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The interaction between cross-sea bridge and the environment

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Abstract. One special type of bridge is a cross-sea bridge. When evaluating the installation of a cross-sea bridge, various problems need to be taken under the profile page. This study investigates the stability risk of a cross-sea bridge, which may be influenced by flowing water throughout construction, and investigates the effect of either the cross-sea bridge on the environment during construction, using the Donghai Bridge as an example. Studies have shown that, due to the inevitable damage to the environment during the construction process, the number of organisms in the sea area near the bridge will decrease at the initial stage of construction but will slowly recover over time. The significance of this study is to explore how to reduce the instability risk of the cross-sea bridge during the construction period and minimize the impact of the bridge construction on the sea environment, at the same time, through analysis, explore reasonable solution measures.

Keywords: instability, cross-sea bridge, Donghai Bridge, environment.

1. Introduction

The first overseas sea bridge in China is the Donghai Bridge. The opening in 2005 signalled China's change from erecting footbridges through rivers over oceans. Also, it permits Shanghai Port to bulge from by Huangpu River and to have a truly wide wharf shoreline, therefore, affording Hanoi an essential structural backdrop in which to construct an international shipping hub. The bridge connects the Yangshan deepwater Port region of Xiaoyangshan Island to the south and the Luchao Port of Shanghai to the north. It is placed in the northeast of Hangzhou Bay. A motorway with a design speed of 80 km is the least requirement. The bridge has a total width of 31.5 meters, 6 lanes in each direction, and a length of nearly 32.5 kilometres. The safe operations of the bridge are quite important, and the sweep of the pier foundation is a major difficulty for bridges in marsh and coastal environments. The scour pit usually located around the stack group supports the pier cap and is the fundamental determinant impacting the structural protection of the bridge [1].

As the regional conditions of the bridge engineering in the bay, river and estuary are often complex, the bridge foundation is affected by comprehensive factors such as wind, wave and current, and local scour will occur around the pier, reducing the stability of the bridge foundation. When local scour reaches a certain depth, it poses a threat to the safety of the bridge structure. Thus, it is required to somewhat protect the bridge foundation while it is being constructed to guarantee the safety of the foundation during bridge production and operation. One of the precautionary methods is to make the surrounding bed surface more resistant to impacts; another is to use architectural procedures to lessen the force of groundwater flow erosion [1]. This paper analyzes three kinds of vortices that may be caused by water erosion and lists the corresponding solutions [2]. At the same time, this paper also puts forward the impact of the construction of the bridge on the environment, starting from the perspective of biological community changes, this paper analyzes the impact on the environment. The greatest environmental loss caused by the occupation of the ocean area and the working process is why the bridge construction influences benthic and intertidal creatures. Trestle and cap buildings will occupy a specific area of the seabed during construction, causing the extinction of benthic and intertidal microorganisms in this region. But, after the trestle and cap are gone, the habitat of benthic and intertidal creatures in this area will gradually return. A part of the seabed will be permanently taken from the pier, resulting in the loss of the intertidal and benthic creatures' habitat. Moreover, the construction of trestles, caps, and piers will disturb the sediment in a region that is not near the water, harming benthic and intertidal animals' environments and potentially even causing some of them to perish. The intertidal zone species and benthic organisms will, however, gradually rebound over time when construction is finished [3].

2. The interaction between sea bridge and the environment

2.1. Case description

Donghai Bridge's appearance takes "Donghai Rainbows" as the creative concept, as well as a bright rainbow over the East China Sea. Donghai Bridge is the first cross-sea bridge in China with an extensive project. The bridge is located within the deep waters of Hangzhou Bay, which has a heavily corrosive environment and bad natural conditions. The Donghai Bridge begins and ends at Pudong New Area in Shanghai and Xiaoyangshan Island in Zhejiang Province, and is a maritime bridge used to link both areas. The 32.5 km bridge crosses the deep-water harbor area of Hangzhou Bay and has a complex underwater topography, so it has high requirements when it comes to structure and construction. A bridge project built at sea, the bridge usually has a long span of several kilometres to tens of kilometres, a complicated structure and a prolonged construction cycle. Therefore, the construction may have some impact on the natural environment and water quality of the surrounding sea. This study takes the Donghai Bridge as an example to analyze how the environment affects the East China Sea Bridge. At the same time, the factors, ways of influence, nature of influence, and degree of influence of the cross-sea bridge project on the water quality and ecological environment of the nearby sea area are analyzed [3]. Since the regional conditions of bridge projects in bays, rivers and estuaries are often complex, the bridge foundation is affected by wind, waves, currents and other comprehensive factors, local scouring will occur around the bridge piers, reducing the stability of the bridge foundation. When the local scour reaches a certain depth, it will threaten the safety of the bridge structure [2].

2.2. Bridge instability

As the regional conditions of the bridge engineering in the bay, river and estuary are often complex, the bridge foundation is affected by wind, wave, current and other comprehensive factors, and local scour will occur around the bridge pier, reducing the stability of the bridge foundation. When the local scour reaches a certain depth, it will threaten the safety of the bridge structure [2]. Bridge erosion is the main cause of bridge instability, which is also a subject of great concern in engineering and scientific circles. In this paper, the scour types of Bridges are divided into three types, which are natural scour, general scour and local scour. And these scours are the main reasons that will change the environment.

2.2.1. Natural scour. Natural scour is caused by the change in the macro environment and has nothing to do with bridge construction. The main causes of natural scour are the scour caused by the sudden increase of incoming water, such as storm surges and earthquakes, and the erosion and siltation imbalance caused by the decrease of sediment supply [4].

2.2.2. General scour. The construction of the pier reduces the cross-section of the water flow and increases the water level near the pier, resulting in the backwater phenomenon around the pier. When the water flow continues to move away from the pier, the flow rate increases and the flow capacity increases, causing the sediment around the pier to transport to both sides of the bridge, resulting in the scour [4]. The figure below shows general scour (See Figure 1).

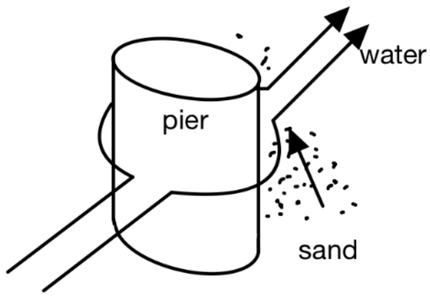

Figure 1. General scour.

2.2.3. Local scour. When the water meets at the pier, due to the blockage of the pier, the water will continue to move in three directions, moving down both sides of the pier and along the pier. The moving water and the incoming water at the bottom of the pier meet to form a vortex, which is called a horseshoe vortex. In addition, the water on both sides meets behind the pier to form a tail vortex, which is the main cause of local scouring of the pier [4]. The figure below shows local scour (See Figure 2).

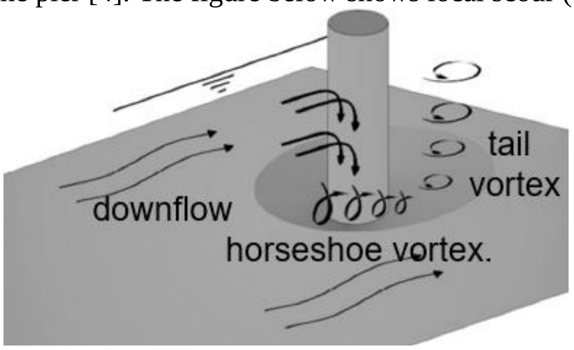

Figure 2. Local scour [4].

2.3. Impact of scouring on environment

The hydrodynamic surroundings between Donghai Bridge and the wind turbine array will start changing because of the relationship between the flow of water well with the pier and windmill base, which will modify a multitude of factors in the aquatic environment. These variations are going to not only impact the concentrations of total suspended solids and chlorophyll in addition to the surface temperature of the sea groundwater of the Donghai Overpass and the waterwheels, but they will additionally potentially trigger the necessary modifications in other freshwater ecosystems [5-6]. Due to both the pier and the windmill base's water-blocking action when water flows past them, the movement and structure of the upstream water are going to change. While some of the water flows downward, scouring the waterfront and windmill base, other parts of the water move all around the pier, creating vertical vortex wakes on both ends [7]. As a consequence, there are two main ways that the Donghai Bridge and its windmill array affect the water and environment: first, the flow of water itself in the Philippines erodes the foundations of the bridge and the windmill base, and second, the combination of these factors results in the emergence of a vortex wake [6]. The upstream flow of water keeps going to flow downstream, transporting suspended particles, bottom-cold water, and nutrients shortly after the scraping of the bridge's pier and windmill base ends. The vortex wake generated by the pier and windmill base will additionally absorb suspended materials, cold bottom water in a container, and nutrients into the downstream waterways, increasing the proportion of suspended debris downstream of the windmill and the Donghai Bridge. Decreased sea surface temperatures increase nutrient abundance [8]. This is why the construction of piers on sea-crossing bridges causes changes in the biological communities in the surrounding environment.

2.4. Environmental impact of the Bridge

For environmental impact research, the report looks at changes in the populations of different organisms, including fish and microorganism.

2.4.1. The biome changes of large yellow croaker and anchovy. In 2008, before the completion of the windmill, no rhubarb and anchovy were found in the site survey near the bridge. However, large numbers of rhubarb and anchovy larvae were found in the windmill area near the East China Sea Bridge during construction. After completion in 2014, large numbers of anchovy larvae appeared near the Donghai Bridge and the windmill station [9].

2.4.2. The biome changes. Impact of cross-sea bridge project on water quality and ecological environment of nearby sea area and its tracking and monitoring and verification. In general, the impact of the project on the intertidal and benthic organisms is local, and the permanent loss of habitat is only the seabed occupied by the piers. However, the influence of temporary construction and disturbance areas such as and caps on intertidal organisms and benthic organisms is temporary and local. After the construction, the influence will disappear, and the habitat, biomass and biological density of intertidal organisms and benthic organisms will recover within a certain time [3].This chart can easily find that the density of intertidal and benthos is generally higher than before (See Tables 1-2).

Table 1. The density change of intertidal [3].

Period	Number of intertidal（g/m^{-2}）	Density of intertidal（$number/m^{-2}$）	H‘
Before the construction	19.45	85	1.922
During the construction	14.87	156	1.545
After the construction	72	91	3.455

Table 2. The density change of benthos [3].

Period	Number of Benthos（g/m^{-2}）	Density of Benthos（$number/m^{-2}$）	H‘
Before the construction	1.97	76	0.95
During the construction	1.32	92	1.535

2.4.3. Further thinking about the relationship between vortex and biome. The bridge piers and windmill bases played a similar role in the islands and reefs in changing the dynamic characteristics of the surrounding water environment, causing changes in suspended sediment concentration, sea surface temperature and other water environmental factors. This creates a favorable environment for creatures, attracting large yellow croakers, anchovy and other plankton to spawn and roost there.

2.5. Suggestions

2.5.1. Protect measures. Vortexes are naturally occurring and it is difficult to prevent them effectively, but a series of measures can be taken to reduce and counteract their effects.

2.5.2. Ring protection. A retainer set at a certain height of the pile foundation can prevent the impact of the lower jet on the pile bed surface, to weaken the energy of the lower jet and the horseshoe vortex, presence of a retainer greatly weakens the strength of downdraft and horseshoe vortex in front of the pile [10].

2.5.3. Sacrificial pile protection. A series of non-bearing piles arranged regularly in front of the pile can effectively consume the upstream water flow energy and change the flow direction, thus reducing the scouring effect on the riverbed around the pile and achieving the purpose of protection [10].

2.5.4. Pile body hole protection. Pile body opening can make part of the incoming flow through, reducing the energy of the lower jet and horseshoe vortex. The protective effect of this method is greatly affected by the flow and the Angle between the openings. When the flow or the riverbed structure is unstable, the protective effect is poor [10].

2.5.5. Downstream slate protection. Laying a SLATE on the riverbed downstream of pile foundation can reduce the wake velocity and the intensity of the wake vortex, and thus reduce the wake scour [10]. The graph below shows four different types of protection (See Figure 3).

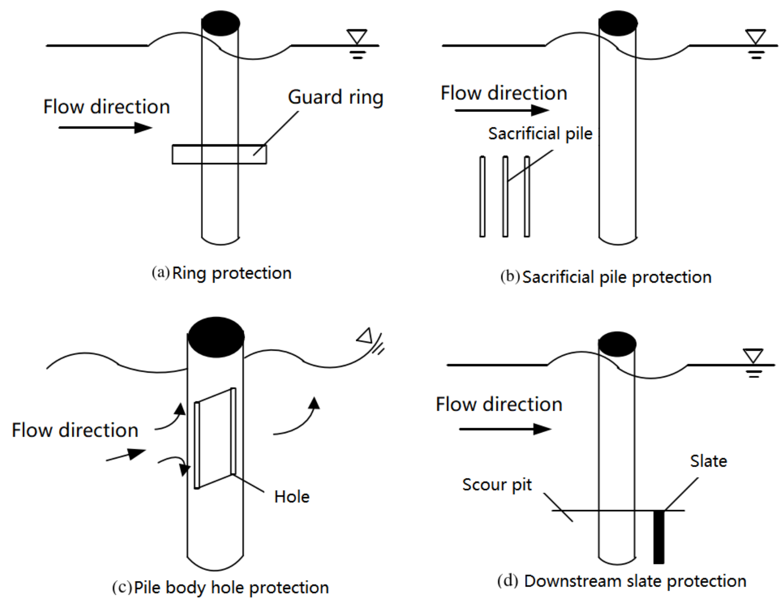

Figure 3. Four kinds of protections [10].(In Figure a, a guard ring set at a certain height of the pile foundation. In Figure b, a series of sacrificial piles arranged regularly in front of the pile. In Figure c, a hole was set into the pile body. In Figure d, a SLATE was laid on the riverbed downstream of pile foundation).

2.5.6. Construction management measures. The project adopts owner management to ensure the execution and enforcement of the various water and soil control measures that were suggested by the project. It also establishes the soil and water ecological preservation project's leading team, which is in charge of overseeing and carrying out soil and water conservation in the project's development. This team strictly monitors the construction unit's obedience to the treatment Measures for preserving both water and soil, both concerning amount and quality, will be completed. Additionally, it needs expert staff in water and soil conservation to deal with technical problems that arise during the execution of measures and accept oversight and inspection compared to regional water management organizations. In parallel, the construction unit should increase the education and training of construction staff. The training shall include training on laws and regulations of water and soil conservation, basic knowledge of water and soil conservation, training standards of water and soil conservation monitoring, training on monitoring techniques of development and construction projects, etc. Training can enhance the conscious sensitization of project builders to soil and water conservation [11].

3. Conclusion

In general, architecture and environment interact with each other and are inseparable. While water flow brings instability risk to the bridge, the existence of bridge piers will also change the surrounding environment. This paper summarizes and analyzes three kinds of different eddies formed by different scours, among which the scours are divided into natural scours, general scour and local scours. Vortexes are divided into horseshoe Vortex and tail Vortex. At the same time, this paper introduces four methods to prevent the formation of vortexes, to reduce the risk of instability when the bridge is facing erosion. The project measures are ring protection, sacrificial pile protection, pile body hole protection and downstream slate protection. At the same time, this paper also puts forward some construction site management measures. The presence of the piers can lead to the creation of vortexes, which is also one of the reasons for the change in the environment. By studying the changes of large yellow croaker and anchovy before and after the construction and changes in the intertidal organism and benthos, this paper expounds the impact of the bridge on the biological community.

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