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System performance of a residential building using the air-based solar heating system

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ABSTRACT

To apprehend the performance of a solar heating system, it is important to first understand the relationship between the heating load and the system elements, such as heat collection, heat storage, and insulation, among others. Due to the fact that the performance of solar heating systems fluctuates with weather conditions, in this study, measurements in three huts were collected at the same time in order to compare the influence by these factors on the system. By installing insulation on concrete, the heat absorption amount of the base concrete was reduced by 13.2% and the heat release amount was increased by 12.0%. This result shows the necessity of insulation in case of using underground space for heat storage in a solar heating system. Also, a possibility of water pack as thermal storage was presented for a solar heating system.

1. Introduction

Energy self-sufficiency rates in Japan are at very low levels of around 4%; not included the nuclear power. Meanwhile, even though housing insulation standards have been improved, heating energy consumption is still large, especially in the north of Japan. The Tohoku region, affected by the Great East Japan Earthquake of 2011, has been severely cold in the winter and the consumed heating energy is large, so utilizing renewable energy sources with a low dependency on grid power and fossil energy is a necessity. Research on a variety of renewable energy sources, such as geothermal, wind power, and tidal power, has been progressing. Particularly, interest in solar heat has been rising due to its system simplicity, superior maintainability, and the convenience it provides by being able to be used even in dwelling units. Also, looking overseas, hot water supply through the means of solar heat has become popular in China, South Korea, and other countries and it is expected its utilization for heating purposes will also increase in the future (Raffenel et al., 2009; Belusko et al., 2004). Furthermore, the energy potential and optimization of solar water heating systems have been studied in recently (Zainine et al., 2017). There are two systems of active type solar heat utilization, roughly divided into liquid type and air type heat collection. Although there are merits and disadvantages to each heat collection method, air-based heat collection has attracted more attention as it is able to heat air that also incorporates fresh outdoor air while also collecting heat (Yang et al., 2012). Also, for improving their thermal efficiency in terms of operating time, solar air heating using latent storage energy has been studied (Arfaoui et al., 2017). The collector of the air heat collecting system handled in this study is a preliminary collector that uses the roof surface finish as a heat collecting surface and a glass collector for high-temperature collection. The air warmed by the preliminary collector and the glass collector flows into the room below the floor and then is exhausted outdoors. A general collector is designed so that the upper limit of the temperature of the collected air in the summer is about 80–100 °C, through simulation. A design method is therefore necessary, taking into account the area and ratio of the preliminary collector and the glass collector in order to cover the indoor heating load during the winter. Also, due to the characteristics of solar heat utilization with heat only being able to be collected during the daytime, there is a difference between the time zone during which the heat can be collected and the time when the heating load occurs in the room. Therefore, for effective solar heat utilization, heat storage is required (Singh et al., 2015; Nicholls et al., 1981). In the case of air heat collection, since the volume-specific air heat is small, it is necessary to store the heat by exchanging heat with a substance that has a large specific heat. In this system, it is assumed that the center of the base concrete floor is used as a heat storage medium. For heat insulation around the base concrete, insulation is installed at the rising portion of the concrete floor which faces the outside air and at its outer circumference. In the existing air-based solar heat collecting system, as shown in Fig. 1, the

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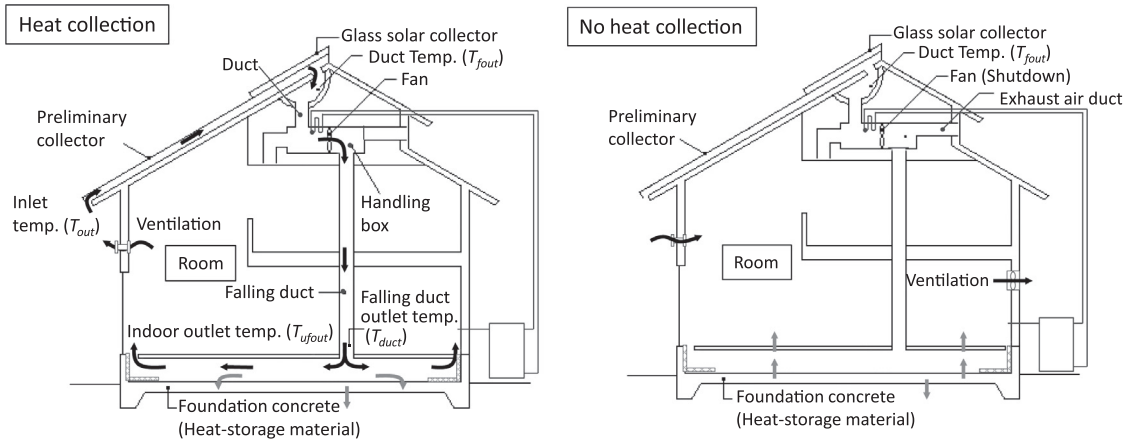

Fig. 1. Existing air-based solar heat collecting system.

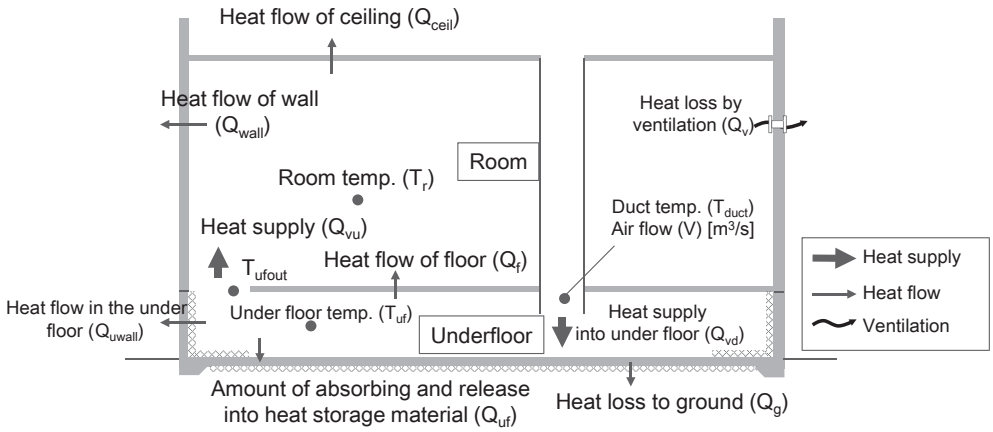

Fig. 2. Definition of heat flux in the underfloor and room.

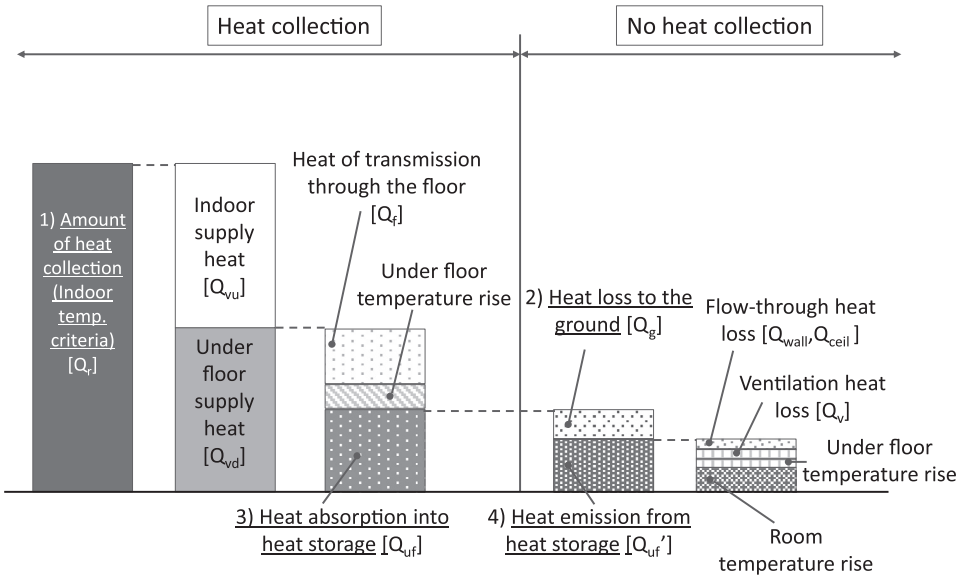

Fig. 3. Heat balance of air-based solar system.