The influence of building envelope design in energy efficiency
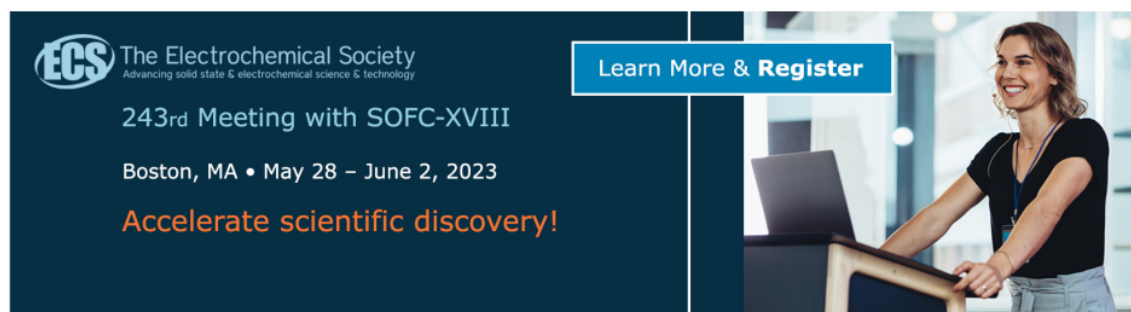
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The influence of building envelope design in energy efficiency: OTTV calculation of multi storey building

P U Pramesti[1*], M Ramandhika[1], M I Hasan[1], H Werdiningsih[2]

[1] Vocational School, Universitas Diponegoro, Semarang, Indonesia 50275
[2] Architecture Department, Faculty of Engineering, Universitas Diponegoro, Semarang, Indonesia 50275

previ.pramesti@gmail.com

Abstract. This study provides calculation of OTTV (Overall Thermal Transfer Value) to multi storey building in Semarang. Case study for this study is Suara Merdeka Tower with the height of 15 floors and dominated by glass on its façade. In addition to OTTV calculation, recommendation provides as well in this study in an effort to reach ideal OTTV value for its façade. To minimize external thermal loads, SNI 03-6389-2011 determines the design criteria for building envelope with the Overall Thermal Transfer Value (OTTV) value must be less than or equal to 35 Watt/m². The method used in this study is by direct measurement in the field using a measuring tool to get the effective temperature and relative humidity of the indoor space. As well as the use of Autodesk Ecotect Software 2011 as a tool that helps obtain Effective Shading Coefficient value with three-dimensional simulation by incorporating climatological data from weatherbase site.The result of this research is obtained OTTV value at each facade that is OTTV value on 9th floor southwest facade equal to 47,07 W/m², on 10th floor southwest facade of 60,60 W/m², at northwest facade 13,61 W/m², on the northeast facade of 24.49 W/m², on the southeast facade of 32.6vW/m², on the eastern fasade of 32.32 W/m², on the western fasade of 47.12 W/m², and on the northern fasade of 32.32 W/m².

1. Introduction

The facade of a building has a role that is the sheath or skin that encloses the building with a choice of robust and transparent material. Field of glass as a building envelope is one of the facade elements that also determines the architectural character and thermal of a building's performance [1]. The glass field required as a visual means between the occupants and the environment outside the building and utilize as natural lighting. The function of the glass field as natural lighting increases the temperature of buildings, in terms of Indonesia, a tropical climate country. Indonesia has a high tropical climate, can reach up to 80%, relatively high air temperatures (can reach 35℃), and stinging and increasing solar radiation [2]. Szokolay (1987) mentioned depends on comfort variables (solar/ radiation, air temperature, humidity, and wind speed) and various individual/subjective factors. Related to Lippsmeier's research (stating at 26 °C TE, humans begin to sweat, and endurance of working begins to decrease) by the distribution of comfortable temperatures of Indonesians according to the LPMB PU Foundation, then we are ready to use for suitable activities at comfortable temperatures optimal (22.8 °C - 25.8 °C with 70% humidity) [3]. This figure is below the temperature in Indonesia, which

can reach 35 °C with 80% humidity. An increase in temperature due to excessive solar radiation can cause discomfort for the inhabitants.

The above condition requires to apply the active design of buildings as a solution to the problems emerge. One of them is the existence of artificial air conditioning or often called AC (Air Conditioning). The use of artificial cooling energy generates the value of the building's energy consumption increase. In order to limit the external loads, the building envelope is one of the critical building elements and deliberation in energy use [4]. Because of its function as an external envelope, the energy conservation criteria need to be considered in the design process of a building, especially concerning the design of exterior fields about the appearance of a building [5]. To reduce the external load on buildings, *Badan Standardisasi Nasional Indonesia* (The Indonesian National Standardization Agency) determines the design criteria for the building envelope stated in the Comprehensive Thermal Transfer Price (OTT), namely OTTV $\leq$ 35 Watt/m² as stipulated in *SNI* 6389: 2011 which is an assessment of SNI 03-6389-2000 [6]. This provision applies to buildings which are conditioned and returned to obtain a building envelope design that can reduce external loads by adding to approved loads. By providing a specific limit value for OTTV then an external load can be given. For this reason, research on the transition value in buildings or OTTV values (Overall Thermal Transfer Value) and the value of thermal transfer in buildings.

One of the high-rise buildings in the city of Semarang is Suara Merdeka Tower, this building is located on Pandanaran Street, Semarang, which owned by Suara Merdeka Group that functions as a rental office building. A multi-storey rental office building is one of the functions that most requires energy savings. The energy-conscious design concept will reduce energy consumption during the operational period, especially when operating at the rental office is the largest level of consumption. The use of energy from buildings is dominated by climate effects because the thermal obtained from direct conduction of thermal sources or infiltration or air filtration through the surface of the building reaches 50-80% of the energy consumed.

Several studies competed related to the influence of building envelope design on the value of solar thermal transfer in high buildings with the dominance of glass material. Among other studies conducted by Sandra Lukita Lecturer in the Faculty of Engineering, Department of Civil Engineering, Petra Christian University, Surabaya in a journal entitled Analysis of Energy Conservation through Building Veils (Civil Engineering Dimension, Vol. 8, No. 2, 93-98, September 2006 *ISSN* 1410-9530) states that Menara Batavia Jakarta has an OTTV value of 61.5 W/m²; Menara Global Jakarta with OTTV value of 68.92 W/m²; Wisma SMR Jakarta with OTTV value of 75.89 W/m² [7]. These buildings have a similarity design that is a multi-storey building with the dominance of glass material as a building envelope and building design without sun-shading/shading devices. In this study, it concluded that the higher the WWR of a building, the greater the OTTV value and the maximum External Cooling Load. It is explained by the greater magnitude of the penetration area, the solar radiation and thermal conduction through the penetration area that enters the building increases. Furthermore, supported by the absence of shading devices as a shadowing element in buildings that function to reduce the thermal entering the building.

From the case above, this study aims to determine the value of OTTV and provide design recommendations to produce more efficient buildings. The limitation of this study is the following criteria :

- 9th and 10th floors are the sample of this study since type of those floorplans are the majority in this building.
- Climatology data of Semarang taken from weatherbase site
- Surrounding the building considered unimpacted the calculation
- Interior properties on wall such as blinds and curtains are uncalculated
- Calculation of this study based on existing material and colour of the building.

2. Methodology

2.1. OTTV

The object of this research is Suara Merdeka Tower Semarang, a 15 floors (exclude two basements) rental office building with glass as dominating façade material. To determine thermal comfort, the value of thermal transfer calculated using OTTV formulation on entire building façade [8]. OTTV concept includes three essential elements of thermal transfer on the building wall as follows:
- Thermal conduction through opaque walls;
- Thermal conduction through glass;
- Transmission of solar radiation through glass.

According to *Standar Nasional Indonesia/SNI* (the Indonesian National Standard) regarding "Energy Conservation of Envelopes on Buildings" this is a revision of SNI 03-6389-2011, the overall thermal transfer value for each area of the building's outer wall of buildings with a specific orientation will be calculated through equation.

$$OTTV = \alpha\left(Uw \times (1 - WWR)\right) \times TDek + (SC \times WWR \times SF) + (Uf \times WWR \times \Delta T) \quad (1)$$

OTTV : Overall thermal transfer value on an external wall that has a specific direction or orientation (Watt/m²).
A   : Absorbance of solar radiation.
Uw   : Wall-less thermal transmittance (Watt/m².K).
WWR : Comparison of window area with the area of the entire outer wall in the orientation specified.
TDek   : Differential temperature equivalent (K).
SC   : Shading coefficient of the fenestration system.
SF   : Solar radiation factor (W/m²).
Uf   : Transmission of thermal fenestration (W/m².K).
ΔT   : Different planning temperatures between the outside and the inside.

In this analysis process, to determine the value of each variable is as follows:

Table 1. Determines the value of each OTTV variable.

Variable Type	Symbol	How to Determine Value
Absorbance of Solar Radiation	α	It has been known in *SNI*, according to the type of material
Wall thermal transmittance is opaque	Uw	It has been known in *SNI*, according to the type of material
Comparison of window area with the area of the entire outer wall in the orientation specified	WWR	Calculated manually, according to building conditions
The equivalent temperature difference	TDek	Has been regulated in *SNI*
The shading coefficient of the fenestration system	SC	ECOTECT simulation
Solar radiation factor	SF	Has been regulated in *SNI*
Thermal transmittance fenestration	Uf	It has been known in *SNI*, according to the type of material
The difference in planning temperature between the outside and the inside	ΔT	Has been regulated in *SNI*, known = 5

Variables with known and pre-arranged values, the constructor does not display in the analysis process. In this analysis chapter, the composer presents the process of obtaining the value of the Shading Coefficient variable for each facade by using Autodesk Ecotect software simulation. Calculation of thermal transfer will be done per-facade of the building with research samples partially in accordance with what has been mentioned in the spatial scope is the 9th and 10th floors, which will then be done as a whole OTTV calculation.

2.2. Determining shading coefficient value using autodesk ecotect software

The steps in conducting the Ecotect simulation to reveal the Shading Coefficient Effective (SC 2) value are as follows:

2.2.1. Modelling Suara Merdeka Tower as built on site. Remodelling the building with Ecotect as follows :
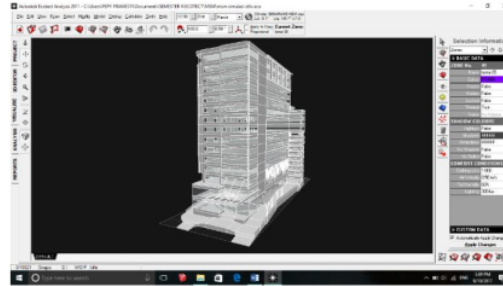

Figure 1. Modelling the building on ecotect software.

2.2.2. Input climatological data. To obtain a real shading model during the simulation, climatological data input for the Semarang area is carried out on the climae data parameter. In this study, the climatological data of Semarang City obtained from website weatherbase.com due to data from the Semarang City *BMKG* is uncompatible with requirement of Ecotect. The climate data needed for software simulation is hourly climate data from outside air temperature, solar radiation (direct solar and indirect solar), hourly air humidity, wind movement.
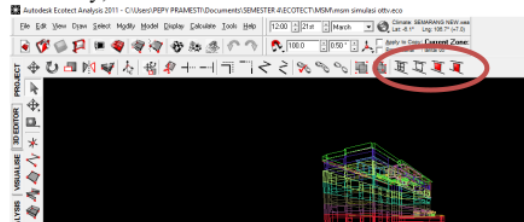

Figure 2. Pairing data from weatherbase.com.

2.2.3. Period adjustment. The period is set on 4 extreme dates of the annual tropical climate period, March 21st, June 22nd, September 23rd and December 22nd, then the time adjusted at the range 7.00 am – 5.00 pm with 1 hour interval.

Figure 3. Adjusting on certain period (left) and adjusting on certain hour (right).

Calculation conducted on each period to obtain solar shade percentage. Data acquire as follows:

- Percentage of slar shade on certain period and stereographic diagram showing hourly gradations into a sun path diagram.
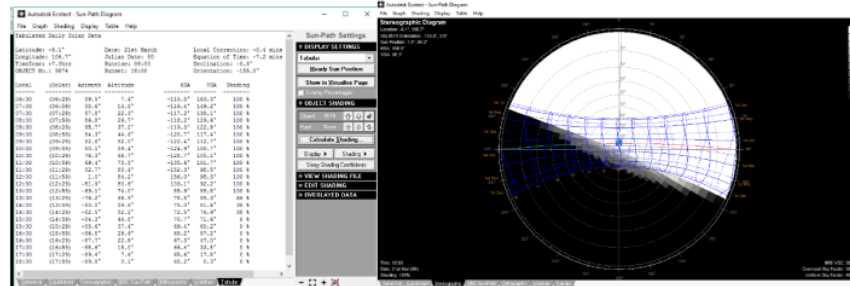

Figure 4. Solar shade data gained (left) and stereographic diagram (right)

The output produced from the simulation is the percentage of solar shade per hour at the extreme times in the annual tropical climate period. The percentage of sun color is then calculated using Normal Direct Radiation (ID) and Diffuse Radiation (Id) (Indonesian National Standard 03-6389-2011).

$$SC - day = \frac{\sum[100\% - SS] x\, ID - Id]}{\sum(ID + Id)} \tag{1}$$

Where,
SC-day   : Shading Coefficient per day
SS   : Solar Shade
ID   : Normal Direct Radiation (W/m^2)
Id   : Diffuse Radiation (W/m^2)
The calculation is valid if ID + Id > 0.

3. Result and Discussion

Simulation of Ecotect gained several values of shading coefficient on entire façade of 9th and 10th floor Suara Merdeka Tower. The next step is to iput this value into the OTTV equation formula along with other variable, hence the overall thermal transfer value is obtained as follows:

Table 2. OTTV mapping on entire façade of 9th and 10th floor.

	Partial OTTV (w/m^2)	*SNI* 6389 : 2011 ≤ 35 w/m^2
Southwest 9th floor	47.07	X
Southwest 10th floor	60.60	X
Nortwest	13.61	V
Norteast	24.49	V
Southeast	32.6	V
East	32.32	V
West	47.12	V
North	32.32	V

4. Conclusion

Southwest has the potential to be exposed to direct solar radiation in December when the sun is south of the equator, and will be completely shadowed around June when the sun is north of the equator. The Southwest side has no sun shading devices, neither do the other sides. The shading formed on the building envelope is caused by the design of the building mass which is influenced by the daily movement of the sun. Another result of this study found that the energy consumption to reduce the effective temperature and relative humidity of the room with a difference of 2.4 °C (between the 10th and 9th floors) is 4.026 Watts (per m³).

Solution recommended in this study to reduce the value of OTTV on the Southwest side is the addition of sun shading device designs and material engineering on building facades with due regard to the following matters:

Design The design of the shading devices is prioritized on the optimal size and shape to reduce heat from solar radiation, but with due regard to the structural aspects by processing the right dimensions. In this case, the recommended forms of shading devices are horizontal, vertical and simple combinations (egg rate). The focus of this design is to provide optimal solutions that can be applied to Suara Merdeka Tower Semarang.

Material Existing glass material is irreplaceable, a solution that can be applied is the addition of a reflective layer to reduce heat entering through the glass. In order to remain uniform with the type of glass material installed in Suara Merdeka Tower, a 60% reflective glass coating was chosen. The material from the shading devices is chosen that has a low conductivity level, so as not to increase the conductivity level of the building envelope material. This can be seen in the U-value of a material, the lower the U-Value, the lower the conductivity value. The recommended material is ACP (Aluminum Composite Panel).

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GENERAL COMMENTS

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