PAPER • **OPEN ACCESS**

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To cite this article: Tran Ngoc Chan and Bui Quang Trung 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **481** 012032

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Technical indexes - building energy in tropical climate

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Abstract: In tropical climate countries including Vietnam, external heat absorbed into buildings in summer time is mainly depended on solar radiation transmitted through glass windows. This article aims to illustrate data representing the relation among SHGC, OTTV, and energy costs of air conditioning system in buildings.

1. Introduction

Abbreviation:
OTTV: Overall Thermal Transfer Value;
SHGC: Solar Heat Gain Coefficient of window glass

Building external structures play an important role to ensure comfortable environment for people working and living inside. Heat insulation requirement of external structures in winter has been regulated in TCVN [1]. For instance, external structure made by refined clay brick of 220 mm thickness secures a heat resistance R_o= 0.584-0.625 m^2.K/W, which is qualified to prevent condensation on the inner surface of the external structure, and prevent cold for human bodies due to heat irradiance from body to wall surface.

Meanwhile, in summer, the heat transmission into air-conditioned buildings due to temperature difference and solar radiation, which transferred through glass windows will be high. This leads to high energy expense for building air-conditioning system. To mitigate such expenses, Vietnamese QCVN 09:2017 sets thresholds for $OTTV_T$ – for walls, and $OTTV_M$ – for roof not exceeded 60 W/m^2 and 25 W/m^2, respectively [2].

Currently, trends of constructing high rise buildings with large glass windows has been common in Vietnam and worldwide, where Window-Wall Ratio (WWR) may be as high as 100%. In such cases, it is necessary to choose glass window with low SHGC to secure the regulated OTTV thresholds.

Apparently, glass with low SHGC is expensive, thus, resulting in investment surge. Nonetheless, in return, the energy expenses for air-conditioning system during the operation of the building would be reduced. To that end, it is crucial to compare different glass using plans with different SHGC to not only secure the threshold under QCVN 09:2017, but also reduce the energy expenses for the air-conditioning system in particular, and the whole building as well.

2. Correlation between SHGC, OTTV and energy expenses

OTTV calculation has been presented in the article [3]. OTTV is mainly dependent on the SHGC of the glass window, especially in the case of high WWR. In practice, when WWR ≥ 40%, heat transmitted through glass window accounts for 85-95% of the total heat absorbed into the building. As such, window glass serves as key element in saving energy consumed by air-conditioning.

To save air-conditioning energy, on one hand, WWR must be lower down, but on the other hand, low SHGC glass window must be chosen, and applying external structure to cover sunlight outside the window [4].

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With the purpose of clarifying the correlation between OTTV and SHGC of window glass, calculations applied to different buildings with different functions, shapes, scales and orientations with four different SHGC have been implemented by computer software [5]. Results are presented in Table 1. Data in Table 1 is presented in Figure 1.

Table 1. Values of OTTVT , W/m^2 in correlation with SHGC of buildings with different WWR.

	Building charateristics and WWR	Plans of SHGC for window glass			
		Plan 1: SHGC=0.85	Plan 2: SHGC=0.65	Plan 3: SHGC=0.45	Plan 4: SHGC=0.30
1	5-storey commercial-service centers, $\sum F_{floor.}$=18,436 m^2, North orientation, WWR=0.705	144.66	113.65	82.54	59.21
2	21-storey office building, $\sum F_{floor\ .}$=36,800 m^2, South orientation, WWR=0.688	137.03	107.88	78.72	56.86
3	23-storey office building,, $\sum F_{floor}$ =37,800 m^2, East orientation, WWR=0.392	87.65	70.15	52.64	39.51
4	14-storey apartment building, $\sum F_{floor\ .}$=18,755 m^2, South West orientation, WWR=0.372	86.32	68.76	50.27	36.76
5	14-storey office building, $\sum F_{floor\ .}$=16,628 m^2, South East orientation, WWR=0.298	69.35	54.92	40.49	29.67

Note: All buildings are located in Hanoi.

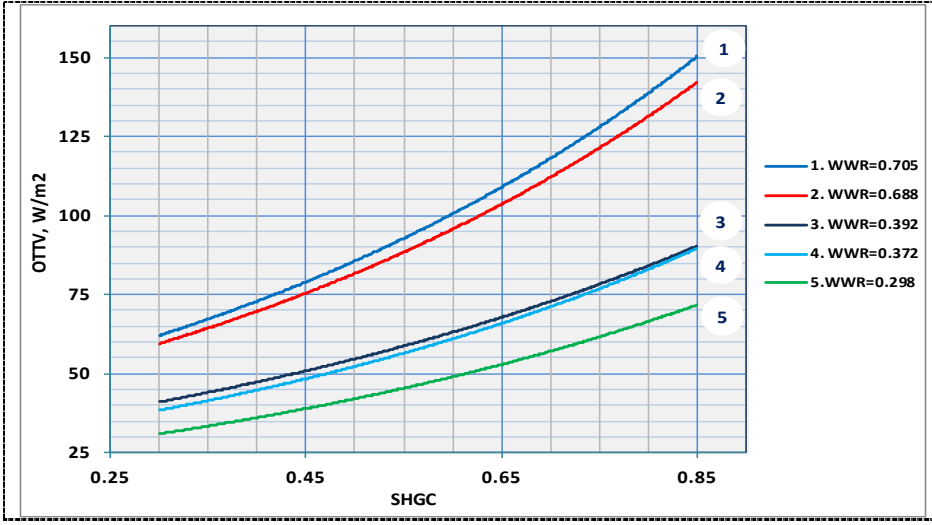

Figure 1. Variability of $OTTV_T$ in correlation with SHGC of buildings with different WWR.

The curves in Figure 1 demonstrate that regardless of difference in shape, scale, and orientation, the curves of the two buildings (Plan 1 and 2 in Table 1) with similar WWR (WWR = 0.705 and 0.688) are close to each other. Similar outcome is found in the Curve 3 and Curve 4 (Plan 3 and Plan 4 in

Table 1) with similar WWR = 0.392 and 0.372, respectively. To that end, $OTTV_T$ of the building is not affected by shape, scale, and orientation of the building, but the WWR.

3. Determination of technical-economic indexes for Commercial-Service Centers

For 5-storey Commercial-Service Centers (Plan 1 in Table 1), detailed calculation is conducted: it is necessary to identify OTTV, energy expenses for different electric usage demands, and investment capital for the window glasses of different SHGC. The Commercial-Service Centers is located in 5-storey podium with 18436 m^2 of a multi-storey complex located in Cau Giay district, Hanoi. The total external wall area is 7172.6 m^2 and total window area is 5059.1 m^2 (WWR = 0.705). Calculated results are presented in Table 2.

Table 2. Technical-economic indexes for Commercial-Service Centers in Cau Giay district, Hanoi.

Technical-Economic Index and its unit	**Plans with SHGC of window glass**			
	Plan 1: SHGC=0.85	**Plan 2: SHGC=0.65**	**Plan 3: SHGC=0.45**	**Plan 4: SHGC=0.30**
$OTTV_T$, W/m^2	144.66	113.65	82.54	59.21
Power expense for air conditioning system, kWh/year	1042,678.5	910,617.3	778,630.9	680,478.6
API, kWh	516.3	450.9	385.5	336.9
AEI, kWh/(m^2.year)	56.6	49.4	42.2	36.9
BEI, kWh/(m^2.year)	100.1	93.0	85.8	80.5
Investment capital for window glass (millionVND)	3642.55	5059.10	6070.92	7588.65

Note:
- API: Air Conditioning Power Index;
- AEI: Air Conditioning Energy Index – energy expense for 1 square metre floor in a year;
- BEI: Building Energy Index – Energy use index for whole building - – annual energy consumption for 1 m^2 of building gross floor are;
- Among the 4 plans, plan with SHGC = 0.3 secures $OTTV_T$ threshold as set forth in QCVN 09:2017;
- Investment capital for window glass for plans 1 to 4: 720,000; 1,000,000; 1,200,000 and 1,500,000 VN Dong/m^2.

Power price applicable to Cau giay -Hanoi area for usage of 401 kWh and higher is VND 2535 for each kWh. Annual economic profit by reducing power expenses is (1,042,678.5 – 680,478 .6)×2,535 = VND 918,176,746.5.

Period for investment return is 3,946,100,000/918,176,746.5 = 4.3 years. Data in Table 2 (Plan 2 and 6) are illustrated in Figure 2.

To detail the correlation between $OTTV_T$ and energy expenses for air conditioning for 1m^2 of the floor in AEI, kWh/(m^2.year), supplementary calculations of other buildings have been conducted and presented in Table 3 and Figure 3

As presented in Figure 3, there is difference between AEI = f ($OTTV_T$) function, and $OTTV_T$ = f (SHGC) function in Figure 1, which is a linear correlation, represented by straight lines (R^2 is approximately equivalent to 1). This facilitates the calculation in designing process to choose optimal $OTTV_T$ for energy saving of air conditioning system.

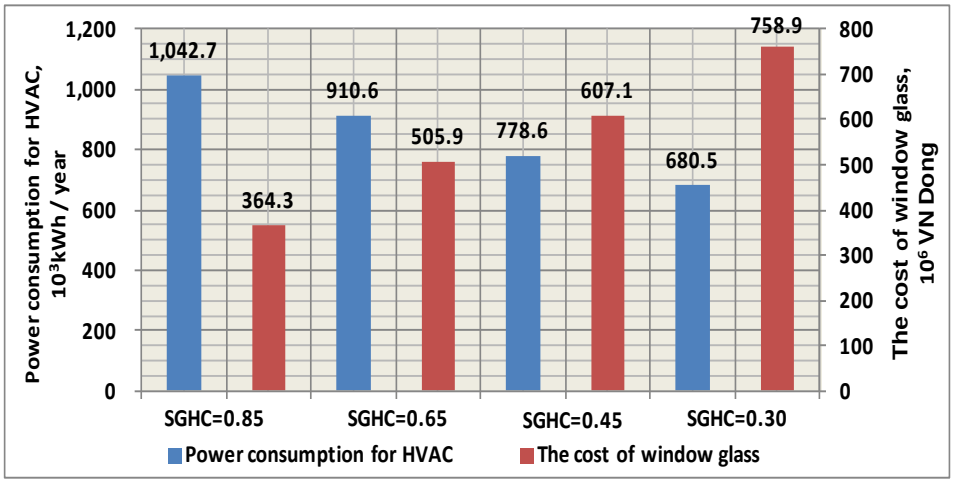

Figure 2. Power expenses and investment capital for window glass in 4 plans of different SHGC for the Commercial-Service Centers in Cau Giay district, Hanoi.

Table 3. $OTTV_T$ and AEI of different buildings of different SHGC in Hanoi.

	Building	Index	SHGC				
			SHGC= 0.85	SHGC= 0.65	SHGC= 0.45	SHGC= 0.30	SHGC= 0.17
1	5-storey commercial-service centers, $\sum F_{floor.}$=18,436 m^2, North orientation, WWR=0.705	$OTTV_T$, W/m^2	144.66	113.65	82.54	59.21	39.0
		AEI, kWh/(m^2.year)	56.6	49.4	42.2	36.9	32.41
2	23-storey office building,, $\sum F_{floor}$ =37,800 m^2, South orientation, WWR=0.392	$OTTV_T$, W/m^2	87.65	70.15	52.64	39.51	28.14
		AEI, kWh/(m^2.year)	57.6	51.53	45.5	41.0	37.26
3	14-storey office building, $\sum F_{floor}$.=10,182 m^2, East orientation, WWR=0.355	$OTTV_T$, W/m^2	96.02	78.35	60.68	47.42	35.94
		AEI, kWh/(m^2.year)	56.7	50.5	44.34	39.73	35.8

4. Conclusion

1. Technical-economic indexes in correlation with OTTV and power expenses in buildings of different functions, shapes, scales, and orientations, located in Hanoi, have been identified. Calculations show that building OTTV is mainly depended on WWR and SHGC of window glass (Figure 1);

2. To complete the calculation, a number of computer software have been programed, of which OTTV calculation software will be applied for implementing QCVN 09:2017;

3. Technical-Economic calculation of the correlation between energy expenses for air-conditioning system and investment capital for window glass of the Commercial-Service Center in Cau giay reveals that to comply with QCVN 09:2017, window glass of SHGC = 0.3 must be installed instead of window glass of SHGC = 0.85. In such cases, investment capital increases by VND 3946.1 million, and would be returned in 4.3 years by energy saving of air-conditioning system.

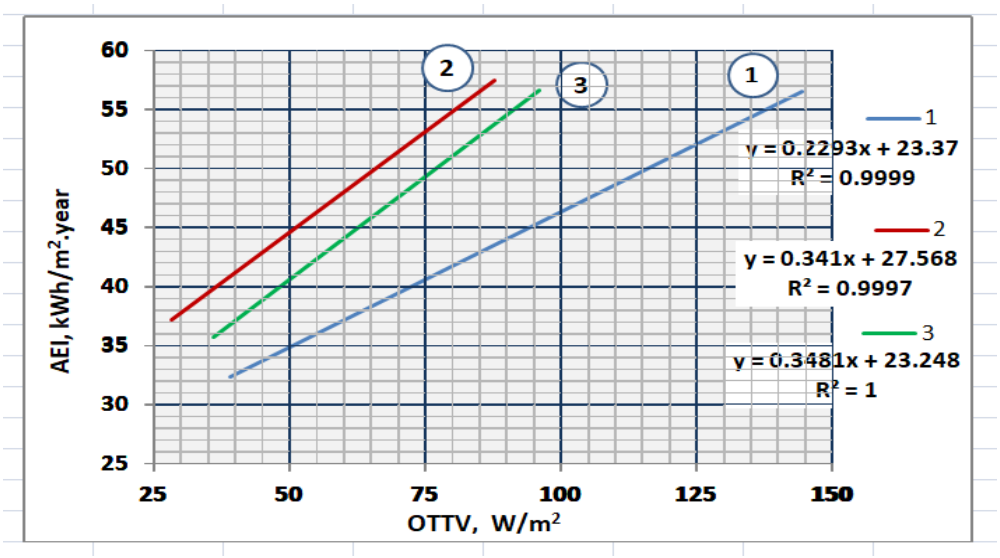

Figure 3. Dependency of AEI in $OTTV_T$ in buildings in Hanoi.
Note: Lines in the Figures are numbered by the order as presented in Table 3.

Reference

[1] Technical Standard TCVN 4605:1988 “Technical issues of covering structure – Designing Standards” 1998 (Hanoi: Construction Publisher) [in Vietnamese]
[2] Technical Regulation QCVN 09.2017/BXD “Buildings of efficient energy usage” 2017 (Hanoi: Construction Publisher) [in Vietnamese]
[3] Tran Ngoc Chan 2014 Limit heat transmitted through covering structure to reduce energy expenses for air-conditioning system *Scientific research journal "Air Quality in Building and Surrounding Environment"* (Haifa, [in Russian].
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