

## Design, Construction and Performance Testing of Passive Cooling System of a Building

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### ABSTRACT

The rate of energy consumption is high in the current world. Day by day, energy consumption is increasing. On the other hand, the number of resources such as oil, coal, gas is decreasing. A large part of energy consumption occurs because of cooling and ventilation and it is because to provide thermal comfort. Nowadays, the building has a low ventilation system. Fans, air conditions are used to cool the building. By using the passive cooling system, the energy consumption of the buildings will be reduced. The thermal load will reduce. The thermal comfort will be increased. It not only improves the natural ventilation but also increases the insulation. The passive cooling system can be solar-powered. A solar chimney can be used to absorb heat from the sun. The solar chimney is black. As a result, it can act as a black body and it is a concentric shape. The metal sheet can be used to make the solar chimney. A passive evaporative cooler can be used to cool the air. The inlet air becomes cool when passes through it and the copper pipe will act as a heat exchanger. A layer of cork sheet can be used to provide more insulation to the building. As a result, the natural ventilation and insulation will increase. The passive model building temperature is compared with the ambient temperature and the ordinary room temperature. The passive model building gave 2°C to 3°C and 3°C to 4°C lower temperature from the ordinary reference model building and the ambient temperature.

Keywords: Passive Cooling, Solar Chimney, Evaporative Cooler, Ventilation.

### 1. Introduction

The passive cooling system is a system that increased thermal comfort and the system takes low or no energy. Human comfort depends on various factors such as the temperature of the air, motion of the air, humidity, etc. The passive cooling system can reduce the temperature of the air, increase the motion of air.

Bangladesh is a developing country. The cost of producing electrical energy is high. The natural resources of our country are decreasing at a higher rate. After some years, some of the resources will have vanished. The amount of natural gas is limited. On the other hand, the necessity of electrical energy is increasing day by day. The number of people is increasing and they need a lot of building. The people of the urban and residential areas are using electrical energy at a high rate for thermal comfort. It creates a large barrier to the development of our country. Sometimes, the load shedding increases. The electrical energy production rate is a very important factor in the development of a country. By using the passive cooling system, the demand can be reduced. It uses solar energy to provide thermal comfort. The temperature of Bangladesh is on an average of 30 to 40 degrees Celsius in summer. The radiation is high in Bangladesh for its location. So, the passive cooling system is very suitable for our country. The passive cooling system can improve the ventilation system [1]. By using the passive cooling system, solar energy can easily be utilized. This system also reduces sound pollution. It is reliable and the maintenance of this system is very easy. The cost is also low for the system. No external device is used to cool the building such as a fan, blower, etc [2]. Passive heating is a comparatively common term than passive cooling. The passive cooling system is used for space cooling and the passive heating

system is used for space heating. The ways of passive heating are many. A Trombe wall is one of them. There are some other processes such as direct gain, transparent insulation [3-7]. The passive cooling system was invented after the passive heating system. Some ideas are based on increasing the ventilation and some of the ideas are based on the insulation and some are heat exchangers. In 1978, N. Bahadhori gave an idea of a passive cooling system [8]. The roof should be dome-shaped and a water pond should be used to apply this system. In 2003, a paper was published based on the passive cooling system. It was based on the modified roof by using reflecting material on the roof to reduce the thermal load of the confined space [9]. The reflecting material reduces the thermal load of the building. A paper was also published based on a passive cooling system by Givoni [10]. A paper was published based on roof garden [11]. This paper also gave an idea of air gap for more insulation. Boucher made an idea that can reduce the temperature by more than 6 degrees Celsius [12]. In this paper, a modified roof design was discussed. They used a water bed that can reduce temperature. The water bed takes heat in the presence of the sun and the water becomes vapor. At night, it removes heat from the surroundings and becomes cool. But this idea is very costly. It is very complicated. Highly skilled people are needed.

Some of the techniques are efficient and some are not. Some techniques are costly and some techniques are not. If the techniques are costly, the poor people cannot afford to select costly techniques. The combination of the system can be more effective. If the ventilation can be increased and the insulation can be increased, the efficiency will comparatively become high. The

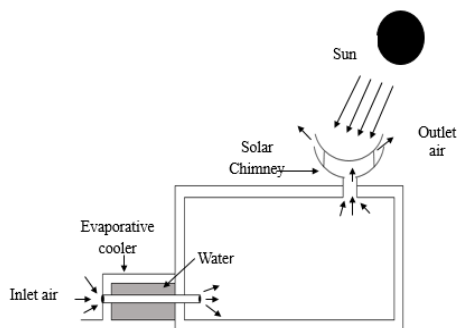
temperature difference between the ambient and the building will be increased. Initially, the cost of the modified building may be high but it will save electrical energy. In my project, I used a solar chimney to increase the ventilation and a cork sheet layer is used to increase the insulation. The price of the MS sheet and cork sheet is not high. So, the cost of the project is low and the poor people can implement easily this technique. Not a highly skilled person is needed to maintain this system.

## 2. Methodology

The passive cooling system has a solar chimney and it is made of MS sheet. It is concentric in shape. Two sheets are used. It is used because the water can't go to the building at the time of rain. It becomes hot in the presence of the sun. The density of the air around the solar chimney will reduce and goes in the upward direction. The density of the model building in the upper portion is lower than the density of the lower portion. So, the stack effect occurs. As a result, the air inside the building goes to the solar chimney and for this reason, the suction occurs. On the other hand, inside the evaporative cooler, a copper pipe is used as a heat exchanger and it is immersed in water. The hot ambient air becomes cool when passing through it. The evaporative cooler also needs to be insulated from the sun. It is needed because if the evaporative cooler becomes hot, the water inside the evaporative cooler becomes hot and no heat transfer will occur. A layer of cork sheet was provided for insulation. It provided a vital role. The cork sheet is a good insulator and it is white.

## 3. Design

The model building is 1.83 meters long, 1.21 meters wide, and 0.91 meters high. It is made of wood and polythene. A layer of cork sheet needs to provide more insulation. The dimension of the ordinary reference building is also the same.



**Fig.1** Passive cooling system of model building

The length of the evaporative cooler is 0.73 meters, the height is 0.31 meters and the width is 0.37 meters according to the ratio of the reference paper. The copper pipe has 0.07 meters [13]. The solar chimney can be made of MS sheet. It is light in weight and can store a large amount of heat. The area of the MS sheet 1.58 meter<sup>2</sup> and it was 1.21 meters wide and 1.29 meters long

[13]. It was rectangular. According to the reference paper, if the concentric shape has taken and two sheets are used as a 3:2 ratio, the diameter will be 0.54 meter and 0.44 meter. The two-sheet is used to protect the model building from the water at the time of rain. The total area of the two concentric mild steel shapes will be 1.58 meters<sup>2</sup>. The solar chimney should be black. As a result, it will act as a black body.



**Fig.2** Evaporative cooler



**Fig.3** Passive model building



**Fig.4** Thermocouple

#### 4. Performance Test

The temperature was taken by thermocouple. The reading was taken from 9 AM to 4PM. The Reading was taken after 1 hour.

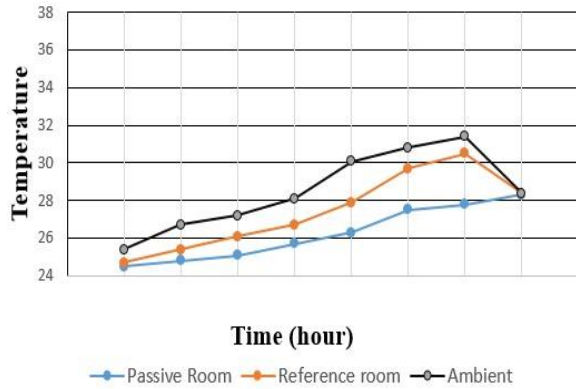


Fig.5 Time vs temperature difference of 5<sup>th</sup> March

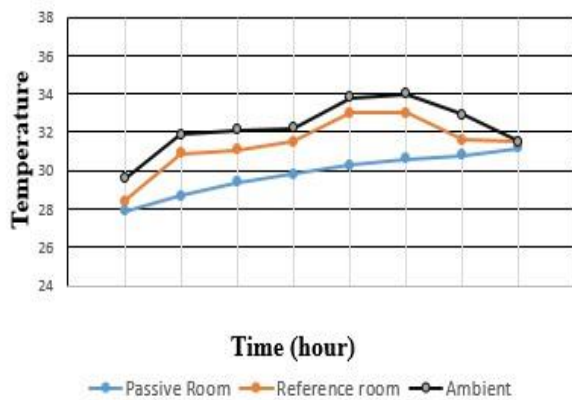


Fig.6 Time vs temperature difference of 8<sup>th</sup> March

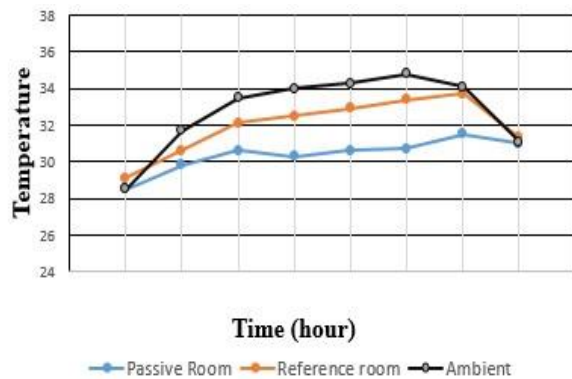


Fig.7 Time vs temperature difference of 9<sup>th</sup> March

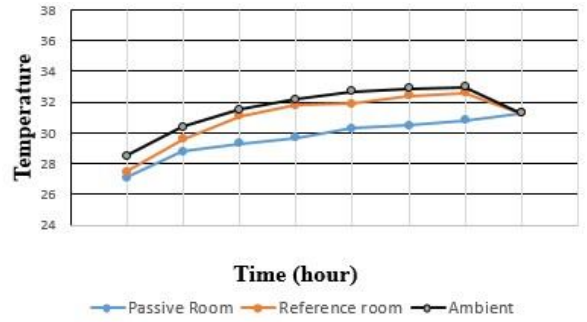


Fig.8 Time vs temperature difference of 12<sup>th</sup> March

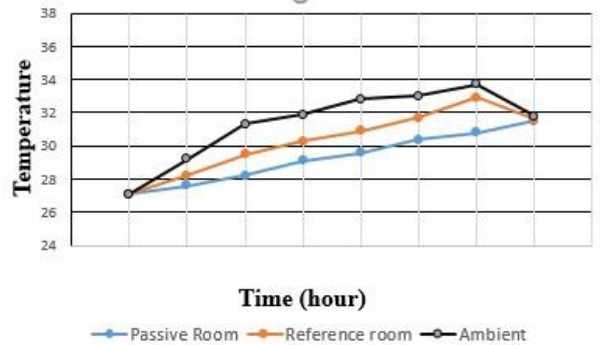


Fig.9 Time vs temperature difference of 13<sup>th</sup> March

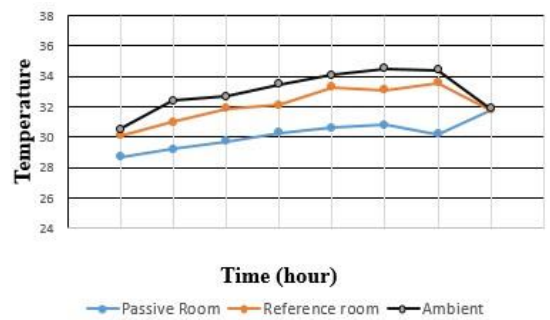


Fig.10 Time vs temperature difference of 14<sup>th</sup> March

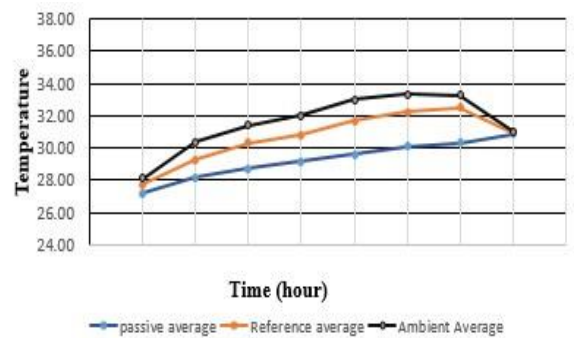


Fig.11 Time vs temperature average

The data was taken for 6 days. The result shows that the passive room temperature is below the ambient and ordinary room. The ordinary room have same dimension with the passive room. The Graph shows that the temperature difference increased at the midday. At 4pm, the temperature difference reduced.

The evaporative cooler and solar chimney are used to increase the ventilation system but this effect is not high. But this can reduce the temperature 2-3 degree Celsius.

## 5. Result and Discussion

In this system, the model buildings are made of wood and polythene. It is used to make the model building air-insulated. No cork sheet is used in the ordinary room. But in the passive cooling system, the cork sheet is used to increase the insulation. As a result, the room temperature will reduce the cork sheet. The solar chimney is nothing but a shape of mil steel used to increase the suction. The natural ventilation is increased for the solar chimney. It is easy to maintain and low cost is needed. The construction process of this system is easy. The evaporative cooler is passive. So the water cannot directly be contacted with the air. So the moisture quantity does not increase in the model building. The temperature difference between the passive room and ordinary room is found 2-3 degree Celsius and the temperature difference between the ambient and ordinary room temperature is 3-4 degree Celsius.

The passive cooling system has some disadvantages also. The passive cooling system does not work when the ambient temperature is low and when the weather is cloudy. It does not work on a rainy day. It needs extra money to install a building. The increase of natural ventilation is not good. The increased insulation plays a vital role in the temperature difference.

Despite have some disadvantages, the passive cooling system can be used to reduce the temperature of the building. As a result, energy consumption can be reduced. The room temperature can be further cooled by using too cooled water in the evaporative cooler.

## 6. Conclusion

The design, construction, and performance test are done for the passive cooling system of a model building. From the date, it is showed that the passive cooling system increases the thermal comfort of a building. The system has a solar chimney, evaporative cooler, and additional wall insulation for cooling of the building. It gives a lower temperature than the reference building and the ambient temperature. It is easy to install and no extra energy is needed to run the system. If the water of the evaporative cooler has a too low temperature, the efficiency will be high. The temperature of the passive model building is 2-3 degrees Celsius lower than the reference building and 3- degrees lower from the ambient temperature.

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