The Comfort Temperature for Exposed Stone Houses and Wooden Houses in Mountainous Areas

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One of the outputs of adaptive thermal comfort theory is the production of occupants' comfort temperature. The comfort temperature for occupants is influenced by microclimate and certain personal factors particularly age and sex. Microclimate in a room of a building is also influenced by wall materials. Different materials will bring about different indoor temperatures. The present study found out the comfort temperature for occupants considering their age and sex in four different seasonal periods. The study was carried out to two types of houses with different wall materials-exposed stone and wood. Data were collected during four seasonal periods including the beginning of the wet season, the middle of the wet season, the beginning of the dry season, and the middle of the dry season. The variables encompass indoor air temperatures and occupants' ASHRAE seven-point thermal sensation scale. The data were then analyzed using linear regression resulting in mathematical equations. The comfort temperature for the occupants was obtained from the calculation of the equations. The study revealed varied comfort temperatures due to different adaptation to the four different seasonal periods. Also, the occupants of the two different types of houses reported different comfort temperatures. Age and sex exert an influence on comfort temperatures.

Keywords: Comfort Temperature; Field Measurement; Mountains; Vernacular

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1. Introduction

The development of thermal comfort science can be divided into two, namely active thermal comfort and passive thermal comfort. The active thermal comfort on which many current studies are based is known as adaptive thermal comfort. Before this adaptive thermal comfort, static thermal comfort or predicted mean vote (PMV) has developed. Comparing the adaptive thermal comfort model to PMV, a more or less 20% difference is found in presenting thermal comfort output [1]. Another study conducted in China also revealed that AMV (actual mean vote) is lower than PMV (predicted mean vote) during winter [2]. The different results of PMV and AMV are so far still found in several studies. The results of a study on naturally-ventilated buildings indicated that PMV can merely predict thermal comfort accurately by 34% [3]. Another study presented a modification of a PMV model into a more accurate model in predicting thermal comfort according to adaptive thermal comfort theories [4]. The adaptive thermal comfort theories are so far used to underlie the analysis of research results [5–7].

Adaptive thermal comfort is considered more accurate in predicting human thermal comfort. The adaptive thermal comfort is thermal comfort based on human thermal perception [8]. The user's thermal perception is closely related to human personal aspects. This is influenced by the building's thermal condition which creates a human's perception of the building [9]. The outputs of adaptive thermal comfort can take the form of a mathematical equation. Besides, the occupants' comfort temperature will be produced. The convenient air temperature is obtained by investigating the indoor and outdoor air temperatures using the adaptive thermal comfort [10].

Comfort temperature is obtained from a mathematical model that can be built using a statistical test [11]. The difference in the air temperature of some areas can be analyzed using the statistical test [12]. This statistical test can give mean value, standard deviation, maximum and minimum values of air temperature from several research objects. Concerning two variables, the influence of air temperature on the surface cover can be revealed using multiple regression analyses and analysis of variants [13]. Regression test is also used to predict residential house's need for energy. The regression test will generate an energy prediction model [14, 15]. The regression test in thermal comfort will create a thermal comfort prediction model with climate and occupant's perception variables [16].

Vernacular houses are believed to be able to create building thermal comfort since they are built based on the adaptation process [17]. This is as found by some research which suggested that the microclimate will make some adaptive thermal comfort difference [18]. The indoor microclimate is affected by the materials of buildings. A study indicated that there is a difference in indoor temperature between local materials and modern materials [19]. The indoor temperature will affect the occupants' thermal sensations. In stone houses in China cold climates affect adaptive thermal comfort. The results showed 47% of residents felt a little cold. This further showed that the adaptation of occupant behavior will affect adaptive thermal comfort [20].

This adaptive thermal comfort is tightly related to the building's microclimate. In a study in Japan, the correlation between microclimate and building materials is investigated in vernacular houses. The study found that vernacular buildings made of wood material can make occupants convenient [21]. Each region with a different microclimate will lead to different adaptation [22]. The occupants of the vernacular houses will adapt to the microclimate of their environment (Fig. 1). In mountainous areas, the adaptation of vernacular houses by the use of local elements presents a part of the ecological principle [23]. Wooden houses can provide energy efficiency and environmental sustainability [24].

One of the regions in Indonesia with climate uniqueness is Wonosobo. In general, humid tropical areas will have hot average air temperature, yet in Wonosobo, the air temperature is below the average. This is because Wonosobo is situated in an area surrounded by such mountains as Sindoro, Sumbing, Paku Wojo, Bismo, and several other mountains. Wonosobo is located at latitude -7º21'32" S and 109o54'11"E. There are many types of local houses. They include exposed stone houses and wooden houses. Houses with local materials are built as a form of adaptation to the microclimate of an area. The present study aimed at finding out the comfort temperature for exposed stone houses and wooden houses in Wonosobo, Indonesia.

2. Experimental Study

The stone house and the wooden house are located in the area of Sindoro mountain, particularly at Gunung Alang Village, Wonosobo Regency. The houses were occupied by several persons. Only four persons living in each house, however, were taken as samples of the present study to represent occupants over the age of 25 and under the age of 25, and their two categories of sex (male and female).

The description of occupants' data can be seen in Table 1.

Table 1. Description of occupants.

Occupants	Sex	Age	Height	Weight
Father	Male	40-50	157-170	51-70
Mother	Female	35-46	155-161	50-68
First child Male	16-24	155-166	52-63	
Second child	Male	8-20	115-164	21-65

The dispersed age of the occupants would show the different prediction models to be built. Their heights and weights seem to have no significant differences. Sex differences were only between fathers and mothers at comparable ages (Table 1). The occupants of a mountainous site commonly wore clothes made of thick materials, such as a jacket, jogger trousers, and a sweater. The activities when they were asked were sitting and standing. The activity value ranged between 1 and 1.2 met. The male occupants more frequently wore sarongs as their daily clothes. During the time for praying around late afternoon to night, sarong was used as an additional item to sleeping wears. The female occupants more frequently wore *jarit* (Javanese traditional clothing) as her daily clothes. Adding *jarit* to the clothes she was wearing could warm the body.

A quantitative and qualitative mixed method was employed in the study. The quantitative method was used to find out the air temperature using a thermal measuring instrument, while the qualitative method was used to discover the occupants' thermal sensation. Both methods need to be combined to obtain a valid research outcome [25]. Temperature is the variable with influence in thermal comfort. Either daily or monthly temperatures might be varied in adaptive thermal comfort [26]. The field measurement was done using a thermal tool fitted at the center of the room at 1.1 m height [27]. The air temperature was measured together with the subjective measurement of the occupants. A thermal comfort instrument was installed

(a) **(b)**

Fig. 1. Sample of House, (a) An exposed stone house, (b) A wooden house.

between 1 meter and 2 meters away from the occupants. A thermal sensation questionnaire from ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) standards was used for the subjective measurement. The thermal sensation has 7-scale measurement, namely -3 (very cold), -2 (cold), -1 (slightly cold), 0 (neutral), +1(warm), +2 (hot), +3 (very hot). The occupants' clothing was not arranged and it ranged between 0.88 and 1.2 clo. Most of the occupants' activities were not far different. They include sitting in silence, sitting while chatting, and standing up while chatting. The value of their activities ranged between 1 and 1.2 met. Stone houses in mountainous areas have a length of 9.4 m, a width of 6 m, and therefore an area of 56.4 m^2. Meanwhile, wooden houses in mountainous areas have a length of 11.8 m, a width of 11.8 m, and therefore an area of 139.24 m^2. Both types of houses have a family/ living room, bedrooms, a kitchen, and a bathroom. There are two kinds of stoves in the kitchen. They are a gas stove and a wood-burning hearth. This study was conducted during rainy and dry seasons, and therefore its results could be more comprehensive. This is because the temperatures occurring during dry and rainy seasons contradicted one another. The questionnaire was filled at least 3 times a day [28]. The thermal sensation questionnaire was taken at the beginning of and middle of the rainy season and the beginning of and middle of the dry season. These inhabitation periods were tightly related to the building occupants' behavior according to the occurring microclimate condition. Occupants would respond to the microclimate as the period changed [29]. The items presented in the questionnaire can be seen from the below figure.

During each period, the measurements were made for 5 days in a row. Every day, the data on thermal sensation were taken at 4 points of time (morning, noon, late afternoon, night). At each point in time, the main data and validating data were taken every 5 minutes. The validating thermal sensation data were taken at least once. An adaptive thermal comfort study will produce the occupants' comfort temperature. The regression analysis was used to predict adaptive thermal comfort. Regression analysis is a statistical analysis that would generate an equation model. In the analysis of thermal comfort research which delivered a mathematical equation model, a statistical analysis was mostly employed just as the case with a study in China which resulted in users' satisfaction percentage to the existing thermal condition [30]. The formula used is TSV=a + b Ta, where TSV is the variable Thermal Sensation Vote and Ta is the indoor air temperature. The value of (a) is the intercept value and (b) is the beta coefficient (slope). The intercept value is the average value of the TSV variable if the Ta variable is 0. Regression equations can be used to find comfort temperature values [31]. The calculation has been used in other studies that compared TSV and PMV models [32].

3. Results and Discussions

Linear regression was employed for data analysis. The test was performed using SPSS software in the Linear Regression menu. The SPSS used is IBM SPSS Statistics Grad Pack 26.0 using license of License Key(s): 67430b9410da1784fbe3. The variables tested include air temperature as the independent variable and thermal sensation of each occupant as the dependent variable. Before performing the regression test, the data should have passed a validity test, a reliabil-

Questionnaire			
Name	:	Weight	:
Sex	:	Height	:
Age	:	Time	:
1. How do you feel about the temperature in the room? -3 -2 -1 0 1 2 3 Very Cold Cold Slighty Cold Neutral Warm Hot Very Hot			
2. What clothes are you wearing?			
3. What are you doing now?			
Air temperature	: .....ºC	Relative Humidity	: …… %
Meant radiant temperature	: .....ºC	Wind Velocity	: .... m/s

Fig. 2. Questionnaire.

ity test, and a classical assumption test. A validity test is useful to test whether the data are valid. The reliability test is used to discover the data consistency level. Meanwhile, the classical assumption test includes a normality test, a multicollinearity test, and a heteroskedasticity test.

The result of the validity test can see in Table 2

The result of the reliability test can be seen in Table 3

The result of the normality test can be seen in Figure 3.

The result of multicollinearity test can see at Table 4.

The result of the heteroskedasticity test can be seen in Figure 4.

The comfort temperature analysis could be calculated using a small amount of data [33]. The small amount of data was not a problem in calculating the comfort temperature. In this study, some obstacles were encountered in the way of getting the data, including the fact that at the beginning of the rainy season the respondents seemed to have outdoor activities. Besides, when the survey was conducted, no guests visited the objects of this study. The amount of Thermal Sensation Vote (TSV) obtained from the survey was 2,228 data (Fig. 5).

A regression test is useful to discover whether or not there is an influence between independent and dependent variables. To determine whether an influence exists between the variables, a comparison can be made between the Sig. value in the Coefficients table and the probability value (0.05). The smaller value of significance means that the independent variables influence the dependent variables, in this case, air temperature and each occupant's perception. Meanwhile, the greater value of significance indicates that no influence exists between the variables.

It could also be determined by finding the comfort temperature experienced by the occupants using a simple linear equation formula, TSV =a + b Ta. The value of a is a constant number of unstandardized coefficients and the value of b is the regression coefficient number. The value of variable TSV is assumed as 0 since what will be sought after is the amount of comfort temperature. TSV is assumed to be 0 because the occupants feel comfortable at a value of 0.

The comfort temperature for exposed stone house occupants at the beginning of the rainy season ranges between 23.3-28.7ºC. The difference between mother and father's comfort temperatures is not too great, i.e. 0.5ºC. The difference in the comfort temperature between the first child and the second child is 4.1º. The difference is caused by the difference in the daily activities performed by the first child in the wet season, i.e. helping to slice tobacco. The comfort temperature in wooden house occupants is higher than that in the exposed stone house in mountainous areas. The formed comfort temperature ranges between 24.8-

Table 2. Validity Test.

		TSV_ Father	Ta_ Father	TSV_ Mother	Ta_ Mother	TSV_ First _Child	Ta_ First _Child	TSV_ Second _Child	Ta_ Second _Child	TSV_ Guest	Ta_ Guest
TSV	Pearson Correlation	1	.482**	1	.379*	1	.638**	1	.579**	1	.519**
	Sig. (2-tailed)		.002		.019		.000		.001		.001
Ta	Pearson Correlation	.482**	1	.379*	1	.638**	1	.579**	1	.519**	1
	Sig. (2-tailed)	.002		.019		.000		.001		.001	

**. Correlation is significant at the 0.05 level (2-tailed).

Table 3. Reliability test.

Respondent	Cronbach's Alpha
Father	.836
Mother	.826
First Child	.752
Second Child	.731
Guest	.801

Table 4. Reliability test.

Respondent	Collinearity Statistics	
	Tolerance	VIF
Father	1.000	1.000
Mother	1.000	1.000
First Child	1.000	1.000
Second Child	1.000	1.000
Guest	1.000	1.000

28.9°C (Table 5). This fairly wide range of temperatures resulted from the fairly high air temperature occurring in the wooden house is considered fairly high. The comfort temperature difference also occurs due to the influence of the occupants' age and sex.

The occupants' comfort temperature ranges between 21.8-26.0°C, and the guest's comfort temperature is fairly high at 26.0°C. The difference in comfort temperature between guests and occupants is more or less 3°C. During the rainy season, the air temperature is fairly low, thus the obtained comfort temperature is pretty low as well. In the mid rainy season, the comfort temperature ranges between 21.8-25.6°C (Table 6). The respondent with the highest comfort temperature is the father who was 50 years old. The second highest one is the first child who was around 24 years old. Due to this difference in age, the difference in comfort temperature is possible to occur.

The difference in father and mother's comfort temperature is 1.8°C. At an air temperature above 26°C, the tendency of comfort temperature for women is higher than that of men. The guest's comfort temperature is relatively high at the beginning of the dry season since the surveyed guest comes from a hot region. The first child's comfort temperature is also relatively high. This first child's activities and clothes exert an influence on the obtained comfort temperature. The result of the regression test of data on the wooden house at the beginning of the dry season shows a high significance rate. The comfort temperature seems to range between 23.6-27.5°C (Table 7). The obtained comfort temperature is indeed fairly high for the first child and the guest. Yet, these comfort temperatures were still within the human comfort temperature range according to other studies.

The father's comfort temperature is the highest among other occupants. In the dry season, the mother and first child's comfort temperatures are the lowest. The average comfort temperature is around 22°C. This comfort temperature is lower than the comfort temperature found in a study in Bandung. While sharing the status of cold regions, the outdoor temperature in Wonosobo is lower than that in Bandung, and therefore the occupants' comfort temperature in Wonosobo is lower than that in Bandung. According to the data on the wooden house at mid dry season, a comfort temperature at 23.7-33.5°C is produced. Father and first child were more likely to have high comfort temperature during the survey at mid dry season. In the first child, the likeliness of high temperature was seen at surveys at other periods. This first child had fairly active activities, so the activities influenced the thermal sensation he perceived. The first children's daily activity in the middle of the dry season is cutting wood to prepare the making of agricultural produce baskets. The respondent's father was active in the dry season since his jobs increased at that time. Additionally, the guest also seemed to have a fairly high comfort temperature at 33.5°C (Table 8). The guest's

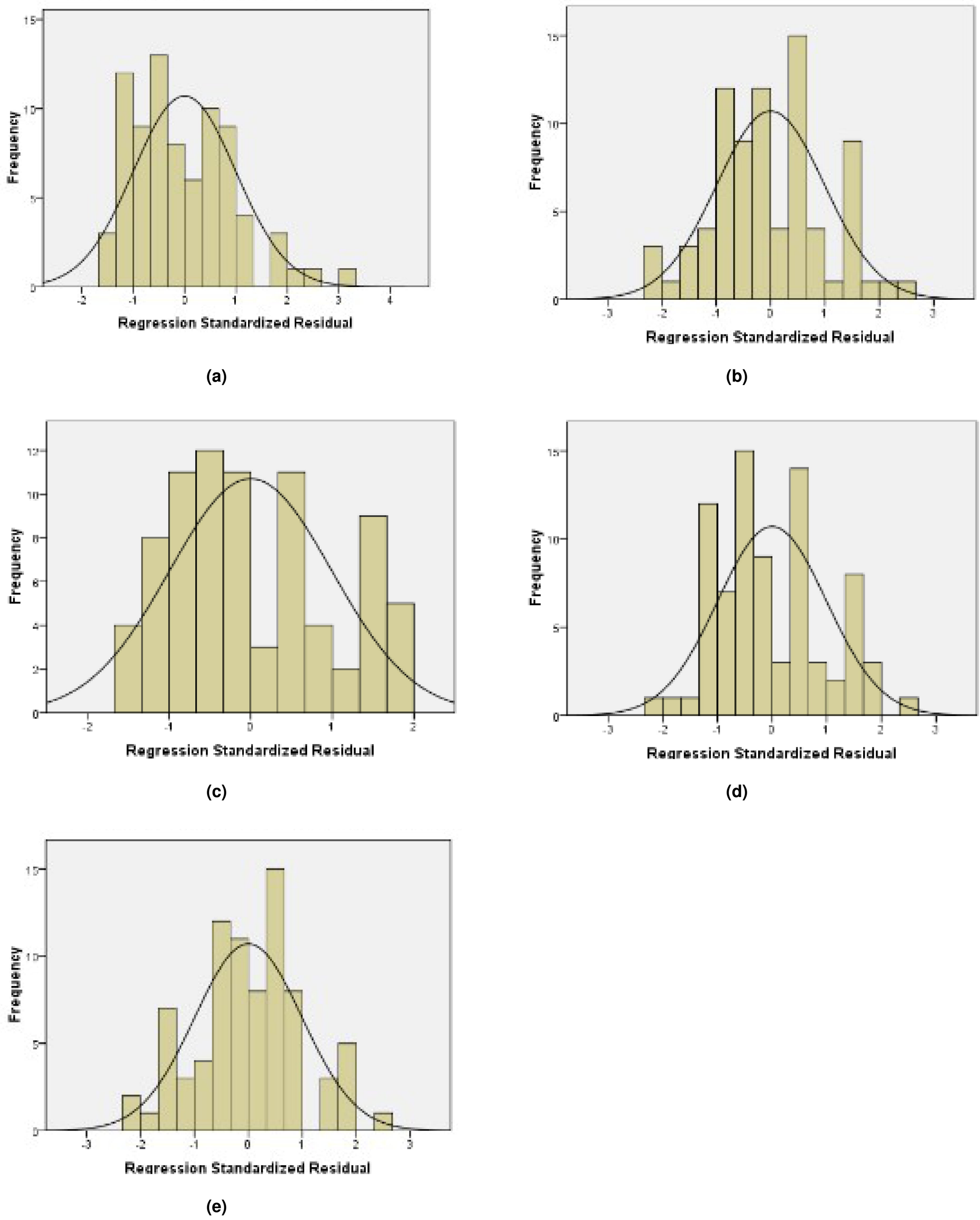

Fig. 3. Normality Test.

comfort temperature is influenced by his origin (he did not belong to the local community).

Note BRS : Beginning of Rainy Season BDS: Beginning of Dry Season RS: Mid Rainy Season DS: Mid Dry Season

Upon comparison, it was found that the comfort temperatures for occupants of exposed stone houses and wooden houses in mountainous areas are not significantly different. The occupants showing the significant difference in comfort temperature are the first child at mid dry season, the guest at the beginning of the dry season, and mid dry season

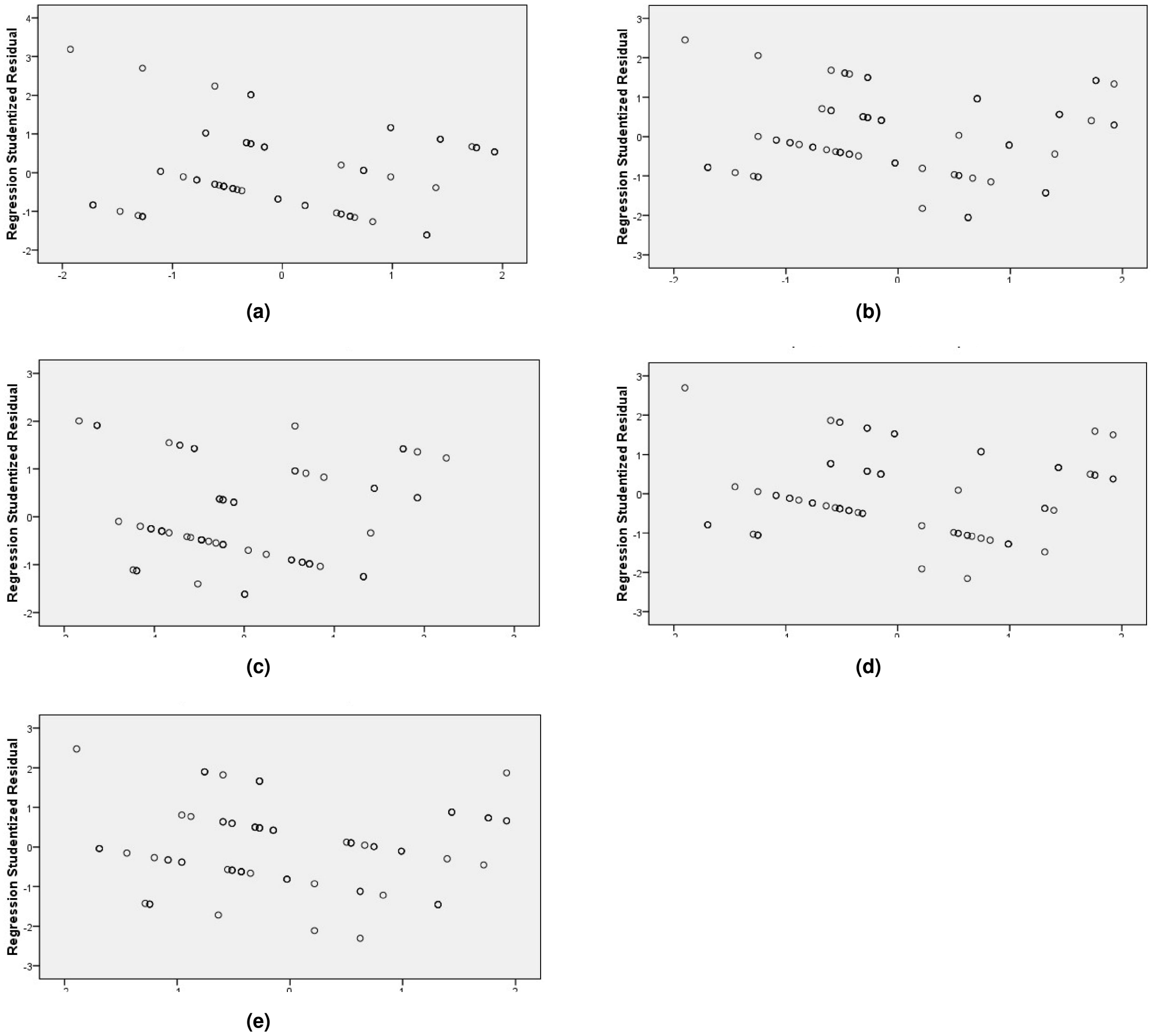

Fig. 4. Heteroskedasticity test.

Table 5. Regression test of data on exposed houses and wooden houses at the beginning of the rainy season.

Respondent	ESH Models	CF	WWH Models	CF
Father	TSV =0.212Ta-5.041	23.8	TSV =0.216Ta-5.545	25.7
Mother	TSV =0.305Ta-7.120	23.3	TSV =0.203Ta-5.354	26.4
First child	TSV =0.087Ta-2.440	28.0	TSV =0.196Ta-5.665	28.9
Second child	TSV =0.090Ta-2.565	28.5	TSV =0.261Ta-6.469	24.8
Guest	TSV =0.113Ta-3.240	28.7	TSV =0.273Ta-7.812	28.6

Annotation: ESH : Exposed Stone Houses, WWH : Wooden Houses, CF : Comfort Temperature (^{o}C)

(Fig. 6). The fairly significant difference results from the influence of the different clothes and activities (from what they usually did and wore on other occasions). The occupants in the wooden house are more likely to have higher comfort temperature than the occupants of the exposed stone house. The wooden house occupants' tolerance to the indoor air temperature is higher than the exposed stone house occupants. Besides, a hearth was more frequently used in the wooden house than in the exposed stone house.

This research result was different from that of other

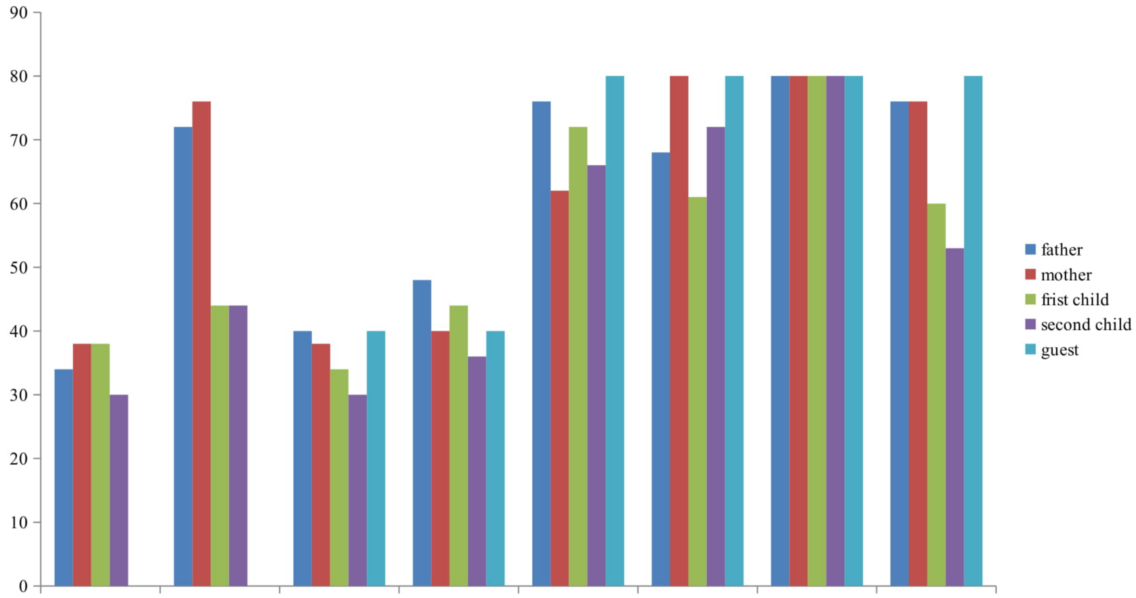

Fig. 5. Amount of Data.

Table 6. Regression test of data on exposed stone houses and wooden houses at mid rainy season.

Respondent	ESH Models	CF	WWH Models	CF
Father	TSV =0.177Ta-4.126	22.0	TSV =0.142Ta-3.638	25.6
Mother	TSV =0.373Ta-8.169	23.3	TSV =0.171Ta-4.062	23.8
First child	TSV =0.452Ta-10.448	23.1	TSV =0.224Ta-5.420	24.2
Second child	TSV =0.526Ta-11.470	21.8	TSV =0.349Ta-7.689	22.0
Guest	TSV =0.275Ta-7.154	26.0	TSV =0.459Ta-10.005	21.8

Annotation : ESH : Exposed Stone Houses, WWH : Wooden Houses,
CF : Comfort Temperature (°C)

Table 7. Regression test of data on exposed stone houses and wooden houses at the beginning of the dry season.

Respondent	ESH Models	CF	WWH Models	CF
Father	TSV =0.174Ta-4.605	26.5	TSV =0.249Ta-5.868	23.6
Mother	TSV =0.096Ta-2.717	28.3	TSV =0.173Ta-4.532	26.2
First child	TSV =0.087Ta-2.452	28.1	TSV =0.148Ta-4.077	27.5
Second child	TSV =0.131Ta-3.779	28.8	TSV =0.163Ta-4.354	26.7
Guest	TSV =0.098Ta-2.770	28.2	TSV =0.181Ta-4.928	27.2

Annotation : ESH : Exposed Stone Houses, WWH : Wooden Houses,
CF : Comfort Temperature (°C)

studies, yet in several cases, the comfort temperature is similar, depending on the outdoor temperature of each area. Other studies found that the comfort temperatures of several cities in Indonesia vary, i.e. Yogyakarta 29.1°C [34], Jakarta 26.4°C [35], Bandung 24.7°C [36], Makassar 27.7°C, Medan 27.9°C and Surabaya 28.9°C [37]. These different comfort temperatures depend on the environmental outdoor temperature and individual characteristics. The

Table 8. Regression test of data on exposed stone- and wood-walled houses at mid dry season.

Respondent	ESH Models	CF	WWH Models	CF
Father	TSV =0.218Ta-4.945	22.7	TSV =0.094Ta-2.718	28.9
Mother	TSV =0.221Ta-4.886	22.1	TSV =0.121Ta-3.440	28.4
First child	TSV =0.179Ta-3.955	22.1	TSV =0.121Ta-3.889	32.1
Second child	TSV =0.220Ta-4.919	22.4	TSV =0.234Ta-5.543	23.7
Guest	TSV =0.160Ta-3.605	22.5	TSV =0.123Ta-4.126	33.5

Annotation : ESH : Exposed Stone Houses, WWH : Wooden Houses,
CF : Comfort Temperature (^{o}C)

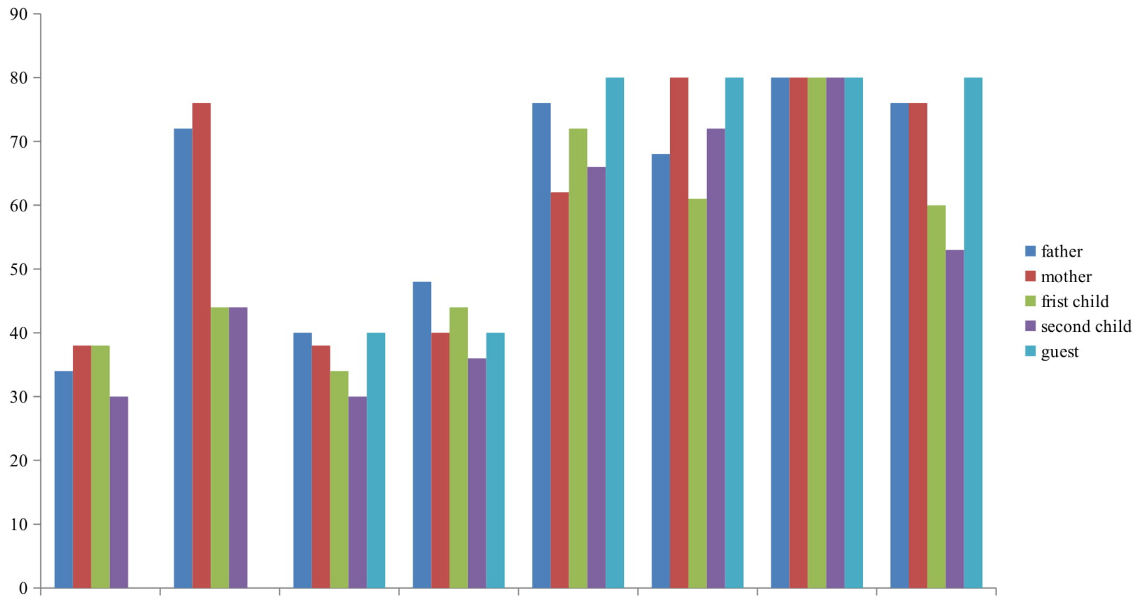

Fig. 6. Recapitulation of comfort temperature. Note BRS : Beginning of Rainy Season BDS: Beginning of Dry Season RS: Mid Rainy Season DS: Mid Dry Season

respondent's age and sex also influence the obtained comfort temperature. Several studies suggested that age and sex influence adaptive thermal comfort [38, 39]. The comfort temperatures vary depending on the conditions of the occupants' adaptation to their environment. A study in Brazil found that female elderly (65-91 years old) are more sensitive than younger women (13-64 years old) [40]. In Australia, a study found that women's thermal sensation is higher than men. Women have 1.79 thermal sensations and men have 1.60 when the temperature is above 24.2^{o}C [41]. This indicates that men are more tolerant of heat than women. Another study also suggested that women often fail to accept a thermal condition [42]. A study in Taiwan found that women have a lower comfort temperature than men when the weather is cold, yet they have a higher comfort temperature than men when the weather is hot [43]. The difference in the comfort temperature is caused by the occupants' adaptation to the microclimate. Most studies on thermal comfort found out that age and sex exert an influence on occupants' thermal sensations. In terms of building materials, building envelopes will affect indoor macroclimatic conditions. Different building materials will create different indoor temperatures [44]. It indirectly follows that materials influence the comfort temperature for the occupants.

4. Conclusions

The findings of the study revealed varied comfort temperatures. The findings expressed similarities and differences with those of other studies. The comfort temperature obtained from the results of this study is seen to be influenced by the adaptation factors of the occupants. Also, this study revealed that the difference in wall materials indirectly influences the comfort temperature for the occupants. In a location that has a similar outdoor climate, the produced model was also similar. The found prediction model is significantly influenced by the outdoor climate. The occurring difference in comfort temperature in each environment is consistent with the adaptive thermal comfort theory which emphasizes that occupants would adapt to their thermal environment. The father's comfort temperature in the exposed stone house is the highest at the beginning of the dry season (26.5°C). The lowest comfort temperature is in the mid rainy season (22.0°C). Meanwhile, the father's comfort temperature in the wooden house is the highest at the mid dry season (28.9°C). The father's lowest comfort temperature is at the beginning of the dry season (23.6°C).

Nearly all respondents' highest comfort temperatures were found at the beginning of the dry season, yet not all respondents had the lowest comfort temperature at mid dry season. The mother and first child's comfort temperatures are the lowest for the exposed stone house at the mid dry season (22.1°C). In the wooden house, the guest and second child's comfort temperatures are the lowest at the rainy season. Therefore, it could be concluded that these varied comfort temperatures are not influenced by the seasons, rather it is the air temperature of each environment which has the influence. The guest's comfort temperature is a little bit hard to serve as a reference as the guest does not belong to the local community. Nevertheless, the obtained comfort temperature could be used for comparison in other studies.

At a certain point in time, the air temperature in a mountainous area is different from that in the lowland. Such is the anomaly specific to the mountainous area. The obtained regression models also vary, yet they are insignificantly different from other studies' findings. The prediction can be made for those areas with similar climate and population characteristics. As a recommendation for further study, a more in-depth analysis of the factors which determine the occupants' adaptation to their thermal environment in the same houses could be employed.

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References

[1] Aiman Albatayneh, Dariusz Alterman, Adrian Page, and Behdad Moghtaderi. The impact of the thermal comfort models on the prediction of building energy consumption. *Sustainability (Switzerland)*, 10(10), 2018.

[2] Yu Jiao, Hang Yu, Tian Wang, Yusong An, and Yifan Yu. Thermal comfort and adaptation of the elderly in free-running environments in Shanghai, China. *Building and Environment*, 118:259–272, 2017.

[3] Toby Cheung, Stefano Schiavon, Thomas Parkinson, Peixian Li, and Gail Brager. Analysis of the accuracy on PMV – PPD model using the ASHRAE Global Thermal Comfort Database II. *Building and Environment*, 153:205–217, 2019.

[4] Shuqin Chen, Xinzhen Wang, Isaac Lun, Yue Chen, Jindong Wu, and Jian Ge. Effect of inhabitant behavioral responses on adaptive thermal comfort under hot summer and cold winter climate in China. *Building and Environment*, 168, 2020.

[5] Xiaoyun He, Le An, Bo Hong, Boze Huang, and Xue Cui. Cross-cultural differences in thermal comfort in campus open spaces: A longitudinal field survey in China's cold region. *Building and Environment*, 172, 2020.

[6] Yu Jiao, Hang Yu, Yifan Yu, Zi Wang, and Qi Wei. Adaptive thermal comfort models for homes for older people in Shanghai, China. *Energy and Buildings*, 215, 2020.

[7] Won Hee Ko, Stefano Schiavon, Hui Zhang, Lindsay T. Graham, Gail Brager, Iris Mauss, and Yu Wen Lin. The impact of a view from a window on thermal comfort, emotion, and cognitive performance. *Building and Environment*, 175, 2020.

[8] Bruna Faitão Balvedi, Enedir Ghisi, and Roberto Lamberts. A review of occupant behaviour in residential buildings, 2018.

[9] Jing Liu, Runming Yao, and Rachel McCloy. A method to weight three categories of adaptive thermal comfort. *Energy and Buildings*, 47:312–320, 2012.

[10] Christhina Candido and Richard de Dear. From thermal boredom to thermal pleasure: a brief literature review. *Ambiente Construído*, 12(1):81–90, 2012.

[11] L. A. López-Pérez, J. J. Flores-Prieto, and C. Ríos-Rojas. Adaptive thermal comfort model for educational buildings in a hot-humid climate. *Building and Environment*, 150:181–194, 2019.

[12] Jared Langevin, Jin Wen, and Patrick L. Gurian. Relating occupant perceived control and thermal comfort: Statistical analysis on the ASHRAE RP-884 database. In *HVAC and R Research*, volume 18, pages 179–194, feb 2012.

[13] Ingegard Eliasson and M. K. Svensson. Spatial air temperature variations and urban land use - A statistical approach. *Meteorological Applications*, 10(2):135–149, 2003.

[14] H Fan, I. F. MacGill, and A. B. Sproul. Statistical anal-

ysis of driving factors of residential energy demand in the greater Sydney region, Australia. *Energy and Buildings*, 105:9–25, 2015.

[15] Hermawan Hermawan, Hadiyanto Hadiyanto, Sunaryo Sunaryo, and Asyhar Kholil. Analysis of thermal performance of wood and exposed stone-walled buildings in mountainous areas with building envelop variations. *Journal of Applied Engineering Science*, 17(3):321–332, 2019.

[16] Anastasios Ioannou, Laure Itard, and Tushar Agarwal. In-situ real time measurements of thermal comfort and comparison with the adaptive comfort theory in Dutch residential dwellings. *Energy and Buildings*, 170:229–241, 2018.

[17] Xiaoyu Du, Regina Bokel, and Andy van den Dobbelsteen. Building microclimate and summer thermal comfort in free-running buildings with diverse spaces: A Chinese vernacular house case. *Building and Environment*, 82:215–227, 2014.

[18] Madhavi Indraganti, Ryozo Ooka, Hom B. Rijal, and Gail S. Brager. Adaptive model of thermal comfort for offices in hot and humid climates of India. *Building and Environment*, 74:39–53, 2014.

[19] D. G. Leo Samuel, K Dharmasastha, S. M. Shiva Nagendra, and M. Prakash Maiya. Thermal comfort in traditional buildings composed of local and modern construction materials. *International Journal of Sustainable Built Environment*, 6(2):463–475, 2017.

[20] Russell Hitchings, Gordon Waitt, Kate Roggeveen, and Catherine Chisholm. Winter cold in a summer place: Perceived norms of seasonal adaptation and cultures of home heating in Australia. *Energy Research and Social Science*, 8:162–172, 2015.

[21] Ayaz Fazeel Hosham and Tetsu Kubota. Effects of building microclimate on the thermal environment of traditional Japanese houses during hot-humid summer. *Buildings*, 9(1), 2019.

[22] Hermawan, Sunaryo, and A Kholil. A thermal performance comparison of residential envelopes at the tropical highland for occupants' thermal comfort. In *IOP Conference Series: Earth and Environmental Science*, volume 200, page 12034, 2018.

[23] Evandro Eduardo Broday, Jéferson Aparecido Moreto, Antonio Augusto de Paula Xavier, and Reginaldo de Oliveira. The approximation between thermal sensation votes (TSV) and predicted mean vote (PMV): A comparative analysis. *International Journal of Industrial Ergonomics*, 69:1–8, 2019.

[24] Erni Setyowati, Retno Widjajanti, Agung Budi Sardjono, and Mochamad Arief Budihardjo. Spatial planning and traditional culture based urban acupuncture concept on upgrading low carbon tourism village. *International Journal of Engineering and Advanced Technology*, 9(1):7087–7095, 2019.

[25] Jozef Švajlenka and Mária Kozlovská. Effect of accumulation elements on the energy consumption of wood constructions. *Energy and Buildings*, 198:160–169, 2019.

[26] Jozef Švajlenka and Mária Kozlovská. Houses based on wood as an ecological and sustainable housing alternative-Case study. *Sustainability (Switzerland)*, 10(5), 2018.

[27] Bin Cheng, Yangliu Fu, Maryam Khoshbakht, Libin Duan, Jian Zhang, and Sara Rashidian. Characteristics of thermal comfort conditions in cold rural areas of China: A case study of stone dwellings in a Tibetan village. *Buildings*, 8(4), 2018.

[28] Harimi Djamila, Chu Chi Ming, and Sivakumar Kumaresan. Investigation on hourly and monthly thermal comfort in the humid tropics of Malaysia. *Buildings*, 5(3):1025–1036, 2015.

[29] American Society of Heating and Undefined Refrigerating. Thermal environmental conditions for human occupancy. *ASHRAE Standard*, (55), 2013.

[30] Andrés Gallardo, Massimo Palme, Andrea Lobato-Cordero, R. David Beltrán, and Gabriel Gaona. Evaluating thermal comfort in a naturally conditioned office in a temperate climate zone. *Buildings*, 6(3):1–20, 2016.

[31] Marika Vellei, Sukumar Natarajan, Benjamin Biri, Julian Padget, and Ian Walker. The effect of real-time context-aware feedback on occupants' heating behaviour and thermal adaptation. *Energy and Buildings*, 123:179–191, 2016.

[32] Jiawei Yao, Feng Yang, Zhi Zhuang, Yuhan Shao, and Philip F Yuan. The effect of personal and microclimatic variables on outdoor thermal comfort: A field study in a cold season in Lujiazui CBD, Shanghai. *Sustainable Cities and Society*, 39:181–188, 2018.

[33] I.D. Griffiths. *Thermal comfort in buildings with passive solar features : field studies*. 1991.

[34] Henry Feriadi and Nyuk Hien Wong. Thermal comfort for naturally ventilated houses in Indonesia. In *Energy and Buildings*, volume 36, pages 614–626, 2004.

[35] Tri Harso Karyono. Thermal comfort for the Indonesian workers in Jakarta: Adopting the current ashrae standard for Jakarta would create cool discomfort and in addition waste energy — a greater understanding of true comfort range is called for. *Building Research & Information*, 23(6):317–323, nov 1995.

[36] Tri Harso Karyono. Bandung thermal comfort study: Assessing the applicability of an adaptive model in in-

donesia. *Architectural Science Review*, 51(1):60–65, 2008.

[37] Tri Harso Karyono. Predicting comfort temperature in Indonesia, an initial step to reduce cooling energy consumption. *Buildings*, 5(3):802–813, 2015.

[38] Igor Knez and Sofia Thorsson. Influences of culture and environmental attitude on thermal, emotional and perceptual evaluations of a public square. *International Journal of Biometeorology*, 50(5):258–268, may 2006.

[39] Salman Shooshtarian and Ian Ridley. The effect of physical and psychological environments on the users thermal perceptions of educational urban precincts. *Building and Environment*, 115:182–198, 2017.

[40] Eduardo L. Krüger and Francine A. Rossi. Effect of personal and microclimatic variables on observed thermal sensation from a field study in southern Brazil. *Building and Environment*, 46(3):690–697, 2011.

[41] Cho Kwong Charlie Lam, Margaret Loughnan, and Nigel Tapper. Visitors' perception of thermal comfort during extreme heat events at the Royal Botanic Garden Melbourne. *International Journal of Biometeorology*, 62(1):97–112, jan 2018.

[42] Katerina Pantavou, George Theoharatos, Mattheos Santamouris, and Dimosthenis Asimakopoulos. Outdoor thermal sensation of pedestrians in a Mediterranean climate and a comparison with UTCI. *Building and Environment*, 66:82–95, 2013.

[43] Chien Hung Tung, Chen Peng Chen, Kang Ting Tsai, Noémi Kántor, Ruey Lung Hwang, Andreas Matzarakis, and Tzu Ping Lin. Outdoor thermal comfort characteristics in the hot and humid region from a gender perspective. *International Journal of Biometeorology*, 58(9):1927–1939, oct 2014.

[44] Hermawan Hermawan, Hadiyanto Hadiyanto, Sunaryo Sunaryo, and Asyhar Kholil. Analysis of thermal performance of wood and exposed stone-walled buildings in mountainous areas with building envelop variations. *Journal of Applied Engineering Science*, 17(3):321–332, 2019.