WEP
Warwick Evans Publishing

Transactions on Engineering and Technology Research
ISSN: 2960-1797, eISSN: 2960-2246 | Volume 4
ACEGE 2024

Study on The Influence of Typhoon on Coastal Bridges and Countermeasures

Baoni Zhu *

Hefei No.1 High School, Hefei, China

* Corresponding Author Email: bnz17566@gmail.com

Abstract. As an important medium connecting land and promoting traffic, the safety of coastal bridge should also be paid attention to. Typhoon as a natural disaster will cause direct and indirect damage to the bridge. This paper studies the influence of typhoon on coastal bridge and its countermeasures. Firstly, the direct damage to bridge structure caused by typhoon wind load and wind direction changes and the indirect damage caused by typhoon erosion, sand damage and concrete carbonation are analyzed. Then, the design scheme and bridge management scheme are proposed to reduce the harm caused by typhoon. Finally, taking Sutong Bridge as an example, the wind resistance design of the bridge is discussed, and the function of the bridge health monitoring system in the operation stage is introduced, which provides important data support for the safety assessment and maintenance of the bridge structure. The results show that the negative impact of typhoon on coastal bridge can be reduced by bridge health management. The research can provide feasible solutions for Bridges to cope with typhoons in the future.

Keywords: Typhoon; Health monitoring; Coastal bridge; Sutong Bridge.

1. Introduction

The coastal bridge generally refers to the cross-sea bridge and the cross-river bridge in the coastal area, and the geographical location is located in the seaside where typhoon disasters are frequent. The piers of coastal bridges are often deep into the seabed to achieve a fixed effect, and the materials used to build coastal bridges are usually moisture-proof and corrosion-resistant to adapt to the coastal environment. The famous coastal Bridges in the world are the Hong Kong-Zhuhai-Macao Bridge, the Golden Gate Bridge and so on. However, typhoons and other natural disasters often occur in the sea, which bring harm to the structure of the coastal bridge. Typhoons are a category of tropical cyclones that are often accompanied by heavy winds and rain. The wind speed of typhoons is about 17 meters/second or more, and some typhoons are even more than 60 meters/second. When super typhoon landfall, super destructive force will cause great damage to bridge, reduce bridge life, increase the risk of bridge collapse. Typhoons in China have three characteristics: First, they are frequent. Typhoons land about nine times a year in China, landing from April to December, and landing most frequently from July to September. Second, typhoons have brought great damage to China's coastal areas, especially in the typhoon-prone southeast, where typhoon disasters are most frequent in Taiwan, Hainan and Guangdong provinces. Third, typhoons are full of destructive power and can also bring storms, tsunamis and other natural disasters, which have caused huge economic losses to China. In September 2024, Typhoon Capricorn brought losses of nearly 80 billion yuan to Hainan Province [1].

This paper will study the influence of typhoon on super long span cable-stayed bridge, and discuss the countermeasures of super long span cable-stayed bridge to typhoon from two aspects of design and operation management. In addition, taking Sutong Bridge as an example, the wind resistance design and wind resistance effect are studied. This paper hopes to provide some theoretical reference for anti-typhoon measures of cable-stayed Bridges in coastal areas.

2. Influence of Typhoon on Coastal Bridge

2.1. Direct Impact

Typhoon has a strong destructive power, it often occurs in the coastal area, will cause direct damage to the structure of the coastal bridge. First of all, the wind speed will directly affect the dynamic pressure on the bridge surface, and the greater the wind speed, the greater the wind load received by the bridge. At present, the construction trend of coastal bridges is deep water and long span, which greatly increases the wind load on Bridges [2]. This kind of load will directly act on the broad deck of the bridge, so that it is subjected to horizontal and vertical wind pressure, resulting in vibration. The stronger the wind load is, the more severe the vibration of the bridge will be, and the deformation of the bridge structure will occur. Secondly, under the action of wind load and self-weight, the bridge will produce static wind instability and torsion and deformation of the main beam. In this case, the bridge will produce torsional deformation and bending, thus affecting the distribution of wind field, thus changing the magnitude and direction of wind and further increasing the structural deformation [3]. Static wind instability is very destructive to the bridge, without any warning before the occurrence, sudden strong. Finally, the change of wind direction will also cause direct damage to the bridge [4]. Because of the temperature difference between land and sea in coastal areas, a bridge over the sea will experience more wind and wind in different directions than a bridge over land. The change of wind direction will cause uneven stress in all parts of the bridge, resulting in torsion phenomenon and local instability, and further lead to the destruction of the bridge structure. In general, typhoons will bring wind loads to Bridges in coastal areas, which will directly damage bridge structures from different aspects.

2.2. Indirect Impact

In addition to the direct damage caused by the typhoon itself, some events caused by the typhoon will also cause indirect damage to the bridge. First, typhoons can cause erosion damage to Bridges in coastal areas. Typhoon will bring big waves to coastal areas, these waves have great energy, and the impact force generated will constantly destroy the foundation support of Bridges, thus causing structural damage. Day after day, the foundation of the bridge is continuously washed by the waves, which can erode, resulting in safety problems such as reduced stability and reduced bridge life. Second, typhoons may indirectly cause sand damage to Bridges. Typhoons are able to move and reshape dunes, bringing sand from different regions to the bridge. Therefore, over time, a large amount of sand and sand will accumulate on the bridge, bringing additional loads to the bridge, increasing the weight of the bridge floor, resulting in an additional load on the bridge. The structure of the bridge can be damaged by the extra weight brought by the large amount of accumulated sand, adding safety risks. Third, typhoon will damage the bridge material - concrete, typhoon will indirectly accelerate the carbonization of concrete. The greenhouse effect is an indirect product of typhoons, and the greenhouse effect means an increase in carbon dioxide. When more and more carbon dioxide react with concrete, pores will be created in the concrete, which will make the concrete in the bridge become fragile, thus endangering the bridge life in the long run [5]. In general, typhoons will bring a lot of additional impacts, which will indirectly affect the safety of Bridges from different aspects.

3. Typhoon Response Measures

3.1. Strengthen Bridge Design

First of all, the core of wind resistance design is to ensure that the bridge can safely withstand the direct and indirect effects of typhoons. Therefore, it is necessary to fully understand the wind characteristics of the bridge location, and based on this, evaluate the impact of wind on the bridge structure, and verify the safety of wind resistance. The key factors in wind resistance design include the following points:

(1) Wind characteristic parameters: Through meteorological data, the wind characteristics near the bridge are accurately grasped, and reasonable parameters are determined by scientific method. Special attention should be paid to unique topography, landforms and wind conditions.

(2) Dynamic characteristics of bridges: Appropriate mechanical model should be used to compare and verify the actual situation of similar Bridges, especially to correctly judge the vertical bending, lateral bending and torsion of main beams.

(3) Wind load and its action: The prediction of the critical flutter wind speed and buffeting response should be based on the dynamic characteristics of the bridge, the aerodynamic characteristics of the main beam section and the turbulent wind characteristics to ensure that the analysis results are accurate and reliable.

In the basic flow of bridge wind resistance design, wind tunnel experiment should be carried out in the preliminary design stage to determine the aerodynamic shape of the main beam section as a basis for further design. In the detailed design stage, it is necessary to carry out more in-depth wind resistance check calculation and wind vibration analysis, and confirm the final results through the wind tunnel experiment of the full bridge model to ensure the safety and reliability of the design. The selection of materials and structures is also an important part of wind resistance design, and strength, durability and wind resistance should be considered comprehensively.

3.2. Bridge Operation Management

The strong wind and storm surge brought by typhoon will have a huge impact on the structure of large coastal bridges, seriously threaten the safety and life of Bridges, and then pose a hidden danger to the operation and traffic safety of Bridges. In order to deal with these security risks, modern scientific and technological methods must be fully utilized to achieve all-round and whole-process monitoring of personnel, equipment, Bridges and related structures. Therefore, it is necessary to establish a high-definition monitoring system with full coverage to quickly respond to emergencies. In order to evaluate the bearing capacity, safety and durability of Bridges during typhoons, it is recommended to establish a Bridge Management System (BMS). Some studies in Taiwan have proposed the construction of BMS. The collapse detection in this study consisted of a hybrid collapse detector and a waterproof box based on the International Protection (IP) 67 standard (Fig. 1) [6].

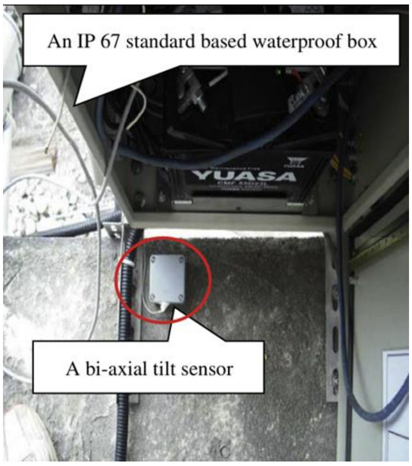

Figure 1. Waterproof box and tilt sensor [6]

4. Case Study

Sutong Bridge (Fig. 2), officially opened to traffic in June 2008, is located in the southeast of Jiangsu Province, connecting Nantong and Suzhou. It is only 108 kilometers away from the Yangtze River estuary, and is an important road transportation hub in the southeast coast. The bridge mainly consists of the north bank connection project, the coastal-river bridge and the south bank connection project. Among them, the bridge acoastal the river is the first long-span steel-box girder cable-stayed bridge with two towers and two cable planes in China. With a clearance height of 62 meters and a main span of 891 meters, the bridge can meet the navigation requirements of 50,000-ton container ships and 48,000-ton fleet [7].

Figure 2. Sutong Bridge [8]

At present, the bridge health detection system is used in Sutong Bridge, including four subsystems: sensor system, data acquisition and transmission system, data processing and control system, and structural health evaluation system. The sensor system consists of 15 types of sensors, including strain gauges, temperature sensors, acceleration sensors, etc., which are placed at key parts of the bridge to monitor the environment and the structural response of the bridge during operation, with a total of 788 sensors installed. In the wind resistance monitoring, four HD2003.1 ultrasonic anemometers are specially installed to monitor wind speed and direction. There are anemometers on the upper and lower parts of the main beam and on the top of the north and south bridge towers, with heights of 76.9 meters and 306 meters respectively. Data recording adopts polar coordinates to accurately capture wind speed changes. The anemometer arrangement of Sutong Bridge is shown in Fig. 3 [9].

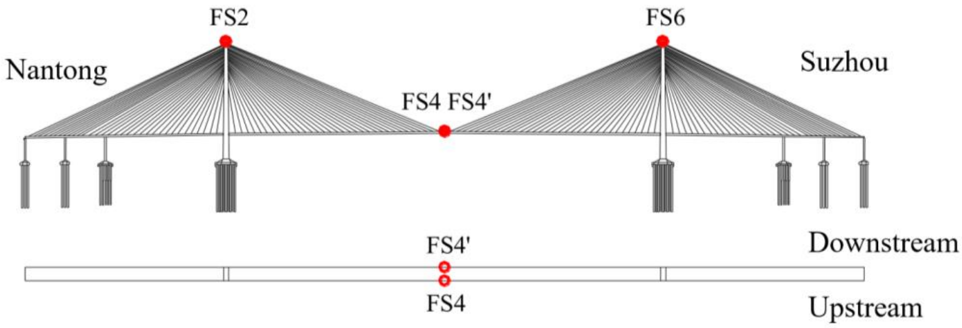

Figure 3. Anemometer layout of Sutong Bridge health monitoring system [9]

5. Conclusion

This paper mainly studies the impression of typhoon on coastal bridge and countermeasures, and draws the following conclusions:

(1) Typhoon has direct and indirect effects on the coastal bridge. The direct effects include vibration and static wind instability caused by wind load, while the indirect hazards include wave erosion, sand damage and carbonization of concrete. As bridge designs move towards deep water and long spans, the risks become more complex.

(2) Measures to strengthen the response to typhoons of coastal bridges include strengthening bridge design and improving operation management. First of all, the bridge design should fully consider the local wind characteristics and carry out wind resistance evaluation. Secondly, it is necessary to establish a comprehensive monitoring system to achieve real-time monitoring of the bridge, especially during typhoons to assess its carrying capacity and safety. In addition, the construction of a BMS can improve the level of bridge operation management and cope with strong winds.

(3) Sutong Bridge, as an important highway transportation hub connecting Nantong and Suzhou in Jiangsu Province, meets the navigation needs of large container ships. The bridge is equipped with an advanced health monitoring system, including 15 types of sensors and 788 monitoring points to monitor the environment and structural response in real time. Since its completion, Sutong Bridge has experienced many typhoon impacts, and has always maintained stable operation with excellent wind resistance design, showing excellent structural safety.

(4) In the future, studies should explore the long-term effects of wind loads on different types of Bridges, and combine new materials and technical means to improve the wind resistance of Bridges. At the same time, as the frequency and intensity of typhoons increase due to climate change, optimizing the dynamic response and health monitoring system of bridges will be an important direction to ensure bridge safety. This will provide strong support for the design and maintenance of large bridges in coastal areas.

References

[1] Information on: https://www.yicai.com/news/102268757.html

[2] Information on: https://www.zzcbjt.com/index.php/lbd-2-11-16998

[3] Information on: https://www.doc88.com/p-28573029362460.html

[4] J.H. Luo, Z.Q. Chen, G.D. Liu, Research on instability mechanism of long-span cable-stayed bridges due to nonlinear aerostatic torsion, Engineering Mechanics 24.S2 (2007) 145-154.

[5] D.V. Ribeiro, N.S.A. Júnior, B.S. Santos, et al. Proposal for classification of concrete quality based on accelerated carbonation tests, Case Studies in Construction Materials 19 (2023) e02466.

[6] N. Yau, M. Tsai, H. Wang, D. Hung, et al. Improving bridge collapse detection and on-site emergency alarms: A case study in Taiwan, Safety Science 70 (2014) 133-142.

[7] H. Wang, A.Q. Li, J. Niu, et al. Long-term monitoring of wind characteristics at Sutong Bridge site, Journal of Wind Engineering and Industrial Aerodynamics 115 (2013) 39-47.

[8] Information on: https://www.thepaper.cn/newsDetail_forward_7445884

[9] H. Wang Z.D. Xu, T.Y. Tao, et al. Analysis on joint distribution of wind speed and direction on Sutong Bridge based on measured data from 2008 to 2015, Journal of Southeast University (Natural Science Edition) 46.4 (2016) 836-841.