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Investigation of Concrete Solar Collector: A Review

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ABSTRACT : *Concrete collectors offer a promising and viable solution over the conventional collectors used today. Concrete has the dual advantage of having high storage capacitance as well as its freedom from corrosion due to alkaline nature of cement. Concrete is the most promising material among low cost energy materials as it is a very common building material and its technology is well established. The present work reviews the literature produced so far on concrete collectors with the aim of sharing the information here gathered for future developments. Therefore it is planned to use metal fiber reinforced concrete for storage cum insulator base of solar collector. Metal fibre reinforced concrete have the advantage of increased thermal conductivity due to inclusion of metal fibres. The proposed work is concerned with the experimental setup of a cheaper and economical 2m X 1m solar concrete collector and analysis of its performance. The objective of present work is to find out daily efficiency and average temperature of the output hot water.*

Keywords: *Metal fibre reinforced concrete, Storage capacitance, Thermal conductivity*

1. INTRODUCTION

A large amount of metal like copper, aluminum etc.is used in conventional flat plate-collector systems. But studies on energy inputs required for the production of different materials indicates that metals need a large amount of fossil fuel energy for their production of different materials indicate that metals need a large amount of fossil fuel energy for their production. Furthermore, individual collector module is connected to form a large array to meet the required demand. Thus, the solar system forms a separate entity, which has its own individual cost and adds dead loads on a building structure .In the long run, it would seem desirable that solar collectors be made an integral part of building elements. Thus the separate solar investment would be partially merged into the building construction investment [2].

1.1 Concrete as Absorber Surface and Use of Dimple Surface

The absorptivity of concrete, if left unfinished is 0.65, indicating that 65% of the solar radiation striking the surface of thermal storage wall is absorbed. Simply painting the concrete with flat black paint can increase the absorptivity to 0.96.Concrete is essentially a mixture of two elements: aggregate and paste. The paste is made of Portland cement and water and it binds the aggregate consisting of crushed stone into a solid mass as it hardens due to chemical reaction between cement and water. In order to make design calculations applicable for all types of metal fibers and assuming random distribution of fibers a minimum value of 4.0 W/mk is chosen for thermal conductivity of metal fiber reinforced concrete as suggested by Nayak [2]. Flow separation occurs when the boundary layer travels far enough against an adverse pressure gradient that the speed of the boundary layer relative to the object falls almost to zero. The fluid flow becomes detached from the surface of the object, and instead takes the form of eddies and vortices. Thus the pressure drag increases. In order to overcome this problem, dimple surfaces are utilized. Each dimple acts as a "Vortex Generator" which provides an intensive and stable heat and mass transfer between the dimpled surface and gaseous heating/ cooling media. Taking advantages of VHTE, as a) higher heat transfer coefficient b)negligible pressure drop penalty c) potential fouling rate reduction d) simplicity in design and fabrication e) compactness and/or lower cost .This method is potentially used in heat transfer enhancement in convective passages for industrial boilers, process heaters and furnaces and heat exchangers variety for other industries like automotive (radiators, oil coolers etc.),heat treating (recuperates etc.), power electronics(convective coolers etc.), aerospace ,military, food processors etc.[6].Because of these advantages dimple surfaces can be used to enhance heat transfer rate of solar collector.

1.2 Literature Review

Relevant literature pertaining to study of performance of solar concrete collectors has been reviewed from different points. A number of studies have utilized concept of concrete collectors. A variety of experimental, analytical and computational research works has been carried out on enhancement of performance of collector. **Turner et al. [1]** studied concrete collectors for applications ranging from de-icing of roads and bridges to water heating required for various applications. **S.P.Sukhatme et al.[2]** carried out experimental studies using PVC pipes embedded in wire mesh reinforced concrete. Consideration was given to tube-to-tube spacing as a parameter and an optimal pitch was established. Pressure drop through the tube network was also studied. The entire PVC pipe mesh was embedded inside the concrete slab. **P.B.L.Chaurasia [3]** carried out similar experiments as that of Sukhatme with the exception of using aluminum tubes instead of the PVC tubes used earlier. Parallel arrangement of pipe was constructed without glazing and 30% of pipe was exposed to sunlight while 70% remained embedded in the concrete. **Sokholof & Reshef [4]** studied thin concrete collectors with embedded tubes as well as transient analysis and concluded that these collectors could be used as building components providing a low cost energy collection means. **Hajami et al**. **[5]** have investigated performance of integrated concrete solar water heater. Absorber area of 5m^2 was constructed which worked on the principle of capillary exchanger embedded in concrete.

2. EXPERIMENTAL SETUP

The cement concrete collector in the form of thin slab have been fabricated and tested for water heating purpose. These reinforced cement concrete slabs have been made from common building materials like cement, sand and coarse aggregate. Approximately 25kg cement, 100 kg sand was used to construct the slab. This mixture is poured into the wooden box at a height of 2cm from the bottom. Mild Steel scrap which is approximately 15kg is used in the fabrication of the slab which gives structural strength to the slab. The thermal conductivity of the slab also increases due to M.S. scrap. Wire mesh is embedded at a height of 1.46cm from bottom which provides reinforcement for the concrete slab.

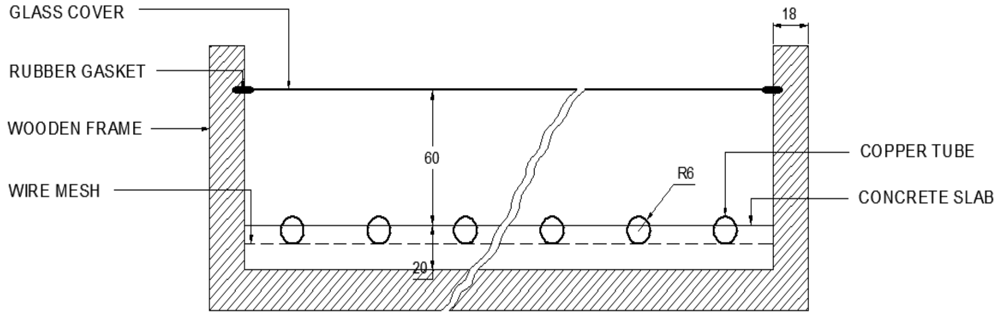

Fig.1 Cross section of concrete collector assembly

Fig.1 shows the structural configuration the concrete slab. The dimensions of the slab are 2m X 1m with an absorbing surface of approx. 2m^2.The thickness of the slab is 2cm.The copper tubes were embedded on the top surface. The arrangement of the copper tubes was made into serpentine flow arrangement. The copper tubes arranged in such a manner that 70% of its portion, along its length, remains inside the concrete slab while 30% remains exposed directly to the sunlight as suggested by Chaurasia [3]. The tube spacing was kept 80mm. This entire setup was placed in a wooden cabinet having inner size of the mould as 2m x 1m X 0.1m. A 18mm water proof plywood was used to make the base and sides of the wooden cabinet. With reference to the copper grid size, two rectangular cuts are made at the side flank to have free access to inlet and outlet pipes. A 3mm thick toughened glass was placed on the top of the wooden cabinet and fixed to it by means of proper gasket which also acts as an insulating tape [3]. A 100 liters capacity storage tank is connected to the collector by means of hose pipe. The collector is painted with blackboard paint to increase the absorptivity. From J.K.Nayak [2] ,a comparison of the performance of collectors having pitches 15, 10, and 8 cm and parallel flow, it is seen that the reduction of pitch from 15 to 10 cm increases the efficiency appreciably. But if the pitch is further reduced to 6 cm, the increase in the efficiency is not that significant. This behavior is observed in the case of both flow rates (1.2 and 0.6 lpm).Under similar conditions, the daily efficiency of a concrete collector at a flow rate of 1.2 lpm is higher than that obtained at a flow rate of 0.6lpm.The difference is appreciable for inlet temperatures close to the ambient. The performance of the collector with a serpentine passage and 8 cm pitch is similar to that of the collectors having parallel flow and pitches of 6 and 10 cm. As expected, the performance of the conventional collector is always better than the concrete collectors.

3. EXPERIMENTAL PROCEDURE

Before starting the experiment glass covers are cleaned. The pyranometer is properly mounted and leveled in the collector plane. The ambient temperature and the solar radiation are recorded every 20 min. The required flow rate is measured with the help of the rotameter. The K type thermocouples are used to measure the desired water temperature. In the early morning hours, the incident solar radiation is not enough to bring the collectors to the operating condition. Therefore, the circulating water loses its heat to the collectors, giving a negative temperature rise. As the collectors gain energy and approach operating conditions, the tank heaters are put off one by one. Once the collectors start giving useful energy (positive temperature rise), the following data are recorded every 20 min: inlet water temperature (Tfi), outlet water temperature (Tfo), temperature rise through the collector (δTf), ambient temperature (To), solar flux incident on the collector plane (It), and volume flow rate (Q) as suggested in Nayak[2].

Table 1 Details of a cement concrete solar collector

S. No.	Design materials/Parameters	Specifications/Details of materials
1	Solar heating systems	Based on cement concrete slabs with glass at the top or insulation at the base
2	Gross dimension of cement slab	2m X1m X 0.1m
3	Absorbing surface area	$2m^2$
4	Absorbing paint	Black paint
5	Flow pipes in heating system	Network of copper pipes embedded at the top of absorbing surface
6	Copper pipes (a) Diameter (b) Length (d) Spacing between two Copper pipes (e) Length of Copper pipes left on each side of cement concrete slab	 12 mm 25 00 mm 80 mm 50 mm
7	Overhead tank (a) Capacity (b) Height from ground	 100 litres 0.90 m
8	Weight of a cement concrete slab	125 kg (approx.)
9	Testing of solar water heating sets	33° due south

4. APPLICATIONS OF SOLAR CONCRETE COLLECTORS

If the roof of a concrete structure is blackened, more hot water will be taken. If the cold water from the overhead tank of the house is drawn through the network of the copper pipes embedded in the cement concrete structure it can easily supply the hot water at a moderate temperature (36°C to 58°C) for meeting the various domestic requirements during the day, e.g. hot water in the bathroom, in the kitchen for utensil washing and cloth washing etc. About 25–40 litres of hot water above the human body's temperature (i.e. above 36°C) can be drawn daily from one square meter area of roof structure after slight modifications in the regions where the horizontal solar insolation exceeds 4 kWh/m^2 [10]. The concept of the cement concrete solar water heating system in the building is shown in Fig. 2 for this purpose, reinforced cement concrete slabs (R.C.C. slabs) can be used or the roof can be modified. The inbuilt cement concrete solar roof system for solar water heating can also be made during the construction of the house. This solar roof can also be employed as a pre-heater to any water heating system. This passive cement concrete solar water heating system can also be used in the summer season for supplying the hot water at relatively higher temperature which may be used according to the requirements of the buildings [8].

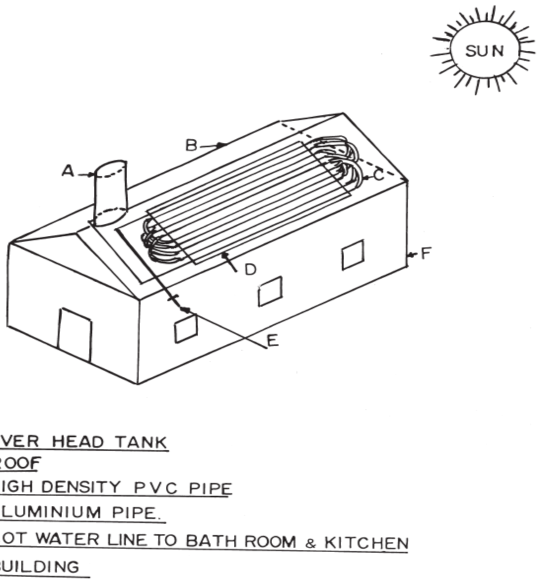

Fig.2. A concept of the cement concrete solar water heating system for passive solar water heating in buildings [3]

5. FUTURE WORK

The future work consists of utilizing dimple surfaces [6] inside the copper tubes in order to enhance the heat transfer rates between the concrete slabs and the water passing through the tubes. Dimple surfaces or depressions in the surfaces are expected to promote turbulent mixing in the flow and enhance the heat transfer, as they behave as a vortex generator. Dimple surfaces promote relatively low pressure loss characteristics. By using dimple surfaces it is expected to enhance the efficiency of the solar concrete collector.

6. CONCLUSION

Hot water at moderate temperature (upto 54°C) can be obtained in buildings during the daytime in winter by using reinforced cement concrete slabs or by slightly modifying the roof structure and laying down a network of copper pipes over it which can offer a low cost passive solar water heating system in the building itself. Inbuilt cement concrete solar water heating system (i.e. integrated cement concrete system with roof) can also be made during the construction of the building. This passive solar water heating technique is easy to fabricate and the mason or skilled person can do this type of job after a little training for it. Solar collector with dimple surface can be used for the further enhancement in heat transfer rate.

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