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Indirect Evaporative Cooling for Thermal Comfort in Buildings in a Humid Tropical Climate

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The engineers and architects today confront the question of how to build energy-efficient buildings. The price of fossil fuels more expensive and limited source is the cause of this issue. The study aims to determine the usage of an indirect evaporative cooling strategy to cool the building for thermal comfort in a tropical humid climate. Comfort ventilation is one of passive cooling strategies that always used to make the thermal comfort, but still there are some schemes that can be used depends not only on the strategy. Hot and humid conditions are a major problem in achieving thermal comfort for buildings and it is necessary to require cooling strategy. In that respect are several strategies for passive cooling but the application of indirect evaporative cooling to buildings in humid tropical climates is still less attention seriously. For this purpose, it is necessary to apply a strategy of indirect evaporative cooling to a building model. A model house has been constructed with plywood for the walls and floors, and roofs of corrugated zinc. A system distribution of spraying water on the roof surface has been utilized and laid on top of the roof. Some measurements have been carried out and from there it can be concluded that this prospective strategy used in buildings, especially to lower the temperature of the surface of the roof. Water spraying can reduce the surface zinc temperature by an average of 4°C. Nevertheless, making less roof surface temperature cannot be secured to reduce directly the average indoor air temperature in the edifice. In this case, there are some other requirements that are responsible for indoor air temperature in the building; especially with large openings. To reach a bigger advantage of making less roof surface temperature required the water spraying in the long duration, approximately 10-15 minutes, which carried out continuously; especially when the external temperature is very high.

Keywords: passive cooling, indirect evaporative cooling, thermal comfort

Introduction

In the building sector, based on several studies that there are around 40% of energy consumption used for cooling of indoor air, particularly in the humid tropical climate. Energy consumption will increase when buildings are designed without considering environmental conditions, utilizing construction materials that are not appropriate, and ignores the protection from direct sunshine. It is intelligible that the average buildings in humid tropical climates facing the trouble of how to preserve the comfortable conditions in the construction.

One of the strategies that are needed for a tropical humid climate conditions is a passive cooling. Indeed, there are some strategies that can be used on buildings in hot and humid climates in Indonesia such as comfort ventilation and soil cooling. Still very rarely use the other available strategies, particularly about how indirect evaporative cooler's ability to achieve thermal comfort simultaneously streamline energy use in buildings. Applying this strategy is highly commended as an endeavour to conserve energy in the domestic sector. Application of passive cooling strategy will save energy and obtain the thermal comfort. Research on indirect evaporative cooling needs to be answered to find the proper scheme.

Research on passive cooling except comfort ventilation is still rare in Indonesia. During this time, the emphasis exclusively on the application of natural ventilation alone. Although some passive cooling strategies are still employed, but just a few are suitable and in conformity with the humid tropical climate. One of passive cooling strategies is still less attention is the indirect evaporative cooling. In principle, this strategy reduces the indoor air temperature without increasing its humidity. Implementation of this system will be able to save energy needs of the building. In terms of energy saving, this scheme can reach down the required energy expended to make a comfortable space condition and efforts to drastically lower the cooling load. Create a comfortable space will have an impact on increasing the productivity of the users of the building.

Several series of studies conducted by the author (Kindangen (1993-2006)) have been put away, particularly on a parametric study of architectural elements to improve the operation of natural ventilation. But aside from the natural ventilation there are other schemes that are included in the passive cooling strategy. Givoni (2007) noted that in different places should be applied different strategies that are appropriate to the characteristics of the suitable climate.

Maerafat et al. (2010) have examined the role of the evaporative cooling cavity in residences, they reasoned that the diligence is actually successful and bring a broad impact on cooling. Likewise with Givoni (2011) has concluded that the passive cooling system can cut the temperature of the room, but this system will differ from one another depending on the particular climate. Kim et al. (2011) have studied the potential energy savings by using direct or indirect evaporative cooling usage of outdoor air. Melero et al. (2011) have also investigated the passive evaporative cooling using porous ceramic incorporated in the trombe wall. Jain et al. (2008) tested the insulation along the roof of the building that can be customized or mobile for the purpose of cooling, the arrangement is given by utilizing an indoor or don't use has demonstrated that this organization can run properly. Givoni (2000) has been experimenting on cooling with indirect evaporative with puddles outside construction.

Kettleborough et al. (1981) have conducted research on how the wet plastic plate as a heat exchange was performed for indirect evaporative cooling. All the same, all these scenes did not delineate how the indirect evaporative cooling can be applied in buildings in a humid tropical climate. Likewise with Costelloe and Finn (2003) stated that passive cooling with air-water system is potentially applied in temperate or moderate climates. It was described by Tang et al. (2005) that the cooling with a puddle on the roof using a floating bag had good performance compared with movable insulation.

Joudi and Mehdi (2000) have examined the indirect evaporative cooling with cooling load varies for housing. All these authors, it is still really rare to check how passive cooling mainly indirect evaporative cooling strategy do for buildings in the humid tropical climate to build an economical cooling strategies and responsive to the climate.

Modelling

A model of the house has been created and the installation of the cooling system have been applied which will be followed by observation and measurement. A house model was built measuring 1.5 x 1.5 m with plywood for the walls while the roof is constructed of corrugated zinc sheets. The base of the house model is constructed of plywood raised about 80 cm from the ground floor. The model has no ceiling, the roof is tilted in one direction only. The construction has openings measuring 30 x 40 cm on the right and left (West and East) and the rear side of ¾ part of the surface area (North), as depicted in Figure 1.

Installation of water to spray the surface of the roof using a closed circuit with submersible pump and pipes set up at the highest edge of the roof. PVC pipe ½' perforated on one position to spray water over the full surface of the cap when the pump is turned on. Measuring instruments used consisted of Hygro-thermometer to measure air temperature and relative humidity and an infrared thermometer to measure the temperature on the surface of the roof, walls and floor.

Figure 1: A building model

Measurements were made with several different scenarios and conditions. The building model is positioned outside the room in the spot as a good deal as possible exposed to the sun the morning until the afternoon. The building model has been in the Faculty of Engineering at the University of Sam Ratulangi, in the parking lot were covered with paving stones; between two buildings Studio Architecture and lecture halls, as presented in Figure 2. Zinc roof has a slope of the front wall or the South side sloping to the back wall or the North position. The West and East side of the wall have each a window.

Measurement of air temperature in the building is performed once per hour; by assessing the surface temperature of the roof, walls, floors and air temperature in the room. The results of the measurements will be used as a database of measurements with different treatment. Different treatment is done to distinguish the benefits of indirect evaporative cooling in some weather. The surface of the roof of the building will be sprayed with water; water temperature measurements previously done in advance. Once sprayed water onto the surface of the roof, the air temperature in the building, the walls and roof of the building make repeated measurements. Such treatment is reported to get enough data for analysis.

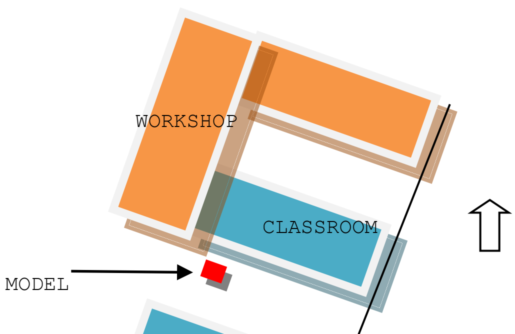

Figure 2: Location and position of the building model

Results and Discussion

The installation of a model building and the device have been implemented, the measurement has been done repeatedly with some preferential treatment. Measurements taken at 14:00 is considered the peak heating of all elements of the construction has been functioning perfectly. Along the sunny weather with high sun intensity indicates that external temperature and its relative humidity is at 31.2°C and 60%. Under such conditions cause the room temperature was at 28.4°C with a relative humidity of 70.5%. At this time, the sun was leaning towards the West which the Western wall is definitely more exposed to direct sunlight. To make sure the effect of the temperature of the walls, the floor temperature and surface temperature of the roof against the average temperature in this room, then the temperature measurement in all fields is done simultaneously. It was observed that the temperature at the Western wall reached 41.7°C, while the temperature of the surface of corrugated zinc roofs 39.6°C. A difference of 2.1°C, in which the Western wall is hotter than the temperature of the surface of the zinc roof, geometrically, due to the Western side of the most exposed to direct sunshine. The temperature of the wall on the other side shows as follows: North of 37.6°C, South side reaches 39°C and the East side at 37°C, while the temperature of the floor made of plywood reached 37.5°C. South side of the wall holds a higher heat caused by sun exposure on the side was pretty extensive. This suggests that relatively long warming will heat up the ramparts and the roof is important.

The measurement is done repeatedly, and shows that when the zinc roof surface temperature reached 38.4°C will cause the temperature of the room at 32.6°C with a relative humidity reached 56.2%. Within 5 seconds, then shows the changes which the roof surface temperature of 33.6°C and the temperature of the air in the space of 20.3°C with relative humidity 56%. This means that in this period only a small drop in air temperature occurs in space despite temperatures of the surface of the zinc roof down by 5.7°C.

On different days, when the weather is sunny at 1:00 pm, noted that the average temperature of the outside air of 18.9°C and relative humidity 56.4%. In such conditions, the corrugated tin roof surface temperatures reached 38.2°C and the temperature of the air in the space of 19.8°C with a relative humidity of 50.4%. After about five minutes later, measured again and showed the following changes in air temperature of 20.9° C with relative humidity of 44.3%. The temperature of the surface of the zinc roof is still the same as in the initial measurement of 38.2°C. The temperature in this room is the accumulation of the temperature of all fields, especially the part that is exposed to direct sunlight will contribute significantly. The consequence was the South wall temperature reaches a temperature of 38.7°C, North side reached 36.9°C, the temperature of the West side of 37.9°C and East walls reach 38.7°C, the temperature of the floor of 37.6°C.

The measurement is done repeatedly, and it can be concluded that without spraying water on the surface of the zinc roof for the period from 11:00 to 15:00, note that the roof surface temperature higher average of 5.6°C compared with an average air temperature in the building, as shown in Figure 3.

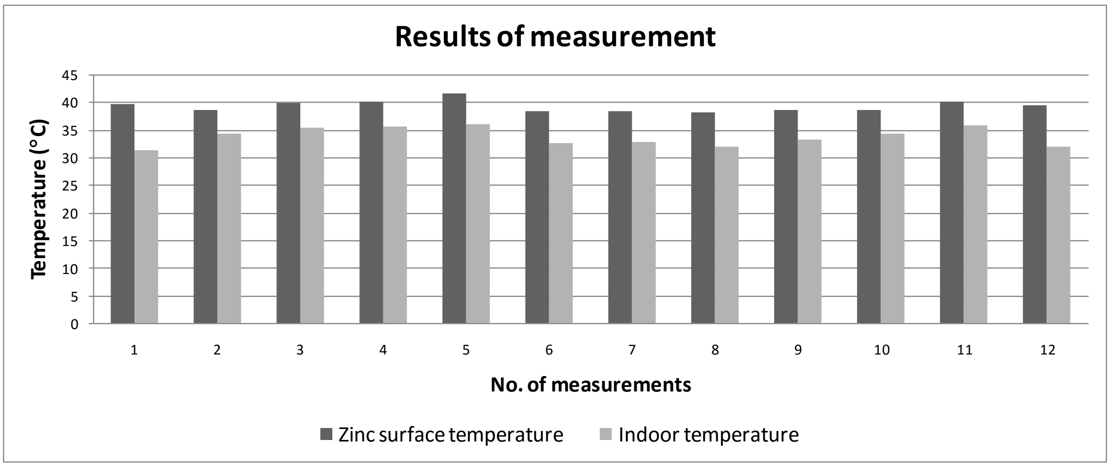

Figure 3: Measurement results of zinc surface roof and indoor temperature

The following treatment for investigating the effect of indirect evaporation cooling strategies with spraying water onto the surface of the zinc roof. At the beginning of the experiment conducted measurements of water temperature, i.e. amounting to 35.7°C, water is sprayed evenly onto the surface of the zinc roof. Note that there is a decrease in the temperature of the surface of the zinc roof by 4°C after spraying water where the temperature at the surface of the roof earlier of 38.2°C changed to 34.2°C. This decrease of the surface temperature on a zinc roof (4°C) not much effect lowering the temperature in the room. This is indicated by the temperature in the room at 33.6°C with relative humidity 44.6%, which does not differ too much from his initial conditions i.e. 33.7°C. Roof surface temperature will increase gradually again after at least 5 minutes later. In addition to that, this measurement is done when the window is opened with the speed of the wind in the room 0.8 m/s; room temperature recorded 33.4°C and relative humidity 45.9%.

The same thing is practised for a dissimilar time, one hour after it; suggest that spraying water-temperature 35.8°C on the surface of the zinc roof with 41.6°C temperatures will bring down its temperature to 37.7°C, or in other words, there was a decrease of 3.9°C. After spraying water onto the surface of the zinc roof immediately note that does not turn down significantly from indoor temperature or relative humidity at the same time due to the effect of the influence of the temperature of the wall is displayed right away in the sunlight. These varieties can be viewed in the following matrix:

Table 1: Comparison of the average condition before and after the water sprayed onto the surface of the zinc roof

NO.	MEASUREMENTS	BEFORE SPRAYING WATER TO ROOF SURFACE	AFTER SPRAYING WATER TO ROOF SURFACE	RESULTS (INCREASE (^) OR DECREASE (v))
1	Temperature of zinc surface	41.6 °C	37.7 °C	v
2	Average indoor temperature	35.6 °C	35.4 °C	v
3	Indoor relative humidity	40%	39.5%	v
4	North wall temperature	37.3 °C	36.5 °C	v
5	South wall temperature	39.6 °C	37.9 °C	v
6	West wall temperature	40.4 °C	40.6 °C	^
7	East wall temperature	37.4 °C	36.3 °C	v
8	Plywood floor temperature	38.3 °C	37.1 °C	v

The results of the measurements as described in Table 1, explaining that by spraying water on the surface of the zinc roof can turn down the temperature significantly but does not ensure it will be capable to bring down the temperature in the room. It identified that if wanting to make a larger profit, building should then be protected from direct sun. The measurement again after more than 5 minutes will then find that zinc roof surface temperature rises gradually. This means that efforts to reduce the temperature of the surface of the zinc roof with direct evaporative strategy by spraying the water must be carried out within the time needed so that, as expected, the drop in temperature of the surface of the roof or inside the room to be more meaningful. In this experiment, a very important time to receive optimal benefits are spraying water an hour after noon 12:00.

The measurement is performed when all windows were opened, which will yield a better chance to attain a more comfortable temperature. This suggests that to improve comfort in buildings it is urged to mix with some other scheme; not just with the strategy of indirect evaporative cooling but can as well be mixed with natural ventilation schemes. In general, the buildings in humid tropical regions will experience warming effectively when the sun is at a high altitude (-60° - +60°); the proper roof materials selection will be very significant in addition to implementing the strategy of indirect evaporative cooling

This strategy can be used and needs to be proceeded with further research, especially the reuse of water after sprayed onto the surface of the roof that automatically will turn hotter. Used water flowed into the tank for reuse so that require heat exchange equipment to convert the temperature of the water being cold again. If so, then a building that utilizes a water recycling system will be a building that is energy efficient and sustainable.

Conclusions

Application of passive cooling strategies primarily indirect evaporative cooling has been drawn. A model building with plywood walls and corrugated zinc roofs had been established for the purposes of this study. Spraying water on the surface of the roof using a perforated pipe laid on the roof. Some measurements have been chosen and understood that this strategy makes it possible to bring down the temperature of the surface of the roof; primarily made from metal. Spray water on the surface of the zinc roof can reduce the average temperature of the surface of the roof by 4°C. However, the roof surface temperature reduction is not automatically can directly lower the average temperature in the room. In the case that there is still a wide range of conditions that must be satisfied in order to bring down the temperature in the space; especially buildings with large openings. As for lowering the temperature of the surface of the roof water spraying is required effectively repeated every 10-15 minutes and practiced continuously, especially when the outside temperature is very high.

Further research regarding reuse of water after spraying is to be performed. The water used can be re-utilized and stored in the reservoir tank that will be practiced effectively.

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