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UNDERSTANDING GURUSINA SA'O IN FLORES, NUSA TENGGARA TIMUR, INDONESIA: HEAT CONDUCTIVITY OF BUILDING ENVELOPE MATERIAL AND THERMAL COMFORT

Khotijah Lahji[1], Agustin Rebecca Lakawa[2], Bambang Susetyarto[3], Rita Walaretina[4]
[1234]Department of Architecture, Faculty of Civil Engineering and Planning
Universitas Trisakti
email: iik_lahji@yahoo.com

Abstract
Sa'o (traditional house) in Gurusina, Flores is a house that was designed based on the local wisdom of Ngadha tribe that is directly or indirectly constructed by considering thermal factors i.e., temperature and humidity, wind speed, and heat gain. The purpose of this paper is to examine the relationship between heat conductivity features of building envelope material towards the aspects of thermal comfort. Data gathered and analyzed through field measurements supported by structural physical figures. The research results show that first, when the study was conducted, the temperature in Gurusina exceeded the lower and upper limit of the average temperature that was considered comfort hot for Indonesians. This affects the high heat transmission through wall material so that the inside temperature is considered uncomfortable. Second, the use of half wall (exceeding 20% of the floor area) and the existence of open space around the building that has the potential to flow the wind with a speed of more than 2m/sc, can reduce the indoor heat temperature due to solar heat transmission from wall and roof materials.

Key words: *thermal comfort; building envelope; traditional house*

INTRODUCTION

A number of studies suggest that traditional architecture is a representation of architectural products that focusing itself on and adapt to the local climate through the use of natural materials. This condition coupled with the structure tectonics created which led to the flow of outside air into inside and vice versa so that it becomes balanced. However, until recently there have been very few studies that attempting to rationalize it through temperature measurements which can prove that temperatures in traditional architectural buildings can indeed be categorized as meeting the comfort of their occupants. This paper presents the results of temperature measurements from traditional Gurusina house in Flores, Nusa Tenggara Timur, Indonesia.

A number of previous studies about Gurusina Traditional Village were carried out among others by Kumi et al (2016) who studied implementation, functions, symbols, and meanings in the Reba tradition. The study shows that the Reba tradition is implemented at every stage of life in the Gurusina community. Reba tradition influences the existence of harmonious relations and unity among tribal members. In the Fundamental research report on Women's Ideology in *Pata Teke* Cultural Text in Gurusina, Ngadha, Flores, Vyane (2011) found that there are two categories of women's ideology, namely the ideology of *ine weta* (as a variant of familial ideology) and vaginal ideology (as a variant of feminist ideology). Further, from her dissertation, Vyane elucidated that the representation of divine and human being imagery in the Sa'o of Ngadha ritual entity in Gurusina among others were: 1) dyadic and triadic; 2) metaphor of relationships between the symbolic and religious body; 3) be part of a sacred, spiritual, and moral entity.

The rationality of thermal comfort in traditional architecture was carried out by Basaria (2005) who found that thermal comfort temperatures for Indonesians were in the temperature range of 22.8°C-25.8°C with 70% humidity by considering sun and wind direction, utilizing architectural elements, and employing building materials. Prianto (2002) conducted a study on the effect of natural ventilated building for architectural design toward thermal comfort. Several alternative architectural designs such as the existence of a balcony and the arrangement of interior layout built based on numerical modeling are tested in this study. The results of the analysis show that the existence of a balcony and interior arrangement has a significant role in efforts to improve the condition of thermal comfort in the room, but it does not need high air-speed. Santoso (2012) found that in general the residents of the dwelling were dissatisfied with the existing comfort conditions (still outside the comfort zone of the ASHRAE 55 standard). Therefore, action is required by regulating the ventilation system mechanically.

Measurement of thermal comfort was carried out by Masarrang et al (2013) on traditional Minahasa architecture. The study findings state that a significant temperature difference between the temperature of the human body and the temperature of the environment causes discomfort. In the development and application of traditional buildings, aspects of thermal comfort and robustness of construction are not considered. Kristianto et al (2014) used the Computational Fluid Dynamic (CFD) program to analyze thermal comfort in traditional architecture. Suwantra et al. (2012) examined the thermal characteristics of the traditional architecture of Uma Lengge (NTT), and found that Uma Lengge could be warm within the room of 0.1^{o}C in the rainy season and 0.8^{o}C lower in the dry season than the outdoor temperature. Tungka et al (2008) conducted a study on thermal sensation evaluation for both, traditional types and modern style of housing in Indonesia. The respondents may feel thermally comfortable in indoor environment with a low air where water velocity is in maximum of 29°C, with air humidity is about 60%. Previous studies on traditional Gurusina architecture are more directly related to anthropological and sociological research. The findings presented in this paper complement the results of previous studies from the architectural point of view that focused its attention on the thermal comfort and the use of building envelope material in the traditional Gurusina house, in Kampung Ngadha.

LITERATURE REVIEW

Thermal Comfort and Micro-Climate

Micro-climate is related to thermal conditions in the environment. To create a comfortable thermal condition, there are several situations that should be understood among others are: (1) air temperature (°C), (2) humidity (%), (3) the air speed/wind (m/sc), (4) the mean radiant temperature (MRT). All of the previous conditions are affecting body heat simultaneously, those four environmental conditions that can remove heat based on Lechner (2001). As a reference from the previous findings (Karyono, 2007; Soegijanto, 1999), temperature category and relative humidity: comfort temperature is between 22,2–27,4^{0} C; comfort cool temperature is between 20,5- 22,8^0 C (T.E)/50%; optimal comfort 22,8-25,8^0 C (T.E)/70-80%; comfort hot 25,8-27,1^0 C (T.E)/60%. TE is indoor temperature which is the mixture from sun radiation, air temperature, air humidity, and wind velocity (Surjatmanto, 2001). The influence of wind velocity towards thermal comfort and its psychological impact according to Frick et.al (2008) are as follows:

Table 1. The effect of wind-speed on thermal comfort

Wind speed	The Effect on Thermal Comfort	Psychological Effect (30°C) Decrease of Equivalent Temperature
1 - 1.5 m/sc	Maximum speed comfort	1.7 – 2.2 °C
1.5 - 2 m/sc	Less comfortable, windy	2 – 3.3°C
> 2	Uncomfortable due to high wind speeds	3. – 4.2 °C

(Source: Frick, et all, 2008)

Building envelope and heat transmission/external heat gain

The building envelope provides protection against undesired external environmental influences such as heat, radiation, wind, rain, noise, pollution (GBCI, 2013). The building envelope component consists of the roof, wall (both massive and transparent, and the floor). The room temperature in the building is influenced by heat transfer) through the building envelope which is dominated by external heat loads, including: (1) heat transfer through windows, (2) heat transfer through walls, (3) heat transfer through roof, (4) Infiltration rate and exfiltration through gaps, floors, walls, windows, and door openings (specifically for air-conditioned buildings) if the building does not employ air conditioning then the infiltration rate is not considered.

Heat transfer through walls is affected by different thickness and thermal properties. The combined conductivity (k) and resistance (R) values of each layer of material determine the thermal properties, the entire wall that can be represented by the U-value (coefficient of wall material). The lower the U-value the better the thermal transfer. The correlation between conduction (k), resistance (R) and U-value can be formulated as follows: R = t/k; the value of U = 1/R1 + R2 + ... Rn (SNI 6389: 2011), R = material thermal resistance, t = material thickness, k = thermal conductivity value (W/m.K).

In the single or low floor buildings with wide roof, the roof can be the main source of heat gain. Hollow roof can minimize heat propagation through air in space (Soerjatmanto, 2002). The density of wall and roof materials determines the conductivity heat value which affect the indoor thermal heat (Table 2).

Table 2. Density and conductivity value of building materials (walls and roofs)

No.	Material of Building	Density	k (w/m.K)
1	Bamboo	717	0.093
2	Hard timber	702	0.138
3	brick	1568	1.154

The coefficient value of heat transmission is determined by the amount of solar radiation. The degree of thermal transmission coefficient/heat transmission (U) is affected by the equivalent difference of wall temperature (SNI, 2011). Formula for the number of heat transmissions due to the massive wall coverage of solar radiation (Qw) as:

$$Q_{wall} = \frac{\alpha \times U_w \times A_w \times TDek}{A_{floor}}$$

The **α** value is determined by wall and roof materials i.e. timber, bamboo, and reeds in which the value is between 0.82; 0.92 and 0.43 (GBCI, 2013). The amount of heat transmission is determined by the coefficient of heat transmission of the material. The greater the U value transmission, the greater the heat gain at indoor space.

METHODOLOGY

This study is qualitative in nature by using field measurements of the relevant aspects coupled with interviewing the occupants of *Sa'o* and other significant figures of traditional village about thermal comfort sensation. The data were gathered through (1) direct measurement of the temperature and humidity of outdoors and indoors of the house, (2) direct measurement of dimensional spaces, (3) direct measurement of the use of materials and the thick of walls, roofs, and floors, (4) direct measurement on the orientation of traditional house. The measurement data were further analyzed by (5) calculating the amount of thermal transmission due to solar heat radiation through building envelops materials, (absorption, density, material conductivity). (6) The data on the design of building envelope of Gurusina *Sa'o* (dimension of wall, roof, and floor), (7) the identification of wind directions, and wind speed which further be analyzed by using the effect of wind speed on thermal comfort, (8) analyzing the stack effect ventilation in order to circulate hot air from indoor to outdoor areas and by flowing the air through the roof of the building (Frick, et al, 2008; Lippsmeier, 1980).

RESULT AND DISCUSSION

1. Context

a. Local Climate

Gurusina village is a traditional village in Flores, Ende, Nusa Tenggara Timur, which is located in the valley surrounded by the hills with a dry climate. The dry climate is affected by monsoons with a short period of rainy season. The dry season is longer, i.e. eight months (from April until November), whereas the rainy season is shorter, i.e. four months (from December until March). The average temperature at the rainy season is 29.7°C in January and the highest is 37.9°C between May-November. The lowest relative humidity is usually happened on the East Monsoon Southeast (63-76%) i.e. from June until November and the highest humidity is on Southwest Season (82-88%) i.e. from December until May. The flow of wind in the middle open space of the village (*loka*) is between 1.6-3.3m/sec (BMKG-NTT, 2017). The center of settlement orientation is this square open space in the middle of the village (l*oka*) that is quite extensive which can be used for joint activities among the indigenous villagers of Gurusina, Ngadha.

b. Geographical Situation

Kampung Gurusina is the native vernacular at Jerebu'u Ngada, Flores, Nusa Tenggara Timur (NTT). Gurusina village is located at 8°53'45.78" South - 120°59'27,89" East and lies in a mountainous valley of Inerie (Figure 1b). In this village, the houses are lined in a rectangle shape with an orientation to the central courtyard (*Kisanata*). In this village, there are 33 traditional houses (*Sa'o*) as in Figure 1a.

The *Loka* and settlement condition is in contoured with a different altitude between the average contour 1:20 cm, each elevation has a different wind speeds. *Sa'o Manu Milo* is located at a height of +2.40m in Gurusina settlement with an average wind speed of 1.6 m/sec, the contour of the top five with a height of +6.00 m and the wind speeds of 3.3 m/sec (Figure 1c).

setting the orientation with centralized pattern. The hierarchy of *Sa'o* consists of indoor spaces as *One*, *Teda One*, *Teda Wewa*, and *Wewa* as can be seen in Figure 2. At *one*, there is a furnace (traditional stove)

Figure 1a: Kampung Gurusina in the valley of Inerie mountain

Figure 1b:
Kampung Gurusina

Figure 1c: Land contour position of Sao at Kisaloka, Gurusina

c. Space Function

The traditional house in Gurusina, Flores is a female traditional house. It is a building that was designed based on local wisdom by considering the concept of tropical architecture. Local wisdom applied in the form of

for cooking when there are ceremonies, for sleeping, for storing valuable things, for storing ingredients of food, and for storing firewood. Whilst at *Teda one,* the room functions as the living room of the nuclear family, as a gathering space; at *Teda wewa*

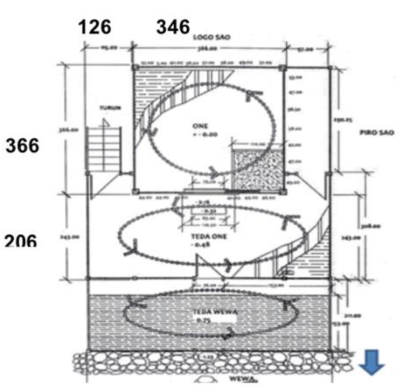


Figure 2: The Plan of Sao at Gurusina

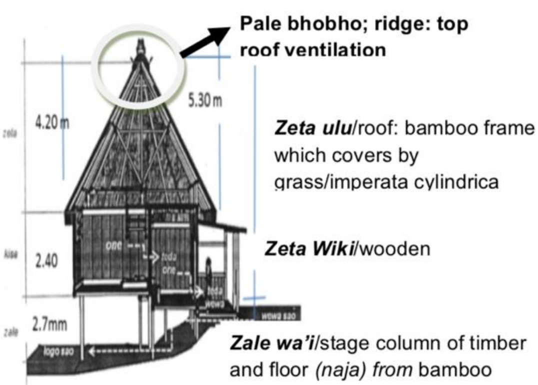


Figure 3: Illustration in construction, dimensions, and material use of Sao traditional house (Source: Susetyarto (2013)

the room is used as a guest room. In *One* space at Gurusina-Ngadha indigenous tribe, the furnace is always lit so as to produce heat and smoke.

Research findings and Recommendation

a. Heat Conductivity through wall materials

Findings

The analysis of heat transmission due to the conduction of material at *one* space through the wooden wall is quite high, reaching 90.08 watt/m² (Table 3 & 4) and heat transmission through the roof of 2.05 watts/m² (Table 3 & 5) so that the average heat transmission due to the sheath is 46.07 watt/m². This value has not been included in the building category as environmentally friendly building based on GBCI (2013) standard which is 35watt/m², plus a furnace in it, so the condition of *one* space becomes un-comfort hot. Referring to the findings of Soegijanto (1999), the temperature and humidity at *one* space on average daytime (TE) is 30^{0} C/72% (Figure 5). The limit of optimal comfort is between 22.8-25.8^{0} C (T.E) with a relative humidity of 70-80%; and the limit of comfort hot is between 25.8-27.1^{0} C (T.E) with a relative humidity of 60% (Soegijanto, 1999).

Recommendation

In order to achieve a comfort temperature, the *stack effect ventilation* area can be enlarged, both on the roof and walls which is attempted to reach 10-20% of the floor area. Based on the data, the *one* floor area is 12.66 m² (Figure 2), so the opening area is 1.2 m². With the wind speed from the direction of *kisanata/loka* of 3.3m/sec, it can reduce the effective temperature from 2.3^{0} C-

Table 3. Material of building envelope at Gurusina Sao (Source: Author 2017)

Materials Construction at One (Exiting Design)					
Number	Elemens of Constructions	Materials	ketebalan(cm)	Density	k (w/m.K)
1	***Zeta wiki ; Midle (Wall Structure)***				
	covering floor/naja	**Betho bamboo**	**1 or 2**	**717**	**0.093**
	wall dan door/*dewa poli weti*	**fai/oja wood**	**4**	**702**	**0.138**
2	***Zeta Ulu :* Roof (Upper structure)**				
	Ladolewa/struss-king post	fai/oja wood	6x12	702	0.138
	paja soku+soku dolu/rafters+battens	Betho bamboo	diameter 7-9	717	0.92
	Covering roof are alang alang	**alang alang**	**30**	**52**	0.035

Table 4. The calculations of external heat gain (heat transmission) through massive wall of *One* at Sao (Source: Author 2017)

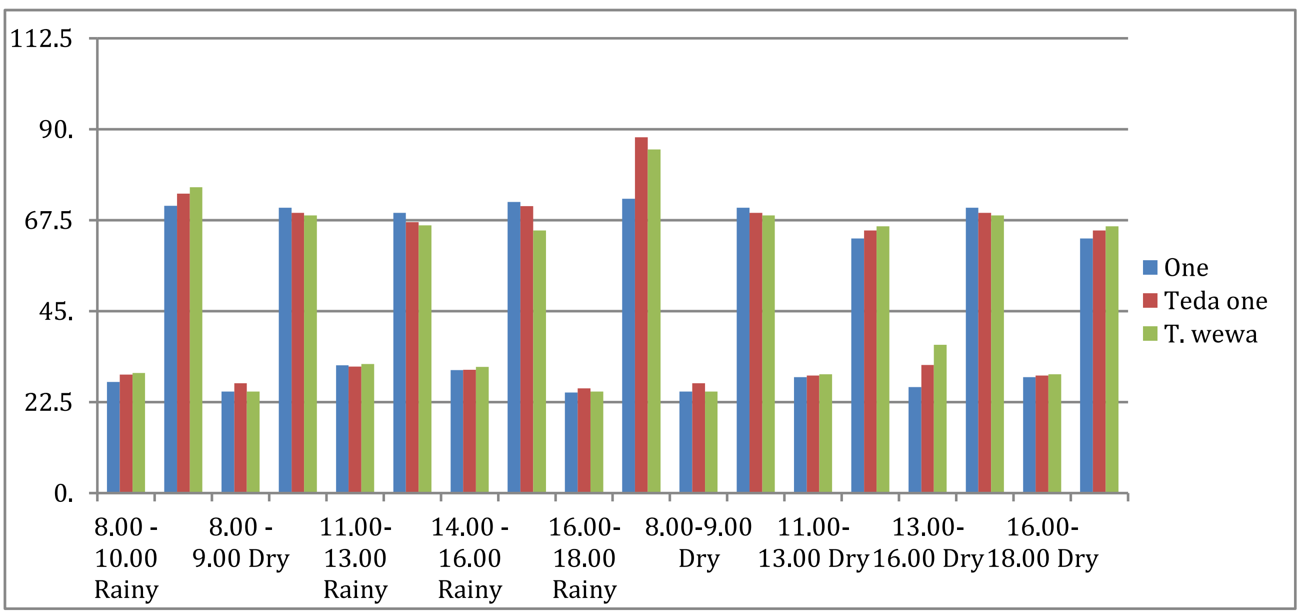
No.	Orien	Material	t :	conduc	R=t/k	U roof	Total	Density	TD ek	A floor	A wall	Q wall		
	tation		thick	tions		1/R	α	kg/m³		A= square	orientasi	(α xUwxAwxTDek/A floor)		
1	Nourt	fai /hard timber	0.3	0.035	8.6	0.12	0.202	52	15	32.86	31.8	0.34		
2	South	fai /hard timber	0.3	0.035	8.6	0.12	0.202	52	15	32.86	31.8	0.34		
3	East	fai /hard timber	0.3	0.035	8.6	0.12	0.202	52	15	32.86	63.6	0.68		
4	West	fai /hard timber	0.3	0.035	8.6	0.12	0.202	52	15	32.86	63.6	0.68		
5		Conduction heat of Sun Radiation throught massive wall										2.05359677	2.05	watt/m²

4.2^0 C, hence the thermal sensation for the occupants is 26.75^0 C (Table 1, Frick 2008) so that it can be categorized as comfort temperature.

Table 5. The calculations of external heat gain (heat transmission) through One Roof at Sao
(Source: Author 2017)

No.	Orientation	Material of building	t : thick	conductions	R=t/k	U wall 1/R	Total α	Density kg/m³	TD ek	A floor A= square	A wall orientasi	Q wall/m² (α xUwxAwxTDek/A floor)	
1	Nourt	fai /hard timber	0.04	0.138	0.3	3.45	0.645	702	15	12.66	8.304	21.89	watt
2	South	fai /hard timber	0.04	0.138	0.3	3.45	0.645	702	15	12.66	8.304	21.89	tidak terkena matahari
3	East	fai /hard timber	0.04	0.138	0.3	3.45	0.645	702	15	12.66	8.784	23.15	watt
4	West	fai /hard timber	0.04	0.138	0.3	3.45	0.645	702	15	12.66	8.784	23.15	watt
5		Conduction heat of Sun Radiation throught massive wall										90.08	watt/m²

Figure 4. Temperature and humidity at Sao
(Source: Author, 2017)



b. Heat conductivity through roof surface

Findings

Referring to the findings of previous studies, 15-20 cm thick reed roofs can reduce heat (Suwantara, et al, 2012), as it was proved in the traditional house of Uma Legge in Mbawa Nusa Tenggara Barat (NTB) village. The material has proven that in the rainy season it can raise the temperature to 0.1ºC-0.8^0 C, and in the dry season it can reduce indoor temperatures to 0.6-1.8^0 C. Thus, the roof of *Sa'o* traditional house which has a similar location and shape as well as design to that of Uma Legge in Mbawa, the roof design of *Sa'o* can reduce the average heat of 1.4^0 C. Therefore, the thermal sensation in indoor reaches 25.35^0 C. The design principle of stage house with the ventilation system derive from the floor can also accelerate air movement upwards. The air movement from the bottom of the floor and the wall can then be released through the opening hole at the top, i.e. the roof hole. The CFD method provides a solution of smoke disposal or air circulation/cross-section air change represents an effort to create optimal thermal performance entails to producing thermal comfort (Yashinta, 2014).

In *Sa'o*, there are several public spaces, other than o*ne,* t*eda one* and *teda wewa* spaces. The sheath material of *teda one* space is the same as at *one space*. Based on the data, the room temperature of *teda one* and *teda wewa* is at the ranges of 30-31^0 C (Figure 4). The existing condition of the ventilation system is relatively good because the opening area exceeds 20% of the floor area of *one* space which has fulfilled the maximum opening requirement (Lechner, 2001). At *teda one,* the front wall of *Sa'o* is bounded by fa*i* timber with 80 cm and 1.50 cm high of sidewalls, so that the ventilation system can achieve comfort thermal zone with an average windspeed of minimal 1.6m/sc. Based on the data of temperature measurement, the effective temperature is between 30-32^0 C (Figure 4). This is resulted by the heat radiation through the roof of *teda wewa* (*lenga*) which is made of half bamboo parts as it can be seen in Figure 5. *Lenga which is* made of bamboo with a total thickness of 10 cm with a slope angle of the roof approximately 10^0 C can be calculated for the heat conduction of the roof which affects the temperature of the *teda wewa* and some of *teda one.* The previous analysis about the transmission of heat through the roof material is 12.01 watts/m² (Table 6) showing that the heat transmission from the existing design of *teda wewa* space based on the floor area. This is a fairly large value, for one roof surface (GBCI 2013).

Recommendation

Based on the calculation on Table 5, it was found that the heat transmission on the roof surface of the existing *teda one* was con-

Table 6. The calculations of external heat gain (heat transmission) through roof surface of '*One'* at Gurusina Sao (Source: Author 2017)

No.	Desain	Material	t :	conduc	R=t/k	U roof	Total	Density	TD ek	A floor	A roof	Q wall		
			thick	tions		1/R	α	kg/m³		A= square	orientasi	(α xUwxAwxTDek/A floor)		
1	Old desain	Bamboo	0.1	0.093	1.1	0.93	0.7	717	15	32.86	10.2	12.01	watt/m²	
2	New Desain	Bamboo	0.2	0.093	2.2	0.47	0.7	717	15	32.86	10.2	6.01	watt/m²	
3		Heat Conduction of Sun Radiation throught Roof												

sidered quite large. Heat transmission can be reduced by using a bamboo pipe and by removing the inner segment so as to allow airflow to reduce heat convection in *teda wewa* space. With a new roof design, the heat transmission was calculated earlier from 12.01 watt/m2 can be reduced into 6,01 watt/.m^2 (Table 6).

CONCLUSION

Based on the measurement of thermal conductivity through wall of *fai* timber, it was revealed that thermal conditions at *one* space can be categorised as uncomfortable hot. The thermal material conductivity contributes on an average of 45.07 watts/m^2, higher than the standard of GBCI (1203) i.e., 35watts/m2. This condition is coupled with the addition of heat transmission to a 2.05 watt/m^2 on the roof and the function of an indoor furnace. This is possible due to the increase of the micro temperature in Gurusina (29.7° C-37.9° C) which exceeds the comfortable heat limit of Indonesians which is $25.8-1^0$ (T.E). The increase in temperature affects the increase in air humidity reaching 63%-88% which exceeds the lower limit and the upper comfortable hot limit of 60% -80%. By making the half-full wall (exceeding 20% of the floor area) in the public spaces (*teda one* and *teda wewa*), and the wind flow with a speed of 3.3 m/sec from the open space resulted on the indoor temperature of the space to decrease from around 23^0 C-42^0 C to 23-32^0 C, although the type of roof material is the same as the roof material of *one.* Efforts are needed to create a number of roof design alternatives by considering the optimal wind flow which entails to the decrease in indoor heat.

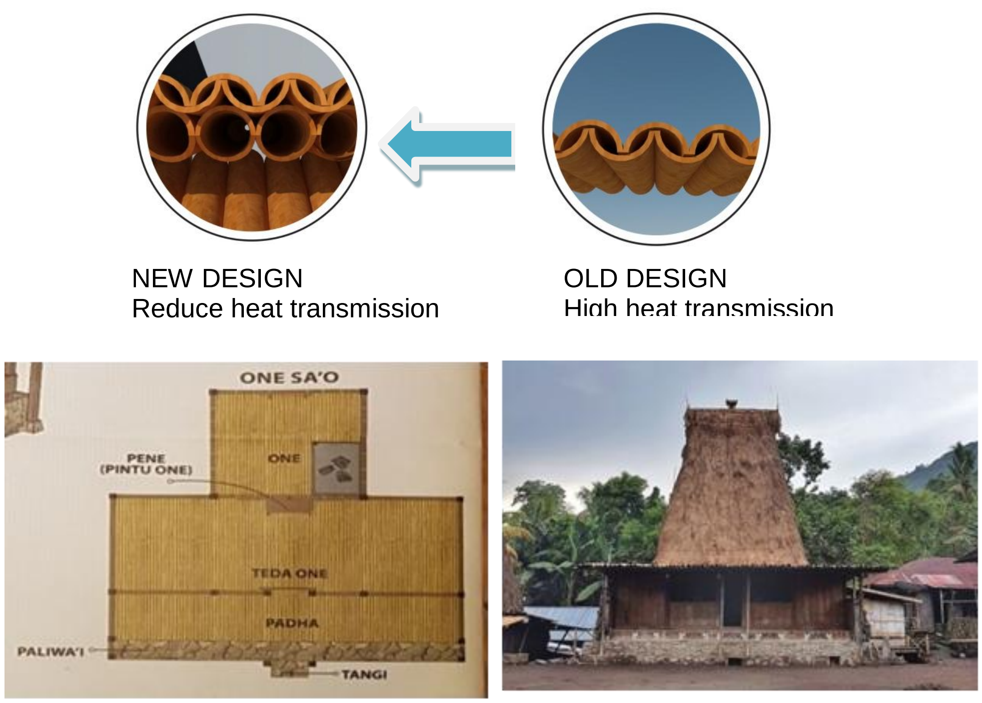


Figure 5. Hollow bamboo as the additional layer
to reduce heat transmission at t*eda wewa*

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