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Review Article

Development and Performance Investigation of Solar Concrete Collector at Different Climatic Conditions

Pratik M Waghmare[a*], & Shrishail B Sollapur[b]

[a]Department of Mechanical Engineering, Savitribai Phule Pune University, Pune 411 007, India

[b]Department of International Institute for Aerospace Engineering and Management (IIAEM), Faculty of Engineering and Technology, JAIN (Deemed to be University), Bengaluru 560 069, India

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The current article discusses the study of the Development and Performance Investigation of a Solar Concrete Collector at Different Climatic Conditions. The solar concrete collector is a modification over conventional solar water heaters. This concrete is mainly made up of sand and cement. The solar concrete collector with an area of 2 m^2 has been developed and tested for all three seasons, i.e., rainy, winter, and summer seasons. The inlet water temperatures and outlet water temperatures have been recorded along with corresponding solar intensities for any five successive days in a month. A family of 5–6 peoples requires about 130–150 liters of water daily for bathing and other purposes. So, we have selected a flow rate of 30 liters per hour of water. These observations have been recorded between 12:00 and 16:00PM. Also, hot water temperatures stored in an isolated storage tank are recorded the very next morning. An arrangement consists of K-type thermocouples, a 12-channel temperature indicator, and a pyranometer. Using recorded observations, the performance of a solar concrete collector has been determined.

Keywords: Solar concrete collector, Pyranometer, Solar intensity, Thermocouple, Temperature indicator

1 Introduction

Solar energy is inexhaustible. Thus, solar energy has the potential to satisfy all our present and future energy needs on a continuing basis. This makes it one of the more promising renewable. The Solar concrete collector is a modification over our conventional solar water heaters. The purpose of this modification is to reduce the cost of the equipment without negatively affecting its performance.

The cost of conventional solar water heaters is high due to the use of copper flow tubes and copper absorber plates. Solar concrete collector aims to minimize the high cost of solar collector without negatively affecting their performance[1]. Experimental tests of concrete solar collectors using PVC pipes[2]. Experimental study on the concrete collector with aluminum flow tubes enclosed in its surface[3]. Recently, an experiment using aluminum pipes instead of PVC pipes with the use of unwanted scraps of iron in the cement concrete observed improvements in the collector's efficiency[4]. An experimental analysis of an integrated solar collector using serpentine copper pipes embedded in the concrete over a total area of 2 sq m[5, 6]. The effect of high temperatures around 100°C on concrete is studied, Splitting tensile strength, modulus of elasticity, and flexural strength of concrete reduces marginally, whereas compressive strength increases slightly and no cracks are observed up to 100°C[7,8]. A steel fiber affects the performance of concrete. Reinforced concrete with steel fiber improves fatigue strength, tensile strength, and energy-absorbing capacity, it also reduces water migration and permeability in concrete, ensuring protection from moisture [9-11]. On the building's roof, concrete collectors can be incorporated, removing the need for a separate supporting framework[12]. The aim is to test the performance of a solar concrete collector and thus determine its suitability for water heating purposes at different climatic conditions.

2 Material and Methods

The solar concrete collector consists mainly of a wooden box of dimensions 1*2*0.1 m, concrete, flow tubes, and a glass cover. Concrete is mainly made up of sand and cement. A mixture of cement and sand in an adequate proportion is poured into the wooden

*Corresponding author (E-mail: pratiik.waghmare@gmail.com)

enclosure box. Wire mesh with some scrap is arranged on the concrete mixture. Then, concrete is poured over the wire mesh and scrap. The copper tubes are assembled in a way that keeps their upper half section exposed to concrete. Then the concrete collector surface is painted black, increasing the absorption capacity of the concrete. Finally, glass is fixed to a wooden box with a thickness of 4 mm, which helps to trap energy. This panel is now placed at an angle equal to the place's latitude, with its horizontal south facing. The cross-section of the concrete collector is shown in figure 1, while the top view is shown in Fig. 2.

The actual setup of a solar concrete collector with a storage tank is shown in Fig. 3.

Solar radiation falls on the collector, and this energy is stored in concrete in the form of heat. The Flow of Energy is as shown in Fig. 4. Then heat transfer has taken place in the flow tubes. This is shown in Fig.5.

2.1 Testing of solar concrete collector

For testing of solar concrete collector for the rainy, winter, and summer seasons, the following equipment's used:

1. Thermocouples
2. Pyronometer
3. Temperature Indicator

2.1.1 Thermocouples

These are utilized to count inlet and outlet water temperatures. The temperature measurement range of this thermocouple is 0°C to 250°C. One end of this thermocouple is kept in contact with the water, and the other with a temperature indicator.

2.1.2 Pyranometer

It is utilized to count the intensity of solar radiation. With the help of a pyranometer, we can calculate the total solar energy incident on the collector panel and the solar energy used for heating purposes. A pyranometer is also called a solarimeter.

2.1.3 Temperature indicator

It shows inlet and outlet water temperatures. This device gives a reading in the form of °C.

3 Results and Discussion

To evaluate the effectiveness of the concrete collector in each season, we took readings each month. There would be a total of five observations per day. These observations will be reported from 12:00 until 16:00. After the observation process was complete, the readings would be evaluated and the solar concrete collector output would be calculated.

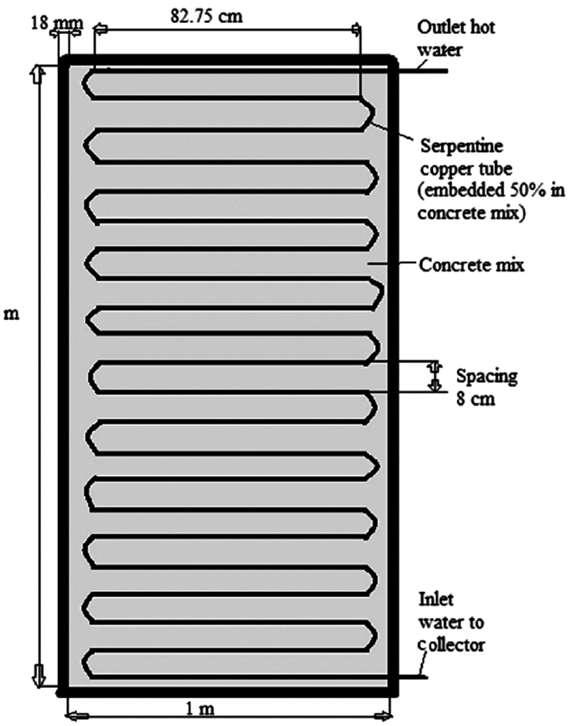

Fig. 1 (b) — Top view of solar concrete collector.

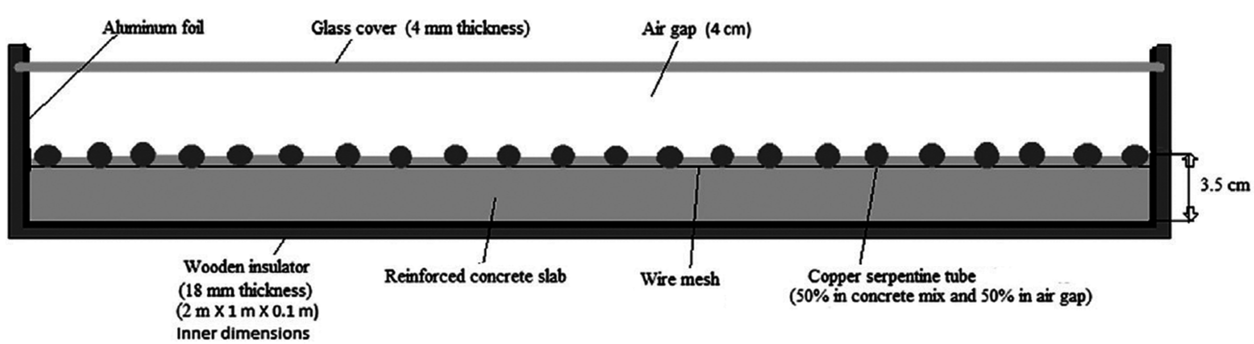

Fig. 1 (a) — Cross-sectional view of solar concrete collector.

Fig. 2 — Experimental set up.

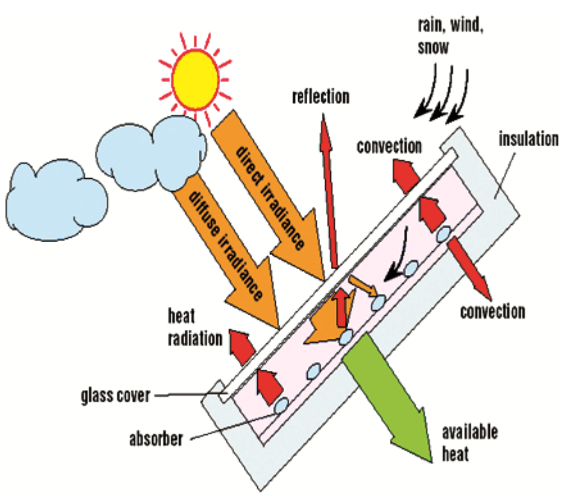

Fig. 3 — Flow of heat.

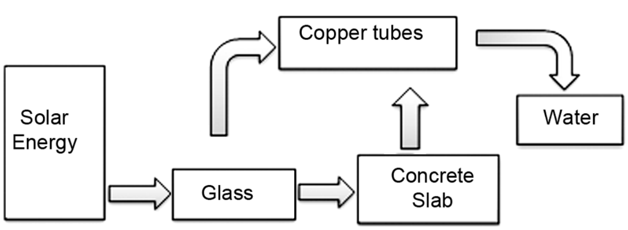

Fig. 4 — Flow of energy.

3.1 Observations for the rainy season (Month of September)

Table 1, shows the observations of the rainy season (September month).

The average temperature of hot water is 47.80 °C. Figure 8 shows the inlet water temperatures and outlet water temperatures for the different time periods.

Incident solar energy, W =Solar Intensity (W/m^2) * Area of collector (m^2)

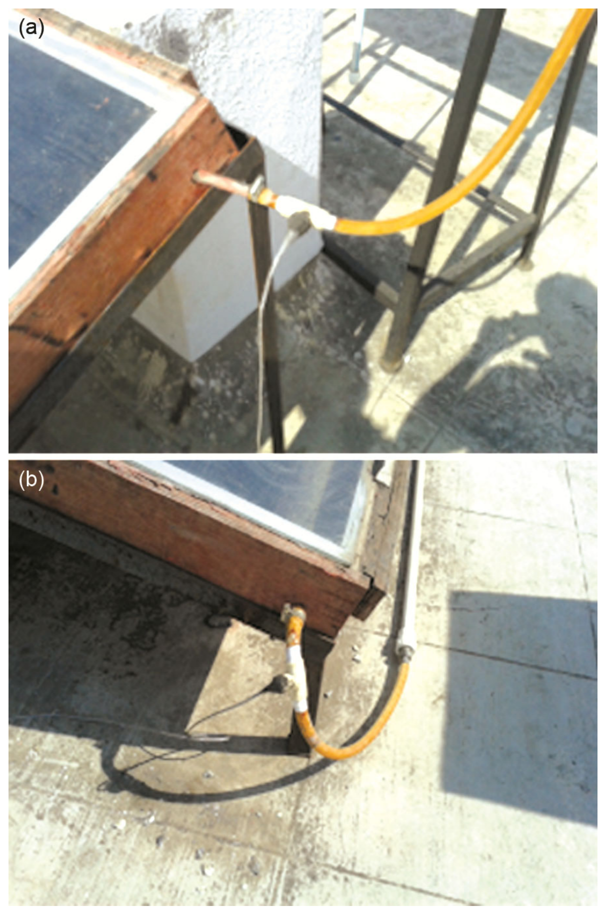

Fig. 5 — Positions of thermocouples.

Useful heat gain = $m * Cp * dT$

Where,

Cp: specific heat = 4.18 kJ/ kgK

m: mass flow rate of water in kg/sec

Figure 9, shows the color combination of blue and brown. The blue color portion indicates the total solar energy incident on the collector panel, while the brown color portion indicates the solar energy used for heating purposes. Some solar energy was reflected from the collector.

3.2 Observations for the winter season (Month of December)

Table 2, shows the observations for winter season (December month).

Figure 10, shows the inlet and outlet water temperatures for the different time period.

Figure 11, shows the color combination of blue and brown. The blue color portion indicates the total solar energy incident on the collector panel, while the brown color portion indicates the solar energy used

Fig. 6 — Pyranometer.

Fig. 7 — Temperature Indicator.

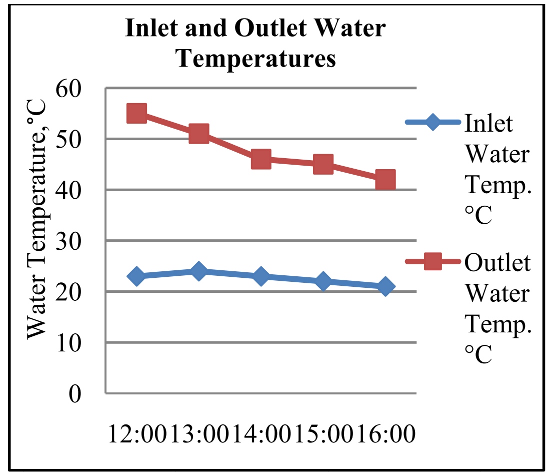

Fig. 8 — Water temperatures with respect to time

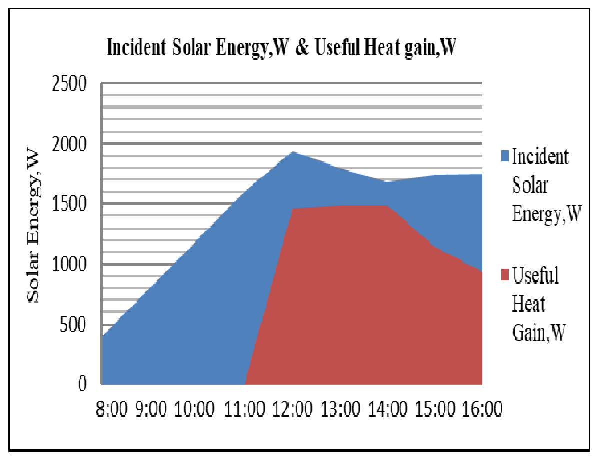

Fig. 9 — Incident solar energy & useful heat gain with respect to time

Table 1 — Observations for the Rainy Season (September month)

Time	Inlet Water Temp. °C	Outlet Water Temp. °C	Solar Intensity W/m^2
12:00	23	55	770.40
13:00	24	51	800.68
14:00	23	46	740.10
15:00	22	45	670.80
16:00	21	42	538.90

Average hot water temperature = 47.80°C
Stored water temperature on very next morning = 43 °C

Table 2 — Observations for the Winter Season (December month)

Time	Inlet Water Temp. °C	Outlet Water Temp. °C	Solar Intensity W/m^2
12:00	23	60	837.40
13:00	24	57	844.71
14:00	25	54	870.25
15:00	25	51	801.42
16:00	24	49	670.70

Average hot water temperature = 54.20 °C
Stored water temperature on very next morning = 49.90 °C

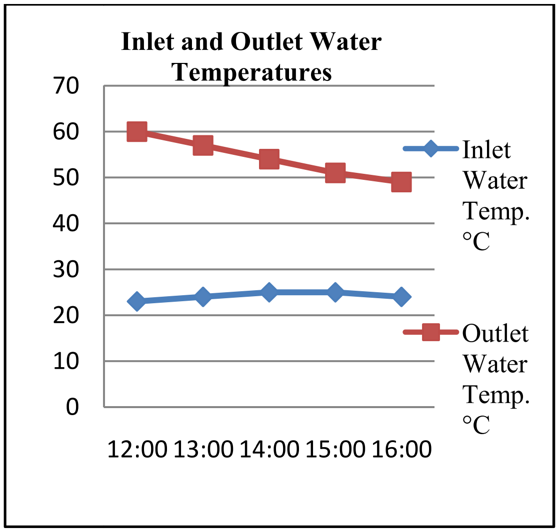

Fig. 10 — Water temperatures with respect to time

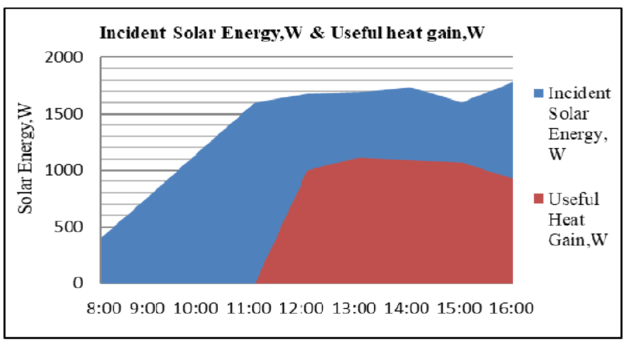

Fig. 11 — Incident solar energy & useful heat gain with respect to time

for heating purposes. Some solar energy was reflected from the collector.

3.3 Observations for the summer season (Month of March)

Table 3, shows the observations of the summer season (i.e., March month). We got an average water temperature of 62.20°C.

Figure 12, shows the inlet and outlet water temperatures for the different time period.

In Fig. 13 the blue color portion indicates the total solar energy incident on the collector panel, while the brown color portion indicates the solar energy used for heating purposes. Some solar energy was reflected from the collector.

4 Conclusion

Developed solar concrete collector's efficiency was tested, and it was discovered that throughout the rainy, winter, and summer seasons, the hot water's temperature ranged from 40 to 55°C, 40 to 61°C, and

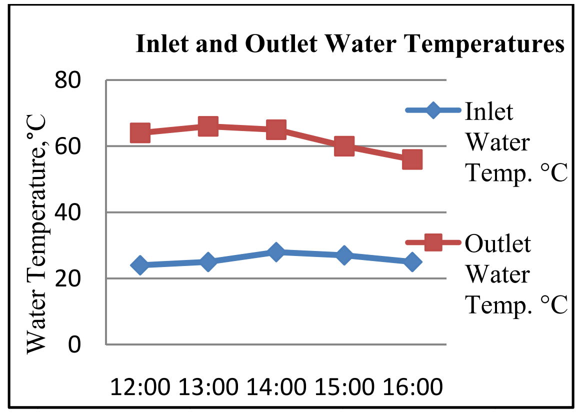

Fig. 12 — Water temperatures with respect to time

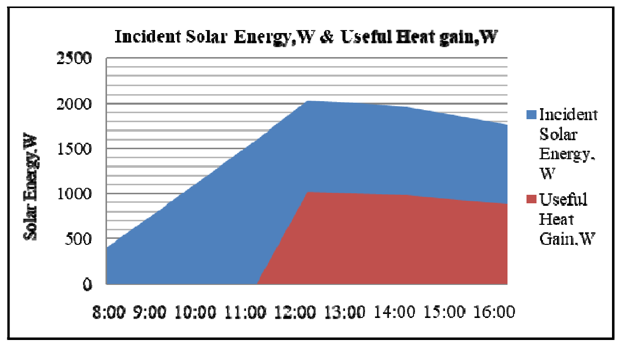

Fig. 13 — Incident solar energy & useful heat gain with respect to time

Table 3 — Observations for the Summer Season (March month)

Time	Inlet Water Temp. °C	Outlet Water Temp. °C	Solar Intensity ,W/m^2
12:00	24	64	1015.54
13:00	25	66	992.67
14:00	28	65	967.92
15:00	27	60	901.94
16:00	25	56	867.37

Average hot water temperature = 62.20°C
Stored water temperature on very next morning = 58.70°C

40 to 66°C, respectively. As a result, we can conclude that concrete collector temperatures can be easily compared to ordinary conventional collector temperatures, which vary from 40 to 70°C. As a result, the solar concrete collector produces enough energy throughout the rainy and winter months, when the demand for hot water is at its highest. This concrete collector can be made in a reasonably simple manner without the use of expert labor, a large workforce, or a specialized workshop. This collector can make at half the price of conventional solar collectors. Anyone can obtain more water by a simple process of manually changing the flow rate of water. This concrete collector

system gives environmental benefits by reducing greenhouse gases and air pollutants, with protection from fuel price hikes and future fuel shortages. Also, these solar concrete collectors can be integrated within a building's roof, eliminating the need for a mounting structure. Thus, a solar concrete collector proves to be a more efficient alternative to conventional solar water heaters.

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