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The Effect of Material and Roof Shape on Thermal Comfort in Residential Buildings

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ABSTRACT

Indonesia is a country that has a tropical climate with humidity high air which can reach 80%, as well as relatively high air temperature (can reach 35°C). While the comfortable air temperature ranges between 22.5°C - 29°C with humidity air ranges from 20% - 50%). Therefore, it is necessary to create comfort thermal space in the space where people perform movement and activity. One of the things the most important thing is the use of the roof. The roof has an influence on temperature and comfort in space, especially in terms of material use and shape selection roof of the building. The use of roof forms with different materials certainly will creates a different effect on buildings.

Keywords: material, residence, shape, thermal comfort

1. Introduction

One of the most important criteria in building design is thermal comfort. Residents' productivity and well-being will be impacted by a thermally pleasant room [Mujan, Geng]. The temperature, humidity, and air distribution pattern within a room are the only factors that affect a building's thermal comfort [1]. Active air conditioning systems are typically used in buildings to provide thermal comfort, particularly in tropical locations. Nevertheless, there are a number of drawbacks to using air conditioners to improve thermal comfort, counting tall electrical vitality utilization, discuss contamination, costly speculation and upkeep costs, and the require for more room for hardware establishment.

Numerous elements, such as weather, the thermal properties of building outer materials, interior gain, occupancy patterns, etc., influence a structure's ability to maintain thermal comfort [2]. A bioclimatic design that closely considers the local climate of the building location is required to increase thermal comfort without using excessive amounts of energy [3]. Passive cooling solutions are one of the strategies included in bioclimatic construction concepts for hot locations. A viable substitute approach for lowering building energy usage in tropical climates is the implementation of passive cooling technology. Increasing the building envelope's thermal performance is crucial for an energy-efficient bioclimatic design. The roof is a crucial

component of the building envelope that affects the thermal performance of the structure. According to a study by [4], one of the primary reasons for building thermal discomfort in the warm, humid climate region is the excessive solar heat gain that is carried via the roof and into the interior of the structure.

Due to its direct exposure to outside air, the roof is the area of the building envelope most impacted by weather variations. It experiences convective heat transfer from the wind, rain, and other external factors in addition to direct exposure to the sun's [5] thermal radiation and that of other nearby objects. Indonesia has a tropical environment with temperatures that can reach 35°C and high humidity levels that can approach 80%. However, the ideal air temperature is between 22.5°C and 29°C, with humidity levels between 20% and 50%. The usage of roofing significantly affects the temperature and comfort of interior spaces, especially when it comes to material choice and building design in a tropical nation like Indonesia [6]. As a result, choosing roofing materials that are appropriate for specific microweather circumstances is an important area of study. The materials chosen for the roof need to satisfy a number of criteria, including thermal, economical, aesthetically pleasing, and structural strength in the face of outside elements like wind and rain. A high-performance roof should have the ability to decrease heat conduction into the room and reduce excessive heat radiation absorption on the surface. By applying a reflective coating to increase the surface's albedo [7] and selecting a material with a high emissivity value [8], one can reduce the absorption of heat radiation. Thermal insulation can be added to reduce heat penetration and boost thermal resistance. Numerous investigations into heat transfer on residential house roofs reveal that the kind of roof has a significant impact on lowering the amount of heat that enters the room [9]. The room's thermal performance is also influenced, as in previous studies, by a number of other factors, such as ventilation, geometry, the effect of internal gain and inertia, warm stratification, the affect of the bay window on lighting and warm comfort [10].

Literature Review

One of the main parts of the building envelope that receives the most amount of incident solar radiation is the roof. As a result, up to 60% of the cooling energy in spaces is used by the roof [11]. From a thermal perspective, a good roof is one that helps the building's interior thermal comfort levels either completely or with minimal energy use from the heating and cooling systems [12]. Therefore, when choosing a suitable roof for a building, there are several things that must be considered, namely the climatic conditions of the surrounding area, the shape and material of the roof itself, and the cost involved. For the choice of roof shape and material, it should be adjusted to the building to be erected. The function of the roof of a building can be categorized into several important points, namely: (1) As a barrier / protection from the sun's heat; (2) As a barrier / protection from rainwater; (3) As a barrier / protection from wind gusts rury. There are some roofing materials that are often used: Clay Tile Roof, Metal Tile Roof, Concrete Tile Roof, Shingle Roof, Tin Roof, Dak Concrete Roof, Polycarbonate Roof and PVC (Polyvinyl Chloride) [13]. And there are various types and forms of roofs that are generally used in residential buildings: Gable Roof, Shield Roof, Flat Roof, Tent Roof, Combination Saddle Shield Roof, Tower Roof, Mansard Roof, Roof Back, Half Ball Roof (Dome) and Roof Saw.

Thermal comfort refers to a person's knowledge of his or her own body temperature and the ability to maintain a neutral state, that is, a state of not sweating in a given thermal environment. [14]. In tropical regions where temperature and humidity are high, thermal discomfort for humans is a major problem. The individual's location influences thermal comfort requirements, as do environmental factors inside and outside the enclosure [15]. According to LPMB PU the comfortable temperature of Indonesians ranges from 22.8°C - 25.8°C with an air humidity of 70%. Meanwhile in Indonesia, the temperature can reach 35°C with 80% humidity, causing discomfort, especially during activities. There are 3 weather conditions that are needed to achieve thermal comfort in the territory of Indonesia, namely: (1) Air temperature 24ºC < T < 26ºC; (2) Humidity 40% < RH < 60%; (3) Air velocity 0.6 m/s < v < 1.5 m/s [16]. The following is a comfortable temperature according to the Standard for Technical Planning Procedures for Energy Conservation in Buildings: (1) Comfortable cool: 20.5°C - 22.8°C, Threshold: 24°C, Humidity: 80%; (2) Optimal comfort: 22.8°C - 25.8°C, Threshold: 28°C, Humidity: 70%; (3) Warm comfortably: 25.8°C - 27.1°C, Threshold: 31°C, Humidity: 60% [16].

2. Method

The research was conducted using a quantitative method. The sequence of implementation is as follows: doing literature study, namely by reading books and journals, determine the experimental design, namely determining the time to carry out temperature measurements in the residence, carrying out experiments, namely carrying out temperature measurements in homes, perform an analysis of the experimental results. The variables in the study include roof material and roof shape. The variables in this study will be crossed between different roof materials and shapes. First, the form of a gable roof with zinc roofing material. Second, the form of a gable roof with tile roof material. Third, form of shield roof with zinc roofing material. And the last one, form of shield roof with tile roof material. This consider utilized both essential and auxiliary information collection strategies. Essential information collection is done on-site at the inquire about area. Specifically, experiments are run on various combinations of materials and roof forms, and in residential buildings, the temperature and humidity are measured using a digital hygrometer as in the figure 1 below.

Figure 1 Digital Hygrometer.

3. Result and Discussion

3.1 Location Selection

This research was conducted on Jalan Bawang, the perumnas area of Simalingkar, Medan, North Sumatra as in the figure 2 below. Measurements were made during the day (12.00-13.00 WIB) when the sun was at its peak, to find out the temperature and humidity in the house in the hottest conditions. The room where the temperature and humidity will be measured is the living room. The object examined in this study is a 1-storey residential house with the following conditions: equally oriented, namely towards the north, has an area ±72m2, gable and shield form, zinc and tile roofing materials.

Figure 2 Map of the Research Area

3.2 First Day Temperature Measurement

Measurements are made during the day at 12.00-13.00 WIB, when the sun is at its peak which causes the warmest air temperature. The measurement results for the first day are presented in the following figure 3 below.

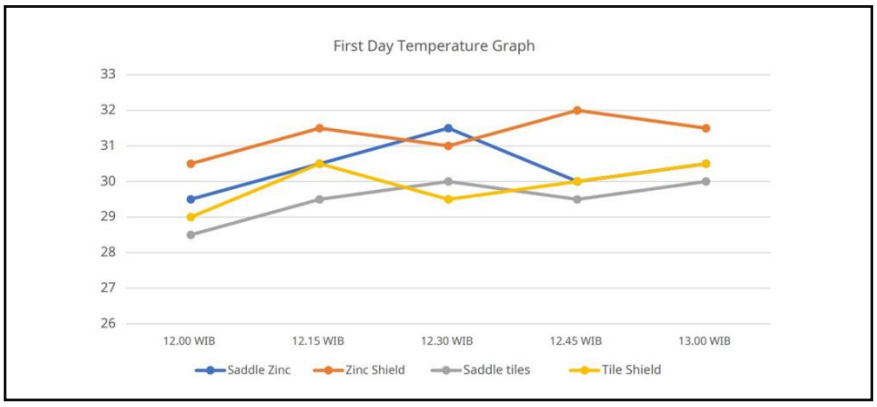

Figure 3 First Day Temperature Measurement Graph

The results of measurements in residential houses with a zinc saddle roof on the first day are: 12.00 WIB: 29.5°C, 12.15 WIB: 30.5°C, 12.30 WIB: 31.5°C, 12.45 WIB: 30°C, 13.00 WIB: 30.5°C. The lowest temperature is 29.5°C at 12.00 WIB, the highest temperature is 31.5°C at 12.30 WIB, with 74% humidity. The temperature differential that exists between the greatest and lowest values is 2°C. The results of measurements in residential houses with a zinc shield roof on the first day are: 12.00 WIB: 31.5°C, 12.15 WIB: 30.5°C, 12.30 WIB: 31°C, 12.45 WIB: 32°C, 13.00 WIB: 31.5°C. The lowest temperature is 30.5°C at 12.15 WIB, the highest temperature is 32°C at 12.45 WIB, with an air humidity of 74%. The temperature differential that exists between the greatest and lowest values is 1.5°C. The results of measurements in residential houses with a saddle tile roof on the first day are: 12.00 WIB: 28.5°C, 12.15 WIB: 29.5°C, 12.30 WIB: 30°C, 12.45 WIB: 29.5°C, 13.00 WIB: 30°C. The lowest temperature is 28.5°C at 12.00 WIB, the highest temperature is 30°C at 12.30 WIB, with an air humidity of 74%. The temperature differential that exists between the greatest and lowest values is 1.5°C. The results of measurements in residential houses with tile shield roofs on the first day are: 12.00 WIB: 29°C, 12.15 WIB: 30.5°C, 12.30 WIB: 29.5°C, 12.45 WIB: 30°C, 13.00 WIB: 30.5°C. The lowest temperature is 29°C at 12.00 WIB, the highest temperature is 30.5°C at12.30 and 13.00 WIB, with 74% humidity. The temperature differential that exists between the greatest and lowest values is 1.5°C.

3.3 Second Day Temperature Measurement

The measurement results for the second day are presented in the following figure 4 below.

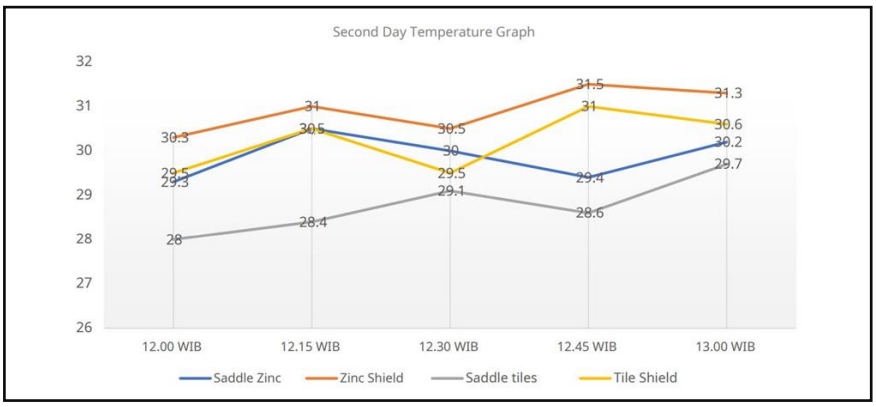

Figure 4 Second Day Temperature Measurement Graph

The results of measurements in residential houses with a zinc gable roof on the second day are: 12.00 WIB: 29.3°C, 12.15 WIB: 30.5°C, 12.30 WIB: 30°C, 12.45 WIB: 29.4°C, 13.00 WIB: 30.2°C. The lowest temperature is 29.3°C at 12.00 WIB, the highest temperature is 30.5°C at 12.15 WIB, with 76% humidity. The

temperature differential that exists between the greatest and lowest values is 1.2°C. The results of measurements in residential houses with a zinc shield roof on the second day are: 12.00 WIB: 30.3°C, 12.15 WIB: 31°C, 12.30 WIB: 30.5°C, 12.45 WIB: 31.5°C, 13.00 WIB: 31.3°C. The lowest temperature is 30.3°C at 12.00 WIB, the highest temperature is 31.5°C at 12:45 WIB, with 76% humidity. The temperature differential that exists between the greatest and lowest values is 1.2°C. The results of measurements in residential houses with a gable tile roof on the second day are: 12.00 WIB: 29.3°C, 12.15 WIB: 30.5°C, 12.30 WIB: 30°C, 12.45 WIB: 29.4°C, 13.00 WIB: 30.2°C. The lowest temperature is 29.3°C at 12.00 WIB, the highest temperature is 30.5°C at 12.15 WIB, with 76% humidity. The temperature differential that exists between the greatest and lowest values is 1.2°C. The results of measurements in residential houses with tile shield roofs on the second day are: 12.00 WIB: 29.5°C, 12.15 WIB: 30.5°C 12.30 WIB: 29.5°C, 12.45 WIB: 31°C, 13.00 WIB: 30.6°C. The lowest temperature is 29.5°C at 12.00 and 12.30 WIB, the highest temperature is 30.6°C at 13.00 WIB, with 76% humidity. The temperature differential that exists between the greatest and lowest values is 1.1°C.

3.4 Third Day Temperature Measurement

The measurement results for the second day are presented in the following figure 5 below.

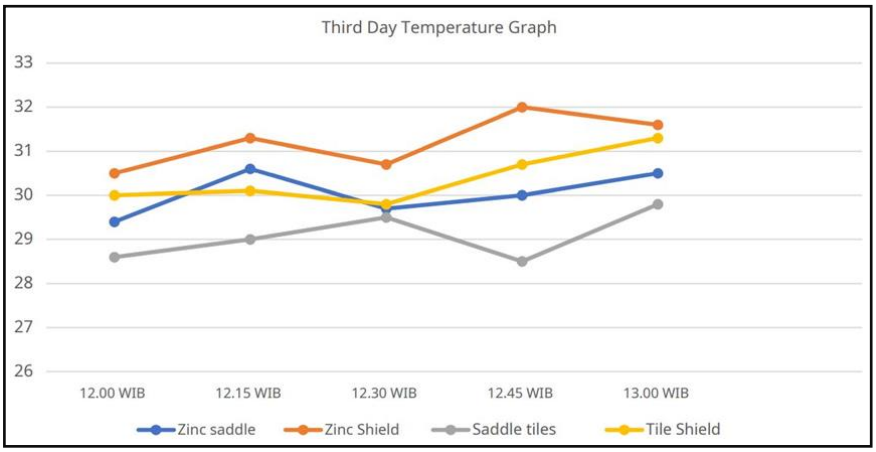

Figure 5 Third Day Temperature Measurement Graph

The results of measurements in residential houses with a zinc gable roof on the third day are: 12.00 WIB: 29.4°C, 12:15 WIB: 30.6°C, 12.30 WIB: 29.7°C, 12.45 WIB: 30°C, 13.00 WIB: 30.5°C. The lowest temperature is 29.4°C at 12.00 WIB, the highest temperature is 30.6°C at 12.15 WIB, with 76% humidity. The temperature differential that exists between the greatest and lowest values is 1.2°C. The results of measurements in residential houses with zinc shield roofs on the third day are: 12.00 WIB: 30.5°C, 12:15 WIB: 31.3°C, 12.30 WIB: 30.7°C, 12.45 WIB: 32°C, 13.00 WIB: 31.6°C. The lowest temperature is 30.5°C at 12.00 WIB, the highest temperature is 32°C at 12.45 WIB, with a humidity of 76%. The temperature differential that exists between the greatest and lowest values is 1.5°C. The results of measurements in residential houses with gable roof tiles on the third day are: 12.00 WIB: 28.6°C, 12.15 WIB: 29°C, 12.30 WIB: 29.5°C, 12.45 WIB: 28.5°C, 13.00 WIB: 29.8°C. The lowest temperature is 28.5°C at 12.45 WIB, the highest temperature is 29.8°C at 13.00 WIB, with 76% humidity. The temperature differential that exists between the greatest and lowest values is 1.3°C. The results of measurements in residential houses with roof tile shields on the third day are: 12.00 WIB: 30°C, 12.15 WIB: 30.1°C, 12.30 WIB: 29.8°C, 12.45 WIB: 30.7°C, 13.00 WIB: 31.3°C. The lowest temperature was 29.8°C at 12.30 WIB, the highest temperature was 31.3°C at 13.00 WIB, with 76% humidity. The temperature differential that exists between the greatest and lowest values is 1.5°C.

4. Conclusion

From the results of measurements of temperature and humidity in households with shapes and materials different roofs, it can be seen that on a zinc gable roof, the average temperature is 30.1°C with an average humidity of 75.3%. On the zinc shield roof, the average temperature 31.14°C with an average humidity of 75.3%. On a gable tile roof, the average temperature 29.4°C with an average humidity of 75.3%. On the roof tile shield, the average temperature 30.16°C with an average humidity 75.3%. The four houses are equally categorized in a comfortable warm temperature. So it can be concluded that the residential building with the highest temperature is a house with a zinc shield roof, the residential building with the lowest temperature is a house with a gable roof rooftile, houses that use a roof with a zinc material, have a temperature that tends to be higher high compared to houses whose roofs use tile material, thermal comfort in residential buildings is more pronounced in houses that are using a roof with tile roof material with a gable roof. Design Suggestions and Solutions: From the results of the study, it was concluded that the roof of the building that can create thermal comfort in residential homes, namely the roof with tile material with the shape of saddle. So the suggestions that can be given are using a roof with clay tile material compared to zinc to reduce heat in the building and make sure to do selection of the shape of the gable roof in residential buildings.

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6. Conflict of Interest

Author declares no conflicts of interest. Both authors certify that the material presented here is accurate and accountable.

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