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IMPROVING THERMAL EFFICIENCY OF SUBSIDIZED HOUSES THROUGH WINDOW-TO-WALL RATIO DESIGN

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ABSTRACT

Subsidized housing in Indonesia is often built with limited consideration for thermal comfort, prompting many residents to rely on air conditioning, which increases energy consumption. One of the factors that influences indoor thermal conditions is the Window-to-Wall Ratio (WWR), which determines how much sunlight and airflow can enter the space. This study explores how different WWR values affect the thermal performance of two subsidized housing types in Godean, Sleman—Griya Moyudan Asri and Godean Jogja Hills. Using quantitative analysis and simulation methods, temperature data were compared across existing conditions and adjusted WWR values of 10%, 20%, and 30%. The findings reveal that an increased WWR tends to elevate indoor temperatures, particularly during periods of high solar intensity. On the other hand, WWR values between 10% and 20% provide more consistent indoor temperatures and improve energy efficiency by reducing dependence on mechanical cooling. These results highlight the potential of passive design strategies, including optimal window sizing, pivot hinges, and effective shading, to enhance thermal comfort in tropical climates.

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1. Introduction

Subsidized housing aims to increase the ownership of livable houses. Until now, the government has still been trying to improve the housing backlog. Public interest in buying subsidized houses has recorded 1.3 million subsidized landed houses sold in Indonesia (Soewarno, 2024). The design of subsidized houses should meet the aspects of thermal comfort, because when viewed from the selling price of subsidized houses, they do not consider aspects of thermal comfort (Mufida et al., 2022). Internal and external factors also influence thermal comfort; this study seeks to achieve thermal comfort, explicitly focusing on the Window-to-Wall Ratio (WWR) in subsidized houses. Thermal comfort is influenced by air temperature, thermal comfort standards in Indonesia follow the SNI 03-6572-2021 standard between 25.8 ° C and 27.1 ° C, and for air humidity around 40%-50% for small-scale spaces. Due to the lack of developers considering aspects of thermal comfort, many subsidized homeowners use air conditioning as a practical step to achieve thermal comfort. The use of air conditioning can increase energy consumption. Energy use by selecting the ideal WWR ratio for subsidized houses.

Research conducted by Rana et al. (2022) has a similar case study, namely the impact of WWR on comfort and energy consumption. This study also focuses on using air conditioning in buildings that impact energy waste; on the other hand, air conditioning is beneficial in thermal comfort. Data and the most significant energy consumption for each WWR ratio are simulated. So WWR has become one of the most effective strategies for increasing comfort and reducing energy consumption.

This research took the object of two subsidized housing schemes, including Griya Moyudan Asri Housing and Godean Jogja Hills Housing. The observation results have fulfilled the aspects of orientation, the length of time the housing has been established, and the differences in design. The orientation of the building in this housing tends to be northeast. Griya Moyudan Asri's housing design uses a sloping roof, and Godean Jogja Hills's housing uses a gable roof, where the use of the roof will affect thermal comfort. Godean Jogja Hills has been established for 5 years, and Griya Moyudan Asri is classified as new housing; the homeowner already uses air conditioning in both housing. The output of this research is the window area, window model design, and WWR ratio, which are ideal for suppressing thermal comfort and low energy.

2. Literature Review

The difference in building orientation does not significantly affect the solar radiation received by the subsidized house building because there is a 6% difference. From this stage, the roof is one of the parts of the building that receives the most significant solar radiation. A review of the wind direction of the building significantly influences the high and low temperatures of the room. However, the building evaluated has different orientations, and the volume of the building assessed is still the same (Soewarno et al., 2024). The selection of building orientation has proven to affect the thermal comfort of the space perceived by homeowners. The south-facing building orientation has the best thermal performance with the lowest air temperature and humidity. Northwest orientation is the most uncomfortable thermal condition (Mufida et al., 2022).

In meeting the thermal comfort, major factors affect the thermal comfort of the building conditions. These factors are the absence of a canopy on the terrace, very minimal ventilation and openings, less shade vegetation around the house, and the selection of paint colors that do not support solar radiation. This factor is directly related to thermal comfort, from sun exposure and poor air circulation (Sitanggang et al., 2021). Window construction is one of the significant influences on thermal comfort. South-facing windows have the best thermal comfort and lowest thermal load, supported by a window-to-wall ratio of 50% and a shading depth of 0.3 m, with a shade count of 4 (Ghorbani et al., 2023). Roofing materials can affect thermal comfort in space; if the roofing material is heat-resistant and of sufficient thickness, it will affect the thermal conditions of the room. Ventilation design and less than optimal design will affect the air entering the room. Windows with jalousie design, when opened, allow almost 90% of the air volume to enter, while windows with top hinges allow about 30% of the air volume to enter through the glass frame (Fitriaty et al., 2024). Building orientation significantly impacts lighting, heating, cooling, and energy consumption. If there is shading on the building and the type of glazing on the windows, there is the greatest U-value of glass in terms of energy. WWR significantly impacts the primary energy demand (Tahsildoost et al., 2020).

Building energy consumption tends to increase yearly, accompanied by an increase in the percentage of WWR. Determining the presentation of WWR is one of the complex tasks because it is a determining factor of thermal comfort. Studies suggest a WWR of 30%-40% with thermal comfort in mind. An ideal WWR ratio can significantly reduce energy efficiency and increase light demand (Rana et al., 2024). Proper window design can substantially reduce thermal discomfort in buildings and building orientation. So, it is essential to design windows well and opening strategies well. Thermal comfort can be achieved by choosing large windows, pivoting hinges, and ventilation holes. Architects often use Ventilation holes in the passive design as a design strategy because they tend to have a low cost. The choice of window design and WWR in buildings can be a relatively inexpensive solution to reduce energy consumption and thermal security (Martins et al., 2024).

3. Research Method

This research uses a simulation-based quantitative method to determine the ideal window dimensions and WWR values. The software used for simulation is Archicad, which is based on the local climate of Yogyakarta and the materials in the existing building. Simulations were conducted with WWR value limitations, existing WWR, 10%, 20%, and 30%, and Orientation in the East direction. The existing WWR compares the difference in WWR ratios of 10%, 20%, and 30%. This WWR research aligns with the research of Rana et al. (2020), who used the same quantitative and simulation methods. Similar research was also conducted on window design and WWR by (Ali et al., 2025).

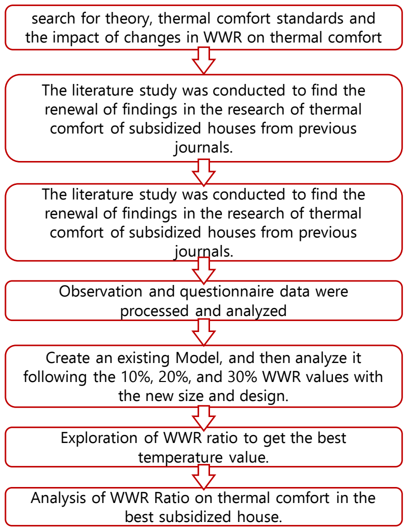

Figure 1. Research flow chart

Data collection was carried out by observation and questionnaires. The questionnaire was conducted to determine whether the house is comfortable based on the room temperature and whether it uses air conditioning. Observations were made to validate the shape and direction of the building. As a population of two subsidized housing units as a simulation object, the sample uses purposive sampling as a representative to represent the population under study.

4. Results and Discussions

Based on observation data and WWR simulation analysis carried out on the object of the house against the existing house window ratio, WWR 10%, WWR 20%, and WWR 30% in Griya Moyudan Asri and Godean Jogja Hills housing. Determining the WWR limitation is based on the limited volume of simulated building objects, so the WWR limitation becomes essential.

This research focuses on two objects in Godean, Sleman, Yogyakarta Special Region. The first is Griya Moyudan Asri subsidized housing, and the second is Godean Jogja Hills housing.

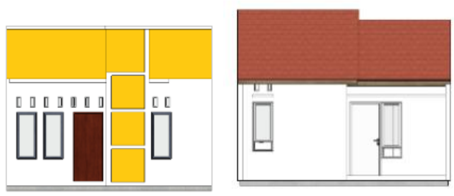

Figure 2. Existing House of Griya Moyudan Asri and Godean Jogja Hills

Figure 2 is a visualization of the existing house, left of Griya Moyudan Asri housing and right of Godean Jogja Hills housing. In both housing, the existing WWR is at 9%. The window materials used in both housing are aluminum and single-glazing glass. The striking difference in using these materials is the wall material; in Griya Moyudan Asri, the walls are made of red brick, and in Godean Jogja Hills, the walls are made of red brick. The use of materials in buildings is described in Table 1:

Table 1. Subsidized Housing Materials

Griya Moyudan Asri		Godean Jogja Hills	
Materials	**Material Type**	**Materials**	**Material Type**
Wall	Red Brick	Wall	Lightweight Brick
Roof	Metal Sand	Roof	Metal Sand
Floor	Tile	Floor	Tile
Door	Plywood	Door	Plywood
Window	Aluminium Single Glass	Window	Aluminium Single Glass

Table 2. Window to Wall Ratio Analysis

WWR	U Value (W/m^2K)	Glazing Ratio (%)	Infiltration at 50PA (ACH	Internal Temperature (Min-Max in °C/Hrs) March	June	Sept	Dec
Subsidized House Griya Moyudan Asri							
Existing	3,25	3	3,91	24,25-30,91	25,90-35,07	24,12-32,67	26,01-33,51
10%	2,91	1	3,57	26,45-31,11	28,02-35,36	26,29-32,89	27,88-33,60
20%	3,08	3	4,19	26,46-31,54	28,07-35,66	26,32-33,21	27,89-33,94
30%	3,09	4	4,93	26,41-31,79	28,09-35,90	26,33-33,45	27,87-34,19
Subsidized House Godean Jogja Hills							
Existing	3,48	3	3,82	24,42-30,72	26,08-34,99	24,36-32,55	26,21-33,39
10%	3.48	2	3,61	24,35-30,20	25,95-34,62	24,27-31,96	26,08-32,68
20%	3,48	2	3,80	24,34-30,17	25,94-34,61	24,26-31,94	26,07-32,64
30%	3,48	3	4,21	24,37-30,28	25,96-34,74	24,27-32,08	26,11-32,74

Table 3. Window Specifications

WWR	Description	Window Area
Subsidized House Griya Moyudan Asri		
Existing	With Shading	2,52
10%	Single Glass, Frame Aluminium, Shading+Louvers+Pivot Hinge	2,88
20%	Single Glass, Frame Aluminium, Shading+Louvers+Pivot Hinge	5,8
30%	Single Glass, Frame Aluminium, Shading+Louvers+Pivot Hinge	8,64
Subsidized House Godean Jogja Hills		
Existing	With Shading	1,8
10%	Single Glass, Frame Aluminium, Shading+Louvers+Pivot Hinge	1,96
20%	Single Glass, Frame Aluminium, Shading+Louvers+Pivot Hinge	3,91
30%	Single Glass, Frame Aluminium, Shading+Louvers+Pivot Hinge	5,78

Table 4. Average internal temperature values

WWR	Marc (°C)	June (°C)	Sept (°C)	Des (°C)
Subsidized House Griya Moyudan Asri				
Existing	**27,07**	**30,25**	**28,12**	**29,55**
10%	**28,19**	**31,29**	**29,12**	**30,39**
20%	**28,32**	**31,51**	**29,30**	**30,60**
30%	**28,40**	**31,67**	**29,44**	**30,76**
Subsidized House Godean Jogja Hills				
Existing	**27,12**	**30,26**	**28,17**	**29,56**
10%	**26,85**	**29,94**	**27,82**	**29,07**
20%	**26,83**	**29,92**	**27,80**	**29,05**
30%	**26,88**	**30,03**	**27,87**	**29,12**

When viewed based on the average temperature in Griya Moyudan Asri housing, there is an increase every month, as can be seen in Figures 3 and 4. The most significant temperature increase from the existing WWR to WWR is 30% in March and December. The existing WWR in March has an average temperature of 27.07°C, in December, the average temperature of the existing WWR is 29.55°C, the 30% WWR in March is 28.40°C, and in December, 30.76°C, the temperature difference from the existing WWR to the 30% WWR reaches 1-3°C. The temperature difference has. Translated with DeepL.com (free version), it shows that the greater the WWR value, the more heat from sunlight will enter the room. In June, all WWR values show that the month has the highest average temperature because the sun's intensity in June is very high. If WWR is used at 30%, thermal comfort will be significantly uncomfortable, increasing energy use. At 10% and 20% WWR, the temperature increase tends to be normal; the temperature difference is still not so far, and natural lighting and thermal comfort are maintained. Based on Godean Jogja Hills housing data, the highest temperature is almost every month in the Existing WWR. While at WWR values of 10%, 20%, and 30%, based on the data, the resulting temperature is lower, the temperature difference from each WWR is still in reasonable numbers, especially the temperatures in March and September. Similar to the highest temperature in Griya Moyudan Asri housing, the highest temperature in Godean Jogja Hills housing is in June, Existing WWR the highest temperature is 26.08-34.99 ° C, WWR 10% the highest temperature is 25.95-34.62 ° C, WWR 20% the highest temperature is 25.94-34.61 ° C, WWR 30% 25.96-34.74 ° C, this highest number occurs in all WWR, this is because the intensity of solar radiation in June is very high. If described, the temperature in June reached 34-35 ° C, exceeding the value of thermal comfort.

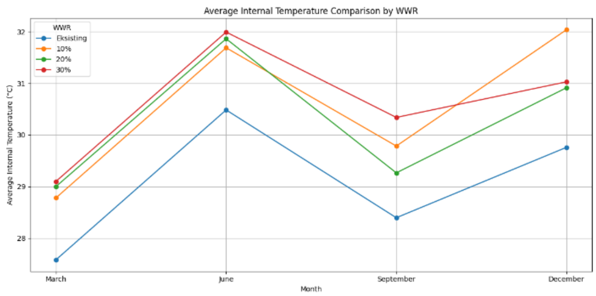

Figure 3. Average Internal Temperature of Griya Moyudan Asri

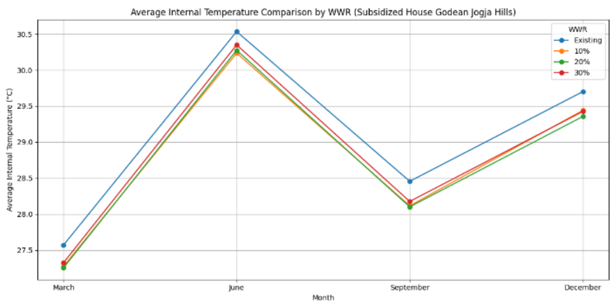

Figure 4. Average Internal Temperature of Godean Jogja Hills

WWRs of 10% and 20% provide better temperature stability because both WWRs have internal temperatures that tend to be consistent and tend to be lower almost every month. This temperature performance shows that a decrease in window area can provide better energy efficiency and natural lighting. All simulations in Godean Jogja Hills housing have a similar ACH value at 3.74 for existing WWR, 10% and 20%, the ACH value of WWR 30% is at 4.42, meaning that more hot air enters the building, so that the room becomes hot. The simulation was conducted with the wind direction facing west. Research conducted by Soewarno (2024) states that the direction of orientation significantly affects the room temperature. In Soewarno's research, 2024 states that a difference of only 6% is noted. In this study, the internal temperature of the building is still within normal limits.

This simulation is also in line with what has been done by Tahsildoost et al., which shows that building orientation has a significant impact on lighting, heating, cooling, and energy consumption. This emphasizes that it has the most fundamental effect on the primary energy demand. Window design plays a vital role in thermal comfort. Research conducted by Fitriaty et al (2024) states that ventilation design and window design, jalousie and pivot hinges, can optimally enter by 90%, which will increase thermal comfort.

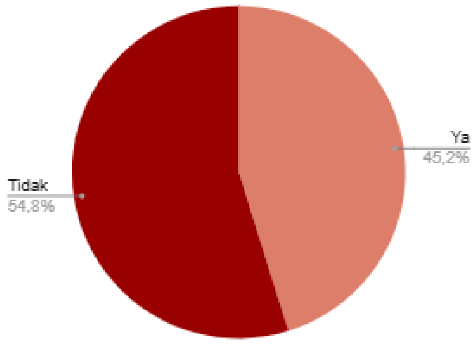

Figure 5. Use of air conditioning in subsidized houses

Figure 5. During observation, research, and data collection through questionnaires, most houses already used air conditioning. As many as 45.2% of subsidized houses use air conditioning as a practical step to create thermal comfort. Research conducted by Soegiono et al (2018) found that using air conditioning causes the energy used to be greater. WWR simulation results on both types show that the ideal WWR ratio is WWR 10% to 20%. In simulating the value of WWR, shading overhang to prove that the ratio of window supports that have deep shading of 60 cm has the best thermal comfort and the lowest thermal load, as in research conducted by Ghorbani et al (2023).

4. Conclusion

From research, observation, and simulation of thermal comfort to the ratio of WWR, it can be concluded that the window size and design significantly affect the thermal comfort in the room. The design includes jalousie and pivot hinges, and air can massively enter the room. This aligns with research conducted by Fitriaty et al. (2024), which found that the volume and design of windows can affect the comfort level. So, from the simulation results, the value of WWR for subsidized houses in tropical climates, especially Sleman, Yogyakarta Special Region, the ideal WWR optimization value is 10% to 20% for thermal comfort and energy efficiency.

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