Energy Efficiency Evaluation of Guangzhou West Tower Façade System[1]

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Abstract: Guangzhou West Tower is an extremely tall public building. The energy efficiency evaluation of its façade should be different than that of ordinary public buildings. Based on the national code GB50189-2005, "Design Standard for Energy efficiency of Public Buildings", typical meteorological yearly data for Guangzhou were used and revised according to architectural character of Guangzhou West Tower. The energy efficiency design of a single skin façade and active airflow curtain wall was analyzed by a dynamic energy simulation tool and modified weather data. The payback period of initial investment in the façade system was evaluated based on simulation results. In addition, the results confirm the façade system scheme of Guangzhou West Tower.

Keywords: public buildings, typical meteorological year, energy efficiency, payback period, double skin

1. INTRODUCTION

In China, energy consumption of public building is very large. Energy consumption index of public building is 10 times bigger than that of ordinary residential building. From 1 July 2005, all public buildings design in China should comply with the requirements stipulated in the Chinese Code GB 50189-2005 "Design Standard for Energy Efficiency of Public Buildings".

The aim of the GB 50189-2005 " Design Standard for Energy Efficiency of Public Buildings" (hereafter Design Standard) is to provide information for building design with adequate level of thermal and energy performance to ensure efficient use of energy. The Design Standard is applicable to new buildings and building alternations.

Firstly, energy efficiency scheme must tally with requirements in the Design Standard, secondly Payback period of façade system investment should be taken into account from practicality.

2. BUILDING DESCRIBE

West Tower is the new mark of Guangzhou. The height of West Tower is 430m. It will be the highest building in Guangzhou and one of the highest buildings in the world. The architectural aspiration

Fig. 1 Concept image of West Tower

for the West Tower is for a building, which is sleek in nature, curvaceous and transparent allowing the structure of the building to be revealed. All glass façades with portrait line are used in the façade design. Main uses of West Tower are office and hotel.

In order to solve the problem of increased energy consumption due to large area glass, two façade energy efficiency designs were taken into account: traditional single skin façade and active airflow curtain wall, as shown in fig.2~3.

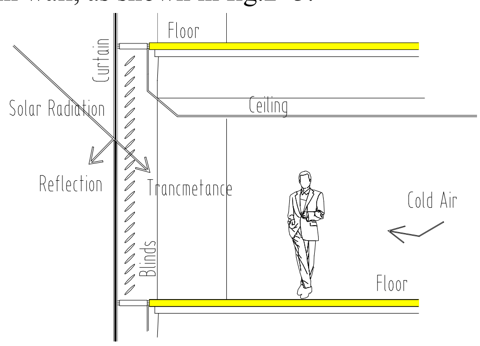

Fig.2 Traditional single skin façade scheme

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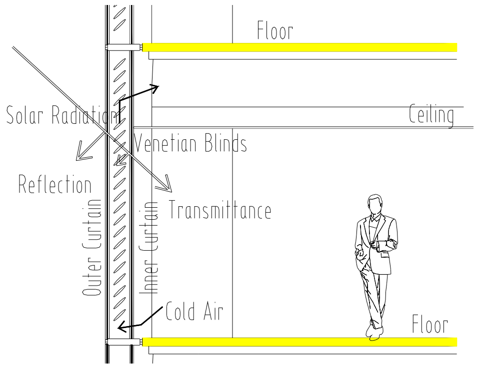

Fig.3 Active airflow curtain wall scheme

3. DESIGN STANDARD REQUIREMENTS

Energy efficiency design of West Tower should be firstly evaluated according to those compulsive items in Design Standard. The maximal *U*-value of opaque envelope and *SC* value of glass in Design Standard are shown in table 1.

Based on the façade character of West Tower, window to facade ratios of each orientation are 0.91 and exceed the limitative value 0.7 in Design Standard. The design can not be changed to meet the standard, so a performance analysis approach would be required according to the Design Standard.

Tab. 1 Façade design criteria for Guangzhou as stipulated in GB 50189-2005

Building Envelope	*U*-value（$W/m^2 \cdot K$）	
Roof	≤0.9	
External wall（including non-transparent curtain wall）	≤1.5	
External window（including curtain wall）	*U*-value（$W/m^2 \cdot K$）	*SC*
0.5<window to façade ratio<0.7	≤3.0	≤0.35/0.45
Roof skylight	≤3.5	≤0.35

4. PERFORMANCE APPROACH

If the façade design cannot fulfill the aforesaid requirements, performance approach can be adopted as an option for evaluating façade performance.

Performance compliance permits a proposed façade design to deviate from requirements provided that the proposed design can be shown to have annual energy consumption no greater than that of a reference case that satisfies the basic/prescriptive requirements. Performance approach to façade design requires more information such as façade material, air conditioning system design, operation mode etc, which is more complicated than just complying with the code requirements.

According to the items of performance approach in Design Standard, Dest, which is an annual dynamic energy simulation tool, was used to calculate energy consumption of air-conditioning equipment of reference building and design building.

4.1 Building model

Total floors of West Tower are 101 and the building height is 430m. In the vertical direction, West Tower is divided into office floors, assistant floors and hotel floors. In order to give prominence to main characters of research object, energy calculation models of office floors, assistant floors and hotel floors were established and calculated respectively.

4.2 Climatic data of Guangzhou

According the requirements of performance approach in Design Standard, typical meteorological year data should be used during energy dynamic calculating procedure. Weather data of Dest are produced by Medpha software which is based on 20 years weather data and random weather mathematic model. Weather data of Dest should be replaced by

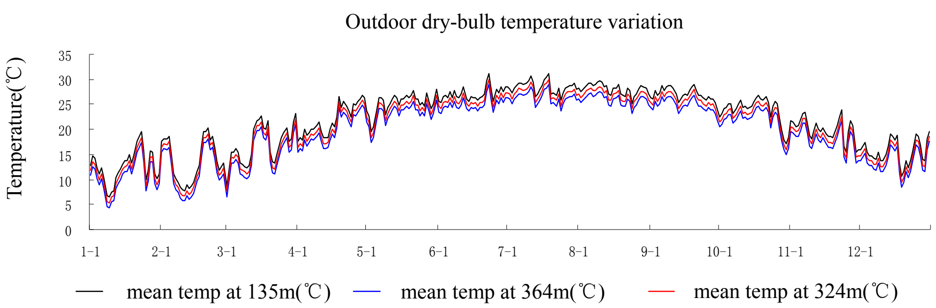

Fig.4 Outdoor dry bulb temperature variation

typical meteorological year data of Guangzhou.

4.2.1 Outdoor air temperature

Outdoor temperature is varied with the increase in height. Temperature is linear with altitude in the troposphere. Temperature decreases 0.6℃ while altitude increases 100m. Since the building height of West Tower is about 430m, therefore these variations should be taken into consideration for the thermal performance analysis, as shown in fig.4.

4.2.2 Revising the convection coefficient of out surface

Because of the gradient wind, it was found that there were significant differences of flow velocities in different floors of West Tower, as shown in fig.5.

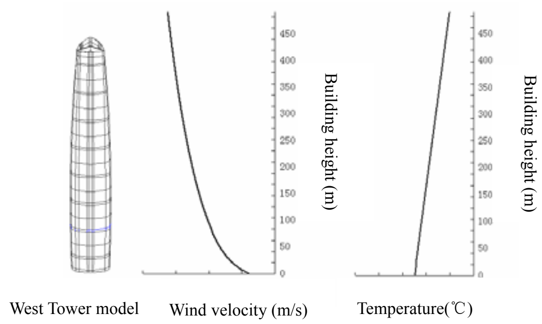

Fig.5 Outdoor air temperature and wind velocity variation

Building out surface convection coefficient has relations to outdoor wind velocity, which is shown as formula (1)

Tab. 2 Configurations of different schemes

Building envelope		Baseline	Reference Building	Single Silver Low-e	Double Silver Low-e	Active Airflow Curtain
Window to façade ratio of each orientation		All 0.91	All 0.7	All 0.91	All 0.91	All 0.91
Out skin glazing	Type	Toughened glass	Double Silver Low-e	Single Silver Low-e	Double Silver Low-e	Single Silver Low-e
	U-value（$W/m^2 \cdot K$）	5.7	1.8	1.94	1.75	1.94
	SC	0.85	0.35	0.57	0.38	0.57
	Visible transmittance	0.8	0.56	0.64	0.53	0.64
	Area (m^2)	6.7	6.7	6.7	6.7	6.7
Inner skin glazing	Type	N/A	N/A	N/A	N/A	Toughened glass
	U-value（$W/m^2 \cdot K$）					5.7
	SC					0.85
	Visible transmittance					0.8
	Area (m^2)					6.6
Shading device	Type	N/A	N/A	Motorized Venetian blinds	Motorized Venetian blinds	Motorized Venetian blinds
	Position			Indoor side	Indoor side	Interspaces of double skin
	SC	1	1	0.3	0.3	0.3
Visible transmittance of façade system		0.8	0.56	0.64	0.53	0.51
Overall *sc* of façade system		0.85	0.35	0.17	0.11	0.14
U-value of External wall（$W/m^2 \cdot K$）		2.35	1.5	Aluminium connect structure	Aluminium connect structure	Aluminium connect structure
U-value of Roof（$W/m^2 \cdot K$）		1.55	0.9	0.88	0.88	0.88
Indoor useable area (m^2)		252,000	252,000	252,000	252,000	247,000

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$W/m^2 \cdot K$; v —air velocity; constant in the formula (1) means natural convection effect.

According to the wind velocity variation of different floors, the outer surface convection coefficient of office floors, assistant floors and hotel floors model should be revised.

4.3 Configurations of different schemes

In order to evaluate energy efficiency effect between traditional single skin and active airflow curtain and compare payback period of these two schemes, annual air-conditioning energy consumption of different schemes, which are shown in table 2, were calculated with the revised typical meteorological year data of Guangzhou and convection coefficient.

In performance approach, day operation schedule and temperature of air conditioning equipment, different hourly occupancy and electrical equipment usage and different power of electrical appliance and lighting should be input. These parameters were all set consistent with items in Design standard.

Air-conditioning energy consumption index of different schemes are shown in fig.6.

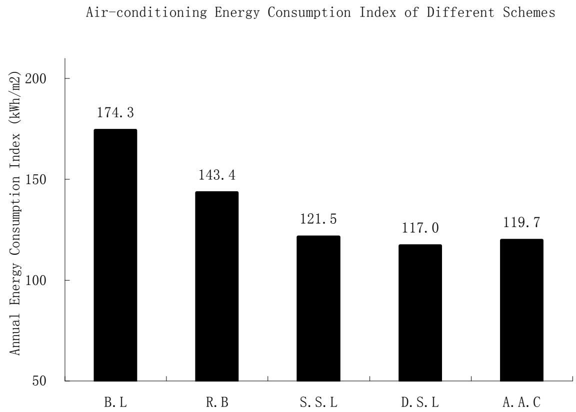

Fig.6 Air-conditioning energy consumption index of different schemes

Tab. 3 Costs breakdown of different façade schemes

Façade components	Baseline	Reference Building	Single Silver Low-e	Double Silver Low-e	Active Airflow Curtain
Glazing-Outer pane	200	660	580	660	580
Glazing-Inner pane	——	——	——	——	200
Venetian blinds	——	——	770	770	770
Railing	40	40	40	40	——
Aluminum sections	800	800	800	800	920
Exhaust system	——	——	——	——	280
Misc. material	400	400	400	400	560
Installation cost	400	400	400	400	560
Total	1840	2300	2990	3070	3870

Tab. 4 Payback period of different façade schemes

	Baseline	Reference Building	Single Silver Low-e	Double Silver Low-e	Active Airflow Curtain
Total cost of façade（RMB）	123,400,000	154,250,000	200,530,000	205,900,000	259,550,000
Investment increase（RMB）	——	30,850,000	77,130,000	82,490,000	136,150,000
Electricity saving（RMB）	——	7,920,000	9,760,000	10,140,000	10,130,000
Payback period of façade	——	3.9	7.9	8.1	13.4

4.4 Result analysis

can be calculated and shown in table 4.

5. CONCLUSION

The height of West Tower is 430m. Glass façade area is 67,000 m^2. West Tower belongs to super tall Building. Because outdoor temperature has relations to height, the results have errors if this variation would not be taken into account. In this article, the climatic data were revised according to the West Tower height and different façade schemes of West Tower were evaluated with the revised data, the results as follows:

1. As shown in fig. 6, annual air-conditioning equipment energy consumption index of two traditional single skin schemes and active airflow curtain scheme are lower than that of reference building. The result meets the requirements of performance approach in Design Standard.

2. Energy efficiency rate of different schemes are shown in fig.7.

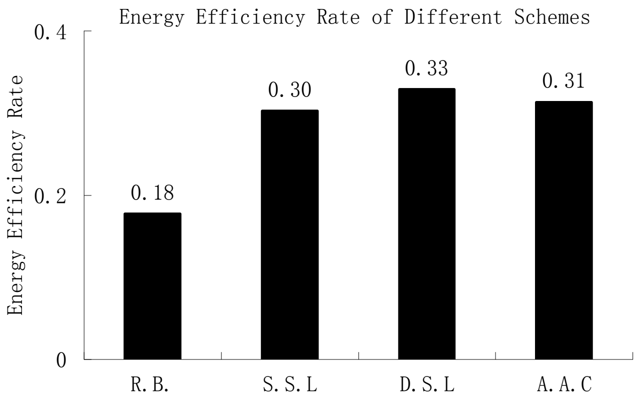

Fig.7 Energy efficiency rates of different schemes

Energy efficiency rate of two traditional single skin schemes and active airflow curtain scheme are higher than 30%, but predominance of active airflow curtain is not obvious, comparing to single silver low-e scheme, the energy saving rate increase by 1%, while comparing to double silver low-e scheme, the energy saving rate decrease by 2%.

3. As shown in table 3, active airflow curtain use double glass skin, initial investment of active airflow curtain is the highest among those schemes, about 3870RMB/m^2. This is 1.3 times the initial investment of traditional single skin scheme.

4. The payback period of Reference building, two traditional single skin and active airflow curtain schemes are shown in table 4. Because initial investment of active airflow scheme is high and energy efficiency predominance is not prominent, payback period of this scheme is the longest among simulated schemes, about 13.4 years. Payback period of two kinds of traditional single skin schemes are about 7.9~8.1 years. The payback period of reference building scheme is the shortest about 3.9 years.

5. As shown in table 2, as far as active airflow curtain is concerned, there is 300mm spacing between two skins. This area can not be calculated in the total indoor space, so indoor usable spacing of active airflow curtain decrease about 5000 m^2. According to the selling price of Guangzhou commercial building, the double skin scheme loses about one hundred million RMB because of the reduced area. Electric blinds operation and ventilation system, control and maintain will consume extra charge.

Double silver low-e skin is the better scheme of West Tower façade design from analyses mentioned above. Firstly, this scheme satisfy the performance approach requirement in Design Standard, secondly, the payback period is relatively short, thirdly, visible transmittance of this scheme is 53% and crystal building design can be realized. Lastly, the double silver low-e scheme offers the most indoor space.

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