

Study on the Effect of Window on Building Energy Consumption of Office Buildings in Northern China

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Abstract: Window is an important part of building, and is also one of the critical factors affecting building energy consumption. Aiming at that, the simulation and calculation of building energy consumption is carried out with TRNSYS software in northern China. Analysis of the effect of window parameters such as transmittance, window-to-wall ratio (WWR), sill and window orientation on heating and cooling energy consumption is also involved in this paper, and some traditional building characters are validated to be right and reasonable for energy saving.

Keywords: window, building energy consumption, TRNSYS software, office building, northern China

1. INTRODUCTION

Energy is a key factor affecting production development and living standard improvement. Since it is not reproducible, the development of energy saving technology and the increase of energy efficiency has been considered as the fifth kind of energy following coal, oil, natural gas and nuclear energy^[1]. With the increase of energy consumption, building energy consumption has become an important part of national total energy consumption both in developed countries and developing countries. Generally the percentage is about 1/3 for developed countries.

Window is a necessary part of building, while it is also the most important factor affecting building energy consumption. It can not only improve indoor daylight environment and natural ventilation for buildings, but also widen the eyeshot of people indoors. From the study of energy consumption for multi-story buildings we know that heat loss of windows accounts for more than 1/3 of the total heat loss of buildings^[2].

2. SIMULATION AND ANALYSIS

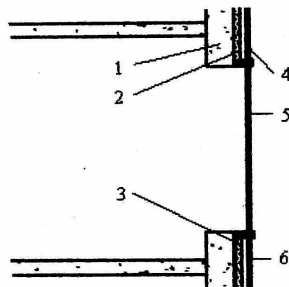
2.1 Model description

A model measuring 6m*4m*3m (Length * Width * Height) is established for simulation based on the analysis of office layout with TRNSYS software. Only

one external wall is involved for the model, which may be considered as an office room or one part of an open office. During the operation of air conditioning system, no heat transfer between each floor is in consideration since the indoor temperature of each room is regarded as the same and the model is assumed to be in standard floor. Fig.1^[4] shows the structure of building envelope.

The opaque sector in Fig.1 consists of

- 1) Concrete wall 0.36 m;
- 2) Insulation 0.1 m;
- 3) Metal sheet 0.001 m;
- 4) Air gap;
- 5) Spandrel glass 0.008 m.



1-Concrete wall; 2-Insulation; 3-Metal sheet;
4-Air gap; 5-Vision glass; 6-Spandrel glass

Figure 1: The structure of building envelope.

The U-value of the opaque sector is $0.337 \text{ W/m}^2 \text{ K}$. The transparent sector, accounting for 36 percent of the external wall, is made up of vision glass with a thickness of 0.008 m and a U-value of $5.8 \text{ W/m}^2 \text{ K}$. The settings of system operation are showed in Tab.1.

2.2 System operating conditions and design parameters

The natural infiltration is set to be 1 1/h during the occupation time from 8:00 am to 18:00 pm and 0.25 1/h during the non-occupation time. The HVAC system working during occupation time has been simulated to maintain the indoor temperature at 24°C and the relative humidity at 50% for every zone. Five working days and no consideration of heat gains of indoor service, human beings and artificial lighting are involved in the simulation.

Table 1: System operating conditions and design parameters.

WORKDAY	ON (8:00-18:00)
WEEKEND	OFF
DAYNIGHT	ON (6:00-18:00)
USE	Mon. to Fri. (WORKDAY) Sat. and Sun. (WEEKEND)
SETOFF	Mon. to Fri. (DAYNIGHT) Sat. and Sun. (WEEKEND)
Natural Infiltration	$0.75 \times \text{USE} + 0.25$ Air Change/hr
Ventilation	$3 \times \text{USE}$ Air Change/hr
Designed Temperature	$50 - 24 \times \text{SETOFF} \quad ^\circ\text{C}$
Humidity for Cooling	50%
Designed Temp.	$20 \times \text{SETOFF} \quad ^\circ\text{C}$
Humidity for Heating	50%

2.3 Weather data

Tianjin is a northern city of China located at the north latitude of 39.1° and the east longitude of 117.2° . It has an altitude of 5 meters and four various

seasons. The annual average air temperature is higher than 11°C . January is the coldest month of the whole year with an average air temperature lower than minus 4°C ; July is the hottest month with an average air temperature higher than 26°C .

2.4 Analysis on affecting factors

2.4.1 The effect of transmittance on H_{ec} and C_{ec}

A model is established with a south external wall, a WWR of 40%, and different transmittance of 0.3, 0.502, 0.617 and 0.81 for simulation.

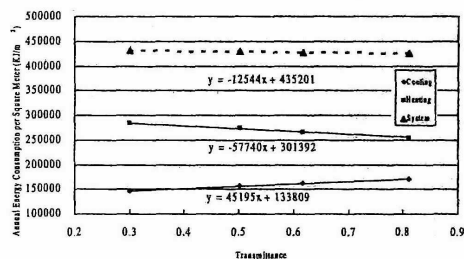


Figure 2: The effect of transmittance on H_{ec} and C_{ec} .

From Fig.2 we can see that the transmittance is linear with H_{ec} and C_{ec} . H_{ec} decreases by 5774 KJ/m^2 as the transmittance increases 0.1, which is equal to $3.6 \times 10^{-4} \text{ Ton Standard Coal (TSC)/m}^2$ with the assumption that heat value of standard coal is about 7000 kcal/kg , boiler efficiency is 65%, and heat distribution efficiency is 85%; C_{ec} increases by 4519.5 KJ/m^2 in the same case equaling to 0.36 KWh/m^2 with the assumption that the COP equals 5, and the electricity consumption of AHU accounts for 70% of that of whole air conditioning system. With the transmittance increasing, indoor heat gain rises up contributing to both the increase of energy consumption of cooling in hot summer and the decrease of energy consumption of heating in cold winter. From Fig.2 we also know that H_{ec} is much higher than C_{ec} , which is caused by the no consideration of heat gain of human beings, equipments and lighting in the simulation. If the above heat gains were considered, the cooling load would be higher and the heating load would be lower.

Based on the above analysis, when the electricity price is 0.59 RMB/KWh and the standard coal price is 417 RMB/Ton , the heating fee would reduce by 0.15 RMB/m^2 and the cooling fee would increase by 0.21 RMB/m^2 with the transmittance increasing by 0.1.

Table 2: Cooling and heating load under different transmittance.

Transmittance	0.3	0.502	0.617	0.81
Cooling Load (w/m ²)	37.2	39.5	40.9	43
Heating Load (w/m ²)	60.6	58.3	56.9	54.3

Note: No consideration of heat gains of human beings, equipments, and lighting.

2.4.2 The effect of WWR on H_{ec} and C_{ec}

A model is established with a south external wall, a transmittance of 0.502, and different WWR of 20%, 24%, 28%, and 32% for simulation.

Fig.3 shows the effect of WWR on H_{ec} and C_{ec} . From Fig.3 we can see that WWR is linear with both H_{ec} and C_{ec} . But its difference from the effect of transmittance is that both H_{ec} and C_{ec} increase with WWR increasing, while C_{ec} increases and H_{ec} decreases with transmittance increasing. C_{ec} increases by 14652KJ/m² equaling 1.11KWh/m², and H_{ec} increases by 13923KJ/m² equaling 4.75×10⁻⁴ Ton Standard Coal/m² as WWR increases by 10%.

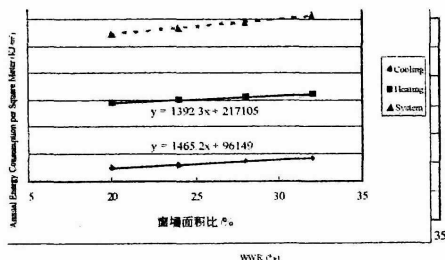


Figure 3: The effect of WWR on H_{ec} and C_{ec} .

Table 3: Cooling and heating load under different WWR.

WWR	20	24	28	32
Cooling Load (w/m ²)	31.7	33.1	34.7	36.1
Heating Load (w/m ²)	52.3	53.6	54.7	55.9

2.4.3 The effect of sill on H_{ec} and C_{ec}

A model is established with a south external wall, a transmittance of 0.502 and WWR of 40%, and

different sill of 0.9m, 1.0m, 1.1m and 1.2m for simulation.

The simulating result shows sill has no effect on H_{ec} and C_{ec} , and H_{ec} is 156420KJ/m² and C_{ec} is 272844KJ/m².

2.4.4 The effect of window orientation on H_{ec} and C_{ec}

A model is established with a transmittance of 0.502, WWR of 40%, and different window orientation of east, west, south and north for simulation.

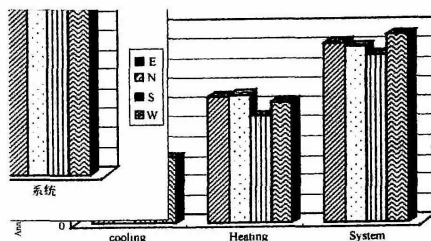


Figure 4: The effect of window orientation on H_{ec} and C_{ec} .

From Fig.4 we can see that different window orientation has a great effect on H_{ec} and C_{ec} , especially on H_{ec} . The minimum of C_{ec} is 123552KJ/m² occurred in north, and the maximum is 168696KJ/m² occurred in west 26.8% higher than the minimum. The minimum of H_{ec} is 272844KJ/m² occurred in south, and the maximum is 327600KJ/m² occurred in north 16.7% higher than the minimum. To sum up, the minimum of annual energy consumption is 429264KJ/m² in south, followed by north and east, and the maximum is 478980KJ/m² occurred in west 10.4% higher than the minimum. Therefore, buildings are generally built along the east-west direction to save building energy consumption.

Table 4: Cooling and heating load under different WWR

Window Orientation	E	N	S	W
Cooling Load (W/m ²)	34.4	31.2	39.5	42.6
Heating Load (W/m ²)	69.1	70	58.3	66.3

From chart 4 we know that the minimum cooling load occurs in north and the maximum in west; while the minimum heating load occurs in south and the maximum in north.

3. CONCLUSIONS

Both transmittance and WWR are linear with H_{ec} and C_{ec} . Sill has no effect on H_{ec} and C_{ec} . Window orientation has a great effect on H_{ec} and C_{ec} . For C_{ec} , the minimum occurs when the window orientation is in north and the maximum occurring with west window which is 26.8% higher than the minimum; for H_{ec} , the minimum occurs when the window orientation is in south and the maximum occurring with north window which is 16.7% higher than the minimum.

4. ACKNOWLEDGEMENTS

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