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Design of Sunshade Board with South External Window of Residential Building in Hangzhou Based on Software Simulation Analysis of Energy Saving

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Abstract

Since the resources of the world are scarce and in high demand. Architects should try to decrease energy consumption through appropriate architectural design. Energy efficient architectural design has been a fast growing global trend. Appropriate external sunshade design can effectively decrease building energy during high consumption times, for example when using air-conditioning in the summer. By using software simulation analysis, this research quantitatively analyzes the design of horizontal sunshade board of southern external windows in Hangzhou's residential buildings. Firstly, according to weather conditions and body comfort degree, it various the setting modes and ranges of shaded area. Secondly, comprehensively considering natural lighting and solar radiation, it provides the ideal size of sunshade board. Lastly, taking the texture of the residential building and elevation design into account, it gives suggestions for incorporating sunshade integrated architectural design. Finally, this paper guarantees that the proposed size of horizontal sunshade board and integrated architectural design will decrease energy consumption.

Keywords: *External Sunshade Board, Simulation Analysis, Architectural Design, Hangzhou*

1. Background

Since the resource of the world going short and short, architects should try to reduce energy consumption of construction by appropriate architectural design. Buildings even consume more than 40% of all the energy utilized in many countries according to the statistic [1] of Luis et al. For example in France, building energy has reduced to 28% of all social cost in 1990, which was almost 42%-45% in 1984. The method was formulating energy-saving index law [2-3]. The main reason of air-condition load of buildings in the summer is that buildings accept overmuch sun radiant heat. In Ralegaonkar's research [4], described architecture should design and set suitable windows to avoid excess solar radiation based on the climate. By developing a passive solar system, Raman et al. made buildings to suit the composite climate throughout the year [5]. Fenestration products which shade wholly from the outside evenly can reduce solar radiation heat by 80% [6]. Kapur strive to design the sunshade which would be harmony or even helpful to the facade design. Therefore, he set a Solar Laboratory at Arizona State University, Arizona, USA to measure the sunshade's effect on reducing solar radiation heat [7]. Giovanni put forward index representing the relationship of solar radiation gain and thermal environment indoor [8]. Through the calculation method proposed by Keller, the relationship between solar heat gain and energy consuming can be drawn [9]. Furthermore, we should pay attention to whether sunshade structure excessively consumes energy or produces CO_2 [10].

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Considering the ordinary residential building, outside windows not only the weak part of blocking heat exchange inside and outside, but also is the core component to accept solar radiation incidence heat. It has great significance in building energy efficiency. Figure 1 describes the whole year cooling load component from energy-saving residential buildings with no external blinds cases in Guangzhou [11]. It shows that set up reasonable outside window sunshade system, plays a major role in reducing building energy consumption of air conditioning in summer. Table 1 shows the energy saving contribution percentage of movable outside sunshade in different types of building from several cities which are in the hot summer and cold winter region [12].

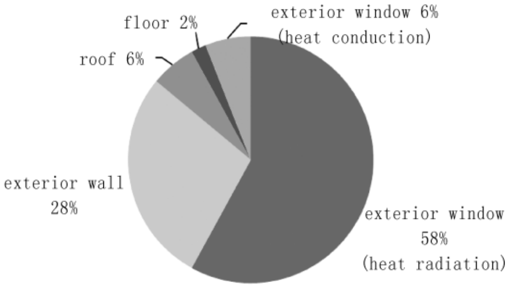

Figure 1. The Whole Year Cooling Load Component from Energy-Saving Residential Buildings

Table 1. The Energy Saving Contribution Percentage of Movable outside Sunshade in Different Types of Building from Several Cities Which Are At Hot Summer and Cold Winter Zone

City	Building Types	Total energy saving rate (%)	Movable outside sunshade contribution rate (%)
Shanghai	Villa	65.23	19.63
	Multi-storey Building	66.12	18.92
	High-rise Building	66.36	20.24
	Hotel	65.07	17.83
	Office Building	65.11	18.17
	Shopping Mall	65.49	19.56
Changsha	Villa	65.07	19.95
	Multi-storey Building	65.16	19.68
	High-rise Building	66.19	20.15
	Hotel	65.11	19.85
	Office Building	65.36	18.87
	Shopping Mall	65.10	18.62
Chongqing	Villa	65.69	21.67
	Multi-storey Building	65.36	22.68
	High-rise Building	66.18	22.15
	Hotel	65.01	19.12
	Office Building	65.05	18.56
	Shopping Mall	65.13	18.23

Hangzhou is in the hot summer and cold winter zone of China, south and nearby windows accepts more solar radiation. According to the sun running law, it is suitable for setting horizontal sunshade [13]. Horizontal sunshade setting in the south has a better effect to stop excessive sun radiate [14]. This paper comprehensively considers factors of the human body comfort, solar radiation, architectural lighting and design; by utilize the software simulation analysis. Quantitative analysis of the horizontal visor design size in the south exterior window in Hangzhou area residential buildings, and according to residential characteristics and building facade design, put forward building shading design integration suggestions.

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2. Basis of Sunshade Design

2.1. Model

This article selects a bedroom from a common residence which faces towards the south in the Hangzhou area as the basic unit model. The entire room is 3.9 m in width, 4.8 m in depth, and 2.9 m in height. The model's window is facing south, which is 1.5 m in width, 1.5 m in height; breast is 0.9 m height. Glazing Ratio is about 1/5 (0.199), glazing floor area ratio is about 1/8 (0.12). The elementary model constructed as shown in Figure 2, size as shown in Table 2, and the specific materials is in Table 3. In this study use no shade component model as the basic reference, and compare it with different shade component form, then give a conclusion of shading effect parameter.

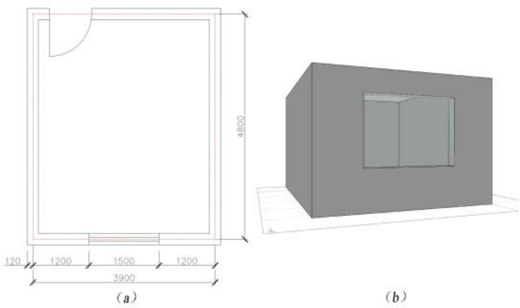

Figure 2. Model Plan and Perspective View: A) Plan, B) Perspective View

Table 2. Model Dimension

Name	Size
Room Size	3.9m (width) * 4.8m (depth) * 2.9m (height)
Window Size	1.5m (width) * 1.5m (depth), breast 0.9m
Glazing Ratio	1 / 5
Glazing Floor Area Ratio	1 / 8

Table 3. Model Enclosure Structure Material

Enclosure Structure	Material
Exterior Wall	Concrete
Interior Wall	Whitewash、Coating Material
Floor	Concrete Slab
External Windows	Ordinary Glazed Aluminum Window，Heat Transfer Coefficient 6.0，Shading Coefficient 0.8

2.2. Weather Condition of Hangzhou

2.2.1. General Condition: The centre geographic coordinates of Hangzhou is located at 120 degrees, 12 minutes east longitude and 30degrees, 16 minutes north latitude. Hangzhou's climate region of building in China is hot summer and cold winter zone. The climate is sultry, humid in summer, cold and dry in winter [15].

2.2.2. Occupant Comfort Temperature: According to the human body comfort index classification description, when DI is 76-79, it is "hot, few people uncomfortable"; 80-84 is "torrid, most people are not comfortable". Thus, this study selects DI = 75-80 for shading effect simulation interval. Based on the relationship between human comfort and

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temperature values, it can be calculated that suggested value of setting sunshade temperature in Hangzhou as shown in Table 4 [16].

Table 4. Suggested Value of Setting Sunshade Temperature in Hangzhou

Month	DI	
	DI=75	DI=80
May	25.4	28.7
June	25	28.1
July	25	28.1
August	25.1	28.2
September	25.3	28.5

2.2.3. Sunshade Hours: According to the typical meteorological year data, get south window sunshade timetable as shown in Table 5.

Table 5. South Window Shade Timetable in Hangzhou

Date	Sunshade Time	
	DI=75	DI=80
06.01 - 06.15	10:00 – 18:00	12:00 - 17:00
06.16 - 06.30	6:00 – 18:00	15:00 - 16:00
07.01 - 07.15	7:00 – 18:00	9:00 – 18:00
07.16 - 07.31	7:00 – 18:00	9:00 – 18:00
08.01 - 08.15	6:00 – 18:00	7:00 – 18:00
08.16 - 08.31	7:00 – 18:00	9:00 – 18:00
09.01 - 09.15	10:00 – 18:00	14:00 – 17:00
09.16 - 09.30	13:00 – 14:00	

3. Size of Sunshade Board

This paper taking into account shading integration design for Hangzhou residence, provisions the distance from under the surface of the visor to the external window edge is 200mm that is 1700mm from the windowsill. Furthermore, it abstract shades structures as level fixed visor, setting shading model schematic as shown in Figure 3. Height from sunshade component parts to window is constant, and width of the structure and length of the east and west wings is variable.

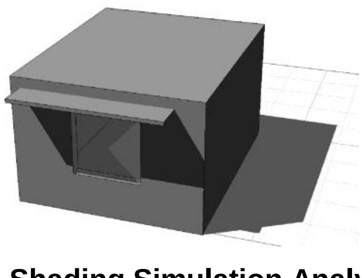

Figure 3. Shading Simulation Analysis Model

This paper is based on the simulation software to weigh shading structure size. Simulation object is 3900mm (width) * 4800mm (depth) * 2900mm (height) abstract model of residential room. Southing exterior window is the only component for lighting. Simulation software utilizes Autodesk Company Ecotect Analysis 2011. It is for indoor shadow, natural lighting, solar radiation simulation calculation and analysis.

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3.1. Size Setting

To meet the sunshade period requirements, by the shadow simulation analysis (structure size use 10 mm as stride), in ensuring that the interior with no direct sun during the required shading period, the horizontal sun visor size are respectively met DI=75 and DI=80 under critical conditions (Table 6).

Table 6. The Horizontal Sun Visor Size under Critical Conditions (mm)

DI=75	3300(length)*730(width)	（exterior 730,west wing 1100, east wing 700）
DI=80	3300(length)*480(width)	（exterior 480,west wing 1100, east wing 700）

3.2. Simulation of Natural Lighting and Solar Radiation

In this paper, it simulates and calculates a series of two indexes (the whole year indoor daylight coefficient and cumulative incident radiation outside the window from May to September). With no shading income data for reference, successively simulate the horizontal visor size when it meets DI = 75-80, the main results as shown in Figs 4-9 and Table 7.

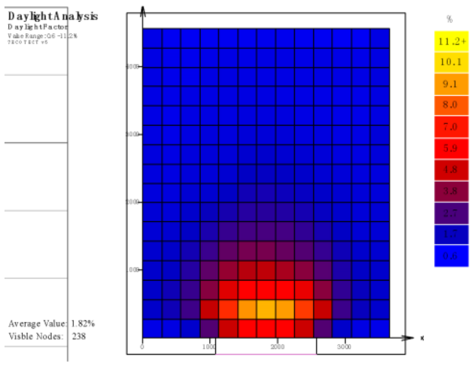

Figure 4. Daylight Analysis (No Shading) - Average Value of Daylight Factor 1.82%

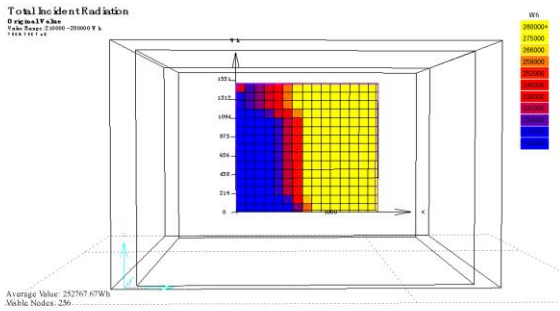

Figure 5. Total Incident Radiation Simulation (No Shading) – Average Value 252767.67Wh

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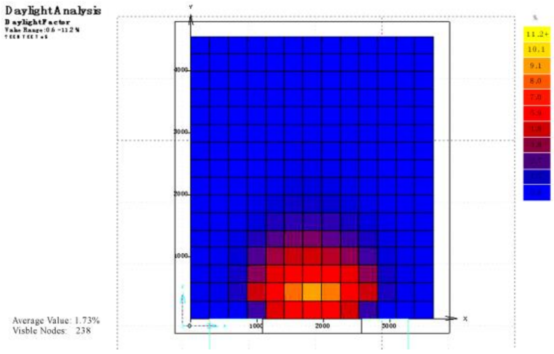

Figure 6. Daylight Analysis (Visor Size 3300*480mm) – Average Value Of daylight factor 1.73%

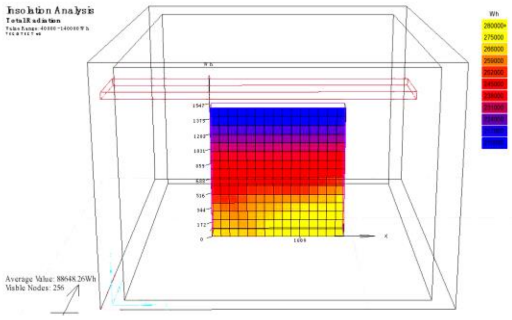

Figure 7. Total Incident Radiation Simulation (Visor Size 3300*480mm) - Average Value 88648.26Wh

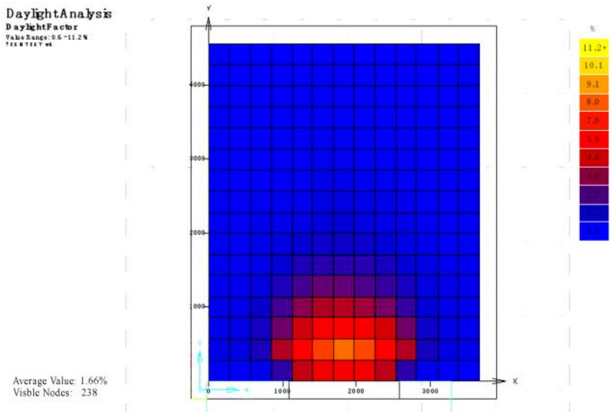

Figure 8. Daylight Analysis (visor size 3300*730mm) – Average Value of Daylight Factor 1.66%

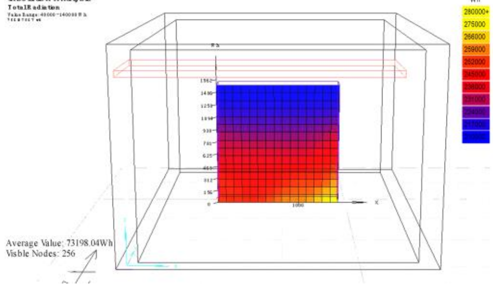

Figure 9. Total Incident Radiation Simulation (visor size 3300*730mm) - Average Value 73198.04Wh

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Sorting the simulation data, and compare with no shading benchmark data, get Table 7 the relationship between main horizontal visor size with daylight factor and incident radiation value.

Table 7. The Relationship between Main Horizontal Visor Size with Daylight Factor and Incident Radiation Value

Visor Size(mm)			Daylight Factor		Incident Radiation Value	
Exterior	Wings Extended Size		Daylight Factor (%)	With No Sunshade Ratio	Incident Radiation Value (Wh)	With No Sunshade Ratio
	East	West				
0	0	0	1.82	100%	252767.67	100%
480	700	1100	1.73	95.1%	88648.26	35.1%
500	700	1100	1.73	95.1%	86587.81	34.3%
530	700	1100	1.72	94.5%	84233.05	33.3%
550	700	1100	1.71	94.0%	82665.47	32.7%
600	700	1100	1.70	93.4%	79659.45	31.5%
620	700	1100	1.70	93.4%	78431.63	31.0%
650	700	1100	1.69	92.9%	76612.55	30.3%
680	700	1100	1.68	92.3%	75182.90	29.7%
700	700	1100	1.67	91.8%	74408.66	29.4%
730	700	1100	1.66	91.2%	73198.04	29.0%

3.3. Analysis of the Size of Sunshade Board

Figure 10 and Figure 11 are based on data collected from Table 7. There is daylight factor value line chart and incident radiation ratio line chart as shown in.

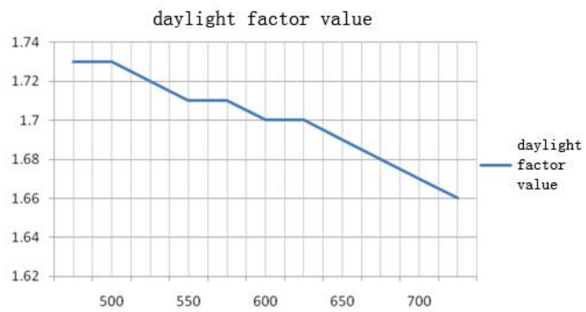

Figure 10. Daylight Factor Value Line Chart

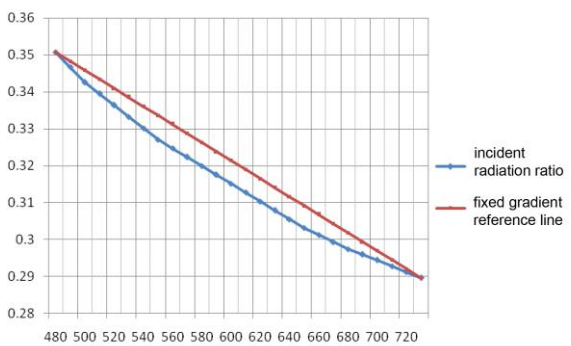

Figure 11. Incident Radiation Ratio Line Chart

From daylight factor value line in figure 10, it can be found that when the horizontal visor extends more than 620-630mm, the daylight factor sharply reduced.

In figure 11, it shows an incident radiation ratio line and a fixed gradient reference line. Compare these two lines, it can be found that the gradient changed obviously when the horizontal visor extends 550mm, 650mm, and 680mm, respectively. The incident radiation decrease trend declines in turn.

According to the above analysis, it is suggested that setting horizontal visor size is 3300 * 620mm or 3300 * 630mm. Visor length is 3300mm. The east wing extends 700mm. Meanwhile, the west wing extends 1100mm. Visor outside width is 620mm or 630mm. The distance from under the surface of the visor to the exterior window upper edge is 200mm.

4. Discussion

4.1. The applicability of this study

This research based on the model of common residential rooms, by means of simple calculation and software simulation, put forward the appropriate size of sunshade board. This study has certain limitations and applicability, basically has the following three aspects: (1) With conventional housing size and material as the research model, the result is applicable, can be used as important design reference, but cannot apply to all buildings, such as the use of French window design or shading by window’s own properties; (2) The human body comfort index does not necessarily fit all physiological feelings; (3) In this paper, considering the visor individually set as a means of shading design. The shading shape design does not count into consideration. The results of this study have a certain meaning and reference value on the residential building similar to the model conditions.

4.2. Integrated Architectural Design with External Sunshade Board

Hangzhou area residential building shading integration design is the mainly target supported by air conditioning cantilever plate and shading component integration. At the same time, the following factors are taking into account. First of all, Table 8 shows conventional air conditioning board size, considering the minimum size for horizontal visor reserve air conditioning placed size is 1050mm (width) * 500mm (depth) * 700mm (height). Secondly, based on the waterproof construction requirements, visor above the wall should get 150-200mm flashing. Thirdly, thickness of horizontal fixed visor structure size is 60-80mm. Therefore, in simulations concluded visor suggests sizing (extend width 620-630mm, the distance from the visor lower surface to the exterior window edge is 200mm) is suitable.

Table 8. Air Conditioning Board Size

Type	Power	Outdoor Unit Size（mm）（width*depth*height）	Air conditioning plate minimum net size（mm）（width*depth*height）	Applying Space（㎡）
Hanging	1P	720*300*550	1050*500*700	14
	1.5P	820*300*650	1100*500*800	14-23
	2P	850*350*750	1100*550*900	24-32
Floor	2P	900*350*750	1200*600*1000	24-32
	3P	950*350*850	1200*600*1100	33-45

Visor size analysis that suggestion visor size is 3300mm long, the east wing extends 700mm, and the west wing extends 1100mm. It can place 2-3 air conditioner external units, so that it could adjust the appropriate position basis of the air conditioner external

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unit size. This integration design not only reached the shading effect, but also avoid the situation that air conditioner external unit place untidy, beautify the appearance of the building.

5. Conclusions

China's building energy consumption is very striking: the process of building alone uses 30% of the total energy consumption of the whole society. Another 20% of national consumption is expended in the production materials themselves. Construction in China requires high energy consumption, and yields low energy efficiency. Energy consumption per unit constructed is 2-3 times higher than the same unit in similar climate countries. In the near future, construction will become China's largest energy consumer. Building energy conservation has become the primary focus of energy conservation in the whole society. Alongside accelerated construction of China’s residential buildings such as residential, apartments. We must vigorously promote energy conservation through smart innovative architecture and design.

Architects have the opportunity, and we would agree, the responsibility, to incorporate energy-saving designs in their practice. Architectural shading is an important method of achieving energy-savings through integrated design. This article has focused on building energy efficiency designs, reported computer model simulations and detailed analysis of such simulations with respect to the sunshade board with south external windows in Hangzhou’s residential buildings. Our model used software to simulate and analyse the effects of the design, comprehensively considering human body comfort, solar radiation, and architectural lighting, while quantitatively analysing factors such as the external window horizontal visor design size. Through layers of data reasoning, testing, and analysis, this study model found the ideal horizontal visor size to be 3300 * 620 mm or 3300 * 630 mm: in this model visor length is 3300 mm, the east wing extends 700 mm, and the west wing extends 1100mm. The visor overhanging width is 620 mm or 630 mm with 200 mm visor surface extending from edge of outside the window visor. Furthermore, this ideal visor setting combined with the architecture sunshade integration design, and based on the residential characteristics and building facade design, together put forward building shading design integration suggestions. Additionally, using the building visor model combined with the design of the air conditioning cantilever plate component yielded a superior result.

In short, building energy efficiency design is a combination of technology and art. Hopefully this paper can be used as a reference for architects in energy efficiency design, and facilitate sustainable development in the current climate of a global resources shortage.

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