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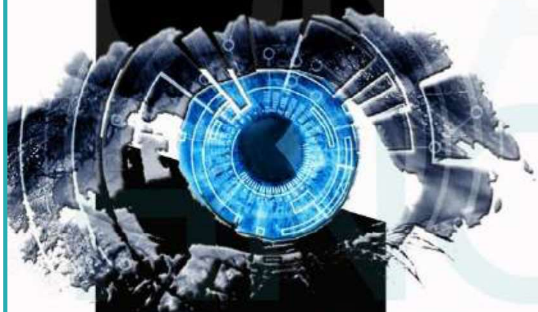

INTERNATIONAL TECHNOLOGICAL SCIENCES And DESIGN SYMPOSIUM

27-29 June 2018

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Experimental Investigation of Thermal Storage Properties of Different Materials Using Solar Air Collector

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Abstract

Air conditioning systems have a high share of energy consumption in the world. Energy dependent countries such as Turkey need to develop different alternative solutions in order to reduce its energy consumption and to meet energy required for heating and cooling applications. Heat storage technologies are an important solution in terms of energy efficiency and energy sustainability. There are many different thermal storage methods, especially in solids, liquids and phase-change materials. In this study, thermal energy storage properties of Urfa stone and basalt stone were investigated experimentally under Şanlıurfa climate conditions. For this purpose, an insulated box where the stone is placed inside, an solar air collector, a fan and an experimental setup with the measuring devices have been used. Solar radiation, air inlet and outlet temperature, stone temperature and ambient temperature were measured and recorded by using a data logger. Air velocity was measured with an anemometer. The thermal energy storage potentials of the stones were determined according to the measurements recorded for different days and the time dependent temperature changes were examined. As a result of this study, it was determined that the thermal storage capacity of the basalt stone is higher than that of the Urfa stone. It has been also observed that the thermal storage potential of natural stones can be used in terms of energy efficiency in heating systems and in drying applications.

Keywords: Thermal storage, Urfa stone, basalt stone, solar air collector

1. Introduction

The use of renewable energy resources and the storage of energy have begun to gain importance due to the ever-decreasing fossil energy resources in the world and their negative effects on the environment. Energy storage is one of a solution for the problem of discontinuity and disconnection of renewable energy sources.

The energy storage is usually carried out as sensible and latent heat storage. In the sensible heat storage method, the sensible heat generated in the change of the temperature of the heat storage material is utilized. Heat storage can be done in liquid, solid, and hybrid materials with liquid and solid. The materials used in sensible heat storage are generally cheap and abundant. The latent heat is the heat that the material receives or gives during the phase change. In the latent heat storage method, Phase Change Materials (PCM), which can store energy as latent heat, are used. At the appropriate temperature limits, the latent heat generated during the phase change of the storage material can be stored. For the purpose of heat storage, materials which undergo phase changes at certain temperatures and whose latent heat values are high are used. Solid-solid and solid-liquid phase changes suitable for heat storage. Liquid-vapor phase change is not suitable for heat storage due to problems such as requiring storage of gas phase in pressure storage tanks. Storage volume of sensible thermal storage is less than that of latent thermal storage.

Due to increased energy costs and time shifts in energy usage, many studies have been carried out on energy storage ((Sharma et al. 2009, Sarbu and Sebarchievici, 2018, Pintaldi et al. 2015)

Li et al. (2018); have investigated composite phase change materials and solar collector / storage system experimentally and numerically. They simulated to investigate the performance of the hybrid system at different temperatures and flow rates. The results show that the composite PCM solar collector / storage system has good thermal storage performance and the average daily storage efficiency reaches 39.98%.

Tian and Zhao (2013); studied thermal collectors and the use of thermal energy storage in thermal applications. Different solar collectors were investigated in terms of optical optimization, reducing heat loss, heat recovery and different solar tracking mechanisms. Various thermal energy storage systems such as sensible heat storage, latent heat storage, chemical storage and cascade storage have also been investigated in the study. As a result of the work it has been stated that PVT solar collectors have the highest performance among the flat collectors and also the molten salts have excellent properties in thermal storage applications.

In another study of thermal energy storage materials and systems for solar energy applications, Alva et al. (2017); have investigated various solar energy thermal energy storage materials and thermal energy storage systems that are currently in use. It has been stated that for the sensible and latent heat storage materials, the technology is commercialized and advanced. However, it is expressed that the thermochemical materials, which have high volumetric energy storage capacity and are expected to have great potential as thermal energy storage materials in the future, are still in the laboratory stage.

Utlu et al. (2014) investigated the availability of thermal energy storage for heating Yıldız Renewable Energy house in Yıldız Technical University Davut Paşa campus in Istanbul with solar collectors. They pointed out the necessity of thermal storage systems during the use of solar energy and ground source heat pumps for heating green buildings. Different methods used in heat storage were investigated and compared. The efficiency of the latent heat tanks which established by utilizing the latent heat of the phase-changing material has been investigated. In addition, thermodynamic analysis of a heating system operating with solar panels, a ground source heat pump and a latent heat storage using paraffin as a phase change material was performed.

Öztürk, (1999) reviewed the criteria to be considered in the selection of phase-change material (FDM) for latent heat technology and solar energy storage applications. Also discussed the effectiveness and applicability of latent heat storage systems and the problems and solutions proposed in latent heat storage systems. According to this study the latent heat storage method can be used in heat engines and power plants, industrial processes, residential air conditioning and commercial applications.

In the work done by Kozak and Kozak (2012), it is aimed to theoretically investigate energy storage and energy storage methods.

It is desirable that the energy is ready for use at the desired time and place. Energy storage is the capture of energy produced at one time for use at a later time. Energy is stored in many different forms.

In this study, thermal energy storage properties of Urfa stone and basalt stone were investigated experimentally in Şanlıurfa climate conditions. For this purpose, an insulated box where the stone is placed inside, an air solar collector, a fan and an experimental setup with the measuring devices have been used.

2. Material and Method

In this study, the thermal storage properties of Urfa stone and basalt stone in Şanlıurfa were investigated theoretically and experimentally with hot air obtained from a solar air collector. The experimental setup used in the experimental study is shown in Figure 1 schematically. Solar radiation and temperature measurement points are given in the figure 1.

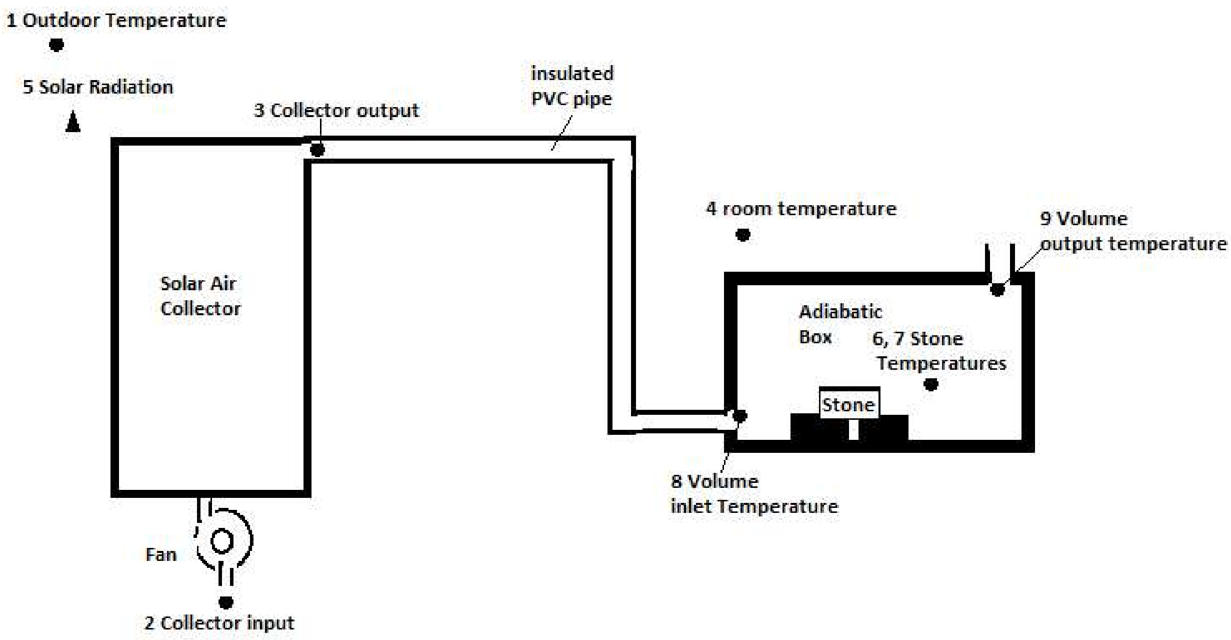
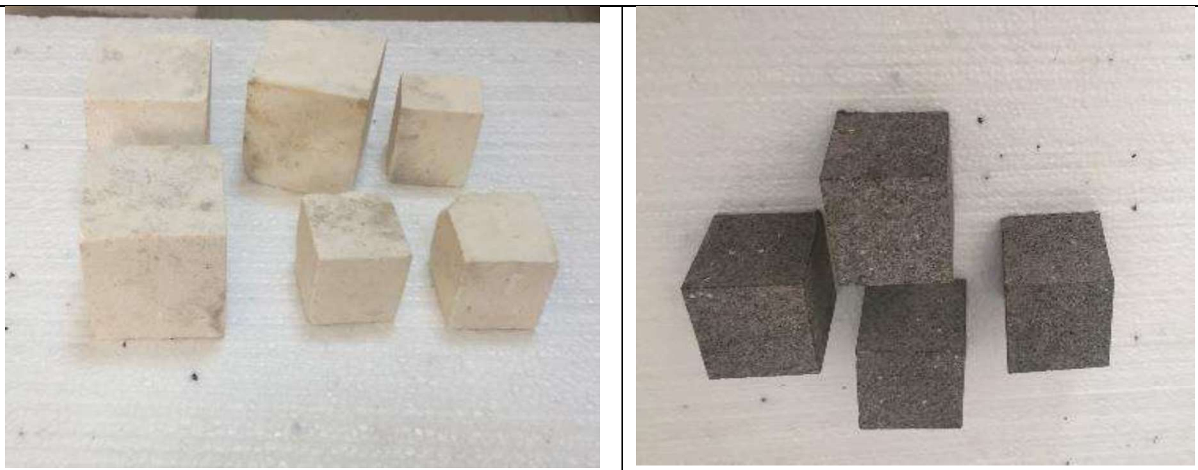


Figure 1. Experimental setup

The thermophysical properties of the natural stones of Şanlıurfa (Figure 2) used in the study are given in Table 1. Urfa stone is a natural limestone that can be easily cut and shaped and used as a building material in different applications (Turgut et al., 2008). Basalt stone is also a natural stone type that is hard and black colored from the volcanic formation of Karacadağ which is located between Diyarbakir and Şanlıurfa (Kahveci and Kadayıfçı, 2013, Günerhan 2009).



a- Urfa Stone	b- Basalt Stone

Figure 2. Natural Stones Used in the study: a- Urfa Stone, b- Basalt Stone

Table 1. Thermophysical Properties of Natural Stones (Turgut et al., 2008, Günerhan 2009.)

Material	Density (kg/m^3)	Coefficient of heat conduction W/mK)	Specific heat (J/kgK)	Coefficient of Thermal Diffusivity (10^{-6} m^2/s)	Heat Capacity (10^6 J/m^{3}K)
Urfa Stone	2570	1.42	1041	0.66	2.68
Basalt Stone	2800	1.513	1500	0.36	4.20

In the system established in Harran University Mechanical Engineering Department laboratory, adiabatic volume (Fig. 3-c) is shown in which the air is passed through the air solar collectors at a speed of 4 m / s (Fig.3-a). The thermal energy obtained is stored as sensible heat in natural stones. Urfa and basalt stone are cube shaped and have dimensions of 7x7x7 cm and 5x5x5 cm. 8 kg of stone was used in each experiment. Temperatures are measured by T-type thermoouples. The solar radiation coming to the surface of the solar collector is measured by a pyranometer (Figure 3-a) Temperature and radiation values are also recorded in the data-logger (Figure 3-b)

a b c

Figure 3- a: Solar Air Collector and pyranometer b: Data-logger and thermocouples c: Adiabatic Volume

3. Results and Discussions

Figure 4 shows the change in Urfa stone temperature and adiabatic volume inlet and outlet temperatures with time. It is understood that the increase of the solar radiation during the day increases the collector outlet temperature and thus the temperature of the air entering the volume and the temperature of Urfa stone are also increased. Urfa stone temperature goes up to 42 ºC. The change of adiabatic volume inlet - outlet and Urfa stone temperatures shows similarity.

The effect of solar radiation on the solar collector output temperature and hence on the volume input temperature is observed in a short time like 30 minutes and the effect on Urfa stone temperature is realized with a certain phase shift such as 1.5 hour. Urfa stone stores heat until 15:00 o'clock. After 15:00 o'clock the decrease of the solar radiation (Figure 4) decreases the temperature of the air leaving the collector and the stored heat is returned as it is lower than the temperature of Urfa stone. It is also observed that the fluctuation in the solar radiation affects the collector outlet temperature and thus the volume inlet temperature.

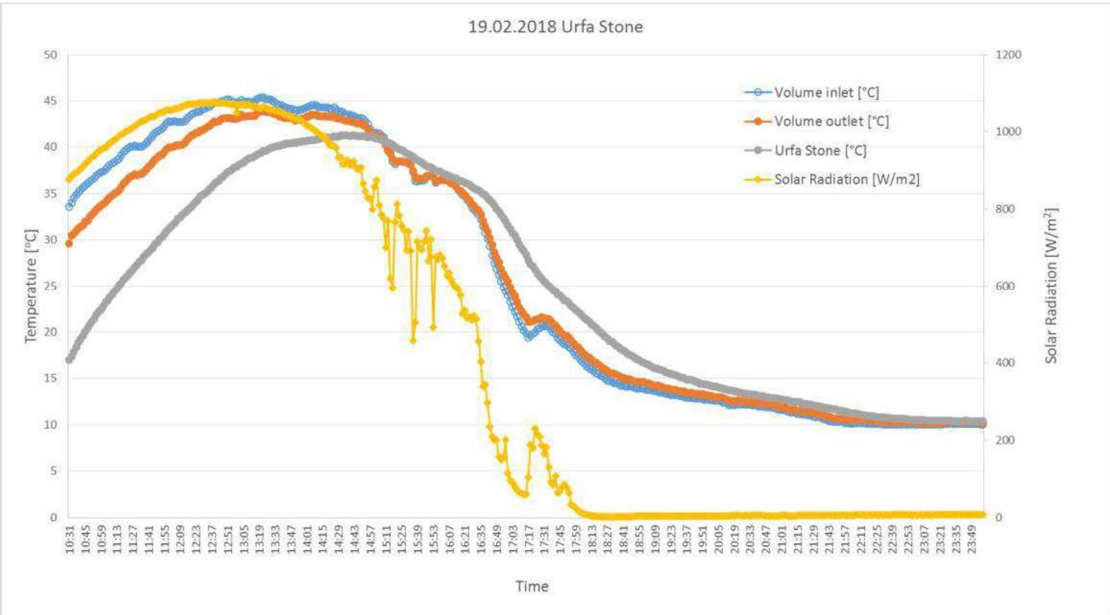


Figure 4: Urfa stone, volume inlet - outlet air temperatures and solar radiation change over time (19 February 2018)

Figures 5 and 6 show basalt stone, volume inlet - outlet temperature and solar radiation change over time for the dates of 6 and 7 February 2018. Figures show that the solar radiation and temperature show similar changes for different phase shifts. A phase shift of 30 minutes was detected at the volume inlet temperature and a phase shift of 60 minutes at the basalt stone temperature was detected. After 15:30, the basalt stone moves to the discharge position and the volume outlet temperature is higher than the inlet temperature. It is seen that the basalt stone's temperature is given to the air until late at night.

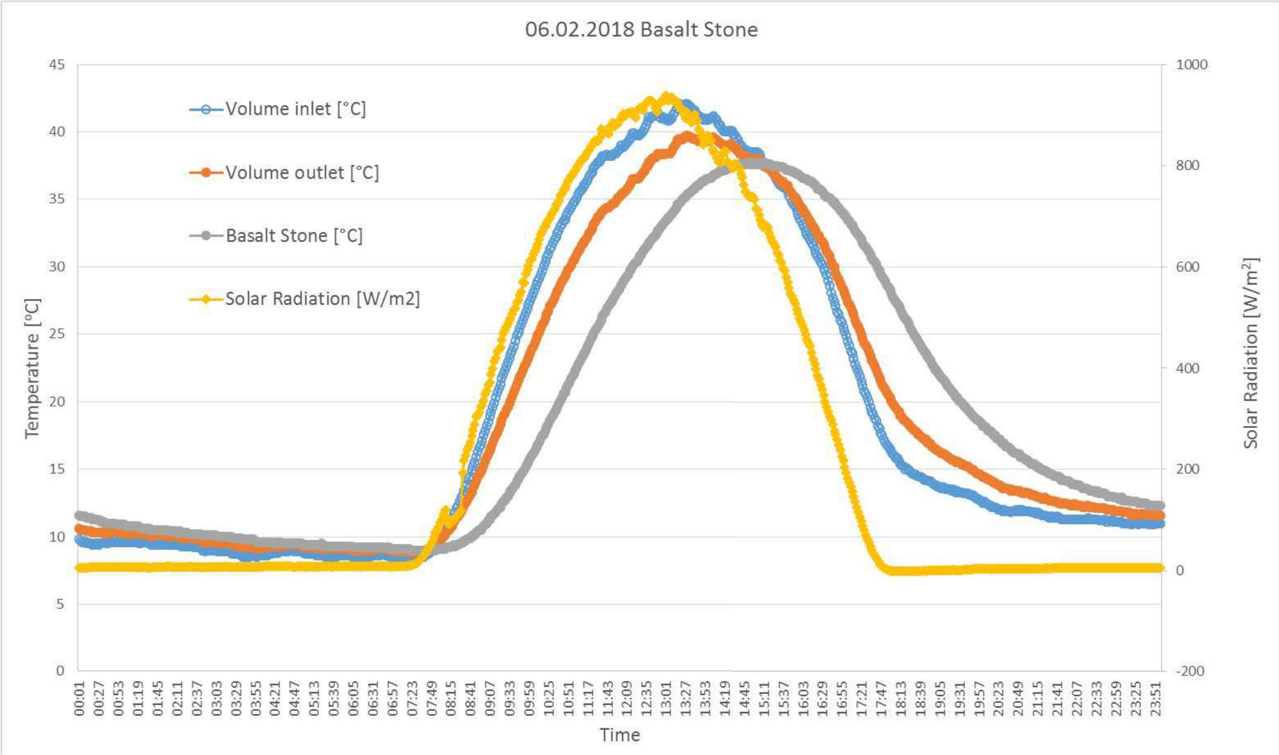


Figure 5. Basalt stone, volume inlet - outlet air temperatures and solar radiation change over time (6 February 2018)

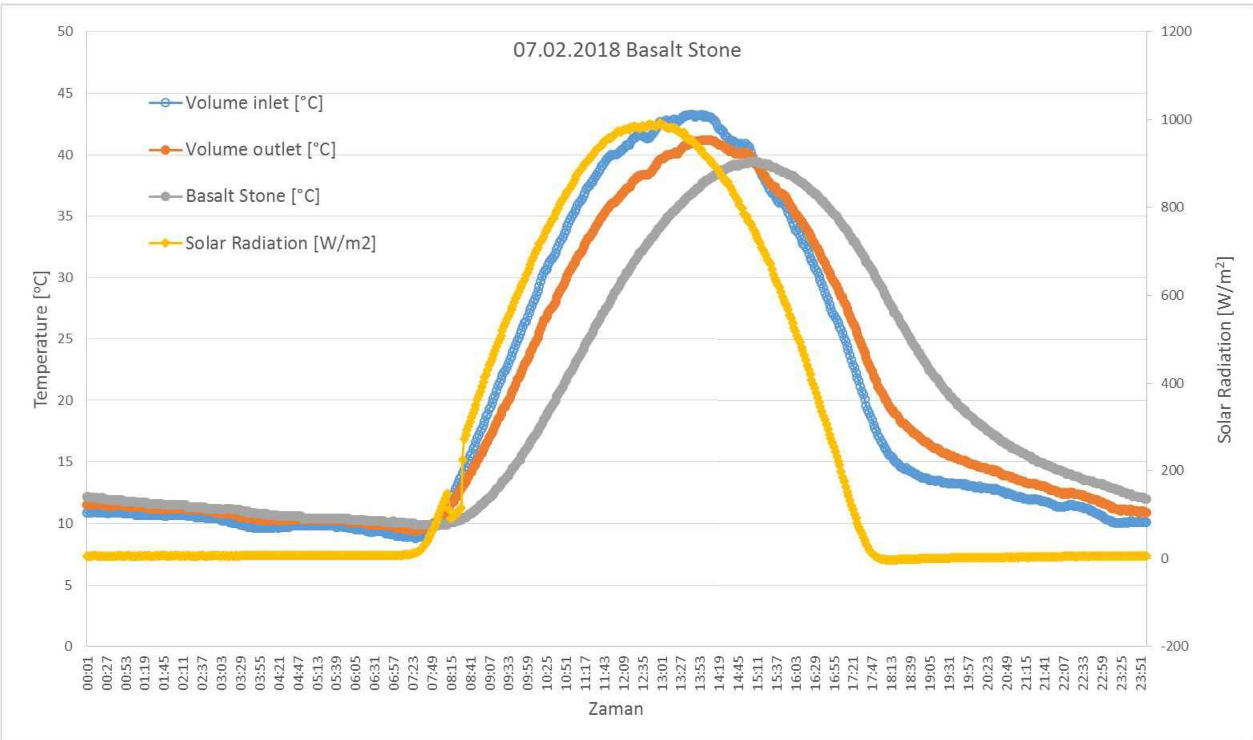


Figure 6. Basalt stone, volume inlet - outlet air temperatures and solar radiation change over time (7 February 2018)

4. Conclusions

In this study it is seen that Basalt and Urfa stone have heat storage properties and can be used as heat storage material. It has been determined that the heat storage capacity of basalt stone is higher than that of Urfa stone and also the efficiency of thermal storage is high in sunny days It was observed that the stone temperatures were up to 50°C depending on the solar radiation and the inlet temperature.

It is understood that the phase shift in the basalt stone is 30 minutes shorter than the Urfa stone. Therefore, basalt stone warms up earlier than Urfa stone. Urfa stone and basalt stone have been found to give heat until late at night and to increase the temperature of the air.

When the experimental results are evaluated, it is understood that basalt stone and Urfa stone in solar air collectors are suitable as thermal storage material. The natural basalt stone can be used as an additional energy source either directly in the heating of the place in winter conditions.

In this case, in order to obtain the most efficient performance in the heating system, it is necessary to install the automation system and good heat insulation of pipes and ducts

In summer conditions, especially solar energy drying systems, daytime heat stored in natural stones can be used as uninterrupted energy source by discharging in night hours.

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