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RESEARCH

Temporary Shelter Simulation Towards Effectiveness Value of OTTV and Thermal Comfort

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ABSTRACT Indonesia is prone to a variety of natural disasters, one of which is earthquakes. Earthquakes are detrimental to human life, causing among other things a loss of shelter. As such, victims of earthquakes need basic assistance in the form of shelter, which the Indonesian government provides in the transition phase of emergency responses. Several innovations in the provision of temporary shelter have arisen in terms of packaging and fast unloading. This research aimed to examine the effective value of OTTV energy (overall thermal transfer value), differences in room temperature, and thermal comfort in existing temporary shelters. OTTV values and thermal comfort are adapted to Indonesia's humid tropical climate, which has a temperature ranging 24–30°C and air humidity of 75%. Temporary shelters were simulated with Rhinoceros and Grasshopper softwares. The simulation was carried out in two stages, with the first stage simulating the temporary shelter materials and the second stage simulating according to a predetermined standard. The results concluded that the effective value of OTTV with the use of Styrofoam-based shelter gives a value of 27.63 W/m^2 with a decrease of up to 4.70 W/m^2, and the temperature drops to 2–3°C.

1. INTRODUCTION

Earthquakes are one of the disasters caused by tectonic movements (Boen 2016). Indonesia is a country that has earthquake potential, and has experienced 143 earthquakes since 2009–2018, as explained by the Indonesian National Board for Disaster Management (Badan Nasional Penanggulangan Bencana, or BNPB).

The damage caused by earthquake is detrimental to the environment, one of which is the loss of a place to live and requires the victims to live in a refugee tent (Rizal and Tavio 2014). Shelter is a basic need for humans, therefore, a help to build a shelter requires a short amount of time. Victims who stay too long in the evacuation tents will have a devastating effect on their psychic, therefore, during the emergency response phase, temporary shelter is needed (Akhmad and Fachruddin 2008; Mahira and Hignasari 2018; Rizal and Tavio 2014). Because the main function of the refugee tent only serve as a temporary emergency tent (Santoso et al. 2016). Temporary shelters have a period of stay of 12 months to 18 months (Affisa and Djunaedi 2014).

Temporary shelter assistance in the post-disaster stage in Indonesia has been widely carried out, one of which is temporary shelter assistance in Gondang. The temporary shelter uses bamboo materials (Putro and Roychansyah 2012). Innovations for temporary shelters have been made in terms of practicality of these shelters, with the aim of installing temporary shelters that is quick, efficient, and effective, and prioritizing reusable materials (Affisa and Djunaedi 2014; Mahira and Hignasari 2018; Santoso et al. 2016).

The problem of this research is to find out the effective value of OTTV (overall thermal transfer value) energy and the value of thermal comfort of temporary shelter materials, which are adjusted to the climate characteristics in Indonesia. The optimum value of OTTV and thermal comfort is done by simulation using Rhinoceros and Grasshopper as an analytical aid. Use this software to help the analysis by using a temporary shelter model by comparing the results of a predetermined temporary shelter model to see the effective value of OTTV and thermal comfort.

2. MATERIALS AND METHODS

2.1 Data sampling

Temporary shelter samples are taken from some literature that has discussed temporary shelter by looking at the variables and indicators that have been determined and noted as shown in Table 1.

In addition, the samples are also viewed from the standard set by BNPB and UNHCR that provide safety requirements, ensure privacy, sized 3 m^2 per person, and minimum space of 18 m^2 which can accommodate 4–5 people. The distribution of temporary shelter can be at least distributed using pickup truck.

TABLE 1. Variables and indicators for the selection of temporary shelter samples.

Variables	Indicators
Effective and efficient	Quick, light
Economical	Pre-fabrication, distribution
Durability	Materials
Safety	Strong/durable
System	Modular (connection)

TABLE 2. Selecting temporary shelter samples.

Sample	Width (m^2)	Distribution	Capacity
A	12	Pick up	4 people
B	18.91	Pick up, truck	5 people
C	18	Truck	4 people
D	19.44	-	1–3 people
E	32.4	-	4–6 people
F	38.88	-	>7 people
G	115.93	-	2 main family
H	21	Pick up, truck, ship, plane	5 people
I	14.76	Container truck	4 people
J	35	-	5 people

From the results of the literature, 10 samples of temporary shelter that meet the variables and indicators were found (Table 2). Then it is sorted again according to the criteria for the standard area, capacity, distribution of temporary shelters, and temporary shelter packaging systems using 1:50 scale mock-ups. This was done to see the dimensions of the temporary shelter and the effective level of making the temporary shelter. After doing this method, four temporary shelter samples were found to be in accordance with the minimum standard of temporary shelter.

Sample A is a temporary shelter designed to be assembled and disassembled quickly within two hours by six people applicators. Sample A is included in the selection because the packaging system and material usage are taken into account. It uses the lightweight, durable, strong, and anti-rust materials (Santoso et al. 2016).

Sample B has a bracket with bolt reinforced connection system on its frame. The use of a lightweight material adds value to sample B. The temporary shelter concept of sample B is one of a portable building with a size of 3.05 m × 6.20 m, which can accommodate five people (Irwan et al. 2016).

Sample C is a temporary shelter in Korea. This temporary shelter can function for more than six months after being built. As well as using materials that can be fabricated, such as metal-based materials, it has a dwelling size of 18 m^2 (Moon and Lee 2007).

Sample H is a temporary shelter by cmax shelter, which has the concept of tents and trailers, a house that can be moved and built anywhere. The module used is 3 m. Because the packaging system is folding, the resulting occupancy volume is 9 m^3 per unit. Sample H can be assembled in 11 minutes with two adult applicators (Pero 2014).

2.2 Sample analysis on OTTV values

OTTV (overall thermal transfer value) is a value of overall thermal transfer by showing the results of heat recovery caused by solar radiation at each value per square meter of wall area (Satwiko 2009). Standard OTTV in Indonesia since 2011 has set at 35 W/m^2 (Hariyadi et al. 2017; Setiani et al. 2017). The OTTV standard aims to make an impact on the energy use in order to prevent an excessive use of energy (Setiani et al. 2017).

The use of OTTV analysis aims to determine the optimum value of energy in temporary shelter samples by knowing the value of WWR (window to wall ratio) and the characteristics of the materials used in temporary shelter samples. The OTTV formula is as follows (Equation 1).

$$\mathrm{OTTV_n} = \alpha\{U(1-\mathrm{WWR})\}.\Delta\mathrm{T_{eq}} + (\mathrm{SC})(\mathrm{WWR})(\mathrm{SF})\mathrm{W/m^2} \quad (1)$$

For WWR values and material characteristic values in samples A, B, C, and H are selected as shown in Table 3.

WWR (window to wall ratio) value and material characteristic values are needed to run an experimental simulation using Rhinoceros and Grasshopper by adding the EnergyPlus, Ladybug, and Honeybee plugins (Table 4).

2.3 Sample analysis on thermal comfort

Thermal comfort in a shelter is important. It is determined by looking at the factors that affect thermal comfort, such as air temperature, wind speed, air humidity, average room temperature, human activities, and clothing used.

The thermal comfort of space can be formed using natural (cross ventilation) and artificial ventilation. But artificial ventilation will add value to the cost and energy in the room (Satwiko 2009).

Thermal comfort in tropical and humid tropics is different. Tropical temperature ranged 23.3–29.4°C with a humidity of 30–70% (Olglay 2015). Whereas in humid tropics, the temperature ranged 27–32°C with a limit of 24°C < T < 26°C and at 24°C, it can be said to be cool with a humidity 40% < RH < 60% (Satwiko 2009). The temperature range of Jakarta is between 24°C and 30°C (Karyono 2013) with a 75% humidity (Hariyadi et al. 2017).

Professor P.O. Fanger has made a PMV (predicted mean value) scale to determine the value of comfort in a room, that is (−3) cold and (+3) hot (Satwiko 2009). PMV is an estimated indicator value of comfortable conditions for res-

TABLE 3. Temporary shelter sample materials and WWR value.

Sample	Materials			Opening area (m^2)	Wall area (m^2)	WWR (%)
	Wall	Floor	Roof			
A	EPS (Styrofoam)	EPS (Styrofoam)	EPS (Styrofoam)	0.98	39.2	2.5
B	Plastic (polypropylene)	Plastic (polypropylene)	Plastic (polypropylene)	2.54	59.52	4.3
C	Metal composite	Plywood	Metal (galvanized)	5.408	63	8.6
H	Membrane	Plastic (polypropylene)	Membrane	0.84	60	1.4

TABLE 4. Characteristic values of temporary shelter sample materials.

Material	Thickness (m)	Roughness	Conductivity (W/m-K)	Density (kg/m^3)	Specific heat (J/m-K)
EPS	0.03	Medium smooth	0.033	8	1170
EPS	0.07	Medium smooth	0.033	8	1170
Plastic	0.1	Smooth	0.2	900	1925
Plywood	0.018	Medium smooth	0.15	600	750
Galvanized	0.0005	Rough	15.1	7135	390
Metal composite	0.005	Rough	15.1	7850	450
Membrane	0.0005	Smooth	0.15	876	1900

idents while carrying out activities associated with PPD (predicted percentage of discomfort) (Karyono 2013).

3. RESULTS AND DISCUSSION

3.1 First stage simulation

The selected temporary shelter samples will be simulated in the first stage using Rhinoceros and Grasshopper. To find out the effective value of OTTV, a plugin is added to the Grasshopper program, namely Honeybee. Because sample A has 12 m^2, an analysis of sample A is carried out by modifying it to 18 m^2 so that the dimensions are in accordance with the minimum standards specified by the law and UNHCR. The accuracy of OTTV values will be viewed using six different directions, north, northeast, east, southeast, south, and west (Figure 1). The simulation will be processed within one year and done by comparison using standard materials in order to know the difference in value produced.

The results of the calculation of energy simulation generated by both OTTV values in the four temporary shelter samples are as follows.

Each sample will be simulated by inserting material into each one of them. For example, sample A will receive material of samples B, C, and H. Comparison is done by finding the value of ETTV (envelope thermal transfer value) to determine the differences in the optimum value between OTTV and ETTV in each materials. In addition to simulating the optimum value of energy, a simulation is carried out to determine the value of the temperature difference indoors and outdoors with the same criteria, that is, each temporary shelter sample receives all materials. The value

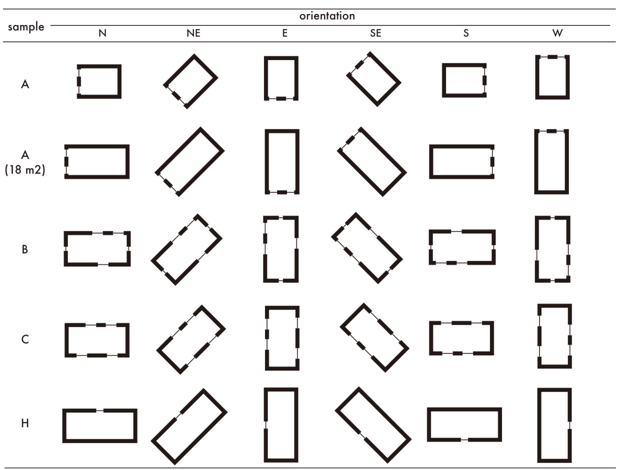

FIGURE 1. Direction of the opening in temporary shelter is in accordance with the direction of the compass.

displayed is the lowest value for each simulation and the position of the temporary shelter that has the lowest value. The simulation is assumed to use AC (air conditioner) and glare glass in each temporary shelter sample. This is done to determine the use of energy and the differences in temperature values in temporary shelter samples.

The next simulation result is an overheated PMV that displays visual comfort in the temporary shelter based on the materials used in each sample.

3.2 Second stage simulation

The second stage simulation is performed to find out the effective value of energy, OTTV, and thermal comfort accurately. The second phase of the simulation is still using Rhinoceros and Grasshopper, but the samples are narrowed to only two temporary shelter samples. Table 7 shows the second stage simulation scenario.

Simulation scenario is a selected sample with occupancy area approaching the standard that is 18 m^2. The materials used are only 3 of the 4 existing materials. The membrane material is not used because of the membrane material character which cannot reduce heat well. Sample A which has been modified is also included in the second stage of the simulation as a comparison. Besides paying attention to the area, we also see the value of WWR in each temporary shelter sample. The following are the results of the second phase simulation.

The second round of the second stage simulation is carried out to strengthen the results of the simulation. The simulation is done according to the scenario in the second stage. The results of OTTV values, temperature differences, and overheated PMV are as follows.

3.3 OTTV energy

There is a difference in the results between the first and second stage of the energy simulation. In the first stage, the OTTV value on temporary shelter sample A (18 m^2) has the lowest OTTV value of 18.87 W/m^2, whereas the sample B reached 47.62 W/m^2 (Table 5). It indicates that sample B, by using plastic (polypropylene) material, does not meet established standards.

When the simulation is done by applying the materials to all temporary shelter samples, the lowest OTTV value was obtained from using EPS materials based on Styrofoam, with a westerly orientation on the sample A, and southward on the sample B, C, and H. However, sample B decreased from 47.62 W/m^2 to 46.32 W/m^2, but it still has not reached the standards determined that is 35 W/m^2.

The second stage simulation is carried out with two scenarios, showing significant differences between the first and the second stage simulation. Especially in sample C, the energy decreased to 4.70 W/m^2 when EPS material is

TABLE 5. Results of OTTV energy simulation values of the temporary shelter samples.

Sample	Material	Energy simulation (kWh/m²)						WWR (%)	OTTV (W/m²)					
		N	NE	E	SE	S	W		N	NE	E	SE	S	W
A	EPS	455.2	455.0	448.8	452.5	451.1	440.5	2.5	36.92	34.99	31.06	34.99	36.81	24.21
	Standard	767.0	772.4	773.5	770.2	763.8	771.2	2.5	42.98	41.05	37.11	41.10	42.91	30.27
A (18 m²)	EPS	415.0	418.2	417.2	416.6	412.2	411.7	1.94	28.83	27.29	24.21	27.30	28.75	18.87
	Standard	709.8	721.0	728.9	719.7	707.7	727.4	1.94	33.35	31.79	28.66	31.84	33.29	23.32
B	Plastic	616.6	628.7	638.3	626.7	613.7	640.7	4.3	49.08	50.36	50.61	48.68	47.62	50.68
	Standard	741.9	757.8	770.9	757.3	740.8	772.5	4.3	51.36	52.56	52.74	50.91	49.11	58.32
C	Metal composite	986.4	1017.4	1044.9	1019.9	986.4	1045.0	8.6	34.09	39.47	46.13	39.53	34.08	44.57
	Standard	793.4	816.3	836.4	817.4	793.4	836.3	8.6	33.57	39.05	44.32	40.13	33.56	46.93
H	Membrane	873.1	902.8	929.4	904.5	872.3	929.9	1.4	18.36	19.33	19.58	17.58	16.03	19.65
	Standard	706.3	721.4	734.3	720.8	705.2	735.8	1.4	15.63	15.01	17.28	13.73	13.32	17.31

placed in the temporary shelters (Table 8). Whereas in the next simulation (Table 9), sample B decreased to 3.60 W/m² from the previous simulation (Table 8). This shows that the EPS material gives influence in terms of the energy used in temporary shelter samples.

3.4 Comparison of indoor and outdoor air temperatures

The simulation results on differences in indoor and outdoor air temperatures, using a reference location in Jakarta, Indonesia, which has a temperature range of 24–30°C Karyono (2013). It is explained in Table 6 that the sample of temporary shelter using EPS material has a difference in temperature of the air temperature inside and outside up to 2–3°C. With the orientation of occupancy facing west for sample A and south for samples B, C, and H. The plastic material (polypropylene) has a difference up to 0.55–1.14°C. The temperature value of composite metal and membranes do not have significant results. The results show that indoor temperature of the temporary shelter is hotter than the outdoor temperature.

In the second stage of the simulation carried out with a scenario (Table 7), it shows the temperature in the room fell to 0.96°C between the temperature inside and outside in sample B. When compared with the results of the first stage of simulation, the temporary shelter samples with composite metal materials had a difference in the temperature, and the outside temperature is higher than the inside. Table 6 shows that the inner temperature reaches 28.5°C and outside 29.35°C, it has a difference of 0.85°C.

The second round of the second simulation stage results show the same thing in the previous simulation. Sample B decreased to 0.85°C and sample C decreased to 0.95°C. The results from the first and second simulation stages for EPS material has a value that falls in the temperature range of Jakarta area, because the temperature range produced by EPS material is between 27.9–29.79°C.

3.5 Thermal comfort (overheated PMV)

The visual result of overheated PMV in the first stage of simulation (Figure 2) shows that the temporary shelter sample A, using EPS material, has a value of 44.17% and the visual result has only a few red patches. This indicates that sample A is more comfortable to inhabit as a temporary shelter. When sample A was modified to 18 m² the PMV value fell 0.74% with a whiter visual result compared to when it had an area of 12 m². In contrast to the temporary shelter sample B, which uses plastic materials (polypropylene), shows the highest value of 68.38% in the orientation position of the east, and shows a red visual. Looking at the maximum indicator of 70.70%, and sample B almost reached this number, indicating that sample B is not comfortable to be inhabited as temporary shelter in humid tropics.

The second stage simulation done with the scenario (Table 7) shows different result from the first stage simu-

TABLE 6. Results of the OTTV energy simulation value and temperature by entering materials into each temporary shelter sample.

Sample	Orientation position	EPS			Plastic			Metal composite			Membrane		
		OTTV	Temp. (°C)		OTTV	Temp. (°C)		OTTV	Temp. (°C)		OTTV	Temp. (°C)	
A	West	24.21	In	27.12	26.03	In	29.05	31.71	In	29.82	33.14	In	29.98
		24.21	Out	30.37	26.03	out	30.19	31.71	Out	29.49	33.14	Out	29.79
A (18 m²)	West	18.87	In	27.10	20.12	In	29.09	24.49	In	29.84	25.70	In	29.99
		18.87	Out	30.39	20.12	Out	30.29	24.49	Out	29.50	25.70	Out	29.79
B	South	46.32	In	27.24	47.62	In	28.90	49.51	In	29.42	50.63	In	29.55
		46.32	Out	29.46	47.62	Out	29.45	49.51	Out	28.94	50.63	Out	29.16
C	North, south	30.59	In	27.53	31.46	In	29.14	34.08	In	29.62	35.05	In	29.78
		30.59	Out	29.73	31.46	Out	29.68	34.08	Out	29.14	35.05	Out	29.37
H	South	9.38	In	27.02	10.38	In	29.12	14.92	In	29.93	16.03	In	30.09
		9.38	Out	30.84	10.38	Out	30.15	14.92	Out	29.71	16.03	Out	30.05

TABLE 7. Second stage simulation scenario.

Sample	WWR (%)	Layer	Wall materials	
			Stage 1	Stage 2
A (18 m^2)	1.94	Out	EPS[a]	EPS[a]
	1.94	In	EPS[a]	EPS[a]
B	4.3	out	Plastic[b]	EPS[a]
	4.3	In	EPS[a]	Plastic[b]
C	8.6	Out	Metal composite	EPS[a]
	8.6	In	EPS[a]	Metal composite

[a]Styrofoam, [b]Polypropylene.
Note: The temporary shelter sample, A, did not experience the addition of wall material both on the outside and inside.

lation. The results displayed visually indicate that there is a decrease when plastic material (polypropylene) is combined with EPS material. Facing at the position of the same east direction, sample B that uses plastic (polypropylene) produces a value of 57.58%, this has decreased by 10.8%. The sample also shows white patches appear in the area near the opening (Figure 3).

In contrast to the visual results (Figure 4), when EPS material is placed on the outside, positioned to face the east direction, sample B shows a uniform red color. This has the same value in the first stage of the simulation using only plastic materials (polypropylene). The results produced reach 60.04% with an indicator limit of 51.69–58.77%. Seeing these results, EPS material is suitable to be placed as the first layer and then the second layer of plastic.

The overheated PMV simulation results between the first and the second stage of simulation shows that EPS material can stand alone as a covering wall, and can be used as insulation in the interior of a temporary shelter, because it has a characteristic to reduce heat. In addition to the type of the material used, the number of openings and the size of the openings (WWR) used will also affect the results of comfort in the temporary shelter space.

4. CONCLUSIONS

The simulation results using the Rhinoceros and Grasshopper programs applied on temporary shelter samples show the effective value of OTTV energy on EPS, which is 27.63 W/m^2. In the second stage simulation EPS gives an impact as an insulation wall and can reduce energy up to 4.70 W/m^2, therefore, EPS material tends to reduce energy use in temporary shelters and enter the specified OTTV standards. Not only OTTV value, the difference between the inside and outside temperature in the temporary shelter ranged from 27.90–29.79°C, which indicates that EPS is included in the average temperature range of Indonesia's humid tropical climate and can reduce the room temperature between 2–3°C. From the result of visual and percentage of overheated PMV, EPS material can reduce heat well.

In the first stage simulation, temporary shelter is applied with the use of materials, showing that the temporary shelter is comfortable to live in, with a little red patch marks and is dominated by white, and it reaches the value of 44.17% with an indicator of 44.25–70.70%. In the second stage of the simulation with the same indicator EPS materials play a good role when being insulated or are on the side of the dwelling, because it gives a comfortable impact with marked red becomes easier and the percentage results show a decrease reaching 9.12% in sample B and 3.69% in sample C compared with the results of the first stage simu-

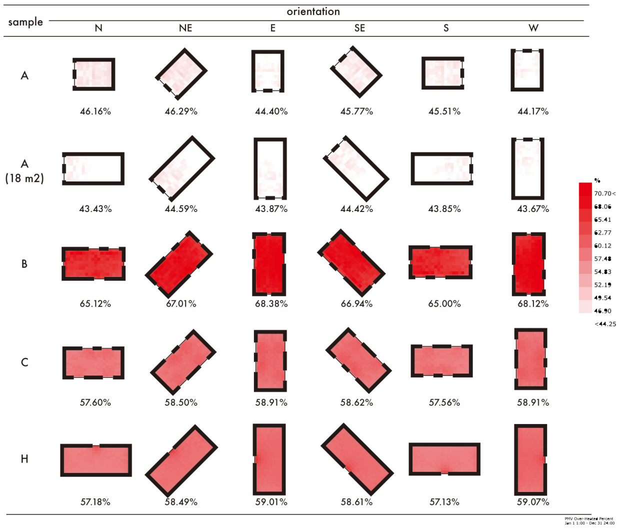

FIGURE 2. Overheated PMV simulation results for each temporary shelter sample, the value generated in the simulation ranged 44.25–70.70%.

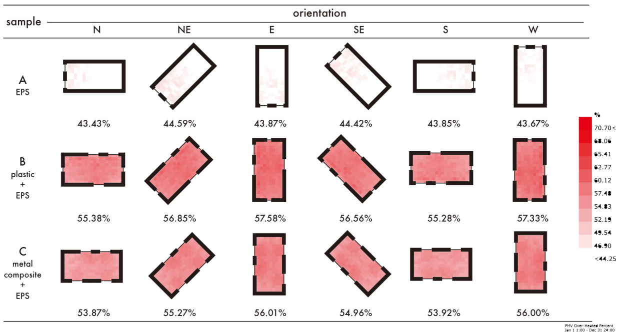

FIGURE 3. Results of overheated PMV in the first round of the second stage simulation, the value generated in the simulation ranged from 44.25–70.70%.

TABLE 8. First round of second simulation results of OTTV values and temperature in temporary shelter samples.

Sample	Material	OTTV (W/m^2)							Temperature (°C)					
		N	NE	E	SE	S	W		N	NE	E	SE	S	W
A	EPS	28.83	27.29	24.21	27.30	28.75	18.87	In	27.26	27.26	27.26	27.22	27.20	27.10
	EPS	28.83	27.29	24.21	27.30	28.75	18.87	Out	30.47	30.48	30.48	30.46	30.44	30.39
B	Plastic, EPS	48.76	50.06	49.83	48.38	46.51	50.41	In	28.54	28.62	28.67	28.60	28.51	28.69
	Plastic, EPS	48.76	50.06	49.83	48.38	46.51	50.41	Out	29.50	29.53	29.52	29.51	29.47	29.54
C	Metal composite, EPS	29.38	35.06	40.46	35.13	29.38	0.63	In	28.50	28.67	28.80	28.67	28.50	28.81
	Metal composite, EPS	29.38	35.06	40.46	35.13	29.38	0.63	Out	29.35	29.44	29.51	29.45	29.35	29.51