



Enhancement of Natural Ventilation in a Room with Combination of Solar Chimney and Mirror

Leelendra Wasnik¹, Dr. V N Bartaria²

leelendra1@gmail.com, vnbartaria@lnct.ac.in

¹ PhD Scholar, Department of Mechanical Engineering, LNCT University Bhopal India

² Associate Professor, Department of Mechanical Engineering, LNCT University Bhopal India

Abstract

Solar chimney is a natural passive system that creates thermal comfort, ventilation, cooling, and heating effects effectively solar chimneys also save lots of power generated in terms of money. At least 60 percent of power consumption is utilized for cooling purposes domestically and commercially. If the solar chimney ventilation effect/performance is raised that can be much support for ventilation purposes like in India. In this experimental research, we applied a 4x4 feet square mirror reflector with a solar chimney to increase the absorber plate temperature, due to the rise in absorber plate temperature air movement will be fast, and as a result, we get more ventilation effect in the room compared to the application of mirror in the solar chimney with almost same parameters and conditions. we observed in this study 15 to 20 percent air velocity in m/s more in the room with a mirror than without a mirror solar chimney.

Key-Words : Solar Chimney, Solar chimney with Mirror Reflector, Solar Chimney Ventilation, Thermal Comfort.

Introduction

solar Chimney is a natural ventilation system applied with the passive strategy for cooling/heating and ventilation in a building which produces thermal comfort, the importance of comfort in rural and hot climates is great because most of the power supply in the rural areas goes off in developing countries, solar Chimney is also a renewable energy Technology usually it consists glazing cavity metallic absorber plate insulation, etc [1]. At present at least 40% of the Total energy produced is utilized in the residential sector for cooling, heating, or ventilation purposes, also produces 30% of carbon dioxide (CO₂) emissions and the energy demand will rise to 50% by 2050. where the use of mechanical air conditioning systems plays the main role in destroying the ozone layer, acid rain, and other environmental issues. So in our recent work, we have applied a passive strategy for condition rooms with solar chimneys with mirrors.

Literature Review

To enhance the ventilation in the room or building many researchers have tried to find out the best combinations with solar chimneys, there we find some of them from the literature available El Hadji I cisse et al. [2] experimented with solar radiation concentration effect on the collector of the solar chimney and measured analytically solar chimney performance with concentrated collector and without concentrated collectors and compared their performance for experiment used conventional tilted solar chimney with three side concentrated reflectors which increases the solar radiation intensity and due to high concentrated solar radiation absorber plate average temperature is 338.3 °k and during without concentrated reflectors the absorber plate average temperature is 323.81 °k which means the rise of absorber plate temperature is 22.22%, which results due to bouncy effect within the space air velocity increased which enhanced ventilation in the room. here with and without concentrated reflectors air velocity was measured as 0.3m/s and 0.2 m/s respectively, and inclination angle was taken as 50° angle towards sun facing with concentrated reflectors fitted with glazing at 45° angle by two sides and in front, from the experiment solar Chimney improved the thermal comfort of the occupants.

Ning Gao et al.[3] designed a solar Chimney with a wind-induced channel to enhance natural ventilation in the room under the combined action of solar energy and wind. used numerical simulation with finite volume method applied for numerical calculations, found maximum ventilation during channel width ratio w_2/w_1 is 0.267 corresponds to maximum mass flow rate 0.591 kg/s and wind speed $u=3$ m/s, also when inclination angle increases from 30° to 90° here maximum ventilation found in 90° inclination angle at solar radiation $I = 600$ W/m² these results found higher ventilation in the room compared to traditional solar chimney. The working principle of this chimney as indoor air enters Channel-I (air from room to chimney) which heats through the absorber plate and glass cover temperature, the hot air density increases and passes upward meanwhile the outer air enters channel-II (air from outside to chimney) through the outer wall opening at a certain speed which pushes existing air to move upward fast and due to this phenomena the circulation of air in the room increased which develops human comfort.

J. Xaman et al. [4] Performed in numerical simulation for heat transfer analysis with three absorbing materials (1) Lightweight Copper plate (2) Phase change material (PCM 46-50) and (3) Heavy-weight concrete wall for solar chimney. Solar radiation is 600 W/m², the Mass flow rate for the copper plate for orientation east, west and South was 0.016 kg/s, 0.019 kg/s, and 0.016 kg/s respectively, where the mass flow rate for PCM was 0.014 kg/s, 0.017 kg/s, and 0.0153 kg/s respectively, orientation for east, west, and South. Whereas the thermal efficiency of a copper plate is 34%, 27%, and 34% orientation for east, west, and South. Similarly, the thermal efficiency of PCM is 28%, 19.8%, and 27.6% respectively for the same orientation direction. Copperplate provides a maximum air velocity of 0.6 m/s and PCM provides a maximum air velocity of 0.45m/s, while concrete walls have lower thermal efficiency, mass flow rate, and air velocity. Hence copper plate and PCM (46-50) material up to some extent improves the ventilation in the room but the concrete wall is not able to generate a ventilation effect.

Jnu Lu et al. [5] studied numerically thermal storage capacity and night ventilation performance of solar chimneys with PCM changing temperatures of 38 C, 44C, 50C, and 63C, results show that PCM of face change of temperature of 38-degree centigrade has maximum energy storage of 4750 KJ/m² maximum ventilation rate of 610 Kg/m², PCM with lower phase temperature can increase the charge ability and discharge ability of solar chimney compare to PCM with higher phase change temperature 44-degree centigrade 50-degree centigrade and 63-degree centigrade. PCM with a face change temperature of 44 degrees centigrade only accounts for 28.6% of the available of solar energy. from glass cover at least 50% of solar energy is lost 2 ambient during day time has the Solar energy utility efficiency is very low. At night hit absorbed by air in the channel is approximately 13% of the Total energy which means the maximum amount of energy stored in PCM is lost to ambient due to radiation through glass cover, To increase night ventilation the radiation heat transfer coefficient of the glass cover has to be.

Kishio Hidaka et al [6] Proposed an energy-efficient building ventilation system that integrates semi-transparent organic photovoltaic (OPV) technology and solar Chimney Technology and found air velocity of 0.25 m/s and electric power generation of approx 1.03 W with artificial light intensity of 320 W/m² corresponding to cloudy weather here OPV device obtained from Konarka Technologies where is small scale prototype model constructed for availability and compatibility of power generation and ventilation. OPV device installed on the surface of solar chimney. Thermal-insulated material Foam polystyrene was used on the outer surface of the chimney and a transparent material polycarbonate plate was used on the inner surface of the chimney, device was partially glued under a polycarbonate plate, and the model was exposed to light from the solar spectrum light source (ES01-297, EKO) and light intensities of 255 W/m², 350 W/m², 350 W/m², 450 W/m², 655 W/m², and 780 W/m², found energy conversion efficiency range from 1% to 1.6% depending on temperature, this integrated technology can also improve ventilation.

Lukas Schwan et al. [7] Experiments to enhance the ventilation effects of solar chimney with wind effect by CFD simulation and Measurement experiment focused on ventilation rate in general and as a function of wind speed with influence by thermal buoyancy effect and solar radiation. Solar Chimneys with wind-driven ventilation systems at the top which offer permanent and sufficient ventilation also avoid negative influences, hands analyzed contribution to ventilation of different kinds of cowls and roof ventilation systems. As a result, with the turbine ventilation system average flow velocity ranges from 0.6m/s to 1.1 m/s different kinds of Cowls are

1) Rotovent Systems cyclone. 2) Rotovent Systems. 3) Rotovent Systems premium. 4) Injection nozzle. which helps to produce a comfortable space.

Marco Manzan et al.[8] investigated a special roofing system behavior for ventilation in a room having a ventilation roof with the wet lower surface of the cavity over which flows external air produces more air flow and cooling effect with Chimney.

Dai et al.[9] parametric analytical study on enhancement of ventilation in the room by the combination of solar chimney and solid adsorption cooling cavity. Both systems work on buoyancy effect induced atmospheric air into the room, to generate cooling effect solar adsorption cooling system components having a flat plate absorber, a condenser, and an evaporator, regenerate absorber during day time because solar radiation heat absorption bed and produce a cooling effect. The water tank stores chilled water from the evaporator circulated by a heat exchanger in a cooling cavity, atmospheric air enters the room passing through the heat exchanger which gets cool, and the cooling cavity continues to draw air into the room due to circulation of chilled water. Cooling increases in the room without changing humidity the arrangements can be applied to both human comfort and cold storage of grain as an energy-efficient and environmentally friendly option.

Ahmed A. Serageledin et al [10] combined an earth-to-air Heat Exchanger with a solar Chimney in a hot arid area and studied the optimization of passive heating, cooling, and ventilation systems. experiment done with a wooden room of volume 8 M³ and 25 x 60 cm opening Chimney, 45° inclination angle, and 1.4 chimney height and room coupled with earth to air heat Exchanger results found wooden room temperature 5°C is less than ambient temperature in summer and 10°C more in winter, also used a fan and found the temperature of wooden room 8 to 9°C less than ambient temperature in summer.

H. Li et al.[11] combined earth-to-air heat exchanger with the solar chimney to find coupled maximum cooling capacity in summer. In experiment earth-to-air heat exchanger, there are two heat transfer modes working in the cooling process first sensible heat transfer mode which reduces and maintains air temperature second the latent heat transfer mode which removes the moisture from the air stream during the cooling process. Experiments done up to 1000 W/m² solar radiation which generates 0.30 m³/s airflow in the room and maintained thermal comfort conditions as indoor temperature 21.3 °C to 25.1 °C while Humidity ratio was maintained as 50% to 70% also found earth to air heat exchanger maximum cooling capacity 3308 W while coupled with solar chimney maximum cooling capacity was 2582 W during natural air flow mode.

R. Elghamry et al [12] experimentally investigated cooling and ventilation effects in a room by a combination of solar chimney geothermal air tube heat exchanger-induced photo voltaic panels. A PV panel was installed at the chimney's backside the chimney and a separate PV panel was installed outside the chimney for power generation and comparison, both facing south direction with 30° and 45° angles with the horizontal. results show that the temperature of the room goes down up to 3.5 °C and changes its air 42 times, whereas the maximum daily heat released from the room is found with a 45° Chimney inclination angle for a natural geothermal earth-to-air heat exchanger- PV system and maximum power output found 70% more in PV panel installed inside the chimney compared with outside the chimney.

KV Rao et al [13] experimentally study on ventilation through solar chimney in real building with full scale in Government woman's Polytechnic College, Bhopal MP solar chimney can move from horizontal to vertical position. They used 30° angle to sun for the study and get data of ventilation in room before applying solar chimney and after applying solar chimney compared and found 15% energy saving with solar chimney.

Experimental Setup

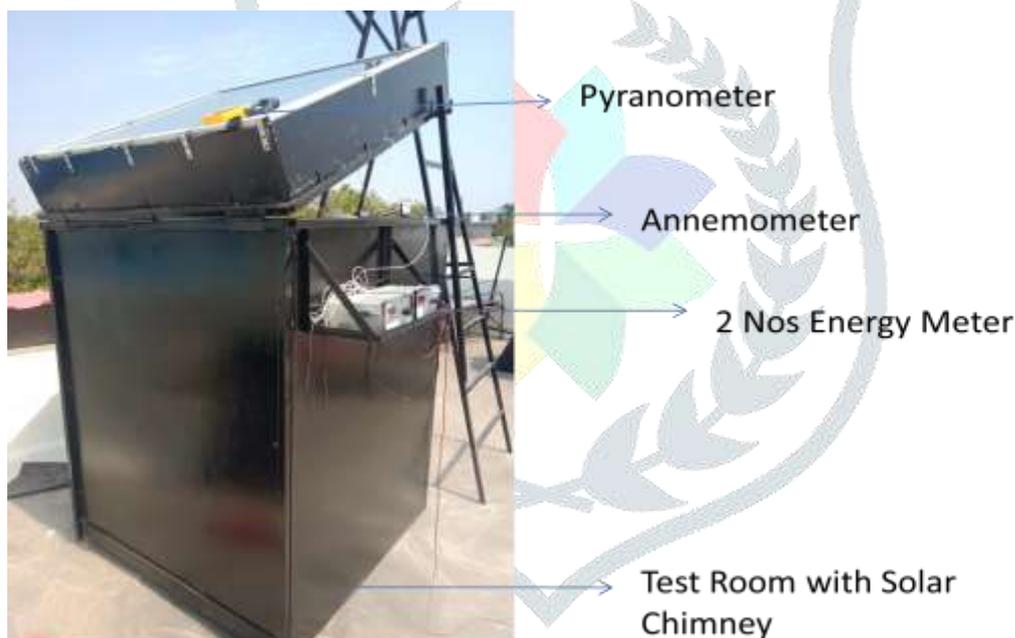


Figure: 1(a) Roof Top Solar Chimney without Mirror



Figure: 2(b) Roof Top Solar Chimney with Mirror

An experimental model prepared of the room made by ply 12 mm thick wall, 5 feet height, 4 feet width and 4 feet length size fitted supported with 3 mm steel frame surrounding for providing strength, joined chimney dimensions 1 feet height, 4 feet width, and 4 feet length made by a same ply of 12 mm thick providing double glass glazing on top with 12 mm gap between glass of 5 mm toughened glass thick provided proper insulation with 1 kg glass wool from the bottom and three sides between GI plate (0.8 mm thick) and Ply to save losses, arranged to extract room air to chimney from passage made by leather airtight, Mirror 5 mm thick 4 x 4 feet square size fitted in ply frame for reflecting solar radiations to chimney. Ply and steel frame fastened properly with screw.

Instruments used-

- Hot wire Anemometer (Make- Testo 405 V1) Ranges from 0.01 m/s to 30 m/s to measure velocity flow inside the room, entering air at the window, ambient air, an inlet of the chimney, the midpoint of the chimney, and exit of the chimney.
- RTD pencil type Temperature sensor, simplex class – B (100 points) MOC: SS-316, size- 6 mm outer diameter with Teflon wire length 3 meters and 5 meters used 19 numbers RTD to measure temperature at different points.
- Multi Point Temperature Indicator (Make – Digiquil, Model- DQ300,12P)
No. of the channel – 12 Nos, Power Supply – 230 V, 1 HP, AC
Range from 0°C to 199.9°C
No. of temperature indicator used – 2 Nos.
- Solar Power Meter (Make- HTC, Lx107)
Range from 0 to 2000 W/m², Resolution: 1 W/m², Accuracy : ± 10 W/m² Or 5%
- Hygrometer ranges from 10% to 100% Relative Humidity.

Experimental Result and Discussions

Table 1 Experiment Readings without Mirror

Sr No.	Time	Air Velocity in m/s	Solar Radiation in W/m ²
1	10 AM	0.16	492
2	11 AM	0.20	577
3	12 Noon	0.26	644
4	1 PM	0.29	672
5	2 PM	0.24	611
6	3 PM	0.19	534
7	4 PM	0.12	365
8	5 PM	0.09	205

Chart -1 Showing graphical presentation of Table 1

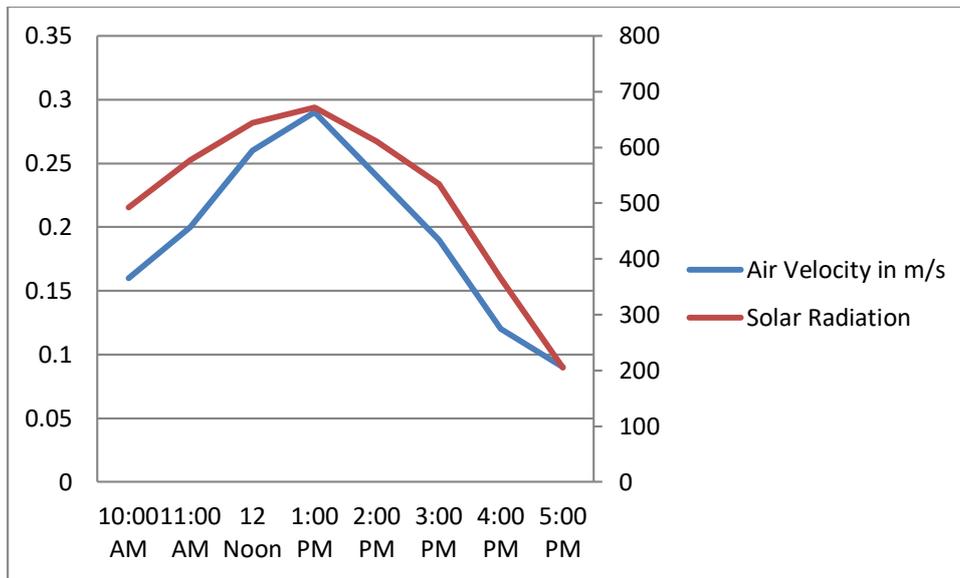
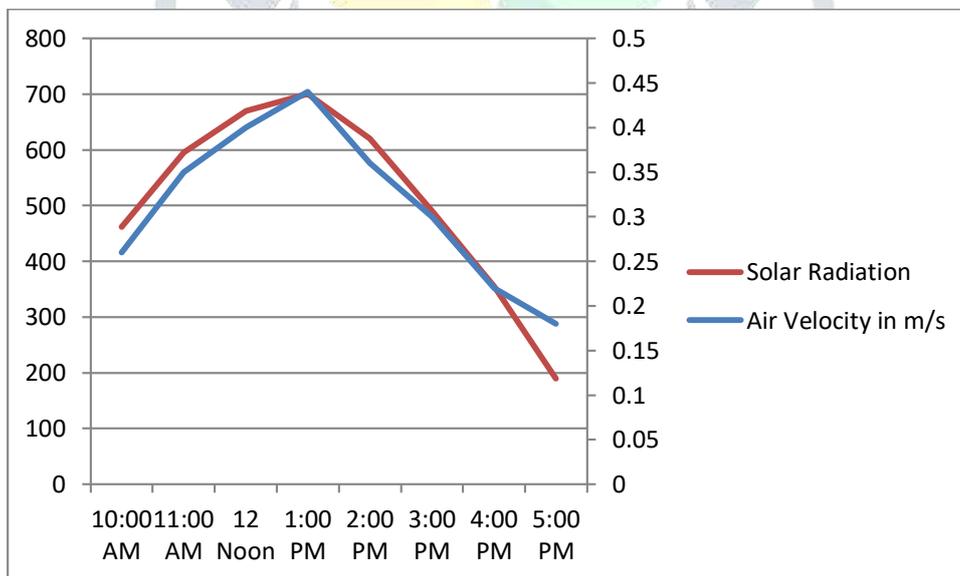


Table – 2 Experiment Readings with Mirror

Sr No.	Time	Air Velocity in m/s	Solar Radiation in W/m ²
1	10 AM	0.26	462
2	11 AM	0.35	595
3	12 Noon	0.40	670
4	1 PM	0.44	700
5	2 PM	0.36	620
6	3 PM	0.30	490
7	4 PM	0.22	355
8	5 PM	0.18	190

Chart -2 Showing graphical presentation of Table 2



The experiment of solar chimney performance without a mirror for our test room was conducted on 10th April 2022 and the same experiment of solar chimney performance with a mirror for our test room was experimented on 11th April 2022 in Bhopal (India), The season was sunny days. The readings were recorded from 10 am to 5 pm and compared to both days' air velocity performance of the solar chimney in the test room. Naturally different days solar radiation was recorded slightly differently. Experimental readings show that the air flow rate in the room was more with a mirror compared to without a mirror solar chimney, as on 10th April at 10 am the air velocity was 0.16 m/s compared to 0.26 m/s on the next day same time, were found maximum air velocity of 4.4 m/s on 11th April compared to 2.9 m/s on 10th April 2022.

Conclusion

In this experimental study, we compared the air Velocity rate in m/s in the test room of length 4feet, Width 4feet, and Height 5feet with a 4x4 feet square mirror reflector which reflects solar radiation to the solar chimney and without any mirror solar chimney air flow rate in m/s in the test room. The results we found in the experiments are as follows:

1. The first experiment readings were recorded on 10th April 2022 and found the maximum air flow rate of 2.9 m/s at 1 pm of the solar chimney without any mirror reflector.
2. The second experiment readings recorded the very next day on 11th April 2022 with almost the same solar radiations found the maximum air flow rate of 4.4 m/s at 1 pm with the use of a mirror that reflects solar radiation to a solar chimney.
3. The temperature of the solar absorber plate increases approximately 20-22 percent which allows fast air movement in the chimney as well as in the test room.

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