PERFORMANCE ANALYSIS ON CONCRETE SOLAR COLLECTOR

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Abstract : In the overall progress of any country in the world energy is an important factor. Besides the other three classical factors, i.e. land, capital and labour, energy is of utmost importance in the context of progress. The energy demand is expected to increase three times the present value in the year 2025. With the increasing per capita power consumption, the depletion of conventional resources, an increase in the cost of power production and environmental pollution are emerging issues of concern in future. Seeking alternate resources and technologies will be solutions to these problems to a great extent.

At present there are many industrial applications of hot water in the temperature range of 45ºC to 65ºC. There are various conventional and non-conventional methods available to produce a large quantity of hot water (45ºC to 65ºC). The global temperature is increasing in all parts of our country. To tackle such a hot ambient conditions prevailing in major parts of country an attempt can be made to use non-conventional cost effective simple method to produce hot water. With these facts in mind two concrete solar collectors, of one by using heat transfer enhancement technique, dimple surface, of size 2 m^2 were developed, designed, fabricated and tested in Pune. Trials were conducted in both winter and summer season on the concrete collector for different mass flow rates from 20 to 45 liter/hr. The average outlet water temperature was found to be 58°C for the collector with plain pipe and 59.5°C for the collector using dimples on pipe. The average overall efficiency of concrete collector is reasonably good 34% for pipe without dimple and 38 % for pipe with dimple.

This research paper aims at ascertaining the practicality of using concrete for producing solar collector and makes the collector more cost effective and efficient. This research work paves way for the possible integration of concrete collector with roof slab to provide human comfort and hot water requirement.

***IndexTerms*- Flat-plate solar collector, concrete, metal fibers, heat transfer enhancement.**

I. INTRODUCTION

1.1 Solar Passive Building

A building isolates within spaces from outside conditions for making steady and agreeable warm conditions for the tenants. The inner condition inside the building comes about because of the reactions of the working to the changing open air sunlight based radiation temperature, stickiness, wind speed and sky conditions. The building ought to be composed with the goal that it opens itself to those climatic variables which make the regular condition more agreeable and closes itself to the ones, which make occasional solaces most exceedingly awful, this diminishes the warming and the cooling heap of the building.[5] Detached advancements go for augmenting the impact of this approach by picking legitimate introduction, size and area of windows, shading and ventilation gadgets, shade of external surfaces, warm resistance and warmth limits of the building components and so on.

1.2 Human Comfort

The environment temperature decides the human comfort. The temperature range in which most human species feel pleasant is between 22^{0}C and 27^{0}C. We realize that, rooftop chunk ends up noticeably hot by engrossing warmth in daytime and it rejects warm inside the working in the evening time. Because of this unavoidable conduct quality of rooftop piece, indoor conditions, turn out to be more awkward to leave. [2]In this way, there is an expansion in the vitality request because of utilization of fans, aeration and cooling systems, icy stockpiling and so on. A possible alternative to reduce this problem is to use concrete collector.

1.3 The Building as a Solar Store House

A vital component of a system which uses solar energy for heating a container for storing heat. Probably the most efficient container is the material, of which the building is built- the walls, floors, roofs, partitions.[5] Solar energy penetrates through the walls, roofs during the day. The short wave light is stopped by the walls and roofs. As it is stopped, it turns into heat,which is absorbed and then released to the cooler objects.

Harold Hay gave the idea of wall construction for increase thermal mass by filling concrete blocks cavities with sand or with plastics/vinyl tubes filled with water as shown in Fig.1.[2]

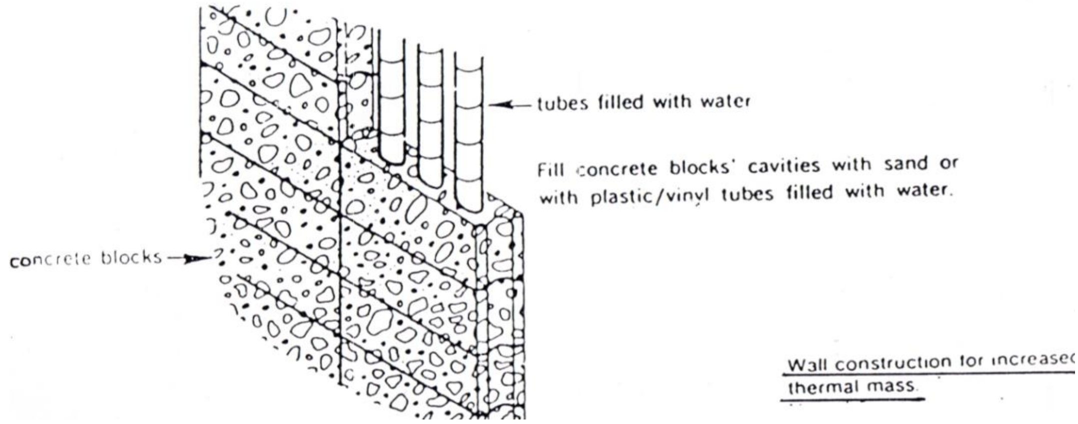

Fig.1**:** Wall Construction for Increased Thermal Mass

1.4 Utilization of "Concrete" as an Absorber Surface

Absorbtivity of concrete, if left unfinished is 0.65. Absorbtivity of concrete may become 0.96 when it is painted with a black paint. However, emissivity is also fairly high as 0.87.

From the point of view of thermal performance, the most important material characteristics of a particular concrete mixture are its conductivity, density, specific heat and thickness. Thermal storage capacity of concrete is high.In general, higher the thermal storage capacity of a given component, better its performance from the passive solar point of view. [6]

Among the low energy cost materials, concrete is the most promising material. In this project, it is proposed to use building elements, i.e. roof and wall panels as solar collectors because this would eventually lead to a flat plate collector which could be integrated into the structure with roof and walls. Hence it is planned to use concrete for making absorber plate.

1. The thermal conductivity of concrete can be increased by adding metal fibres into the concrete.
2. The materials used for preparation are abundantly available (workshop waste, scrap electrical wirings).
3. Because of the alkaline nature of cement concrete as well as metal fibres are corrosion free.
4. Since concrete is plastic in the primary state, it could be moulded into any shape.
5. It is possible to pre-fabricate hybrid absorber panels at factory or site.
6. It is possible to control thermal conductivity of hybrid by controlling the type and percentage of metal fibres in concrete. [8]

Usually copper does not corrode in concrete, but it has been found that thin copper sheets can be perforated when soluble chlorides contact them. Also, nitrates present in concrete may create stress corrosion cracking. But very little work on corrosion of copper in concrete is reported as copper, brass, red brass and copper silicon alloys have hold good corrosion resistance in concrete. Copper and copper alloys when used with concrete do not usually react with moisture. But the presence of soluble chlorides in concrete may lead to corrosion if both concrete and metal come in contact with moisture. It has been found that corrosion due to interaction of copper with dry and wet concrete is not much of a concern. However, copper if comes in contact with the compounds of sulphur, which may be present in concrete mixtures should be avoided. The pulverized limestone mixture used as backfill of copper tube will eliminate corrosion effects. When copper is embedded in normal cement it is never corroded even in the worst conditions. Hence the hard drawn and annealed copper tube is acceptable in the concrete. Copper is corrosion resistant in a vast range of pH when comes in contact with water and neutral salts.(Fig.2) [7,9]

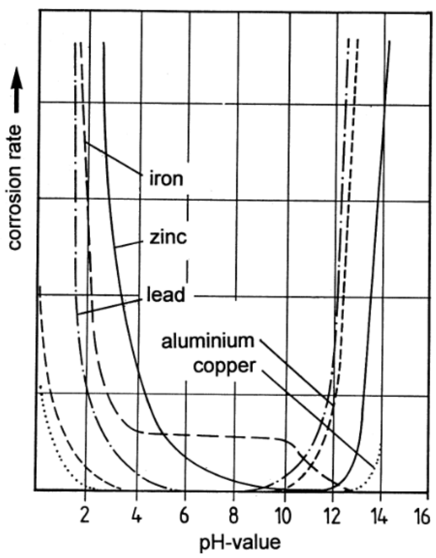

Fig. 2: Effect of pH on the Corrosion of Metals

1.5 Heat Transfer Enhancement:

Heat transfer enhancement is nothing but to increase the rate of heat transfer by adding something to the system. In case of rough surface the rate of heat transfer is more compared to the smooth surfaces as heat transfer coefficient increases in case of rough surfaces.

$$h_f = k/\Delta \qquad (1)$$

From above equation it is observed that the heat transfer coefficient is inversely proportional to thermal boundary layer thickness. In case of turbulent flow in pipe any uneven surface that interrupts laminar sub-layer will increase the heat transfer. But in case of laminar flow heat transfer can be increased by the method of whirling the flow.

Dimpled surface may be utilized in compact to reinforce the heat transfer with lesser frictional resistance. Dimple surfaces interrupt the thermal boundary layer and improves convective heat transfer.

Dimple surfaces reduces the thickness of the laminar sub layer, generates vortices, increases turbulence and hence reinforce convection. [3,10]

Fig.3:Dimpled Tube

II. METHODOLOGIES AND TECHNIQUES

An attempt will be made to study the above problem experimentally. In this research an attempt has been made to manufacture a model of the passive cum active type of solar collector, in which absorber surface is made of concrete. The copper pipe grid is embedded in the absorber surface.

While designing the concrete collector the following parameters were calculated.

Flow rate=25 kg/hr
Duct spacing = 0.08m
Overall heat loss coefficient=10 W/m^2 K
Thickness of plate=0.03m
Tube diameter = 0.008m

The experimental set up for the study is as follows.

2.1 Experimental Setup

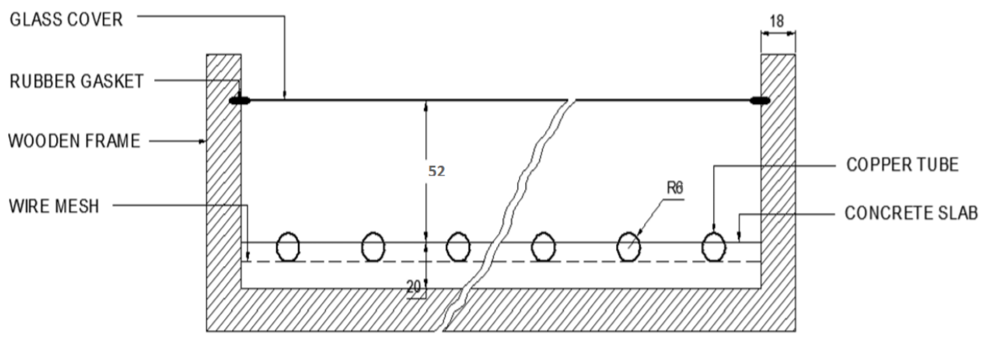

Fig. 4: Cross Section of Solar Concrete Collector

The different components of concrete solar flat plate collector are then placed properly in the following order.

1. Position of collector stand
2. Placing of collector on collector stand

3. A glass of 4 to 5 mm thickness is fixed.
4. Connection of hose pipe to the inlet & the outlet connection of the collector.[1]

2.2 Experimental Procedure

First the dust from the glass cover is removed. The pyranometer is correctly placed and leveled with the collector plane. Solar radiation data are measured along with the testing setup only using pyranometer. Readings of the surrounding temperature and solar radiation are recorded each one hour. Inlet and outlet water temperatures are sensed with the help of digital temperature indicator and thermocouples. Measuring flask is used to count the mass flow rate of water. Experimental results are verified.

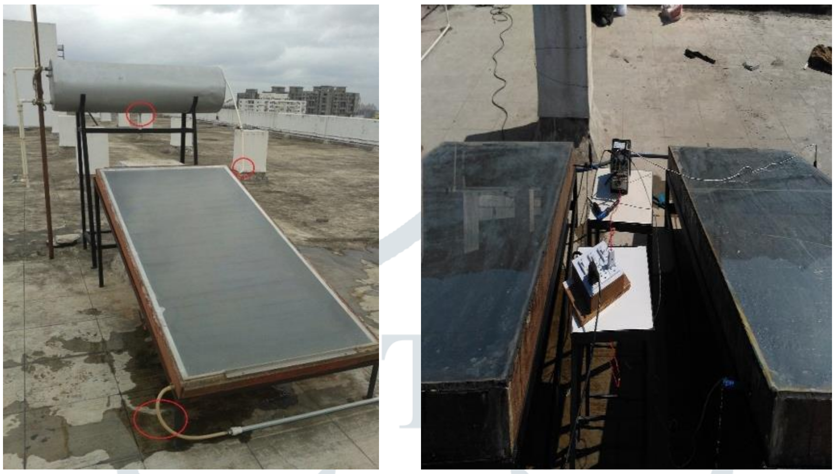

Fig.5: Solar Concrete Collectors

Fig.6: Temperature Indicator

Fig.7: Pyranometer

III. RESULTS AND DISCUSSION

3.1 Results

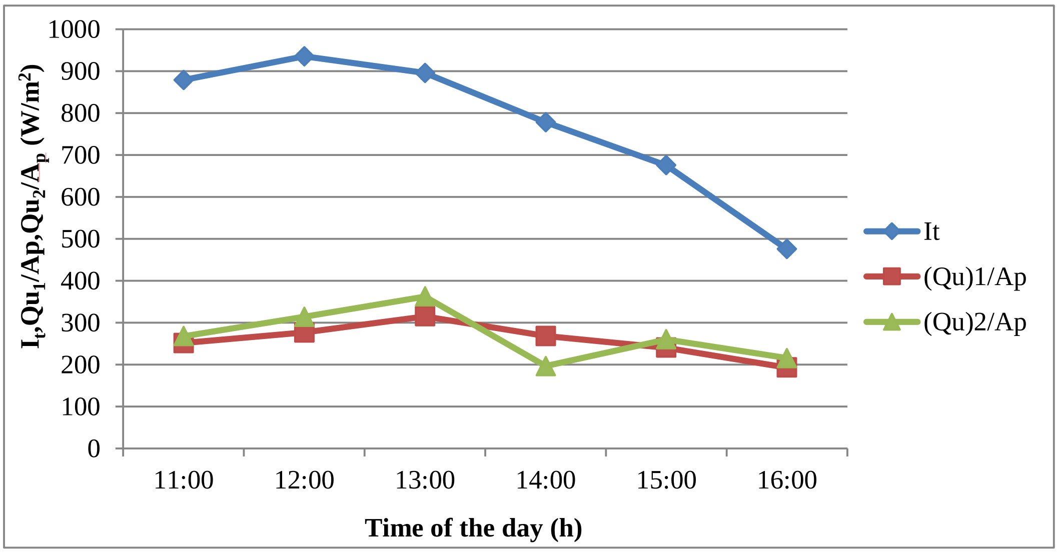

Fig.8 : Variation in It, $Qu_1$and Qu_2 with respect to Time of Day (Average)

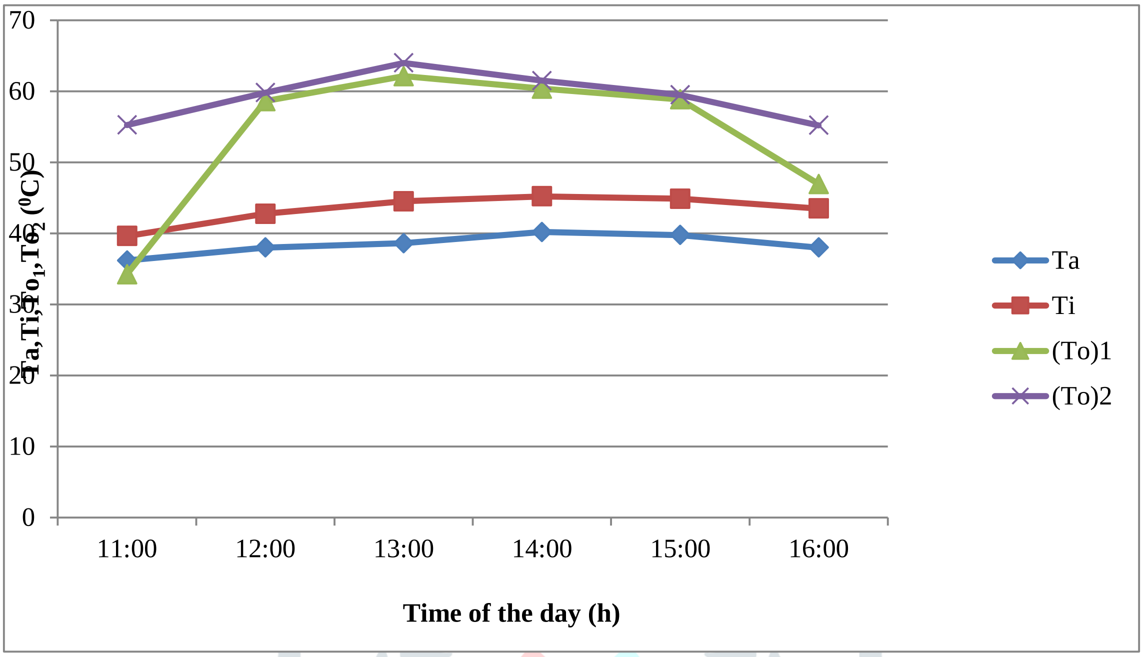

Fig. 9:Variation in T_a, T_i, and T_o with respect to Time of Day (Average)

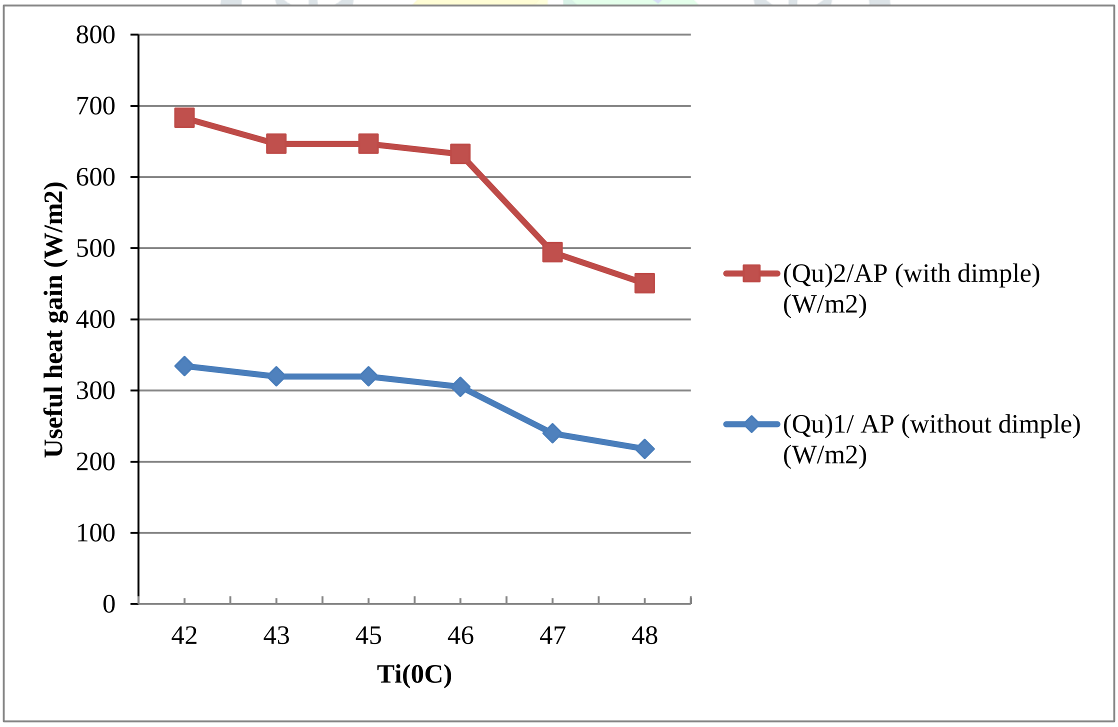

Fig. 10:Effect of Inlet Temperature on Useful Heat Gain of Concrete Solar Collector

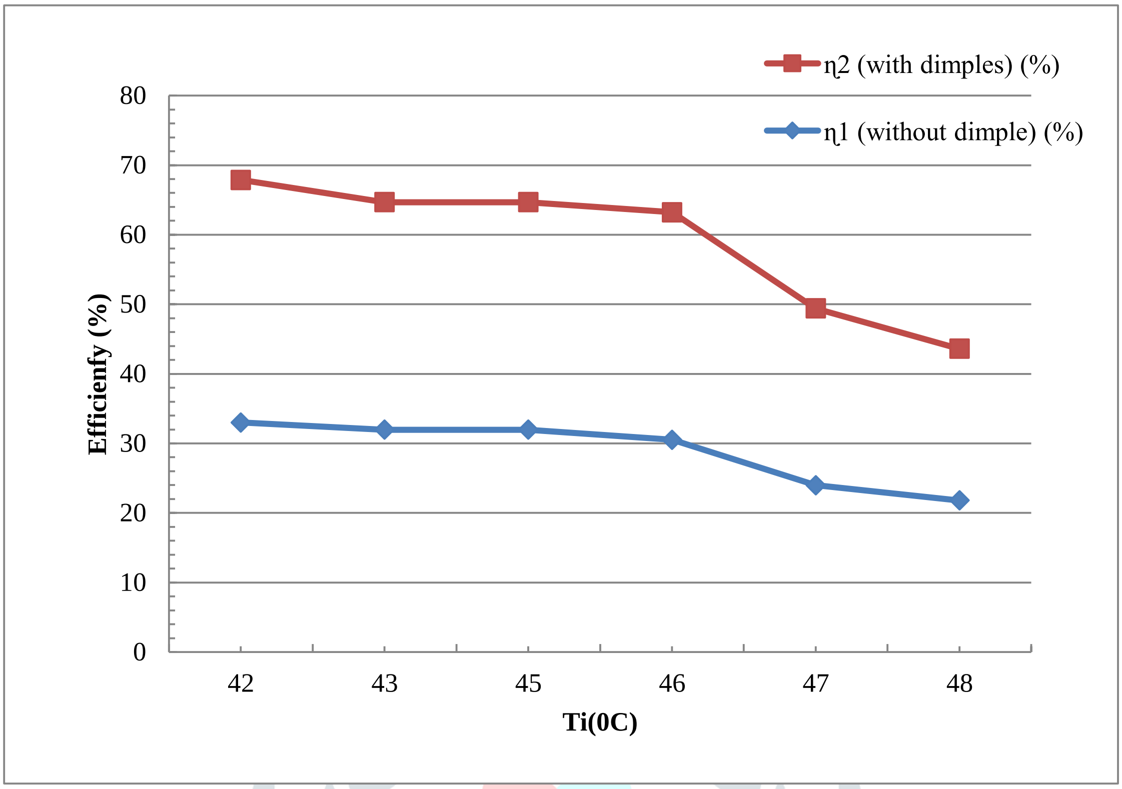

Fig. 11: Effect of Inlet Temperature on Efficiency of Concrete Solar Collector

3.2 Efficiency curves for a Concrete Solar Collector

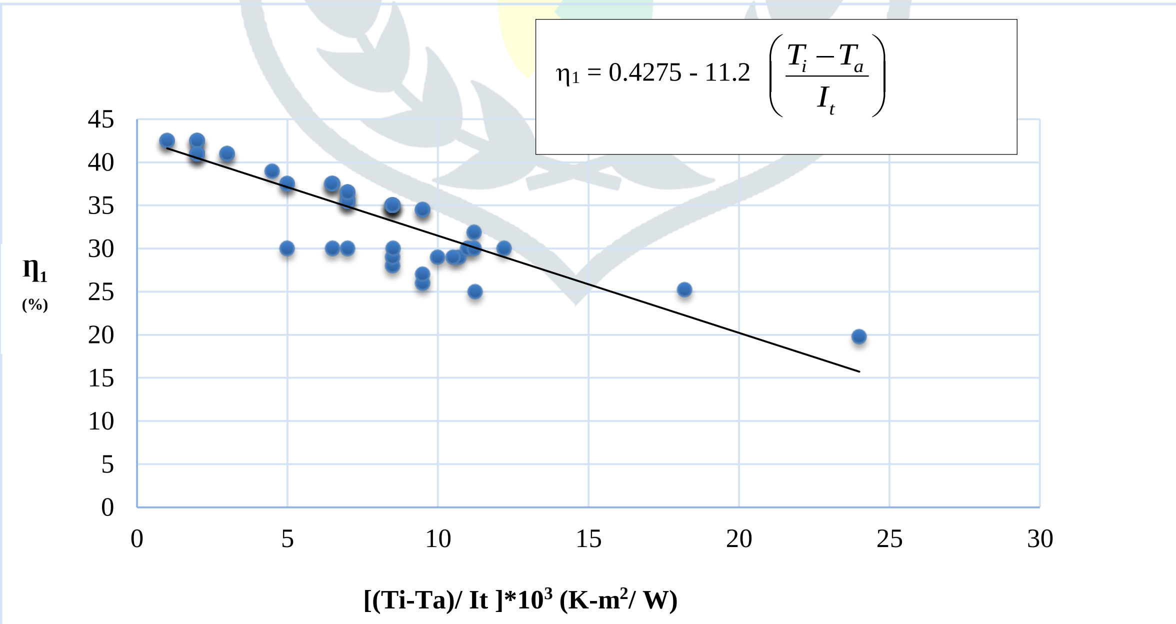

Fig.12 :Variation in η_1 with respect to (Ti-Ta / It)

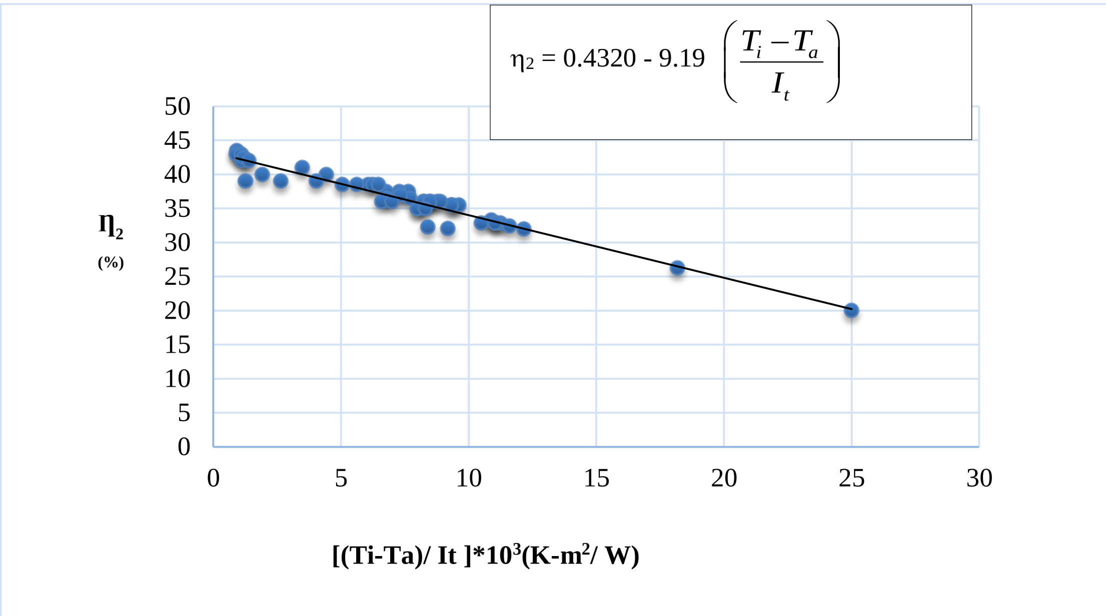

Fig.13: Variation in η_2 with respect to (Ti-Ta / It)

Experimental values of efficiency are plotted against the parameter $\frac{T_i - T_a}{I_t}$ according to Hottel-Whillier-Bliss equation, which is widely accepted relationship for measuring collector energy gain. Experimental values η_1 and η_2 are plotted against parameter $\frac{T_i - T_a}{I_t}$ generally gives straight lines. However, the scatter of data is very large. A straight line can be fitted by the method of least squares giving below equations.

$$\eta_1 = 0.4275 - 11.2 \left(\frac{T_i - T_a}{I_t}\right) \quad (2)$$

$$\eta_2 = 0.4320 - 9.19 \left(\frac{T_i - T_a}{I_t}\right) \quad (3)$$

The slope of this line represents the overall heat loss coefficient and y-intercept gives maximum collector efficiency called optical efficiency.[4]

3.3 Discussions

Trials were conducted in both winter and summer season on the concrete collector for different mass flow rates from 20 to 45 liter/hr. The average outlet water temperature was found to be 58°C (pipe without dimple) and 59.5°C (pipe with dimple). The highest water temperature is observed at about 1.00 pm.

The average overall efficiency of concrete collector is reasonably good 34% for pipe without dimple and 38 % for pipe with dimple. The efficiency of collector decreases sharply and at an increasing rate with the values of the T_i. The percentage increase in the efficiency of concrete collector pipes with dimple surface is found to be 10%.

The thermal efficiency of concrete collector is found to be 25% to 35%, but this system will provide an outlet temperature of the water of around 50°C to 55°C at a mass flow rate 20 to 25 kg/hr.

The phase lag being about 40 to 45 minutes between the maxima of useful heat gain and incident insolation is quite high especially in the morning phase.

Small fluctuations of about 2% to 3% in the insolation incident on the collector surface have little reaction on the behavior of the collector.

IV. CONCLUSION

Following important conclusions are made after performing tests on solar concrete collectors.

Of the concrete collectors tested, the pipe with dimple surface collector gives higher outlet water temperature compared to plain pipe collector. The rise of temperature is in the range of 1˚C to 2.5˚C.

From cost estimates, it becomes clear that the overall cost of concrete collector is less than the conventional metallic collector.

By and large, one can conclude after going through the experience of this study that the concept of making flat plate solar collectors out of building materials is feasible.

NOMENCLATURE

A_p	Area of absorber plate surface (m^2)
h_f	Heat transfer coefficient on inside surface of tube (W/m^2K)
I_t	Solar insolation (W/m^2)
K	Thermal conductivity (W/m K)
Q_u	Rate of useful heat gain (W)
$(Q_u)_1$	Rate of useful heat gain without dimple surface (W)
$(Q_u)_2$	Rate of useful heat gain with dimple surface (W)
T_a	Ambient temperature (˚C)
T_i	Inlet water temperature (˚C)
T_O	Outlet water temperature (˚C)
$(T_O)_1$	Outlet water temperature without dimple surface (˚C)
$(T_O)_2$	Outlet water temperature with dimple surface (˚C)
η_1	Instantaneous collector efficiency without dimple surface (percentage)
η_2	Instantaneous collector efficiency with dimple surface (percentage)
Δ	Thermal Boundary Layer Thickness

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