Energy and Buildings 84 (2014) 501–505

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Experimental analysis of concrete absorber solar water heating systems

V. Krishnavel, A. Karthick, K. Kalidasa Murugavel *

Centre for Energy Studies, National Engineering College, Kovilpatti, K. R. Nagar 628 503, Tamil Nadu, India

ARTICLE INFO

Article history:
Received 28 November 2013
Received in revised form 28 June 2014
Accepted 18 August 2014
Available online 27 August 2014

Keywords:
Solar water heater
Concrete absorber
Different inclination
Performance
Building integrated solar water heating (BISWH)

ABSTRACT

In the present work, three different types of solar water heaters with concrete absorber have been fabricated with different collector design, experiments were conducted simultaneously and comparative performance study has been made. First collector has been fabricated with concrete embedded with aluminium pipes for water flow while in second design, thermal conductive material has been added with concrete. In third heater, instead of aluminium pipe, PVC pipes are used. Metallic scrap and wire mesh have been used as a thermal conductivity materials to increase the thermal conductivity of the absorber plate. The collectors were tested at the insolation levels from 300 to 900 W/m during the month of March 2013–May 2013. Experiments were also conducted at different inclination angles of 0°, 18°, and 30°. Possibilities of using open terrace of the concrete buildings as solar waters has been explored.

1. Introduction

Solar collector is a device that collects and converts solar radiation into useful heat which is transferred to the fluid flowing through the collector. The flat plate collectors [1–4] and evacuated tube collectors [5,6] are used as water collector in the different climatic regions. In conventional flat plate collector solar water heaters, copper, aluminium, or mild steel plate embedded with galvanized iron, mild steel pipes are used as absorber, and glass wool or coir is used as insulation material [7–10].

However, to supply hot water to domestic and industrial applications, only little efforts have been made to develop building integrated solar water heating (BISWH) technology[11,12]. Water tube embedded concrete terrace exposed to sun will act as solar collector [13]. Either separate storage tank with circulation technology or integrated collector storage technology can be employed. The investigational results confirms that, the day time thermal efficiency was about 60% and overall efficiencies was about 40% [14]. Comparative performance analysis has been carried out on conventional glazed collectors and the unglazed collectors for heating and cooling. It is concluded that the unglazed collector has the potential of meeting 60% domestic energy needs [15]. The experimental studies were carried out with poly vinyl chloride (PVC) [16] and aluminium [17] embedded in wire mesh shatterproof concrete collector to study the effect of tube-to-tube spacing and the pressure drop. The transient analysis for the collectors was performed and it was evident that solar concrete collector can be used as building components for providing a low cost energy [18]. In the building integrated solar applications, solar photovoltaic technologies [19–21] and solar water heating are in the developing stage. In such cases, domestic user prefers the solar water collector for various applications such as de-icing of roads, bridges, and domestic water heating system depending on its cost effective, reliability easy maintenance and its installations [22–23].

Above study clearly indicates that, solar concrete collectors without glass has the potential to meet significant part of the domestic energy needs and the need to develop suitable BISWH technology. In this work, solar water heating systems with different types of concrete absorber were fabricated and experiments were conducted to compare their performance. Aluminium and PVC piping were used. Wire mesh with metal scraps was used to enhance the thermal conductivity of the concrete absorber.

2. Experimental setup and procedure

Three concrete solar collectors were fabricated with mixture of gravel cement, sand, pebbles, and iron rods The overall concrete dimension was 1.75 m long × 1.28 m wide and thickness 0.10 m. In collector 1 (slab 1) and collector 2 (slab 2),

* Corresponding author. Tel.: +91 9677928940; fax: +91 4632232749.
E-mail addresses: kali_vel@rediffmail.com, kkmmech@nec.edu.in, hodces@nec.edu.in (K.K. Murugavel).

http://dx.doi.org/10.1016/j.enbuild.2014.08.025
0378-7788/

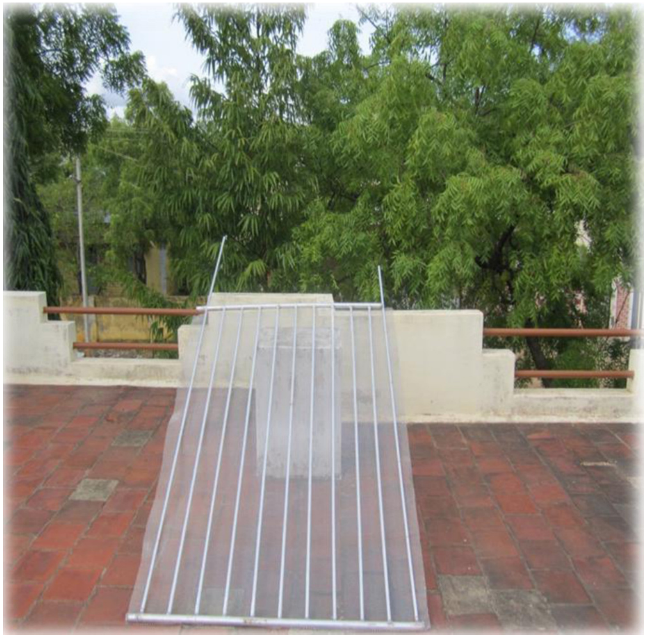

Fig. 1. Aluminium tubing with header and aluminium wire mesh.

to increase the thermal conductivity, along with concrete, aluminium wire mesh and iron scraps were used. Aluminium pipes (11 Nos × 0.0125 m dia × 1.54 m) were embedded in the slab 1 where as PVC pipes (11 Nos × 0.0125 m dia × 1.54 m) were embedded in the slab 2. Collector 2 (slab-2) was made up of thermal conductivity materials and PVC flow pipes. In collector 3 (slab-3), only conventional materials were used for fabrication and PVC pipes were embedded. At the bottom and top, header pipes (2 Nos × 0.025 m dia × 1.14 m length) were used uniformly to distribute the flow to all pipes. Fig. 1 shows the photograph of aluminium pipes with header with aluminium wire mesh embedded in the slab 2. All the pipes were completely immersed inside the slab. The bottom heater pipe had the provision for water inlet which was connected to water outlet from well insulated 60 L storage tank. The upper header pipe was connected to storage tank water inlet and control valves were used to control the circulation and delivery. The concrete solar collector was placed on a steel structure with the provision to adjust the angle of inclination of the solar collector. The collector surface was black painted to increase the absorption. The accuracies and error for various measuring instruments are given in Table 1.

K-type thermocouples were placed to measure water inlet, water exit and absorber plate temperatures. PV type solar radiation meter was used to measure the global radiation. Measuring jar with stop watch was used to measure the hot water flow. The complete solar water heater experimental setups was installed at the Energy Park, National Engineering College, Kovilpatti (9°11′N, 77°52′E) Tamil Nadu, India (Fig. 2). The experiments were conducted during the month of March–May, 2013 for the radiation and atmospheric temperature variation given in Fig. 3. Control valves were adjusted to maintain the hot water flow of 0.02 kg/s during

Table 1
Accuracy and error limits for various measuring instruments.

Sl. no.	Instrument	Accuracy	Range	% Error
1	Thermometer	±1 °C	0–100 °C	0.25
2	Thermocouple	±0.1 °C	0–100 °C	0.5
3	PV type sun meter	±1 W/m^2	0–2.500 W/m^2	2.5
4	Measuring jar	±10 ml	0–1000 ml	10

Fig. 2. Concrete slab solar water heating system slab-1 is made up of thermal conductivity materials and aluminium flow pipes. Slab-2 is made up of thermal conductivity materials and PVC flow pipes. Slab-3 is made up of without thermal conductivity materials and PVC flow pipes.

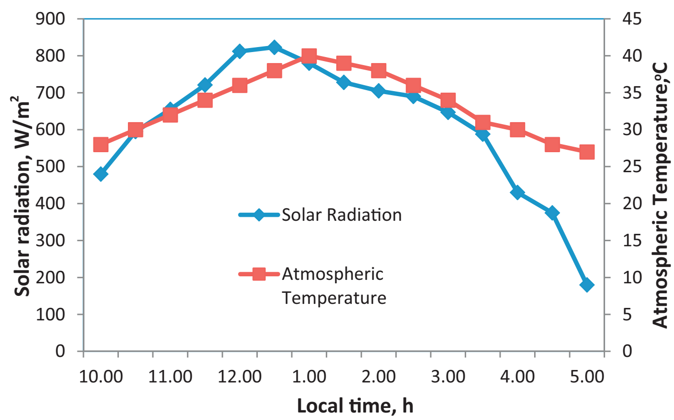

Fig. 3. Variation of solar radiation and atmospheric temperature.

the experiment period. The readings were taken from morning 10 AM to 5.00 PM, for every 60 min interval simultaneously on three types of water heaters. Comparative performance of the systems was studied for three different collector position: (i) horizontal, (ii) with 18° inclination facing south and (iii) with 30° inclination facing south. The experiments were also conducted to compare the performance with and without green cover (Table 2).

Table 2
materials added to make the concrete slab solar collector.

No	Parameters	Specifications
1	Flow and header pipes in slab-1	Aluminium
2	Flow and header pipes in slab-2	PVC
3	Flow and header pipes in slab-3	PVC
4	Header tubes diameter	25 mm
5	Header tube length	1.14 m
6	Flow tubes diameter	12.5 mm
7	Flow tube length	1.54 m
8	Area of collector	1.75 × 1.28 = 2.24 m^2
9	Tank capacity	60 L
10	Thickness of slab	100 mm
11	Absorbing surfaces on concrete slab collector	1. Black paint 2. Green house cover
12	Thermal conductivity material for slab-1 and slab-2	3. Aluminium wire mesh 4. Metal scrap 5. Iron rod 6. Gravels and sand
13	Thermal conductivity material for slab-3	7. Iron rod 8. Gravels and sand
14	Testing of concrete slab solar water heating system	9. Horizontal plane 10. 18° due south 11. 30° due south