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# Heat Transfer Reduction Using Self Shading Strategy in Energy Commission Building in Malaysia

[1,2]Mansour Nikpour, [1]Mohd Zin Kandar, [1,2]Mohsen Ghasemi,
[1]Mohammad Ghomeshi and [3]Mohammad Reza Safizadeh
[1]Universiti Teknologi Malaysia, Malaysia
[2]Islamic Azad University, Bam Branch, Iran
[3]NUS Graduate School for Integrative Science and Engineering,
National University of Singapore, Singapore

**Abstract:** Most office buildings have been constructed without enough strategies for appropriate use of solar energy, especially in tropical regions. Different forms of buildings and strategies were recommended. Whereas conventional building envelops receive more solar radiation, self-shading strategy was suggested as a form of building to eliminate direct solar radiation; as a result, it causes less energy for cooling office spaces. Energy commission diamond building in Malaysia is an actual model of self-shading building. In this study, the objective is to investigate the amount of Overall Thermal Transfer Value (OTTV) reduction in energy commission diamond building. To this end, the effectiveness of self-shading strategy on OTTV is investigated through experimental and analytical approaches. Findings of this research demonstrate that the significant reduction occurs in using self-shading strategy. This strategy can be applied for forthcoming design of office buildings to reduce energy consumption as well as to meet the purpose of sustainable architecture.

**Key words:** Heat gain, overall thermal transfer value, self-shading strategy, shading coefficient

## INTRODUCTION

As demand for the office jobs has been increasing dramatically and employees spend most of their time in buildings, the minimum environmental comfort conditions such as solar irradiation, ventilation, thermal conditions should be provided. However, providing the environmental comfort conditions is decidedly related to higher energy consumption; therefore, the attempts like sustainable and green architecture, usage of renewable energy and development of electricity-efficient heating and cooling system have been made towards satisfaction of lower energy consumption and comfort levels (Anselm, 2006). In this regard, recently, most countries have taken a lot of initiatives and standards for buildings, industries and transportation in reduction of fossil fuels and increasing the alternative and clean energies instead to avoid the climate changes and increment of greenhouse gases (Begum *et al*., 2011). For instance, according to Malaysian Standard (MS) 1525 (2007), code of practice for non-residential buildings on energy efficiency and use of renewable energy, the non-residential building should comply with an annual energy consumption of less than: $\frac{135\frac{\text{kWh}}{\text{yr}}}{\text{m}^2}$ therefore, it's important for professionals and architects to reduce annual energy consumption especially in office buildings to reach the purpose of (MS) 1525:2007, code of practice on energy efficiency and use of renewable energy (Malaysian Standard (MS) 1525, 2007). Towards these objectives, there has been intensive research conducted in architect, building construction, heating and cooling systems and energy management sectors. The comfort temperature and room's temperature distribution was evaluated using Computational Fluid Dynamics (CFD) in order to simulate the optimum temperature level accepted by 80% occupants (Kwong *et al*., 2009). Bhaskoro and Gilani (2011) investigated three methods (solution) in reduction of air-conditioning systems in tropical region (Malaysia). They proposed the energy reduction methods for cooling load characteristic during peak month (March) including, external shading devices for wall, double window glazing and adjustable room temperature set-point which reduce the air-conditioner consumption energy by 6, 1.7 and 27.4%, respectively. In the first method, energy reduction was due to minimization of heat gain from building

**Corresponding Author:** Mansour Nikpour, M4-05-200, Melana Apartment, Skudai, 81300, Tmn Universiti, Johor, Malaysia Tel: +60177388722

envelope, second method diminishes direct irradiation to the test room and finally, the energy consumption reduction was effected by designing the automatic set-point control that set the room temperature at 28°C in un-occupied period.

Base on literature, architects usually concentrate more on aesthetics values rather than climate situation in Malaysia and energy saving (Sulaiman and Hassan, 2011a). They studied the cooling load of highly glazed a non-commercial building as well as the ways to reduce the energy. In another study, they investigated the effects of building orientation, wall shades, space overcooling and outdoor infiltration on air-conditioning system's energy consumption (Sulaiman and Hassan, 2011b). Window-to-Wall Ratio (WWR), shading coefficient and U-Value of wall and windows are effective factors for OTTV determination (Lam, 2000). Energy consumption in buildings can be controlled using two approaches which are OTTV and day lighting (Li *et al*., 2002). OTTV is considered a better performance index than thermal transmittance (U-value) because it takes into account the impact of direct solar energy on the envelope of mechanically cooled buildings (Saidur *et al*., 2009). Capeluto (2003) suggested the self-shading geometric forms provide the best solution for betterment use of energy in buildings. Kadiri and Okosun (2006) examine the area of room that are most uncomfortable in maximum irradiation period (12:00-3:00 pm), discovered the main heat source in this period and investigated the effect of shading devices on room thermal comfort level in Ile-Ife, Nigeria. The internal courtyard impact on thermal performance in tropical buildings was studied (Sadafi *et al*., 2008). By simulation, they proved that courtyard reduces the energy consumption by increasing the natural ventilation; in addition, they proposed the self-shading devices for courtyard in order to moderate the enlarged solar radiation.

Self-protected form is one of possible ways against the impact of solar radiation in high rise buildings. Self-shading building envelopes were suggested for solar prevention (Capeluto, 2003; Chia, 2007) identified optimum self-shading projection ratio for high rise building in Malaysia. Researcher identified the optimum form for office building in Malaysia through reducing solar insolation on envelops with self-shades form (Chia, 2007).

On the basis of definition, the amount of heat that transfer from outside to the inside of the buildings through building envelope is considered as Overall Thermal Transfer Value (OTTV). Since a large amount of solar heat gain transfer through window, window area is one of effective parameters on the amount of OTTV (Tzikopoulos *et al*., 2005). Besides, solar heat gain through fenestration is considered as the largest provider to building envelope cooling load and the most important parameter for OTTV determinations (Lam and Goodsall, 1994).

One way to reduce electricity consumption would be to limit heat gain into the buildings and hence reduce the demand for air-conditioning during hot summer months. Key factors affecting heat gain through building envelopes into the buildings, are building orientation, exterior wall area and its construction type (i.e. thermal insulation and U-value) and surface finish (wall absorption coefficient), window area, glass type (U-value and shading coefficient), external shading and roof area and its construction details (Lam *et al*., 2005).

**OTTV according to Malaysian standard 1525:2007:** The solar heat gain through the building envelope constitutes an important part in cooling load in an air conditioned building. Solar heat gain into a building is a very important consideration in the design of an energy efficient building. The purpose of OTTV is to obtain the optimal design of building envelope to reduce external heat gain to reduce the cooling load of the air-conditioning system. In this research, the OTTV of the building envelope for a building, having a total air-conditioned area exceeding 4000 $m^2$ and above, should not exceed 50 W $m^{-2}$.

The OTTV of building envelope is given by following formula:

$$OTTV = \frac{[A1\times OTTV1 + A2\times OTTV2 + .... + An\times OTTVn]}{[A1 + A2 + .... + An]}$$

where, Ai is the gross exterior wall area for orientation i; and $OTTV_i$ is the OTTV value for orientation i from below equation.

For a fenestration at a given orientation, the formula is given as below:

$$OTTV = 15\times a\times(1\text{-}WWR)\times UW+6\times(WWR)\times Uf+(194\times Cf\times WWR\times SC)$$

where, WWR is the window-to-gross exterior wall area ratio for the orientation under consideration;

- $U_w$ is the thermal transmittance of opaque wall ($W/m^2$ K)
- $U_f$ is the thermal transmittance of fenestration system ($W/m^2$ K)

Table 1: Solar correction factor (Malaysian standard (MS) 1525, 2007)

| Orientation | CF |
|---|---|
| North | 0.90 |
| Northeast | 1.09 |
| East | 1.23 |
| Southeast | 1.13 |
| South | 0.92 |
| Southwest | 0.90 |
| West | 0.94 |
| Northwest | 0.90 |

Table 2: Shading coefficient of horizontal projection (Malaysian standard (MS) 1525, 2007)

| | | |
|---|---|---|
| 0.3-0.4 | North/South | 0.77 |
| 0.3-0.4 | East | 0.77 |
| 0.3-0.4 | West | 0.79 |
| 0.3-0.4 | Northeast/Southeast | 0.77 |
| 0.3-0.4 | Northwest/Southwest | 0.79 |
| 0.5-0.7 | North/South | 0.71 |
| 0.5-0.7 | East | 0.68 |
| 0.5-0.7 | West | 0.71 |
| 0.5-0.7 | Northeast/Southeast | 0.69 |
| 0.5-0.7 | Northwest/Southwest | 0.72 |
| 0.8-1.20 | North/South | 0.67 |
| 0.8-1.20 | East | 0.60 |
| 0.8-1.20 | West | 0.65 |
| 0.8-1.20 | Northeast/Southeast | 0.63 |
| 0.8-1.20 | Northwest/Southwest | 0.66 |
| 1.30-2.00 | North/South | 0.65 |
| 1.30-2.00 | East | 0.55 |
| 1.30-2.00 | West | 0.61 |
| 1.30-2.00 | Northeast/Southeast | 0.60 |
| 1.30-2.00 | Northwest/Southwest | 0.63 |

CF is the solar correction factor which is shown in Table 1. Table 1 specifies CF for the various orientation of the fenestration. It is recommended to select the nearest predominant orientation for the calculation of CF. Fenestration system may consist of a glazing material such as glass, a shading device and a combination of both (Malaysian Standard (MS) 1525 (2007).

SC is the shading coefficient of the fenestration system. Where, SC is the effective shading coefficient of the fenestration system; the shading coefficient of external shading devices can be obtained from Table 2. R1 in Table 2 is the ratio of width of horizontal projection per height of fenestration (Malaysian Standard (MS) 1525 (2007).

**The energy commission diamond building:** The Energy Commission Malaysia is an energy efficient office which is located in the commercial and business district of core Island, Putrajaya, Malaysia. It is considered as a sustainable building or green building in Malaysia. As it is obviously shown in Fig. 1, the diamond-shaped building is slanted downwards and inwards to provide self-shading form as a passive design strategy. The facade is integrated with internal light shelves to direct natural daylight deep into the office space at the same time as the glazing is specially coated with low-energy coating to address the heat. The building energy index is designed to be $85 \frac{\frac{kWh}{m^2}}{yr}$ (Ahmed, 2010).

Fig. 1: Energy commission diamond building (Author)

## MATERIALS AND METHODS

The OTTV equation is used to compute the amount of reduced OTTV in energy commission building by applying the self-shading strategy (Nikpour *et al*., 2011). In addition, the amount of OTTV is compared with conventional building which has no shading devices. Some parameters in OTTV equation such as WWR should be measured physically. Therefore, some parameters and values are substituted by experimental measurements of building in the OTTV equation, directly and indirectly. Some parameters in OTTV equation remain in parametric shape, which are considered the same for both conditions (conventional and self-shaded buildings); and some of them could be omitted in determination process.

## RESULTS

According to Malaysian standard 1525:2007, the amounts of solar Correction Factors (CF) for each orientation is given in Table 1. Therefore, CFs for different orientations strategy from the (North, South, East and West) are 0.9, 0.92, 1.23 and 0.94, respectively.

In order to clarify the effectiveness of self-shading passive strategy on overall thermal transfer value, the amount of OTTV is calculated by subtracting the amount of OTTV when there is no shading strategy from the amount of OTTV when self-shading strategy is applied. In OTTV calculation process, all parameters are considered constant and some of parameters could be omitted in calculation process; therefore some parameters such as area of wall (a), $U_w$ and $U_f$ were remained parametrically. WWR of this building were considered 60% from experimental measurement of energy commission building.

CF for North and south is 0.9 also CFs for east and west orientations are considered 1.23 and 0.94, respectively.

SC (shading coefficient) for conventional building that has no shading device is equal to 1.

OTTV with this assumption that building has no shading devices is as follow:

$$OTTVn = 15\times\alpha\times(1-0.6)\times Uw+6\times(0.6)\times Uf+(194\times 0.90\times 0.6\times 1)$$
$$OTTVn = 6\alpha Uw+3.6Uf+104.76$$
$$OTTVs = 15\times\alpha\times(1-0.6)\times Uw+6\times(0.6)\times Uf+(194\times 0.92\times 0.6\times 1)$$
$$OTTVs = 6\alpha Uw+3.6Uf+107.08$$
$$OTTVe = 15\times\alpha\times(1-06)\times UW+6\times(0.6)\times Uf+(194\times 1.23\times 0.6\times 1)$$
$$OTTVe = 6\alpha Uw+3.6Uf+143.172$$
$$OTTVw = 15\times\alpha\times(1-06)\times Uw+6\times(0.6)\times Uf+(194\times 0.94\times 0.6\times 1)$$
$$OTTVw = 6\alpha Uw+3.6Uf+109.416$$

$$OTTV = \frac{[An\times OTTVn+As\times OTTVs+Ae\times OTTVw+Aw\times OTTw]}{[An+As+Ae+Aw]}$$

$$OTTV = \frac{A[(6\times\alpha\times Uw+3.6\times Uf+104.76)+(6\times\alpha\times Uw+3.6\times Uf+107.08)+(6\times\alpha\times Uw+3.6\times Uf+13.172)+(6\alpha Uw+3.6Uf+109))]}{[4(A)]}$$

$$OTTV = \frac{A[(18\alpha Uw+10.8Uf+464.42)]}{4A}$$

$$OTTV = \frac{[(18\alpha Uw+10.8Uf+464.42)]}{4}$$

Suppose that all parameters are equal for the building with no shading strategy except SC which is related to shading strategy; therefore SC for energy commission building can be calculated in following section.

As it was mentioned, the ratio R1 in Table 2 that is defined as the ratio of width of horizontal projection per height of fenestration for energy commission building which is 0.8 in this study; therefore, SC is equal to 0.67 for north and south orientation and SC for east and west are 0.6 and 0.65, respectively.

OTTV with this building can be calculated as follow: where, OTTVss is identified as OTTV self-shading building:

$$OTTVnss = 15\times\alpha\times(1-0.6)\times Uw+6\times(0.6)\times Uf+(194\times 0.90\times 0.6\times 0.67)$$
$$OTTVnss = 6\alpha Uw+3.6Uf+70.18$$
$$OTTVsss = 15\times\alpha\times(1-0.6)\times Uw+6\times(0.6)\times Uf+(194\times 0.92\times 0.6\times 0.67)$$
$$OTTVsss = 6\alpha Uw+3.6Uf+71.74$$
$$OTTVess = 15\times\alpha\times(1-0.6)\times Uw+6\times(0.6)\times Uf+(194\times 1.23\times 0.6\times 0.6)$$
$$OTTVess = 6\alpha Uw+3.6Uf+85.90$$
$$OTTVwss = 15\times\alpha\times(1-0.6)\times Uw+6\times(0.6)\times Uf+(194\times 0.94\times 0.6\times 0.6)$$
$$ITTVwss = 6\alpha Uw+3.6Uf+71.12$$

$$OTTVss = \frac{[Anss\times OTTVnss+Asss\times OTTVsss+Aess\times OTTVess+Awss\times OTTVwss]}{[Anss+Asss+Aess+Awss]}$$

$$OTTVss = \frac{A[(6\alpha Uw+3.6Uf+70.08)+(9\alpha Uw+3.6Uf+71.74)+(6\alpha Uw+3.6Uf+85.90)+(6\alpha Uw+3.6Uf+71.12)]}{[(4A)]}$$

$$OTTVss = \frac{A[18\alpha Uw+10.8Uf+298.94]}{4(A)} = \frac{18\alpha Uw+10.8Uf+298.84}{4}$$

The amount of OTTV reduction can be calculated by subtracting of OTTV in two conditions. Therefore:

$$OTTV - OTTVss = \frac{464.42-298.94}{4}$$

$$OTTV - OTTVss = 41.37\frac{w}{m2}$$

Therefore, the amount of OTTV shows 41.37 w $m^{-2}$ reductions with applying self shading strategy in this building.

## CONCLUSION

Self-shading strategy has significant impact on preventing direct solar radiation that caused less heat gain. By applying this strategy, the amount of overall thermal transfer value of Energy Commission Diamond Building is obviously reduced with significant amount of 41.37 w $m^{-2}$ compare to the conventional building without any shading devices. Therefore, self-shading designs has considerable affect to reduce solar radiant heat gain to comply the current code of practice for overall thermal-transfer value OTTV standard. This is a substantial opportunity for architecture to design energy-efficient and green building using this strategy. Energy savings mean not only low electric-lighting but also reduced cooling loads and the potential for smaller Heating, Ventilating and Air-Conditioning (HVAC) systems. In addition maintenance costs of a building due to lower HVAC systems can be reduced.

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