Assessment of Overall Thermal Transfer Value (OTTV) in Buildings with Inclined Glass Wall
การประเมินค่าการถ่ายเทความร้อนรวม (OTTV) ของอาคารผนังกระจกเอียง

Sudaporn Sudprasert and Sivayu Klinsmith

สุดาภรณ์ สุดประเสริฐ และ ศิวายุ กลิ่นสมิทธิ์

Faculty of Architecture and Planning, Thammasat University, Pathumthani, 12121, Thailand

คณะสถาปัตยกรรมศาสตร์และการผังเมือง มหาวิทยาลัยธรรมศาสตร์ จังหวัดปทุมธานี 12121

E-mail: sudaporn@ap.tu.ac.th

Abstract

The Ministry of Energy of Thailand promulgated the criteria for computing the Overall Thermal Transfer Values (OTTV) to manage building energy efficiency in 1992. These criteria were improved in 2009 to cover dissimilar heat transfer rates in the daytime and the nighttime for offices, stores and hotels constructed with 0 to 90-degree roofs and walls. However, the assessment of OTTV of buildings with wall inclinations greater than 90 degrees has been excluded with only approximate values being used in the calculation. The objective of this paper, therefore, is to propose a calculation method of Effective Solar Radiation *(ESR)*, a variable in OTTV equation, for office buildings with 105-150 degree wall inclinations, taking into account the effects of ground reflectance values of 0.05, 0.2 and 0.32 for water, grass, and white concrete, respectively. The *ESR* values for the inclined glass wall were obtained from the slope of linear relationship between the simulated solar heat gain and the glass's Solar Heat Gain Coefficient (SHGC). The simulated results and the regression analysis showed that the derived *ESR* values of the vertical wall were compatible with the *ESR* values in the building energy code (BEC) and the energy used index, similar to that obtained from energy audits. The *ESR* values decreased by 2.7-37% as the glass wall inclination increased, resulting in a decrease of the OTTV by 2.0-17%. For the high ground reflectance of 0.32 and SHGC of 0.54, the results showed that the OTTVs of the building with inclined walls exceeded 50 W/m^2. Therefore, grass and water are recommended for the landscape around energy efficient buildings.

บทคัดย่อ

กระทรวงพลังงานของประเทศไทยได้ประกาศใช้หลักเกณฑ์การคำนวณค่าการถ่ายเทความร้อนรวม (OTTV) เพื่อการจัดการประสิทธิภาพการใช้พลังงานในอาคารในปี 1992 เกณฑ์นี้ได้รับการปรับปรุงในปี 2009 โดยคำนึงถึงการถ่ายเทความร้อนที่แตกต่างกันในช่วงเวลากลางวันและกลางคืนสำหรับอาคารประเภทสำนักงาน ร้านค้าและโรงแรมที่มีมุมเอียงของผนังและหลังคาอยู่ระหว่าง 0-90 องศา อย่างไรก็ตามการประเมินค่า OTTV ดังกล่าวไม่รวมถึงผนังที่เอียงมากกว่า 90 องศาโดยยอมรับให้นำค่าประมาณการมาใช้แทน วัตถุประสงค์ของการวิจัยนี้คือการนำเสนอวิธีการคำนวณค่ารังสีอาทิตย์ที่มีผลต่อการถ่ายเทความร้อนผ่านผนังโปร่งแสง *(ESR)* ของอาคารสำนักงานที่มีผนังกระจกเอียงตั้งแต่ 105 ถึง 150 องศาจากแนวนอน โดยคำนึงถึงผลกระทบของน้ำ หญ้า และคอนกรีตสีขาวที่อยู่รอบอาคารผนังเอียงที่มีค่าการสะท้อนจากพื้นเท่ากับ 0.05 0.2 และ 0.32 ตามลำดับ โปรแกรม eQuest 3.6 จะคำนวณค่าความร้อนจากดวงอาทิตย์ที่อาคารตัวอย่างได้รับแล้วจึงนำค่ามาวิเคราะห์สมการถดถอยที่มีความสัมพันธ์เชิงเส้นกับค่าสัมประสิทธิ์การถ่ายความร้อนจากรังสีอาทิตย์ที่ส่องผ่านผนังโปร่งแสงหรือกระจก *(SHGC)* ผลการวิเคราะห์คือค่า *(ESR)* ซึ่งเป็นตัวแปรในสมการ OTTV ผลการจำลองและการวิเคราะห์แสดงว่าค่า *ESR* ของผนังแนวตั้งสอดคล้องกับค่า *ESR* ที่ระบุในกฎหมายพลังงานในอาคาร (BEC) โดยอาคารตัวอย่างมีค่าดัชนีการใช้พลังงานใกล้เคียงกับค่าที่ได้จากการสำรวจ ในอาคารที่มีผนังเอียงที่มุม 105-150 องศา พบว่ามีค่า *ESR* ลดลง 2.7-37% เมื่อมุมเอียงผนังกระจกเพิ่มขึ้นจะลดค่า OTTV ลง 2.0-17 % อาคารผนังกระจกเอียง 90-150 องศา ที่มีค่า SHGC เท่ากับ 0.54 และได้รับการสะท้อนจากพื้นสูงเท่ากับ 0.32 พบว่า มีค่า OTTVs ของอาคารเกิน 50 W/m^2 ดังนั้น จึงแนะนำให้ใช้พื้นหญ้าและพื้นน้ำสำหรับภูมิทัศน์รอบอาคารที่มีค่าการสะท้อนต่ำเพื่อประสิทธิภาพด้านพลังงาน

Keywords (คำสำคัญ)

Overall Thermal Transfer Value (ค่าการถ่ายเทความร้อนรวม)
Inclined Wall (ผนังเอียง)
Effective Solar Radiation (ค่ารังสีอาทิตย์ที่มีผลต่อการถ่ายเทความร้อนผ่านผนังโปร่งแสง)
Building Energy Simulation (การจำลองพลังงานในอาคาร)
Ground Reflectance (ค่าการสะท้อนจากพื้น)

1. Introduction

The development of the building energy code (BEC) in Thailand is important because it has been developed, promoted, implemented and improved during the last two decades (1992-present). The Overall Thermal Transfer Value (OTTV) is the requirement in accordance with BEC for commercial buildings with floor areas equal to or larger than 2,000 m2. The previous formula of bye-law OTTV was found to be an effective indicator of the thermal performance of the office building's envelope but it overestimated the performance of hospital buildings (Chungloo, Limmeechokchai & Chungpaibulpatana, pp. 125-143, 2001). Presently, the maximum allowable OTTV of buildings such as office buildings, department stores and hotels is 50, 40 and 30 W/m^2, respectively. The current $OTTV_i$ formulation takes the form (DEDE, 2007)

$$OTTV_i = (1-WWR)(TD_{eq})(U_w) + (WWR)(\Delta T)(U_f) + (WWR)(SHGC)(SC)(ESR) \quad (1)$$

where *WWR* is the ratio of window to the total wall, TD_{eq} is the equivalent temperature across the opaque wall, U_w is the overall coefficient of heat transfer for the opaque wall, ΔT is the temperature difference between indoors and outdoors, *SHGC* is the solar heat gain coefficient of the glazing, SC is the shading coefficient of the external shading device, and *ESR* is the effective solar radiation on the window. The first term represents heat gain through the opaque wall via a conduction process, the second term represents heat gain through the window by conduction and the third term represents the solar transmission through the window.

The OTTV measures average heat gain of the building façades and links to the computation of the cooling energy consumption. The $OTTV_i$ of a building façade represents heat gain through the given building façade. Hence, the smaller the OTTV the less energy is used for cooling. Prediction of energy use in commercial buildings in Singapore was presented as a simple formulation of OTTV using the DOE-2 program (Chou & Chang, 1995, 1996). Applying similar methods, the cooling requirements for commercial buildings in Thailand was found to be related to OTTV through a regression analysis and the OTTV formulation was validated with the data of field audits (Chirarattananon & Taveekun, 2004). The current BEC of Thailand requires lower values of OTTV and higher values of coefficient of performance (COP) in air conditioning systems than that currently being implemented in existing buildings. By applying the new BEC in the country, it is expected that electric energy savings in commercial buildings will reach 10-20 % within 6 to 12 years (Chirarattananon, Chaiwiwatworakul, Hien, Rakkwamsuk & Kubaha, 2010, pp. 1741-1753).

Nowadays, architects, developers, and building owners are concerned that the construction of buildings conforms to the Building Energy Code (BEC). The building configuration called "inverted pyramid or the diamond shape" has been accepted for cooling energy savings because the inclined walls provide self-shading during the required periods. Several examples of the inverted pyramidal buildings can be found in Chan and Chow (2014). The diamond shape building in Malaysia showed that the OTTV was reduced by 35.6% taking into account the building self-shading (Nikpour, Kandar, Ghasemi, Ghomeshi & Safizadeh, 2012, pp. 897-901). Building designers in Israel developed a computer program to compute the annual energy performance of diamond-shape buildings and courtyard buildings to reflect both the solar collection and the solar shading. The strong dependency of buildings with inclined walls on the climatic condition was found in previous research in the climates of Hong Kong, Shanghai and Beijing. In Hong Kong the total cooling energy saving was 0.6-10.9 %, however, the increase in heating energy was found in the other two cities (Chan & Chow, 2014). In Thailand, the inverted pyramid buildings was considered unfamiliar (Horayangura, 2011, pp. 1-19); however, the energy saving was around 6.0% in an experimental study compared to the test unit (Asavapitayanont, 2010). Considering the increase of average surface temperature by 14°C during 1994-2009 (Srivanich & Hukao, 2012, pp. 83-100) high effect of ground reflectance on inclined building wall is expected. The main objective of this paper is to compute the Overall Thermal Transfer Values for the wall inclination of 105-150 degree taking into account the ground reflectance of the surrounding landscape. The derived OTTV(s) are related with simulated energy consumption to assess the cooling coil load of the generic office building with inclined walls.

2. Generic Office Building Model

The generic building is a reference building representing a sample of buildings. In this study the generic reference office building is a one-floor building with flat roof and floor, one vertical glass wall and three vertical opaque walls as shown in figure 1a. The glazing material of the glass wall is green tinted glass with a thickness of 6 mm. The roof and floor are interior adiabatic surfaces with an overall heat transfer coefficient (*U-value*) value of zero. The three walls are exterior concrete walls with a *U-value* of 3.926 W/m^{2}°C. The simulation results of the generic office building are compared to the results of similar buildings with an inclined glass wall shown in figure 1b and figure 2. The inclination angles of the glass wall of the simulated buildings are 105, 120, 135 and 150 degrees measured from the horizontal plane.

The characteristics of the generic office building are summarized in Table 1. The energy use index of 142.6 kWh/sq.m/year is the simulated result that was derived from an energy building simulation program (eQuest 3.64). Given that this value well agrees with the average energy use index of audited office buildings of 146.4 kWh/sq.m/year in the DEDE database (2007), the generic office building in this study can be considered to represent office buildings in Thailand. As the direction of the glass wall was in the North, East, South and West, the $OTTV_i$ of the generic office building are 66.6, 80.6 80.7 and 80.67 W/m^2, respectively. These values are higher than the requirement of BEC due to the high Effective Solar Radiation *(ESR)* obtained later in this study.

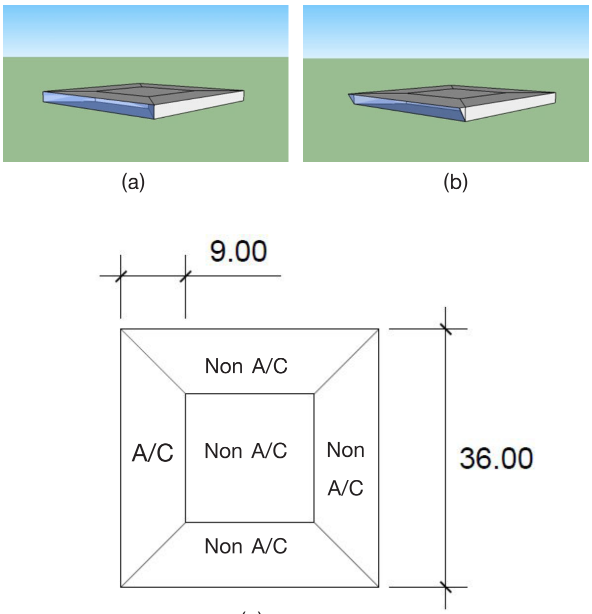


Figure 1. (a) The generic reference building (b) The building with an inclined wall (c) The building plan and zones

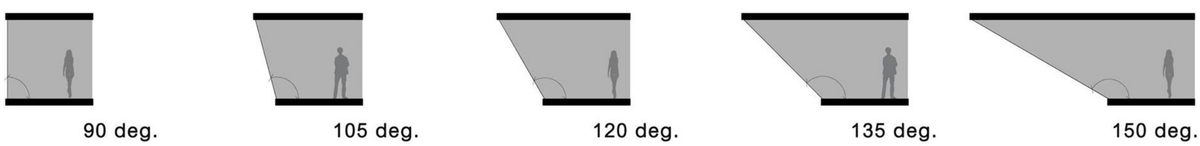


Figure 2. The building with wall inclinations of 90, 105, 120, 135 and 150 degrees.

Table 1. Summary of the characteristics of the generic office building.

Type	Detail
Weather file	THA_Bangkok_IWEC.bin
Annual operation hour	8.00 a.m. to 5.00 p.m. (ex. Weekend)
	Total = 2349 hrs.
Building type	Office
Total building area	1,296 m^2
Floor to floor	3.65 m
Floor to ceiling	2.75 m
Depth from building perimeter	9 m
Opaque roof U_w-value (W/m^{2o}C)	0.0
Opaque wall U_w-value (W/m^{2o}C)	3.926
Solar absorptance	0.3
Glazing properties	Green tinted glass 6 mm. thickness
- SHGC	0.54
- glazing area (sq. m)	98.8
- U_f-value (W/m^{2o}C)	5.87
Ground reflectance (default)	0.2
Lighting power density (W/sq.m)	14.0
Equipment power density (W/sq.m)	16.2
Area per person (m^2/person)	20
Designed ventilation (cfm/person)	20
Cooling Setpoint (occupied)	24.5 °C
Cooling Setpoint (unoccupied)	27.8 °C
Cooling source	Chilling water coil
Average energy use index (kWh/sq.m/yr)	142.6
OTTV (W/sq.m) glass wall facing N, E, S, W	66.6 80.6 80.7 and 80.67

3. The Studied Parameters

The values of Effective Solar Radiation *(ESR)*, a variable in the OTTV equation, for the glass wall with an inclination of 105-150 degrees are computed through Eq. (1). By setting up the value of *WWR* equal to 1.0, i.e. a façade with 100 percent glazing, the first term disappears and only two terms of heat gain through the window remain. The second term in Eq. (1), representing the conduction heat transfer through glass, was assumed constant when the inclination angles of the glass wall were modified. The solar heat gain through the window, the third term of Eq. (1), are similar to the hourly solar heat gain ($Q_{win,\ rad/year}$, Watts) obtained from the computer program eQuest 3.64. Therefore, the simulation results of $Q_{win,\ rad/year}$ combined with the annual operating hours *(AOH)* takes the form of Eq. (2)

$$Q_{win,\ rad/year} = ESR\ (A \times SC_f \times AOH) \qquad (2)$$

where SC_f is the ratio of solar heat gain coefficient of a glass unit *(SHGC)* to the solar heat gain coefficient of the 3 mm Clear Float Glass *($SHGC_{ref}$ = 0.86)*. For the SC_f values of 0.26-0.96, the average hourly solar heat gain is obtained from the simulation results. Hence, the *ESR* values are derived from the slope of the linear relationships between the SC_f and

Table 2. Summary of simulation run

Variables	Values	Number of variables	Number of computer runs
SHGC/$SHGC_f$ of glazing materials	0.26, 0.34, 0.49, 0.57, 0.71, 0.81, 0.96	7	7
Direction of glass wall	North, East, West, South	4	28
Inclination of glass wall	90, 105, 120, 135, 150	5	140
Ground reflectance	0.05, 0.20, 0.32	3	420

the $(Q_{win,\ rad/year})/(A \times AOH)$. The parameterization includes the glass wall with glazing materials of $SC_f = 0.26\text{-}0.96$, varying in five wall inclinations, four directions and three types of surrounding land covering shown in Table 2. The simulation results of 420 cases give the average hourly solar heat gain $(Q_{win,\ rad/year})/(A \times AOH)$ of the generic office building.

4. Results and Discussion

4.1 The ESR values of inclined glass walls

Figure 3 shows a comparison of the computed *ESR* values to the *ESR* obtained in the existing Building Energy Code (BEC). To evaluate the performance of the proposed method, the *ESR* values of the 0-90-degree wall was also studied. The computed values from this study are higher than the *ESR* in BEC by 18% for the horizontal wall and by 2% for the vertical wall. These discrepancies could be the results of wide range of SC_f values in this study that cause high slope in the regression lines.

The example of regression lines in this study is illustrated in Figure 4. The solar heat gain in 0, 45 and 90-degree inclined walls suddenly rises as the SC_f = 0.96. Nevertheless, the *ESR* patterns from the computation is highly compatible with the value from BEC for the high ground reflectance such as grass and white concrete.

Table 3 shows the results of Effective Solar Radiation *(ESR)* values derived from the regression analysis of 420 cases. All the correlation values (R^2) exceed 0.91, showing strong linear relationships between the space solar gain, $Q_{win,\ rad/year}$, and the glazing property, SC_f. The analysis reveals that the *ESR* values decrease as the inclination angles increase

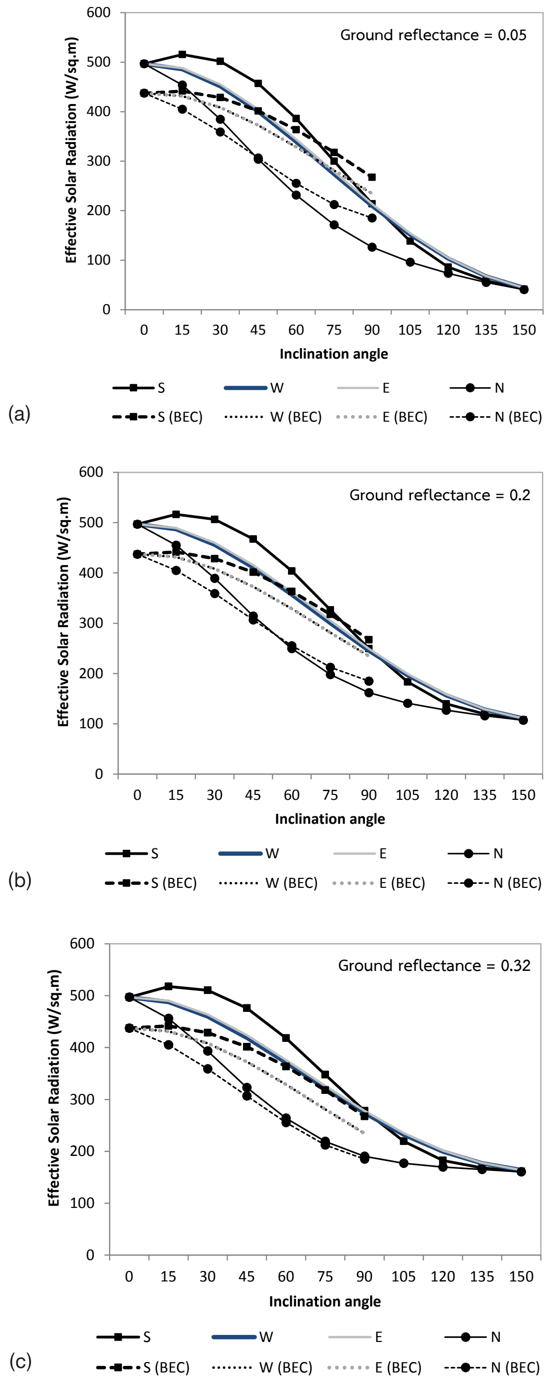


Figure 3. The simulated Effective Solar Radiation *(ESR)* values and the *ESR* values in the Building Energy Code (BEC) in the South, West, East and North directions for ground reflectance of (a) 0.05 (b) 0.20 and (c) 0.32.

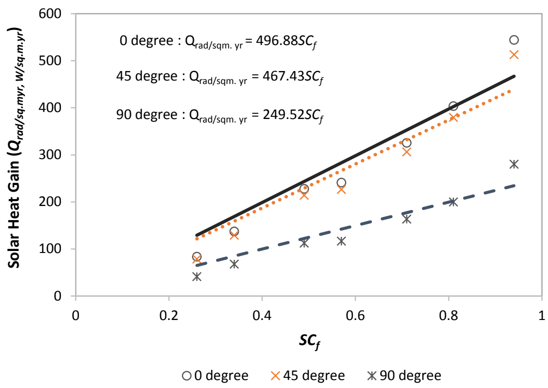


Figure 4. The linear regression lines of solar heat gain and SC_f values for inclined walls of 0, 45 and 90 degrees (ground reflectance = 0.20).

for any directions and types of ground reflectance. The increase of inclination angle by 15-60° from the vertical reduces the ESR values for the glass wall in the South, West, North and East directions by 29.3-37.8%, 27.8-34.7%, 23.9-26.5% and 27.8-35.1%, respectively. When the inclination angle and ground reflectance increase, the reduction rate of ESR values decrease.

4.2 The OTTV of building with an inclined glass wall

Typically, the area of an inclined wall is larger than the vertical wall. Taking into account these variations, the areas of glass wall with inclination angles of 90-150 degrees shown in Table 4 are used to calculate the OTTV.

The results of OTTV of buildings with an inclined glass wall are computed by substituting the values of U_f and U_w from Table 1, *ESR* from Table 3, and glass wall areas from Table 4, into Eq. (1). Figure 5 displays the results of the calculated OTTV against *ESR* values for the glass wall facing to the South, West, East and North, respectively. The glazing material is tinted glass with *SHGC* = 0.54. The ground reflectance highly effects the OTTV because the ground reflectance = 0.05 (water surface) meets the OTTV requirement of 50 W/sq.m, but the ground reflectance of 0.20 (grass) and 0.32 (white concrete) contribute to the OTTV ranges of 60-70 W/sq.m and 65-70 W/sq.m, respectively. The OTTV of a building with a vertical glass wall exceeds 50 W/sq.m in any

Table 3. The results of Effective Solar Radiation for Wall Inclination of 0° (horizontal) to 150°

Ground Reflectance	Direction	Inclination angles										
		0	15	30	45	60	75	90	105	120	135	150
0.05	S	496.9	515.4	501.6	457.0	386.1	299.9	213.8	138.5	86.1	58.5	41.3
	W	496.9	485.8	451.3	400.2	339.1	273.7	209.6	151.4	103.1	67.3	43.9
	E	496.9	488.0	455.2	405.0	344.1	278.5	213.6	154.4	104.9	68.1	44.1
	N	496.9	453.9	384.8	304.0	231.7	171.4	126.3	96.1	73.5	55.2	40.6
0.20	S	496.9	516.6	506.4	467.4	403.9	326.4	249.5	183.5	139.7	119.4	108.0
	W	496.9	487.0	456.0	410.6	356.9	300.2	245.3	196.3	156.7	128.2	110.6
	E	496.9	489.3	460.0	415.5	362.0	305.0	249.3	199.3	158.5	129.0	110.8
	N	496.9	455.1	389.5	314.4	249.5	197.9	162.0	141.1	127.1	116.2	107.2
0.32	S	496.9	517.6	510.2	475.8	418.2	347.6	278.1	219.4	182.6	168.2	161.3
	W	496.9	487.9	459.9	419.0	371.2	321.4	273.9	232.3	199.6	177.0	163.9
	E	496.9	490.2	463.8	423.8	376.2	326.2	277.9	235.3	201.4	177.8	164.1
	N	496.9	456.1	393.4	322.8	263.8	219.1	190.6	177.1	169.9	165.0	160.5

Table 4. The area of glass wall with inclination angles of 90-150 degrees.

Inclination angle (°)	90	105	120	135	150
Area (m^2)	98.8	102.2	114.0	139.7	197.5
% increase		3	15	41	100

direction and it needs at least 105 to 122-degree glass wall inclination surrounded by water in order to comply with the OTTV requirement. In addition, the excessively high inclination angles such as 135 and 150 degrees lead to the increase of OTTV because the large glass area allows high solar heat and ground reflection.

Figure 5 together with the *ESR* in Table 3 can be used to calculate OTTV for office buildings with an inclined glass wall. For example, a building designer decides to build a 120-degree inclined glass wall for an office building that also complies with the OTTV requirement. As indicated by Table 3, if the designer chooses the 120-degree inclined glass wall in the West direction and the grass landscape in front of the glass wall, the *ESR* value will be 156.7 W/sq.m After that, the designer discovers the OTTV around 57 W/sq.m from Fig. 5b (the filled triangle markers). The results suggest that this building's OTTV would exceed the expected OTTV. To reduce the OTTV, adding insulation in the opaque wall or using energy efficient glazing is suggested.

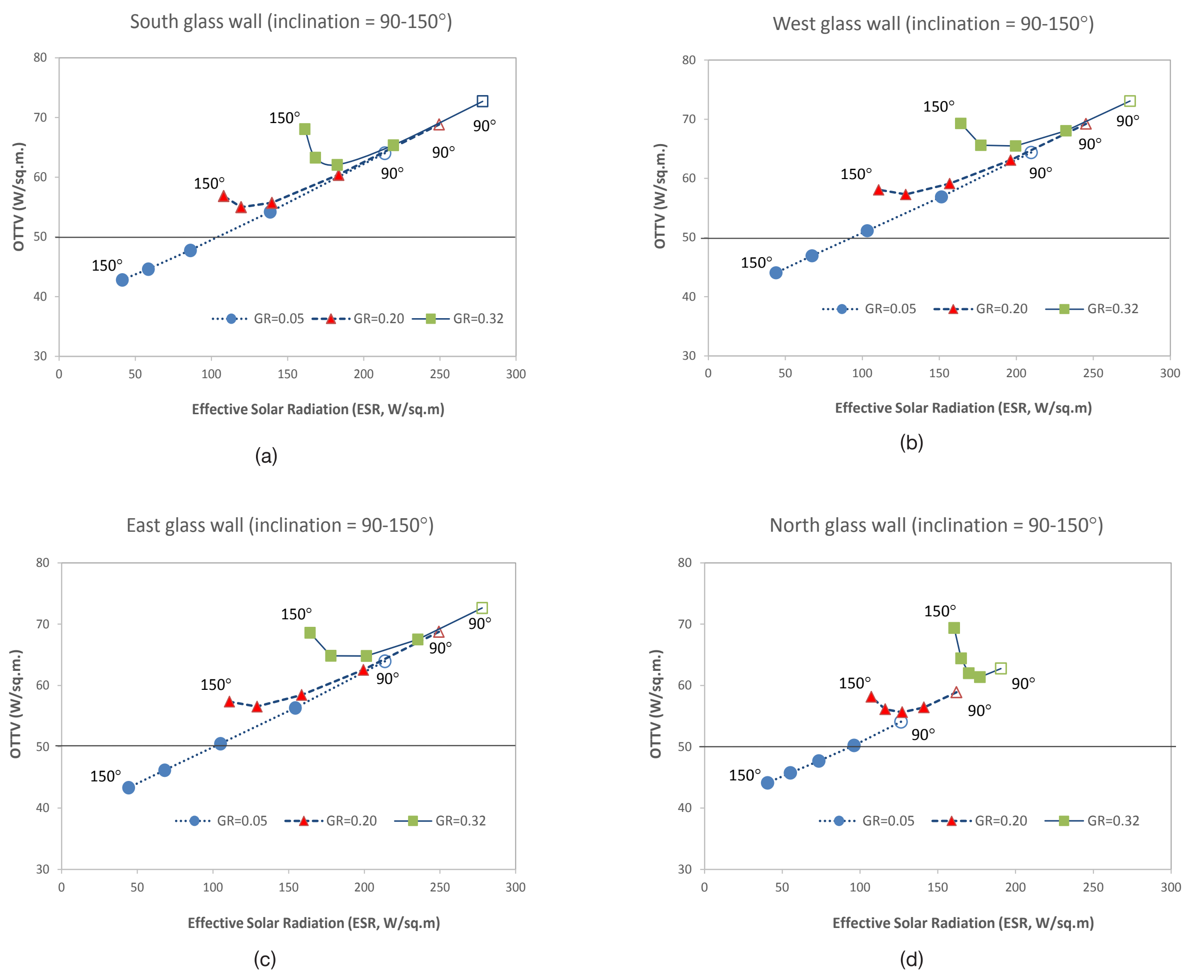
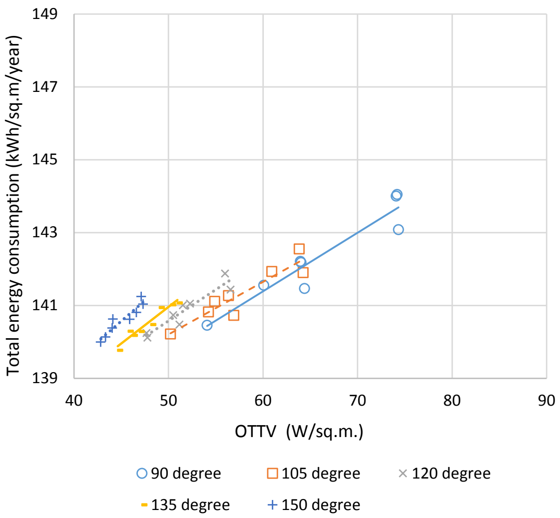


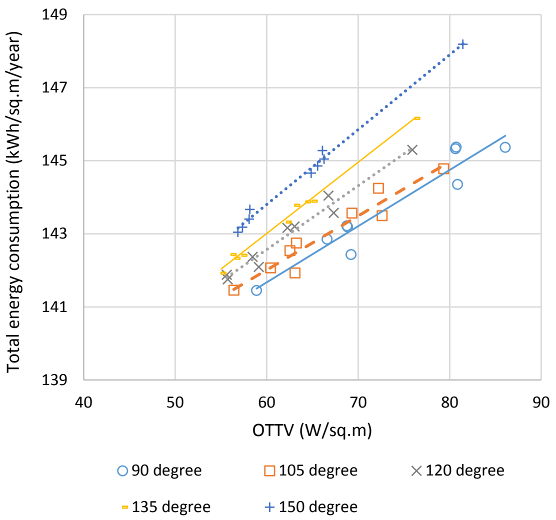
Figure 5. Calculated OTTV vs. *ESR* values for the glass wall (SHGC = 0.54) facing to the South, West, East and North

4.3 *Prediction of cooling energy in buildings with an inclined glass wall*

The results of building energy consumption against the calculated OTTV of the vertical (90 degree) and inclined glass walls (105-150 degree) for ground reflectance of 0.05 and 0.20 are shown in Figures 6a and 6b, respectively. The markers represent the total energy consumption of buildings with two glazing materials: the clear floated glass and the green tinted glass, in four directions. The energy consumption of buildings with vertical and inclined walls was obtained from the simulation results of the eQuest 3.64 program.



a)



b)

Figure 6. The OTTV vs. total energy consumption of vertical and inclined glass walls for ground reflectance of (a) 0.05 and (b) 0.20.

Representing average heat transfer through the building envelope, OTTV directly links to the cooling load of the building. One question that occurs during the improvement of the building envelope is how building energy performance improves for the reduction of OTTV by 1 W/sq.m. The answer is derived from simple calculation of line slopes shown in Fig. 6. For example, the shifting of the 90-degree line to the left, i.e., to a 120-degree line, can reduce the OTTV from 55-75 W/sq.m by 20-25 W/sq.m. Accordingly, the energy consumption range of 139.5-143.5 kWh/sq.m/year decreases by 2.5 kWh/sq.m/year. This reduction of total energy consumption is approximately equal to 0.125 kWh/sq.m/year for 1 W/sq.m of OTTV reduction, which is quite minimal. The small reduction in energy consumption was caused by the increase of window areas as the inclination angle increases. The limited reduction of energy consumption is also clearly seen in the case of high ground reflectance, shown in Figure 6b. The range of OTTV and the range of energy consumption are similar regardless of the inclination angle.

5. Conclusions

The method to calculate the Effective Solar Radiation *(ESR)*, a variable in Overall Thermal Transfer Value (OTTV) in the Building Energy Code (BEC), for buildings with an inclined glass wall of 105-150 degrees from the plane considering the effect of ground reflectance has been shown in this paper. The method was verified with the *ESR* values of the wall with a 0-90 degree inclination previously prescribed by the Building Energy Code (BEC), finding a discrepancy of 2-18%. The error was presumed to be caused by the different range in the Solar Heat Gain Coefficient (SHGC) values. In applying the derived *ESR* for the inclined glass walls, the OTTV of a generic building was obtained. It was found that the inclined glass wall was unable to trade off the increase of the glass wall area in order to achieve the prescribed OTTV. In order to meet the OTTV requirements, adding insulation, using energy efficient windows or keeping the low reflectance from water surfaces is recommended. The ground reflectance also plays an important role in the total energy consumption of the building. For ground surfaces with high ground reflectance, such as grass and white concrete, it was not possible to reduce the building's energy consumption by increasing the glass wall area and its inclination.

6. Acknowledgements

This research was partially supported by a research fund from the Faculty of Architecture and Planning, Thammasat University.

References

Asavapitayanont, A. (2010). *Energy conservation performance in building with tilted envelope in hot humid climate* [Unpublished]. Master Thesis, Faculty of Architecture and Planning, Thammasat University, Bangkok, Thailand.

Chan, A. L. S., & Chow, T. T. (2014). Thermal performance of air conditioned office building constructed with inclined walls in different climates in China. *Applied Energy, 114,* 45-57.

Chirarattananon, S., Chaiwiwatworakul, P., Hien, V.D., Rakkwamsuk, P., & Kubaha, K. (2010). Assessment of energy savings from the revised building energy code of Thailand. *Energy, 35*(4), 1741-1753.

Chirarattananon, S., & Taveekun, J. (2004). An OTTV-based energy estimation model for commercial buildings in Thailand. *Energy and Buildings, 36*(7), 680-89.

Chou, S. K., & Chang, W. L. (1996). A generalized methodology for determining the total heat gain through building envelopes. *International Journal of Energy Research, 20*(10), 887-901.

Chow, W. K., & Chan, K. T. (1995). Parameterization study of the overall thermal-transfer value equation for buildings. *Applied Energy, 50*(3), 247-268.

Chungloo, S. Limmeechokchai, B., & Chungpaibulpatana, S. (2001). Parametric analysis of energy efficient building envelope in Thailand. *Asian Journal of Energy and Environment, 2*(2), 125-143.

Department for Alternative Energy Development and Energy Efficiency [DEDE]. (2007). *Ministry of energy, the royal government of Thailand, Manual of building energy conservation standard.* (In Thai). Bangkok: Author.

Horayangura, V. (2011). The creation of cultural heritage towards the development of a modern Thai architectural identity. *Journal of Architectural/Planning Research and Studies, 8*(1), 1-19.

Nikpour, M., Kandar, M. Z., Ghasemi, M., Ghomeshi, M., & Safizadeh, M. R. (2012). Heat transfer reduction using self shading strategy in energy commission building in Malaysia. *Journal of Applied Sciences, 12*(9), 897-901.

Srivanich, M., & Hukao, K. (2012). Thermal infrared remote sensing for urban climate and environmental studies: An application for the city of Bangkok, Thailand. *Journal of Architectural/Planning Research and Studies, 9*(1), 83-100.