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Evaluation of The Energy Performance of Shading Devices based on Incremental Costs

Jian Yao, Chengwen Yan

***Abstract*—**Solar shading designs are important for reduction of building energy consumption and improvement of indoor thermal environment. This paper carried out a number of building simulations for evaluation of the energy performance of different shading devices based on incremental costs. The results show that movable shading devices lower incremental costs by up to 50% compared with fixed ones for the same building energy efficiency for residential buildings, and wing panel shadings are much more suitable in commercial buildings than baring screen ones and overhangs for commercial buildings.

***Keywords*—**Solar shading, Incremental costs, Building energy consumption.

I. Introduction

ENERGY use in buildings account for approximately 46.7% of the total energy consumption in China [1]. A number of measures are applied in buildings for diminishing energy demand [2-4]. Among them, solar shading plays a significant role in reduction of building energy consumption. In hot summer and cold winter zone, shading designs are recognized an effective measure in reducing cooling energy demand and increasing indoor thermal comfort while providing a visual contact with the outside environment. Although a lot of researchers have studied the energy performance of solar shading devices, they mainly focused on shading devices alone [5-6]. China, as a developing country, needs to adopt cost effective measures for building energy efficiency. Thus the evaluation of the costs for different design options is very important before a building was constructed. This paper gives a detailed analysis of the energy performance of different shading devices based on incremental cost through a number of building simulations.

II. Methodology

A. Building models

A typical six-floor residential building and a typical commercial building in Ningbo was considered in this study. The thermal designs for the envelope of these two buildings were set to comply with the design standards [7-8]. The window to wall area ratios for residential building was 0.35 for east, south and west windows and 0.26 for north windows, and it was 0.5 for south and north windows and 0.4 for east and west windows. Simulations were carried out with the program DOE-2. Figs. 1 and 2 show the modeled buildings for simulations.

Jian Yao is with the Faculty of Architectural, Civil Engineering and Environment, Ningbo University, Ningbo, China, e-mail: yaojian@ nbu.edu.cn.

Chengwen Yan is with the Faculty of Architectural, Civil Engineering and Environment, Ningbo University, Ningbo, China, e-mail: yanchengwen@ nbu.edu.cn.

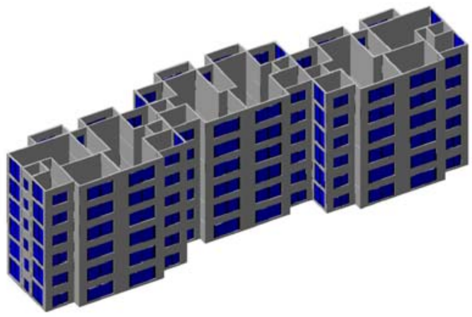

Fig. 1 The residential building

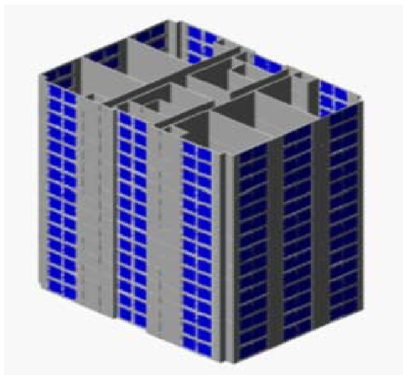

Fig. 2 The commercial building

B. Solar shading scenarios

Six solar shading scenarios were considered in this paper, in which movable shadings were switched to block the solar radiation from 8:00 to 18:00, at the beginning of June 1 to September 30. These scenarios were simulated for the whole year energy demands.

Scenario 1 : East, south and west windows were shaded by overhangs with the length of 400mm , and north windows were shaded by vertical fins with the length of 400mm;

Scenario 2 : East and west windows were shaded by overhangs and vertical fins with the length of 400mm , and south windows were shaded by overhangs with the length of

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400mm;

Scenario 3：All windows were shaded by fixed vertical wing panels with the characteristic dimension of 1;

Scenario 4：Low-e windows, SC=0.3;

Scenario 5：East, south and west windows were shaded by movable horizontal wing panels and north windows were shaded by movable vertical wing panels, and the characteristic dimension was 1 for east and west directions, 0.1 for south and west directions;

Scenario 6：All windows were shaded by baring screen shades with the characteristic dimension of 1.

To compare the incremental costs for different combinations of design options, such as adding wall insulation, selection of energy-efficient windows and adoption of shading devices, we tried several simulations for achieving the same energy efficiency through adjustments like changing the thickness of wall insulation materials. The prices for different solar shading devices, insulation materials and windows are list in tables 1 and 2.

TABLE I
PRICES FOR DIFFERENT SOLAR SHADING DEVICES

TYPE	PRICE(YUAN/ M^2)			
	MANUAL (LOW QUALITY)	MOTORIZED (LOW QUALITY)	MANUAL (HIGH QUALITY)	MOTORIZED (HIGH QUALITY)
Fabric	200～ 400	400～ 500	1200	1600
Roll-down shade screens	600～ 700	700～ 800	1000～ 1200	1400～ 1700
Shutters	600～ 800	800～ 1000	1000～ 1500	1500～ 2500
Wing panels	800～ 900	900～ 1000	1400～ 1500	1500～ 2000

TABLE II
PRICES FOR DIFFERENT INSULATING MATERIALS AND WINDOWS

MATERIALS (THICKNESS) AND WINDOWS	PRICE(YUAN/ M^2)
Expanded Polystyrene EPS (20mm)	40
Expanded Polystyrene EPS (25mm)	45
Expanded Polystyrene EPS (30mm)	50
Expanded Polystyrene EPS (35mm)	55
Expanded Polystyrene EPS (40mm)	60
plastic steel double-glazed windows	300
Heat-insulated aluminum double-glazed windows	650
Heat-insulated aluminum Low-e double-glazed windows（Sc=0.5）	800
Heat-insulated aluminum Low-e double-glazed windows（Sc=0.4）	900
Heat-insulated aluminum Low-e double-glazed windows（Sc=0.3）	1100

III. RESULTS AND DISCUSSION

Table III gives the incremental costs for different design options. It is clear fixed solar shading devices increase initial costs much more than movable ones. For residential buildings movable shading devices made of fabric materials with plastic steel double-glazed windows and EPS of 20mm thickness is more suitable and affordable in Ningbo. The incremental costs are about 656-1040 10^3 yuan, depending on the shading materials. It is almost half the costs of regular design options like fixed shading devices.

Table 4 lists the incremental costs of different design options for the commercial building. The shading devices play a much more important role than residential buildings because the wall insulation material would be unpractical thick if the same energy efficiency need to be reached and thus the costs would be greatly high such as the first design option. Apparently, the design options with scenarios of 3 and 5 are both suitable in application. Selection of appropriate shading devices is also very significant. Wing panel shadings are much more suitable in commercial buildings than baring screen ones and overhangs. Moreover, wing panels have a better mechanic performance than fabric materials and thus have a potential in high rise buildings.

TABLE III
INCREMENTAL COSTS FOR DIFFERENT COMBINATIONS OF DESIGN OPTIONS FOR THE RESIDENTIAL BUILDING

WALLS	WINDOWS		INCREMENTAL COSTS (1000 YUAN)
35mmEPS	Heat-insulated aluminum Low-e double-glazed windows（Sc=0.3）	Scenario 1	1210
40mmEPS	Heat-insulated aluminum Low-e double-glazed windows（Sc=0.4）	Scenario 2	1034
40mmEPS	Heat-insulated aluminum Low-e double-glazed windows（Sc=0.3）	Scenario 3	1224
30mmEPS	Heat-insulated aluminum Low-e double-glazed windows（Sc=0.4）	Scenario 4	1005
20mmEPS	Plastic steel double-glazed windows	Scenario 5	656~1040
30mmEPS	Plastic steel double-glazed windows	Scenario 6	600～881

TABLE IV
INCREMENTAL COSTS FOR DIFFERENT COMBINATIONS OF DESIGN OPTIONS FOR THE COMMERCIAL BUILDING

WALLS	WINDOWS		INCREMENTAL COSTS (1000 YUAN)
100mmEPS(internal)+100mm(external)	Heat-insulated aluminum Low-e double-glazed windows（Sc=0.3）	Scenario 1	4848
90mmEPS(internal)+90mm(external)	Heat-insulated aluminum Low-e double-glazed windows（Sc=0.3）	Scenario 2	4773
35mmEPS	Heat-insulated aluminum double-glazed windows	Scenario 3	3306~4283
80mmEPS(internal)+80mm(external)	Heat-insulated aluminum Low-e double-glazed windows（Sc=0.3）	Scenario 4	4697
30mmEPS	Heat-insulated aluminum double-glazed windows	Scenario 5	3268~4245
90mmEPS(internal)+90mm(external)	Heat-insulated aluminum Low-e double-glazed windows（Sc=0.3）	Scenario 6	4773

IV. CONCLUSIONS

Solar shading can help to reduce cooling energy consumption and improve indoor thermal environment. Appropriate shading design not only achieves higher energy efficiency, but also reduces incremental costs. This paper provides suggestions for solar shading designs for both residential and commercial buildings by comparison of the incremental costs. These results help architects optimize the building design with suitable solar shading devices.

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