The Case Analysis of Green Office Buildings through Physical Environment Simulation

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ABSTRACT

This paper is aimed to analyze the design process of three green office buildings designed by Foster + Partners, through physical environment simulation. Simulation tools can provide the quantitative statistics to the rational judgment about the typical green architecture design logic, and make it possible to represent the generation of architectural forms more exactly and clearly, which consequently contributes to the summary of strategies and method about green office buildings practice and the methodological guidance for green architecture practice.

KEYWORDS

Physical Environment Simulation, Case Analysis, Design Process, Form Logic

INTRODUCTION

In terms of sustainable development, the conceptual form of architecture is determined by the environmental particularity, which can contribute to the form innovation through a design workflow of simulation based on some environmental elements, such as sunshine and wind. So a brand-new method should be explored which architects need to grasp as the guidance for green architecture practice.

There exist a large number of typical green architecture practices in the range of office buildings in all over the world by various famous architects, such as Norman Foster, SOM, and so on, which means the methodology exploration of this content tends to be most practiced and relatively mature. Moreover, office buildings' needs for the innovative thoughts about the performance improvement also vary from the interior light environment and natural ventilation, to the shading system, solar heat gain, the outdoor wind environment, and so on, which can present the huge potential to realize the form innovation in any single direction above, consequently leaving it as

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a test bed for design method.

Case analysis is an effective way for architects to grasp the logic organization of green architectural form and get a deep understanding of green architecture design. Still confined to the qualitative diagram analysis and the incomplete data references, the current case analysis cannot provide enough information for a rational and systematized study. However, simulation tools can provide the quantitative statistics to the rational judgment about the green architecture design logic, and make it possible to represent the generation of architectural forms more exactly and clearly, which consequently contributes to expand the range of case study and deepen the understanding of green architecture design process.

Based on the above views, the paper is aimed to analyze the green architecture design process through physical environment simulation, illustrated by three green office buildings designed by Foster + Partners in different climates. According to the design concepts made by the architects, the analysis is developed by the means of quantitative statistics comparison showed in a visualization way to represent the design logic and explore the rationality of the conceptual form, which is good to make the rational judgment about the design process and consequently contributes to the summary of strategies about green office buildings practice.

RESEARCH METHODS

1. Swiss Re Headquarters

Swiss Re Headquarters				
	The Spindly Shape	The Spiral Atria		

Figure 1. *Design Feature*

Located in the dense financial district of London which has a temperate oceanic climate[3] with the pleasant outdoor wind environment, the Swiss Re Headquarters was shaped into a radial geometry with low energy consumption by the Aerodynamic Principles − the spindly shape encourages wind to flow around the building smoothly reducing the disturbance in the surrounding wind field, the spiral atria introduces natural ventilation to improve the indoor thermal environmental quality and enhance the indoor comfort.

1.1 From the Architect

As London’s first ecological tall building, the headquarters designed for Swiss

[3] http://en.wikipedia.org/wiki/London#Climate.

Re is rooted in a radical approach − technically, architecturally, socially and spatially.

Norman Foster has explained that, environmentally, its profile reduces wind deflections compared with a rectilinear tower of similar size, helping to maintain a comfortable environment at ground level, and creates external pressure differentials that are exploited to drive a unique system of natural ventilation. Atria between the radiating fingers of each floor link vertically to form a series of informal break-out spaces that spiral up the building. These spaces are a natural social focus – places for refreshment points and meeting areas – and function as the building's 'lungs', distributing fresh air drawn in through opening panels in the facade. This system reduces the building's reliance on air conditioning and together with other sustainable measures, means that it uses only half the energy consumed by a conventionally air-conditioned office tower.[4]

1.2 Simulations Analysis

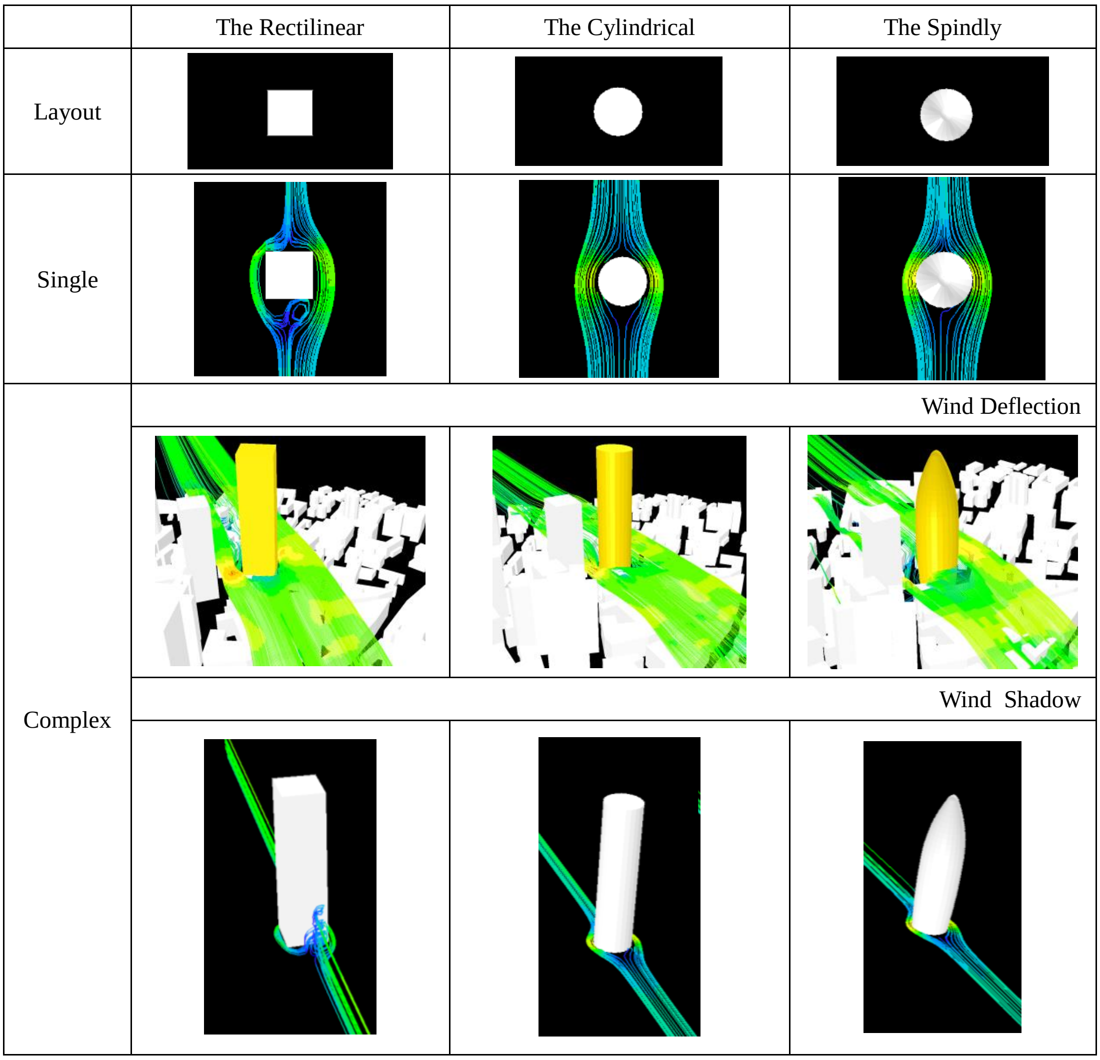


Figure 2. *Wind Behavior of the high-rise*

Based on the above points from the architect, the wind environment around the

[4] http://www.fosterandpartners.com/projects/30-st-mary-axe/.

Gherkin as well as inside the atria is simulated comparatively by the means of Phoenics[5] to demonstrate how the wind and architectural form logically interact with each other in the process of design.

As shown in the Figure 2 which represents the comparison results of the wind behavior around the rectilinear, the cylindrical and the spindly in both single and complex context, the rectilinear form turns to make the worst impact on the outdoor wind environment than the other two, in consequence of the powerful vortices around the sharp edges and the large area of wind shadow in the separated flow region. On the other hand, it is difficult to find the obvious distinction between the cylindrical and the spindly in terms of hydrodynamics characteristics in this simulation.

The Cylindrical	The Spindly

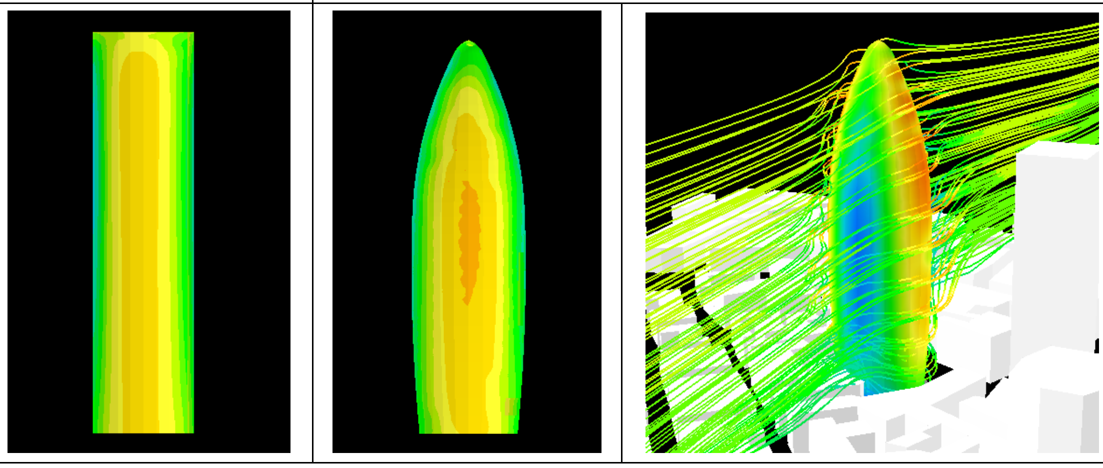


Figure 3. *Pressure Distribution on the surfaces of model buildings*

Consequently, the simulation about the two model buildings' aerodynamics performance in the same outdoor wind environment is made for the further research in the pressure distribution on the surfaces of the two, the cylindrical and the spindly. As shown in the Figure 3, the value of wind pressure on the top of the cylindrical exceeds the one on the top of the spindly designed by the architect on the purpose of reducing the wind load as well as the skin-load through the form transformation. Meanwhile, the spindly form also immediately responds to the function arrangement – the most part area is set vertically in the middle to keep the right scale, due to the sharp decrease in the top part for the reduction of wind load and the bottom for the maximization of the public realm at street level. Therefore, the spindle turns to be more reasonable and expressive in the form logic organization, which can result from the individual and subjective control of the architectural form design, contributing to the distinctive form style.

[5] Phoenics (Parabolic Hyperbolic or Elliptic Numerical Integration Code Series) is a kind of computational fluid dynamics with wide compatibility in the CAD.

Figure 4.*The Multiple Attempts on the Atrium Form*

As shown in the Figure 4, the architect made multiple attempts on the atrium form before the spiral came out. So the next step is to analyze the wind field inside the vertical and the spiral atria through the simulation about the natural ventilation by wind pressure.

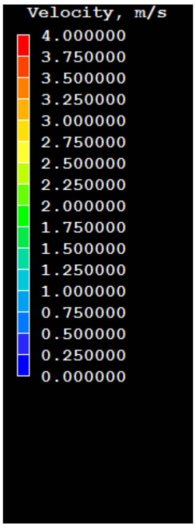
Velocity	Vertical Atria	Spiral Atria
		

Figure 5.*The Comparison of Natural Ventilation between the Vertical and Spiral Atria*

The Figure 5 shows the wind field inside the atria in one moment from which we can see the wind behavior in the vertical and spiral atria. As shown in the Figure 5, there exist two comparative results. The natural ventilation by wind pressure in the vertical atria turns great differences on the upwind side and the leeside, which demonstrates that the vertical atria cannot adapt itself to the variation of wind direction in the site. On the other hand, in the same outdoor wind conditions, the upwind can be directed by the spiral atria toward the back, which will improve the wind field on the leeside to balance the need for natural ventilation in the whole directions. Due to the combination of the improvement for the interior natural ventilation and the visual response to the air motion inside the spiral atria, the architect managed to integrate the aerodynamic concept with the architectural form in a simple but distinctive way.

2. National Bank of Kuwait

Located on a prominent site with the splendid landscape in Kuwait City which has the extreme solar radiation in the typical desert climate, the 300-metre-high headquarters tower for the National Bank is designed into a highly efficient passive form equipped with a high-performance glass curtain wall, combining structural innovation with a shielding and the large scale of view with the natural lighting, which could cut down the cold production energy consumption at the average temperature of 40 degrees in the summer.

National Bank of Kuwait			
	Outline	Plan	Top Space

Figure 6. *Design Feature*

2.1 From the Architect

The project targets a LEED Gold rating, for which Norman Foster explained that: The tower's cylindrical form opens like a shell to the north to avoid solar gain, while revealing views of the Arabian Gulf. The southern façade is shaded by a series of concrete fins, which extend the full height of the tower to provide structural support. As well as contributing to the environmental strategy, these ribs help to evoke a sense of place in echoing the form of the dhow sailing boat – a reference to the city's roots in international trade. By tapering towards the base, the design maximizes floor space in the upper levels and promotes self-shading, as the overhanging floor plates shelter the offices below.[6]

2.2 Simulations Analysis

Based on the above points from the architect, the cumulative values of multi-day solar radiation on the surface of the building during the hottest months is calculated by the means of Vasari[7] to analyze the form's shading performance.

As shown in the Figure7, any part of the form facing to the south is shaded well by the concrete fins into a low value of solar radiation, except the middle part exposed

[6] http://www.fosterandpartners.com/projects/national-bank-of-kuwait/.

[7] Vasari is focused on conceptual building design using both geometric and parametric modeling. It supports performance-based design via integrated energy modeling and analysis features.

to the extreme solar radiation which is occupied by the concrete core tube – elevators, stairs, equipment rooms and so on. The result of simulation demonstrates that the cell-like shape with the reasonable layout in the north – most part of office space is arranged in the north far away from the direct solar radiation – and the concrete fins shading the surface toward the south do improve the high-rise's performance in the extreme hot climate through form transformation.

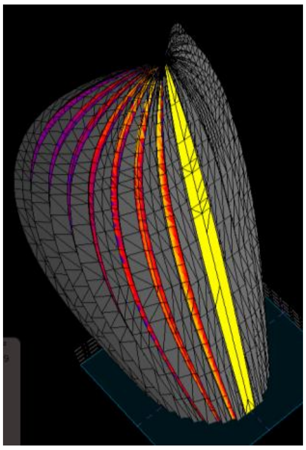
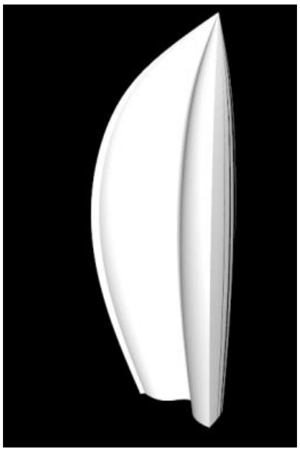
Design Concept	Solar Radiation	Conceptual Form
The cylindrical form, shaded by a series of concrete fins, opens like a shell to the north to avoid solar gain, while revealing views of the Arabian Gulf.		

Figure 7.*The Solar Radiation Simulation*

3. The Bow

Located on a major axis through downtown Calgary of Canada which has a typical continental climate with harsh winters, the Bow is shaped into a curved form to gain more sunshine and evade the cold wind for lower energy consumption in the winter.

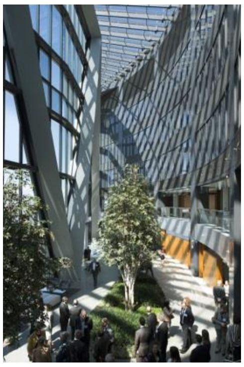
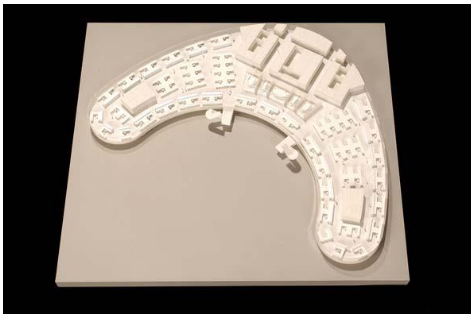
		
Outline	Atria	Plan

Figure 8. *Design Feature*

3.1 From the Architect

Providing a headquarters for a major energy company, its form was shaped by both environmental and organizational analysis. The tower faces south, curving towards the sun to take advantage of daylight and heat, while the resulting bow-shaped plan that gives the tower its name maximizes the perimeter for cellular offices with views of the Rocky Mountains. By turning the convex facade into the prevailing wind, the structural loading is minimized, so reducing the amount of steel required for the inherently efficient diagrid structural system.

3.2 Simulations Analysis

Based on the above points from the architect, the cumulative values of multi-day solar radiation on the surface of the building during the hottest months and the wind conditions in the prevailing wind direction are calculated by the means of Vasari and Phoenics to analyze the form's passive performance.

As shown in the Figure 9, the cumulative values of multi-day solar radiation on the southern surface of the building during the coldest months is relatively high which demonstrates the bow-like shape can gain more daylight and heat for the interior behavior in the winter. Meanwhile the cold wind, screened by the curved shape, can form large areas of vortices in low speed, and moves smoothly around the rounded building edges, which contributes to the pleasant outdoor wind environment and the structural loading minimization.

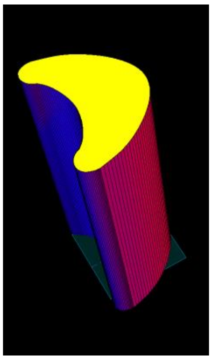
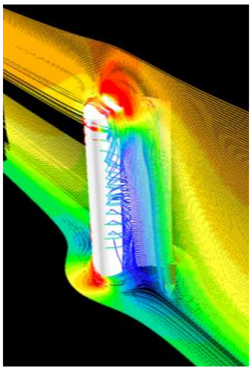
			
The Bow	Solar Radiation	Wind Environment	Model Building

Figure 9. *The Simulation of Solar Radiation and Wind Environment*

DISCUSSION

According to the above case studies through the physical simulation analysis, the general knowledge about design strategies and method on the green office buildings has come into being.

A series of design strategies about green office buildings – daylight and shading, especially the form shading for the solar radiation and heat in the extreme climate which tends to be the icon of the specific architectural language, natural ventilation, especially the atria created for a better ecological and social space, and the form transformation to reduce the wind deflection and maximize the public realm at street level –contribute to the key architectural performance in the energy consumption and environmental suitability by a passive way. And these strategies, based on the environment and energy consumption, turn to transform the conventional office layout with the special practice in the core tube location, atria's shape and the space of the top and bottom of a building.

These strategies need to be transformed into architectural languages through the architects' form creation and the physical simulation analysis. It is still a typical thinking process of design concept and form logic based on the conventional architecture aesthetics, which provides the architects priority in the subjective control of the high-performance forms aesthetically and architecturally. To avoid the subjective judgment about the reality, simulation tools can provide the detailed quantitative statistics of the building performance and show some unknown form flaw under the seemingly reasonable design logic, contributing to the rational judgment about the design logic and the right suggestions in the wide range of possibilities among the form choices.

After all, there may exist some errors in the simulation due to the limitation of the architecture background and the drawback of tools' accuracy and operability. This paper is aimed to start a discussion and a study through the simulation tools for a further evolution of the green architecture design.

CONCLUSION AND IMPLICATIONS

The design strategies and simulation research method in this paper are used to make a better and clearer understanding about the green architecture design mode, and discover the limitations or advantages of simulation tools in the passive form design process, which will provide a different view in the field of case studies, design method exploration and design tools development.

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