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Alternative Room Cooling System

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ABSTRACT: *The rapidly growing population results in an increasing demand for much more residential and commercial buildings, which leads to vertical growth of the buildings and needs proper ventilation of those buildings. Natural air ventilation system is not sufficient for conventional building structures. Hence fans and air-conditioners are must to meet the requirement of proper ventilation as well as space conditioning. Globally building sector consumes largest energy in heating, cooling, ventilation and space conditioning. This load can be minimized by the application of solar chimney and modification in building structure for heating, cooling, ventilation and space conditioning. Passive solar cooling is a subject of interest to provide cooling by using the sun, a powerful energy source. This is done for ensuring human comfort in hot climates. ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) defines Comfort as 'that state of mind which expresses satisfaction with the thermal environment.' The present paper describes the development of a solar passive cooling system, which can provide thermal cooling throughout the summer season in hot and humid climates. The constructed passive system works on natural convection mode of air. Such system reduces the inside temperature of up to 5°C from the atmospheric temperature. Temperature can further be reduced by the judicious use of night ventilation.*

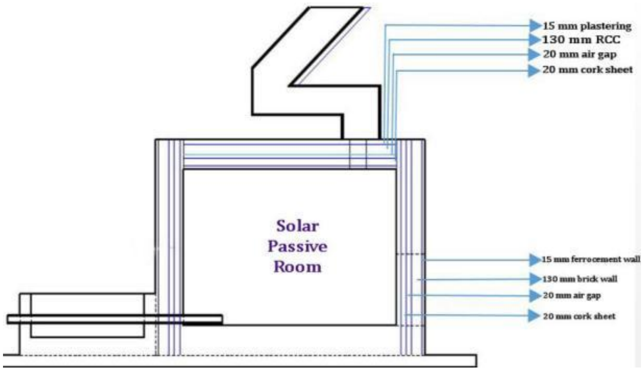
Keywords **-** *Passive cooling, Human comfort, Solar chimney*

I. INTRODUCTION

The residential and commercial buildings consume largest amount of energy (almost 40% of total country's energy consumption) every year. And 50-60% of this energy is because of heating, ventilation and space conditioning in buildings [1]. Cooling means the transfer of energy of air from a space in order to maintain lower temperature with respect to natural surroundings. Comfort is that state of mind which expresses satisfaction with the thermal environment [2]. In regions with hot and humid climates, excessive heat is the major problem which causes human thermal discomfort [3]. Then cooling becomes the vital requirement for the people in the buildings. In modern buildings, this is accomplished thru mechanical and electrical instruments which cause greater energy consumption as told earlier. With the advent of the energy crisis, there had been a renewed interest in those aspects of architecture which contributed to thermal comfort in a building without or with minimum energy consumption in hot and humid climates. There are numerous techniques for passive heating in cold climates; such as direct gain, trombe wall, transparent insulation etc. [4]. Solar passive cooling techniques are not so much well-established as well as well-standardized like the solar passive heating techniques due to the dependency on the judicious use of night ventilation, shading, evaporative cooling etc. Ancient methods of cooling in arid zones have been described in Bahadori [5], and a summary of the state-of-art of passive cooling systems has been given in Givoni [6]. Hay's sky-therm system was tried in India several years ago, but no systematic follow-up studies were made [7]. Some of the techniques used for passive cooling do not remove the cooling load of a building itself, but rather extend the tolerance limits of humans for thermal comfort in a given space. Natural cooling refers to the use of natural heat sinks for excess heat dissipation from interior spaces, including ventilation, ground cooling, evaporative cooling and radiated cooling. So, by the combination of different passive and natural cooling techniques, it is possible to prevent overheating problems, decrease cooling loads and improve comfort conditions in buildings [8].The present paper describes the research and developmental efforts of a solar passive cooling system for providing thermal cooling inside a building throughout the summer season in hot and humid climates.

II. M ETHODOLOGY

The solar passive model (Fig.1.) consists of a solar chimney or solar air heater or simply a ventilator. This solar air heater is placed on the roof which acts as an exhaust fan by sucking hot air from room and venting it out during daytime. On the ground level, there is a bottom collector which is used as an evaporative cooler. This bottom collector is nothing but a water tank. A copper duct of circular cross- section is kept inside the collector. One end of the duct is connected to the room and the other end is open to atmosphere. The copper duct is completely immersed in the water tank. The collector is insulated and shadow is provided above the collector to neglect radiation absorption. Hot and light air moves out thru the chimney, and at the same time cool air gets in the room thru the copper duct due to creation of negative pressure inside the room.



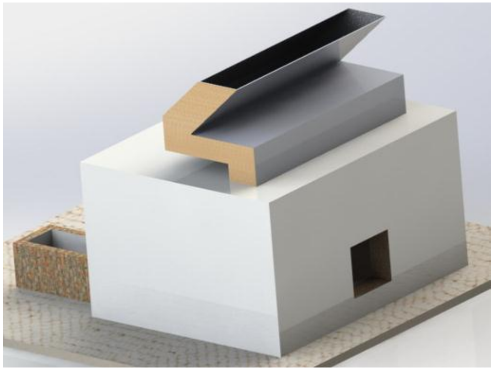


Fig 1: Cross-sectional view of solar passive cooling model **Fig 2:** 3D view of solar passive cooling model.

III. DESIGN

3.1. Reduction of Total Thermal Load of an Ordinary Room thru Modification

The existing single room is 5 feet long, 4 feet wide and 3 feet high. The longer side is oriented along the east-west direction. It has masonry brick walls of 130 mm (5 inch) thickness, with a reinforced concrete slab of 100 mm (4 inch) thickness. A wooden door of area 2 ft2 is provided on the north facing wall. A standard thermal network analysis was planned to find out the total thermal conditioning load of the building for a design inside-outside temperature difference of 5˚C, which was found to be as 66.70 Watt. In order to reduce the total thermal conditioning load of the room, some retrofitting measures were carried out.

- The door was insulated by adding a cork sheet of thickness 2 cm.
- All the four walls were insulated from outside atmosphere by providing a 2 cm cork sheet and a 2 cm air gap. Ferrocement cladding was constructed around the walls to create the air gap.
- The roof was insulated by providing a 2 cm cork sheet. In addition, a wooden sheet was providing for creating the air gap. Applying the thermal network analysis again, the total thermal load of the modified room was calculated to be as 23.25 Watt.

3.2. Solar Chimney Design

Basically the solar chimney is nothing but a solar air heater operating under natural convection mode. The solar chimney considered for analysis is a collector (made by sheet of mild steel) of 51 inch length and 48 inch width. Glaswool insulation is provided in the bottom and the sides are made up of wood. The north facing, open loop system is set with a tilt of 45° from horizontal, has an air flow passage below the absorber plate.

3.3. Evaporative Cooler Design

The evaporative cooler is an insulated water tank, in which a copper pipe (of 3 inch diameter) is immersed. One end of the pipe is opened to the atmosphere and the other end is connected to the room.

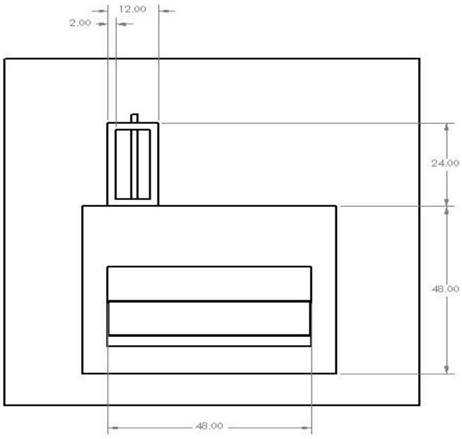


Fig 3: Front-view of solar passive cooling model.

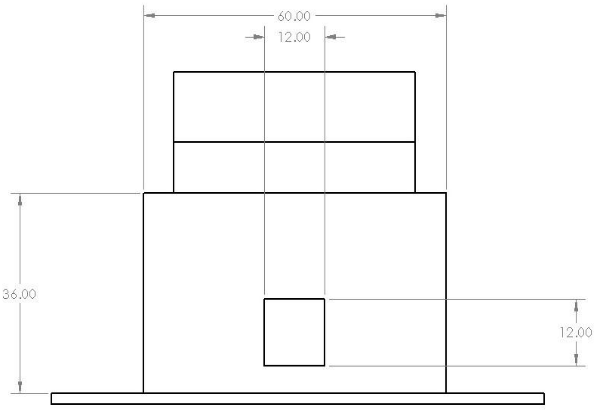


Fig 4: Top-view of solar passive cooling model.

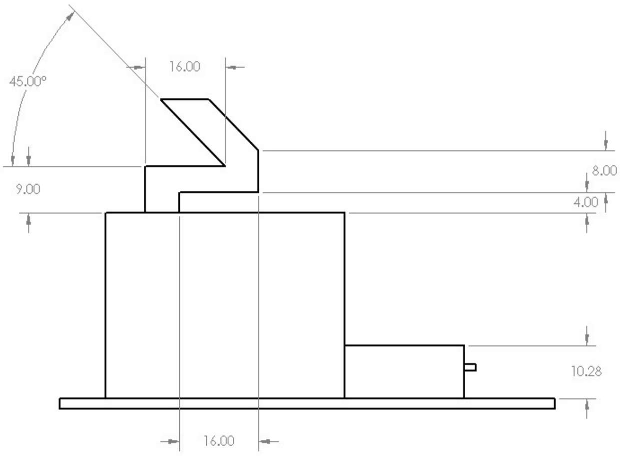


Fig 5: Right-side-view of solar passive cooling model.

Fig 6: Photograph of constructed solar passive cooling

IV. PERFORMANCE ANALYSIS

An ordinary room (5ft X 4ft X 3ft) of similar size as the solar passive room is selected as the reference/ordinary room. Fig. 7 to fig. 11 illustrate various temperature variations from 21st May, 2014 to 25th May, 2014. It can be seen that, the passive room maintained temperature at about 4˚C to 5˚C below the ambient condition and at about 2˚C to 3˚C below the reference room temperature, which can be considered as comfortable.

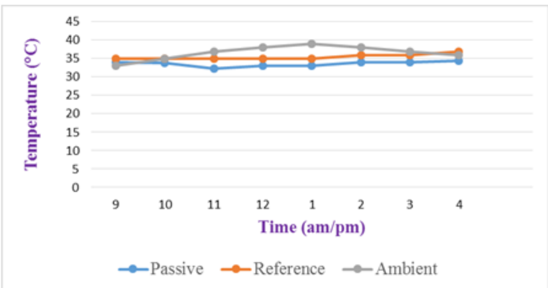


Fig 7: Variation in temperature between passive room, reference room and ambient atmosphere (for May 21st, 2014).

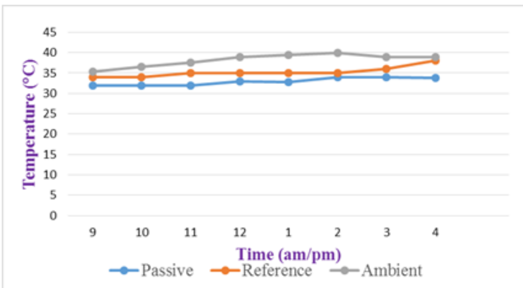


Fig 8: Variation in temperature between passive room, reference room and ambient atmosphere (for May 22nd, 2014).

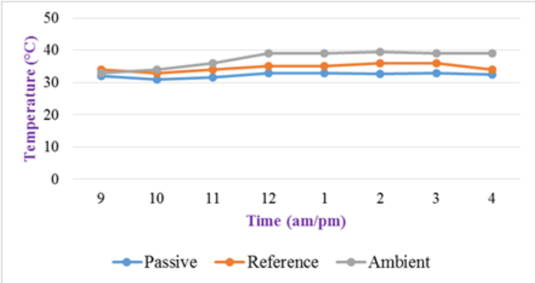


Fig 10: Variation in temperature between passive room, reference room and ambient atmosphere (for May 24th, 2014).

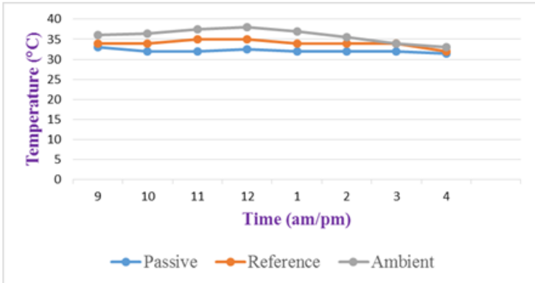


Fig 9: Variation in temperature between passive room, reference room and ambient atmosphere (for May 23rd, 2014).

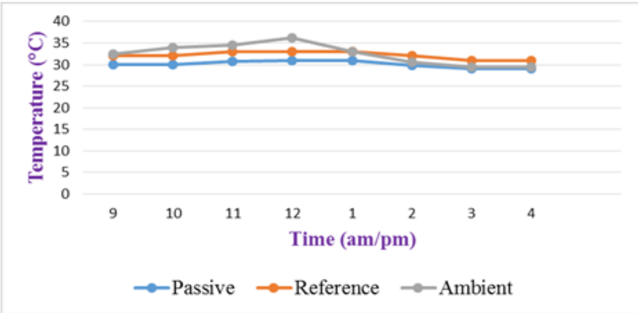


Fig 11: Variation in temperature between passive room, reference room and ambient atmosphere (for May 25th, 2014).

V. DISCUSSION

A solar passive cooling system consisting of solar chimney, evaporative cooler and additional wall insulation described in this paper seems to have good performance for providing thermal cooling in summer season. It also has the ability to reduce the thermal conditioning load of buildings in summer season. This system can be easily adopted to existing single floor houses. Performance data are taken for an empty room. Thermal loads due to human activity, appliances, metabolism etc. will affect the performance. However, judicious use of night ventilation will enhance the performance. The incremental cost of providing solar chimney, evaporative cooler and wall insulation was estimated to be about 10% of the cost of a conventional room. Thus the passive system described in this paper seems to have good potential, judging from the rapidly increasing cost of electricity and deteriorating power situation.

VI. CONCLUSION

The solar passive cooling system for summer season has been tested on an experimental room in Khulna University of Engineering & Technology, Bangladesh. The experimental data has proven the effectiveness of the system in comparison to a reference room and ambient temperature. Hence, cooling inside buildings can be improved by the application of such a passive cooling design.

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