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Experimental Analysis of Solar Chimney with Thermal Mass

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Abstract—*Natural ventilation driven by a solar chimney attached to a single room building was studied experimentally. The experiments were conducted in a real time scenario. During the experiments, the thermal mass on one side of the chimney was heated by means of solar radiation.*
Results showed the difference on using the thermal mass like granite, marble, brick. The flow pattern and the various parameters like air flow, radiation input were studied.

1. INTRODUCTION

Solar chimneys are a form of passive building design. Solar chimneys are generally tall, wide structures constructed, facing the sun, with a dark coloured, matt surface designed to absorb solar radiation. As the chimney becomes hot, so it heats the air inside it. The hot air rises up the chimney and is vented out of the top, and in so doing it draws more air in at the bottom of the chimney.

Solar chimneys are particularly effective in climates that are humid and hot. They are most efficient when they are tall and wide, but not very deep. This maximizes the surface area that can absorb solar radiation and maximizes the surface area in contact with the air inside the chimney. Variations in design can incorporate multiple chambers to further increase surface area and may use materials with high solar absorption such as metal to maximize the temperatures achieved within the chimney. Low emissivity coatings, and glazing can also be used to reduce heat losses back to the outside, similar to the design of trombe wall.

The thermal performance of solar chimneys using different configurations has been experimentally investigated by different researchers. One of the most complete studies on a full scale chimney made under laboratory conditions was carried out by Bouchair [1,2]. The chimney's dimensions were 2 m high, 3 m wide, variable depth (0.1–1.0 m) and two values for inlet (0.1 m and 0.4 m high). The chimney was part of a room of 12 m3 in volume. A theoretical and experimental study on a Metallic Solar Wall of a chimney (MSW) was carried out by Hirunlabh et al. [3]. The MSW was built and placed on the south wall of a room of 31m3 in volume, the chimney's dimensions were varied 1–2 m height, 0.1–0.145 m depth and 1 m wide. Optimal ventilation was achieved for chimney's dimensions of 2 m high and 0.145 m deep. Four passive systems coupled to a room of 25 m3 in volume were studied by Khedari et al. [4], those systems were: the roof solar collector (RSC), the modified Trombe wall (MTW), the Trombe wall (TW) and the metallic solar wall (MSW). The results showed that the room air temperature was decreased between 3 and 6°C using these passive systems, so that natural ventilation was enhanced.

2. EXPERIMENTAL SETUP

The apparatus was designed to study the effect of the thermal mass on air flow and heat transfer in the cavity. The thermal capacity of the material around the cavity may be large in relation to the thermal changes taking place in it. The heat removed by the air is small in relation to the heat stored in the walls. The observations were made in real time conditions, to study the diurnal variation and its effect on the system. The cavity had two parallel surfaces made of plywood coated with white to reflect all unnecessary radiations on it. The distance between the side walls were kept constant (0.2m). Glass was fitted along the direction perpendicular to the side wall. Plywood was used as insulation board for the thermal mass. Aluminum based channels were fitted to provide support to the stacked thermal mass. The thermal mass used were varied with the cases of granite, marble and brick.

To simulate a real building, a test room of external dimensions (1.83m wide, 2.11m height, and 1.83m length) was constructed. The room was constructed with an unshaded window of size 0.6*0.6mts and a door made of PVC of size 1.97*0.83mts. The window was positioned on the east facing wall and the door was on the north side of the room. The ventilation was largely based on the opening and closing of the PVC door. There was a small opening of size 0.2*0.2mts made on the base for the cavity of the solar chimney.

Fig. 1: Layout of the test room

The thermal mass was varied in three cases with marble, granite and brick. The width and the length of the cavity of the solar chimney were kept constant to study the change in these cases. The incident solar radiation acted as the heat source in all cases. Heat loss of the apparatus was reduced using an insulation of plywood of 12mm thickness. The gaps and cracks were sealed using polystyrene foam.

The room was left unpainted to study the effect of paint as a resistance medium in the heat transfer to the inside environment.

Temperatures were measured by using RTD based thermocouples at various entry and exit points.

2.1 Measurement Apparatus

Air temperature at the inlet and the outlet of the solar chimney was required to study the rate of heat transfer. The RTD based thermocouples of type 'TI 141' from Sansel instruments were employed. The temperature leads were made of stainless steel for rugged usage.

2.2 Measurement Procedure

The apparatus was built to measure the speed and the temperature of air at a real time scenario. The thermocouples were positioned after conducting a trail run. The room temperature was measured by means of taking the average of the thermocouples positioned at various points. The inlet and outlet of the solar chimney was also noted by means of the thermocouples.

Obstructions were moved from the way to allow free air flow. Only one probe was used in all the cases to prevent any hindrance to the air flow.

The objective of this paper deals with the effect of thermal mass on the performance of the solar chimney and on the cooling effect of the room.

3. RESULTS AND DISCUSSION

The experiments were conducted during the daytime between 9.00 and 15.30 hours on different days. The readings were taken at the duration of ten minutes. The three thermal masses which were used had various results which can be comprehended from the graphs shown.

3.1 Pressure drop in the chimney cavity

The cavity of the chimney experiences a pressure drop due to change in density along the cavity. Therefore there is a drop in pressure which helps in analyzing the performance of the chimney.

As for the case of granite, the drop in pressure is comparatively high when compared to all the three cases.

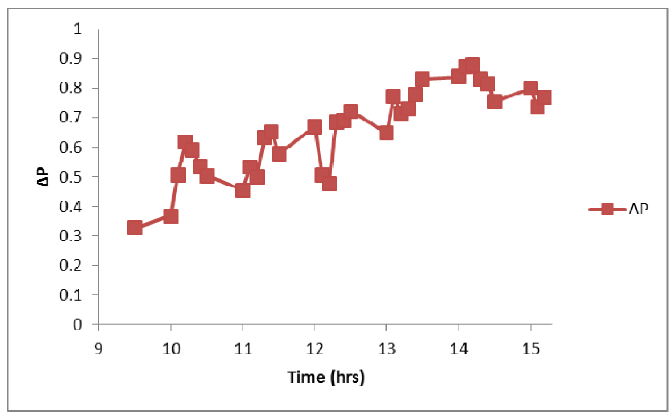

Fig. 2: Pressure drop across the cavity (SC-Granite)

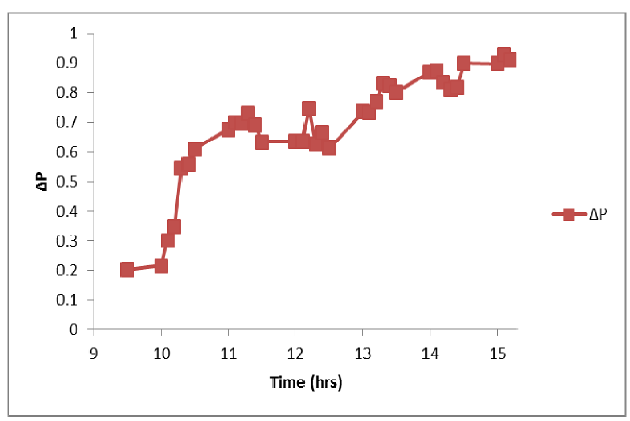

Fig. 3: Pressure drop across the cavity (SC-Marble)

Finally in the case of brick in the solar chimney, there is a constant pressure drop. But, unlike all the other cases, the pressure drop is only around 0.65. But, we can see a constant drop across the day even during the absence of radiation.

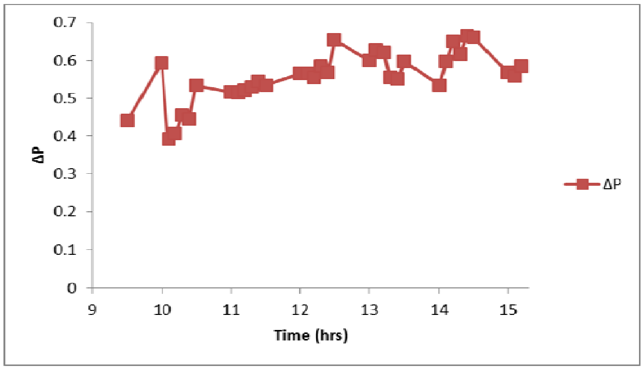

Fig. 4: Pressure drop across the cavity (SC-Brick)

3.2 Stack effect across the chimney cavity

Due to direct solar radiation across the glass, there is a temperature rise across the channel of the solar chimney. The rise in temperature varies with respect to the thermal masses which are used in all three cases of granite, marble and brick. The temperature rise across the channel is found to be high which is directly related to the stack effect and is because of radiation throughout the day. But the high draft is seen only when sun approaches west.

The stack draft was found to be high at 15.15hrs at 0.033 which was found to be high in all three cases in the marble chimney.

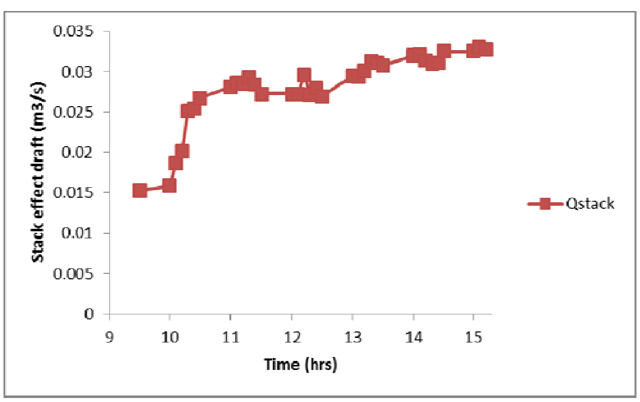

Fig. 5: Stack effect in the marble chimney

The maximum draft reached across the channel using brick was found to be around 0.028 during 14.15hrs. In comparison with the other chimneys, there is a constant draft experienced in the case of brick based cavity.

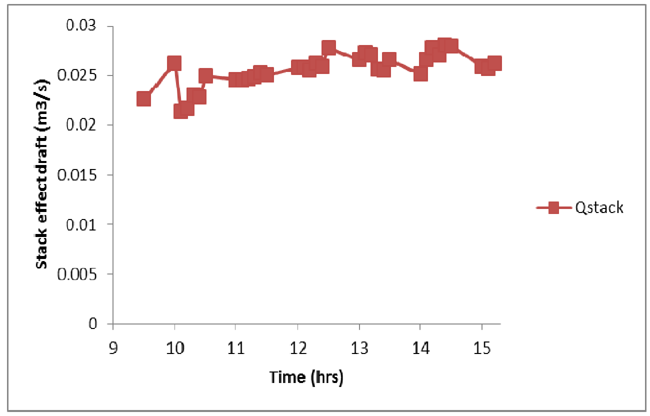

Fig. 6: Stack effect in the brick chimney

As for the case of granite chimney, the maximum draft reached across the channel using granite was found to be around 0.034 during 14.30hrs. The draft was almost close in comparison with the case of marble based chimney.

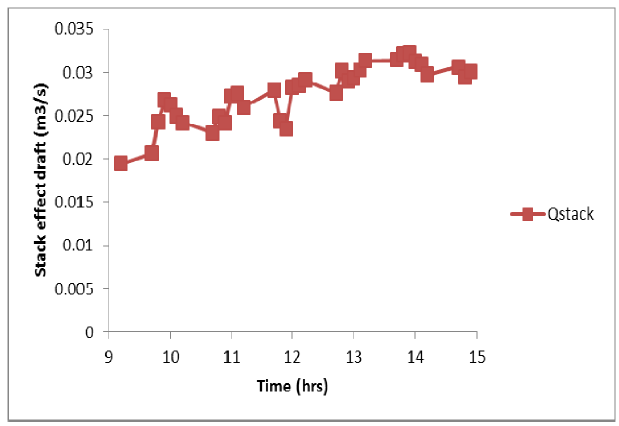

Fig. 7: Temperature rise in the granite chimney

4. CONCLUSION

Marble and Granite was found to perform effectively during daytime but it must be noted that brick was found to absorb the maximum heat during the day time from the solar radiation thereby favouring night time ventilation. The night time ventilation is recommended for the continuation of the process in the absence of radiation where the brick was found to be effective. The maximum draft was noted with marble and granite chimney. Due to the specific heat capacity of brick, the time it retains heat is pretty low. As the tests were conducted on different days, the cases of marble and granite cannot be effectively compared.

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