Rule of thumb for the calculation of overall transfer thermal value in Bandung

by Erni Setyowati

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Abstract. The rule of thumb for heat transfer in building envelopes is made to make it easier to calculate heat transfer using the OTTV formula from SNI. Using this formula, it often makes it difficult for architects to quickly estimate the heat transfer value of a building. The OTTV formula variable issued by SNI is not an architectural design variable. Only one variable that is in accordance with the field of architecture is the window to wall ratio (WWR). The use of the OTTV formula is very dependent on the location of the building and solar radiation. So to overcome this difficulty, the researcher tries to offer a rule of thumb formula for calculating heat transfer. To get the OTTV formula by rule of thumb by means of design variable regression. With the rule of thumb formula for calculating OTTV, it is hoped that it can make it easier for architects to consider designs that are adapted to local conditions.

1. Introduction

The Buildings contribute a lot to the increased heat in their environment which results in increasing temperatures in the building. From a number of cities, for example, Jakarta, where daily temperatures range from 27 °C to 33 °C, humidity ranges from 50% to 70%, wind speed which is almost always 0 m /s. With such high temperature and humidity, it is often difficult to make buildings cool. Especially if the air circulation is not enough, then to make the space comfortable, the user will solve it by turning on the air conditioner. In such conditions, if the building is designed following the principles of energy-efficient building, the use of artificial ventilation can be reduced [1].

Many buildings pay less attention to the local climate, even though the surrounding climate and indoor conditions have a big impact on the energy performance of the building. Likewise, the orientation of the building face and the materials used in the building envelope can cause solar radiation to affect the cooling load and lighting design of buildings [2].

One of the building components commonly affected by the external environment is the building envelope, with thermal energy commonly transferred through its transparent and non-transparent walls and roofs [3,4]. Therefore, it is necessary to determine the performance of the building, in accordance with the thermal carried by sunlight through the building envelope. This is because some designs such

as double skin/glass, absorbing, and reflective glass, adding horizontal, vertical, and egg-crate overhang aid in conducting thermal transfer [5,6].

According to several studies, the right building orientation produces good thermal performance. Similarly, increasing the building's width helps to decrease the amount of sun's rays that enter the rooms, thereby, obtaining a more comfortable thermal performance. However, the thickness of the walls did not contribute to a significant reduction in the temperature of the interior space [7]. Regarding the use of materials, the proper shape of the building envelope has the ability to reduce room temperature and save energy with ease of workmanship, efficiency, maintenance costs, and minimum OTTV [8,9]. The local climate needs to be considered while developing the building's envelope shape, type, and material because it greatly impacts the comfort inside the building. Therefore, with the use of the right type of sheath in hot, dry, humid, or very hot climates, the cooling load tends to decrease [10]. Horizontal, vertical, and grid types of building envelopes reduce solar radiation/cooling load in the east, west, and south orientations [11,12]. According to Chua, et al. the sheath that acts as the shading device is suitable for buildings facing north and south, while horizontal overhangs inclined at 30° downward are suitable for east and west region [13]. But another opinion states that diagonal building envelopes are better than vertical and egg-crate in reducing room temperature [14]. Generally, it was found that there is no common method used to access the building envelope [15].

The amount of thermal transfer value is calculated by the OTTV formula, which is an index used to compare the performance of buildings. It consists of three main components, namely [3]: (a) conduction through a massive wall ($\alpha[(Uw \times (1 - WWR) \times (TDek])$, (b) conduction through a transparent wall ($Uf \times WWR \times \Delta T$), (c) solar radiation through the glass ($SC \times WWR \times SF$). The overall thermal transfer value of the exterior wall and the roof transfer thermal value (RTTV) are commonly determined. According to the OTTV regulation from SNI: 2011, all buildings that use artificial ventilation need to be designed with a maximum value of 35w / m2.

This formula is written as follows:

$$OTTV = (\alpha[(Uw \times (1 - WWR) \times TDek]) + (Uf \times WWR \times \Delta T) + (SC \times WWR \times SF)[3].$$

Where,

OTTV: Overall thermal transfer value (W/m²)
A   : Abstorttance of solar radiation
Uw   : Thermal transmittance of opaque wall (W/m².K°)
WWR: Window to wall ratio
TDek : Equivalent temperature difference (K)
Uf   : Thermal transmittance of fenestration (W/m².K°)
ΔT   : Temperature difference between exterior and interior design conditions (5°K)
SC   : Shading coefficient of fenestration (where $SC = SCeff \times SCglass$)
SF   : Solar factor (W/m²)

WWR is always present in the three main components listed above. It plays an important role in OTTV calculations. Besides that, to respond to climate change that is getting hotter, Ruey, et al. Have taken an approach in changing the OTTV index [16]. For example, it can be seen in some formulas used in Hong Kong and Taiwan in calculating the heat transfer entering the building [16,17].

Besides WWR, another important variable is the value of SC and SF [3]. SC is related to design, however, obtaining its value is quite complicated. This is because, the architects needs to carefully analyze the pieces in the CAD drawings by measuring the width ratio of the overhang projection factor (OPF) to the surface exposed to sunlight. From the OPF value, the SC is obtained, as shown in the SNI: 2011 table. This makes it easy for the value to be directly used, however, assuming there is no exact value in the table, the interpolation method is used for its calculation.

SC values are also used in the Ecotect program, which was originally modeled to determine the value of the shading coefficient of the fenestration system. After the model is made, on the transparent (glass) part, the SC value is located on the tap. Users are advised to click to calculate SC, and in the SunPath

diagram with the time adjusted to 21st March, June, September, and December. This is followed by clicking on the tab and exporting to Ms. excel sheet, from there, the normal direct radiation is obtained according to the angle of the sun in accordance with SNI [3] .Therefore, architects are likely to acquire an average SC value in a year. The SF values used to determine the location variables are more complicated to obtain. This is because it needs to explore the distribution of sunlight obtained from the climatological aspects.

In addition, expertise is needed to calculate the amount of sun's thermal transfer value into the building, even though the subject is less familiar to an architect. Therefore, in designing a building, an architect or student needs to possess adequate knowledge of the thermal transfer problem design building envelopes that meet green standards. The use of the OTTV SNI: 2011 formula often makes it difficult for users to quickly estimate the value of building thermal transfer, especially for amateurs. The formula makes it difficult for users, especially an architecture student trying to determine the right energy needed for the building. The OTTV formula variable issued by SNI is not an architectural design, and therefore, it is new to architects. The only variant that fits the architecture field is WWR, which is the ratio of the window area to the entire outer wall in the orientation specified. The use of the OTTV formula depends on the location of the building and the sun's radiation.

The rule of thumb for one-sided ventilation in buildings is carried out in the field of architecture. For spaces with access to only one facade, ventilation on one side works to a maximum depth of 6.00 m. Windows are used because they provide ventilation and sunlight. The opening area is at least 5% of the ventilated floor, and it is more in hot climate regions with low wind speeds [18]. The construction sector uses a lot of rules of thumb over other technology sectors such as a beam with a span of 4.00 m and a height of 1/20 x 3.50 m = 0.175 m. In the era of design, with the help of computers, CAD, and building information modeling (BIM), the rule of thumb remains an invaluable verification tool [19,20]. It comprises of simple principles, which are generally reliable, and provide a broad view of how to achieve goals [21]. It is defined as a set of principles based on experience [22]. Rule of thumb is more reliable based on scientific experiments with efforts taken to clarify most of the assumptions [23].

Therefore, to overcome the difficulties faced by the use of the OTTV-SNI: 2011 formula by the architect, the rule of thumb formula was developed by utilizing WWR in line with other countries.

2. Material and methods

The object to be studied is the building envelope in C, the use of this building is only as a basic idea by taking one bay which is then simulated. Building C is a faculty building with mixed activities (office, study room, library and laboratory). The building was taken to represent the buildings on the Trisakti University campus, and because it has a distinctive character that is almost equilateral with two faces (north and south) with an overhang without louvers as sun protection and the other two faces (west and east) with an overhang equipped with louvers. Building C was drawn using CAD with one bay drawn from a column to another. One bay is simulated with various forms of shading device and produce various forms of the facade, which are variables of OTTV. This research uses model simulation, for example Karim, et al. Have simulated 54 windows to get the heat gain value [24].

The basis for calculating OTTV is to use the standard SNI 6389: 2011 - Energy Conservation of Building Envelopes in Buildings. It also requires data on the building materials used, absorption value, thermal transmittance, equivalent temperature, solar factor, and the value of SCef (shading coefficients effective). Effective SC is obtained from SC glass multiplied by SC from the OPF-overhead project factor or SPF-sidefin project factor. In this calculation the building material is not changed, what is changed in various alternatives is the design of the shading device. To calculate OTTV is quite complicated, then this OTTV formula will then be simplified by means of the rule of thumb.
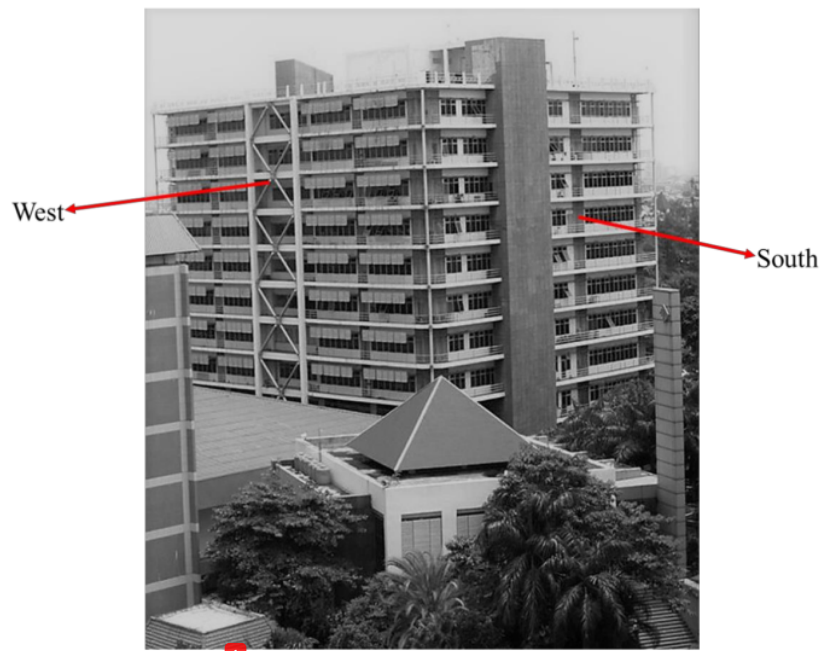
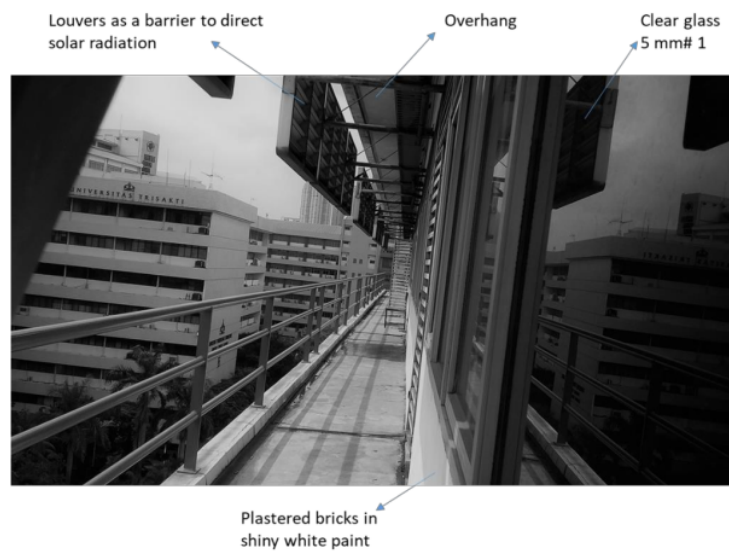**Figure 1.** Building C on campus A of Trisakti University.

Louvers as a barrier to direct solar radiation

Overhang

Clear glass 5 mm# 1

Plastered bricks in shiny white paint

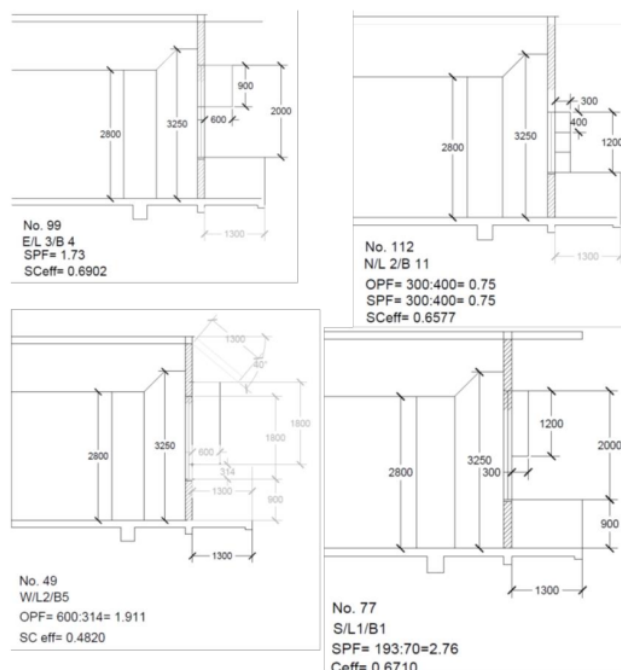**Figure 2.** Building facade.

Figure 3. Example of multiple pieces of window unit.

To obtain the OTTV rule of thumb from WWR, the following were carried out:

First, make a simulation bay in the facade of 300 cases; The facade is designed based on the configuration of the variables, such as WWR, which was randomly obtained; WWR is considered an independent variable. OTTV is calculated using the OTTV-SNI: 2011 formula, which is considered a dependent variable. Then, to obtain the OTTV rule of thumb = WWR function curve estimation method is used from SPSS 26.0. When a stepwise regression is made, the best rule of thumb is taken from the regression equation with the largest R square value.

3. Results and discussion

From the stepwise regression analysis, the results are as follows:

Table 1. Variables entered/removed[a]

Model	Variables Entered	Variables Removed	Method
1	WWR	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: OTTV-SNI

Table 2. Model summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.918[a]	.843	.843	4.00910254

a. Predictors: (Constant), WWR

Table 3. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.137	.555		12.863	.000
	WWR	102.657	2.565	918	40.030	.000

a. Dependent Variable: OTTV-SNI

From the stepwise regression, the result is R = 0.918, then the rule of thumb formula is obtained as follows:

$$OTTV = 7.137 + 102.657 \times WWR$$

Of the 30 cases of facades that were not used to produce a rule of thumb above, it was obtained RMSE (root meaning square error) = 0.50 with an error factor = 0%.

4. Conclusion

The formula for a rule of thumb with OTTV as a WWR function has been obtained; it is hoped that this rule of thumb will be useful for architects and students in calculating OTTV on facade designs; this rule only applies in Bandung, therefore a similar study is needed for other cities in Indonesia. By using the rule of thumb formula for $OTTV = 7.137 + 102.657 \times WWR$, the architects can find out the OTTV from their design, so their work has filled the green building.

Acknowledgment

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