that consume less energy during the planning, constructing, and operating phases, sometimes even by adapting and retrofitting existing or old buildings (Hariyadi et al. 2017). T

he construction sector is one of the most significant energy users. Hence policymakers frequently implement and enforce building energy indices to guide building design in an energy-efficient direction (Lakhiar & Lakhiar 2021). Metropolises like Kuala Lumpur are much more vulnerable to the urban heat island effect due to their fast expansion and unsustainable modern way of life (Singh et al. 2020). In general, an urban heat island is characterised by an increase in temperature in a metropolis compared to nearby rural areas (Heaviside et al. 2017). When assessing thermal building design for occupant thermal comfort, it is critical to minimise energy usage and carbon dioxide emissions(Vakalis et al. 2021) because any variation in the external air temperature would affect the inside air temperature. In return, it will harm the environment, production, and people's physical and mental health. Additionally, an urban heat island will raise peak electricity consumption. (Cianconi et al. 2020). Building designers must be more conscious of thermal envelope performance and structural material selection to improve building energy efficiency.

Building thermal performance may be ascribed to modelling heat transmission between the building envelopes and their surrounding environment. Thermal performance is simply the process of exchanging heat via glass and opaque walls (F Abass et al. 2020). A building envelope, which includes the facade and roof, is the structure's exterior face that includes fenestration and other components that define the building's shape and aesthetics, allow for indoor climatic control, and protect inhabitants from weathering (Rathore et al. 2022). In order to regulate indoor temperature and reduce the amount of energy needed for heating and cooling, the building envelope is crucial. The choice of material for the building envelope must be made carefully to prevent excessive heat transmission to maintain a pleasant temperature in the building efficiently. According to studies (Yu et al. 2015; Zhang & Yang 2019), the envelope accounts for 20-50% of cooling and heating energy consumption. Conventional materials such as concrete, glass, and bricks are usually utilised in construction in Malaysia. Several studies have identified such materials as the source of non-comfort conditions for indoor areas in a hot and humid climate (Lakhiar et al. 2022; THAPA, 2020). The primary causes of indoor discomfort are the thermal transmitter and the roof construction materials (F. Abass et al. 2020). Leong (Leong 2009) estimates that just 5% of the heat from a single-storey building penetrated through the roof, contrasted to 50% for a double-story building. The rising concern regarding building thermal performance and energy efficiency prompted the establishment of numerous policies. Several governments around the globe have undertaken initiatives to reduce energy consumption in the construction sector (Gul & Patidar 2015). They have begun to enforce energy-saving design guidelines in an effort to develop more efficient building designs. Building energy conservation regulations are introduced as part of an energy policy to foster conservation and reduce energy consumption in building structures (Chan, 2021). Building energy conservation rules or standards promote the creation of energy-efficient building products, increase awareness of building energy conservation concerns, and provide a foundation for evaluating the energy performance of buildings (Chan 2021; Natephra et al. 2018).

Two building standards are frequently used to evaluate the thermal performance of a building envelope worldwide: (1) Thermal insulation standards, primarily, are employed in cold areas. Thermal transmittance values (U-values) of the envelope material are measured using this standard, (2) Overall Thermal Transfer Value (OTTV) building regulations are often employed in hot areas, particularly in Southeast Asia. On the contrary Overall Thermal Transfer Value (OTTV) is among the performance-based methods for regulating the design of an energy-efficient building envelope. In contrast, OTTV is a measure of the overall heat gain transferred into a structure through the building envelope that governs building design to achieve a reasonable OTTV limit in order to reduce electricity consumption from air-conditioning systems and hence greenhouse gas emissions from power production plants (Chan 2021). Moreover, the OTTV regulation applies to mechanically cooled buildings. OTTV has emerged as one of the most significant parameters for new or existing building envelope design, particularly for office buildings, to decrease heat gain and hence minimise the cooling load of the air conditioning system (Karim et al. 2019).

1.1 Objectives

The main objective of this research is to assess the thermal performance of office building facades in Malaysia's tropical environment. In order to accomplish this objective, the thermal performance of the chosen case study will first be assessed using the steady-state U-value and OTTV standardised calculation method and a comparison will be conducted to the minimal standards outlined in MS 1525:19. Recommendations are proposed if the value is higher than the standard value until this criterion is fulfilled.

2. Literature Review

2.1 Thermal transmittance or U-values

Generally, one of two construction standards is used to assess the thermal performance of a structure's exterior walls: Thermal insulation regulations are employed in cold areas. Whereas the thermal insulation standard adopts thermal transmittance (U-values). Further, it is utilised to measure the thermal transmittance (U-values) of wall structure and materials. in hot locations, the overall thermal transfer value (OTTV) standard is employed (Bahdad et al. 2021). Thermal transmittance (also known as U-value) is one of the most critical properties defining the building envelope's energy behaviour (Bienvenido-Huertas et al. 2018). The concept of thermal transmittance, widely referred to as U-values, has emerged as an essential standard for assessing the thermal performance of a building façade and showing steady-state thermal transfer performance (Tejedor et al. 2017). Thermal transmittance, or U-Value, is the amount of heat energy that passes through a particular element per unit of area and time.

This indicates that when thermal transmittance is low, conductive heat may be transported between interior and external environments (Nasir & Hassan, 2020). There are two methods for determining the thermal transmittance of an opaque building façade: computation based on EN ISO 6946 and in-situ measurement utilizing heat flux meter analysis or a thermometric approach based on ISO 9869. The U-value of glazing is a measurement of conduction heat gain through the glazing unit; the lower the value. Less heat is transferred through the glass. In contrast to SHGC, the U-value of glass has a much less impact on the energy consumption of buildings in tropical climates. An example of the criteria for the U-value of building envelopes in cold-climate regions is specified in British Standards (BS) EN ISO 8990. It serves as a measuring standard for the U-Value of building elements such as walls, roofs, and floors, as well as BS EN ISO 12567-1 for windows and doors and BS EN ISO 12567-2 for roof lights. Rather than U-value, the OTTV is recommended and regarded as a superior indicator since it considers the impact of solar heat gain on the façade (Bahdad et al. 2021).

2.2 Overall thermal transfer value (OTTV)

OTTV is a frequently used technique for evaluating the thermal performance of building envelopes in warm regions. It is utilised to evaluate heat gained from the outside through a building's envelope and how much energy an air conditioning system requires. The OTTV calculation has three key components: (i) conduction through an opaque wall, (ii) conduction through fenestration, and (iii) solar radiation through fenestration (Seghier et al. 2022). A building usually has two sets of OTTV, one for the external walls (OTTVwall) and one for the roof (OTTVroof). The weighted average of the OTTVs of a building's external walls and roof gives the OTTV of the entire structure (Seghier et al.2022).

Malaysian government introduced the Overall Thermal Transfer Value (OTTV) as a thermal performance index for building façade of commercial building energy standards in 1987 (Nasir & Hassan 2020). Since then, the OTTV formula has been modified multiple times to match the standards of local construction methods and Malaysia's tropical climatic conditions. The concept is included in the Malaysian Standards MS1525, which permits buildings with air-conditioned areas larger than 1000 sq.m to take into consideration OTTV values lower than or equal to 50Wm-2. In accordance with Malaysian Standards MS1525:19, The OTTV is defined as a design parameter representing solar thermal load transferred through the building envelope except for the roof. According to research conducted in Malaysia, (Aun, 2009), heat conduction must be regulated between 0.2 and 5% of the computed OTTV, whereas heat conduction via windows accounts for 10-20% of the component of OTTV. Solar radiation, an essential element in OTTV, accounted for 70-85% of the prescribed OTTV. The OTTV is considered a superior measure to thermal transmittance (U-value) since it considers the effect of solar heat gain on the facade (Hassan & Nasir, 2016). The greater the OTTV, the greater the cooling demand for the air conditioning system (Nasir & Hassan, 2020).

The initial OTTV formula, developed by ASHRAE Standard 90:75, included considering building design characteristics and climatic parameters. The initial OTTV formula provided in (1) presumes that for a particular climatic region, the climatic and the local parameters remain constant; these parameters are expressed by the solar factor (SF), equivalent temperature difference (TDeq), and temperature difference (ΔT). These factors represent average values for solar radiation and outside ambient temperature. As stated in equation (1), the general OTTV equation may be represented in terms of WWR following ASHRAE 90A-1980 (Standard 1975).

$$OTTV_{ASHRAE} = TDeq\ (1-WWR)\ UW + \Delta T\ (WWR)\ Uf + CF \times SF\ (WWR)\ SC \quad (1)$$

In Malaysia, the most recent OTTV formula (2) established by Malaysian Standards MS1525:14 replaces these parameters with numerical coefficients to reduce the complexity of the estimation calculation.

$$OTTV_{MS1525:19} = 15\ \alpha\ (1-WWR)\ UW + 6\ WWR\ Uf + (194 \times OF \times WWR \times SC) \quad (2)$$

Where:
WWR = The window-to-gross exterior wall area ratio for a specific orientation
UW = U-values of the wall (W/m²·K)
Uf = U-values of fenestration (W/m²·K)
∝ = Solar absorptivity of wall
SC = Shading Coefficient of the glazing
OF = Orientation Factor
SHGC = Solar heat gain coefficient
The method of computing OTTV for this paper is based on Malaysian Standard 1525:2019, as indicated below:

$$OTTV = (A1 \text{ x } OTTV1) + (A2 \text{ x } OTTV2) + \ldots + (An \text{ x } OTTVn) / A1 + A2 + \ldots + An \quad (3)$$

Where:
A1, A2 = Gross exterior wall area for orientations 1 and 2
OTTV2 = OTTV value for orientation 1 from equation (2)

2.3 Case study

In this study, an office building, i.e. Wisma Rehda, located in Kelana Jaya, Petaling Jaya, Selangor, was used as a case study to investigate the OTTV of a building, as shown in figure 1. Initially, the Wisma Rehda was constructed by Real Estate and Housing Developers' Association Malaysia (REHDA) with consideration of sustainability features. The construction was finished in 2012 before the association introduced its GREEN rating certification (GreenRE) in 2013. Wisma Rehda is a three-storey building with a total built-up area of 29,000 square feet. However, Malaysian developers face significant challenges in designing and building structures that can withstand the hot and humid climate. For instance, Wisma Rehda is designed to face south to prevent direct sunlight. It is recognised as a green building because of its efficient energy use, water conservation systems, and passive ventilation. In contrast, its double skin feature is given significant attention. Further, each office space is oriented on the north and east sides of the building, whereby they are well protected from direct sunlight.

Figure 1. Wisma rehda building

3. Methodology

The study methodology begins with identifying the building specifications, i.e. building envelopes such as glass type, thickness and properties, then proceeds to the mathematical calculation of thermal transmittance and the overall thermal transfer value (OTTV). The calculation comprises three criteria of the OTTV formula: i) heat conduction through walls, ii) heat conduction through window glass, and iii) solar radiation through window glass. These three criteria will be determined using the variables: U-Value, Shading Coefficient (SC), and Window-to-Wall Ratio (WWR). Building information like the facade and window area of all four building elevations is obtained as a constant in OTTV calculations. The results are compared to Malaysian Standard 1525:2019 in the final stage. The OTTV of commercial buildings with a total air-conditioned area of 4000 sq.m and above shall not exceed 50 W/sq.m under MS 1525:2019. The best feasible new building specifications will be recommended to achieve OTTV of less than 50 W/sq.m if present building specifications contribute to OTTV greater than 50 W/sq.m. However, Figure 2 illustrates the overall research methodology. The goal is to improve design efficiency while preserving the present facade appearance and other architectural aspects of the building.

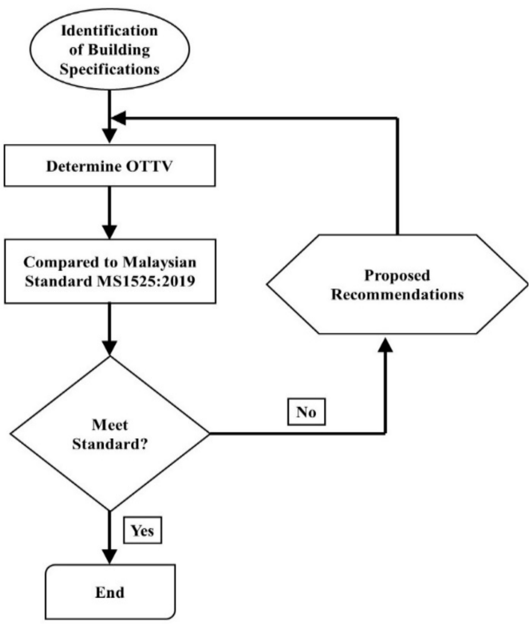

Figure 2. Research Methodology

4. Data Collection

4.1 Building Specifications

The initial data was gathered through the case study of the three-story Wisma Rehda building. Based on the building's elevation, the walls are split into four parts: North, east, south, and west. Figure 3 depicts the views of each wall elevation. During a site visit, a wall's solar absorption factor (α) was determined to be 0.29. In contrast, a laser distance meter was utilised to carry out side measurements to calculate the area of the facade and windows.

Furthermore, The entire windows are made of single clear glass with a U-value of 5.85 W/m²·K. Similarly, the U-value of each wall is projected to be 1.29 W/m²·K, except south type 1a-1b wall = 1.77 W/m²·K. Solar orientation correction factor, CF for each window is 1.23 for East, 0.94 for West, 0.92 for South, and 0.9 for North.

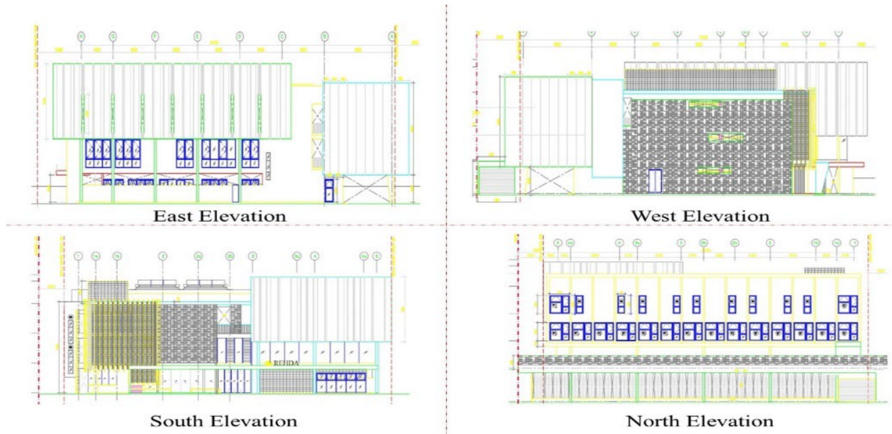

Figure 3. Elevations of the case study building

5. Results and Discussion

5.1 Mathematical Calculations

The calculation begins by determining the U-value of the opaque wall and glass. The study uses the ISO 6946 calculation method to calculate the wall U-value. The formula below is used to achieve this aim.

$$\text{Thermal transmittance, U-value} = 1 / (\sum R+Ri+R0)$$

Where R = the thickness of each layer (mm) / the thermal conductivity of that layer, k (W/mK)
Therefore, Brick Wall, U-value = 1.29 W/m²·K; U-value south type 1a-1b wall = 1.77 W/m²·K .
For the thermal transmittance (U-value) of glazing, Since the façade is constructed from single-glazed tinted material, a value of 5.85 W/m²·K is determined.
Under Malaysian Standards (MS1525:19), the overall thermal transfer value (OTTV) equation may be represented as follows:

$$OTTV = 15\,\alpha\,(1-WWR)\,UW + 6\,WWR\,Uf + (194\times OF\times WWR\times SC)$$

The overall thermal transfer value (OTTV) includes three methods of thermal transfer across building façades: heat conduction through opaque walls, heat conduction through transparent windows, and solar heat gain through transparent windows. Figures 4 -7 depict the division of the thermal transfer method formulas as indicated in the OTTV formula per Malaysian Standards (MS1525:19). The calculation findings of each constituent thermal transfer method responsible for OTTV are shown in Figures 4 -7.

Figure 4 indicates the OTTV calculation on the east facade of the building, and the finding showed that solar heat gain through windows has a significant contribution to the OTTV on the east facade, mainly as a result of the selection of window material. It contributed around 28.45 W/sq.m out of the total 61.76 W/sq.m heat gained, dominating 46.07% on the overall OTTV. These results were compatible with Yao and Zhu's (Yao & Zhu 2012) finding that windows are the building envelope's weakest spot in terms of lowering building energy consumption. The second highest component of the OTTV is heat conduction through opaque walls, which accounts for 27.05 W/sq.m and 43.79% of all heat transfer through the facade. This figure is considerably more significant than the recommended threshold, which is between 0.2 and 5% of the total OTTV. Heat conduction through windows accounts for a minor percentage of total OTTV, accounting for just 10.13% of total OTTV. The quantity of heat conduction through windows fulfils the recommended percentage and generally constitutes 10%–20% of the overall OTTV.

Similarly, the OTTV calculation on the west facade is shown in Figure 5. The result demonstrated that heat conduction through the opaque wall is the most significant parameter of the OTTV, accounting for 5.57 W/sq.m, representing 80.37% of all OTTV on the west facade. Solar heat gain through windows constitutes 1.08 W/sq.m indicating 15.54% of total OTTV. Heat conduction through windows contributes 0.28 W/sq.m, representing 4.04% of overall OTTV on the west facade.

Figure 6 presents the OTTV calculation on the South facade of the building. It showed heat conduction through opaque walls contributed first at 69.86 W/sq.m, accounting for 61.12%. It resulted from the wall's vast area, followed by solar heat gain through windows at 33.96 W/sq.m reflects 29.71%, heat conduction through windows at 10.47 W/sq m indicates 9.16% of overall OTTV on the west facade.

The results highlighted that solar heat gain through the windows contributes significantly to the OTTV for the north facade, as shown in Figure 7. It obtained 20.50 W/sq.m of a total of 38.27 W/sq.m representing 53.56% of the overall OTTV of the north facade. Whereas heat conduction through opaque wall accounts for 9.66 W/sq.m and 25.24% of all heat transfer through the facade, heat conduction through windows contributed 8.11 W/sq.m and 21.19% of overall OTTV on the north facade.

Compt.	Wall	Area	Const.	α	WWR	1-WWR	U-Value	CF	SC	OTTV	A x OTTV
Heat Conduction through Opaque Wall	East (E-1)	602.6	15	0.29	0.067	0.933	1.29	-	-	5.24	3154.93
	East (E-2)	602.6	15	0.29	0.084	0.916	1.29	-	-	5.14	3097.44
	East (E-3)	602.6	15	0.29	0.019	0.981	1.29	-	-	5.50	3317.24
	East (Stair)	602.6	15	0.29	0.003	0.997	1.29	-	-	5.59	3371.35
	East (D-R)	602.6	15	0.29	0.005	0.995	1.29	-	-	5.58	3364.58
Equation for Heat Conduction through Walls = 15 x α x (1-WWR) x Uw										∑	16305.54
Heat Conduction through Windows	East (E-1)	602.6	6	-	0.067	-	5.85	-	-	2.35	1417.13
	East (E-2)	602.6	6	-	0.084	-	5.85	-	-	2.95	1776.71
	East (E-3)	602.6	6	-	0.019	-	5.85	-	-	0.67	401.87
	East (Stair)	602.6	6	-	0.003	-	5.85	-	-	0.11	63.45
	East (D-R)	602.6	6	-	0.005	-	5.85	-	-	0.18	105.76
Equation for Heat Conduction through Windows = 6 x WWR x Uf										∑	3764.92
Solar Heat Gain through Windows	East (E-1)	602.6	194	-	0.067	-	-	1.23	0.72	11.57	6973.16
	East (E-2)	602.6	194	-	0.084	-	-	1.23	0.56	11.30	6812.31
	East (E-3)	602.6	194	-	0.019	-	-	1.23	0.94	4.26	2568.13
	East (Stair)	602.6	194	-	0.003	-	-	1.23	0.63	0.46	275.74
	East (D-R)	602.6	194	-	0.005	-	-	1.23	0.72	0.86	520.38
Equation for Solar Heat Gain through Windows = 194 x CF x WWR x SC										∑	17149.72
											∑ Wall OTTV =37220.19
											∑ Wall Area =3013
											OTTV =61.76

Figure 4. East facade OTTV calculation

Compt.	Wall	Area	Const.	α	WWR	1-WWR	U-Value	CF	SC	OTTV	A x OTTV
Heat Conduction through Opaque Wall	West (W1)	586.56	15	0.29	0.008	0.992	1.29	-	-	5.57	3265.15
Equation for Heat Conduction through Walls = 15 x α x (1-WWR) x Uw										∑	3265.15
Heat Conduction through Windows	West (W1)	586.56	6	-	0.008	-	5.85	-	-	0.28	164.71
Equation for Heat Conduction through Windows = 6 x WWR x Uf										∑	164.71
Solar Heat Gain through Windows	West (W1)	586.56	194	-	0.008	-	-	0.94	0.74	1.08	635.46
Equation for Solar Heat Gain through Windows = 194 x CF x WWR x SC										∑	635.46
											∑ Wall OTTV=4065.31
											∑ Wall Area=586.56
											OTTV=6.93

Figure 5. West facade OTTV calculation

Compt.	Wall	Area	Const.	α	WWR	1-WWR	U-Value	CF	SC	OTTV	A x OTTV
Heat Conduction through Opaque Wall	South (Type 1a)	63.9	15	0.29	0	1	1.77	-	-	7.70	492.00
	South (Type 1b)	63.9	15	0.29	0	1	1.77	-	-	7.70	492.00
	South (Type 2) W1	341.38	15	0.29	0.004	0.996	1.29	-	-	5.59	1907.99
	South (Type 2) W2	341.38	15	0.29	0.012	0.988	1.29	-	-	5.54	1892.67
	South (Type 2) W3	341.38	15	0.29	0.013	0.987	1.29	-	-	5.54	1890.75
	South (Type 2) W4	341.38	15	0.29	0.045	0.955	1.29	-	-	5.36	1829.45
	South (Type 2) W5	341.38	15	0.29	0.011	0.989	1.29	-	-	5.55	1894.58
	South (Type 2) W6	341.38	15	0.29	0.033	0.967	1.29	-	-	5.43	1852.44
	South (Type 2) W7	341.38	15	0.29	0.042	0.958	1.29	-	-	5.38	1835.20
	South (Type 2) W8	341.38	15	0.29	0.035	0.965	1.29	-	-	5.42	1848.61
	South (Type 2) W9	341.38	15	0.29	0.049	0.951	1.29	-	-	5.34	1821.79
	South (Type 2) W10	341.38	15	0.29	0.054	0.946	1.29	-	-	5.31	1812.21
Equation for Heat Conduction through Walls = 15 x α x (1-WWR) x Uw										∑	19569.67
Heat Conduction through Windows	South (Type 1a)	63.9	6	-	0	-	5.85	-	-	0.00	0.00
	South (Type 1b)	63.9	6	-	0	-	5.85	-	-	0.00	0.00
	South (Type 2) W1	341.38	6	-	0.004	-	5.85	-	-	0.14	47.93
	South (Type 2) W2	341.38	6	-	0.012	-	5.85	-	-	0.42	143.79
	South (Type 2) W3	341.38	6	-	0.013	-	5.85	-	-	0.46	155.77
	South (Type 2) W4	341.38	6	-	0.045	-	5.85	-	-	1.58	539.21
	South (Type 2) W5	341.38	6	-	0.011	-	5.85	-	-	0.39	131.81
	South (Type 2) W6	341.38	6	-	0.033	-	5.85	-	-	1.16	395.42
	South (Type 2) W7	341.38	6	-	0.042	-	5.85	-	-	1.47	503.26
	South (Type 2) W8	341.38	6	-	0.035	-	5.85	-	-	1.23	419.39
	South (Type 2) W9	341.38	6	-	0.049	-	5.85	-	-	1.72	587.14
	South (Type 2) W10	341.38	6	-	0.054	-	5.85	-	-	1.90	647.05
Equation for Heat Conduction through Windows = 6 x WWR x Uf										∑	3570.77
Solar Heat Gain through Windows	South (Type 1a)	63.9	194	-	0	-	-	0.92	0.52	0.00	0.00
	South (Type 1b)	63.9	194	-	0	-	-	0.92	0.52	0.00	0.00
	South (Type 2) W1	341.38	194	-	0.004	-	-	0.92	0.61	0.44	148.91
	South (Type 2) W2	341.38	194	-	0.012	-	-	0.92	0.61	1.31	446.74
	South (Type 2) W3	341.38	194	-	0.013	-	-	0.92	0.72	1.68	573.31
	South (Type 2) W4	341.38	194		0.045			0.92	0.61	4.91	1675.26
	South (Type 2) W5	341.38	194		0.011			0.92	0.72	1.42	485.11
	South (Type 2) W6	341.38	194		0.033			0.92	0.72	4.26	1455.33
	South (Type 2) W7	341.38	194		0.042			0.92	0.61	4.58	1563.57
	South (Type 2) W8	341.38	194		0.035			0.92	0.66	4.17	1423.25
	South (Type 2) W9	341.38	194		0.049			0.92	0.66	5.84	1992.55
	South (Type 2) W10	341.38	194		0.054			0.92	0.55	5.35	1824.74
Equation for Solar Heat Gain through Windows = 194 x CF x WWR x SC										∑	11588.77
											∑ Wall OTTV=34729.20
											∑ Wall Area=3541.6
											OTTV=114.29

Figure 6. South facade OTTV calculation

Compt.	Wall	Area	Const.	α	WWR	1-WWR	U-Value	CF	SC	OTTV	A x OTTV
Heat Conduction through Opaque Wall	North (W1)	481.82	15	0.29	0.11	0.89	1.29	-	-	4.99	2406.32
	North (W2)	481.82	15	0.29	0.17	0.83	1.29			4.67	2252.21
Equation for Heat Conduction through Walls = 15 x α x (1-WWR) x Uw										∑	4658.53
Heat Conduction through Windows	North (W1)	481.82	6	-	0.064	-	5.85	-	-	2.25	1082.36
	North (W2)	481.82	6		0.167		5.85			5.86	2824.28
Equation for Heat Conduction through Windows = 6 x WWR x Uf										∑	3906.64
Solar Heat Gain through Windows	North (W1)	481.82	194	-	0.064	-	-	0.9	0.46	5.15	2479.89
	North (W2)	481.82	194		0.167			0.9	0.52	15.35	7395.40
Equation for Solar Heat Gain through Windows = 194 x CF x WWR x SC										∑	9875.29
∑ Wall OTTV=18440.47											
∑ Wall Area=963.64											
OTTV=38.27											

Figure 7. North facade OTTV calculation

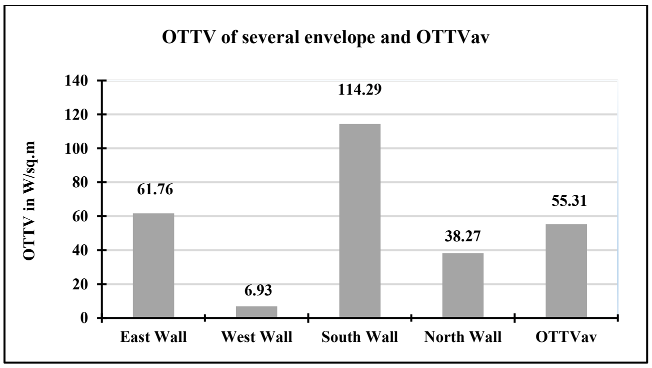

Figure 8. OTTV for each façade

Furthermore, it is evident from Figure 4 clearly illustrates that east windows get the greatest solar heat, at 28.45 W/sq.m, due to their high CF and large window area. Regarding heat conduction through the wall, the south facade wall has the most significant value of 69.86 W/sq.m compared to other wall facades. In an aspect of heat conduction through windows, the south facade wall received a higher OTTV of 10.47 W/sq.m. In terms of facade orientation, the south facade contributed the highest OTTV (114.29 W/sq.m), followed by the east facade (61.76 W/sq.m), north wall (38.27 W/sq.m) and the lowest west wall (6.93 W/sq.m) as demonstrated in Figure 8. The estimated total OTTV of the building is 55.31 W/sq.m which is more significant than what the Malaysian Standard recommends (50 W/sq.m). Higher OTTV will result in significant solar heat gain through the building envelope, raising the building's cooling load because the cooling load is highly reliant on the building envelope. It is recommended to modify building envelope specifications to minimise OTTV while also lowering the cooling load of the building.

A passive design technique is a strategy used to lower OTTV by improving building envelope specifications (Sukri et al. 2012). This technique was primarily selected because the building already existed. Unfortunately, there is no way to enhance CF, and changing the window to improve WWR requires significant reworking and might be pretty expensive. It was selected because passive design techniques, such as facade colours, glazing type, and shading devices, significantly influence the thermal performance of buildings. Furthermore, OTTV is very sensitive to SC (Yik & Wan, 2005), and a large amount of solar heat gain in buildings comes from vertical surfaces, particularly windows (Li & Lam 2000).

It is recommended to upgrade the current window glass at all facades with 6 mm single glaze low e. With this upgrade, U values for windows will be reduced from 5.85 to 4.0 W/sq.m.K. and SC to 0.38.

Compt.	Wall	Area	Const.	α	WWR	1-WWR	U-Value	CF	SC	OTTV	A x OTTV
Heat Conduction through Opaque Wall	East (E-1)	602.6	15	0.29	0.067	0.933	1.29	-	-	5.24	3154.93
	East (E-2)	602.6	15	0.29	0.084	0.916	1.29	-	-	5.14	3097.44
	East (E-3)	602.6	15	0.29	0.019	0.981	1.29	-	-	5.50	3317.24
	East (Stair)	602.6	15	0.29	0.003	0.997	1.29	-	-	5.59	3371.35
	East (D-R)	602.6	15	0.29	0.005	0.995	1.29	-	-	5.58	3364.58
Equation for Heat Conduction through Walls = 15 x α x (1-WWR) x Uw										∑	16305.54
Heat Conduction through Windows	East (E-1)	602.6	6	-	0.067	-	4.00	-	-	1.60	964.16
	East (E-2)	602.6	6	-	0.084	-	4.00	-	-	2.01	1211.22
	East (E-3)	602.6	6	-	0.019	-	4.00	-	-	0.45	271.17
	East (Stair)	602.6	6	-	0.003	-	4.00	-	-	0.07	42.18
	East (D-R)	602.6	6	-	0.005	-	4.00	-	-	0.12	72.31
Equation for Heat Conduction through Windows = 6 x WWR x Uf										∑	2561.04
Solar Heat Gain through Windows	East (E-1)	602.6	194	-	0.067	-	-	1.23	0.38	6.07	3657.78
	East (E-2)	602.6	194	-	0.084	-	-	1.23	0.38	7.61	4585.78
	East (E-3)	602.6	194	-	0.019	-	-	1.23	0.38	1.72	1036.47
	East (Stair)	602.6	194	-	0.003	-	-	1.23	0.38	0.27	162.70
	East (D-R)	602.6	194	-	0.005	-	-	1.23	0.38	0.45	271.17
Equation for Solar Heat Gain through Windows = 194 x CF x WWR x SC										∑	9713.9
											∑ Wall OTTV=28580.48
											∑ Wall Area=3013
											OTTV=47.42

Figure 9. Modified east facade OTTV calculation

Compt.	Wall	Area	Const.	α	WWR	1-WWR	U-Value	CF	SC	OTTV	A x OTTV
Heat Conduction through Opaque Wall	West (W1)	586.56	15	0.29	0.008	0.992	1.29	-	-	5.57	3265.15
Equation for Heat Conduction through Walls = 15 x α x (1-WWR) x Uw										∑	3265.15
Heat Conduction through Windows	West (W1)	586.56	6	-	0.008	-	4.00	-	-	0.19	111.44
Equation for Heat Conduction through Windows = 6 x WWR x Uf										∑	111.44
Solar Heat Gain through Windows	West (W1)	586.56	194	-	0.008	-	-	0.94	0.38	0.55	322.60
Equation for Solar Heat Gain through Windows = 194 x CF x WWR x SC										∑	322.60
											∑ Wall OTTV=3699.19
											∑ Wall Area=586.56
											OTTV=6.31

Figure 10. Modified west facade OTTV calculation

Compt.	Wall	Area	Const.	α	WWR	1-WWR	U-Value	CF	SC	OTTV	A x OTTV
Heat Conduction through Opaque Wall	South (Type 1a)	63.9	15	0.29	0	1	1.77	-	-	7.70	492.00
	South (Type 1b)	63.9	15	0.29	0	1	1.77	-	-	7.70	492.00
	South (Type 2) W1	341.38	15	0.29	0.004	0.996	1.29	-	-	5.59	1907.99
	South (Type 2) W2	341.38	15	0.29	0.012	0.988	1.29	-	-	5.54	1892.67
	South (Type 2) W3	341.38	15	0.29	0.013	0.987	1.29	-	-	5.54	1890.75
	South (Type 2) W4	341.38	15	0.29	0.045	0.955	1.29	-	-	5.36	1829.45
	South (Type 2) W5	341.38	15	0.29	0.011	0.989	1.29	-	-	5.55	1894.58
	South (Type 2) W6	341.38	15	0.29	0.033	0.967	1.29	-	-	5.43	1852.44
	South (Type 2) W7	341.38	15	0.29	0.042	0.958	1.29	-	-	5.38	1835.20
	South (Type 2) W8	341.38	15	0.29	0.035	0.965	1.29	-	-	5.42	1848.61
	South (Type 2) W9	341.38	15	0.29	0.049	0.951	1.29	-	-	5.34	1821.79
	South (Type 2) W10	341.38	15	0.29	0.054	0.946	1.29	-	-	5.31	1812.21
Equation for Heat Conduction through Walls = 15 x α x (1-WWR) x Uw										∑	19569.67
Heat Conduction through Windows	South (Type 1a)	63.9	6	-	0	-	4.00	-	-	0.00	0.00
	South (Type 1b)	63.9	6	-	0	-	4.00	-	-	0.00	0.00
	South (Type 2) W1	341.38	6	-	0.004	-	4.00	-	-	0.09	30.72
	South (Type 2) W2	341.38	6	-	0.012	-	4.00	-	-	0.28	95.58
	South (Type 2) W3	341.38	6	-	0.013	-	4.00	-	-	0.31	105.82
	South (Type 2) W4	341.38	6	-	0.045	-	4.00	-	-	1.08	368.69
	South (Type 2) W5	341.38	6	-	0.011	-	4.00	-	-	0.26	88.75
	South (Type 2) W6	341.38	6	-	0.033	-	4.00	-	-	0.79	269.69
	South (Type 2) W7	341.38	6	-	0.042	-	4.00	-	-	1.00	341.38
	South (Type 2) W8	341.38	6	-	0.035	-	4.00	-	-	0.84	286.75
	South (Type 2) W9	341.38	6	-	0.049	-	4.00	-	-	1.17	399.41
	South (Type 2) W10	341.38	6	-	0.054	-	4.00	-	-	1.29	440.38
Equation for Heat Conduction through Windows = 6 x WWR x Uf										∑	2427.17
Solar Heat Gain through Windows	South (Type 1a)	63.9	194	-	0	-	-	0.92	0.38	0.00	0.00
	South (Type 1b)	63.9	194	-	0	-	-	0.92	0.38	0.00	0.00
	South (Type 2) W1	341.38	194	-	0.004	-	-	0.92	0.38	0.27	92.17
	South (Type 2) W2	341.38	194	-	0.012	-	-	0.92	0.38	0.81	276.51
	South (Type 2) W3	341.38	194	-	0.013	-	-	0.92	0.38	0.88	300.41
	South (Type 2) W4	341.38	194		0.045			0.92	0.38	3.05	1041.20
	South (Type 2) W5	341.38	194		0.011			0.92	0.38	0.74	252.61
	South (Type 2) W6	341.38	194		0.033			0.92	0.38	2.23	761.27
	South (Type 2) W7	341.38	194		0.042			0.92	0.38	2.84	969.51
	South (Type 2) W8	341.38	194		0.035			0.92	0.38	2.37	809.07
	South (Type 2) W9	341.38	194		0.049			0.92	0.38	3.32	1133.38
	South (Type 2) W10	341.38	194		0.054			0.92	0.38	3.66	1249.45
Equation for Solar Heat Gain through Windows = 194 x CF x WWR x SC										∑	6885.58
											∑ Wall OTTV=28882.42
											∑ Wall Area=3541.6
											OTTV=97.14

Figure 11. Modified south facade OTTV calculation

Compt.	Wall	Area	Const.	α	WWR	1-WWR	U-Value	CF	SC	OTTV	A x OTTV
Heat Conduction through Opaque Wall	North (W1)	481.82	15	0.29	0.11	0.89	1.29	-	-	4.99	2406.32
	North (W2)	481.82	15	0.29	0.17	0.83	1.29			4.67	2252.21
Equation for Heat Conduction through Walls = 15 x α x (1-WWR) x Uw										∑	4658.53
Heat Conduction through Windows	North (W1)	481.82	6	-	0.064	-	4.00	-	-	1.53	737.18
	North (W2)	481.82	6		0.167		4.00			4.00	1927.28
Equation for Heat Conduction through Windows = 6 x WWR x Uf										∑	2664.46
Solar Heat Gain through Windows	North (W1)	481.82	194	-	0.064	-	-	0.9	0.38	4.24	2042.91
	North (W2)	481.82	194		0.167			0.9	0.38	11.08	5338.56
Equation for Solar Heat Gain through Windows = 194 x CF x WWR x SC										∑	7381.47
											∑ Wall OTTV=14704.46
											∑ Wall Area=963.64
											OTTV=30.51

Figure 12. Modified north facade OTTV calculation

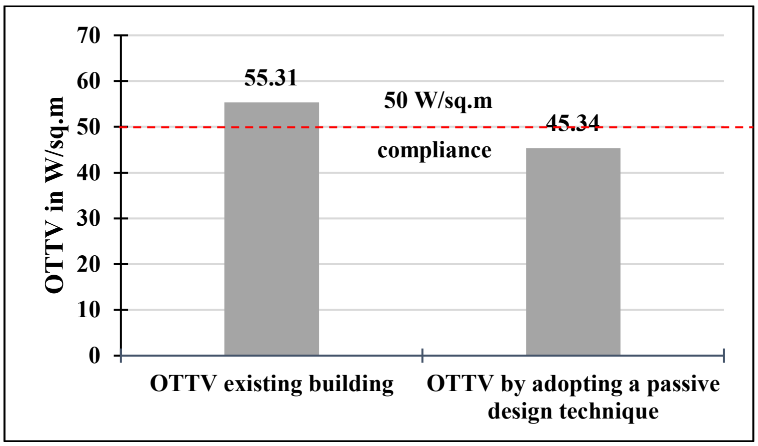

Figure 13. Comparison of OTTV score between OTTV of the existing building and OTTV by the adoption of passive design technique

The impact of this passive design technique on two critical components of an OTTV can be seen in Figures 9-12 and compared to prior results in Figures 4-7. As indicated in Figure 9-12, heat conduction through windows of all facades (east, west, south & North) was lowered to 4.25 W/sq.m, 0.19 W/sq.m, 7.11 W/sq.m and 5.53 W/sq.m, further solar heat gain through windows reduced to 16.12 W/sq.m, 0.55 W/sq.m, 20.17 W/sq.m, and 15.32 W/sq.m. Likewise, the OTTV on each facade (east, west, south & North) also reduced to 47.42 W/sq.m, 6.31 W/sq.m, 97.14 W/sq.m, and 30.51 W/sq.m. Therefore, the adoption of passive design techniques, including such new glazing type, has been clearly demonstrated to significantly impact the reduction of overall OTTV to 45.34 W/sq.m, as shown in Figure 3. Hence the new estimated total OTTV of building 45.34 W/sq.m meets the mandatory compliance value of 50 W/sq.m. Since a significant portion of the energy used by typical office buildings is for air conditioning, reducing OTTV will likely lead to a reduction in the cooling load for the building's air conditioning system and potentially bring BEI within the range of energy-efficient building practice.

6. Proposed Improvements

Single clear glass may be substituted with 6 mm single glaze low e since it has a far lower U-value than clear glass, with a U-value of 0.25. It can potentially reduce the OTTV value from 55.31 W/sq.m to 45.34 W/sq.m.

1) Window to Wall Ratio (WWR) in buildings also affects the OTTV score. The WWR could be improved by lowering the window area. Spandrel glass may also be utilised.
2) External shading devices might be provided or improved for the facade that contributes the highest OTTV.

7. Conclusion

Controlling the overall thermal transfer value (OTTV) of a building has become a common practice in many nations and localities. No question controlling an OTTV of the building can improve the building envelope's energy-efficient design and reduce greenhouse gas emissions. The study demonstrates that various facade designs produce different OTTVs. Building's east and south facade with larger window area contributes to a rise in WWR, which raises the value of solar heat gain and heat conduction through windows. However, the OTTV for existing building facades have been calculated at 55.31 W/sq.m, surpassing the OTTV of 50 W/sq.m specified by Malaysian standards. As a result, more cooling load is necessary to significantly reduce heat absorption through the building envelope to achieve energy-efficient indoor environmental quality. The highest amount of OTTV is produced by solar heat gain through windows and heat conduction through the opaque wall. The use of passive design techniques can reduce OTTV for existing buildings. In this study, passive design techniques such as a new type of glass were proposed; hence, OTTV was effectively reduced to 45.34 W/sq.m.

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Muhammad Tarique Lakhiar is a PhD student currently pursuing his PhD in Civil Engineering from Universiti Tunku Abdul Rahman Malaysia. His PhD research project is focused on Predicting Thermal Physiological Effects on Human Behaviour using Energy Modelling. The author was born on December 12th, 1996, in Mehar, Sindh, Pakistan. He received his primary schooling from VIP high School Mehar. He received his college education in the Pre-Engineering Group from Mehran University Public School, Jamshoro, Pakistan. He pursued his degree at the Mehran University of Engineering and Technology (MUET), Jamshoro, Pakistan and graduated with a Bachelor of Engineering (B.E) in Civil Engineering in 2019. Muhammad Tarique Lakhiar pursued his post-graduate education in Civil Engineering from Universiti Tun Hussein Onn Malaysia in 2020. He has authored and co-authored five papers.

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