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REVIEW

A literature review on the improvement strategies of passive design for the roofing system of the modern house in a hot and humid climate region

Qairuniza Roslan[a,*], Siti Halipah Ibrahim[a], Rohaida Affandi[a], Mohd Nasrun Mohd Nawi[b], Azhaili Baharun[a]

[a]*Faculty of Civil Engineering, Universiti Malaysia Sarawak, Sarawak 94300, Malaysia*
[b]*School of Technology Management and Logistics, Universiti Utara Malaysia, Kedah 06010, Malaysia*

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Abstract
Increase of indoor temperature compared with outdoor temperature is a major concern in modern house design. Occupants suffer from this uncomfortable condition because of overheating indoor temperature. Poor passive design causes heat to be trapped, which influences the rise in indoor temperature. The upper part, which covers the area of the roof, is the most critical part of the house that is exposed to heat caused by high solar radiation and high emissivity levels. During daytime, the roof accumulates heat, which increases the indoor temperature and affects the comfort level of the occupants. To maintain the indoor temperature within the comfort level, most house designs usually depend on mechanical means by using fans or air conditioning systems. The dependence on a mechanical ventilation system could lead to additional costs for its installation, operation, and maintenance. Thus, this study concentrates on reviews on passive design and suggests recommendations for future developments. New proposals or strategies are proposed to improve the current passive design through ventilated and cool roof systems. It is possible to achieve the comfort level inside a house throughout the day by reducing the transmitted heat into the indoor environment and eliminating the internal hot air. These recommendations could become attractive strategies in

*Corresponding author. Tel.: +60 10 9824051.
E-mail address: qairunziaroslan@gmail.com (Q. Roslan).
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providing a comfortable indoor temperature to the occupants as well as in minimizing energy consumption.

Contents

1. Introduction

Malaysia is located at 3° N from the equator in the tropical region and experiences an equally distributed amount of rainfall throughout the year. High temperature (between 22 °C and 33 °C) is felt because of high solar radiation level and high relative humidity (Al Yacouby et al., 2011). The average solar radiation level for a tropical climate ranges from 4.21 kW h/m^2 to 5.56 kW h/m^2 per year (Azhari et al., 2008) and receives a duration of sunlight of up to 8.7 h per day (Malaysia Meterological Department, 2014). Abdul Rahman et al. (2009) showed that the hottest time of the day is between 11.30 a.m. and 4.30 p.m. Jones et al. (1993) indicated that the acceptable thermal comfort temperature inside a house for the Malaysian climate is between 25.5 °C and 28.5 °C. In compliance with ASHRAE 55-1992 (1992) standards, the recommended comfort temperature under the climatic condition for the dwellers is around 24 ± 1 °C. Noor Aziah (2008) identified that the concrete terrace houses in Malaysia are thermally comfortable to be occupied for only a few hours per day. The indoor temperature within the thermal comfort temperature is only at a certain period before it exceeds the comfort temperature level. Fig. 1 shows the outdoor temperature versus the daily indoor temperature.

Fig. 1 shows that the indoor temperature of the concrete house reached peaks of more than 30 °C during daytime. The increase in temperature is due to the poor passive design of the house. Passive design could help maintain the temperature inside the house within the comfortable temperature range. The heat transmitted through the roof building and the poor passive design of the structure are the main reasons for the discomfort of occupants in a non-air conditioned building (Vijaykumar et al., 2007). A roof design problem occurs because of the poor ventilation provisions in the modern low-income housing design (Ibrahim, 2004). Thus, the main concern of the present study is the top part of a building that is exposed to direct sunlight. An amount of heat, which is transmitted from the roof surface, is trapped in the attic area. Thus, this creates a higher temperature in the upper part of the house. Because of poor passive design, the trapped heat generates a higher temperature in the attic area, especially during peak hours in the hot climate region. Heat transmits from the roof to the ceiling, stores inside the concrete walls and floor slabs, and creates greater indoor temperature because of stagnant air (Abdul Wahab and Ismail, 2012). Tinker et al. (2004) showed that the internal temperature of the modern low-cost house is higher than the required temperature for an occupant's comfort level. Therefore, it could lead to high power usage of mechanical means and increase energy consumption. The highest daily electricity demand of 345.25 GW h was reported in 2013, which increased by 5% from 2012. Meanwhile, the annual electricity demand also

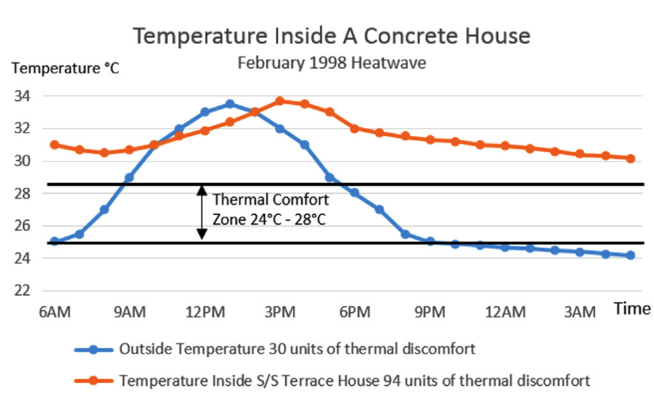

Fig. 1 Temperature inside a concrete house.
Source: Reducing urban heat island effect with thermal comfort housing and honeycomb township (Davis et al., 2005).