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Using phase change material in under floor heating

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Abstract

In the last decade, studying of thermal energy storage systems using phase change material (PCM) in the field of building has been increasingly developed. Indeed, it decreases the energy consumption used for indoor heating system while maintaining maximum thermal comfort for the occupants. This paper presents a study on application of white petroleum jelly, which is used as a phase change material, with an electrical under floor heating system. To proceed, a prototype of a well-insulated house is constructed. An experimental study was carried out in a relatively cold weather to investigate the thermal behavior of using phase change material. Results show that at an average ambient temperature (T_{avg})of 14°C the electrical consumption was shifted by an average of 6 hours due to the latent heat stored in PCM.

Keywords: PCM, thermal energy storage, energy saving, latent heat, under floor heating.

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Introduction:

In cold climate, intense fuel consumption occurs during winter which causes a severe increase in fuel consumption. Due to the environment and economic concern, it is necessary to orient our studies toward friendly environmental systems such as heat storage systems [1-5], renewable energy systems [6-11], and heat recovery systems [12-18].

Some countries implement price scales depending on a time period [3]; peak period has a high cost in comparison to off-peak period which has a low cost. The goal is to store thermal energy during off-peak period, and release it during peak period. Sunlight, or solar energy, can be directly used to heat homes and other buildings, as well as to provide electrical energy. Consequently, solar energy is a renewable source of energy that can be considered as an alternative electric source; thus, solar energy is considered as an input power to supply electricity to the insulated house and under floor electric heating system. This kind of energy source is not available at night, for this reason, latent heat storage system in phase change materials (PCMs) has been widely used due to its high heat storage capacity, which permit act as a thermal battery. Also, most phase change materials are relatively cheap, and not toxicity. [19-20] However, the conventional PCMs, like "Petroleum Jelly," have the disadvantage of low thermal conductivity. Accordingly, an enhancement has been made.

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Many studies are dedicated to balance the effects caused by indoor temperature fluctuations through phase change wallboards and to maintain comfort for building occupants. An experimental study presented by Zhang et al. [21] showed that about 15% heat energy was lost through the insulation when a 120 mm-thick polystyrene insulation was included in the under-floor heating system. In addition, most studies have been focused on thermo-physical properties (phase change temperature and enthalpy); while few works have been devoted to analyze the effect of thermal conductivity although it is of crucial parameter for such applications [22, 23]. Improving the thermal conductivity of PCM in a certain range can greatly reduce the heat leakage ratio and the PCM will show more uniform and stability in temperature distribution. Thus, the energy efficiency of the under-floor heating system would be greatly affected. Cheng et al. [3] conducted simulations and experiments with an EHF with a shape-stabilized PCM. The heating time lasted 10 hours and the intermittent time lasted 14 hours, with outdoor temperature between 0 ˚C and 6 ˚C. In comparison with other heating strategies (i.e., operating all day), the EHF with PCM was able to completely shift the load from peak periods to off-peak periods. This paper presents an experimental study on the effect of electrical under floor heating system incorporating phase change material on the construction elements -'walls, ceiling and floor'- and on the heating process of the prototype of an insulated house. Moreover, White Petroleum Jelly was used as a phase change material, and its low thermal conductivity was increased by mixing a specific amount of high thermal conductivity material. Significantly, the energy savings and economic benefits were theoretically and experimentally studied

2. Materials and methods

In this section, the foundation of the tested house (section 2.1), the prototype implementation (section 2.2), and the results and analysis (section 2.3) are presented.

2.1. Foundation

The basis of the prototype is to shift electrical consumption, as well as to provide thermal comfort. In addition, and due to the environmental concern, the house is designed to be electrically supplied by solar energy, which is a green energy. To achieve the desired aim, a low voltage electric heating system is used, and placed under the floor of the insulated house. This heating system will convert electric energy, which is the input power provided by the solar system, to thermal energy, which is the desired output. However, due to the fact that sun's radiation is available at day and unavailable at night, the system will be inactive at the night time; thus, an assisting system is required to provide thermal energy at night time. This assisting system is represented as a phase change material (PCM), which is placed under the floor of the insulated house, along with the electric heating system. This PCM can be viewed as a thermal battery that stores and releases heat; therefore, it can store heat at day and release it at night. Consequently, the insulated house, which is supplied by an under-floor electric heating system with PCM, can shift the electrical consumption while providing thermal comfort.

2.2. Prototype

To study the effect and the role of phase change material in heating mode, its performance is analyzed by heating the insulated house with under-floor electric heating system under relatively cold weather. The prototype is constructed, as shown schematically in Figure 1.