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Renewable Night Cooled Chill Water Source for Energy Efficient Indoor Radiant Cooling

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Abstract This study investigates cooling of water at night in Malaysian climate as renewable cooling medium source for radiant cooling purpose. An experiment with a 1.95 m² steel roof rig structure was constructed and night cooling cycle was conducted during the hot season and cold season of the year. Regression model was developed to predict water temperature after the night cooling process and the corresponding water and roof ratio was established. An annual simulation of a low income home model retrofitted with radiant cooling system charged by night cooled water as cooling medium shows that 99% of the time the thermal condition could meet ISO 7730 category C Predicted Mean Vote (PMV) between -0.7 and + 0.7 . For an outdoor American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) design day condition, the peak indoor operative temperature of 37°C could be lowered to about 30°C with the use of radiant cooling system. The calculated energy saving for the home model was 85% or about 15% of the conventional air system operating cost.

Introduction

Building sector account for 40% of the total energy consumption and most of the energy is used to maintain an adequate thermal indoor climate condition by heating, cooling and ventilation [1]. Typically 60% energy is used for building indoor air cooling in hot and humid region [2]. High saving potential is possible with the current technology that optimizes the building envelope as well as the HVAC system. Radiant system integrated in building is able to provide such saving where 12% to 18% energy reduction is a minimum expectation for a radiant system in comparison to a convective system providing equivalent comfort [3]. Energy conservation of building using a radiant cooling system are on the order of 17%-53% better than the threshold set by ASHRAE Standard 90.1-2010 [4]. This is due to the efficient operating modes by allowing chiller to operate at a higher temperature and thus lower overall energy use. Temperature between 12.7°C to 17.2°C is the typical temperature for a radiant cooling system therefore allow chiller to operate in efficient range. However some researcher have restricted the temperature between 20°C to 25°C [5-7] due to dew point and condensation restriction in hot and humid climate and that lower temperature is advisable with the use of a desiccant dehumidification as a mean to improve the performance of radiant cooling panel in hot and humid climate. Ideal water temperature to be used in this region is in the range of 21°C to 25°C and in Malaysian climate the yearly minimum temperature could provide such cooling source. Due to the higher temperature operation range, there is potential alternative source for chilled water which may include fluid coolers, geothermal heat pumps or lake water [4]. Combining radiant cooling system with a free cooling source can reduce energy consumption by 80-90% since traditional chillers can be eliminated and only electricity for circulation pumps is needed [1].

A high potential cool water source in this hot and humid region is the cooling of water via long wave radiation to the night sky. There are several ways or device that could be used to cool the