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# Design, Development and Performance Study of an Economic Thermal Energy Storage

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**ABSTRACT**

*The present work discusses methods and applications for sensible thermal energy storage. The three materials used in this work are crushed stone, brick and sand. During experiments, the average temperature was found as $52^0c$ in the test the speed of air flow is 4.722 m / s. This prototype works on the natural convection method where the hot air flowing upward direction. The duration of this experiment for each storage material (stone, brick, sand) was 8 hours, 10 hrs to 17 hrs respectively. The experiment was conducted in the month of June and July 2018 in the longitude of $23.8133^0$ N, and latitude of $91.2700^0$ E. The data was taken in the gap of 1 hour. Three types of data were taken those are temperature with respect to time, moisture content in air with time and air flow rate with time. During experiments in between 13 to 14 hrs the highest temperatures are recorded in stone chips, brick chips and sands as $53.6^0$C, $51.5^0$C and $53.7^0$C respectively whereas the lowest temperatures are recorded in between 10 to 11 hrs as $37.8^0$C, $36.2^0$C and $35.2^0$C respectively. The highest and lowest moisture contents of air were detected as 55% (10 to 11 hrs) and 31% (14 to 15 hrs) respectively. The maximum and minimum air flow rates were found as 0.0044 m/s (16 to 17 hrs) and 0.00278 m/s (10 to11 hrs) respectively.*

***Keywords:*** *Design, Development, Thermal Energy storage, Performance, Economic.*

## 1. INTRODUCTION

Solar energy is free of cost and renewable, so we must use solar thermal energy storage to reduce pollution; the production of these energy storages is not very complicated. This heat energy storage is also called as packed bed heat energy storage and can maintain heat energy supply uninterruptedly without the use of fossil fuels. In most cases, two types of TES systems are used, namely, sensible heat storage (e.g. water, rock etc.) and latent heat storage (e.g. water/ice, salt hydrates, paraffin wax etc.). In this regard, N. T. Ahmad (2001) worked on an agricultural solar air collector made of cheap plastic wrap film. This type of collector can be installed in greenhouses that are mostly used in that area [1]. Karim and Hawaladar (2004) worked on improving solar air collectors for drying applications and found that the V-wave collector is the most efficient collector and the flat plate collector is the least efficient [2]. Aben et al. (2004) investigated to increase the efficiency - the rise in temperature of the steam of the dynamic flat plate solar collector with respect to some types of slope problems [3]. Luna et al. (2010) developed a traditional model based on linearization of energy conservation equations [4]. El-Sawi et al. (2010) found that depending on the size and operating conditions, the chevron pump is the most efficient and the flat pump is the least efficient [5]. Meat L. (2012) examined that flat air heaters typically produce hot air at low temperatures and are ideal for drying agricultural produce [6]. Chamoli et al. (2012) reviewed that most studies of two-pass solar heating combine porous media with expanded space [7]. Majid et al. (2015) found that the heating and cooling characteristics of a hollow square metal absorber can be determined by the relationship between surface temperature and internal temperature of the absorber [8]. Gulcimen et al. (2016) found that collector efficiency is improved when the air flow rate varied between 29 and 63% [9]. Razak et al. (2016) reviewed that the performance of the matrix absorber is strongly influenced by the matrix pore index, geometric parameters, matrix thickness, earth density, and thermo-physical properties of the material [10]. From the investigation of these literature reviews, it has been found that thermal energy storage can be made from economical, locally available and eco-friendly materials. It is widely used in agriculture for crop drying and the high-quality dry vegetables come out from the greenhouse dryer by the help of thermal energy storage.

## 2. MATERIALS AND METHODS

The concept of this project arose from the need to transmit energy at a low cost with better efficiency. The first step after choosing a project is drawing and designing. Materials needed to execute this work are 7 pieces of wood, one piece of transparent glass, iron mesh, aluminum foil paper, two pieces each of pipe and valve and storage material (stone, brick, sand). The dimension of the bed is (452 x 310 x 16) mm.

Fig. 1 Bed and Wall of the TES, Transparent glass and Door hinges

The dimensions of the upper and lower walls are 310 mm x 120 mm x 25.4 mm. Side dimensions are 457.2 mm x 120 mm x 25.4 mm. One transparent glass is needed for the passage of solar energy. Sunlight passes through the glass and heats the stone, accumulating thermal energy or heat energy. Two door hinges are required to open or close the glove box door freely. For this reason, from time to time, we change or replace the storage material. Economic natural storage material such as stones, bricks, water, concrete, sand etc were choosen. This material can store heat energy with proper insulation upto six to seven hours.

Fig. 2 Stone chips, Brick chips and Sand

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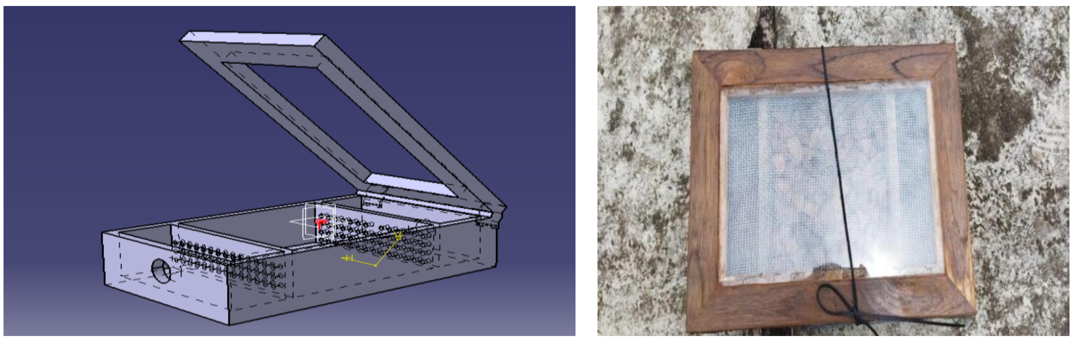
The working fluid is air, so two pipes are needed to transfer heat through the air. One is inlet pipe and another is outlet pipe. From inlet pipe normal air first enter the inlet planner and then passes through the stones heated by the sun. Now the hot air trapped inside the outlet planer and go out with the help of outlet pipe. To protect the glass, an iron net should be placed on the bottom of the glass. When moving the storage, the storage material like stone or brick etc can hit



the glass cover. So, prevent that kindof accident a net of iron must be needed.

Fig.3 3D and working model of the set up

The diagram below shows the basic layout of the bulkhead in a three-compartment, pin-mounted arrangement. There are two slits to separate the storage material chamber, the partition has a mini hole on it for air passage. Transparent glass placed on the upper side of the device for direct heating of the storage material. A rubber pad gasket should be used to seal the gap between the compartment and the cover for minimal heat loss. This device can store energy four to five hours. It can be used as air conditioner in winter season for heating the room, can be used inside a greenhouse as a heater and also can be utilized as a crop dryer.

## 3. RESULTS AND DISCUSSION

Experiment was done in the summer and month of July in longitude of $23.8133^0$ N and latitude of $91.2700^0$ E.

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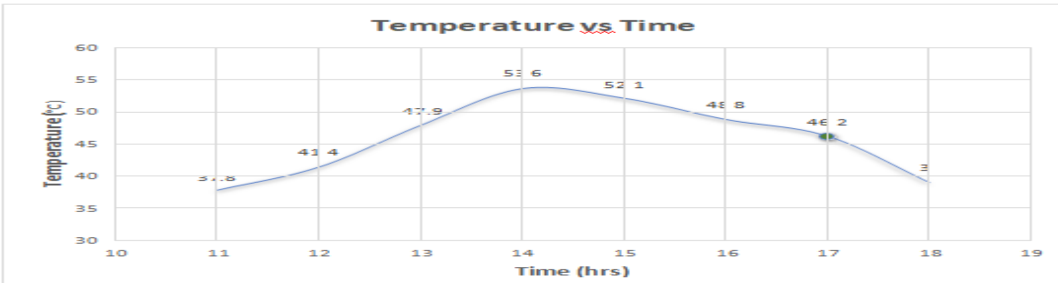
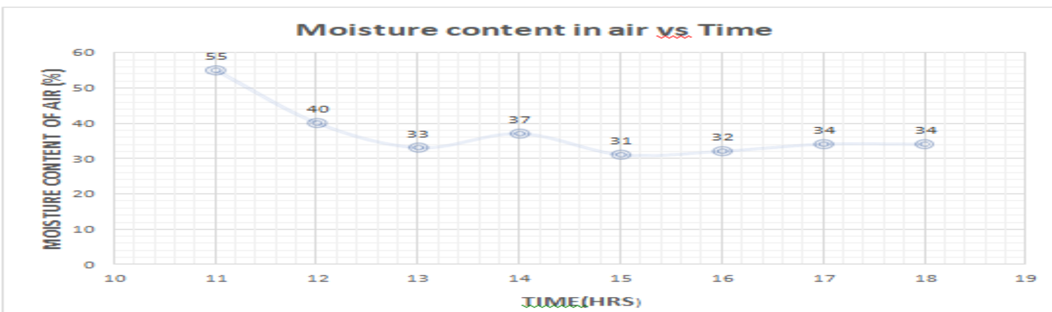


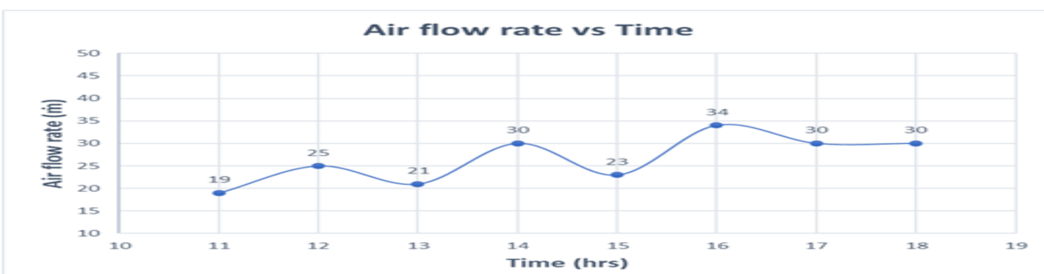
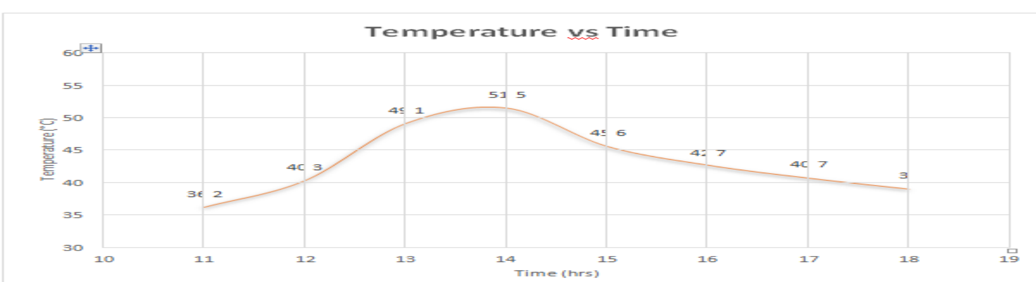




Fig.4 Temperature, Moisture Content and Air flow rate vs Time graph for stone chips



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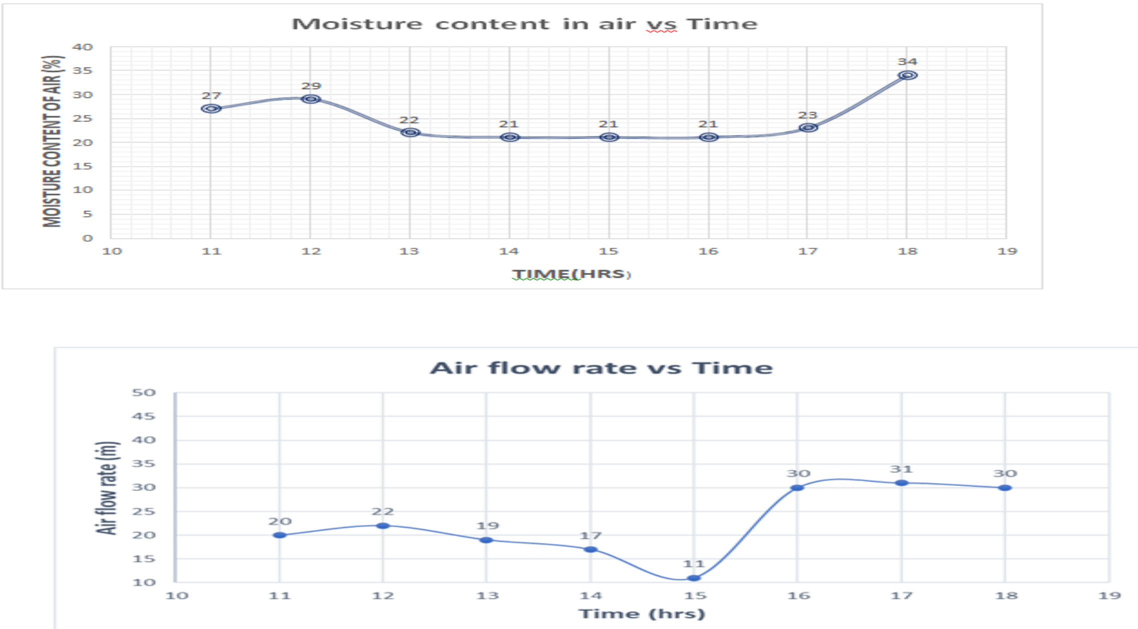
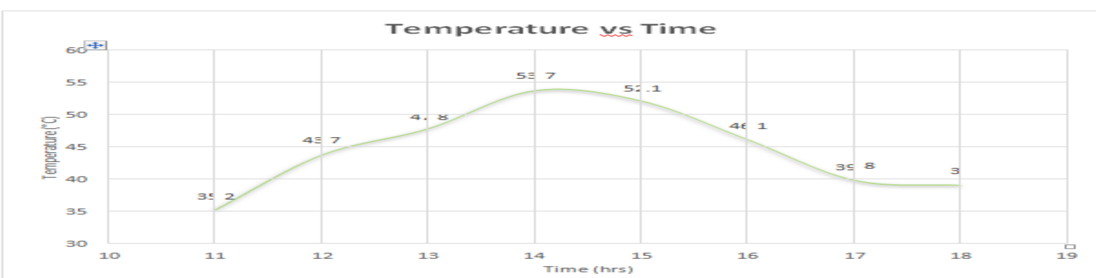
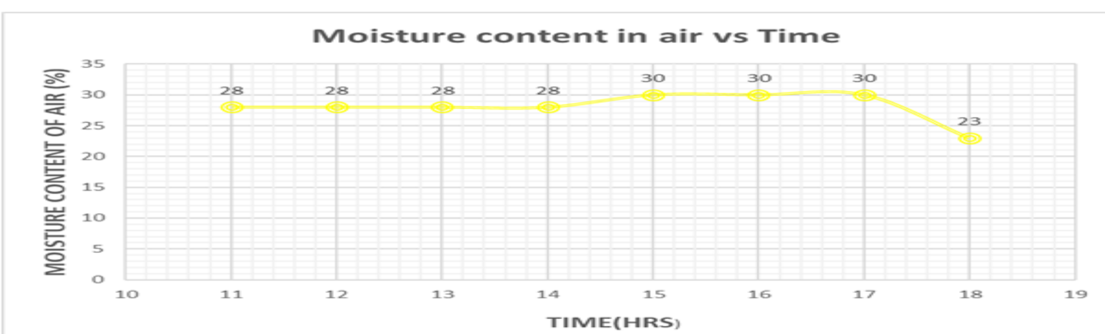



Fig.5 Temperature, Moisture content, Air flow rate vs Time graph for brick chips



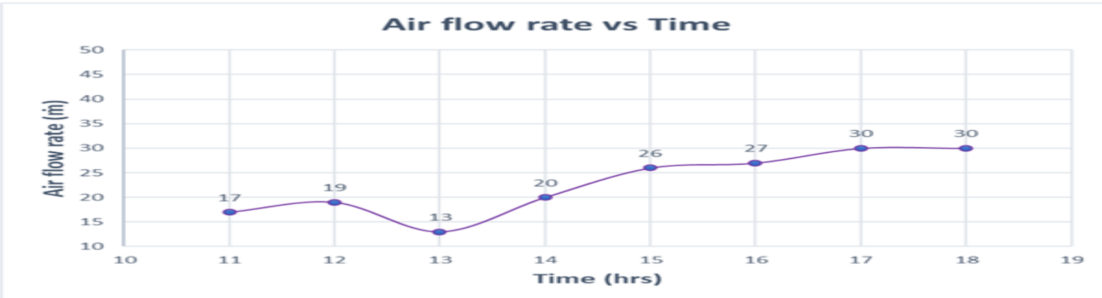



Fig.6 Temperature, Moisture content, Air flow rate vs Time graph for sand

The graphs in Fig. 4, 5 and 6 show the variation of temperature, moisture content and air flow rate with respect to time for stone chips, brick chips and sands.

## 4. CONCLUSION

The best result was recorded for stone temperature respect time was 53.6$^0$C in 14 hrs with moisture content in air average 30% with the average air flow rate of 6.944 m/s. The finest outcome was noted for brick temperature respect time was 51.5$^0$C in 14 hrs with moisture content in air average 21% with the average air flow rate of 5.556 m/s. The highest data was logged for sand temperature respect time was 53.7$^0$C in 14 hrs with moisture content in air average 28% with the average air flow rate of 5.278 m/s. The set up was performed very well during experimentation and worked as per design. The set up can be used as an attachment for heat source of small solar dryer which will be beneficial for the rural farmers. There is further scope for development of this present set up by incorporating different storage material like pebbles, metal chips etc. for increase the efficiency.

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