Title: **The Passive Design of High-Rise Envelope**

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Subjects: Building Case Study
Façade Design

Keywords: Façade
Passive Design

Publication Date: 2014

Original Publication: CTBUH 2014 Shanghai Conference Proceedings

Paper Type:
1. Book chapter/Part chapter
2. Journal paper
3. **Conference proceeding**
4. Unpublished conference paper
5. Magazine article
6. Unpublished

The Passive Design of High-Rise Envelope
高层建筑围护结构的被动式设计

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Abstract

From the perspective of the application of the high-rise envelope technology, this paper attempts to quantify the effectiveness of passive measures, and provide the adequate basis for architects' decision. A project in Wuhan is analyzed in this paper, and details are as follows:

1. Transparent curtain wall analysis
2. Opaque curtain wall analysis
3. Feasibility of various shading types
4. Building self-shading analysis
5. Feasibility of all kinds of skylight

This paper makes a passive design and analysis for the space form, material and construction of the high-rise envelope, and facilitates the architect's decision.

Keywords: Passive Envelope; Shading; Building Self-Shading; Skylight

摘要

从围护结构被动式技术的应用角度出发，本文尝试将围护结构被动措施的有效性量化，使之能为建筑师的决策提供充分的依据。本文以中国武汉的一个项目为例进行分析，主要内容如下:

1. 透明幕墙分析
2. 非透明幕墙分析
3. 不同遮阳类型的适用性
4. 建筑自遮阳的分析
5. 不同形式采光顶的适用性。

本文通过具体项目对围护结构的形式、材质与构造的被动式设计与分析，为建筑师的决策提供了便利。

关键词: 被动式围护结构; 遮阳; 建筑自遮阳; 采光顶

Project Introduction

The name of the captioned project is Wuhan Aqua City which is located in Jianghan District. Wuhan lies in the middle and lower reaches of Yangtze River, with a coordinates range of 113°41'~115°05' Longitude and 29°58'~31°22' Latitude. It belongs to a hot summer and cold winter zone according to the standard of climatic regionalization for architecture. The south elevation of the building faces 38 degrees east of south.

The project consists of commercial, offices and apartments with a gross floor area of 213,934 m^2. The podium is for commercial use consisting of 11 stories with a roof elevation at 57 m. The office tower lies south of the site and is 54 stories high with a roof elevation at 242.2 m. The apartments are on the northern part of the site with 31 floors and a roof elevation at 122.0 m. The total curtain wall area is about 95,000 m^2. Figure 1 is the architectural rendering drawing of the project.

工程概况

本项目名称为武汉水游城，位于武汉市江汉区。武汉地处长江中下游，东经113°41′～115°05′，北纬29°58′～31°22′。根据中国气候分区武汉属于夏热冬冷区(IIIB)。夏季闷热，冬季阴冷，为中国三大火炉之一。建筑南立面朝向为南偏东38°。

本项目由商业、办公和公寓组成。地上总建筑面积达213934平方米。裙房为商业，共11层，屋顶标高为57.0米。办公位于基地南面，共计54层，大屋面结构标高242.4米。公寓位于基地北侧，总层数为31层，屋面标高为122.0米。本项目幕墙面积约95000m^2。图1为本工程效果图。

不同窗墙比的围护结构传热分布

由图2可知，对于20%窗墙比的建筑，夏季能耗中，直接阳光辐射得热与热传导产生

Figure 1. Rendering Drawing of Wuhan Aqua City (Source: Mixstudio)
图1 武汉水游城效果图 (来自:Mixstudio)

Heat Transfer Distribution of Building Envelope of Different Ratio of Window-Wall

Figure 2 shows that in terms of summer energy consumption, for buildings with window-wall ratio(WWR) of 20%, solar heat gain is close to that produced by thermal conduction, while indirect solar gain is about 3% of the total of the aforesaid two. As for winter energy consumption, thermal conduction is one of the major factors while direct and indirect solar heat gain are also favorable contributors, each is about 11% and 0.6% of energy consumption of thermal conduction respectively.

For buildings with WWR of 57%, direct solar heat gain is the major factor in summer energy consumption. Energy consumption of thermal conduction is about 51 % of direct solar heat gain while indirect solar heat gain is around 0.7% of the sum of aforesaid two factors. As for winter energy consumption, thermal conduction is the major factor while direct solar heat gain and indirect solar heat gain are favorable factors, each at 20% and 0.2% of thermal conduction.

If the project adopts a lower WWR, attention should be paid to thermal conduction and shading of the wall during summer, with measures attempting to reduce solar heat gain of the opaque wall. During winter, the issue of thermal conduction of the wall should be adequately addressed. For buildings with a higher WWR, shading of transparent area is the focus during summer. In winter, thermal conduction still plays a major role and direct solar heat gain is also a positive factor. If the transparent area can both reduce solar heat gain in summer and increase solar heat gain in winter, it will significantly contribute to energy saving.

Material Selection for Transparent Area

Glass

According to the previous analysis, regardless of whatever value of WWR in this project, shading of transparent area is the main issue in this case. Besides, attention should be paid to thermal conduction of transparent area in winter particularly.

Among the six kinds of glass shown in Figure 3, High transparency Low-E glass, Sun Low-E glass and Double silver low-E glass are frequently used. Insulating glass with double air layer and double glass with shading blinds in the air layer are less used because of their relatively higher cost. The rare usage of ordinary double glass is due to its incapability to meet the required thermal parameters.

的能耗接近，而间接阳光辐射得热约为前二者之和的3%; 冬季能耗中，热传导是能耗的主要因素，直接和间接阳光辐射得热均为有利因素，其中直接阳光辐射只有热传导的11%，间接阳光辐射只有热传导的0.6%。

对于57%窗墙比的建筑，夏季能耗中，直接阳光辐射得热为主导因素，热传导的能耗约为直接阳光辐射得热的51%，而间接阳光辐射得热约为前二者之和的0.7%; 冬季能耗中，热传导是能耗的主要因素，直接和间接阳光辐射得热均为有利因素，其中直接阳光辐射约为热传导的20%，间接阳光辐射只有热传导的0.2%。

		U value(W/m2.K) U值	SHGC 得热系数
Ordinary Double Glass 普通双层玻璃		2.7	0.75
High Tranparency Low-E glass 高透明度Low—E玻璃		1.7	0.55
Sun Low-E glass 太阳Low—E玻璃		1.6	0.22
Double Silver Low-E Glass 双层镀银Low—E玻璃		1.6	0.33
Insulating Glass with Double Air Layer 中空玻璃加双空气层		0.9	0.24
Double Glass with Shading Blinds in the Air Layer 双层玻璃加空气层遮阳板	Blinds Closed 遮阳板关闭	2.0	0.16
	Blinds Opened 遮阳板打开	2.7	0.51
	Blinds Packed Up 收起	2.9	0.55

Table 1. Parameters of glass
表1 玻璃参数

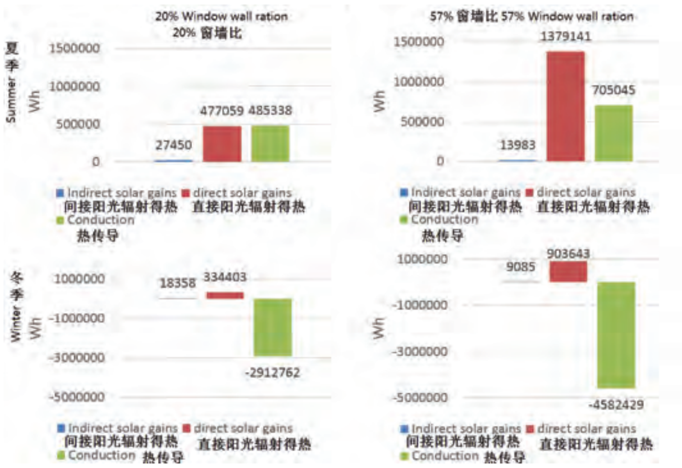

Figure 2. Heat transfer distribution of building envelope of different ratio of window-wall (Source: Jie Zhang)
图2 不同窗墙比的围护结构传热分布情况 (来自: 张杰)

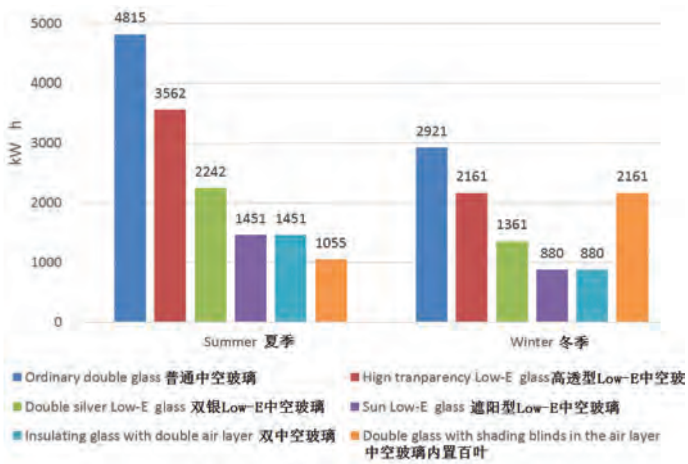

Figure 3. Direct solar gain of different kinds of glass (Source: Jie Zhang)
图3不同类型玻璃的直接阳光辐射得热 (来自: 张杰)

Figure 3 shows that double glass with shading blinds in the air layer delivers the best sun shading effect, followed by sun Low-E glass and Insulating glass with double air layer. For buildings with a higher WWR in Wuhan region, the main issue in summer lies in sun-shading rather than U value of building envelope. Therefore, the aforesaid three types of glass with lower shading coefficient achieve the best performance in summer.

In winter, ordinary double glass permits the highest level of sunlight, with high transparency Low-E glass and double glass with shading blinds in the next places. However, it should be clear that thermal conduction is the main issue of Wuhan in winter while solar heat gain is a secondary issue. In terms of energy saving in winter, insulating glass with double air layer is most effective followed by high transparency Low-E glass and double silver Low-E glass.

As illustrated by Figure 4, the ranking of annual energy consumption of different kinds of glass is as follows: insulating glass with double air layer < sun Low-E glass < double Silver Low-E glass < double glass with shading blinds in the air layer < high transparency Low-E glass < ordinary double glass. Energy consumption of insulating glass with double air layer is 3.5% less than that of Sun Low-E glass, nonetheless the price is almost 4 times higher.

Contribution of Curtain

As reflected from the previous discussion, sun Low-E glass is most favorable for energy conservation, albeit it blocks the sunlight not only in summer but also in winter. If we adopt high transparency Low-E glass with curtain, it can block sunlight from entering interior space in summer while transmit more sunlight in winter. Figure 5 illustrates the comparison between the two kinds of glasses, demonstrating that adoption of curtain reduces direct solar gain in summer. Figure 5 nonetheless shows that the cumulative energy consumption in summer and winter of high transparency Low-E glass with curtain is still higher than that of solar Low-E glass.

Applicability of Opaque Curtain Wall Material and its Construction Analysis

Impact of Air Layer and Aluminum Foil

Indicated by Figure 6, when compared with the system "Aluminum + 50mm Insulation + 200mm Brick", the indirect solar gain of system "Aluminum + 60mm Air layer + 50mm Insulation + 200mm Brick" is 13.7% lower whereas system "Aluminum + 60mm Air layer + aluminum foil + 50mm Insulation + 200mm Brick" is 30.1% lower.

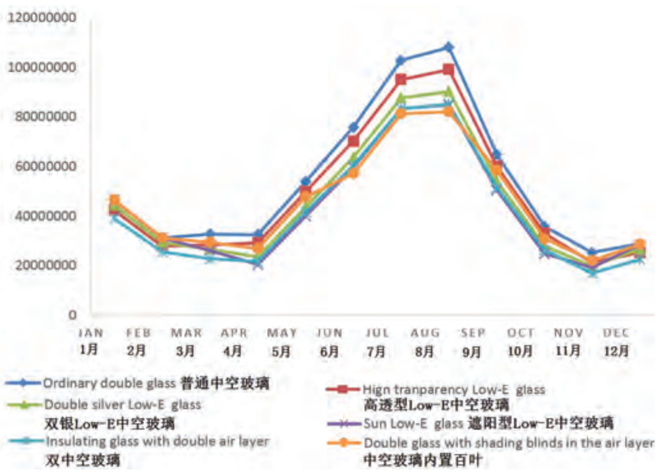

Figure 4. Comparison of Monthly energy consumption of different kinds of glass (Source: Jie Zhang)
图4 不同类型玻璃类型的逐月能耗比较 (来自: 张杰)

本项目若采用较低的窗墙比，夏季应同时重视墙体的传热和遮阳问题，设法降低非透明墙体的辐射得热也有一定的意义; 冬季应重点关注墙体传热的问题。对于窗墙比比较高的建筑，夏季透明区域的防晒成为重点; 冬季热传导依然是主要因素，而直接阳光辐射也成为明显的有利因素，透明区域若能同时降低夏季的阳光辐射和提高冬季的阳光辐射，对于节能将非常得有利。

透明区域主材的选择

玻璃

从前面的分析可知，本项目中，无论窗墙比高或低，透明区域夏季的防晒均是分析的重点; 另外冬季透明区域的热传导，也需重点关注。

图3的六种玻璃中，高透型Low-E，遮阳型Low-E以及双银Low-E为较常使用的玻璃。双中空玻璃和百叶中空玻璃价格较高，较少使用。而普通中空玻璃，由于较难满足热工参数也很少使用。

从图3可知，夏季中空百叶玻璃遮挡阳光效果最好，其次为遮阳型Low-E玻璃与双中空玻璃。对于武汉地区窗墙比较高的建筑，夏季最主要的问题是遮阳，而非围护结构的U值，因此这三种遮阳系数较低的玻璃夏季效果最好。

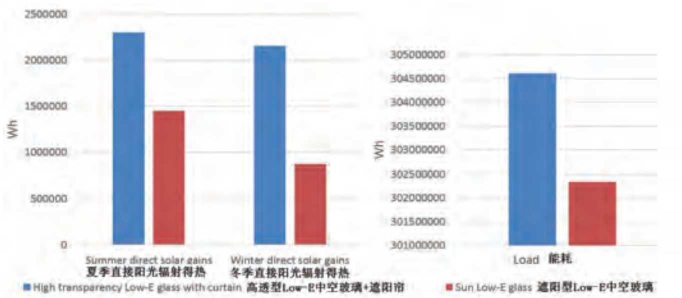

Figure 5. Comparison between High transparency Low-E glass with curtain and Sun Low-E glass (Source: Jie Zhang)
图5 高透型Low-E玻璃加遮阳帘与遮阳型玻璃的比较 (来自: 张杰)

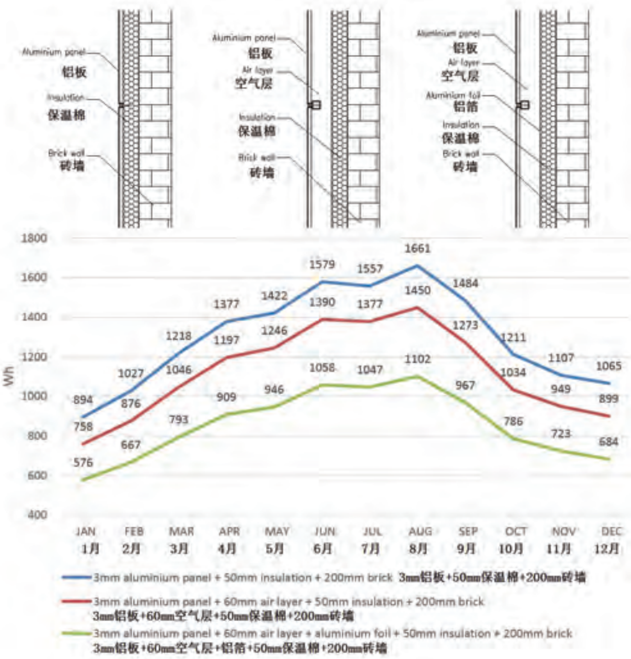

Figure 6. Impact of air layer and aluminum foil on indirect solar gain in opaque wall system (Source: Jie Zhang)
图6 非透明区域空气层与铝箔对间接阳光辐射的影响 (来自: 张杰)

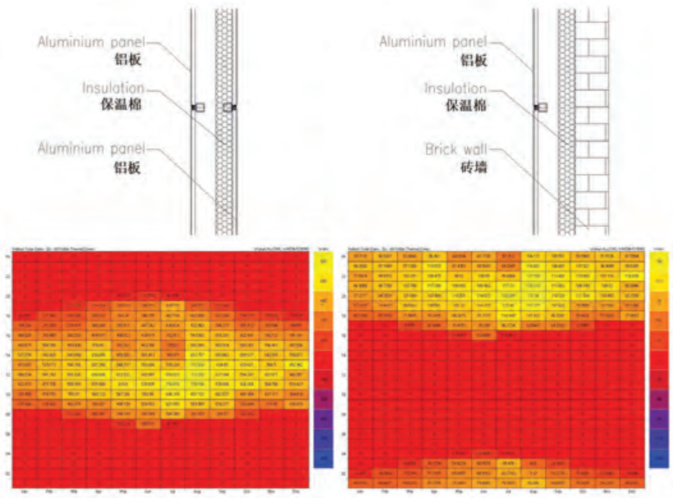

Figure 7. Impact of brick wall on indirect solar gain in opaque wall system (Source: Jie Zhang)
图7 非透明区域砖墙对间接阳光辐射得热的影响 (来自: 张杰)

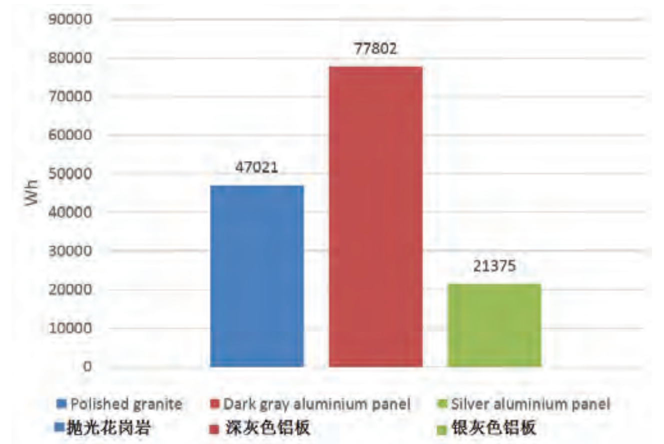

Figure 8. Impact of Surface materials and Surface treatment on indirect solar gain (Source : Jie Zhang)
图8 表面材料与表面处理对间接阳光辐射的影响 (来自: 张杰)

Impact of Brick Wall

In Figure 7, the lower left is the analysis of indirect solar gain of a wall without a brick wall on the inside while the lower right is the analysis of indirect solar gain of a wall with inner brick layer. Y axis represents 24 hours and X axis represents 12 months. Compared with the one without a brick wall, the one with a brick wall postpones the indirect solar gain up to 7 hours. In other words, indirect solar gain of a wall system without a brick wall on the inside mainly takes place during daytime, whereas for a wall system with an inner brick wall usually takes place at night. For offices operated during the daytime, a wall system with an inner brick wall helps to reduce energy consumption. Moreover, the indirect solar heat transmitted through a brick wall to interior space is only 17% of that aluminum panel, which means a brick wall not only has a delayed effect of heat transfer but also substantial depreciation of radiation.

Different Surface Materials and Surface Treatment

Absorption coefficient of different materials varies greatly: 0.25 for silver aluminum panel, 0.91 for dark grey aluminum panel and 0.55 for polished granite. Applied to the same wall system, indirect solar gain of the dark grey aluminum panel can reach 3.64 times as much as that of the silver aluminum panel. Therefore, for buildings with lower WWR, selection of surface material with lower absorption coefficient is beneficial to energy efficiency in Wuhan region.

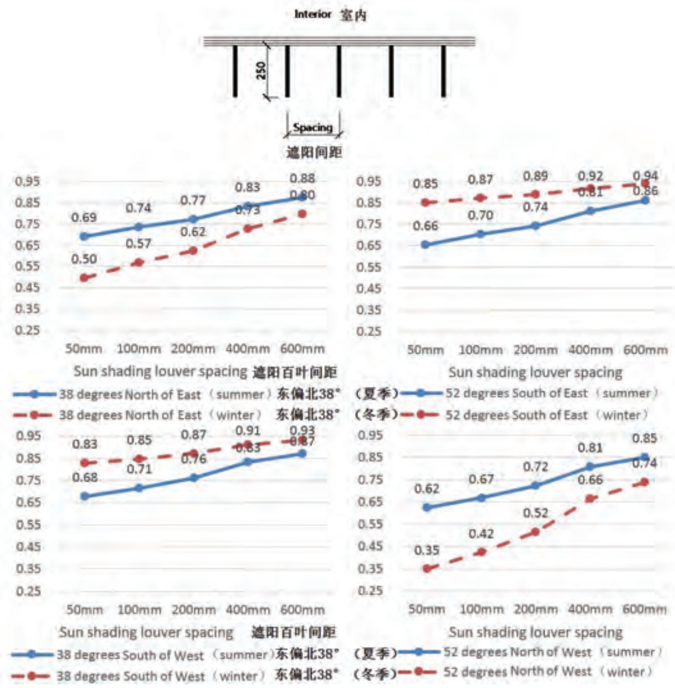

Figure 9. External shading coefficient of vertical louver system on façades (Source: Jie Zhang)
图9 各立面采用垂直遮阳的外遮阳系数 (来自: 张杰)

冬季普通中空玻璃可以接收最多的阳光，其次为高透型Low-E玻璃和中空百叶玻璃。但是由于武汉地区冬季最主要的问题是热传导，其次才是阳光辐射得热，因此从冬季的能耗看，双中空效果最好，其次为高透型Low-E中空玻璃和双银Low-E中空玻璃。

由图4可知，使用不同玻璃类型，全年能耗的排序为: 双中空玻璃<遮阳型Low-E中空玻璃<双银Low-E中空玻璃<中空百叶玻璃<高透型Low-E中空玻璃<普通中空玻璃。双中空玻璃比遮阳型Low-E中空玻璃能耗低约3.5%，但价格几乎高了4倍。

遮阳帘的贡献

从前面的内容可知，遮阳型的玻璃节能效果较好。但是遮阳型的玻璃不仅仅在夏季遮挡了阳光，冬季同样也会遮挡阳光。那么如果采用高透型Low-E中空玻璃加遮阳帘，夏季可以阻挡阳光进入室内，而冬季可以让更多的阳光进入室内。图5反映了二者比较的情况，采用高反射的遮阳帘降低了夏季的直接阳光辐射得热，但图5中的能耗分析，也表明高透型Low-E玻璃加遮阳帘的冬季与夏季的累计能耗依然高于遮阳型Low-E玻璃。

非透明墙体的材料及构造层的适用性

空气层与铝箔的影响

由图6可知，相对于"3mm铝板+50mm保温棉+200mm砖墙"，"3mm铝板+60mm空气层+50mm保温棉+200mm砖墙"的间接阳光辐射得热降低约13.7%，而"3mm铝板+60mm空气层+铝箔+50mm保温棉+200mm砖墙"的间接阳光辐射得热降低约30.1%。

砖墙的影响

图7左下方为室内侧无砖墙的间接阳光辐射分析，右下方为有砖墙的分析。纵坐标代表一天的24小时，横坐标为12个月。相对于"铝板+空气层+保温棉+铝板"，"铝板+空气层+保温棉+砖墙"的间接阳光辐射得热延迟约7小时。即对于室内侧无砖墙的情况，间接阳光辐射得热主要在白天; 而对于室内侧有砖墙的情况，间接阳光辐射得热主要在傍晚及夜间，对于白天耗能的办公建筑，减小了能耗。另外通过砖墙释放到室内侧的间接阳光辐射得热只有铝板的17%，这意味着砖墙不仅仅有延迟效应，而且有很大幅度的衰减。

Applicability of Shading

External Shading Coefficient of Vertical Louver

Figure 9 hypothesize that fix vertical louvers are installed on the external side of transparent area with blinds width of 250mm. Blinds of louvers are placed perpendicular to the glass surface. According to the analysis, façades facing 52 degrees south of east and 38 degrees south of west achieve better shading effect when vertical louvers are installed, with higher shading coefficient (0.83-0.94) in winter and a lower shading coefficient (0.66-0.86) in summer. Application of vertical louvers on façades facing 38 degrees north of east and 52 degrees north of west have poor effect since the louvers significantly blocks the sunlight from entering the interior space in winter, especially 52 degrees north of west whose winter shading coefficient appears to drop considerably.

External Shading Coefficient of Horizontal Shading

Figure 10 assumes that horizontal louver system is installed at the top of transparent area with various cantilever dimensions. In analysis, façades facing 52 degrees south of east and 38 degrees south of west has better shading effect as winter external shading coefficient are always higher than that of summer. In the case of façades facing 38 degrees north of east and 52 degrees north of west, winter external shading coefficient are consistently lower than that of summer. However, the solar radiation from the northeast and northwest elevation in winter is much lower than that in summer and there is minor loss of heat gain in winter. Application of vertical louver system in these two directions is still beneficial for energy saving.

Illustrated by Figure 10, both vertical and horizontal louver system are more feasible for façades facing 52 degrees south of east and 38 degrees south of west in this project while vertical louver system is the most effective with low external shading coefficient in summer. For façades facing 38 degrees north of east and 52 degrees north of west, application of horizontal louver is acceptable whereas vertical louver is inapplicable, particularly worst to the façade facing 52 degrees north of west.

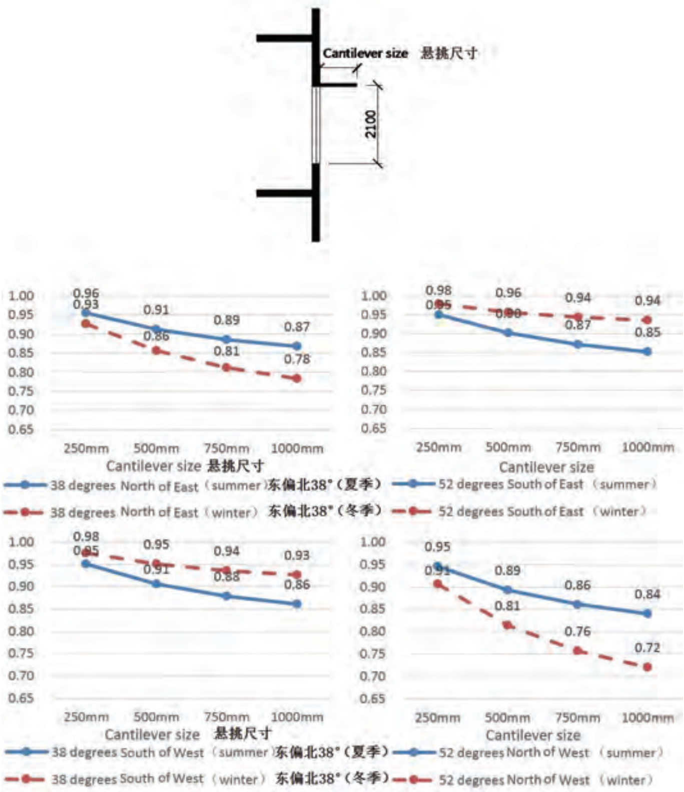

Figure 10. External Shading Coefficient of Horizontal Shading on Façades (Source: Jie Zhang)
图10 各立面采用水平遮阳板的外遮阳系数 (来自: 张杰)

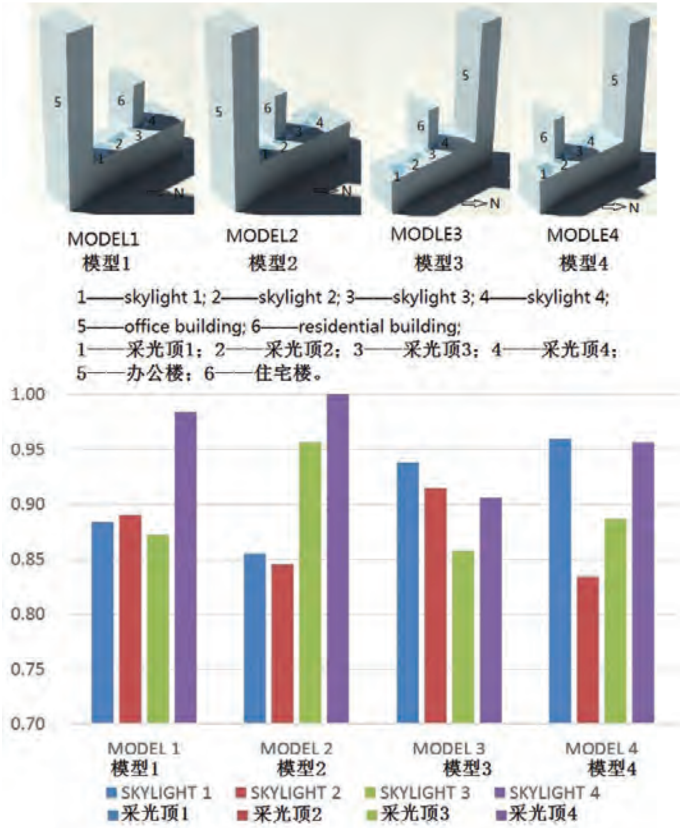

Figure 11. Impact of different Architectural Arrangement on Summer External Shading Coefficient of Skylight (Source: Jie Zhang)
图11不同的体块布置对采光顶夏季外遮阳系数的影响 (来自: 张杰)

不同表面材质或表面处理

由图8可知，不同材料的表面吸收系数差别很大，银色漆铝板表面为0.25，深灰色漆铝板表面为0.91，抛光花岗岩表面为0.55。对于同样的构造，深灰色铝板的间接阳光辐射得热可达为银色铝板的3.64倍。因此对于窗墙比较小的建筑，在武汉地区选择吸收系数较小的表面材料对于节约能源是有益的

遮阳的适用性

垂直遮阳百叶外遮阳系数

图9假定在透明区域采用固定垂直遮阳百叶，遮阳宽度为250mm，百叶方向垂直于玻璃面。由分析可知，东偏南52度立面和西偏南38度立面采用垂直遮阳效果较好，冬季外遮阳系数较高 (0.83-0.94)，夏季外遮阳系数较低 (0.66~0.86)；东偏北38度与西偏北52度立面采用垂直遮阳的效果均较差，这两个方向的垂直遮阳在冬季均较严重的阻挡了阳光进入室内，特别是西偏北52度立面，冬季外遮阳系数下降较多。

水平遮阳的外遮阳系数

图10假定在透明区域顶部采用水平外挑遮阳板，遮阳悬挑尺寸为变化值。由分析可知，东偏南52度立面与西偏南38度立面采用水平遮阳效果较好，冬季外遮阳系数均高于夏季；东偏北38度与西偏北52度立面，冬季的外遮阳系数均低于夏季，但是东北与西北方向冬季阳光辐射远弱于夏季，冬季得热损失较小，这两个方向采用水平遮阳板仍然有益于节能。

由图10可知，对于本项目东偏南52度立面与西偏南38度立面，垂直遮阳和水平遮阳板适用性均较强，其中垂直遮阳夏季外遮阳系数很低，效果最好。对于东偏北38度和西偏北52度立面水平遮阳板的效果可以接受，但是垂直遮阳不适用，特别是西偏北52度立面采用垂直遮阳效果最差。

Architectural Self-Shading Analysis

Illustrated by Figure 11, in model 2, skylight 1 has the lowest shading coefficient as the residential building partially block the light from the west. Likewise, skylight 2 has the lowest shading coefficient in model 2 and model 4 as the residential building block most of the light from the west. The lowest shading coefficient for skylight 3 takes place in model 1 and model 3. Skylight 4 has the lowest shading coefficient in model 3, as the residential building partially blocks the light from the west for skylight 4. Overall, on the term of area weighted average shading coefficient of the four skylights, the lowest is 0.89 in model 1, while the highest is 0.92 in model 4.

Applicability of Different Types of Skylight

The upper left graphic in Figure 12 shows the cumulative direct solar radiation of skylight 1 in summer. The other pictures show three options for skylight. Option 1 adopts shading panels with fixed spacing perpendicular to skylight. The height of louver changes according to the variation of solar radiation. Through analysis, option 1 reduces 20% direct solar radiation compared with louver installed at a fixed height. Option 2 arranges aluminum panel and glass panel as the lower left picture in Figure 12. The area of aluminum panel and glass varies according to the change of direct solar radiation. Option 2 reduces 18% of direct solar radiation compared to evenly distributed composition of aluminum panel and glass blinds. Option 3 adopts louvers with uniformly spaced, but use different angles in different position. Option 2 3 reduces 27% of direct solar radiation compared to louver all installed vertical to the skylight.

Conclusion

From the perspective of the application of the high-rise envelope technology, this article, through the analysis of Wuhan Aqua project based on the characteristics of local climate and the building shape, examines the feasibility of self-shading, transparent and opaque materials and models of skylight, and arrives at the following conclusions:

- Window-wall ratio determines the heat transfer ratio of different forms of heat transfer of envelope structure. For buildings with higher ratio, summer direct solar gain and winter heat conduction are the major contributors. As with buildings with lower ratio, summer direct solar gain is equally important as thermal conduction, while indirect solar gain shall not be ignored. Winter conduction is the major factor of energy consumption.
- Through comparison of different types of glasses, Sun Low-E insulated glass achieves the best performance for sun shading. In terms of year-round energy consumption, Sun Low-E insulated glass is second only to insulated glass with double air layer, while the latter is far more expensive than the former. In terms of energy consumption, Sun Low-E insulated glass is moderately low compared to others. Therefore, Sun Low-E insulated glass is the most appropriate material for the transparent area of the project.

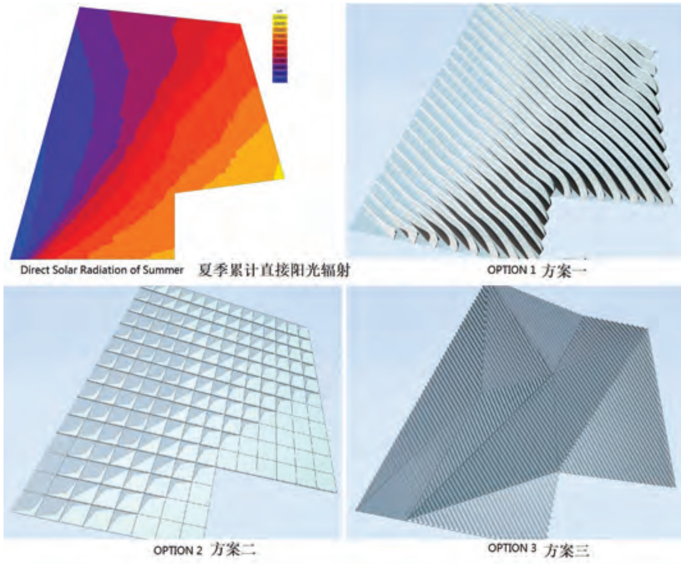

Figure 12. Options for Skylight 1(Source: Song Mo)
图12 采光顶1的方案 (来自: 莫松)

建筑自遮阳分析

由图11可知，对于采光顶1，遮阳系数最低的是模型2，这是由于模型2的公寓楼遮挡了采光顶1部分西侧的阳光; 对于采光顶2，遮阳系数最低的是模型2与模型4，这是同样由于公寓楼遮挡了采光顶2大部分西侧的阳光; 对于采光顶3，遮阳系数最低的是模型1与模型3; 对于采光顶4，遮阳系数最低的是模型3，这是由于住宅楼遮挡了采光顶4部分西侧的阳光。综合来看，四个采光顶按面积加权平均的外遮阳系数，模型1最低是0.89，模型4最高是0.92。

不同类型采光顶的适用性

图12左上方为采光顶1的夏季累计直接阳光辐射，其它为三种采光顶方案。方案一采用了垂直于采光顶的遮阳板，遮阳板间距固定，遮阳板高度变化随阳光辐射量变化。由分析可知，方案一相对于采用固定高度的遮阳板，减少了20%的直接阳光辐射。方案二采用铝板与玻璃间隔布置的形式，铝板与玻璃面积的大小根据直接阳光辐射的强弱变化。方案二相对于玻璃铝板均等布置的方案可减少18%的直接阳光辐射。方案三采用了等间距的遮阳格栅，但不同位置的遮阳格栅采用了不同角度。相对于全部垂直于玻璃面的遮阳格栅，方案三减少了27%的直接阳光辐射。

结论

本文通过武汉水游城项目，根据当地的气候和建筑体型的特点，从围护结构被动式技术的应用角度出发，对围护结构的遮阳、自遮阳、透明材料、非透明材料及采光顶形式的适用性进行了分析，主要得出如下一些结论:

- 窗墙比决定了围护结构的几种传热形式的传热比例。对于高窗墙比的建筑，夏季的直接阳光辐射和冬季的热传导是主要因素。对于低窗墙比的建筑，夏季直接阳光辐射和热传导同样重要，而间接阳光辐射也不可忽视; 冬季热传导是能耗的主要因素。

- The air layer and aluminum foil of the construction in opaque area is instrumental in reducing indirect solar radiation; the bricks in opaque area not only can postpone the effect of indirect solar radiation, but also result in its considerable depreciation; the surface material and finishes in opaque area have great impact on indirect solar radiation, and the indirect solar heat gain between dark color aluminum panel and bright color can vary substantially.
- Both vertical louver and horizontal shading have stronger feasibility on the southeast and southwest elevation of the project; Given the effect, It is permissible to apply overhangs shading on the building facing northeast and northwest, but vertical louver is not applicable on these two orientations.
- Since the podiums of the project are mostly with skylight, model 1 of architectural arranges high-rises to the southeast orientation, which is beneficial to the formation of shading for skylight during summer.
- All 3 options of skylight layout have been adjusted in form according to the condition of direct solar radiation, which reduce direct solar radiation during summer under the condition of same area of shading panel or glass panel.

- 从各种玻璃的对比可以看出，遮阳型Low-E中空玻璃夏季遮挡阳光的效果最佳。从全年能耗看，遮阳型Low-E中空玻璃仅次于双中空玻璃，但是双中空玻璃价格远远高于遮阳型Low-E中空玻璃。与高透型Low-E中空玻璃与遮阳帘的结合使用相比较，遮阳型Low-E中空玻璃的能耗也略低。因此遮阳型Low-E中空玻璃是本项目透明区域较适合的材料。
- 非透明区域构造层中的空气层和铝箔对降低间接阳光辐射有较大的帮助; 非透明区域构造层中的砖墙不仅仅对间接阳光辐射有延迟的作用，而且也会对其有大幅度的衰减; 非透明区域的表面材质和表面处理对间接阳光辐射有较大影响，深色铝板与浅色铝板的间接阳光辐射得热可以相差数倍。
- 本项目的东南与西南方向，垂直遮阳格栅与水平遮阳板适用性均较强; 东北与西北方向的采用水平遮阳板的效果尚可接受，但垂直遮阳格栅在这两个方向并不适用。
- 本项目裙房有较多的采光顶，体块布置方案一将高层布置在东南一端，有利于在夏季形成对采光顶的遮挡。
- 三种采光顶方案均根据直接阳光辐射的情况做了形式上的调整，在同样的遮阳板面积或同样的玻璃面积情况下减少了夏季的直接阳光辐射。