



Experimental Analysis of Concrete Slab Solar Collector Using Phase Change Material

¹Vikas Yadav, ²Prashant Saini

¹P.G Student, ² Assistant Professor

^{1, 2} Madan Mohan Malaviya University of Technology
Gorakhpur, Uttar Pradesh, INDIA

Abstract: In the present work, concrete slab solar collector which is used for domestic and industrial water heating purpose is discussed. Heating of water or other fluid is done by solar insolation incident on absorber plate. In this paper concrete slab, a solar collector with phase change material over the copper pipe experiments is done and working methodology is discussed. First absorber plate is fabricated which has 0.5 m² area. glazing over the surface is used. For reducing the heat loss insolation at back and side is used. However acrylic sheet is used over the top surface. Absorber plate is put into an open environment in the south direction for better solar insolation. The experiment is conducted and shows the maximum temperature of outlet water. This present work shows the efficiency of concrete slab solar collector and benefit of using phase change material for heating of water after a sunshine hour. The experiment was conducted at a different tilt angle from 10° to 50°.

Keywords: concrete collector, phase change material, tilt angle

I. Introduction

The crisis of non-renewable sources and depletion of these sources attract the focus of researcher and world environmentalist to move towards the renewable sources. These renewable sources are available in nature without any cost. Wind energy, solar energy, and geothermal energy have a very rich Source in the atmosphere.

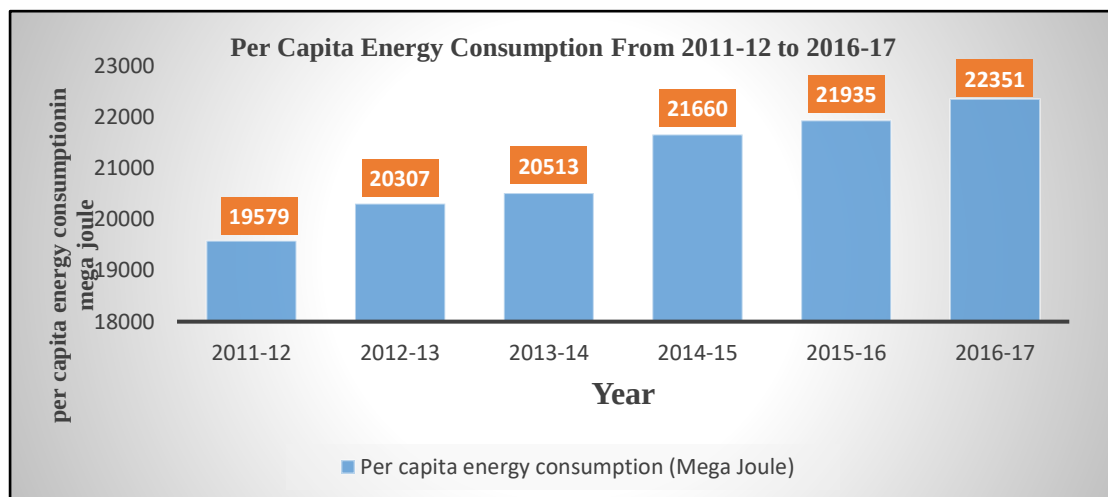


Figure 1: Per Capita Energy Consumption from 2011 to 2017[1]

As in many research, it is shown that solar energy is leading to other renewable sources in terms of the potential of power and availability. In usual, heating of water for domestic purpose need burning of non-renewable fuel like firewood in a rural area and in industrial purpose and urban area fuels like kerosene, coal, LPG and electricity is used. In India, solar energy is available in abundant form so the solar water heater based on concrete slab collector is a reasonable alternative to commercial fuel. Solar water heaters based on concrete slab solar collector has a variety of materials used in their manufacturing like concrete, aluminium galvanized iron, mild steel sheet; glass wool insulation, plain glass or Plexiglas, copper or aluminium pipes, fittings etc. The study on energy inputs

required for the manufacture of different materials points out that metals need a large number of fossil fuels for their production.

A solar water heating system based on flat plate concrete slab collector is mostly used for heating of water for industrial and domestic purposes because of its easy fabrication and simple working. In the given **Error! Reference source not found.** the growing trend in consumption is showing the ever growing energy demand and the upcoming energy crisis. Sustainable development means the use of naturally occurring energy sources in such a manner so as to make it available to the future generation. Sustainability reduces the stress laid on the natural resources. So as consumer demand is increases and supply is not as par demand to decrease this mismatch or to reduce the gap between demand and supply use of renewable sources have to be increased.

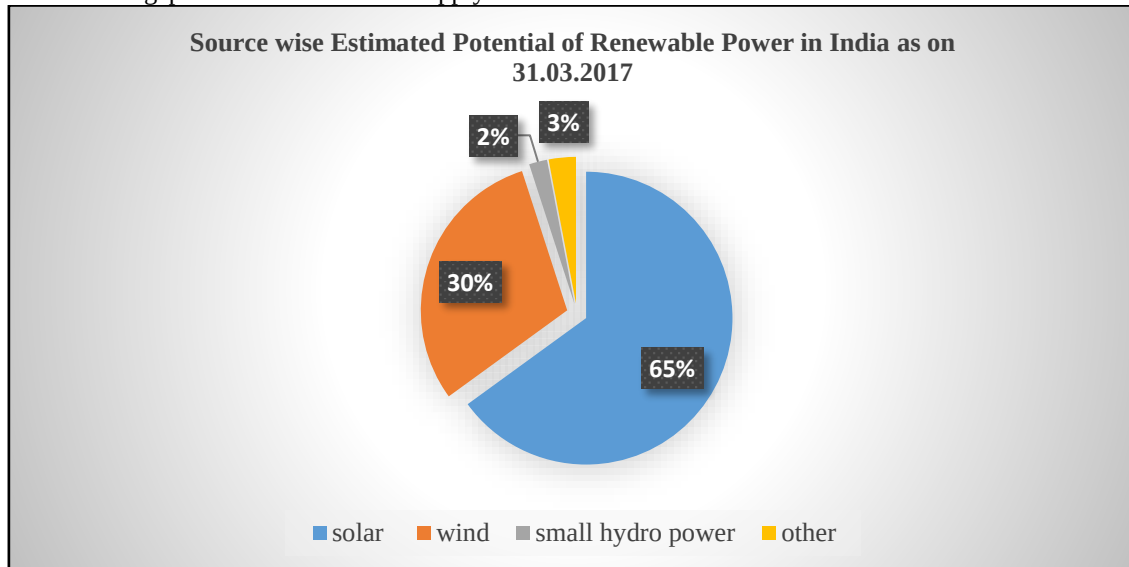


Figure 1: Source wise Estimated Potential of Renewable Power in India as on 31.03.2017 [1]

Solar energy is derived from the sun in the manner of solar radiation. Solar energy storage is categorized into two type (i) active storage (ii) passive storage, in both storage solar insolation is stored in form of heat. In a passive storage system, solar energy is stored in material like concrete, copper plate, aluminium plate etc. and then transfer into flowing medium. A country like India where large energy consumption occurs mainly in domestic and industries. Water heating is one of them which consumed a lot of electricity and in rural areas where electricity is major problem biomass like wood, dung cake, rice husk is used for water heating. As shown in Figure 1 Solar energy is found in a rich manner in India due to its geographical location. So concrete slab solar water heater is the best alternative for a reduction in electricity consumption. Concrete slab solar collector is a device which converts solar insolation into heat and conducted into flowing medium. The solar water heater is basically three type as flat plate collector, evacuated tube collector and concentrated or parabolic collector. They all used in the different climatic condition as per requirement of heat and budget. Here flat plate collector is investigated in this a network of copper, aluminium or PVC pipe is used for flowing of working fluid. For an absorber plate concrete slab, copper, aluminium or galvanized iron plate is used. Using PVC pipe gives better result [2] but copper have better thermal conductivity so in this work it is using for water flow.

II. Experimental setup and procedure

Absorber plate is constructed with the concrete mixture with M-20 ratio in which pebbles, sand, cement is used in a specified ratio. Mixture settled into the galvanized iron box in the same area for preventing heat loss from the bottom. Absorber plate is in the dimension of 1m × 0.5 m and the upper surface is painted black in colour for better absorption of insolation. A network of copper pipe with 12 mm inner diameter is used for flowing of water. Each pipe having 60 mm pitch and margin from the edge of the concrete slab is 55 mm on both side. Copper pipe has 20 mm length outside the concrete slab and connects with plastic pipe with the same diameter and another side of the pipe is connected to the tank.

So phase change material used in this work is paraffin wax which is suitable for working condition. After that, the tank is mounted 1.5 m above the horizontal plane on the iron stand and stopper is fabricated in the stand for different tilt angle. In present work, the tilt angle is taken from 10° to 50°. Absorber plate is insulated by three sides in the bottom there is a G.I sheet which prevents heat loss and traps into the concrete. A cover is used for reducing upper surface heat loss and incident radiation trapped into the gap between absorber plate and cover. A plexiglass (acrylic sheet) is used as a cover into the setup due to better properties. It is mounted over the plate and gap in the side is seal with thermocol. K type thermocouple is used to measure the temperature of water outlet and absorber plate temperature. Anemometer is used to measure the speed of ambient air and ambient temperature.

Solar power metre calculates the solar insolation incident on absorber plate in $\text{w/m}^2 \text{ K}$. Experiment is conducted in the month of April in Gorakhpur and data is recorded at every 60-minute interval from 10:00 A.M. to 6:00 P.M. all the manual and equipment error is considered. The leak-proof connection of absorber plate with water tank is done. Concrete slab solar collector is the type of flat plate collector so the process of water heating in the present system is similar to the flat plate collector. In present work solar insolation incident on absorber plate which is absorb the radiation and get heated and conducted heat to inside copper pipe and phase change material. And then convection phenomenon occurs between the pipe and flowing water and temperature of water increases and outlet water is circulated to tank by natural circulation. In the inlet and outlet temperature difference is occurred and due to this density difference raise the outlet water again into the water tank.



Figure 2: Concrete Slab Solar Water Heating System

III. Result and discussion

Figure 4-8 shows the result of solar insolation on absorber plate at 10° tilt angle. In the present paper, the maximum solar insolation is $1090 \text{ w/m}^2 \text{ K}$ at 10° tilt angle. Efficiency is recorded 51.44% at 2 P.M. at this water outlet temperature is 51° C . figure (5-8) shows the result at a different tilt angle and it shows the variation of insolation and efficiency at a different time. In this experiment maximum efficiency is recorded at 30° tilt angle which is 69.21% . In the given figure it was observed that during off sunshine hour when solar insolation is very low but the temperature of outlet water is high. Phase change material; have a property to absorb heat and releases at a certain temperature. In this paper, paraffin is used as phase change material. It has a low melting point. The melting point of paraffin is $46\text{--}58^\circ \text{ C}$ and heat of fusion is $200\text{--}220 \text{ J/g}$ which is suitable for the working condition. The experiment is conducted at Gorakhpur (26.734° N , 83.336° E) in open environment for better insolation. The efficiency of solar collector is measure and it is seen that phase change material is beneficial for providing hot water after a sunshine hour.

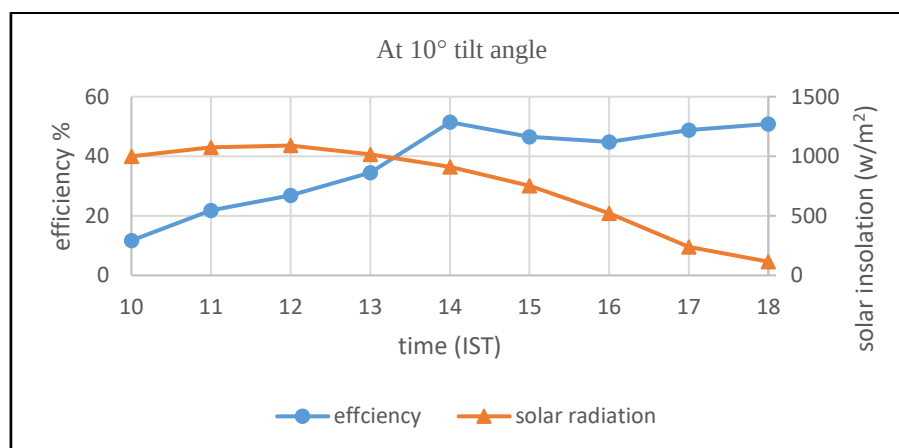


Figure 3: Efficiency and Solar Radiation Comparison at 10° Tilt Angle

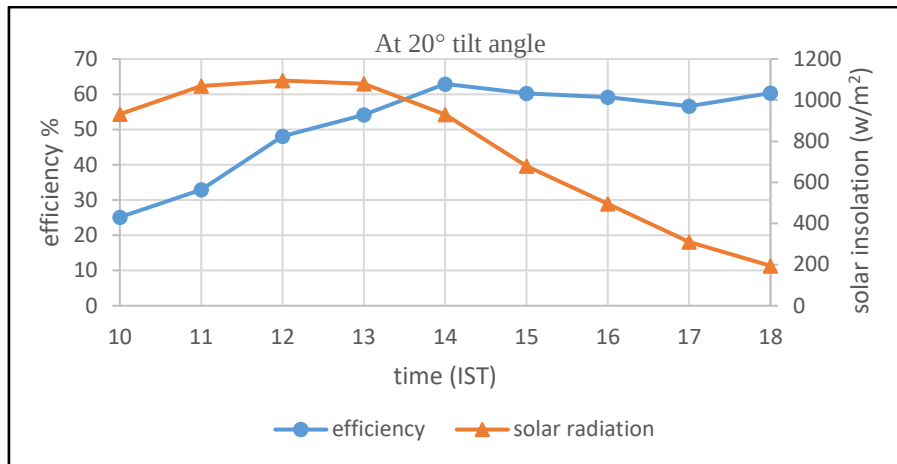


Figure 4: Efficiency and Solar Radiation Comparison at 20° Tilt Angle

From all these curves it is observed that efficiency of concrete slab solar collector is maximum at 30° tilt angle and maximum insolation is got at 12.00 P.M to 1.00 P.M.

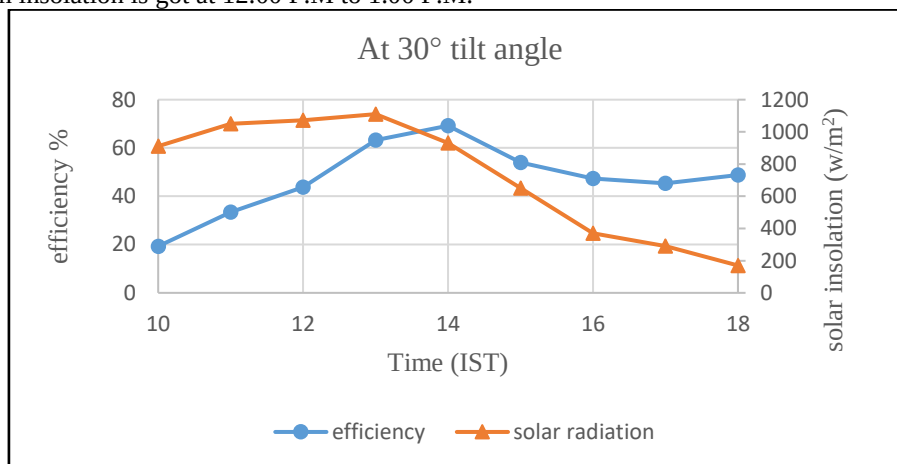


Figure 5: Efficiency and Solar Radiation Comparison at 30° Tilt Angle

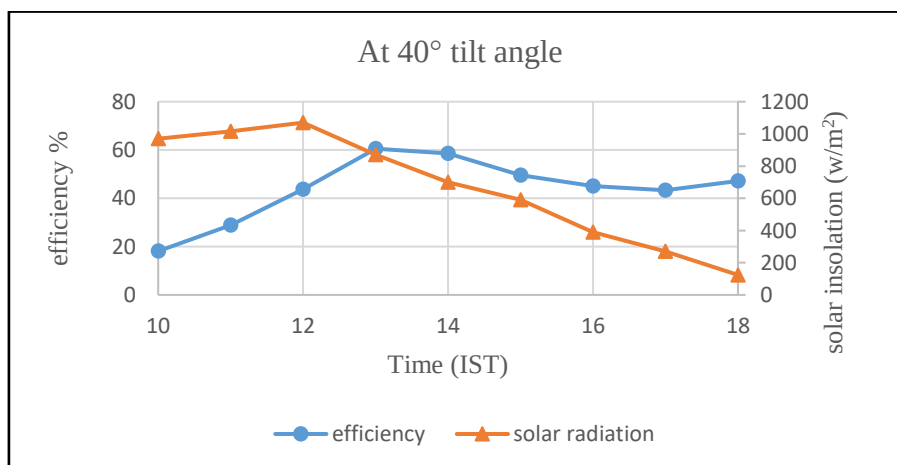


Figure 6: Efficiency and Solar Radiation Comparison at 40° Tilt Angle

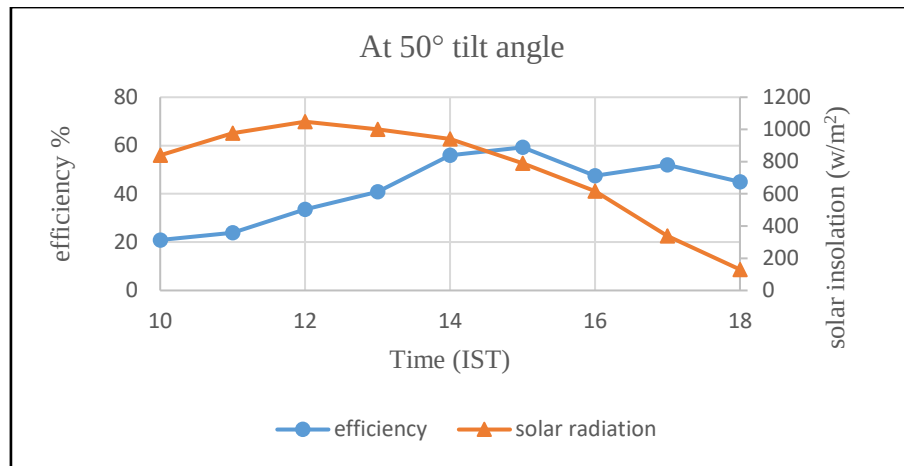


Figure 7: Efficiency and Solar Radiation Comparison at 50° Tilt Angle

The efficiency of solar collector is measured by the ratio of heat consumed by water to solar radiation incident on collector area

$$\eta = Q/IA_c$$

Where Q is heat rejected by absorber I indicate the insolation incident on absorber plate and A_c denotes area of collector (absorber plate) area. [3]

IV. Conclusion

In present work, concrete slab solar collector has experimented for solar water heating and data is recorded. According to recorded parameters and calculated efficiency, it is observed that during low sunshine hour temperature of outlet water is high compared to ambient temperature because of latent heat storage material. The concrete slab solar water heater is also constructed into the roof by some modification in building so cost is reduced. In Concrete slab, solar water heater phase change material gives heat to water due to its latent heat storage capacity and it provides heat also when the sun is not in the sky and continuous hot water is supplied for a certain time period after sunset. It is very useful in rural areas where water is heated by biofuel and coal for the domestic purpose, it is also beneficial in industrial purposes and ton of coal is saved in a year by using this. In industries heat requirement is high so getting that much amount of heat it is possible with an increment of the size of absorber plate and setup. It is recommended for domestic and industrial water heating purposes.

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