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ORIGINAL ARTICLE

ANALYSIS OF THERMAL TRANSFER VALUES IN TEACHING CLASSROOMS

Tri Wulan Sari[1] • Dyah Nurwidyaningrum[1] • Jonathan Saputra[1] • Denny Yatmadi[1] • Sujito[2]

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Abstract Erratic weather, such as intense heat followed by heavy rain, is causing air pollution in the sky of Jakarta. According to the SNI 03-6389-2011, which deals with energy conservation in building envelopes, the overall thermal transfer value (OTTV) for walls should not exceed 35 W/m2. This study aims to analyze OTTV in Class T and Class S. Class S uses clear glass, while Class T has a shading device in the form of a sunglass sticker. The method used involves calculating the total outer wall area, glass area, window-to-wall ratio (WWR), solar factor value, and then obtaining the OTTV. The results of the study show that the WWR value for Class T was 0.5, while for Class S it was 0.4. The OTTV value in Class T is 58.74 W/m2, whereas the OTTV in Class S is 70.64 W/m2. Despite both classrooms not meeting the SNI requirements, the classrooms using shading devices have OTTV values closer to the SNI standard.

Keywords: Green Buildings · SNI 03-6389-201 · WWR · OTTV · Thermal

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✉ Tri Wulan Sari
tri.wulansari@sipil.pnj.ac.id

[1] Civil Engineering Department, Politeknik Negeri Jakarta, Indonesia.

[2]Department of Physics, Universitas Negeri Malang, Indonesia.

Introduction

Unpredictable weather, such as extreme heat followed by heavy rain, is currently causing fog, which contributes to air pollution in Jakarta's skies. This is seen as an indication of climate change, defined by rapidly rising temperatures due to global warming (Rochmayanto et al., 2014). Global warming is also a result of the Earth's average temperature of the ocean, land, and atmosphere. Over the past 100 years, the average global surface temperature has increased by 0.74 ± 0.18°C (1.33 ± 0.32°F) (Dlh, 2019; Network, 2024). Additionally, global warming can be caused by excessive energy use in buildings, leading to an energy crisis.

The consumption of large amounts of energy in buildings requires energy-saving technology to limit energy use (Naimah et al., 2021). Building as manifestation culture and form work architecture own very large role and contribution in formation global warming (Wibawa and Hutama, 2019). Therefore, buildings are not only required in terms of strong structural quality but also energy saving pay attention to ventilation and lighting depending on conditions windows, and environmentally friendly or what we usually know as Green Building. A green building is a building that has the characteristics of saving energy, and resources and being environmentally friendly (Amelyana et al., 2021). In school buildings, it is required to provide rooms that meet the lighting system, acoustic system, and thermal system aspects (Nurwidyaningrum et al., 2022).

In buildings, the thermal comfort inside a room is influenced by the area's ventilation or openings (Mustamin et al., 2023). The ideal opening would bring fresh air into the

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environment, allowing for the process of heat displacement through convection. An aperture works as a space to "breathe" and supply clean air (Kartika and Iswanto, 2020). The area of the aperture is the result of a big or small Overall Thermal Transfer Value (OTTV). According to SNI 03-6389-2000, openings in walls, known as the Window-to-Wall Ratio (WWR), affect the component OTTV (Nasional, 2000). In Indonesia, the standard regarding the OTTV formula is standardized in SNI 6389:2011 concerning Conservation Energy Sheath Buildings in Buildings. Understanding OTTV itself is something that signifies the displacement from the outside to the inside through the building sheath (Vijayalaxmi, 2010). The lowest OTTV value of a building means better ventilation and increased comfort. Additionally, a lower incoming heat load into a building result in a less burdensome cooling system (Dimas et al., 2011).

The OTTV concept assumes that the building's envelope is completely enclosed. There are two values that influence it: Envelope Thermal Transfer Value (ETTV) and Roof Transfer Value (RTTV). ETTV measures heat transfer through the walls or building envelope, while RTTV measures heat transfer through the roof of the building. Therefore, OTTV is the total value of ETTV and RTTV. The calculations for RTTV are relatively simple, as they are caused by roofs that may not have any glass, except in the case of roofs with skylights (Vijayalaxmi, 2010). Meanwhile, ETTV calculations depend on: (a) conduction through opaque walls, (b) conduction through window glass, and (c) solar radiation through window glass (Nasional, 2011; Vijayalaxmi, 2010).

According to research conducted by Shaeri et al. (2019) in (Dwiana et al., 2021), Window-to-Wall Ratio (WWR) can be determined precisely depending on the location, orientation, and type of the building. This research aims to conduct a comprehensive analysis of thermal transfer values in classroom T and classroom S. The differences in the shape and dimensions of classrooms T and S influence the distribution of incoming light. The square plan shape creates potential zones that do not receive the contribution of natural light. Meanwhile, in a rectangular plan, the light distribution is more even because it has no center (Kartika and Elsiana, 2021). Utilizing the potential of natural lighting can have a positive impact on humans, namely reducing electrical energy loads while achieving optimal visual comfort (Kartika and Elsiana, 2021).

Based on the background description above, no one has conducted OTTV measurements in classrooms T and S. Therefore, the purpose of this study is to calculate the value of OTTV in classrooms T and S. Then an OTTV analysis was carried out based on SNI SNI 03-6389-2011.

Materials and Methods

Data was collected in two classes: class T in the Civil Engineering Department, and class S in the Postgraduate program at Jakarta State Polytechnic. The data collection methods included direct and indirect approaches. The direct method involved taking measurements and making observations in the classrooms to gather primary data (Mustamin et al., 2023). These included obtaining the dimensions and size of the classroom, as well as the shape, size, and orientation of the openings in the sample classroom (Senoaji et al., 2019). The research focused on a specific classroom chosen by the author, which did not rely solely on natural openings for ventilation but also included air conditioning.

After gathering the data, the first step is to calculate the window area and the total wall area. Once you have these numbers, you can proceed to calculate the WWR (Window-to-wall ratio), which is the ratio of the window area to the entire outer wall area at a specific orientation (Iqbal, 2019; Nasional, 2000, 2011). The optimal window-to-wall ratio (WWR) can help determine the window area, thereby reducing the total annual energy requirements for cooling, heating, and artificial lighting (Purwoko and Purwanto, 2022). Once you have the WWR value, you can calculate the thermal displacement value for each orientation. Next, you should determine the radiation absorbance value, shading coefficient of the fenestration system, and thermal

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transmittance based on the standards in SNI. In Indonesia, the formula used to calculate the heat transfer from outside to inside a building is OTTV, which is standardized in SNI 03-6389: 2011 concerning energy conservation of building envelopes in buildings (Dimas et al., 2011). The flow diagram for this research is shown in Figure 1a.

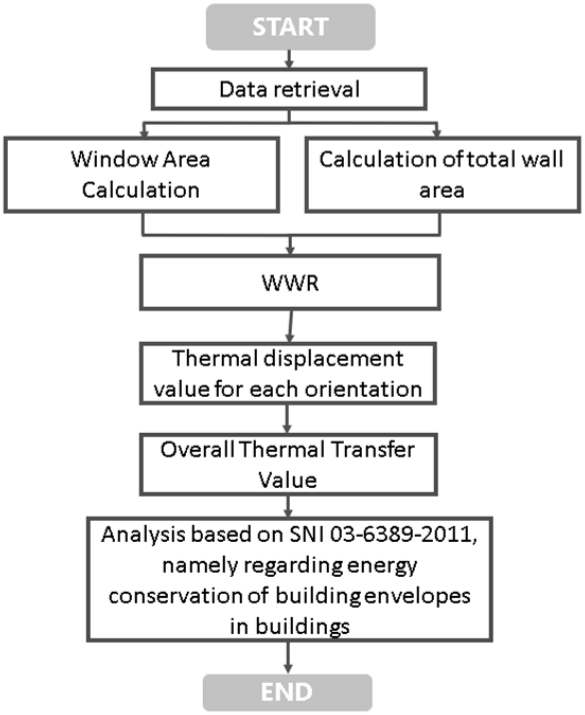


Figure 1a: Flow diagram study Overall Thermal Transfer Value (OTTV) analysis

The formula for calculating OTTV according to previous research (Amelyana et al., 2021; Dimas et al., 2011; Maulidina et al., 2020; Nasional, 2011; NurSetiani et al., 2017; Wibawa and Hutama, 2019). The factor that influences OTTV value on orientation building is the solar radiation factor (CF) value (Table 1 and figure 1b) as for the CF value and method to read orientation aperture is as follows

Table 1. Solar radiation factor (CF)

No.	Orientation	CF
1	North	0.90
2	Northeast	1.09
3	East	1.23
4	Southeast	1.13
5	South	0.92
6	Southwest	0.90
7	West	0.94
8	Northwest	0.90

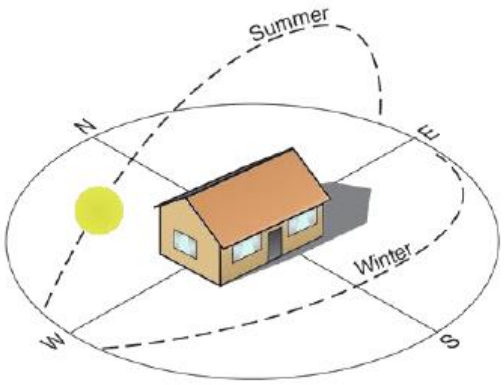


Figure 1b: CF value and Orientation Values Aperture

The results of measuring the length and width of windows in room class T of the Civil Engineering Department are shown in Table 2a, and for room class S in the Postgraduate S class are shown in Table 2b. The direct measurements show a difference in values for length and width between the T and S room classes.

Table 2a. Retrieval of data from the T classroom window

Location	Orientation	l(m)	T(m)
1st floor	North	6.84	5.58
	East	0	0
	South	1.5; 0.75x9	2.05; 0.7
	West	0	0

Table 2b. Retrieval of data from the Classroom S window

Location	Orientation	l(m)	T(m)
2nd Floor	North	3,4	2.9
	East	0	0
	South	1.5	2.1
	West	0	0

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The direct observation results reveal the contrast between the glass used in windows and the width of the opening. In Figure 2, the window in room class T has shading devices, sunglass, and wall stickers adjacent to the north full glass (color marked with red line). On the other hand, Figure 3 shows that space S class utilizes clear glass and not full glass (color marked with blue line).



Figure 2. Measuring wide openings in room T class



Figure 3. Measuring wide of opening in room S class

The size of the windows and the type of glass used in a room can impact its value. This is influenced by the Window Wall Ratio (WWR) and overall thermal transfer (OTTV), which also vary. It is important to understand how these differences affect the overall value. The results can be analyzed using the 2011 Building Energy Conservation Standards (SNI) which is a revision of SNI 03-6389 in 2011. The comfort level of the room should meet the OTTV requirement, which should be no more than 35 W/m^2 (Amelyana et al., 2021; National, 2011).

Results and Discussion

Window Area Calculation

The results for the size of the T-classroom window are presented in Table 3. The area is calculated using the formula for a rectangular window, where the width is multiplied by the height. The calculated area for the T-classroom window is 20.52 square meters.

The formula for determining the area of the window in the Postgraduate S-classroom is the same as that for the T-classroom. Based on direct measurements, the area of the window in the S-classroom is 8.08 square meters (see Table 4). Comparing the data from Tables 3 and 4, it is evident that the window area in the T-classroom is larger than that in the S-classroom.

Table 3. Calculation of window area for class T

Location	Orientation	l(m)	T(m)	A (m^2)
1st floor	North	2.28	1.86	12.72
	East	0	0	0
	South	1.5	2.05	7.8
	West	0	0	0
				20.52

Table 4. Calculation of Window Area for Class S Rooms

Location	Orientation	l(m)	T(m)	A (m^2)
2nd Floor	North	1.7	1.45	4.93
	East	0	0	0
	South	1.5	2.1	3.15
	West	0	0	0
				8.08

Calculation Area Entire Outer Wall

Calculation area entire outer wall results area shown in Table 5. The wall of the whole room is a rectangle, and the formula we used to find its area is length multiplied by width, resulting in 106.5 m^2.

Table 5. Calculation Area Entire Outer Wall room class T

Location	Orientation	L(m)	T(m)	A (m^2)
1st floor	North	8.35	3.27	27.3
	East	7.94	3.27	26.0
	South	8.35	3.27	27.3
	West	7.94	3.27	26.0
	Total			106.5

The formula from the count area wall outside room S class is the same as the count area in space class T. Based on the results obtained, the big area wall outside whole class S is 62.7 m^2 (table 6). Based on Tables 5 and 6 obtained area data outside wall whole room class T is bigger compared to space S class.

Table 6. Calculations Area Entire Outer Wall of the room S class

Location	Orientation	L(m)	T(m)	A (m^2)
2nd Floor	North	5.55	2.75	15.3
	East	5.85	2.75	16.1
	South	5.55	2.75	15.3
	West	5.85	2.75	16.1
	Total			62.7

Window Wall Ratio (WWR)

WWR room results in class T are shown in Table 7. The formula used _ is a comparison between a wide window and with wide wall whole. Obtained room WWR value class T of 0.8.

Table 7. Window Wall Ratio (WWR) analysis of space class T

Location	Orientation	A Facade (m2)	A Window (m2)	WWR
1st floor	North	27.3	12.72	0.5
	East	26.0	0	0.0
	South	27.3	7.8	0.3
	West	26.0	0	0.0
	Total WWR 20.52			**0**.8

The formula to calculate the Window-to-Wall Ratio (WWR) for space class S is the same as the formula to calculate the WWR for space class T. Based on the data analysis conducted, the WWR for space class S is 0.5 (refer to Table 8). Referring to Tables 7 and 8, it is evident that the WWR for space class T is significantly larger than that of space class S.

Table 8. Analysis of the Window Wall Ratio (WWR) of the room S class

Location	Orientation	A Facade (m2)	A Window (m2)	WWR
2nd Floor	North	15.2625	4.93	0.3
	East	16.0875	0	0.0
	South	15.2625	3.15	0.2
	West	16.0875	0	0.0
	Total WWR			0.5

Each Thermal Transfer Value Orientation

The results calculation of the overall thermal transfer (OTTV) of space class T is shown in Table 9. Formula used found in methodology study. Obtained room OTTV value class T orientation north amounting to 96.08 W/m^2, east 82.96 W/m^2, south 72.02 W/m^2, and west 178.46 W /m^2; OTTV on orientation the western part is visible tall compared with other orientations due to mark of Solar Factor (SF) tends to be high.

Table 9. Calculation of each OTTV orientation room class T

Location	K Wall	K. Glass	Rad. Glass	OTTV (W/m^2)
North	0.65	0.652	94.78	96.082
East	0.65	0.652	81.66	82.959
South	0.65	0.652	70.72	72.023
West	0.65	0.652	177.16	178.467

The results for the Overall Thermal Transfer Value (OTTV) of space class S can be found in Table 10. The formula used for calculating this value is detailed in the methodology study. The obtained OTTV values for a room with a north orientation are 67.6 W/m2, east orientation is 58.4 W/m^2, south orientation is 125.7 W/m2, and west orientation are 125.7 W/m2. It is worth noting that the OTTV for the western orientation is the same as for the southern orientation. The OTTV value for a building should not exceed 35 W/m^2 according to SNI 03-6389-2011.

Table 10. Calculation of each OTTV orientation room S class

Location	K Wall	K. Glass	Rad. Glass	OTTV (W/m2)
North	0.46	0.459	66.76	67.676
East	0.46	0.459	57.51	58.433
South	0.46	0.459	124.79	125.704
West	0.46	0.459	124.79	125.704

Analysis of Thermal Transfer Value Analysis based on SNI 03-6389-2011 about Conservation Energy Sheath Buildings in Buildings 2010. The results calculate the average overall thermal transfer (OTTV) in space class T shown in Table 11. The formula used was found in the methodology study. Obtained room OTTV value

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class T average is 106.80 W/m^2. Class T room experiences overthermal if no added another shade, because an OTTV value building should Not exceed or the same with 35 W/m^2 (*SNI 03-6389-2011*).

Table 11. Average OTTV value in space class T

Location	Orientation	A. Facade (m^2)	OTTV	A. OTTV	Total OTTV (W/m^2)
1st floor	North	27.30	96.08	2623.48	11377.64
	East	26.0	82.96	2153.93	
	South	27.30	72.02	1966,56	
	West	26.0	178.47	4633.67	
OTTV Avg					106.80

The calculation results of average overall thermal transfer (OTTV) in space class S are shown in Table 12. The formula used was found in the methodology study. Obtained room OTTV value class S average is 94.32 W/m2. Class T room experiences overthermal if no added shade because an OTTV value building should No exceed or be the same as 35 W/m^2 (*SNI 03-6389-2011)*.

Table 12. Average OTTV value in space S class

Location	Orientation	A. Facade (m^2)	OTTV	A. OTTV	Total OTTV (W/m^2)
1st floor	North	15.26	67.68	1032.91	5913.76
	East	16.09	58.43	940.04	
	South	15.26	125.70	1918.55	
	West	16.09	125.70	2022,26	
OTTV Avg					**94.32**

Analysis based on SNI Energy building Conservation03-6389-2011 requires an OTTV value building the same with or no more than 35 W/m2 (Amelyana et al., 2021; Iqbal, 2019; National, 2011). The results obtained, space class T which experiences over thermal, namely the OTTV value of 106.8 W/m^2. Whereas For room S also experienced over thermal OTTV value is 94.32 W/m^2. Space T and S classes are necessary to add sun shading to reduce OTTV and space classes become comfortable.

Conclusion

The classrooms T and S in the building have different window types and glass, resulting in different OTTV values. OTTV values indicate the amount of solar heat that passes through the glass. Classroom T exceeds the standard OTTV value stated in SNI 03-6389:2011 at 106.8 W/m^2, while classroom S has a value of 94.32 W/m^2. It is noted that rooms with smaller windows have OTTV values closer to the SNI standard compared to rooms with larger windows. Despite using sunglass stickers as shading devices in classroom T, it still experiences overthermal.

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Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

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