

Occupants' Thermal Comfort in Reading Room of CSA Building, Faculty of Engineering Hasanuddin University

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Abstract— Some literature finds that there is a positive correlation between thermal environment and worker productivity in office buildings. Similar to the office building, thermal comfort is also an important requirement in educational buildings so that it is possible for students to study productively. Therefore, in the building of a library, class, or reading room, thermal comfort is highly preferred. As in the Reading Room of Center of Scientific Activities (CSA) building, Faculty of Engineering Hasanuddin University (Unhas) where the use of transparent glass in the reading room of the Faculty of Engineering Unhas CSA building makes users feel hot. The scope taken was two rooms, namely the glass-walled reading room and the brick-walled reading room. This first room has a glass wall which is quite optimal. Whereas the bricks-walled reading room that is close to the glass reading room also has the same function. The measurement results of the highest temperature objective data for five days carried out measurement is 27.5 °C for the reading room with brick walls and the highest is 28.2 °C for the reading room with glass walls which can be concluded that it does not meet the standard of comfort temperature according to SNI. The air velocity is around 0.22-0.24 m/s for the brick wall reading room and 0.10-0.15 m/s for the glass-walled reading room so that it is also concluded that it does not meet the standard of comfort temperature according to SNI. Furthermore, for the humidity of the surrounding air is 50.9-55.2% for the reading room with brick walls and 47.8-52% for the glass-walled reading room where the humidity is included in the comfortable category according to the SNI air humidity comfort standard. The respondents of the reading room with the brick-walled room wanted no change in the temperature of the reading room with brick walls while in the glass-walled reading room, respondents wanted a little cooler. The reading room with brick-walled room wants no slight windy changes for reading room airspace with brick walls while for glass-walled reading rooms it is found that more respondents want to increase the speed of the wind, and about the sensation of air humidity felt for reading rooms with brick walls most respondents gave answers that were a little dry-it was suitable as well as reading rooms with glass walls but more of them gave slightly dry answers. From the simulation results, it is explained that the higher the reflectivity in the glass material and the lower the U-value, the more difficult it is to enter the temperature from outside the building into the building. Providing sun shadings on building facades is also one of the solutions to filter the heat that enters the building.

Keywords— Comfort, Thermal, Glass, Bricks

I. INTRODUCTION

Three of the goals that need to be fulfilled by an architectural work are the fulfillment of aesthetic demands, the fulfillment of the demands of comfort (psychological and physical) and fulfillment of energy-saving demands. [1] Good architecture is the architecture that is designed in such a way as to be able to modify the uncomfortable outside climate to be comfortable by using the help of electrical or mechanical equipment to a minimum [2]. In today's era, various functions are developed with diverse technologies and are not often combined with many other aspects to achieve the aesthetics and comfort that the user wants. The dominant use of glass in building materials is familiar to us in modern buildings because it is not only aesthetics but also because its function which is to minimize artificial lighting so that it saves energy that is used. Glass material that is closely related to the use of technology brings the basic view of society as building material that is valued futuristic, modern but minimalist [3]. The simplicity simply makes consumers judge that this material will be easily applied in order to maximize natural lighting and view to the influence of the psychological aspects of the user. In a similar position, the demand for networks related to the user's main activities is also very closely related to the intensity of the use of the dominant glass material, that the impact can greatly affect the pattern of activities in the building [4]. Some literature finds that there is a positive correlation between thermal environment and worker productivity in office buildings [5]. Similar to office buildings, thermal comfort is also an important requirement in educational buildings to enable students to study productively [6]. Therefore, the building of the library, class, or reading room is also very concerned with thermal comfort.

Lighting is one of the most important aspects of a building. The building envelope is the main and first way for natural light to enter. In this section access to light must be designed and calculated correctly. Its existence certainly influences the appearance of the building and must be a consideration in a design. Natural light coming from outside the building must be included in the right way so that the comfort of space can be created. As in the case study of one of the reading rooms at the Central Library of the Faculty of Engineering, Unhas Gowa, which applies natural lighting throughout the day by incorporating natural light through transparent glass material on the walls of the building also incorporates heat in the building which affects the thermal comfort of the user.

Giving curtains on the glass side of the reading room to reduce the entry of heat also reduces the entry of natural light so that the incoming natural light is not optimal. In addition to using curtains in this room also uses AC that uses electrical energy to reduce the effects of extreme heat when working.

The results of my brief interview with the majority of users found that most of them were more comfortable in the reading room with brick walls than in the reading room with glass walls even though in the both of these rooms are provided with AC. According to [7] temperatures that are too hot and too cold will have an effect that is equally not good for the health and productivity of space users. This is one of the answers to reading room users when I interviewed them about the reason for choosing a reading room with stone walls than a glass-walled reading room.

Since it is found that the use of transparent glass in the reading room of the Faculty of Engineering Universitas Hasanuddin (Unhas) Gowa's library building makes users feel hot, the formulation of the problem that can be raised is how the level of thermal comfort in glass-walled reading rooms and bricks-walled reading rooms of the library at Faculty of Engineering and how the adaptive behavior of users at glass-walled reading room and brick-walled at the library of the Faculty of Engineering Unhas.

II. RESEARCH METHOD

A. Research Design

The research methods used in this study were literature studies, observations, respondent questionnaires, and measurements with Hobo thermal measuring instruments. Literature studies are used to find out information on the comfort of reading room users according to standards while observations are used to find out the effectiveness of the activities of building users. Personal data was collected by collecting clothes and activities of each respondent.

B. Location and Time of Research

This research was carried out at the Faculty of Engineering, Gowa Hasanuddin University, Jalan Poros Malino, Gowa Regency.

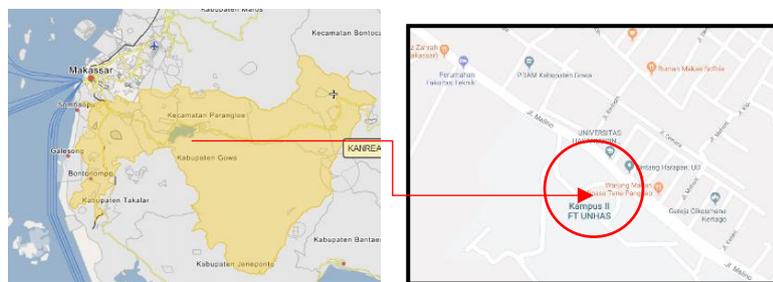


Figure 1. The Location of Research

The scope taken was 2 rooms, namely the glass-walled reading room and the brick-walled reading room. This first room has a glass wall which is quite optimal. Whereas the bricks-walled reading room that is close to the glass reading room also has the same function.

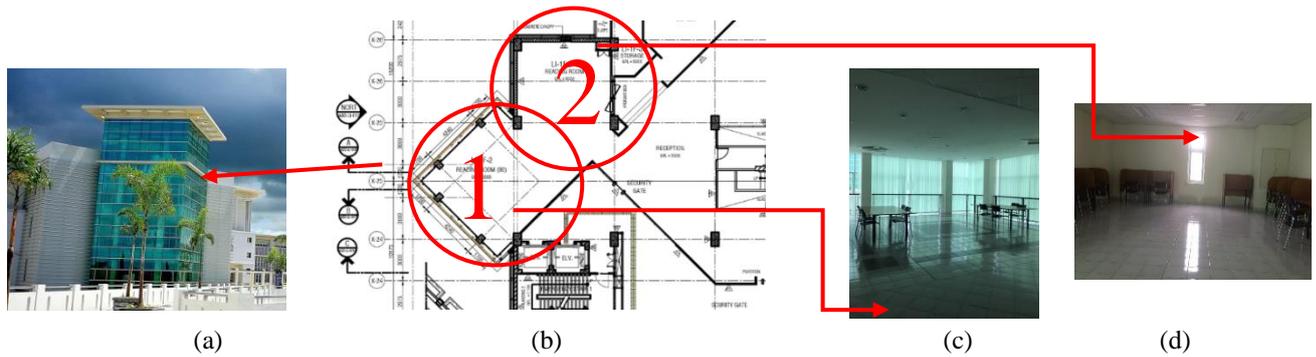


Figure 2. (a) Outer Space of Research Location, (b) Layout of Physical Data Space, (c) Room Photograph in a Glass-Walled Reading Room, (d) Room Photograph in a Bricks-Walled Reading Room

C. Population and Sampling Techniques

The population in this study was the Reading Room of the Faculty of Engineering Library at Hasanuddin University. Samples in the study were air temperature, air humidity, and wind speed in the reading room of the Faculty of Engineering at Hasanuddin University.

The sampling technique used was purposive sampling technique in the process of taking sample data such as air temperature, humidity, and wind speed.

D. Variables of Research

In this study, the dependent variable as the object of this research focus is the thermal comfort of the glass reading room of the Engineering Faculty library at Hasanuddin University, while the independent variables of this study are air temperature, air humidity, air velocity, clothing, and user activity.

E. Method of Data Collection

Measurements were made using six tools, namely four Hobo-1 and two Hobo-2. The first tool, HOBO temperature / RH logger (HOBO-1) is used to measure air temperature and relative humidity, while the second tool, HOBO temp / RH / Light / External (HOBO-2) is used to measure air temperature, relative humidity, and speed air flow. Both of these tools are used simultaneously so that the data from the three climate elements were obtained from the same conditions at each measurement point.

Objective data involves physical measurements of the library's reading room and taking readings of indoor air temperature, relative humidity, and air movement. In collecting this data, researchers measured the temperature of the room if they did not use air conditioning and used air conditioners which coincided with the collection of questionnaires in the range of five consecutive days, namely Monday to Friday that was done at three times which is in the morning, afternoon and evening.

Subjective data is a questionnaire that looks for student perceptions on various items assessed and adopting the seven-point ASHRAE standard 55-2013 scale which is widely used where questionnaire items take the opinion of thermal sensation (TSV) and thermal comfort opinions (TCV) and analyze thermal sensations, thermal preferences, activities, and clothing isolation of reading room users. In addition, questions related to airspeed and humidity was also included in the questionnaire. In the subjective data retrieval process, respondents are allowed to take actions that make them feel comfortable at that time and fill it in one of the questionnaire items. Sensors for measuring environmental data are installed at 100 cm above the floor surface.[6]

F. Data Analysis Techniques

Data processing was done by MS Excel spreadsheet software and statistical package for social science (SPSS). Spreadsheets have been used to calculate the average value of thermal environment variables and to produce tables that show microclimate conditions [6]. For statistical analysis, SPSS version 16 statistical software was used to calculate the descriptive analysis of the questionnaire frequency and sample T-test. The sample T-test was conducted to compare two samples. Frequency descriptive analysis also was used to discuss the statistical size of the questionnaire containing vote TSVs that were grouped according to the ASHRAE scale, and TCV grouped using the Bedford scale. Then the analysis results were compared with thermal comfort standards.

III. RESULT AND DISCUSSION

A. Thermal Comfort

Based on the results of measuring the highest temperature objective data for five days, we measured the temperature difference of the reading room with glass walls and brick walls where the highest temperature was 27.5 °C for the reading room with brick walls and 28.2 °C for the reading room with glass walls, so it can be concluded that it did not meet standard of comfort temperature according to Indonesian Nasional Standard (SNI), which according to national standard SNI 03-6572-2001, where the building must provide the following thermal environment as follows:

1. Cool Comfortable: 20.5–22.8°C (Te);
2. Comfortable: 22.8–25.8°C (Te); dan
3. Warm Comfortable: 25.8–27.1°C (Te).

Another thermal comfort study conducted by Karyono in Jakarta involved 596 respondents consisting of employees who worked in seven office buildings resulting in a comfortable temperature of the respondents namely 26.4°C Ta or 26.7°C To [8]

The measurement results can be seen in the first table and first graph below.

TABLE I
AVERAGE OF TEMPERATURE ON GLASS-WALLED READING ROOM AND BRICKS-WALLED READING ROOM

Time	Brick	Glass
09.00-10.00	27.4	27.9
10.00-11.00	27.4	28.2
11.00-12.00	27.4	27.9
12.00-13.00	27.5	28
13.00-14.00	27.6	28.1
14.00-15.00	27.2	27.8

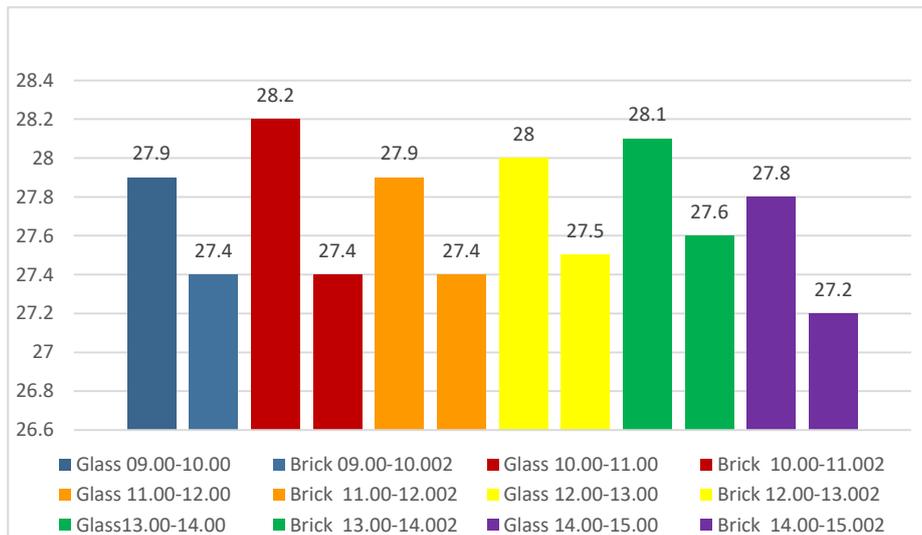


Figure 3. Average of temperature on glass-walled reading room and bricks-walled reading room

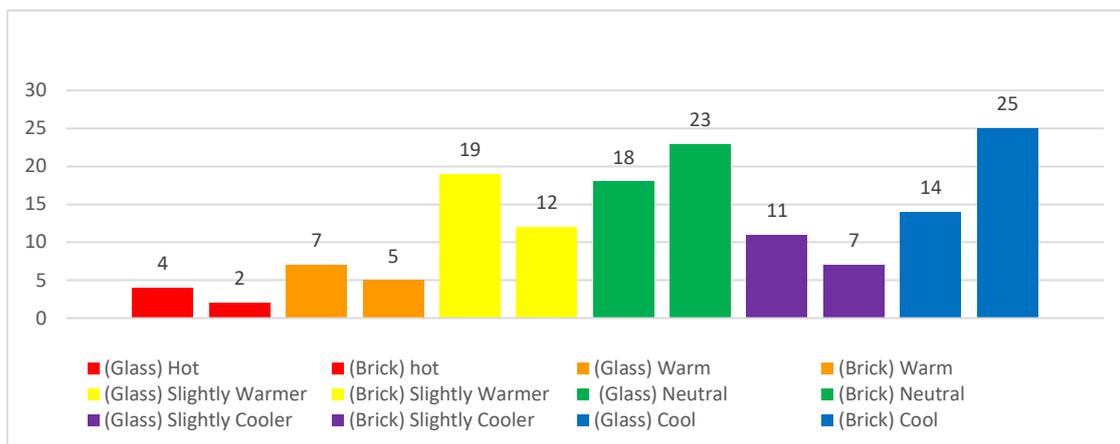


Figure 4. TSV statistics of temperature on reading rooms

Subjective data, based on the fourth Figure, shows that users of glass-walled reading rooms feel a slightly warmer sensation (-1) to the temperature when they are in a glass-walled reading room whereas, for reading room users with brick walls, they feel more neutral at temperature (0).

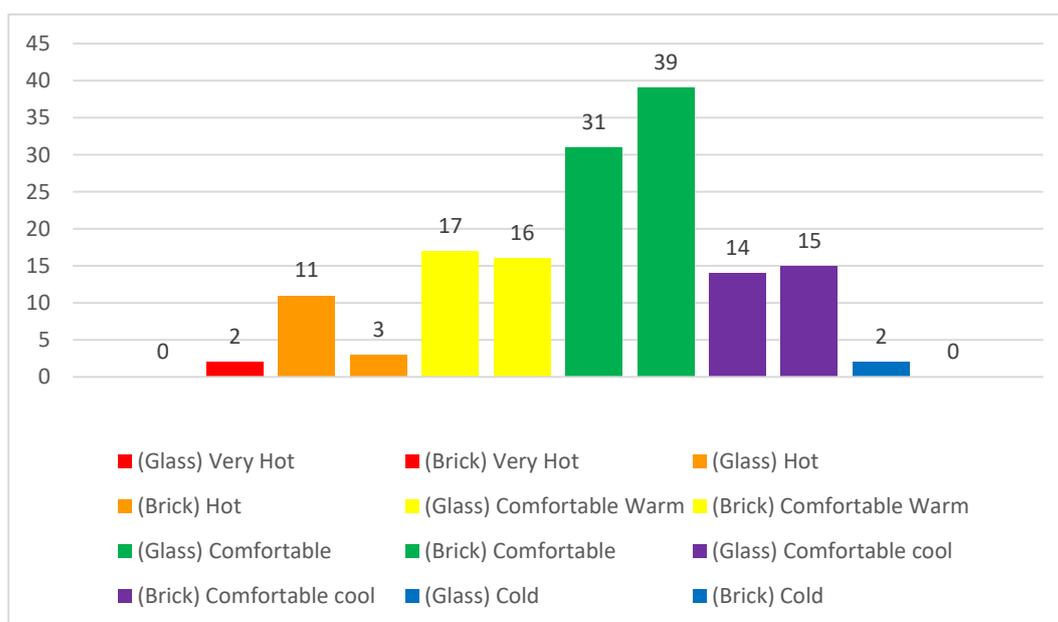


Figure 5. Statistics of TCV temperature in the reading room

Based on fifth Figure, it can be seen that Glass-walled reading room users who feel comfortable warm (-1) 22.7% while reading rooms with Brick walls are only 21.3% while those who feel comfortable reading rooms have 41.3% glass walls and walled reading rooms Bata is more than half of the respondents, which is 52%.

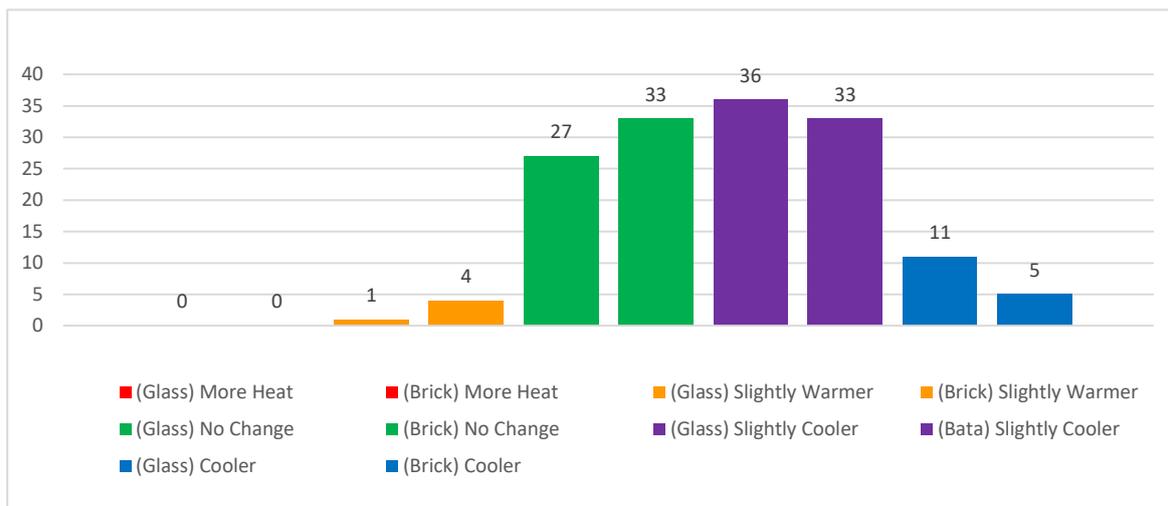


Figure 6. Statistics of TCV temperature in the reading room

Based on sixth figure, it can be seen that Glass-walled reading room users who want a little cooler is (-1) 48% while for the Brick wall reading room is only 33% while those who want there are no changes in the temperature of the glass-walled reading room is 36% and reading room with Brick walls is 44%.

TABLE II
AVERAGE OF AIRSPEED IN BRICKS-WALLED READING ROOM AND GLASS-WALLED READING ROOM

Time	Brick (m/s)	Glass (m/s)
09.00-10.00	0.22	0.15
10.00-11.00	0.24	0.10
11.00-12.00	0.23	0.11
12.00-13.00	0.22	0.10
13.00-14.00	0.24	0.10
14.00-15.00	0.23	0.12

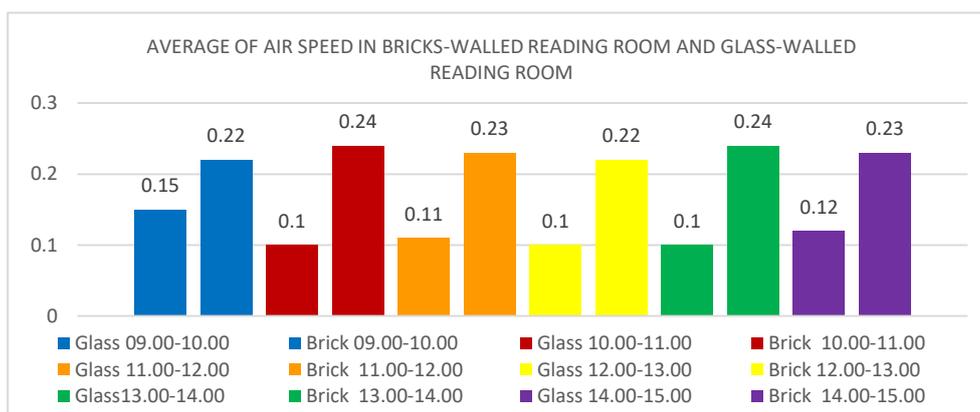


Figure 7. Average of airspeed in the bricks-walled reading room and glass-walled reading room

The results of air velocity measurements using hobo for 5 days at 09.00-15.00 WITA in the glass-walled reading room and reading room with brick walls are comfortable airspeeds according to SNI. According to SNI, the air velocity is most comfortable around 0.25-0.5 m/s. In the reading room with glass walls, the lowest air velocity is 0.10 m/s while the highest is 0.15 m/s. The next is for reading rooms with brick walls which has the lowest temperature which is 0.22 m/s and the highest temperature is 0.24 m/s. It is nearing the most comfortable standard that can be seen in the following second tables and seventh figures.

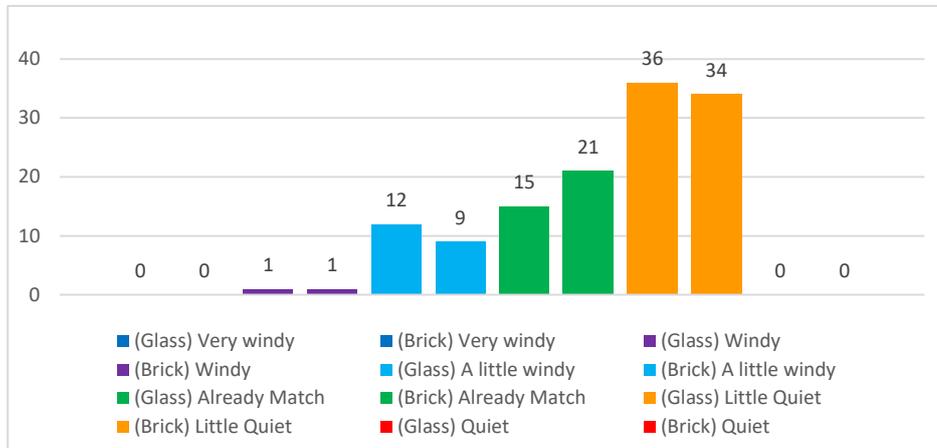


Figure 8. Statistics of speed air TSV on the reading room users

Based on the eighth Figure, it can be seen that the users of glass-walled reading rooms feel a little calmer (-1) to the air velocity when they are in the glass-walled reading room. Whereas for reading room users with brick walls, they feel more appropriate at airspeed which is (0).

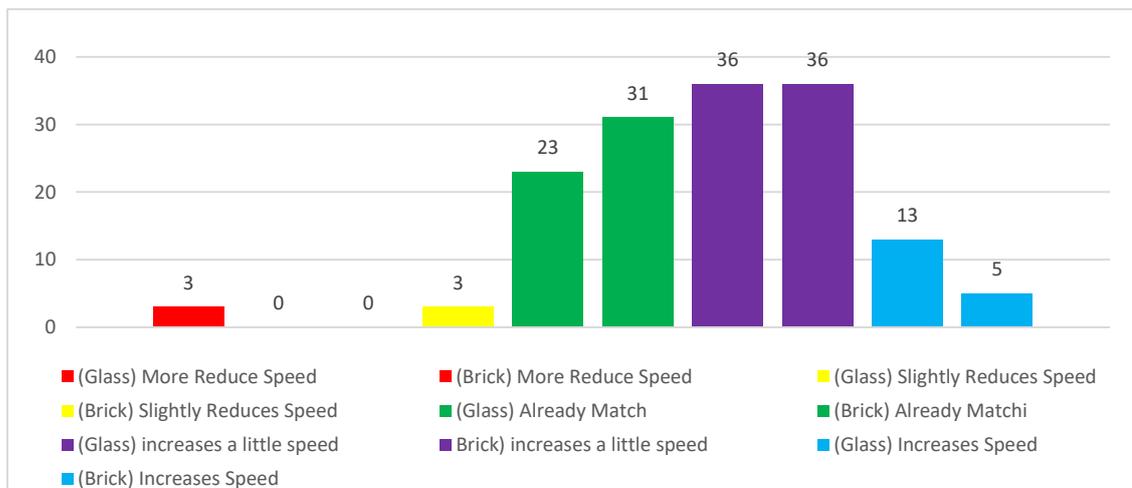


Figure 9. Statistics of reading room users desires on airspeed

Based on the ninth Figure, it can be seen that the Glass-walled reading room users who want no change (0) is 30.7% and those who want a little airspeed speed (-1) is 48% while the users of Brick wall reading room who wants no change (0) is 41.3% and wants little speed airspeed (-1) is 48%.

TABLE III
AVERAGE OF AIR HUMIDITY IN GLASS-WALLED AND BRICKS-WALLED READING ROOMS

Time	Brick (%)	Glass (%)
09.00-10.00	50.9	47.8
10.00-11.00	51.9	48.6
11.00-12.00	52.7	48.8
12.00-13.00	53.3	49.3
13.00-14.00	54	51.2
14.00-15.00	55.2	52

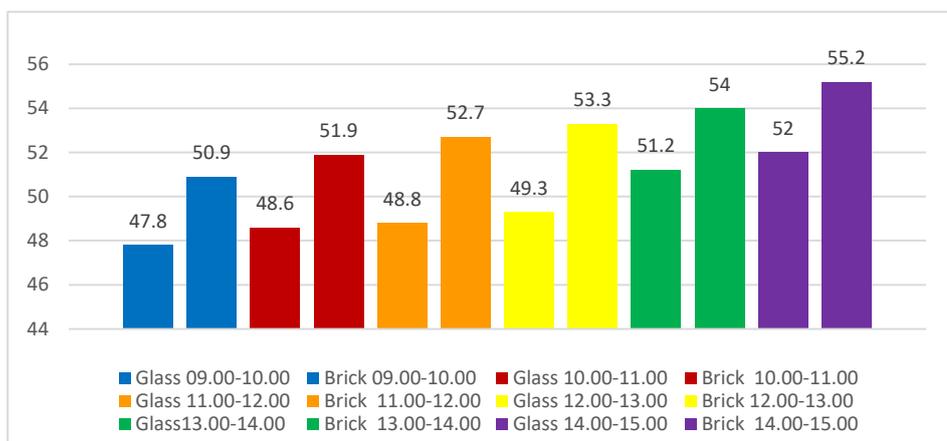


Figure 10. Average of air humidity in glass-walled and bricks-walled reading rooms

The measurement results which was carried out for 5 days in the glass-walled reading room and brick-walled reading room from 09.00-15.00 WITA meet the comfort airspeed standards according to SNI where according to the SNI Standards the thermal comfort in buildings that are conditioned for Indonesians is 40% - 70% and yield the lowest measurement of air humidity for glass-walled reading rooms is 47.8% and the highest is 52%. For reading rooms with brick walls has air humidity of at least 50.9% and air humidity is at the highest 55.2%. This data can be seen in the third tables and the tenth figure below.

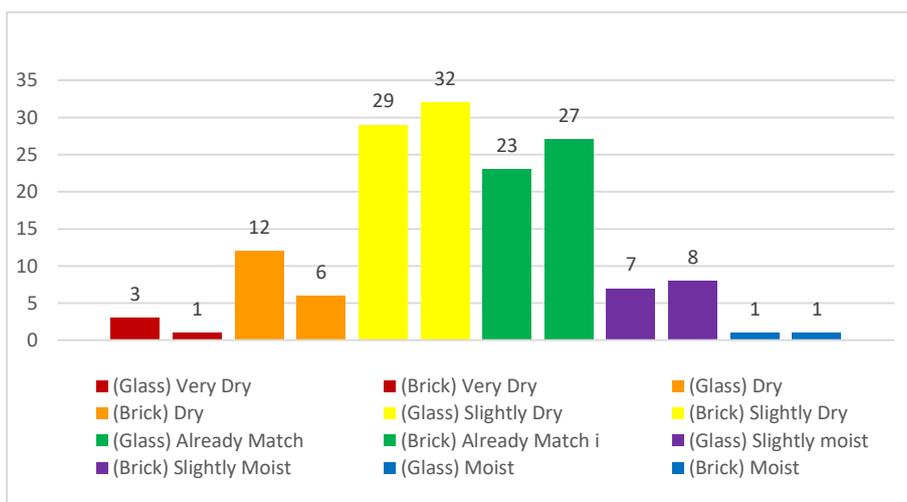


Figure 11. Statistics of TSV humidity on reading room users

Subjective data, based on Figure 11 it can be seen that the percentage of the glass-walled reading room users who feel a little dry (-1) is 38.7% of the air humidity when they are in the glass-walled reading room and feel it is appropriate for air humidity (0) which is 30.7%, while for brick walled reading room users, the percentage of those who feel a little dry (-1) is 42.7% of the air humidity when in the glass-walled reading room and feel it is appropriate for air humidity (0) which is 36%.

B. Adaptive Behaviour

The basic assumption of adaptive approaches is expressed by adaptive principles: if the change occurs as it produces discomfort, people react in ways that tend to restore their comfort [9]. The adaptive hypothesis states that one's satisfaction with the indoor climate is achieved by matching the actual thermal environment conditions that apply at that time in space and time to one's thermal expectations as to what the climate in the room should be [10]. It is true that residents will feel more comfortable when they are allowed to take action, such as wearing/removing clothes, opening/closing windows, turning on/off the fan or heating and taking hot/cold drinks[11].

The results of the analysis of respondents data some respondents answered that they took an action to create their own comfort, the following is explained in the table below.

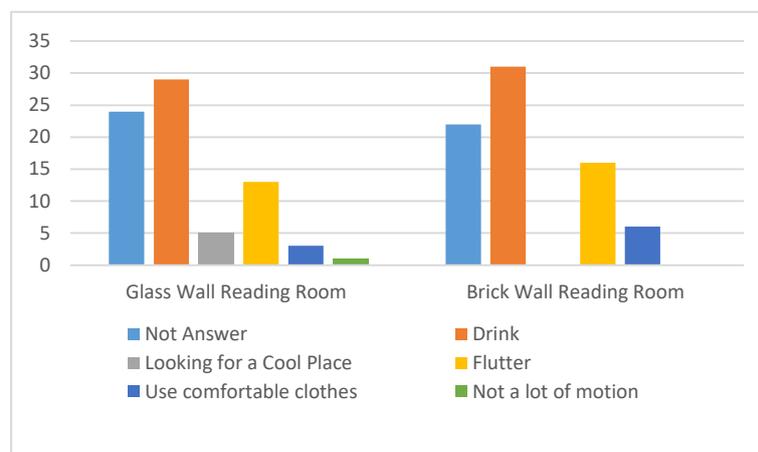


Figure 12. Adaptive behavior of respondents in creating thermal comfort

In Figure 12, it was explained that respondents were more likely to "drink" to create thermal comfort, namely 36.7% of respondents in the glass-walled reading room and 41.3% of respondents in bricks-walled reading room, followed by fans, wearing comfortable clothes, looking for cold places, and also don't do a lot of movement. Seen in the graph above, the glass reading room has more behavioral actions to create comfort than the reading room with brick walls because according to respondents the glass-walled space is more uncomfortable than the reading room with brick walls.

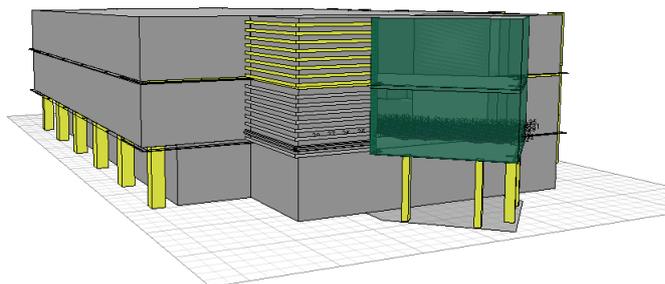
C. The T-Test (Multiple Samples)

The result of T TEST correlation between the two variables is 0.958 which states that the correlation between glass-walled reading rooms and reading rooms with brick walls is very close and is significantly related, and probability is 0.000. Because of the probability <0.05 then H_0 is rejected. Thus reading rooms with glass walls and reading rooms with brick walls are not the same.

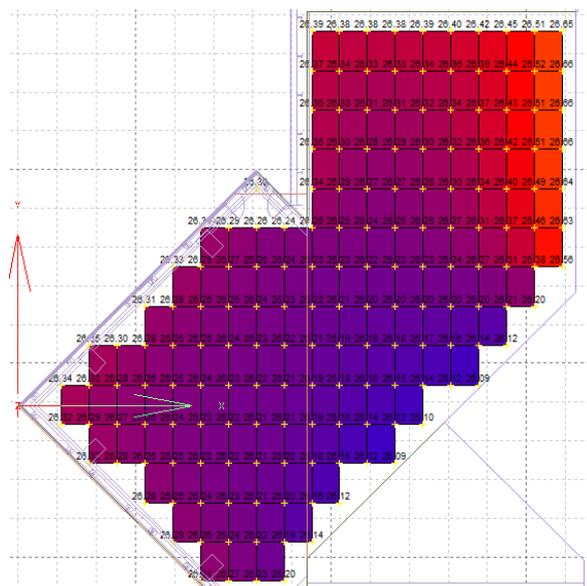
D. Simulation of Thermal Comfort in Reading Room Using Ecotect

The first experiment with the replacement of glass material also affected the temperature of the reading room with brick walls because by replacing the glass material makes the reading room temperature with brick walls also changed lower.

(a)



(b)



(c)

U-Value (W/m ² .K):	4.400
Admittance (W/m ² .K):	4.400
Solar Heat Gain Coeff. (0-1):	0.35
Visible Transmittance (0-1):	0.264
Refractive Index of Glass:	7
Alt Solar Gain (Heavywt):	0.35
Alt Solar Gain (Lightwt):	0.64

Figure 13. (a) Ecotect Design by Replacing Glass Material in Reading Room, (b) Asahimas Glass Specifications "sunergy sigma green", (c) Analysis Grid Spatial Comfort by replacing glass wall material

Figure 13 above which explains about the grid analysis shows the radiant temperature changes in the reading room. It can be seen that the temperature of the glass-walled reading room which (26.1 °C - 26.3 °C) is lower than the reading room with brick walls which is (26.2 °C - 26.7 °C).

The second experimental result was by replacing glass material and providing sun shading on the glass wall of the library reading room of the Faculty of Engineering Hasanuddin University. Providing sun shadings on building facades is also one of the solutions to filter the heat that enters the building because from simulations conducted using Ecotect sun shading on building facades can further reduce the temperature in the room.

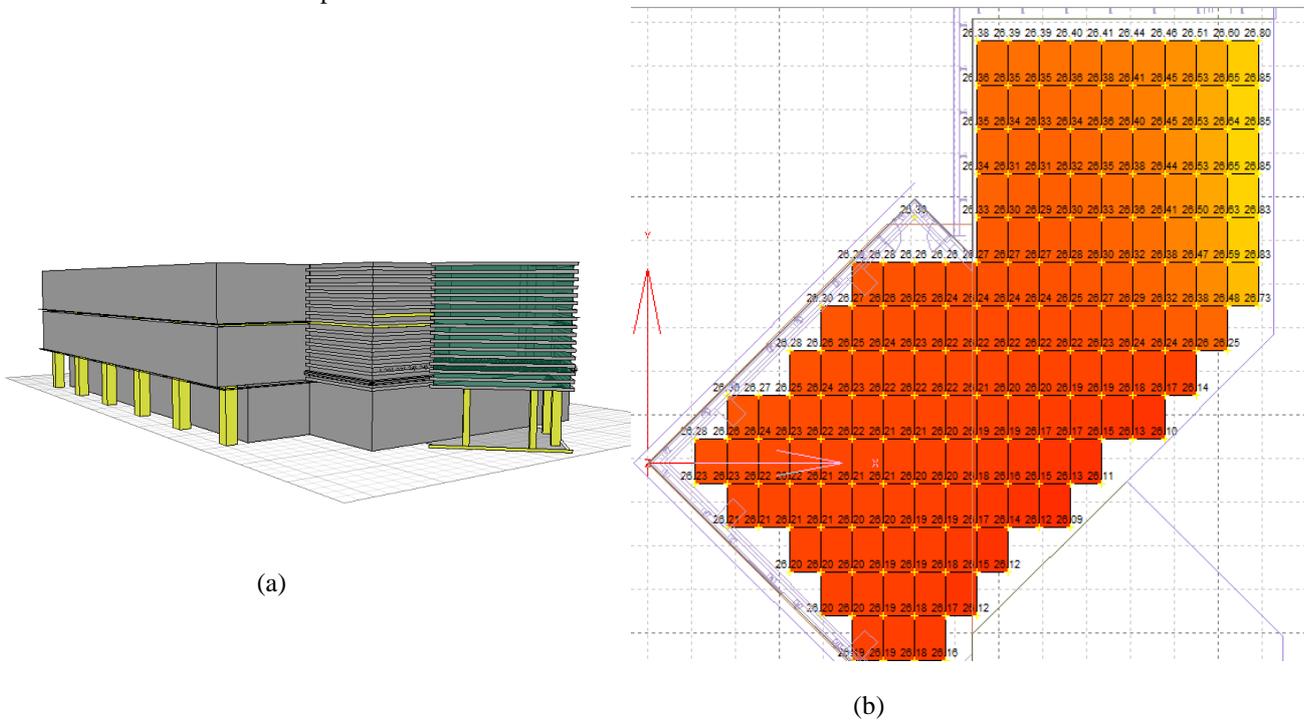


Figure 14. (a) Ecotect Design by Replacing Glass Material Types Reading Room and providing sun shading on the glass wall of the reading room, (b) Analysis Grid Spatial Comfort by replacing glass wall material and providing sun shading on the glass wall of the reading room

The picture above shows changes in the radiant temperature of the reading room. It can be seen that the temperature of the glass-walled reading room is lower than the first experiment (26.1 °C - 26.3 °C) from the reading room with brick walls (26.2 °C - 26.6 °C).

This experiment is more recommended for glass buildings that are located densely around the building so that reflective glass does not interfere with buildings or users around the outside of the building.

IV. CONCLUSION

Based on the results of the measurement of objective data, the highest temperature found for five days of measurement is 27.5 °C for reading rooms with brick walls and 28.2 °C for reading rooms with glass walls. From these data, it can be concluded that the reading room temperature does not meet the comfort temperature standards according to SNI. The air velocity is around 0.22-0.24 m/s for brick-walled reading rooms and 0.10-0.15 m/s for glass-walled reading rooms so that it does not meet the comfort temperature standards according to SNI. Next is about the humidity of the surrounding air, which is 50.9-55.2% for reading rooms with brick walls and 47.8-52% for glass-walled reading rooms where the data is included in the comfortable category according to SNI air humidity standards.

The respondents of a reading room with brick-walled room users wanted no change in the temperature of the reading room with brick walls, while for the glass-walled reading room, respondents wanted a little cooler. The brick-walled reading room respondents wanted no slight windy changes to airspeed in the brick-walled reading room, while for glass-walled reading rooms, more respondents wanted a slight increase in speed. About the sensation of air humidity felt for reading rooms with brick walls, the answers of most respondents that it has been a little dry-it's appropriate so does the reading room with glass walls but more than giving answers to a little dry.

Based on the results of the respondent's answers through a statement in the questionnaire, it was found that there are some statements about adaptive behavior that they do to create thermal comfort. More respondents create comfort by drinking, fans, using comfortable clothes, looking for a cool place, and also not doing much movement.

The result of T TEST correlation between the two variables is 0.958 which states that the correlation between glass-walled reading rooms and reading rooms with brick walls is very close and is significantly related, and probability is 0.000 because of the probability <0.05 then H_0 is rejected. Thus reading rooms with glass walls and reading rooms with brick walls are not the same.

From the simulation results explain the reflective height in the glass material and the lower the U-value, the more difficult it is to enter the temperature from outside the building into the building.

Providing sun shadings on building facades is also one of the solutions to filter the heat that enters the building since the simulations carried out using Ecotect sun shading on building facades can reduce indoor temperatures. However, providing sun shadings can reduce the incoming natural light so this solution is better used for buildings that are densely located so that reflective glass does not disturb users outside the building.

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