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Experimental investigation on heat gain reduction using a vinyl perforated ceiling

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Abstract

This paper is investigated the ceiling heat gain reduction by using the vinyl perforated ceiling. Two model houses are served to investigate with the ceiling area about 1.44 m^2. The vinyl perforated ceiling made from the vinyl soffit panels, the original dimension as (W:33×H:300×t:0.1 cm). Three vinyl ceiling area ratios (vinyl perforated area/ solid vinyl area) were considered. The experiments have been carried out under the climatic conditions of Thailand. The performance of vinyl perforated ceiling was investigated experimentally and compared to a common ceiling (gypsum board). The results indicated that the vinyl perforated ceiling can reduce the ceiling heat gain and attic temperatures are 1-7 W/m^2 and 1-4°C, respectively. The percentage of ceiling heat gain reduction is much sufficiently.

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Keywords: Vinyl perforated ceiling, common ceiling, vinyl panel, thermal performance, ceiling heat gain

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1. Introduction

In many countries with predominantly hot and humid climates, energy consumption in residential has to be considered to achieve an efficient building design. Passive solar design can be applied easily to residential house. Such designs convert solar energy into usable heat, cause air movement for ventilation. The effect of heat accumulation under the roof caused the room to be hot; accordingly, the attic ventilation is essential to proceed in the residential house. Nowadays, the most widely used ventilation systems in the attic and room spaces are combining natural and forced ventilations. Actually, natural ventilation is sufficiently to remove heat accumulation.

In Thailand, Roof Solar Collector (RSC) has been continuously studied to remove heat accumulation in attic area. First researcher [1] reported one of the first detailed investigations of natural ventilation of air between two plate layers. His experiments were performed on a small scale test. The results were described that, the suitable material on the upper layer is CPAC Monier and the lower layer is gypsum board. Recently, Phiraphat et al. [2] developed an original roof solar collector, which called photovoltaic roof solar collector (PV-RSC). The PV-RSC consists of a PV panel on the upper layer and the lower layer is an aluminum plate. The experiments were carried out to investigate the thermal performance and also reducing ceiling heat gain. Nevertheless, most of these studies were done under conditions more applicable to roof tiles applications.

A novel type of ventilated roof tile (VRT) proposed in 2014 [3], the VRT composed of two layer with a 3 cm air gap for airflow through the middle section, each layer has a thickness of 1 cm. The dimension was 40×40 cm^2 on the top layer and 10 cm overlap (installation). The thickness of each concrete plate was 1 cm. The dimension of top gable tiles was 20×40 cm^2 (each side). The results indicate that the VRT provide high ventilation and reducing ceiling heat gain. Later, Juengpimonyanon et al. [4] proposed a tile ventilator to reduce heat accumulation in attic area by natural attic ventilation. A tile ventilator has been designed appropriate to ventilate in attic area. Two model houses were used to investigate the thermal performance of tile ventilator. The results were performed that the tile ventilator is effective to reduce attic temperature and improved natural attic ventilation.

In the part of ceiling ventilation, full-vent perforated soffit and ceiling [5] presented in 2006. A residential house used for field-testing, it is located in Bangkok. This house has two stories. The roof was made of dark red CPAC Monier concrete tiles (corrugated tiles). The full-vent perforated soffit was installed in the place of wood soffit and also in the place of gypsum board ceiling. The experiments focused analysis on measured temperature and relative humidity as indicators of the combined effect of full vent soffit-ceiling ventilation. The experimental results pointed out that perforated ceiling was very effective for reducing attic air temperature and moisture accumulation in the bathroom. A novel ventilation concept was proposed recently, named as diffuse ceiling ventilation. Experimental and numerical has been proposed to study the parametric analysis of the diffuse ceiling ventilation in the office room [6] and classroom [7]. The experiments were carried out in a test chamber to examine the impact of diffuse ceiling opening area on the system cooling capacity and thermal comfort. The results were indicated that diffuse ceiling ventilation provides a satisfied thermal comfort level in the occupied zone even under a high ventilation rate and high heat load condition.

The objective of this research is to investigate thermal performance of a vinyl perforated ceiling (VPC). Three vinyl ceiling area ratios (vinyl perforated area/ solid vinyl area) were considered viz. 0.01, 0.02 and 0.03, respectively. To assess the thermal performance of VPC, the following important parameters were considered: the attic temperature, indoor temperature and heat gain reduction.

2. Experimental set-up

Two model houses used for testing is show in Fig. 1. They were located at Rajamangala University of Technology Rattanakosin, Salaya, Nakhon-Pathom THAILAND. They were built from steel structure, and all of masonry walls. The roof is gable roof, and thatched by corrugated concrete tiles (brown color). The attic had a length of 2 m and width of 2 m, the roof angle was 30°. The ridge was oriented from east to west. There is no insulation on top of the ceiling. The reference house was installed the common ceiling (suspended ceiling) and the other house was installed the vinyl perforated ceiling. The perforated ceiling vents area is 0.042 m^2 and ridge vents area is 0.04 m^2 (outlet). A wood door with air grille at the bottom was installed on the east. The model houses were built on the top of the building. The data were recorded every 10 minutes throughout the day.