CONSTRUCTION AND PERFORMANCE STUDY OF A ROCK BED BLACK AGATE HOME TYPE SOLAR AIR HEATER WITH SOLAR DRYER

Nurmanova Makhfuza Urozovna
doctoral student (PhD)
Samarkand State University of Architecture and Construction
named after Mirzo Ulugbek
E-mail: maxfuzaxon1483@gmail.com

ABSTRACT

This article presents an evaluation of the construction and performance of a Black Agate stone bed. The house has a new type of solar air heating system with a total area of $1m^2$. The system is made from locally available materials and installations, operations are carried out in the developing country of Uzbekistan. Rock is used as thermal mass storing heat from the sun and releasing heat in the absence of effective radiation. Drying indicators were with hygroscopic products is carried out using a solar dryer. Solar air heater performance is rated differently air flow rate and the optimal air flow rate is 0.0122 kg/s. The result shows that the solar air heater is capable of this maximum outlet air temperature is 66°C, relative humidity is 1%, thermal efficiency is 39% and delivered energy is 4.4 kW. The system is also able to deliver efficient hot air during non-sunlight hours duration 6 hours. The maximum moisture removal efficiency of the dryer is 36%. The total moisture removal for 9 hours of drying is 25% without affecting the quality and identity of the product moisture absorption is 7 gm/kW.

Keywords: Hygroscopic materials, heat accumulator, solar air collection, heat dryer, thermal mass.

INTRODUCTION

The decree of the President of the Republic of Uzbekistan. № PF-60 of January 28, 2022 states, among other things, the following: to increase the energy efficiency of the economy by 20% by 2026 and reduce the amount of harmful gases released into the air by 20% by actively introducing "Green Economy" technologies in all sectors measures should be taken" [1].Providing hot air is necessary for drying hygroscopic products, fruits, agricultural crops, industrial drying and drying winter room heating purposes, as well as countries that survive cold weather conditions [2]. The conventional method of producing hot air is by burning fossil fuel or using fossil based electricity. Researchers are discouraging freedom to consume such limited fossil sources due to rapid depletion, high price and future environmental threats [3]. The effort on research and development to deliver hot air and to avoid the use of fossil sources are growing continuously over the world. Solar air heater is a system used to deliver such hot air and well recognized in tropical and semitropical countries [4]. Though the technology is simple, cost effective, free and eco- friendly [5], the reliable useful output from the solar air heating system is vulnerable due to intermittent solar radiation and the system need to use in off-sunshine hours. The system cannot deliver useful output at night time or during low solar insolation result is poor performance of the system [6]. Energy storage materials can improve the reliability to deliver useful output of the system [7].

Literatures on solar air heating system integrated with solar dryer using different energy storage materials are exists [8]. It is found that, solar air heating system with phase change material (PCM) storage is better than sensible storage in the sense of low space required and high heat storage capacity, though sensible

heat storage materials are low cost compared to the latent heat storage materials[1].

MATERIALS AND METHOD

A critical review of the literature on conservation of solar energy Bangladeshi scientists Dr. Shozibuddin, Masud Parvez and Dr. Enamulqe, Department of Engineering, Rajshahi University of Engineering and Technology, Rajshahi 6204, purchased the solar air device from a 3 mm thick glass box (Fig. 1.a).

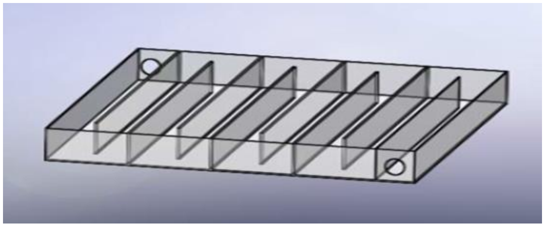

Fig. 1.a. Scheme of the collector channel box.

Solar air heater in this study consist a glass box of thickness is 3 mm (Fig.1a). The area of the box is 1 m^2. There are 9 channel inside the box are partitioned by glass. Metamorphic black rock diameter of 5-6 cm and weight of 42 kg is placed in the channel uniformly with an aim to absorb heat from solar radiation during

sunshine hour. The glass box is placed on the wooden board. Insulation is made under the glass box by 0.4 kg cock sheet and 2 kg cotton. The glass box has two opening, one is for input the outside air and other is for exit the hot air. The box containing rock is act as absorber of the system. Hence, there is no need to make separate absorber or cover glass. The system is installed on the base frame made of wood at an angle of 24^o south facing as the country latitude is 24^o [9].

The drying chamber is made of wooden frame covered with 3.5 mm glass (Fig. 1 b). The drying chamber is 70 cm height and 35 cm wide. Three trays are made of non corrosive sieve type wire net and mounted inside the drying chamber. The trays were set 20 cm apart to ensure the better circulation of hot air through the drying product. The dryer is connected with solar air heater using well insulated PVC pipe of 3.5 cm in diameter. One end of the pipe connected with solar air heater and other end of the pipe connected with bottom of the dryer. A distributor is installed inside the dryer at the end of the connected pipe to ensure better

circulation of the hot air inside. There are small exhaust opening at the top of the side wall to move out the inside air slowly.

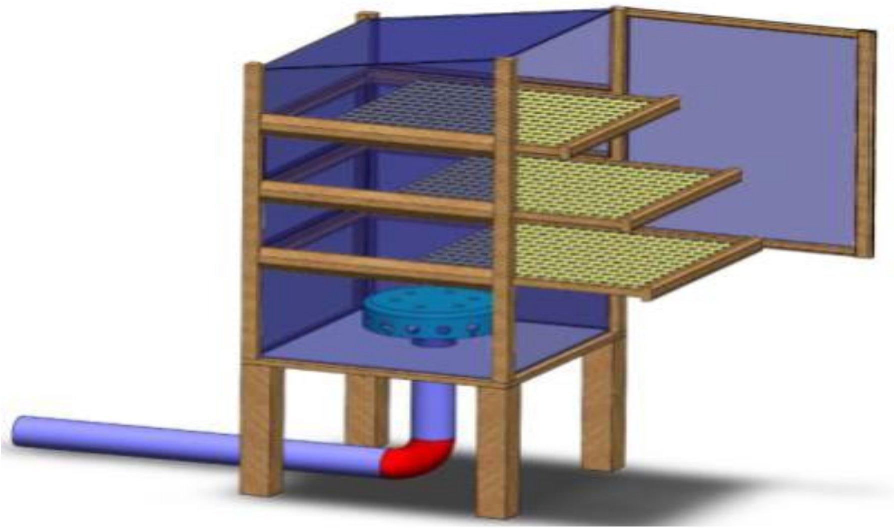

Fig. 1. b. Scheme of a greenhouse-type dryer

Fig. 1.s. The scheme of the solar cell is a collector combined with a dryer.

ITSD with heat or thermal storage system is useful for continuing the drying process after sunset so that processing time can be reduced significantly [10]. Solar heat can be stored in the form of SH and LH in the thermal heat storage devices as shown in Fig. 2(a), (b) and –(c)–. In Fig. 2(a)

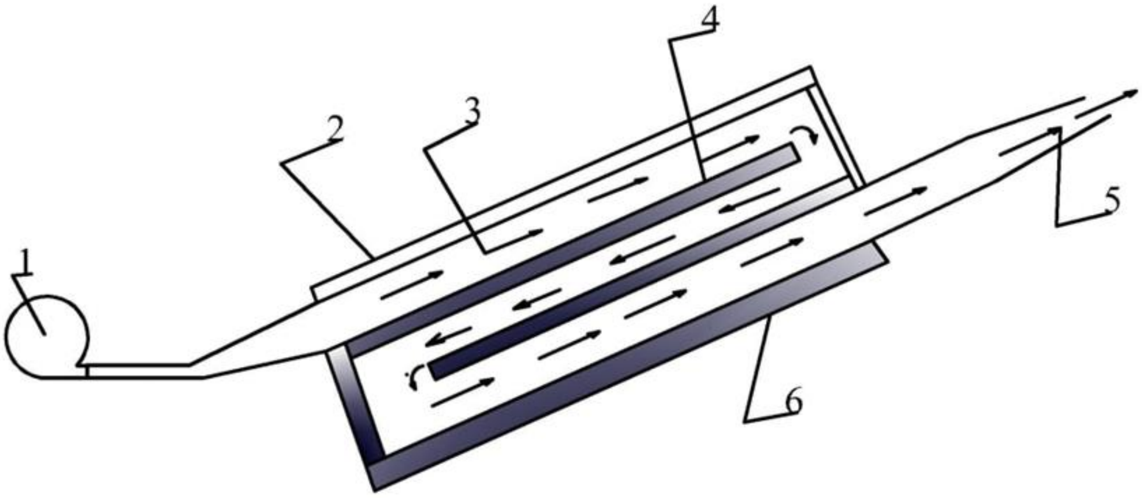

Fig. 2(a), Solar air collector with thermal storage material (a) below the absorber.

here :

1- blower; 2- glass cover; 3- air in; 4- absorber plate;

5- air out to the drying chamber; 6- insulation.

TES material is stored below the absorber plate. As TES material is directly in contact with the absorber plate, the heat energy is conducted from the absorber plate to TES system. In Fig. 2(b) TES material is placed in the heat exchanger or storage tank. Solar flat plate water heater is used to heat the water. This heat is transferred from water to TES material which acts as a heat exchanger. The heat stored in the heat exchanger can be utilised for heating the air for drying food

products.

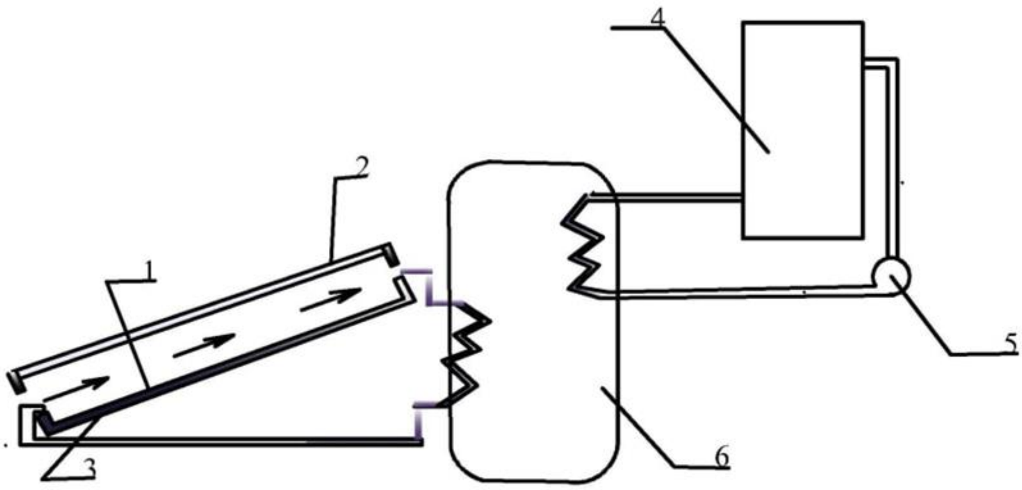

Fig. 2(b), in heat exchanger.

here :

1- glass cover; 2- absorber plate; 3- insulation; 4- drying chamber;

5- blower; 6- heat exchanger.

TES material is kept at the bottom of the drying chamber as can be seen in Fig. 2(c). Hot air from the collector flows through the storage system where heat is absorbed by TES material and it can be utilised in off-sunshine hour [11]. In this section different ITSDs provided with heat storage system are reviewed.

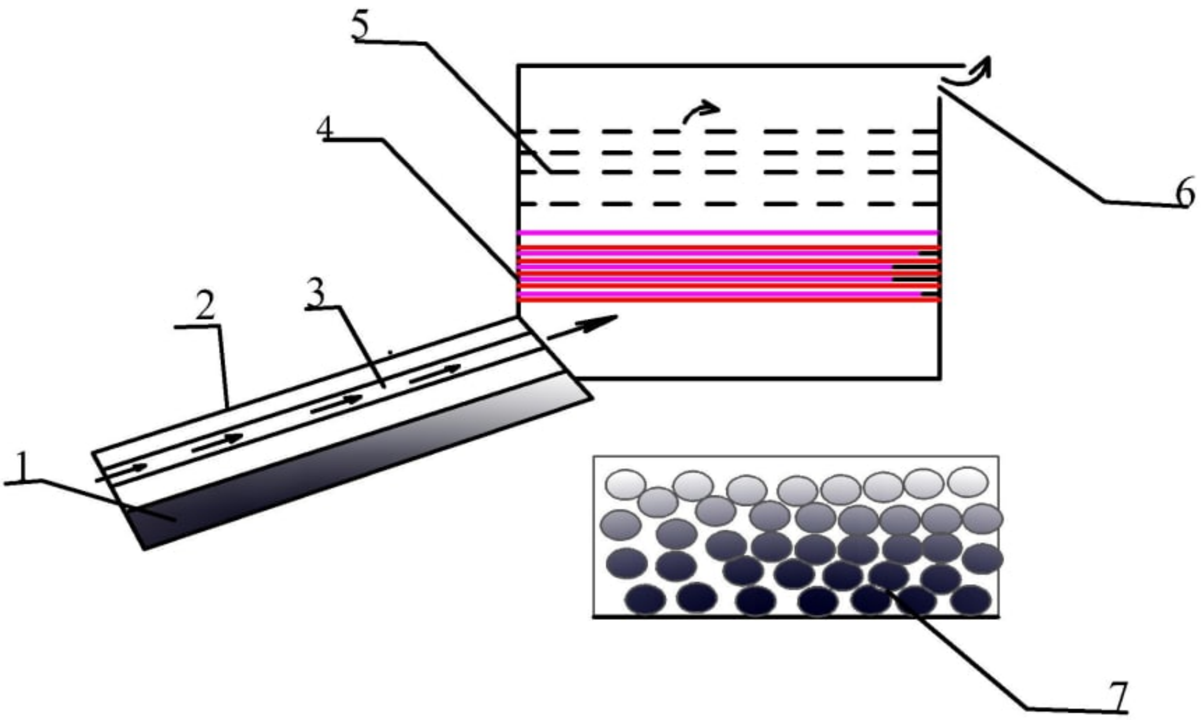

Fig. 2(c), inside the drying chamber.
here :
1- insulation; 2- glass cover; 3- air in; 4-packed bed thermal heat storage system; 5- drying chamber; 6- exit air; 7-front view of packed system.

After studying their work, we proposed several innovative designs of a solar air collector drying device for drying hygroscopic materials. One of the main elements of solar devices is the heat accumulators in it. The use of thermal accumulators in solar devices not only eliminates the imbalance between energy consumption and its production, but also serves to increase their efficiency. Various constructions of today's solar heat accumulators are offered, in which accumulator materials are processed in quality natural stones, metal fragments and other accumulator materials. However, proposals for accumulative materials, especially thermal-physical products and mineralogical production of natural cheap and local types, have not been studied. Accumulator on the basis of natural stones on the basis of agate mineral. Accumulator on the basis of structural stones. [12].

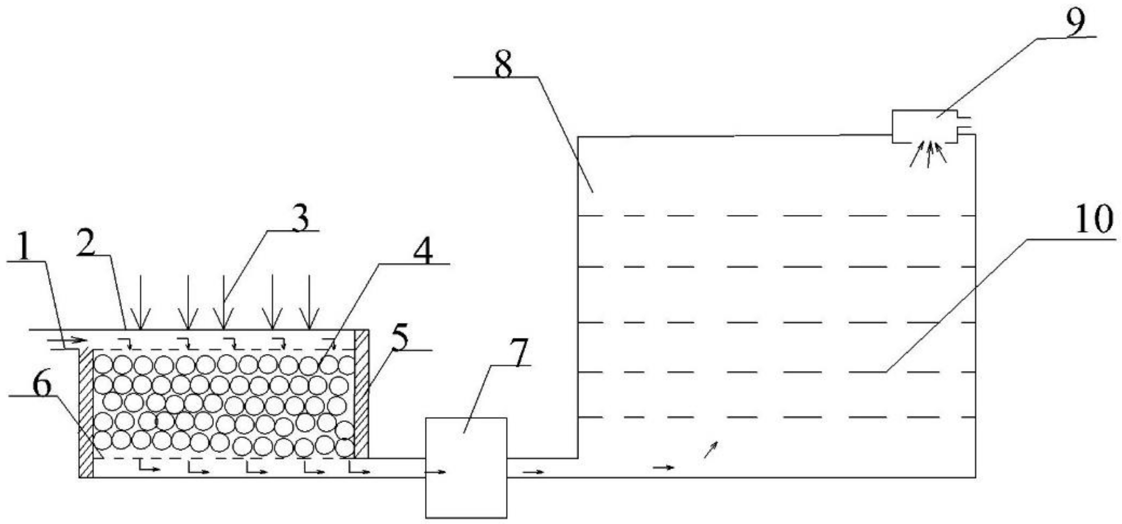

Fig. 3. Black agate home type solar air heater with solar dryer.

here :

1-air in; 2- glass cover; 3- the flow of sunlight; 4 thermal agate heat storage system; 5- collector housing drying chamber; 6- hot air flow; 7- hot air intake fan; 8- drying chamber; 9- humid air exhaust deflector; 10- compartment with floors for product drying.

CONCLUSIONS

Forced convection solar dryer was a new type of greenhouse solar air heater installed with stone bed constructed and experimental performance using local material was evaluated in this study. The performance of the solar air heater was optimized by changing the air flow rate. Optimal condition of the air heater

used for drying hygroscopic products in a dryer. The solar air heater is capable of delivering hot air at 65°C and 1% humidity at maximum conditions at an air flow rate of 0.0124 kg/s. The maximum thermal efficiency is 38% and the delivered energy rate is 4.2 kW. The proposed solar drying device for drying hygroscopic materials is an environmentally friendly and energy efficient solar device with a high FIK.

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