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SPECULATION ON OTTV VALUE IN BUILDINGS WITH PREDOMINANCE OF CONCRETE CLADDING IN HUMID TROPICAL AREAS

Case Study: Tree Inn Hotel in Batu

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Abstract

One initiative that can be implemented involves formulating an architectural sustainability paradigm that is conscious and responsive to energy conservation. The use of energy for cooling buildings is a crucial factor in global energy consumption. The envelope of a building, which encompasses its walls, windows, and roof, plays a crucial role in determining the building's thermal performance. The Overall Thermal Transmittance Value (OTTV) is a parameter used to measure external heat gain through the building envelope. High OTTV values can increase the energy consumption of buildings, especially in the cooling system. The primary objective of this study is to evaluate the impact of OTTV on the building envelope, with the aim of promoting energy conservation. By understanding the value of OTTV, this study will analyze and relate it to the design of buildings dominated by concrete, which resembles the trunk of a giant tree, and assess whether it will have a significant heat gain. This research is quantitative and will be conducted using both simulation and experimental methods. The results of this study will also inform guidelines for designing energy-efficient buildings based on national standards, such as SNI 6389-2020. This research will be carried out in several stages, namely selecting a specific building as a case, identifying dimensional and material specifications, Data Collection, Data Analysis, and Conclusion. This research is expected to provide a clear picture of how to analyze the OTTV value on the building envelope for energy conservation, especially at the Tree Inn Hotel located in Batu Tourism City. Because the Tree Inn Hotel building has a specific building envelope, the envelope consists of a concrete blanket on one side, whereas the opposite side does not utilize a concrete blanket envelope.

Keywords: Energy Conservation, OTTV, Tree Inn Hotel

1. Introduction

Analysis and optimization of the Overall Thermal Transfer Value (OTTV) is essential to improve energy conservation in building design. OTTV serves as a key metric for assessing heat gain through building envelopes, which is crucial for enhancing energy efficiency, particularly in high-rise structures (Chan & Chow, 2013). Effective Solar Radiation (ESR) is a critical variable in the OTTV equation, particularly for buildings with sloping walls, as it accounts for solar heat gain and can significantly impact OTTV values (Sudaporn & Sivayu, 2014). Incorporating high-quality thermal insulation materials is essential for reducing heat transfer, thereby lowering OTTV values and contributing to energy savings (Zhukov et al.,

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2018). Additionally, strategic building orientation and layout can maximize natural light while minimizing unwanted heat gain, thereby further optimizing OTTV performance.

Additionally, addressing thermal bridges is essential, as it can lead to increased heat loss and gain, which adversely affects the overall thermal performance of the building envelope (Theodosiou et al., 2019). By integrating these effective insulation strategies, optimal orientation, and thermal bridge mitigation, designers can significantly enhance the energy efficiency of buildings, ensure compliance with OTTV regulations, and promote sustainable practices in architecture. Total Thermal Transfer Value (OTTV) is a measure of the average heat gain into a building through the building envelope. This is a widely adopted measure in many countries aimed at improving energy-efficient building design. Over the last decade, the application of green roofs in commercial buildings has increased, aiming to improve building insulation and reduce heat gain through the roof area, as well as the cooling needs of buildings (Chan & Chow, 2013). Overall Thermal Transfer Value (OTTV) control in buildings is one of the important building energy regulations that govern the design of energy-efficient building envelopes. Based on the results of this study, 24-hour operation buildings can be well-designed under OTTV regulations to achieve good energy efficiency in both the cooling and heating seasons. Currently, there are two different strategies for OTTV control: a single OTTV limit that applies to all types of buildings, regardless of their diverse operating hours, and a second, differentiated OTTV limit for different types of buildings (Chan, 2023).

In practical terms, the overall thermal transfer (OTTV) value is often used to assess this aspect of the building. Managing the heat transfer capabilities of building enclosures, particularly in high-rise structures, is a crucial design approach for enhancing building energy efficiency. The efficacy of this process is shown through a case study in the subtropical climate of Hanoi (Khanh Phuong et al., 2024). The thermal conductivity value of traditional insulation materials is compared to determine the importance of thermal insulation materials in energy saving, and to discuss the properties of innovative materials. The application of insulation materials is made in accordance with TS 825 (the standard for thermal insulation rules in buildings) in our country. Problems in isolation are directly related to energy, earthquakes, fires, environmental health, human health, and safety (Buyukakinci et al., 2023).

The use of thermal insulation materials is an effective way to form a building's thermal envelope, reduce energy costs, and improve the durability of building structures. The formation of an insulating shell for an object in the oil and gas industry is possible only when considering the special features of the thermal insulation layer in construction and the use of high-quality materials that retain their characteristics, both at the initial stage of operation and throughout the calculation period. The use of materials in the design should ensure maximum performance and durability (Zhukov et al., 2018). Thermal insulators play a crucial role in reducing the energy consumption of operational buildings (Mohamed et al., 2022). The results were then applied to a case study of an office building, aiming to measure the overall contribution of the point thermal bridge to the heat flow through the building envelope. The overall effect on the DSF can exceed 25% of the total heat flow of the casing, leading to a large estimate of the actual heat flow through the building envelope.

Although it provides potential for high-energy-efficient buildings, other important parameters, such as the problem of point thermal bridges, are, in most cases, ignored (Theodosiou et al., 2019). Thermal bridges affect the thermal standards of a building's envelope. In this study, a methodology for measuring the actual thermal bridge performance was developed. They are taken into account in linear thermal conductivity or Ψ-values, and can be estimated from tabulation values for standard building details or from numerical modeling

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(O'Grady et al., 2019). Thermal bridges can have a significant impact on the thermal performance of the building envelope, substantially increasing winter heat loss and summer heat gain. The effect of bridges in reducing the overall thermal resistance of assemblies is examined, and some common solutions to bridge problems are investigated for their effectiveness. Furthermore, condensation on the thermal connecting elements can result in the growth of mold and mildew (with the accompanying deterioration of air quality), surface staining, and serious damage to building components.

A passive solar design strategy encompasses several key approaches to reduce the energy consumption of heating, cooling, and lighting buildings. Here, we provide a complete review of previous studies on simulation-based optimization of passive solar design strategies, with a particular focus on the latest research results. Although it is relatively simple to reduce energy use to some extent by implementing individual strategies, achieving very high levels of energy performance requires the application of an optimal combination of several strategies, as verified through building energy simulations (Stevanović, 2013). Passive design strategies are among the most cost-effective methods for reducing energy consumption in buildings. Using satellite imagery, each building is evaluated for three passive design strategies: orientation, roof color, and shade level. Less intuitively, in terms of what appears to be optimal passive design, buildings in the High Plains and Ohio Valley generally have lighter-colored roofs than buildings in the warmer Southwest regions (Kruzner et al., 2013).

The primary goal of passive design is to create a thermally comfortable building by minimizing the demand for active forms of mechanical heating, air conditioning, and ventilation. It will also help explain the benefits and operations of passive solar design to clients. The concept of sustainability in building materials revolves around the development and use of environmentally friendly materials that possess the same or improved properties as conventional building materials. However, in the past, the use of conventional building materials in construction has led to environmental degradation. Good design, along with the properties of materials (chemical, physical, and mechanical), is responsible for the strength of building materials (Jeeva Chithambaram et al., 2022).

Using sustainable building materials is a promising alternative in building envelope applications to improve energy efficiency in use. These materials, with a low environmental impact, offer the benefits of being renewable and containing low energy, contributing to global sustainability. This comprehensive literature review provides a broad overview of the hygrothermal characteristics, thermal performance, and energy use of these materials (Nasr et al., 2023). Materials in this category have the potential to make a substantial contribution to sustainability in the construction sector. The production of building materials significantly contributes to greenhouse gas emissions (Adebowale & Agumba, 2023).

The green building certification system evaluates the green performance of buildings and verifies the status of green buildings through established frameworks and targets aimed at achieving green building status. The primary objective of this study is to analyze and clarify the issues surrounding green buildings and green building certification in the building market. Green buildings minimize the environmental impact of buildings and provide better workspaces and living spaces (Özden et al., 2013). Green building certification provides a means to enhance the environmental performance of existing buildings. Amid the literature on green building certification for new design and construction, several studies have been conducted on green building certification for existing buildings. In Sweden, existing office building property owners are interested in escalating, maintaining, or achieving green building certification to improve their competitiveness in the market and improve their company's overall

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environmental performance portfolio (Charlotte, 2015). Green building certification was initially applied as a tool to create more sustainable buildings. The increase in the operating price of buildings and utilities has a major impact on the conceptual design and implementation of sustainable architecture. The result of this paper is an objective assessment of six LEED-certified buildings, comparing their water and energy consumption to that of reference buildings (Dobiáš & Macek, 2014).

Pohon Inn in Batu, East Java, is a multi-storey hotel. Geographically, Batu City is located in the highlands of the tropics, characterized by high humidity. The Inn Hotel tree has a very specific design. Almost all of the cladding (the exterior covering of the building) has been applied, leaving a small opening for the window, as seen in Figure 1. Concrete materials have specific characteristics in storing and transferring heat to the inner space. Therefore, the size of OTTV for buildings with a predominance of concrete on this cladding is very interesting to study.

Figure 1: Figure description Pohon Inn Hotel

2. Method

This is a speculative study that employs a descriptive approach to suggest that buildings with a predominance of concrete cladding may be at risk of a very large OTTV value.

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2.1. The first stage

A survey was conducted to determine the specifications (dimensions and materials) of the building. This is done by visiting the location, measuring, and taking data from the documents obtained. The result of stage 1 is a drawing of the cut and material specifications. From this step, it can be seen that the cladding has a distance from the interior wall.

2.2. Second stage

This is a simulation stage that is carried out through OTTV calculations. The case building is used as the object of the OTTV calculation study with the available formula. The results of this stage can be referred to as the theoretical OTTV value of the Tree Inn building for this hotel. This study will assess the building's envelope in relation to OTTV metrics. The OTTV metric that meets the energy conservation standard as set by SNI 6389-2020 is ≤ 45 W/m². The focus of the analysis is the building's envelope, including wall materials, paint pigmentation, and the presence or absence of shading devices. The orientation of the selected structure consists of four cardinal directions: north, south, east, and west. The goal is to ensure the appropriate OTTV value for each orientation. The solar radiation factor (SRF) used is based on the SRF value described in SNI (National Standardization Agency, 2020). Non-structural external components of the building, such as adjacent structures, large vegetation, and window coverings, are not included in the consideration. The characteristics of the building sheath, including materials and colors, are in harmony with the applicable design parameters. The External Thermal Transmission (OTTV) value for each external wall segment of a structure that has a specific orientation can be determined by using the following formula:

$$OTTV = a. [(Uw \times (1 -- WWR)] \times TDeK + (SC \times WWR \times SF) + (Uf \times WWR \times DT)$$

The above criteria have the following benchmark equations:

- ❖ Absorption of solar radiation (α)
- ❖ Thermal transmittance of roof/impermeable walls (W/m². K)
- ❖ Area of non-transparent roof/wall (m²)
- ❖ Temperature difference equivalent (K)
- ❖ Shade coefficient of the fenestration system
- ❖ Solar radiation factor (W/m²)
- ❖ The difference in temperature planning between the outside and the inside
- ❖ WWR
- ❖ Sunlight radiation factor (SF)
- ❖ Thermal transmittance value of the fenestration system (Uf)
- ❖ OTTV rating should not exceed 45 W/m²

This stage is suspected to yield results that have a chance of the OTTV value being large or even small. This suspicion is due to the fact that approximately half of the building's envelope features external cladding walls, resulting in a significant air gap with the inner wall. This situation will diminish the value of OTTV. However, approximately half of the building envelope area lacks external cladding, which will increase the OTTV value.

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2.3. Third Stage

If direct experiments are carried out in the field, at the location of the Tree Inn Hotel, then what can be done is temperature and humidity measurement activities in important spaces and carried out at important times, namely in the morning, at noon, in the afternoon, and at night, with a better time interval every 1/2 or 1 hour break. The important room in question is the hotel room, where there are air conditioning facilities on the double-clad side and rooms with air conditioning facilities on the single-clad side. The results of this stage are 24-hour temperature profiles and 24-hour humidity profiles for each of these rooms. The conjecture that can be conveyed is that air-conditioned rooms on the side of a wall with double cladding will have a lower temperature than air-conditioned rooms with walls without double cladding.

2.4. Fourth Stage

It is the analysis stage. The result of this stage is a discussion of OTTV values and temperature profiles. The OTTV value obtained can be compared with the maximum OTTV value from SNI, allowing for analysis and discussion. The next discussion is the temperature profile for rooms without air conditioning facilities and rooms with air conditioning facilities. Thus conclusions can be drawn.

3. Result and Discussion

The possibilities resulting from the discussion are:

3.1. OTTV Analysis Results

This study will reveal that the OTTV value for the shroud of the Tree Inn Hotel building can be determined after theoretical calculations. The results of this calculation are used to determine whether it meets the standards of energy-efficient buildings, as compared to the SNI SNI 6389-2020 reference of 35 W/m². The subsequent discussion can be informed by examining these results. If the OTTV value is smaller than the standard, this is quite surprising, as it is possible that the double wall's performance is actually effective. However, if the OTTV value exceeds the standard, this aligns with the original assumption. Thus, it is conceivable to take steps to reduce it. Impact of Building Casing Design.

3.2.Building envelope design

The unique design of the building's casing is believed to be robust, which may contribute to higher heat gain. This study examines the impact of specific materials, including double walls, and the construction techniques employed in building walls, windows, and roofs, on the overall thermal performance and energy consumption. Since this cladding wall is only a blanket on the outside, the inner wall is very protected from sun exposure. Thus, the OTTV value will be small. The concrete blanket on the outside of the building envelope also produces wall thickening, so that the windows seem to get shade or sun shading, which greatly helps to reduce the OTTV value.

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3.3.Optimization Strategy

The discussion highlighted various strategies to optimize OTTV, including increasing isolation, utilizing energy-efficient windows, and incorporating shade devices. This strategy aims to reduce heat gain and, consequently, lower the energy required for the cooling system. This strategy is implemented in the Tree Inn hotel building, specifically by installing cladding, or the outer sheath of a concrete building, on the outside and between the room walls. This creates an air gap as insulation. Additionally, the use of cladding also provides shade, thereby reducing the value of OTTV. This strategy can be confirmed with the architect to ensure the concept's outcome.

3.4.Potential Energy Savings

By implementing the recommended optimization strategies, the study estimates a significant reduction in energy consumption. This not only contributes to energy conservation but also increases the level of comfort inside the building, making it more suitable for occupants.

3.5.Guidelines for Future Design

These findings provide valuable guidance for architects and builders in designing energy-efficient buildings. The study emphasizes the importance of complying with national standards, such as SNI 6389-2020, to ensure that new construction is optimized for energy efficiency.

3.6.Contribution to Sustainable Practices

The results of this study contribute to a broader discourse on sustainable building practices. By focusing on OTTV optimization, the research aligns with global efforts to reduce carbon emissions and combat climate change through improving energy efficiency in buildings

4. Conclusion

The design of the Tree Inn hotel, which at first glance shows the concern that the dominance of the building envelope made of concrete will provide a large contribution to the transmission of solar temperature and will have the effect of heating the inner space, and will result in the OTTV value being so large that it needs to be calculated and measured. The use of concrete building envelopes, which serve as the outer walls, is suspected to be a shade for the inner walls because air is formed between the inner walls and the building envelope, which actually forms insulation to prevent heat from spreading into the building. The wall thickness resulting from the sheath of this additional concrete building has the consequence of thickening the overall wall, so that the installed windows will receive significant shade, which has an impact on reducing the OTTV value.

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