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The Effect of Vegetable Garden on the Roof Building Due to the Indoor Thermal Comfortability

Case study: A classroom in Surabaya Indonesia

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ABSTRACT

This research investigated the level of thermal comfortability in class room after being applied organic vegetable on the building roof. It was due to the arangement of organic vegetable area and classroom condition when there was carried out the teaching-learning process by opening the whole window and closing the door. Research conducted in University of Merdeka, Surabaya of Indonesia. The methodology consisted of carrying out the objective measuring related to air temperature, relative humidity, wind velocity for each condition of garden wide number, while subjective survey was involving the quesionaire about thermal environment perception and air quality in room by classroom user such as students and lecturers. The results showed that the maximum garden area (full cover underneath the roof room) produces a decrease in air temperature in the optimal room and although the air temperature in the chamber decreased on average 0.5 º C during the dry season and 2.7 º C in the rainy season, but there was no one class room had thermal condition in comfortability zone of ASHRAE (American Society of Heating, Refrigerating. and Air Conditioning Engineers) standard 55 and neutral temperature was higher than ASHRAE standard in all of the condition. Subjective result presented that the users had thermal comfortability level higher than PMV (Predicted Mean Vote)

KEYWORDS: thermal comfortability, vegetable garden, neutral temperature, comfortability perception

1. INTRODUCTION

Indonesia is geographically located on the north longitude of 6 º until south longitude of 11º, so Indonesia is classified on climate characteristic of humid tropic. Generally, Indonesian climate such as radiation, air temperature, air humidity, and rainfall are so high and always as cloudy sky. However, not all of Indonesian regions are thermally as tropical area because tropical area due to the temperature measuring is a region with average temperature of 20 ºC, but average temperature in Indonesia regions generally can reach 35 ºC with high humidity of 85 % (humid hot tropical climate) [1].

Surabaya city is located on the south longitude of 7.21º with the elevation of sea level is ± 6 meters. According to the Meteorological and Geophysical Department (BMG) of Surabaya, it indicated that there was trend of extreem micro climate condition (more than general climate condition in Indonesia) and maximal temperature during 5 years from 2001 to 2005 has reached 34.4 ºC. Even according to Wijaya [2], in last decade of 15 years, the increasing of temperature in Surabaya was in average more than 1.5 ºC such as from 34.5 ºC up to 36.4 ºC. By average increasing only of 1 ºC, temperature of Surabaya was as the highest value of temperature increasing in the world which in average only reached 0.3 ºC. In the temperature condition like as above, the problem is how to get space thermal comfortability on the formed environment.

Talarosa [3] presented that the cheapest manner for getting thermal comfortability was naturally through architectural approach such as by designing the building with the considerations as follow: 1) the orientation of sun and wind direction; 2) the usage of architectural element and building material; and 3) the usage of landscape elements. For new environment, the architectural approach of first and second manner can be carried out, for developed environment, there can not be used the first and second manner but it had to carry out the third manner such as by using the element of landscape or vegetation,

The objectives of this research were as foollow: 1) to identify and evaluate thermal comfoetability condition in classroom of school after being given the organic vegetable garden on the building roof; 2) to analyze the neutral temperature of class room after being given roof-garden condition; and 3) to compare ASHRAE (American Society of Heating, Refrigerating. and Air Conditioning Engineers) standard 55.[4]; 4) to know changes in air quality (CO_2 and O_2) in the room after being granted a garden on the roof ; 5) to know the inhabitant perception of thermal comfortability level in classroom through the subjective approach.

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Most of the previous studies that relate to thermal comfort using configuration ventilation openings on the building facade, whereas in this study the aim of the research of the use of horizontal vegetable garden arrangement configuration as a medium for creating thermal comfort room

2. MATERIALS AND METHODS

This experimental research was conducted at April 2012 in class room of Agricultural Faculty, University of Merdeka Surabaya (UMS). Room dimension is 7.00 m of length, 5.00 m of width, and 3.50 m of depth (Figure 1). The volume of room is 122.50 m^3 and wide number of floor was 35 m^2. Room is bordered by three walls that limited the interior and one wall that limited the exterior with opening of window or ventilation. Floor of teraso stone and ceiling without ceiling cover (concrete slab with 15 cm of thickness). Capacity of class is 31 persons (30 students and 1 lecturer). There is window leaf that can be opened or closed and ventilation that is closed by crossed glass with the length of 4.50 m and the width of 1.32 m in border wall of class room which faced to exterior. The window or ventilation is 1 m above the floor surface and 1 m from the ceiling with opening wide number of 5.94 m^2, while there is a door with area of 2.25 m^2 and ventilation with wide number of 1.12 m^2 in the room border wall that faces to coridor. Wall that limits the exterior faces to east side so sun shine can perforate into room, but the other fields can not be affected by sun shine because being limited with interior.Class room condition that was carried out when the investigation was class room with always closed door and opened window.

a. Field which limited with coridor (west side) b. Field which limited with outdoor (east side)

Figure 1: Classroom with opening window and digital thermo-hygro

2.1 Roof garden

Roof garden is a garden which is located above building roof and its existing is as the solution to obtain green opened area which is very seldom in cityfield [5]. Roof garden is able to create micro climate which can decrease buiding temperature of 3 – 4 ºC lower that temperatute in buildung outside and cooling building roof surface from 58 ºC to 31 ºC [6].

In this research, roof garden was cropped by using vegetation or vegetable which had life ability in research location (Surabaya city). Selection of cropping was based criteria-criteria: crop ability in absorbing CO_2, crop temperature and producing interesting aesthetic composition, but for estetic aim it was nacessary to select crop type which high aesthetic and because of being cropped in cityfield, it had to be fitted to cityfield environment mainly in the relation with the growing condition of crop Productive crop which is easy for arrangement in garden such as vegetable crop with the consideration that the harvest time was relatively fast so that can be changed and regulated back due to the willingness, its crop media could relatively be little, and the production was not depended on season. Three of ten vegetable types were selected such as caisim/ *Brassica rapa cv caisim* (absorption rate of CO_2 = 83.00 μmol/CO_2/m^2/s), cabbage lettuce/ *Lactuca sativa* (absorption rate of CO_2 = 79,40 μmol/CO_2/m^2/s), and red spinach/ *Amaranthus sp* (laju serapan CO_2 = 76,60 μmol/CO_2/m^2/s) [7]. The Arranging pattern of crop was carried out with each crop distance of 25 cm, so there was 25 crops per-1 m^2 and using organic cropping media which was located in polybag (Figure 2).

a. Arrangement of crop wide number = ofwide number of under room

b. Arrangement of crop wide number = 2/3 of outside room

Figure 2: Arrangement of vegetable garden on building roof

2.2 Organic cropping

Organic cropping is related to carry out agricultural system which is depended on organic and natural productions, and totally it is not included the usage of synthetic materials [8]. Based on the results of research in Rodale Institute during 10 years and it was carried out since 1990. They presented that the usage of trial composs (composs and organic manure) on corn crop with crop rotation in organic system could absorb CO_2 until 2,000 lbs/ac/year. It meant that more than 7,000 pound/ac/year, CO_2 was absorbed from air and it was saved in soil. In conventional dry field with corn crop which used chemical manure, CO_2 in soil was fast missing or loosing to atmosphere almost 300 pound/ac/year. With organic cropping systems better ensure sustainability and environmentally friendly [9]

2.3. Influence of plants on air quality

Plant is an element that is very reliable in suppressing the temperature increase and maintain the balance of the composition of air through a very large role in absorbing carbon dioxide (CO_2) and produce oxygen (O_2) through the process of photosynthesis. Namely CO_2 capture process and produces O_2 with the help of light energy occurs in With the ability to carry out day activities of evapo-transpiration, vegetation in green space can lower levels of urban air temperature [10]

Carbon dioxide (CO_2) gases tend to float at a height of two meters above the ground with an urgent space that should be occupied by O_2 gas, this condition disebsbkan because CO_2 gas has a density 1.5 times higher than oxygen gas (O_2), lack of adequate O_2 resulting in hypoxia or difficulty breathing, therefore, that the function of the respiratory system was normal, recommended levels of CO_2 do not exceed 0.05% by volume of air or 5000 ppm (parts per million) [11]

2.3 Research approach

This experimental research used 3 treatments, the first by using roof garden with wide number was the same as researched room, the second by using roof garden with wide number was 2/3 of researched room, and the third by using 1/3 of researched room, of the three treatments which are able to lower the optimum temperature will be used to examine the level of indoor thermal comfort. Thermal comfortability level of indoor was measured by using digital Thermo-Hygrometer. This tool has ability to measure relative air humidity and dry ball temperature, but digital Anemometer is able to measure air velocity. Then, the obtained data were analyzed by using Psycrometri for knowing wet ball air temperature. For the next, Effective temperature (TE) or neutral temperature was analyzed by using Effective Temperature Diagram.

All of measuring were carried out at elevation of 1.0 m above floor such as representing inhabitant elevation when there were most activities in class room such as sitting. Measuring tool was located in center point of class room, then data was recorded avery hour beginning from 07.00 am to 16.00 pm (activity hour in class room). Class inhabitants were assumed that generally included male by using long trousers, short leg shirt, and shoe, but female by using dress, light catoon shirt, and shoe with coefficient of Clo (hot proof) was 0.55. In this study, metabolism level was regulated based on the activity level such as index of 1.2 which was as fixed activities like office, residence, school, laboratory [12].

2.4 Subjective measuring

Survey for obtaining subjective data of thermal comfortability was recorded by using questionaire which was developed into 4 main parts as follow: demography information, existing thermal comfortability, thermal sensation and preference, and clothes at this time.

Sample size was 21 and it included 20 under graduate students and a lecturer, but only 20 under graduate students has taken part in this survey. The students were given one hour time to answer the questioanire and then returned it back. Sex distribution included 40 % of male and 60 % of female, and response level was total of 100 %. Before survey, subjects were allowed to sit in their chairs during about 30 minutes with most of activities were remained [13]. There was needed enough time for initial condition of body in every survey. It meant for maintaining the respondent metabolism (M) on the same level along the study.

3. RESULTS AND DISCUSSION

3.1. Temperatures in terms of arrangement the treatment garden area

Results of research related to air parameters are presented in figure 3 and table 2 below:

Table 1: Results of air parameter measurements on average.

Location	Thermal comfort Parameter					
	Before there was the garden			After the garden		
	Temp.	RH	Air velocity	Temp.	RH	Air velocity
	ºC	%	m/det	ºC	%	m/det
Indoor	30,8	73	0,1	-	-	-
1	-	-	-	28	83	0,08
2	-	-	-	28,3	80	0,08
3	-	-	-	28,9	80	0,08

Note :
1 Garden area = 1/3 of room area
2. Garden area = 2/3 of room area
3. Garden area = room area

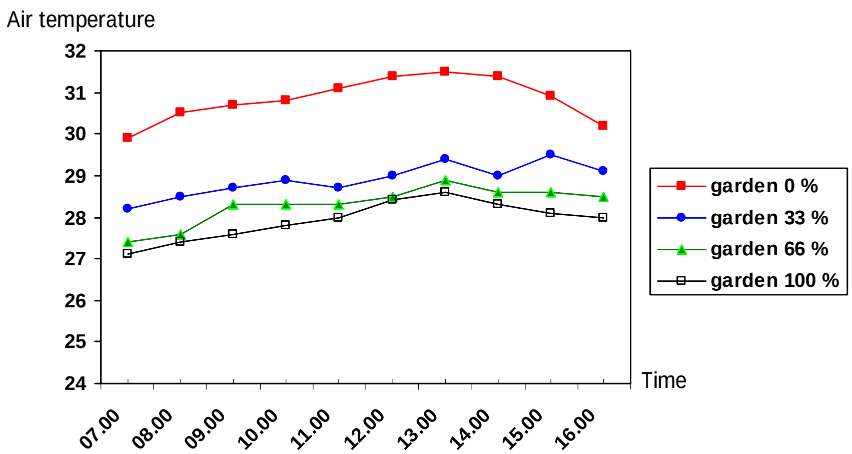


Figure 3: Measuring result of indoor air temperature on several conditions of roof garden area

Figure 3 showed that before the treatment and after the vegetable garden vegetable garden given the treatment, since the air temperature increased 07.00 am until reaching a maximum at 13.00 pm, then gradually decreased until the afternoon.

Indoor air temperature was relatively significant decreasing after being given the treatment of vegetable garden on building roof. The more wider area of cropped vegetable garden on building roof would cause the more decreasing of air temperature. Result of research presented that before the garden treatment, the average of air temperature was 30.8 ºC, by 1/3 of garden treatment room area below caused the average of indoor temperature of 28.9 ºC , and by 2/3 of garden treatment room area below caused the average of indoor temperature of 28.0 ºC (Table 2).

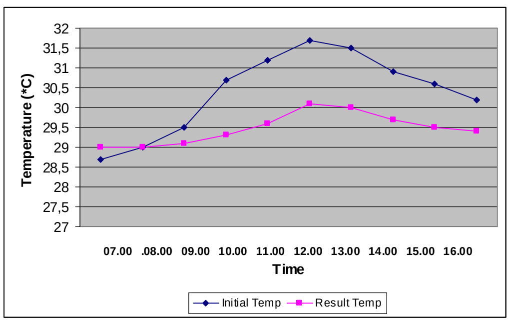
On indoor air temperature decreases each treatment arrangement the vast vegetable garden, vegetable garden more extensive treatment the greater the reduction of indoor air temperature. Average indoor air temperature decreased 1.9 º C, 2.5 º C and 2.8 º C for each area of the garden one third, two thirds and the same with the room area (Table 2)

This condition indicates that the maximum roof area of the garden will be able to reduce the air temperature in the chamber below the optimal

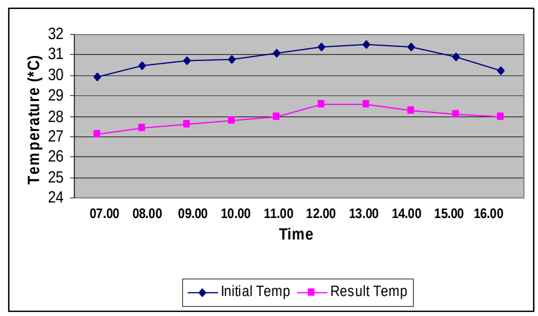
3.2. Review of thermal comfort based on ASHRAE 55 using Psycrometri Diagram and Effective Temperature Chart

Graph in Figure 4, shows that the decrease in air temperature occurred after 08.00 am, whereas before 08.00 am temperatures higher than before the garden. This occurs because of the presence of a garden on the roof of the building, the air humidity in the classroom in the morning is still relatively high, around 80%, while before there is a garden just reached 59% humidity so that the air temperature in the room does not decline, even tend to be higher than before the garden (Table 2). After 08.00 am, where radiation from the sun has begun to enter the room thus reducing the humidity in the chamber, the air temperature in the room started to decline.

The average daily temperature before reaching the park 29.8 º C while the results of the study after the garden daily average temperature to 29.3 º C, so the decrease in the average air temperature in the classroom only at 0.5 º C. (Figure 4). Indoor air temperature decrease is due to the decrease in solar radiation which is quite large at around 160 W/m2 (Table 2). Decrease in solar radiation in room occurs because the sun is shining on the surface of the roof was blocked / closed if the garden so there is no heat radiation received by a roof and no heat radiation is transmitted into space. Sun is shining on the garden partly reflected and partly absorbed by plants and not passed on into space. While the absorption of sunlight by the plant is used for photosynthesis by plants.



Figur 4: Graphs the average air temperature indoor (class) in the dry season



Figur 5: Graphs the average air temperature indoor (class) in the Rainy season

Tabel 2: Measurement results humidity, air velocity and intensity of sunshine on average in the study of indoor (classrooms)

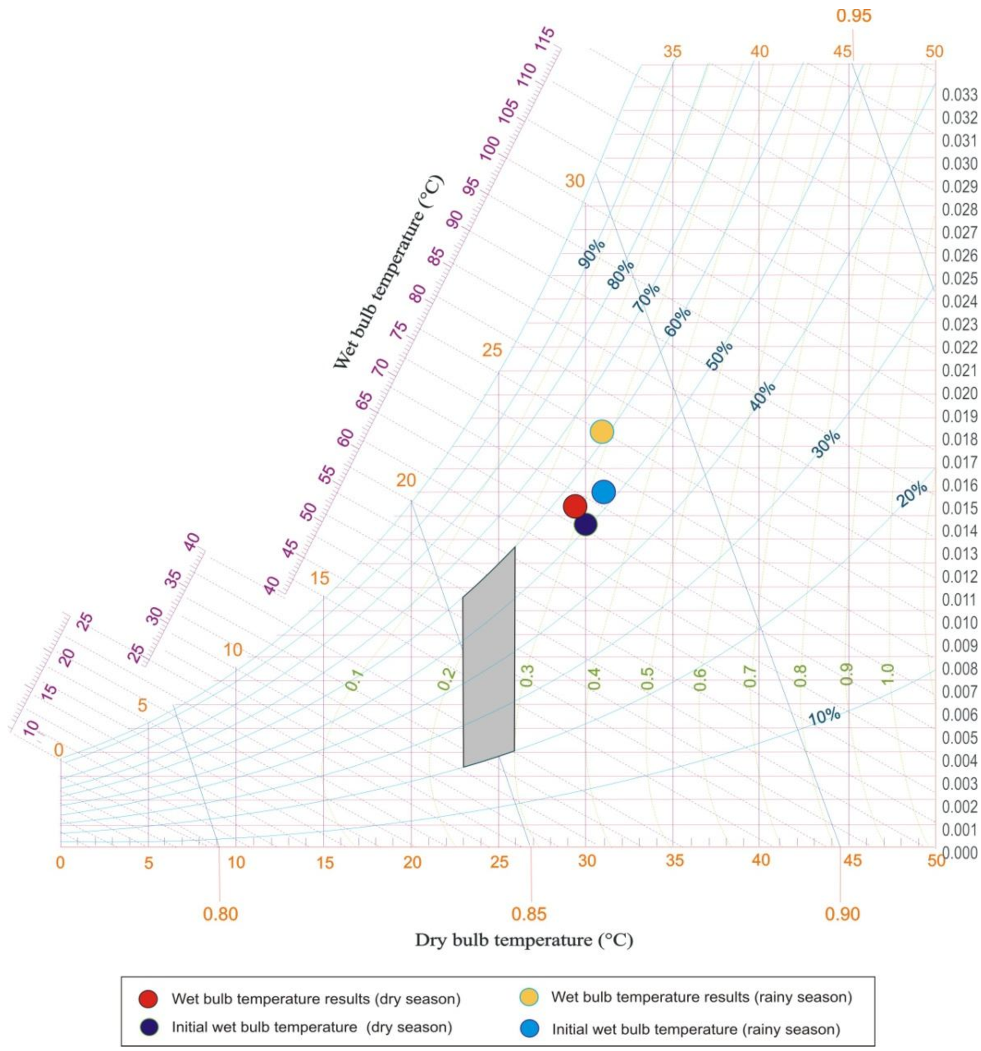
Research	**Season**	**RH** %	**Radiation** W/m2	**Air Velo.** m/sec	**CO2 ambient** ppm	**O2 ambient** %
Initial	Dry	53	201	0,00	25,31	20,73
(Exixting)	Rainy	65	125	0,00	26,00	20,70
Result	Dry	56	41	0,00	27,50	20,36
(with garden)	Rainy	69	27	0,00	27,75	20,30

Figure 5, shows that the decline in the rainy season the air temperature (dry bulb temperature) in a fairly large room, where fluctuations in air temperature drop that occurs between the before and after there is a garden park looks almost the same average. The average daily temperature in the classroom before the garden reached 30.4 º C, while the results of the study after the garden daily temperatures average in the class reached

27.7 º C. so that the average daily temperature decreased by 2.7 º C. Daily air temperature decrease on average this occurs because of the reduced heat radiation into the space radiation especially from the roof of the building due manas absorbed by plants, reaching 92 W/m2 (Table 2)

In this case, although the temperature was decreased to 2.7 º C, but the air quality (CO_2 and O_2) in the room (classroom) does not increase. The results showed ambient CO_2 levels rose after the garden around 1.75 to 2.19 ppm, while the ambient O_2 decreased by about 0.37 to 0.4%. This condition occurs due to a barrier between the concrete roof with an indoor garden so that the outcome of the process of photosynthesis plants in the garden not to affect the air in the room, but not until the solar radiation transmitted into space because it is absorbed by plants to process fosintesis. (Table 2)

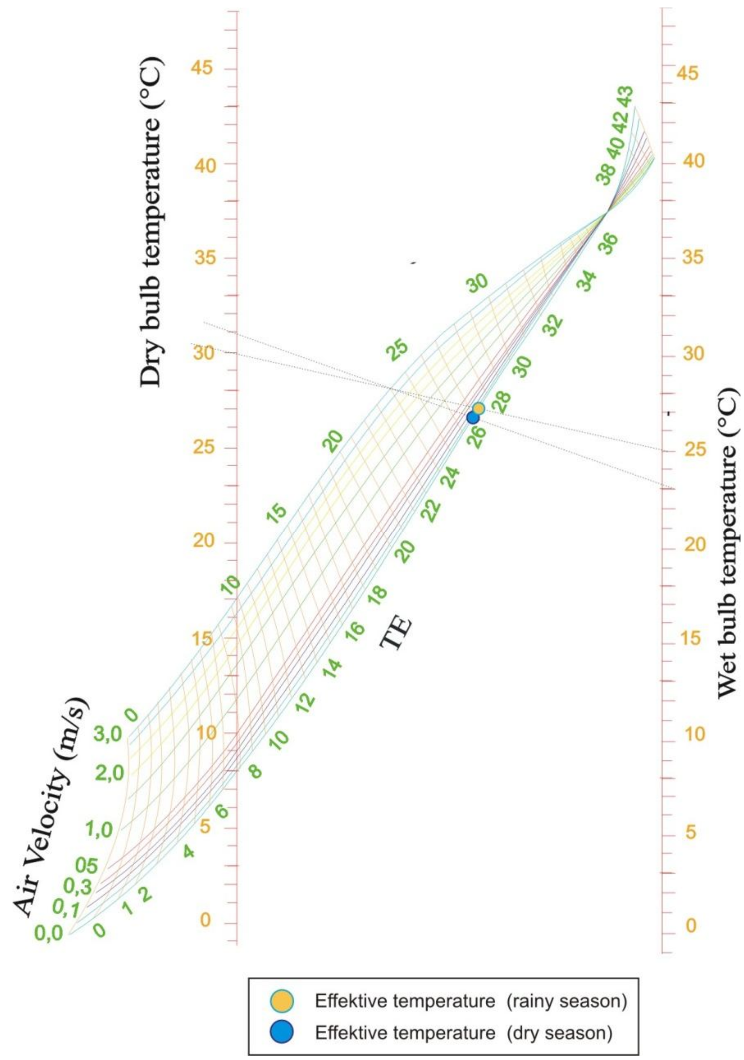
To determine the Effective Temperature (TE) analysis using diagrams Effective Temperature [14] which takes the variable wet bulb temperature, dry bulb temperature and wind speed. The dry bulb temperature measurement data (field measurements) are used to determine the wet-bulb temperature analysis using charts / diagrams psicrometry [15]



Figur 6: Analysis of the results of the study of indoor (classrooms) using Diagram psicrometry

Figure 6 shows that in the dry season and the rainy season the air temperature in all circumstances, both before and after the garden there is a garden air temperature is not included in the ASHRAE thermal comfort zone. The results after the park wet air temperature during the dry season showed lower (22.5 º C) than the air temperature wet in the rainy season (25 º C) this is because the humidity is lower in the dry season (56%) than in the rainy season (69%)

Humidity greatly affects the temperature of moist air (air temperature wet-bulb) the lower the humidity, the air temperature wet vanishingly small, as seen in the study before there is a park with a humidity of 53% in the dry season, the temperature of wet air at 22 º C, while the with 56% humidity during the rainy season, the wet air temperature of 23.3 º C (Figure 6)



Figur 7: Analysis of Thermal Comfort/Neutral Temperature of indoor (classrooms)using Diagram psicrometry

Based on (Figure 7) Effective Temperature Chart to determine neutral temperature or indoor thermal comfort, the necessary variables, wet bulb temperature analysis using diagrams Psikorometri and dry-bulb temperature and wind speed measurements in the field (Table 2). In the dry season, the wet-bulb temperature reached 22.5 º C, and the dry air temperature 29.3 º C and wind speed of 0 m / s. While in the rainy season, wet-bulb temperature reaches 25 º C, and the dry air temperature of 27.7 º C, and wind speeds 0 m / sec. From the analysis using temperature charts effectively, then we obtain a neutral temperature or thermal comfort in the classrooms of the Faculty of Agriculture, University Merdeka Surabaya during the dry season reached 25.6 º C TE and the rainy season reached 26.3 º C TE

Based on ASHRAE Standard 55-1992 states that comfort zone in the summer of thermal comfort temperature between 20,5 º C – 24,5 º C with a relative humidity between 20% - 60% (Figure 5). The results showed that the classes are not in a comfort zone during hours of learning takes place

3.3. Review by due to Neutral Temperature

Some previous studies in humid hot climate location (surround of South East Asia) at class school building and neutral temperature house produced higher temperature than recommendation of ASHRASE standard 55 such as 24.5 ºC. For the building condition with natural ventilation, the whole studies indicated higher comfortability temperature (2.2 – 3.7 ºC) than recommended.

Among them, study school building / classroom in Singapore Effective temperature reached 28.9 º C [16], an office in Malaysia reached 27.5 º C [17]. While on house building in Indonesia Jogjakarta reached 29.2 º C [13], Banjarmasin reached 27.8 º C [18]

Equation for acceptable probability 90%, the recommended thermal comfort is Tn (neutral temperature) ±

2.5 TE (Effective Temperature), while 80% may be received, the recommended thermal comfort is Mr. ± 3.5 TE. [12]. Acceptable to the possibility of 80% and 90% in each condition class (study site) in accordance with that given in Table 3.

Tabel 3: Thermal Comfort Parameter Measurrement Result

Location	Thermal Comfort Parameter							Neutral Temp /Effective Temp (TE)				
Indoor	Initial Data			Stdy result				TE	90 % Acceptable		80 % Acceptable	
	Temp	RH	Wind	DBT	WBT	RH	Wind	ºC	TE-2,5	TE+2,5	TE-3,5	TE+3,5
	ºC	%	m/sec	ºC	ºC	%	m/sec		ºC	ºC	ºC	ºC
Classroom												
Dry season	29,8	53	0	29,3	22,5	56	0	25,6	23,1	28,1	22,1	29,1
Wet season	30,4	63	0	27,7	25	69	0	26,3	23,8	28,8	22,8	29,8

Note: DBT = Dry Bulb Temperature
WBT = Wet Bulb Temperature
RH = Relative Humadity

3.4 Review due to the subjectivity

Evaluation of thermal comfortability was based on the perception response of inhabitant on survey through questionaire that was given in the same time with physical measuring in every condition. There were 20 respondents have participated in questionaire responses. The respondents included 8 males and 12 females which were as unser graduate students of Agricultural Faculty, University of Merdeka Surabaya with the age between 19 – 25 years old. This data was presented as in Table 4.

Table 4: Data of respondent

Sex	Age			Total
	18–20 years old	21 – 23 years old	24 – 25 years old	
Male	3	3	2	8
Female	8	3	1	12
Total	11	6	3	20

3.5 Clothes type of respondent

Clothes which was used on teaching-learning activity inclass room were as follow: 100 % of males used long trouser and short leg shirt, while 50 % of females used long leg shirt, 30 % of females used dress, and the others used dress and short leg shirt. By assumption that there was light activity (sitting and discussion), so suitable insulation of clothes for humid tropic region was 0.55. [12]

3.6 Predicted mean vote (PMV) analysis due to ASHRAE standard 55

In this study, indices PMV (Predicted Mean Vote) by Finger used in the calculation and analysis. Explanation PMV index is numerically described as: cooler (-3), cold (-2), somewhat cold (-1), neutral (0), slightly warm (1) warm (2), hot (3). Microclimate index calculation in the field shows the range of average sound prediction (PMV) between (-1) and (+1), while based on ISO 773-94 as a comfort range of comfortable conditions when PMV has a value between -1 and +1. The results sound 100% of respondents said conditions monsoon air temperature in the range of -1 and +1, while in the dry season, 70% said that the range of -1 and +1 (slightly warm) (Figure 8)

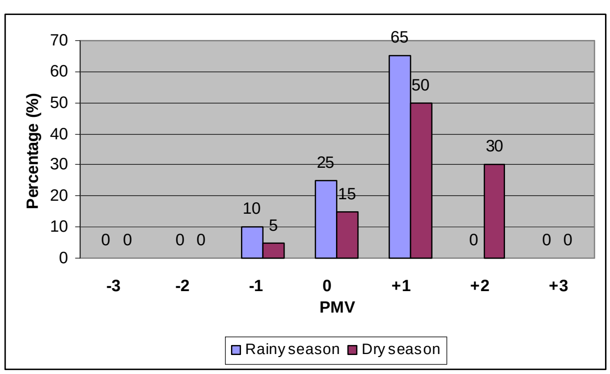


Figure 8 Analysis PMV based on ASHRAE scale

Results of physical parameters in some conditions mainly on garden arrangement above roof with the same area number as under room indicated that most of respondents expressed that air temperature could still be accepted. It was caused by the decreasing of air temperature and air moving indoor (when there was activity in class, window was conditioned as opening) although it was relative small. In this condition, respondents could still feel the comfortability indoor, so the subjective evaluation indicated that thermal comfortability was still in the tolerant limitation of respondent, although this condition was still under the thermal comfortability zone limited condition of ASHRAE standard 55

Results of this study also indicated that standard of international thermal comfortability was as the ASHRAE 55, for being able to be applied in Indonesia especially in Surabaya city was difficult to be reached with only due to the natural climating system. Thermal comfortability temperature based on the research result with maximal condition indicated that TE (effective temperature) was 26.3 ºC , while standard of ASHRAE 55 was conditioned as maximum of 24,5 ºC.

CONCLUSION

Based on the thermal comfortability study, class (indoor) indicated that most of PMV condition when teaching-learning activity by giving the treatment of garden regulation on building roof was in the range of +1 (less hot) with neutral temperature between 25.6 ºC until 26.3 ºC It indicated that thermal comfortability of class in the whole conditions did not fulfill the comfortability zone of ASHRAE standar 55.

Indoor air quality have not improved because there is no direct relationship between the indoor garden on the roof so that the plant photosynthesis does not give effect to changes in indoor air quality

The neutral temperature which was reached by inhabitant could still give tolerance for accepting climate condition in class room (indoor) although it was in outside of comfortability standard of ASHRAE. This study indicated that by being accepted the temperature in outside of comfortability standard, it showed that ASHRAE 55 standard was not absolute for class room with the garden treatment above the roof and humid tropic climate in Indonesia especially Surabaya city. Result of this study indicates some free comfortability of climate in Indonesia to be suggested by international standard which will show that Indonesia can aclimatisation to the higher environmental temperature.

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