WEENTECH Proceedings in Energy

ICEEE 2016

16th -18th August 2016
Heriot-Watt University, Edinburgh
United Kingdom

Volume 3: International Conference on Energy, Environment and Economics, September 2016

ISSN: 2059-2353
ISBN: 978-9932795-2-2
www.weentech.co.uk

Edited by:
Dr. Renu Singh, IARI, New Delhi, India
Dr. Anil Kumar, PSU, Thailand
Published by World Energy and Environment Technology Ltd.

Passive façade design for minimized cooling energy consumption of high-rise office buildings in the hot-humid climate of Malaysia

Allen Khin Kiet Lau, Elias Salleh, Chin Haw Lim

Solar Energy Research Institute (SERI), Universiti Kebangsaan Malaysia, Malaysia

*Corresponding author's mail: allenlkk@gmail.com

Abstract

Highly glazed façades of high-rise office buildings in Malaysia has caused excessive amounts of solar heat radiated to internal building spaces under the hot-humid climatic conditions. This has caused high cooling energy requirements. This study is aimed to address the problem by proposing passive façade design strategies for minimized cooling energy consumption. This was done through case study of an office building in Kuala Lumpur using IES (VE) software. The recommended glazing orientations in sequence are North, South, Southeast, Southwest, Northwest, Northeast, East and lastly West. Concrete blocks are recommended as façade materials compared to clay bricks. Triple glazing is recommended followed by double low-e glazing, double clear glazing, and lastly single clear glazing. This study recommends the use of low-e glazing to minimize indoor solar heat transfer and thus cooling energy requirements. From the simulation results, lower WWR results in higher cooling energy savings. Egg-crate shadings are most effective compared to horizontal and vertical shadings. However, horizontal shadings are recommended on West followed by East façades and vertical shadings are recommended on South followed by North façades. This study concludes that there is no specific passive façade design solution but the proposed strategies and simulation results provide guidance for designers to compare the different energy saving impacts and helping them in choosing the most appropriate strategies for optimized cooling energy savings.

Keywords: Cooling energy; façade design; high-rise office buildings; hot-humid climates; passive design.

1. Introduction

As one of the developing countries, Malaysia is experiencing rapid economic growth in manufacturing, tourism, education and commercial sectors. This has caused rapid increasing needs for office buildings, which has increased the overall electricity demand in the country. Globally, buildings consumed up to 40% of total energy use. In the perspective of Malaysia, buildings consumed a total of 48 % of the electricity generated in the country [1]. From the statistics of electricity use in Malaysia carried out by Energy Commission Malaysia in 2013 as shown in Table 1, commercial sector in Malaysia consumed a high percentage of electricity use at 32.7% compared to other sectors [2]. This is because commercial buildings in the hot-humid climate in Malaysia are often installed with air conditioning systems which consume the most energy among all building services [3]. Other sectors including industrial, residential, agriculture and transportation consumed 45.4%, 21.4%, 0.3% and 0.2% of electricity in the country respectively.

Table 1 Statistics of electricity use in Malaysia, 2013

Sector	Energy Use, %
Industrial	45.4
Commercial	32.7
Residential	21.4
Agriculture	0.3
Transportation	0.2
Total	100

(Source: Energy Commission Malaysia, 2013)

1.1. Climate of Malaysia

Malaysia is positioned on the South China Sea. This country lies between 1º and 7º in North latitude, and 100º and 120º in East longitude [4]. Malaysia is geographically located close to the equator with hot and humid climatic conditions. The characteristic features of the hot and humid climate are uniform temperature, high humidity and copious rainfall. Malaysia naturally has abundant sunshine and thus abundant solar radiation [5]. On the average, Malaysia receives about 6 hours of sunshine per day and receives an average solar radiation of 400–600 MJ/m² per month [6].

As shown in Figure 1, temperatures in Malaysia typically vary from 24 °C to 34 °C and is rarely below 23 °C or above 35 °C (Weatherspark, 2016). The weather condition 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 [7]. Northeast monsoon and Southwest monsoon are the two types of monsoons that occur in Malaysia yearly. 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.

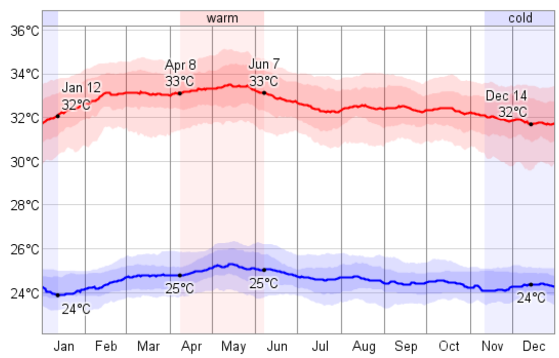

Fig. 1 Daily average low (blue) and high (red) temperatures in Malaysia
(Source: Weatherspark, 2016)

1.2. The research problem and the aim of study

Due to modern architecture movement, vast glazed façades are introduced to high-rise office buildings for aesthetic values [8]. Due to the high solar radiation under the Malaysian climatic conditions, the major contribution factor in the high cooling energy requirement is the solar heat gain through building envelopes [9]. For office buildings in equatorial regions including Malaysia, the building envelope has been said to be a major source of heat gain and fenestration has always been regarded as the weak element in the building envelope due to its role in determining the energy balance of a building [10]. Therefore, energy consumption remains the most important building issue in Malaysia not only because of environmental impacts, but also because of higher energy costs in the future [11]. Office buildings in Malaysia consume between 200 - 250 kWh/m²/year of energy of which about 64% is for air conditioning, 12% for lighting and 24% for general equipment [12]. Another study also showed that cooling energy is considered as the major energy consumption in the view that air conditioning has the highest energy consumption at 57%, followed by lighting at 19%, elevators at 18%, pumps and other equipment at 6% [13]. To address these issues, passive design strategies are being envisioned as a viable solution to the problems of energy crisis and environmental pollution. It can be achieved through improvements to building envelope elements [14]. Therefore, the aim of this study is to propose passive façade design strategies for minimized cooling energy consumption of high-rise office buildings in Malaysia. It is aimed that the results and recommendations of this study is able to provide guidance for façade designers to compare the different energy saving effects of various strategies and helping them in the design decision making for optimized cooling energy savings.

2. Literature review

In recent years, many researches and studies were carried out investigating the design strategies, elements and materials of high-rise building façades for improved thermal and energy performances. However, this study will focus on the comparisons of different passive façade design strategies and their different impacts on cooling energy savings in order to provide guidance for designers in choosing the most suitable passive façade design approach to meet different energy performance requirements of high-rise office buildings in Malaysia.

A previous study regarded windows as one of the most important building components and windows are acknowledged for their positive influence on the health and well-being of building occupants. The same study noted that windows play an important role not only in providing daylight and view, but also in shaping the overall energy demand in buildings [15]. Façade configurations are predicted to be responsible for up to 45% of the building's cooling loads [16]. In a recent study carried out comparing thermal performance of double glazed and triple glazed windows, the annual energy consumption for the double glazed window was higher than the triple glazed window. The result of this study highlighted that double glazed fenestration systems allowed more solar heat gain compared to triple glazed windows [17]. A previous study on thermal performance of glazing noted that spectrally selective low-e coatings allow the visible light of the solar spectrum and block the other wavelengths that are generally responsible for solar heat gains. According to this study, low-e coatings are placed on the inside surface of the external glazing pane as most absorbed solar energy will be dissipated to the ambient air [18].

From the study of annual energy requirements per floor area at four climates in Turkey through four different WWR of 20%, 40% (Base case), 60% and 80%, it was found that energy requirement became higher when the glazed area increased. This study concluded that annual cooling energy requirements and annual total energy requirements of the studied office buildings with high quantities of glazing increase significantly as compared to the studied office buildings with lower glazing quantities [19]. In the research on the HVAC energy consumption, a previous study used building thermal simulation software on office building with different WWR at different building orientation. The study found that the heating energy consumption, air-conditioning energy consumption and total energy consumption were gradually increased with the increase of the WWR under the same orientation [20]. Similarly, results of another recent research showed that the total building energy consumption increased when the WWR was also increased. In the study on the relationship of WWR and orientation on the building energy consumption, the analysis results showed that the increase of building energy consumption caused by increased WWR appeared more obvious on the East and West orientation [21].

From a previous study, external shading devices are referred to as the most effective ones comparing to internal shadings (since in this case, all the heat has already entered the space) [22]. From this study, fixed external shading is a feature of the architecture of the tropics. However, it is used less in temperate climates. In opposite, vertical shading devices are used extensively in temperate climates. Another previous research studied the effectiveness of window shading devices on cooling energy savings for East and West windows of residential buildings in Singapore. The study shows that under hot-humid climate, 2.62%-3.24% of energy cooling load can be saved by applying a simple 30cm deep horizontal shading device to the window. When the depth of the window shading device is 60cm, 5.85%-7.06% of the cooling load could be saved. When the depth of the shading reaches 90cm, the cooling load of the room is reduced by 8.27%-10.13% [23]. Another previous study on a high-rise residential building in Taiwan indicated that envelope shading is the best strategy to decrease cooling energy consumption, which achieved savings of 11.3% on electricity consumption [24]. A research paper discussed the measurement of indoor temperature and relative humidity for office room with three different types of shading devices namely vertical shading, horizontal shading and egg-crate shading. Indoor temperature and relative humidity equipment (HOBO Data Logger) was used in this study. The results indicated that egg-crate shading has significant impact on decreasing indoor temperature as well as discomfort hours compared with other shading types [25]. Another study also mentioned that egg-crate devices are the best in reducing indoor air temperature and decreasing the number of discomfort hours because of their configuration i.e., combination of overhangs and fins. The egg-crate devices avoid solar radiation from varied sun angles [26].

3. Methodology

After comparisons of various building thermal simulation software on their capabilities, user-friendly and accuracy aspects, Integrated Environmental Solutions Virtual Environment IES (VE) was selected as the simulation software for this study. IES (VE) provides an environment for the detailed evaluation of building and system designs, allowing them to be optimized with regard to comfort criteria and energy use [27]. From previous studies, it was recommended that IES (VE) is with high accuracy. It is because from previous research findings, it was concluded that there was no considerable statistical difference in the mean values between IES (VE) simulated results and measured data [28]. Kuala Lumpur weather data from IES (VE) itself was used in all the simulations in this study.

In regard to the definition of high-rise, it was found that there is no national building code or regulation in Malaysia defining the minimum height or number of floors for high-rise buildings. However, the definition of high-rise office buildings in this study is based on International Building Code IBC 2009 as well as National Fire Protection Association NFPA code, defining high-rise buildings as buildings with a minimum height of 75 feet (22.9 meter) above ground level. Referring to typical office buildings' floor height of approximately 3.8m in Malaysia, 22.9m will be the height of a seven-floor office building. Therefore, seven floors is the minimum number of floors acceptable as high-rise throughout this study.

A high-rise office building in Kuala Lumpur was selected as case study building. The building consists of a 4-storey high entrance lobby with 41 floors of occupied office levels. The floor-to-floor height is 4000 mm with the clear ceiling height for the typical office areas ranging from 2700 mm (with 150 mm raised floor system) to 2725 mm (with 125 mm raised floor system). Each floor boasts an efficient floor plate of approximately 1,393.55 m² with total gross floor area of 72,000 m². The layout design utilizes perimeter of the tower as office spaces whereas the service zone is located at the center of the tower which include mechanical/ electrical rooms, toilets, pantry, and vertical transportation such as lifts and fire staircases, as shown in Figure 2.

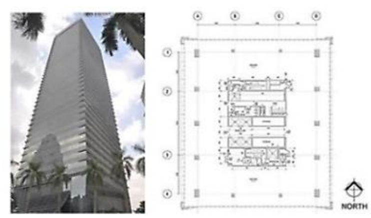

Fig. 2 External view and typical floor layout of the case study high-rise office building

The case study building model was constructed and simulated in the IES (VE) software based on the actual building design specifications. Summary of the specifications for the building model is shown in Table 2. The information was extracted from the building specifications obtained from the building's website available online.

Table 2 Summary of case study office building specification

Description	Building Design / Material
Number of floors	42
Total gross floor area	72,000 m²
Floor-to-floor height	4,000 mm
Occupancy load	10 m²/person
Roof construction	RC slab with water membrane insulation covered with concrete pavers
Internal ceiling and	Raised floor system above RC slab with air

floor construction	plenum and suspended ceiling below slab
Window to wall ratio	1.0
External glazing	Double layers of laminated low-e glazing, Shading Coefficient 0.448, U-value 3.35W/m²k
Indoor temperature	23°C
Air conditioning	Chilled water cooling with 23 VAV boxes/floor
Lighting system	400 LUX - Public Area 400 LUX - Ground floor 300 LUX - Corridor 200 LUX - Staircases 400 LUX - Lift lobbies 100 LUX - Car park 250 LUX - Lift 400 LUX - Office Area

This study involved two stages of simulations. First stage involved the simulations of the case study building base case model based on the actual construction and materials. The next stage of simulations involved modifications on the building façades with proposed passive façade design strategies and materials which include glazing orientations, wall materials, glazing materials, WWR and shading devices. Simulation results were analyzed and compared before conclusions and recommendations were made.

4. Results and discussions

4.1 Base case building simulation

The simulation results on monthly cooling energy consumption for the base case model are shown in Figure 3. Based on the results, the lowest monthly cooling energy consumption of 304.4 MWh was shown in February. Meanwhile, the highest monthly cooling energy consumption was shown in March with 369.2 MWh. Results indicated difference of 64.8 MWh between the lowest and the highest monthly cooling energy consumption. From the annual building energy consumption of 8,963.89 MWh and annual cooling energy consumption of 4,111.16 MWh, 45.9% of building energy was used for cooling purposes annually. Based on the total floor area of 72,000 m², the Building Energy Intensity BEI of the base case model is 124.5 kWh/m²/year.

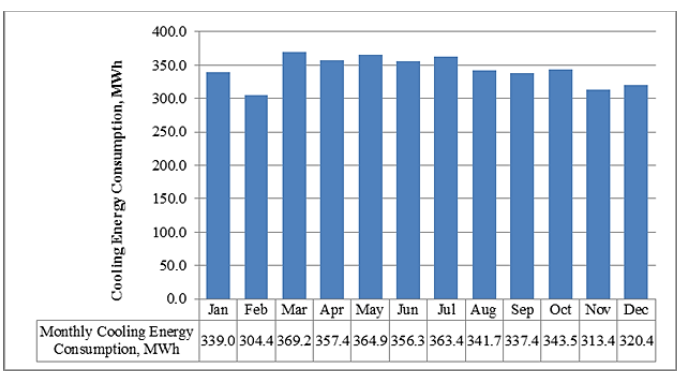

Fig. 3 Monthly cooling energy consumption (MWh) of base case model

4.2 Simulations on different glazing orientations

In order to study the effect of glazing orientations on cooling energy consumption of high-rise office buildings, full glazing was applied on one façade of the building model meanwhile the rest of façades were fully solid without any glazing. The full glazing was applied on different façades on different building models i.e. North, Northeast, East, Southeast, South, Southwest, West and Northwest and simulated individually for the annual cooling energy consumption. From the simulated results shown in Figure 4, glazing orientation of West resulted the highest annual cooling energy of 812.1 MWh. This is followed by glazing orientation of East with annual cooling energy of 805.1 MWh, glazing orientation of Northeast with annual cooling energy of 792.7 MWh, glazing orientation of Northwest with annual cooling energy of 785.2 MWh, glazing orientation of Southwest with annual cooling energy of 783.0 MWh, glazing orientation of Southeast with annual cooling energy of 782.9 MWh, and glazing orientation of South with annual cooling energy of 778.6 MWh. Based on the simulation results, glazing orientation of North resulted in the lowest annual cooling energy of 778.2 MWh. The simulation results indicated that North façade receives the least solar radiation and thus requires the least cooling energy compared to all other façades. On the other hand, West façade receives the most solar radiation and thus requires the most cooling energy compared to all other façades.

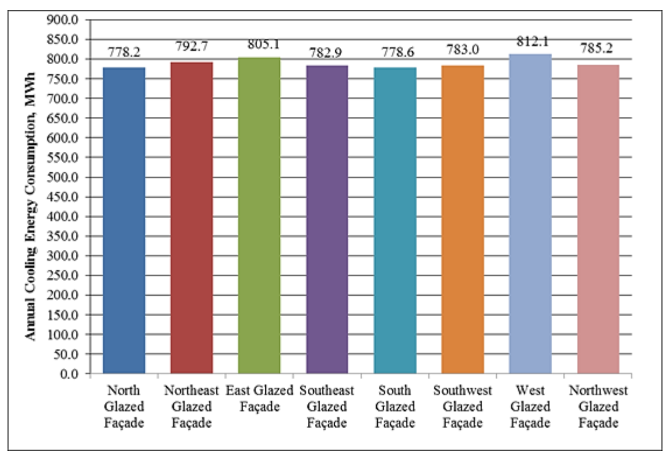

Fig. 4 Annual cooling energy (MWh) with various glazing orientations

4.3 Simulations on exterior wall materials

This part of the simulations involved the use of different exterior wall materials on different building models for simulations of annual cooling energy requirements. Simulation results are shown in Figure 5. The modified base case building model with 110mm brickwork and 20mm plaster on both exterior and interior resulted in 803.6 MWh annual cooling energy consumption. The simulation results indicated that with the change of 110 mm brickwork to 150 mm concrete block and by maintaining 20 mm plaster on both exterior and interior sides, the annual cooling energy consumption was reduced to 755.6 MWh. This indicated annual cooling energy reduction of 48 MWh with savings of 6%. However, with the use of aluminum cladding panels and 30 mm granite blocks replacing 20 mm plaster on the exterior, the difference in cooling energy savings are almost negligible. This is due to the removal of the 20 mm plaster on exterior and there are air gaps in between external cladding materials (aluminum cladding panels or granite blocks) and the 150 mm concrete blocks, which is common construction practice in Malaysia.

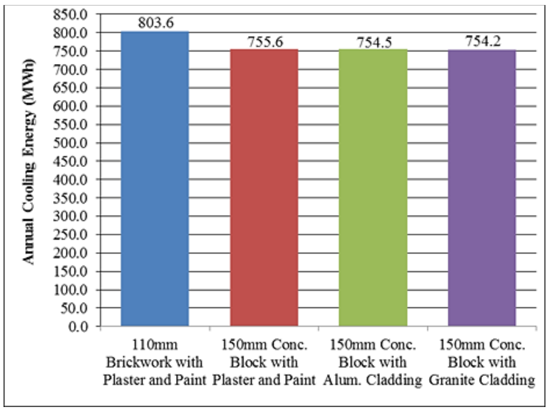

Fig. 5 Annual cooling energy consumption (MWh) of different wall materials

4.4 Simulations on glazing materials

Glazing is challenging in determining buildings' indoor thermal conditions and often lets in or out too much energy, which needs to be compensated by energy-guzzling cooling or heating [29]. Under the hot-humid climate in Malaysia, the challenge will be huge amounts of solar heat radiation to internal spaces through huge or fully glazed façades. Fully glazed façades will cause higher energy consumption and thermal discomfort due to higher solar gain [30]. However, different glazing specifications will cause different amounts of solar heat radiated to internal spaces and thus the cooling requirements. The simulation results shown in Figure 6 indicated that the building model with single clear glazing has resulted in the highest annual cooling energy consumption of 1,166.6 MWh. This is due to the reason that only 4 mm single clear glass panel is used and it is without any low-e coating. The use of double 4 mm clear glazing with 16 mm Argon in between has reduced annual cooling energy consumption to 1,094.0 MWh. This has resulted in annual cooling energy savings of 6.2%. When the same double glazing is added with low-e coatings on the outer panel, the result has indicated a significant decrease in annual cooling energy consumption to 836.5 MWh, with energy savings of 28.3% compared to single clear glazing. This is due to the use of low-e coatings which reduce the solar heat transfer from exterior to interior spaces. The next simulation involved triple glazing in the configurations of 4 mm low-e coated glazing on the outside, 16 mm Argon, 4 mm low-e coated glazing in the middle, 16 mm Argon, and 4 mm clear glazing on the inside. The triple glazing has further decreased the annual cooling energy consumption to 733.9 MWh, with energy savings of 37.1% compared to single clear glazing.

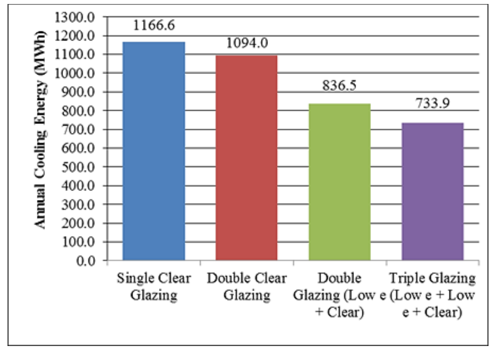

Fig. 6 Annual cooling energy savings (MWh) of different glazing materials

4.5 Simulations on Window-to-Wall Ratio

Five different simulations were carried out on WWR of 0.2, 0.4, 0.6 0.8 and 1.0. WWR 1.0 represents fully glazed façades. The results on annual cooling energy consumption are shown in Figure 7. The building façades with the lowest glazing areas of WWR 0.2 have a result of the lowest annual cooling energy consumption of 803.6 MWh. This is followed by increased WWR 0.4 with increased annual cooling energy consumption of 912.3 MWh; WWR 0.6 with annual cooling energy consumption of 1008.2 MWh; WWR 0.8 with annual cooling energy consumption of 1083.1 MWh; and lastly the WWR 1.0 for building with fully glazed façades with the highest annual cooling energy consumption of 1166.6 MWh.

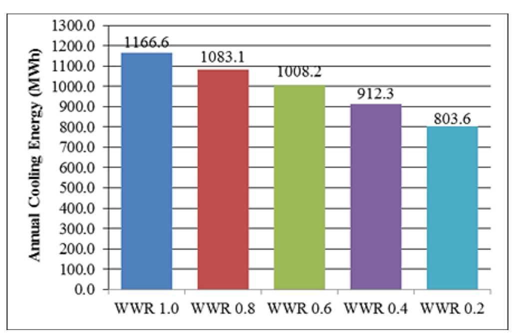

Fig. 7 Annual cooling energy consumption (MWh) of different WWR

4.6 Simulations on external shadings

In this study, there were 13 building models with different types of shading devices at different façade orientations being simulated. The width of the shading devices was fixed at 600mm as recommended by many studies conducted in the tropics with considerations on day lighting, aesthetic and the view angle requirements from the internal spaces [26, 31]. Figure 8 indicated egg-crate as the best shading type for optimum cooling energy savings. This is followed by vertical shading and lastly horizontal shading. The highest energy savings of 3.4% was estimated by applying egg-crate shadings on the West façade. This is followed by 3.3% savings on the East façade and 2.6% savings on the North and South façades. The use of horizontal shading devices has resulted annual energy savings of 1.4% on the East and West façades, and 1.0% on the North and South façades. Vertical shading devices has resulted higher energy savings of 2.4% on the East façade and 2.1% energy savings on the West façade comparing to only 1.9% and 1.7% energy savings on the South and North façades respectively.

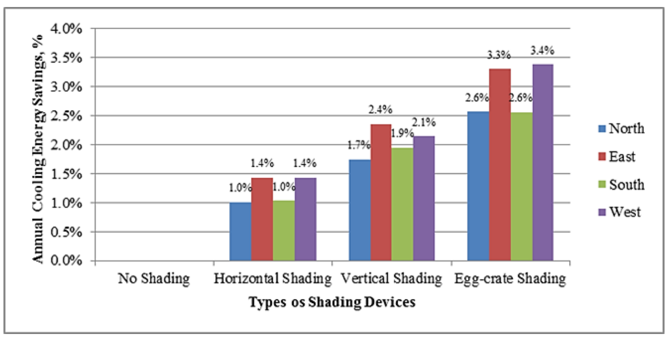

Fig. 8 Annual cooling energy savings by different types of shading devices

5 Conclusions and recommendations

Based on the simulation results from this study, it can be suggested that high-rise office buildings in Malaysia consume approximately 45.9% of total building energy for cooling purposes. This study recommends appropriate use of passive façade design strategies and materials to reduce cooling energy requirements of high-rise office buildings in Malaysia. However, it cannot be stated that any one of the strategies has a higher priority than the rest. All of the strategies need to be considered and compared during the design process for optimum energy performance. The recommended passive façade design strategies are summarized in Table 3.

Table 3 Recommended passive façade design strategies for high-rise office buildings in Malaysia

S/N	Recommended Strategies
1.	**Glazing Orientation** - The preferred glazing orientation in sequence is North, South, Southeast, Southwest, Northwest, Northeast, East and West.
2.	**Wall Materials** - Use concrete blocks instead of clay bricks to reduce the indoor heat transfer and cooling energy consumption. - Not to exclude the 20mm plaster on exterior wall when external façade cladding materials such as aluminum cladding and granite are used as this will increase cooling energy consumption.
3.	**Glazing Materials** - The preferred glazing materials in sequence are triple glazing (4mm low-e + 16mm Argon + 4mm low-e + 16mm Argon + 4mm Clear Glass), double glazing (4mm low-e + 16mm Argon + 4mm Clear Glass), double clear glazing (4mm Clear Glass + 16mm Argon + 4mm Clear Glass), single 6mm clear glazing. - It is recommended to use low-e glazing instead of clear glazing.
4.	**Window to Wall Ratio** - Introduce lower WWR for higher cooling energy savings. - The preferred WWR on each façade could vary by referring to the recommended glazing orientation stated in (1) above.
5.	**External Shading** - Introduce horizontal shadings on West and East façades. - Introduce vertical shadings on the South and North façades. - Egg-crate shadings are more effective in cooling energy savings compared to horizontal and vertical shadings.

The findings on annual cooling energy savings by different passive façade design strategies are summarized in Figure 9. These findings are references to guide façade designers in deciding between different strategies and materials in order to meet specific energy performance requirements of each specific high-rise office building development in Malaysia.

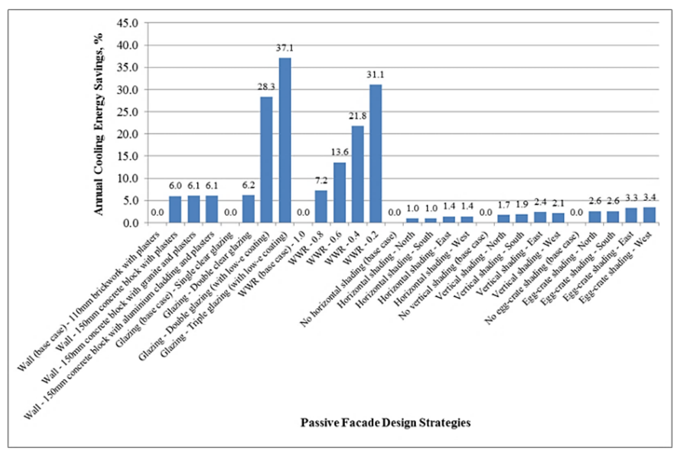

Fig. 9 Annual cooling energy savings by different passive façade design strategies

It is important to conclude that there is no specific passive façade design solution. However, the results in this study are able to provide guidance for designers to compare the different energy saving impacts by different passive façade design strategies and materials. This can guide them in the design decision making for optimized cooling energy savings of high-rise office buildings under the hot-humid climate of Malaysia. This study recommends for further economic studies on each strategies. This will help façade designers when deciding between thermal performances and financial aspects of the façade design strategies.

References

[1] J. S. Hassan, R. M. Zin, M. Z. Abd Majid, S. Balubaid & M. R. Hainin. (2014) Building energy consumption in Malaysia: An overview. Jurnal Teknologi 70 (7): 33–38.

[2] Energy Commission Malaysia. (2016) Electricity - Final Electricity Consumption. Available at: http://meih.st.gov.my/statistics?p_auth=g5ODWRHT&p_p_id=Eng_Statistic_WAR_STOASPublicPortlet&p_p_lifecycle=1&p_p_state=maximized&p_p_mode=view&p_p_col_id=column-1&p_p_col_pos=1&p_p_col_count=2&_Eng_Statistic_WAR_STOASPublicPortlet_execution=e1s1&_Eng_Statistic_WAR_STOASPublicPortlet__eventId=ViewStatistic3&categoryId=4&flowId=7. (Accessed on 8 May 2016).

[3] Qi Jie Kwong, Nor Mariah Adam & B.B. Sahari. (2014) Thermal comfort assessment and potential for energy efficiency enhancement in modern tropical buildings: A review. Energy and Buildings 68: 547–557.

[4] Nugroho, A.M., 2010. The impact of solar chimney geometry for stack ventilation in Malaysia's single storey terraced house. Malaysia's Geography (Jan), 163–177.

[5] Ministry of Science, Technology and Innovation (MOSTI). Malaysian Meteorological Department (MetMalaysia): General climate of Malaysia. http://www.met.gov.my/web/metmalaysia/climate/generalinformation/malaysia?p_p_id=56_INSTANCE_zMn7KdXJhAGe&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-1&p_p_col_pos=1&p_p_col_count=2&_56_INSTANCE_zMn7KdXJhAGe_page=3 (Last accessed: 8 May2016).

[6] S. Mekhilef, A. Safaria, W.E.S. Mustaffaa, R. Saidurb, R. Omara & M.A.A. Younis. (2012) Solar energy in Malaysia: Current state and prospects. Renewable and Sustainable Energy Reviews 15 (1): 386-396.

[7] Seyedehzahra Mirrahimi, Mohd Farid Mohamed, Lim Chin Haw, Nik Lukman Nik Ibrahim, Wardah Fatimah Mohammad Yusoff & Ardalan Aflaki. (2016) The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot–humid climate. Renewable and Sustainable Energy Reviews 53: 1508–1519.

[8] N. Hashemi, R. Fayaz & M. Sarshar. 2010. Thermal behavior of a ventilated double skin façade in hot arid climate. Energy and Buildings 42: 1823-1832.

[9] Joseph C. Lam, C.L. Tsang, Danny H.W. Li & S.O. Cheung. 2005. Residential building envelope heat gain and cooling energy requirements. Energy 30 (7): 933–951.

[10] K. Tsikaloudaki, K. Laskos, Th. Theodosiou & D. Bikas. 2012. Assessing cooling energy performance of windows for office buildings in the Mediterranean zone. Energy and Buildings 49: 192-199.

[11] Hew Zhi Xin & S. P. Rao. 2012. Active energy conserving strategies of the Malaysia energy commission diamond building. Procedia Environmental Sciences 17: 75-784.

[12] Chan, S.A. (2009). Green Building Index – MS1525 Applying MS1525:2007 Code of practice on energy efficiency and use of renewable energy for non-residential buildings. p. 1–22.

[13] R. Saidur. 2009. Energy consumption, energy savings, and emission analysis in Malaysian office buildings. Energy Policy 37 (10): 4104–4113.

[14] Suresh B. Sadineni, Srikanth Madala & Robert F. Boehm. 2011. Passive building energy savings: A review of building envelope components. Renewable and Sustainable Energy Reviews 15: 3617–3631.

[15] M. Bodart & A. de Herde. (2002). Global energy savings in offices buildings by the use of daylighting. Energy and Buildings 34 (5): 421–429.

[16] Neveen Hamza. (2008). Double versus single skin façades in hot arid areas. Energy and Buildings 40 (3): 240-248.

[17] Shakouri MH, Tahmasebia MM & Banihashemib S. 2011. Assessment of the variation impacts of window on energy consumption and carbon footprint. In: proceedings of the international conference on green buildings and sustainable cities: 1-7.

[18] Robinson PD & Hutchins M. G. 1994. Advanced glazing technology for low energy buildings in the UK. Renewable Energy 5 (1–4): 298-309.

[19] Nurdil Eskin & Hamdi Tu¨rkmen. (2008). Analysis of annual heating and cooling energy requirements for office buildings in different climates in Turkey. Energy and Buildings 40: 763–773.

[20] Z. Yu, W. L. Zhang, & T. Y. Fang. (2013). Impact of building orientation and window-wall ratio on the office building energy consumption. Applied Mechanics and Materials (409-410): 606–611.

[21] Qiaoxia Yang, Meng Liu, Chang Shu, Daniel Mmereki, Md. Uzzal Hossain & Xiang Zhan. (2015). Impact analysis of Window-Wall Ratio on heating and cooling energy consumption of residential buildings in hot summer and winter zone in China. Journal of Engineering (2015): Article ID 538254, 17 pages.

[22] Anickan Offiong & A.U. Ukpoho. 2004. External window shading treatment effects on internal environmental temperature of buildings. Renewable Energy 29: 2153–2165.

[23] Wong. N. H. & S. Li. 2007. A study of the effectiveness of passive climate control in naturally ventilated residential buildings in Singapore. Building and Environment 42: 1395–1405.

[24] Yu. J., C. Yang & L. Tian. 2008. Low-energy envelope design of residential building in hot summer and cold winter zone in China. Energy and Buildings 40 (8): 1536–1546.

[25] Nor Azah Arifin & Zuraini Denan. 2015. An Analysis of Indoor Air Temperature and Relative Humidity in Office Room with Various External Shading Devices in Malaysia. Procedia - Social and Behavioral Sciences 179: 290-296.

[26] Nedhal A. Al-Tamimia & Sharifah Fairuz Syed Fadzil. 2011. The potential of shading devices for temperature reduction in high-rise residential buildings in the tropics. Procedia Engineering 21: 273-282.

[27] Drury B. Crawley, Jon W. Hand, Michael Kummert & Brent. T. Griffith. 2005. Contrasting the capabilities of building energy performance simulation programs. Ninth International IBPSA Conference, Montréal, Canada, page 231-238.

[28] Chinnayeluka S. R. 2011. Performance Assessment of Innovative Framing Systems through Building Information Modeling Based Energy Simulation, Master Thesis, Osmania University.

[29] C.G. Granqvist. 2015. Eco-Efficient Materials for Mitigating Building Cooling Needs. Design, Properties and Applications: 441–471.

[30] Wong Nyuk Hien, Wang Liping, Aida Noplie Chandra, Anupama Rana Pandey & Wei Xiaolin. 2005. Effects of double glazed façade on energy consumption, thermal comfort and condensation for a typical office building in Singapore. Energy and Buildings 37 (6): 563–572.

[31] Liping. W. & W.N. Hien. 2007. The impacts of ventilation strategies and façade on indoor thermal environment for naturally ventilated residential buildings in Singapore. Building and Environment 42(12): 4006–4015.

Commonwealth Energy and Sustainable Development Network (CESD-Net)

CESD-Net is a major global initiative in energy and sustainable development. The objective of network is to promote energy and sustainable development in commonwealth countries.
Focussing on Multidisciplinary Research, Promoting Future Low Carbon Innovations, Transferring Knowledge and Stimulating Networking among Stakeholders to Ensure the UK Achieves World Leading Status in Energy and Sustainable Development. https://www.weentech.co.uk/cesd-net/

The 1st International Conference on Energy, Environment and Economics (ICEEE 2016) was held at Heriot-Watt University, Edinburgh, EH14 4AS, UK, 16-18 August 2016. ICEEE2016 focused on energy, environment and economics of energy systems and their applications. More than fifty eight delegates from 31 countries with diverse expertise ranging from energy economics, solar thermal, water engineering, automotive, energy, economics and policy, sustainable development, bio fuels, Nano technologies, climate change, life cycle analysis etc. made conference true to its name and completely international. During conference total 51 oral presentations and six posters were shared between delegates. The presentations showed the depth and breadth of research across different research areas ranging from diverse background. ICEEE2016 aimed:

- To identify and share experiences, challenges and technical expertise on how to tackle growing energy use and greenhouse gas emissions and how to promote sustainability and economical, cost effective energy efficiency measures.

In total 11 technical sessions and two invited talks both from academia and industry provided insight into the recent development on the proposed theme of the conference. Preparation, organisation and delivery of the conference started from July 2015 and further co-ordinated by vibrant team of Conference Centre, Heriot Watt University. Conference organisers would like to acknowledge support from the sponsors particularly World Scientific Publication ltd and its team members for the delivery of the conference. Organisers are also thankful to all reviewers who contributed during peer review process and their contributions are well appreciated. At the end and during vote of thanks following awards have been announced and we would like to congratulate all well deserving delegates.

- Best Paper –Academia: Amela Ajanovic, EEG, TU Vienna, Austria
- Best Paper – Student : Christian Jenne,University of Duisburg-Essen, Germany
- Best Poster – Student: Yoann Guinard, University of New South Wales, Sydney, Australia
- Best Poster – Academia: E. Salleh, Universiti Kebangsaan Malaysia, Malaysia
- Active Participation Award - Yoann Guinard, University of New South Wales, Sydney, Australia

At the end we would like to extend our gratitude to all of you for your participation and hopefully welcome you again during ICEEE2017.

Editors:
Dr. Singh is Senior Scientist at Indian Agricultural Research Institute, New Delhi, India. Her area of expertise are bio energy and bio fuels, environmental engineering, carbon accounting and renewable energy integration for rural development.
Dr. Kumar is visiting faculty at Prince of Songkla University, Thailand. He have 16 years of research and teaching experience in the field of solar energy, drying and energy efficiency.

WEENTECH Proceedings in Energy- International Conference on Energy, Environment and Economics, September 2016
Edited by:
Dr. Renu Singh, IARI, New Delhi, India
Dr. Anil Kumar, PSU, Thailand
Publisher: World Energy and Environment Technology Ltd., Coventry, United Kingdom
Publication date: 12 September 2016
ISSN: 2059-2353
ISBN: 978-9932795-2-2
To purchase e-book online visit www.weentech.co.uk or email conference@weentech.co.uk