Research on the Variable Building Forms Used in Coastal Areas to Cope with Typhoons: Building Interaction

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Abstract. Typhoons, as a type of tropical cyclone, are mostly generated in tropical oceans. Tropical coastal areas are often affected by typhoons, posing a huge threat to the safety of buildings and residents. Economic development is very important in coastal areas, which are mostly port cities. Typhoon weather has a potentially safety-threatening effect on tall buildings, which are mostly irregular in shape. Taking the coastal areas of southern China as an example, this paper explores how to reduce the impact of typhoons on buildings by changing the form of high-rise buildings while ensuring the aesthetics of the buildings. At present, the development of interactive buildings is relatively mature. Through the case analysis of several existing variable building forms in the world, such as the French Stadium, The Shed and other works, and the comparison between the advantages and disadvantages of their practical application in daily life, the architectural forms that can be used in coastal cities in typhoon weather are obtained - adding movable built-in to the building "shell" and add wind sensors on the outside.

Keywords: Variable building · interactive · design · typhoon · coastal region

1 Introduction

In recent years, typhoon has frequently appeared in coastal cities. Typhoons are tropical cyclones that occur in tropical and subtropical waters and affect a wide range of areas, often hitting the west coast of the Pacific Ocean and the entire Indian Ocean coast. Landfall of a typhoon can easily cause damage to the ground, especially high-rise buildings. Falling objects caused by typhoons have huge safety risks, and also have a certain impact on the stability of buildings.

In 2014, Hainan Province in southern China, a tropical island, was hit by super typhoon "Rammasun", causing significant property damage. Rammasun is the strongest typhoon that has landed in China since the founding of the People's Republic of China. When it landed, it reached a level of 17 or above, and the lowest pressure was 899hpa. It caused damage to about 7.423 million people, and the direct economic loss reached 26.55 billion yuan. Many houses collapsed, trees were uprooted, and tiles and glass on the surface of high-rise buildings fell to the ground (Fig. 1).

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Fig. 1. The impact of Typhoon Rammasun on houses in Haikou city

But under the premise of economic development, to ensure the safety of all people to build ugly but typhoon-proof buildings is not realistic. At the same time, the cost of building low-rise houses is too high because of the cost of commercial land. Before this, coastal cities came up with various solutions to cope with the typhoons that hit each year. In recent years, the rapid development of human-computer interaction technology has combined with the current building of interaction technology in other aspects of the application. This paper exactly explores the possibility of applying building interaction technology to coastal cities and proposes the application of building interaction technology in natural disasters, which will help to further improve and broaden the application channels of this technology in disaster prevention.

2 Existing Measures to Cope with Typhoons and Shortcomings

2.1 Wind Damping Device (High-Rise Building)

The damper is a device used to provide motion resistance and consume motion energy. From the point of view of energy, the energy input into the structure by the seismic action is composed of the kinetic energy, deformation energy and damping energy of the system, and the strain energy of the system is composed of three parts: elastic deformation energy, plastic deformation energy and hysteretic energy dissipation [1]. The energy dissipation technology aims to concentrate the energy input by the earthquake by increasing the damping of the structure, so as to avoid and reduce the damage to the main structure and achieve the purpose of shock absorption. For this kind of windproof measure, there are two defects:

First. The damping device has certain limitations. Low-rise buildings are difficult to install, and can only ensure the safety of high-rise buildings during typhoons.

Second, the damping device can only guarantee the overall structure of the house, but nor guarantee the safety of the facade. Safety problems such as falling of the outer wall and hurting passers-by are likely to occur.

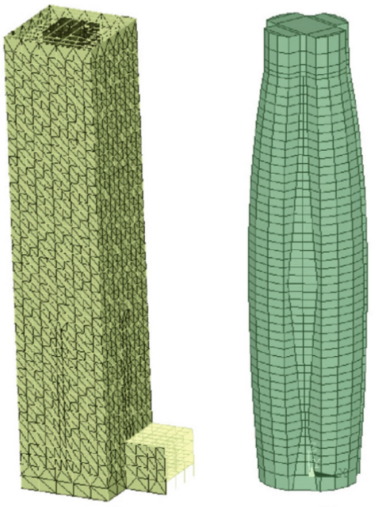

Fig. 2. Two buildings in Haikou

2.2 Special Cladding Materials (Low-Rise Buildings)

The definition of low-rise buildings refers to buildings with a height of less than 24 m and seven storeys and below [2]. The effect of the wind on the building is generally the average wind pressure caused by the average wind speed of the incoming flow on the surface of the structure. At present, some construction companies use special materials to reduce the wind pressure on the surface. However, this kind of construction's cost is relatively high and is generally only used for low-rise buildings.

Based on the above, what kind of architectural form should be used for business during a typhoon has become a problem for us to study.

3 Analysis of Three Models Based on 3 Cases

The impact of typhoons on high-rise buildings is beyond doubt. According to data research [3], take two high-rise buildings of different shapes in Haikou City, Hainan Province as an example (one with a regular shape and the other with an irregular shape). From the data analysis of different building shapes under the action of a typhoon, it can be seen that different parts receive different wind pressures. A comprehensive analysis of the simulation data shows that, under the same natural environment conditions, tall buildings with regular shapes are more prone to displacement (either longitudinally or laterally). This phenomenon will generate more or less safety hazards over time, which will reduce the comfort of people's work and life, and increase the possibility of accidents (Figs. 2 and 3).

In view of the above problems, a new type of building that can sense the wind and change its shape can be designed and conceived, so as to ensure the beauty and safety of the building.

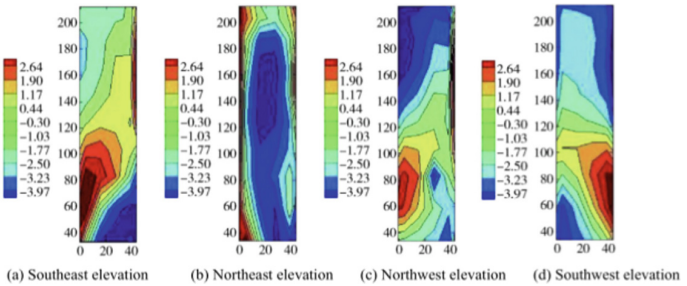

Fig. 3. Facades standard layer fluctuating pressure coefficient contour map

In the current cases of variable buildings in the world, we can see that the fields of variable building applications are very wide. Works from various designers also have different characteristics. What we want to explore is how to apply these cases to high-rise buildings in a typhoon environment.

Take "The Shed" in New York City by Diller Scofidio + Renfro Architects and Rockwell Group as an example. "The Shed" is an arts center with various arts venues such as theaters, creative labs, and more. On the outside of "The Shed" is a removable shell made of steel ramps with a translucent underlayment. The materials it uses have good thermal insulation properties and are not easily damaged. The design of its powertrain is derived from the industrial history of the elevated railway, and the When this steel structure roof is drawn out, it can be used as an event venue. "housing" slides are derived from a track-guided bogie wheel [4]. The building adopts a "slide-type" design to create a huge canopy of a steel structure that can be used for movement. When sliding out, as a venue. While ensuring the beauty of the day, it also ensures the normal use of the venue in different weather. The special feature of this design is that the steel canopy is usually embedded in the building structure itself, and only extends when it is needed. But so far, this "shell" design has only been applied to the plaza on the ground floor. Therefore, according to the building needs of the typhoon weather mentioned above, this kind of building structure can be used in the typhoon weather to better increase the safety of the building (Fig. 4).

There is also such an application in the field of sports, where the view of the spectator area will be affected when the Stade de France is used for different purposes. The world-famous Stade de France has millions of fans, track and field enthusiasts, and is a pilgrimage site for French fans. It is a young stadium, which is different from the historically rich stadiums of other countries. The stadium was established in 1998, and in the same year, the French national team won the World Cup. It is jointly constructed by the three major French construction companies Boisgis, Marseille Large Transport Company and Enterprise Corporation [5]. Therefore, the overall facility is advanced and expensive. In addition to a very modern exterior design, for a large audience, France ushered in a new era of "stands". In response to this situation, the Stade de France innovatively designed a movable spectator area for 25,000 people. The stand was placed on a "big trolley" with air cushions installed at the bottom. During football matches, the stand slides into the track area, giving spectators a better view of the pitch from a shorter distance. In the track and field competition, that is, when the external plastic

Fig. 4. The Shed in New York

track is to be used, the lower and middle platforms will be lowered to restore the track and field track to its original state. At present, this design has begun to be widely used in various advanced golf courses. But its downside is that the movement of the stand is not flexible enough, requiring manual intervention to adjust its position. This architectural structure skillfully utilizes architectural ingenuity and it can be combined with the case of "The Shed" to design a more space-saving retractable typhoon-resistant shell embedded within the building (Fig. 5).

At the same time, the appearance of the building also has a great influence. In 2020, Chinese scholars Zhu and Ai proposed the concept of "folding space" [6]. This is a very abstract concept. From the 16th century to the present, architects from various countries have been working hard to apply the "fold" to architecture. It is the product of the fusion of cultural facilities based on urban interactive thinking and contemporary urban space. It can be a building that is movable like a structural device, or it can be a building that has been transformed in the external shape. "Streamline" is a major element of the "folding" concept. Among them, the works from CCDI in the China Pavilion at the 2010 Shanghai World Expo are very representative. Although this work was not selected, its impact on the creation of the entire public building is enormous. That is "Streamline" (Fig. 6).

In the application of "Streamline", the "Streamline" Maritime Art Center in Sanya, China has an important inspiration for the architectural form of typhoon weather. The exterior is covered by a staggered "streamlined" surface, which has been proven by data analysis to effectively reduce the impact of typhoons on the building itself. At the beginning of its design, its art pavilion itself is a work of art, but it has strong practical value. Directly changing the shape of the building surface can effectively solve the wind resistance of the building. This has an important reference value for the building shape in typhoon weather. But this measure also has its limitations, which is that it limits the shape of the building. It is difficult to design a distinctive building, which is not conducive to the creation of urban landmarks. What needs to be done is to find a way to apply it to the exterior of the building without compromising the usual aesthetics of the building (Fig. 7).

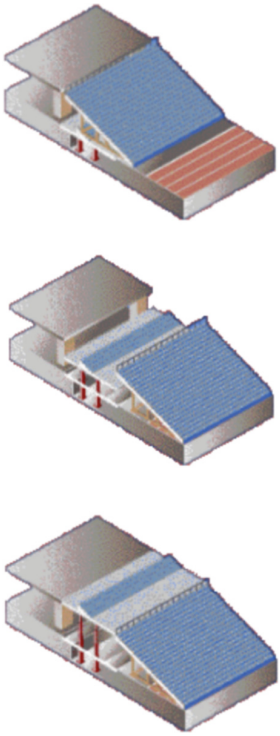

Fig. 5. Stade de France's retractable spectator area

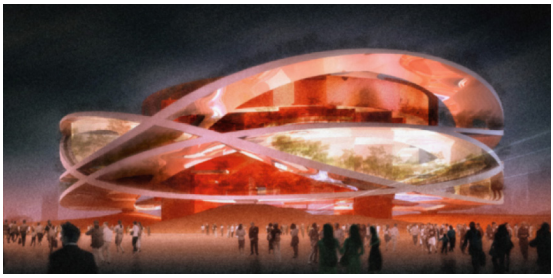

Fig. 6. Works from CCDI in the China Pavilion at the World Expo, 2010

Combining the above three forms, under typhoon weather, we can give a "shell" to the irregular-shaped high-rise building located in the commercial center. The material of the shell needs to be light and thin, referring to the light material of "The Shed". At the beginning of construction, the inner space of the shell is reserved in the interior, so as to achieve the purpose of the shell not protruding in normal weather. For the shape of the shell, inspired by the Sanya Maritime Art Center, the regular "streamline" is the first choice to ensure an effective windproof effect on typhoon days. At the same time, in order to achieve intelligence, multiple wind speed sensors will be installed on the

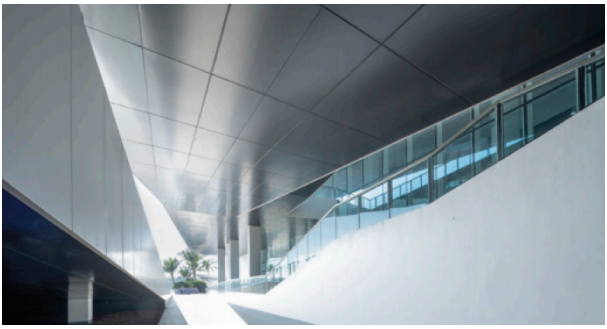

Fig. 7. Internal structure of Maritime Art Center

surface of the building to ensure timely sensing and take effect at the first time. Once the wind reaches a strength that threatens the structural stability of the building, the "shell" automatically extends, protecting the entire building.

4 Conclusion

This article discusses how to design high-rise buildings while maintaining aesthetics and safety in typhoon weather. First of all, there are some defects in the existing measures for typhoon protection, which cannot be applied to high-rise buildings without guaranteeing safety and economic cost. Through analyzing the existing data on the influence of wind on high-rise buildings of different shapes, and synthesizing several existing movable or foldable buildings in the world, this paper discusses: 1). Whether a "shell" can be added to the exterior of the building 2). How to become "movable" 3). The role of a streamlined appearance in typhoon weather, and combining it with the "shell". From these three points, a method that can reduce the impact of typhoons on buildings in an intelligent way is derived. Consider designing a built-in shell in the building. When the outer wind sensor senses the wind reaching a certain level, the shell automatically extends to wrap the inner building. At the same time, in order to minimize the impact of typhoon weather on the building, a streamlined design is adopted for the shape of the shell. In normal weather the shell is embedded inside the building. Does not affect the aesthetics of the building. However, this paper still has limitations in practical operation, and it remains to be further explored whether the safety of the "retractable shell" in high-rise buildings can be guaranteed.

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