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Potential of shading devices and glazing configurations on cooling energy savings for high-rise office buildings in hot-humid climates: The case of Malaysia

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Abstract

Rapid growing of energy use has raised critical concerns over energy supply difficulties and negative environmental impacts globally and among ASEAN countries. Malaysia is experiencing a high average annual energy demand growth rate of approximately 2.3% which large portion of that energy is used by office buildings. Under the hot-humid climatic conditions in Malaysia, high-rise office buildings with large or fully glazed façades are facing a major problem of overheating due to high solar radiation through the glazed façades. This has caused high cooling energy requirements. The aim of this study is to investigate the potential of three types of shading devices on cooling energy savings when applied at different façade orientations. The aim also extends to investigations on different cooling energy savings when shading devices are applied on façade glazing with different configurations and thermal performances. This was done through a case study of a high-rise office building in Kuala Lumpur, Malaysia using IES (VE) building thermal simulation software. Twenty simulation building models were applied with different shading devices at different façade orientations and with high and low performance façade glazing. The simulation results indicate that high-rise office buildings in Malaysia use approximately 45.9% of total building energy for cooling purposes. The results also suggest that use of various shading devices on low-e double glazed façades will result between 1.0% and 3.4% annual cooling energy savings, depending on the types of shading devices and façade orientations. The estimated annual cooling energy savings increase to between 5.0% and 9.9% when the shading devices are applied to all orientations of low-e double glazed façades. The estimated annual cooling energy savings further increase to between 5.6% and 10.4% when the façade glazing is replaced by single clear glazing. This study recommends prioritizing shading devices on the East and West façades for optimized annual cooling energy savings. The simulation results show that egg-crate shadings are able to produce the highest annual cooling energy savings compared to vertical shadings and horizontal shadings. It is recommended to use shading devices on low performance glazing compared to high performance glazing since the energy savings are more significant when shading devices are used on low performance glazing. In conclusion, the use of shading devices is more effective in achieving cooling energy savings compared to the use of high performance glazing under the hot-humid climate of Malaysia.

Keywords: Cooling energy; High-rise office building; Hot-humid climate; Shading devices

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1. Introduction

Rapid growing of energy use is a major issue at the global perspective with concerns over supply difficulties, exhaustion of energy resources and environmental impacts (Pérez-Lombard et al., 2008). According to International Energy Agency, the energy use growing trend is also very critical among ASEAN countries. As shown in Table 1, an average annual energy demand growth rate of 2.5% is predicted between the year of 2011–2035. In the case of Malaysia, the predicted growth rate is 2.3%. The same data predicted that Malaysia will experience an increase of 29.7% of energy demand from 2011 to 2020, with an average annual growth rate of 3.3% (Birol, 2013).

Buildings consumed up to 40% of total energy globally (Hassan et al., 2014). In the context of Malaysia, buildings consumed a total of 48% of the electricity generated in the country (Chua and Oh, 2011). According to Energy Commission Malaysia, commercial buildings consumed a high percentage of 32.7% of total energy used in the country in 2013 (Energy Commission Malaysia, 2016). This is because commercial buildings in hot-humid climates such as is found in Malaysia are often installed with air conditioning and mechanical ventilation systems to sustain and improve indoor thermal comfort. Most of the time, these systems consume the most energy among all other building services (Kwong et al., 2014). Other sectors including industrial, residential, agricultural and transport consumed 45.4%, 21.4%, 0.3% and 0.2% of electricity respectively, as shown in Table 2.

1.1. Hot-humid climate of Malaysia

Malaysia is positioned on the South China Sea. This country lies between 1° and 7° in North latitude, and 100° and 120° in East longitude (Nugroho, 2010). Malaysia is experiencing hot-humid climatic conditions with characteristics of uniform temperature, high humidity and copious rainfall. Malaysia naturally has abundant sunshine and thus abundant solar radiation throughout the year (Ministry of Science, Technology and Innovation (MOSTI), 2015). Malaysia receives an average solar radiation of 400–600 MJ/m^2 per month (Mekhilef et al., 2012). The annual average solar radiation (MJ/m^2/day) is shown in Fig. 1. Table 3 shows the yearly average solar radiation levels throughout different cities in Malaysia.

Due to geographical position, temperature in Malaysia typically varies from 24 °C to 34 °C and is rarely below 23 °C or above 35 °C, as shown in Fig. 2. The relative humidity varies from 54% to 96% over the course of the year and rarely drops below 44% or reaches 100% (Weatherspark, 2016). The weather conditions in Malaysia is such that it is a rare circumstance to witness days completely without sunshine except during the Northeast monsoon season and it is unusual to witness a whole day with a clear sky in drought season (Mirrahimi et al., 2016). There are two types of monsoons that occur yearly, namely Northeast monsoon and Southwest monsoon. Northeast monsoon occurs between November and March. Meanwhile, the Southwest monsoon occurs between May and September. Winter-monsoon occurs during April and October and between September and December. Malaysia experiences heavy rainfall with the measurement of 2500 mm per year.

1.2. Problem of high cooling energy consumption due to overheating

Highly glazed buildings have become a worldwide design trend in modern architecture for any climate (Chown et al., 2010). In developing countries including Malaysia, huge façade glazing has been widely used to present positive architectural images such as transparency and modernity. Besides, huge façade glazing can also provide full external views. However, this causes higher energy consumption and thermal discomfort due to higher solar gain (Hien et al., 2005). From previous studies, high-rise buildings in hot-humid climate are experiencing overheating due to high solar radiation. Large glazed façades are said to be the main cause of this problem (Ling et al., 2007; Kirimtata et al., 2016). Due to the overheating condition caused by

Table 2
Statistics of electricity use in Malaysia, 2013. *Source*: Energy Commission Malaysia, 2013.

Sector	Consumption coverage, %
Agriculture	0.3
Commercial	32.7
Industrial	45.4
Residential	21.4
Transport	0.2

Table 1
Primary energy demand by ASEAN countries (Mtoe). *Source*: International Energy Agency IEA, 2013.

	1990	2011	2020	2025	2035	Average Annual Growth Rate (2011–2035) (%)
Indonesia	89	196	252	282	358	2.5
Malaysia	21	74	96	106	128	2.3
Philippines	29	40	58	69	92	3.5
Thailand	42	118	151	168	206	2.3
Rest of ASEAN	42	119	161	178	221	2.6
Total ASEAN	223	549	718	804	1004	2.5

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