ATLANTIS PRESS

Advances in Engineering Research, volume 208

Proceedings of the International Conference on Innovation in Science and Technology (ICIST 2020)

The Effect of Application Vertical Garden in the Wall to the Wall Thermal Transmittance in the Room and Its Energy Consumption

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***Abstract*—One of the efforts applied to green building is the concept of vertical garden, where plantation crops which are usually planted on the ground are now planted on the walls of buildings that apply the green building concept. The existence of a vertical garden in the building is considered quite beneficial both in terms of air quality around the building and in terms of the use of electrical energy in the cooling machine because it can reduce the conduction load (thermal transmittance) on the walls of the room. The problem is the extent to which the vertical garden concept can save electricity costs incurred if solar radiation in buildings can be inhibited. In this study, the vertical garden effect will be tested on the cooling load of the room and the consumption of electrical energy. Two simulation rooms have been created and one of the rooms is equipped with a vertical garden on the wall. Both rooms are equipped with air conditioners to handle a cooling load to the room. Tests carried out by measuring the temperature of the outer wall and the inner wall of both rooms using data acquisition and conducted during the day. From the results of tests that have been carried out the wall temperature in the vertical garden is lower 1.2ºC when compared to the wall without the vertical garden. Whereas for thermal transmittance and AC electrical energy consumption they were reduced by 8.6% and 11.3% respectively.**

***Keywords*—green building, vertical garden, thermal transmittance**

I. INTRODUCTION

Green building or environmentally friendly buildings has become one of the topics that have been raised since a few years ago. This topic is related to the construction of houses, apartments, offices, shop houses, and other buildings that are environmentally friendly. This is also often said to be important for the future, but it is not yet understood by most people.

In general, green building is building planning to make life better and meet the needs of the next generation. Especially those related to nature conservation, health, and also social. This is due to the natural damage that has occurred in various lines of life and trigger various disasters. Air pollution above the normal threshold is vulnerable to causing Climate Change, as a result, the weather can no longer be accurately predicted. The cause of air pollution is caused by the presence of several factors and human activities on earth, such as motor vehicles, the results of burning fuel from factory industrial activities that emerge from the chimney, forest fires, and so forth [1]. Some people also aggressively voiced improvements and environmental balance. One of the programs is the vertical garden concept which targets the construction of buildings, houses, apartments, offices, and so on. The application is a landscaping system that utilizes the potential height and narrow land as much as possible in a perpendicular field that is applied to the walls of high-rise buildings in a relatively long time. Widiastuti et al., [2] Widiastuti et al., [3] According vertical garden applications can reduce residential temperatures by 2°C to 3°C and increase air humidity by 10% to 20% to create clean and beautiful air. Vertical Garden Wall application can be applied in various multi-story buildings such as Hotels, Super Markets, Hospitals, and others in the hope of suppressing temperature, noise due to motor vehicles, air pollution, and others. Stated that the shadow effect resulting from a vertical greening system can reduce the energy used for cooling by about 23% and 20% of the energy used by fans, resulting in an 8% reduction in energy consumption annually [4].

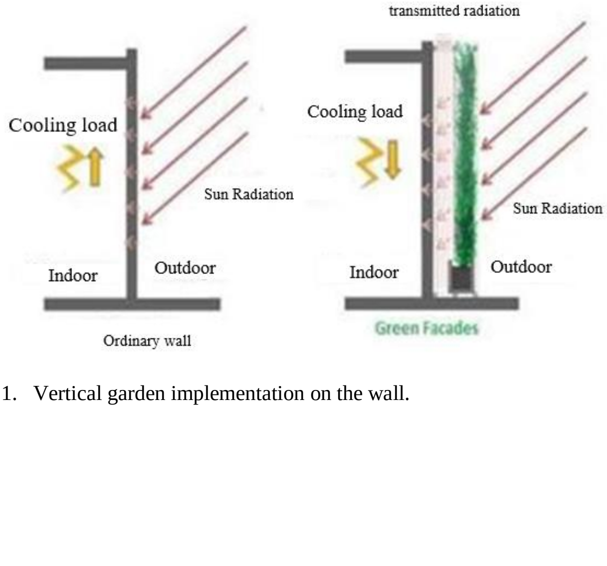

Fig. 1. Vertical garden implementation on the wall.

In the picture above it can be seen that the Vertical Garden implementation method on the wall is by growing plants on fences, carports, and high-rise buildings such as house walls, office building walls in cities, hotel walls, and shopping centers. The concept is trying to make efficiency in saving energy considering the vertical garden concept is believed tobe able to inhibit the heat of solar radiation so that the use of electricity for the cooling system (The Air Conditioning System) is reduced.

The problem is the extent to which the vertical garden concept can save electricity costs incurred if solar radiation in buildings can be inhibited. The most dominant influence from the inhibition of solar radiation is actually from the side of the outside air wall temperature. If the outside air temperature of the wall is reduced, the cooling load will also room will also be reduced. In fact, this vertical garden concept also has various types that may have different effects on the cooling load.

Based on the above problems, this research will examine the effect of the vertical garden on room temperature conditions in this case the cooling load, and the effect on the use of electricity costs.

II. Review of Theory

To make it easier to evaluate the heat conduction of the walls, then in the room there are no other sources of heat so that the cooling load only comes from the conduction load of the walls and roof. Analysis of the calculation of the conduction load of the walls and roof is also carried out using a one-dimensional analysis as shown in the following image [5,6].

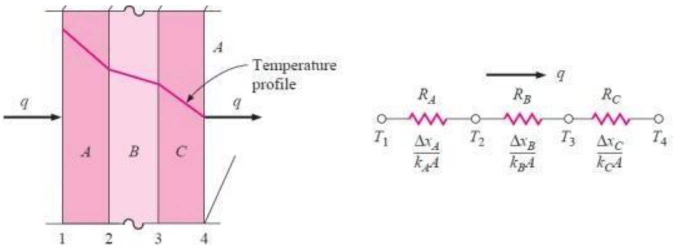

Fig. 2. Schematic of heat transfer on the wall and the analogy of thermal resistance.

$$q = \frac{T_1 - T_4}{\Delta x_A / k_A A + \Delta x_B / k_B A + \Delta x_C / k_C A} \quad (1)$$

The conduction cooling load formula in equation (1) above applies in general and can be added with other material resistance according to the amount of wall material. Considering there are differences in the construction of the walls with and without vertical gardens, the determination of the conduction cooling load value in equation (1) above will also experience a difference. The following is the actual equation used to determine the cooling load according to the material forming their respective walls. Non-vertical garden wall on the non-vertical garden wall, there is only 5mm asbestos material and 0.1mm PP plastic. However, considering the thickness of the plastic is very thin, the thermal resistance value is very small and can be ignored, so the equation used to calculate the cooling conduction load on the wall can be seen in the following formula:

$$q_1 = \frac{T_1 - T_2}{x_A \; k_A} \quad (2)$$

Vertical garden wall

On the non-vertical garden wall, there is 5mm asbestos material, 0.1mm PP plastic, 0.1mm fabric, and 50mm soil. However, given the thickness of the plastic and the fabric is very thin, the thermal resistance value is very small and can be ignored, so the equation used to calculate the cooling conduction load on the wall can be seen in the following formula:

$$q_2 = \frac{T_1 - T_2}{x_A \; k_A \; A + x_B \; k_B \; A} \quad (3)$$

Considering the clay in the vertical garden wall only covers 50% of the wall, the determination of conduction heat in the vertical garden wall uses the following equation:

$$q_{VG} = 0.5 q_1 + 0.5 q_2 \quad (4)$$

III. Methods

The initial stages that will be carried out in the implementation of this research are first to make a design (design) of 2 simulation rooms with and without a vertical garden on the walls. The two rooms are each measuring 3 x 3 meters wide with a height of about 2 meters. One of the rooms was added to a vertical garden on the sidewall and behind, while on the front wall the vertical garden was not installed so. that the room was only covered vertically by 75% of the wall. Two AC units are installed in the two rooms to determine the difference in electrical energy consumption. The following figure is the second drawing of the simulation room that has been made.

Fig. 3. Simulation room with and without vertical garden on the wall.

Information: 1. Right vertical garden wall, 2. non-vertical garden room, 3. AC room 1, 4. AC room 2, 5. Left vertical garden wall, 6. Watering tank.

The construction of the walls of the room without the vertical garden consists of a 5mm asbestos layer on the inside, and the outside is coated with 0.1mm PP plastic. As for the construction of the vertical garden wall, in addition to having the inside made the same, there is also an additional fabric and 5 cm clay to attach the plants to the outside of the walls. On the ceiling of both rooms there is also 5mm asbestos and for the outer roof using sheet metal roofing (spandex).

To find out the difference in the heat conduction of the wall will be measured by the temperature of the outer wall and inner wall and the temperature and RH of each room. The process of taking temperature and RH data is carried out using a microcontroller-based data acquisition type Arduino Uno which is installed in each room and is carried out from 06.00 WIB to 18.00 WIB. Data retrieval is done every 5 minutes automatically and the results are immediately stored on a memory card installed in the data acquisition. Placement of the measuring point of the test is carried out on the hottest wall on the north wall.

IV. RESULTS

Based on the results of the tests that have been completed. The following results were obtained:

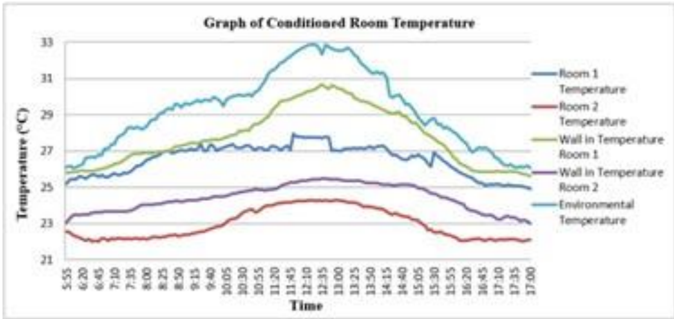

Fig. 4. Conditioned room temperature.

In Figure 4, it can be seen that the ambient temperature has the highest value of 32.88 °C, while the temperature in room 1 is 31.67 °C while at room temperature 2 the highest is 24.29 °C. The maximum temperature value occurs at 12.00-13.00. Where the average value of the ambient temperature is 29.32 °C, the average temperature of room 1 is 27.33 °C, the average temperature of room 2 is 22.95 °C this is because the room temperature that is conditioned turns out to be the addition of a vertical garden affects the conditioning in the room.

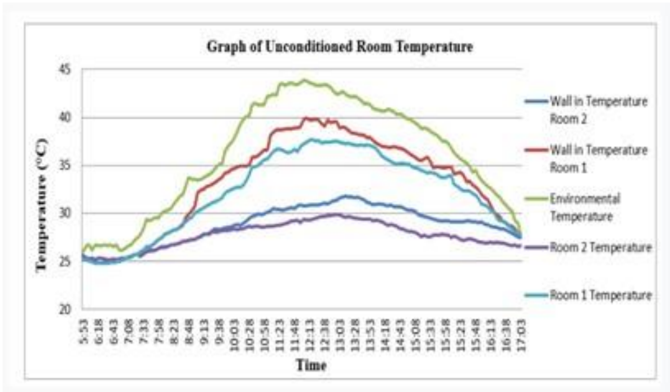

Fig. 5. Unconditioned room temperature.

In Figure 5, the highest environmental temperature is 43.83 °C while at room temperature 1 the highest value is 37.59 °C while at room temperature 2 the highest is 29.83 °C. The maximum temperature occurs at 12.00-13.00. The average temperature of the environment is 36.62 °C, the average room temperature is 32.16 °C, the average temperature is 27.70 °C. Based on these results, the heat from outside can directly affect the conditions in the room.

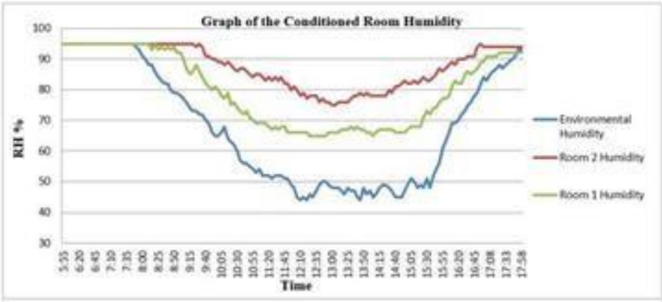

Fig. 6. RH conditioned room.

Based on Figure 6, it shows the highest environmental humidity (RH) level of 95%, the highest RH of room 1 is 95%, the highest RH of room 2 is 95%. RH is at 06.00-07.00. while the average RH of the environment is 65.6%, the average RH of room 1 is 74.75%, the average RH of room 2 is 84.5%, the RH decrease occurs at noon, namely at 11.00-15.00 hours, by looking at in these conditions the room which is added to the vertical garden does not affect RH.

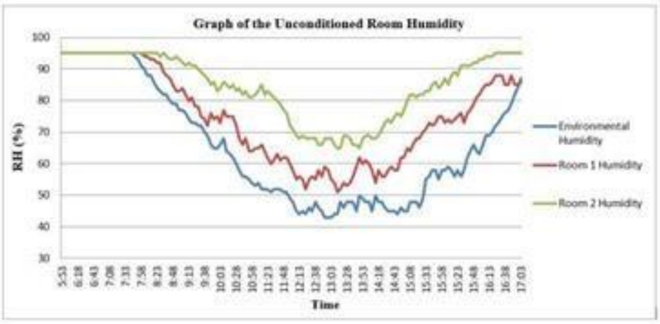

Fig. 7. RH unconditioned room.

In Figure 7, it shows that the RH of the highest environment is 95%; The highest RH of room 1 is 95%; The highest RH of room 2 is 95%. RH is at 06.00 - 07.00. The average RH of the environment is 65.6%, the average RH of room 1 is 74.75%, the RH of the average room 2 is 84.5%, the room that is not conditioned has an effect on the increase in humidity level (RH).

Based on the tests that have been carried out, Figure 8 below is fluctuations in wall temperature that have been measured from 06.00 WIB to 19.00 WIB. Seen in the table and the three graphs above, for the wall in the vertical garden temperature lower when compared to non-vertical garden walls. Wall in a vertical garden has an average temperature of 32.7 ºC and wall temperature in non-vertical garden has average 33.9 ºC is higher by 1.2 ºC. Decrease in temperature by 1.2 ºC is relatively smaller when compared with previous studies that have been done and there is a decrease inner wall temperature of about 2.1 ºC. This is due to testing previously used actual space with a brick wall that was thicker in comparison with this test that only uses asbestos walls which have a smaller resistance thermal.

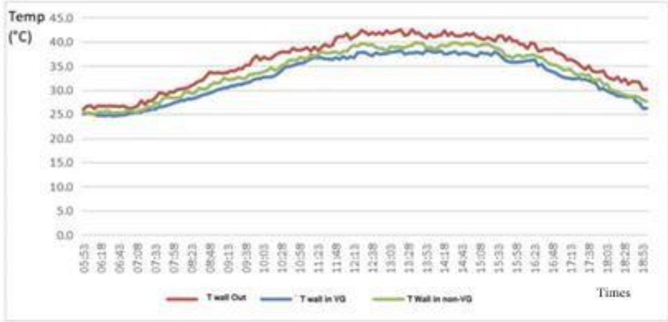

Fig. 8. Graph of measured wall temperature.

TABLE I. RESULTS OF TESTING DATA PROCESSING

No	Parameter	VG Wall	Non-VG Wall
1	Higest temperature out wall(ºC)	42,5	42,5
2	Average temperature out wall (ºC)	35,9	35,9
3	Higest temperature inside wall (ºC)	38,2	39,8
4	Average temperature insidewall (ºC)	32,7	33,9
5	Average difference temperature (ºC)	3,27	2,08
6	Average thermal transmittance (Watt)	1414	1547
7	Electrical consumption of AC (kWh)	1,26	1,42
8	Difference thermal transmittance (%)		8,6
9	Difference electrical consumption (%)		11,3

See in table 1 with a decrease in temperature of 1.2ºC on the vertical wall of the garden it turns out that it can reduce the thermal transmittance on the wall by 8.6%, while for the consumption of electrical energy in the air conditioner there is an saving of 11.3%. Thus it can be concluded that the vertical garden on the walls of buildings can reduce the temperature of the inner walls while reducing the consumption of electrical energy in the use of air conditioners.

V. CONCLUSION

Based on these experiments, a number of conclusions can be drawn, such as the following: 1. The inner wall of the vertical garden can be lower 1.2ºC compared to the wall without the vertical garden, while for the conduction heat with the vertical garden wall is about 8.6% lower so that the vertical garden in the wall is proven to be able to inhibit the heat conduction in the wall. 2. In addition to reducing the temperature of the inner walls, the addition of vertical gardens to the walls can also reduce the electricity consumption of the use of air-conditioning by 11.3% when compared to rooms that are not equipped with vertical gardens on the walls.

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