An Analysis of The Use of Insulation Systems on OTTV Values of Residential Building in Hot Humid Climate

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Abstract. In tropical climates, the main problems are high solar radiation and humidity. The aim of this study is to find the right insulation material to provide thermal comfort of BSPS houses in Pamekasan Regency. The method use in this study is experimental with quantitative data analysis. Experiments were conducted on aspects that affect the value of thermal transmittance (U-value) and type of materials (glass wool, VIPs, and aerogel). The result shows that the best insulation material for thermal comfort is Vacuum Insulation Panels (VIPs). It could provide a significant reduction in OTTV value. The final results of the research by applying the insulation system to the BSPS house of Pamekasan Regency, Proppo Subdistrict, Panaguan Village show that the OTTV value of the alternative model in a house type 24 m2 is 29.505-23.462 W/m2 with a decrease of 22.86%-38.66% while in a house type 33.12 m2 it is 30.205-24.217 W/m2 with a decrease of 22.74% -38.06% and in a house type 84.46 m2 it is 27.223-21.084 W/m2 with a decrease of 26.19%-42.84%. Furthermore, the best type and thickness of insulation material used in this study is Vacuum Insulation Panels (VIPs).

1 Introduction

The level of comfort in a house building is influenced by various aspects including lighting aspects, psychological aspects, thermal aspects and airing / airing aspects. The thermal aspect is influenced by air temperature, humidity, wind speed and besides that it is also concerned with the activities or activities of residents and environmental models around the house[1]. Thermal comfort in space cannot be separated by air temperature, which is the earliest indicator used as a measure of comfort [2]. Indonesia's geographical location in the humid tropics causes Indonesia's climate to be thermally uncomfortable [3]. So, this model is less favorable for humans in carrying out their activities because human work productivity tends to decrease or be low in uncomfortable air models such as too cold or too hot [4].

According to Nugroho's research, the temperature inside the house in Madura, precisely Pamekasan, can reach a temperature of 32.7 ºC [5]. On the other hand, the comfortable temperature range for humans in humid tropical climates is 24-30ºC [6]. According to this

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explanation, there is a solution to overcome this. The utilization of natural ventilation is a great opportunity to overcome thermal comfort problem [7]. The building envelope is an important component in manipulating the potential and constraints of the external climate to achieve thermal comfort in the space according to the demands of its inhabitants [8]. The building envelope on the west and east sides of the building in humid tropical climates has the ability as a heat capacity, which can store and release heat when there is a difference in air temperature in the space inside and outside the building, and has a large energy content because it gets a lot of sunlight. The importance of applying thermal insulation to building envelope walls in humid tropical climates can be used as a heating prevention strategy to cool buildings, one of which is by inhibiting heat absorption through material insulation technology in the building envelope [9]. There is also the advantage of using sustainable insulation materials with low energy, leading to reduced environmental emissions. So more and more popular and innovative types of insulation continue to enter the market [10].

Therefore, the authors conducted a study entitled "Analysis of the Application of Variations in the Thickness of Wall Insulation Systems to OTTV Values in Buildings in the Humid Tropics (Case Study: Self-Help Housing Stimulant Assistance (BSPS) Houses in Pamekasan Regency". The benefit of this research is done to be able to know the thickness of wall insulation which effectively affects the thermal performance and increase comfort in the building envelope banguanan habitable house Self-Help Housing Stimulant Assistance (BSPS) in Pamekasan Regency to overcome the problem of uncomfortable indoor thermal conditions with reference to the requirements of SNI 03-6389 Year 2020 on Energy Conversion Building Envelope in Building.

2 Materials and Methods

The research method used in this research is an experimental method with quantitative data analysis. Where this type of research will produce data obtained through statistical procedures or other ways of quantification (measurement).

2.1 Materials

Experiments were conducted on aspects that affect the value of thermal transmittance (U-value), namely the use of wall insulation material thickness. While the quantitative method is used to obtain numerical data from the research results, namely the OTTV value. OTTV calculations are carried out on each change in the type of wall insulation thickness, then analyzed the effect of various wall insulation thicknesses on OTTV, so that conclusions can be drawn about the influence and effectiveness of the use of wall insulation materials and wall insulation thickness settings. OTTV itself is a value that indicates how much heat is transferred from the outside to the inside of the building through the building envelope, and has become a benchmark standard for building envelope performance in various countries [11].

According to Lechner (2015), it is explained that insulation materials in their application have the characteristics of moisture resistance, fire resistance, physical resistance, and stability over time. Most insulation materials also work by creating mini air spaces. Insulation must be on the perimeter of the building envelope to prevent heat bridges. So in its application, insulation is widely used in walls, roofs, under floors, and foundation walls (basements) [12].

The research will be conducted in Panaguan Village, Proppo District, Pamekasan Regency, East Java with the objects studied are three BSPS houses of types 24 m2, 33.12 m2 and 84.46 m2. With the aspects studied, namely the thermal comfort aspect of the OTTV parameter which refers to SNI 03-6389 of 2020 concerning Energy Conversion of Building

Envelope in Building. Data collection is done through material specification data and existing building conditions.

2.2 Methods

In calculating the Total OTTV value, there are several steps that must be done first, including the following according to SNI 03-6389 of 2020:

1. The first stage before calculating the partial OTTV value is to calculate the building envelope area including the area of transparent or non-transparent openings or windows and then calculate the WWR (Window Wall Ratio) which is the ratio of the window area to the total area of the specified building envelope.
2. Determine the absorbance of solar radiation (α) which is determined based on the type of wall material or material and paint or color of the outer wall surface.
3. Determine the thermal transmittance of opaque walls (U_W). Influenced by the total thermal resistance (RTotal), because the value (U_W) is one pernilai (R_{Total}). The component (R_{Total}) itself consists of the thickness of the material (t) and the thermal conductivity value of the material (k).
4. Determine the thermal transmittance of fenestration or windows (Uf) based on the type of window or glass and then obtained the thermal conductivity of the material from the results of combining the U value of Glass and the U value of the frame.
5. Determine the equivalent temperature difference (TDEK) obtained from determining the density of wall and window materials, as well as the thickness of the material to obtain the weight of the unit area.
6. Determine the solar radiation factor (SF) according to the orientation of the building in obtaining irradiation from the sun.
7. Determine the shading coefficient of the fenestration system/SC (Shading Coefficient) calculated by controlling the values of SCk and SCeff where SCk or the effective shading coefficient of the glass must refer to the International Glazing Database or a value certified by an accredited test institution.
8. All of the above variables are calculated using the equation to get the result of the calculation of the partial OTTV value for each orientation, namely:

$$OTTVi = \alpha[(U_w \times (1 - WWR) \times TD_{EK}] + \left(U_f \times WWR \times \Delta T\right) + (SC \times WWR \times SF) \quad 1)$$

With :

OTTV = Total thermal transfer value on the outer wall that has a certain direction or orientation (W/m2);
α = Absorbance of solar radiation;
UW = Thermal transmittance of opaque walls (W/m2.K);
WWR = The ratio of the window area to the area of the entire external wall at the specified orientation.
TDEK = Equivalent temperature difference (K);
SF = Solar radiation factor (W/m2);
SC = Shading coefficient of the fenestration system;
Uf = Thermal transmittance of the fenestration (W/m2.K);
ΔT (K) = Planning temperature difference between the outside and the inside (taken 5K)

9. The partial OTTV value is multiplied by the total envelope area of each orientation divided by the total area of the building envelope without deducting the area of openings or windows to calculate the Total OTTV with the following formula:

$$OTTV = \frac{(Ao1 \times OTTV1)+(Ao2 \times OTTV2)+\cdots+(Aoi \times OTTVi)}{Ao1+Ao2+\cdots Aoi} \qquad 2)$$

Aoi = Wall area of the external wall (m2). This total area includes all non-translucent wall surfaces and the surface area of the window surface area contained in the wall sectio;
OTTVi= Total thermal transfer value on the wall section i (Watt/m2)

10. The results of partial OTTV value of each orientation and OTTV Total analyzed whether it meets the reference SNI 03-6389-2011 with a standard value of 35 W/m2

3 Result and Discussion

3.1 Overall Thermal Transfer Value (OTTV)

The following is the calculation of the Overall Transfer Thermal Value (OTTV) value, the calculation of the OTTV value on existing models are shown in Table 1 - Table 3.

Table 1. OTTV Value Calculation on Existing Model House A.

Orien-tation	**α**	**Uw (W/m^2.K)**	**WWR**	**TDEK (K)**	**Uf (W/m^{2}K)**	**SC**	**SF (W/m^2)**	**OTTVi (W/m^2)**	**OTTV Total (W/m^2)**
East	0,76	1,88	0,11	12	4,829	0,94	167,00	35,69	38,251
West	0,86	1,88	0,11	12	4,829	0,94	167,00	37,76	
South	0,86	1,88	0,17	12	4,829	0,94	104,00	36,86	
North	0,86	1,88	0,17	12	4,829	0,94	150,00	44,21	

Table 2. OTTV Value Calculation on Existing Model House B.

Orien-tation	**α**	**Uw (W/m^2.K)**	**WWR**	**TDEK (K)**	**Uf (W/m^{2}K)**	**SC**	**SF (W/m$^{2)}$**	**OTTVi (W/m^2)**	**OTTV Total (W/m^2)**
East	0,76	1,88	0,15	12	4,829	0,94	167,00	41,36	39,095
West	0,86	1,88	0,15	12	4,829	0,94	167,00	43,34	
South	0,86	1,88	0,14	12	4,829	0,94	104,00	33,95	
North	0,86	1,88	0,14	12	4,829	0,94	150,00	40,08	

Table 3. OTTV Value Calculation on Existing Model House C.

Orien-tation	**α**	**Uw (W/m^2.K)**	**WWR**	**TDEK (K)**	**Uf (W/m^2 K)**	**SC**	**SF (W/m^2)**	**OTTVi (W/m^2)**	**OTTV Total (W/m^2)**
South west	0,76	1,88	0,14	12	4,829	0,94	129,00	35,20	36,883
North east	0,86	1,88	0,09	12	4,829	0,94	166,00	34,54	
North west	0,86	1,88	0,13	12	4,829	0,94	166,00	40,57	
South east	0,86	1,88	0,13	12	4,829	0,94	167,00	40,70	

The following is the calculation of the Overall Transfer Thermal Value (OTTV) value, the calculation of the OTTV on alternatives models value is shown in Table 4 - Table 6.

Table 4. OTTV Value Calculation on Alternative Model House A.

Type	Orientation	α	Uw (W/m².K)	WWR	TDEK (K)	Uf (W/m² K)	SC	SF (W/ m²)	OTTVi (W/m²)	OTTV Total (W/m²)
AG42	E	0,72	0,629	0,113	12	4,829	0,941	167	25,347	26,774
	W	0,72	0,629	0,113	12	4,829	0,941	167	25,347	
	S	0,72	0,629	0,170	12	4,829	0,941	104	25,235	
	N	0,72	0,629	0,170	12	4,829	0,941	150	32,593	
AV42	E	0,72	0,184	0,113	12	4,829	0,941	167	21,948	23,462
	W	0,72	0,184	0,113	12	4,829	0,941	167	21,948	
	S	0,72	0,184	0,170	12	4,829	0,941	104	22,053	
	N	0,72	0,184	0,170	12	4,829	0,941	150	29,412	
AA42	E	0,72	0,303	0,113	12	4,829	0,941	167	22,857	24,347
	W	0,72	0,303	0,113	12	4,829	0,941	167	22,857	
	S	0,72	0,303	0,170	12	4,829	0,941	104	22,904	
	N	0,72	0,303	0,170	12	4,829	0,941	150	30,263	

Table 5. OTTV Value Calculation on Alternative Model House B.

Type	Orientation	α	Uw (W/m².K)	WWR	TDEK (K)	Uf (W/m²K)	SC	SF (W/ m²)	OTTVi (W/m²)	OTTV Total (W/m²)
BG42	E	0,72	0,629	0,148	12	4,829	0,941	167	31,413	27,498
	W	0,72	0,629	0,148	12	4,829	0,941	167	31,413	
	S	0,72	0,629	0,142	12	4,829	0,941	104	21,931	
	N	0,72	0,629	0,142	12	4,829	0,941	150	28,064	
BV42	E	0,72	0,184	0,148	12	4,829	0,941	167	28,147	24,217
	W	0,72	0,184	0,148	12	4,829	0,941	167	28,147	
	S	0,72	0,184	0,142	12	4,829	0,941	104	18,641	
	N	0,72	0,184	0,142	12	4,829	0,941	150	24,773	
BA42	E	0,72	0,303	0,148	12	4,829	0,941	167	29,020	25,095
	W	0,72	0,303	0,148	12	4,829	0,941	167	29,020	
	S	0,72	0,303	0,142	12	4,829	0,941	104	19,521	
	N	0,72	0,303	0,142	12	4,829	0,941	150	25,653	

Table 6. OTTV Value Calculation on Alternative Model House C.

Type	Orientation	α	Uw (W/m^2.K)	WWR	TDEK (K)	Uf (W/m^{2}K)	SC	SF (W/m^2)	OTTVi (W/m^2)	OTTV Total (W/m^2)
CG42	SW	0,72	0,629	0,141	12	4,829	0,941	129	25,173	24,448
	NE	0,72	0,629	0,094	12	4,829	0,941	166	21,859	
	NW	0,72	0,629	0,131	12	4,829	0,941	166	28,413	
	SE	0,72	0,629	0,131	12	4,829	0,941	130	23,959	
CV42	SW	0,72	0,184	0,141	12	4,829	0,941	129	21,880	21,084
	NE	0,72	0,184	0,094	12	4,829	0,941	166	18,387	
	NW	0,72	0,184	0,131	12	4,829	0,941	166	25,084	
	SE	0,72	0,184	0,131	12	4,829	0,941	130	20,630	
CA42	SW	0,72	0,303	0,141	12	4,829	0,941	129	22,760	21,984
	NE	0,72	0,303	0,094	12	4,829	0,941	166	19,315	
	NW	0,72	0,303	0,131	12	4,829	0,941	166	25,974	
	SE	0,72	0,303	0,131	12	4,829	0,941	130	21,520	

3.2 Effectiveness of Insulation Materials on Overall Thermal Transfer Value (OTTV)

The calculation of the effectiveness of the OTTV value in the alternative model is the difference between the OTTV value of the alternative and existing models compared to the existing OTTV value multiplied by one hundred. The calculation of the percentage decrease in OTTV of the alternative model is shown in Table 7.

Table 7. OTTV Percentage Decrease Calculation

House Type	**Material**	**OTTV**		**Decrease**	**Percentage Decrease**
		Existing (W/m2)	**Alternative (W/m2)**		**(%)**
A	Glasswool	38,251	26,774	11,477	30,00%
	VIPs	38,251	23,462	14,789	38,66%
	Aerogel	38,251	24,347	13,903	36,35%
B	Glasswool	39,095	27,498	11,597	29,66%
	VIPs	39,095	24,217	14,878	38,06%
	Aerogel	39,095	25,095	14	35,81%
C	Glasswool	36,883	24,448	12,435	33,71%
	VIPs	36,883	21,084	15,799	42,84%
	Aerogel	36,883	21,984	14,9	40,40%

The results of the calculation of the OTTV value of this alternative model experiment were carried out with the addition of insulation materials, including glasswool, VIPs and Aerogel. The OTTV value data will then be compared with the standard OTTV value regulated in SNI 6389 2020 and the existing model. Data on the percentage decrease in OTTV value of the alternative model reviewing the variation of insulation materials is presented in Figure 1:

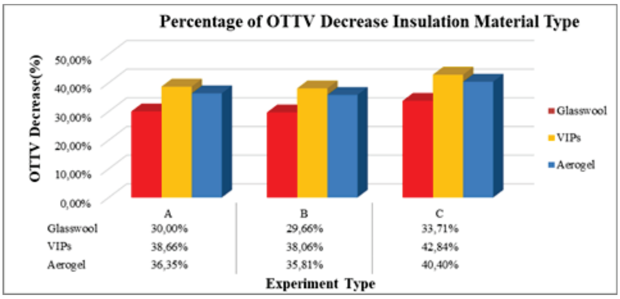

Fig. 1. Percentage of OTTV Value Decrease Against Insulation Material Thickness Variation

From Figure 1, it can be seen that of the three types of insulation materials used, Vacuum Insulation Panels (VIPs) type insulation material is the best insulation material used in each type of house A, B, and C because the OTTV value produced is the smallest and meets the standard value set in SNI 6389 2020. This is influenced by the thermal conductivity value of the material, with the thermal conductivity value of VIPs material is 0.008 W/m.K, while aerogel is 0.014 W/m.K, and glasswool is 0.035 W/m.K [13].

According to research conducted by Wahyudi et al. (2018) states that the smaller the thermal conductivity value of the insulation material, the greater the insulation / resistance coefficient and the smaller the OTTV value [14]. Corroborated with research conducted by Makrygiannis, et all (2023) states that the lowest thermal conductivity value of the three types of insulation material by applying insulation material is polyurethane (PUR) with a value of 0.022 W / m.ºC compared to glasswool material is 0.049 W / m.ºC, and also rockwool material is 0.039 W / m.ºC this also causes the value of thermal resistance and the percentage decrease in OTTV value polyurethane material has the highest value of 50%, followed by rockwool material is 40% and glasswool material is 30% [15]. From changes in the value of thermal conductivity that occurs due to the addition of insulation material on the wall, affects the thermal transmittance value of the opaque wall (U_W), which initially in the existing model amounted to 1.881 W/m^2.K. In the alternative model of the smallest glasswool insulation material with a value of 0.629 W/m^2.K, the smallest VIPs with a value of 0.184 W/m^2.K, and the smallest aerogel with a value of 0.303 W/m^2.K. A material should have a small transmittance value so that the absorbance value will be small as well. With a small transmittance and absorbance value, it will be difficult for a material to transmit and absorb incoming radiation so that the OTTV in the building will be smaller [16].

4 Result and Discussion

The best type of insulation material to be applied to BSPS houses in Pamekasan Regency, Proppo Subdistrict, Panaguan Village is Vacuum Insulation Panels (VIPs) when viewed from the Overall Thermal Transfer Value (OTTV) value, which provides the best OTTV value reduction, namely in houses of type 24 m2 by 38.66%, while in houses of type 33.12 m2 by 38.06%, and in houses of type 84.46 m2 by 42.84% W/m2. This is because the value of thermal conductivity owned by VIPs insuasi material is smaller than other insulation material variations is 0.008 W/m.K.

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