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Mechanism and Protective Measures of Local Scouring of Bridge Piers

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Abstract

With the rapid development of China's bridge cause, more and more Bridges are being built across the country, and the protection of bridge piers has become more and more important. Based on the local erosion mechanism of bridge pier, this paper summarizes and analyzes the influencing factors of local erosion and the evolution process of erosion pit, and puts forward a series of protective measures. Finally, we put forward suggestions on the future development direction for the shortcomings of the existing research.

Keywords

Pier; Local Scour; Erosion Mechanism; Protective Measures.

1. Introduction

As an important part of the transportation line, the construction of the bridge is constantly improving people's lives, but at the same time, the earthquake, flood, design and construction and foundation protection and other factors are easy to cause the bridge instability damage, resulting in serious losses. The British Engineer, Statistical analysis of the causes of 143 bridge accidents between 1847 and 1975 shows that about 50% of the bridge damage was caused by flood erosion; This paper analyzes the causes of 179 bridge damage accidents in the 15 years since the 21st century in China, and finds that about 32% of them are caused by flood erosion[1]. It can be proved that flood scour is one of the main causes of bridge damage. Many years of practical engineering experience has proved that local erosion is the most important factor causing bridge flood damage.

Therefore, this paper reviews the research progress of local erosion of bridge pier, mainly including three aspects of local erosion pier peripheral water flow structure, erosion pit evolution process and influencing factors, and expounds the development trend by summarizing the existing research problems.

2. Local Scour Concept

After the bridge is built, in addition to the natural evolution of the riverbed, there are also the riverbed erosion caused by the bridge pier interference with the water flow and sediment movement, they are intertwined at the same time, the erosion process is very complex[2]. In order to facilitate research and calculation, the maximum erosion depth of the bridge pier is often divided into three independent parts: erosion caused by natural evolution, general erosion and local erosion, among which the most important is local erosion.

Due to the current impact and vortex flow resistance, the 3 D boundary layer is separated around the pier, thus producing the local water flow with high turbulence and high flow velocity characteristics, causing the vortex and leading to the downstream transmission and development, producing a large bed surface shear force, the local bed deformation formed around the pier is called the local erosion of the pier.

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3. Local Scour Mechanism

3.1. Overview of the Scour Mechanism

There are many factors affecting the local erosion depth of the pier, and the local erosion mechanism is closely related to the shape of the pier, the water flow strength near the pier and the composition of the riverbed. In summary, there are mainly the following three views:

1) Vortex system of pier peripheral flow field. A bridge pier is put into a three-dimensional undisturbed flow speed field. After the flow at the front edge of the pier is blocked, due to the small flow speed near the bottom of the river and the large upper part, the horizontal axis vortex forms clockwise rotation at the bottom of the river, and moves to the two sides of the pier along the bed surface to form a horseshoe vortex system around the flow. Local erosion around the pier is formed by the high riverbed shear generated by the horseshoe vortex system.

2) Impact effect of the descending water flow in front of the pier. The obstruction of the water flow by the pier causes drastic changes in the water flow structure around the pier, forming a "falling water flow" at the front edge of the pier head, which vertically washes the sediment on the bed surface, and forms a scouring pit in front of the pier.

3) The water flow is compressed by the bridge piers. The local erosion around the pier is due to the compression of the water flow by the pier, which changes the original flow rate distribution around the pier. The flow rate on both sides of the pier is relatively increased, so that the two sides of the pier first cause scour, and the erosion gradually develops to the front of the pier. According to the flow structure during local scour test.

The above three views are not isolated effect, but interrelated affect each other, it can be seen that the pier of the water flow compression and obstruction, make the pier around the flow field changes, resulting pier on both sides of the "concentrated flow" and pier "flow", "flow" and "flow" is the internal cause of the formation of the horseshoe vortex, and horseshoe vortex system is the direct cause of the pier around local erosion.

3.2. Scour Pit Evolution Process

When the pier blocks the water flow, the complex 3 D water flow structure around the pier will cause local scouring pit around the pier. Qi Meilan[3] also divide the scouring pit into three stages: starting stage, scouring pit develops rapidly and the maximum depth can reach three quarters of the maximum balance depth; in development stage, the scope and depth are still increasing; At the equilibrium stage, the development of the scour hole is extremely slow, so it can be considered that the scour hole is almost no longer developed and reaches the equilibrium state.

In foreign countries, scholars' research on local scour evolution mostly focuses on the computational prediction of scour depth development over time.The law of the local scouring depth under uniform, heterogeneous and stratified sediment is studied. Indoor water erosion test, studied the change of local erosion pit depth in uniform sand riverbed, and proposed the prediction and calculation formula of local erosion depth development over time based on the experimental data; The time evolution of local erosion depth in piers and abutment beds under clear water condition is studied, and the time evolution equation is established, and the formula is verified by the existing literature, which is then introduced into the local erosion of Ding dam.Indoor erosion test was conducted, and the influence of sediment coarse degree (the ratio of pier width to sediment median particle size) on the equilibrium erosion depth was studied, and then the local flushing depth time evolution formula was established[4-6].

In China, there are few studies on the evolution calculation of local erosion depth with time, and more studies are qualitative studies on the evolution process of erosion pit.The ultrasonic topographic instrument is used to measure the pier surrounding terrain in the water erosion test, this method can carry out real-time underwater non-contact dynamic measurement,

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improve the accuracy of the results, the test found that the pier side and before the pier first erosion, after the pier gradually erosion, and the pier front and before the pier erosion pit is deep. The sediment transport characteristics in the evolution process of clean water erosion and moving bed erosion under the cylindrical pier were studied, and the rate of suspension quality and passage mass transport was the largest at the beginning of scour and decreased rapidly with the development of scour pit.

3.3. Factors Affecting Local Erosion

1) Water flow factors. The near velocity in the local erosion of the pier refers to the average flow velocity of the incoming section upstream of the pier. When the near velocity is less than the sediment starting velocity, the pier has no upstream sand replenishment in the pit, which is called water scouring; when the near velocity is greater than the sediment starting velocity, the scouring pit can get sand replenishment, which is called moving bed scouring. The local erosion depth of the pier is closely related to the near current velocity. Due to the complexity of the water flow, the influence law of the near current velocity on the local erosion of the pier has not been concluded at home and abroad.

2) Sediment factors. Three kinds of bed sand with different particle sizes were used and the results showed that the smaller the particle size, the easier the sediment is to start, and the larger the scouring pit depth. But when the particle size is small to a certain extent, the viscosity between the sediment began to play a role.

3) Pier factor. The study shows that pier factors such as pier length and pier width (or diameter) are an important factor affecting local pier erosion. The diameter of the cylindrical pier was changed in the erosion test, and the results showed that the larger the diameter was, the larger the scouring pit range was. Under the condition of clean water erosion, the maximum depth of the scouring pit increases first and then decreases with the diameter of the pier, while the maximum depth of the scouring pit increases with the diameter under the condition of moving bed scouring.

4. Protective Measures

Acluvial river around the pier local erosion is almost an inevitable problem, bridge designers in the bridge foundation design, must consider some protection works around the pier bed protection, to ensure the safety and stability of the pier, and in the bridge base erosion early or endanger the most appropriate protection measures to prevent the bridge gene naked and damage is the biggest challenge in engineering technology. So far, the local erosion protection project of the piers has been one of the important measures to prevent the bed surface erosion around the pier, pier instability and bridge water damage in the river trough.

According to the different scour protection principle can be divided into active protection and passive protection, from the change of scour object and sediment characteristics, to improve the anti-erosion performance of riverbed materials, this method is passive protection; in practical engineering, can add a base plate or protective ring near the riverbed elevation, to reduce the anti-scour performance, this "flushing reduction" protection method is the active protection.

4.1. Passive Protection

1) Riprap protection. It is the main pier protection engineering measure, its working principle is that the riprap protects the bed sand, increasing the flow rate required for the bed sand movement or lifting; second, the riprap can increase the local roughness near the pier, and also plays a positive role in reducing the flow rate near the pier.

2) Expand the protection of bridge pier foundation. The expansion of the foundation protection of the bridge pier refers to the protection engineering measures of burying the steel cofferdam

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into a certain depth below the river bed surface in the construction stage, then carrying out the lower pile foundation construction, the foundation construction is completed, then reserving a certain height above the bed surface, and then placing the bridge pier on the top surface. The main working principle of this protection method is to use the expansion of the top surface of the pier foundation.

3) Four-foot concrete block protection. Four-legged concrete blocks (tetrapods) were at first used for coastal protection. In 1993, The feasibility study of local erosion protection of four-foot concrete block is conducted[7]. It is found that the unique connection of the pier itself makes the four-foot concrete block with better stability than the size and quality of the retainer stone, and has a better protective effect.

4.2. Active Protection

1) Protection circle protection. Generally speaking, active protection works are more economical and practical, especially if there is not enough stone to mine near the bridge site. The coil protection method is a typical active protection engineering measure, which is protected by using the principle of the top surface of the coil to block and reduce the strength of the horseshoe vortex.

2) Bridge ier opening protection. The pier before the surface of the water and formed in the erosion pit front edge around the pier on both sides of the downstream of the combination of the horseshoe vortex led to the erosion of the bed around the pier, so one way to control and reduce the scour is to reduce the strength of the water and the horseshoe vortex, or completely prevent the formation of the two kinds of water flow structure. It is believed that the existence of the seam can make the downward water flow toward the riverbed deflect, this is because the seam makes the bottom boundary layer water flow itself like a jet acceleration, and when the seam is in the position near the river bed[8], will make the horseshoe vortex disintegration, when located near the water surface, the seam can well reduce the falling water flow and the horseshoe vortex.When the ratio of holding joint width to pier width is 0.25, the erosion depth increases with the erosion Angle. When the angle increases to 45°, the effect of reducing the scouring effect is almost gone.

3) Protection of front pier. Pier front pile protection refers to the upstream pier according to certain rules set a certain number of pile group, when the pier in the wake area of pile group, for pier local erosion protection pile itself will be washed by water, so it can make the pier before the high speed current direction deviation, and can form a wake area, effectively reduce the dynamic strength of vortex system around the pier, thus effectively curb the local erosion around the pier.

4) Submergence threshold protection. The submerged sill protection is an engineering measure to bury the bottom sill or corner sill of a certain distance upstream of the water surface to protect the bed surface around the bridge pier by affecting the scouring ability of the water flow.

The current protection methods in engineering are mainly passive protection, among which riprap protection is the most common. As mentioned above, although this kind of method is simple to operate, but because the passive protection is only to mechanically improve the anti-erosion ability around the mound soil, often need to repair and maintenance, the cost is high, the workload is large, especially when the water flow effect and the effect changes greatly, the riprap is easy to lose, resulting in serious economic losses. On the contrary, active protection focuses on the root of erosion, starting from the disturbance flow structure, reduce the role of the flow, so as to play a good protection effect, should be the future development direction of local erosion protection. This paper analyzes the mechanism of the local erosion of the bridge pier, and summarizes the action mechanism, the protection effect and the corresponding advantages and disadvantages. In order to better and better put the bridge pier protection measures into the engineering practice, the relevant theory and test research need to continue,

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and the relevant test equipment and technical means should also be carried out continuously. At the same time, we should continue to find the convergence point of active and passive protection, and organically connect the two, for all-round protection.

5. Conclusion

This paper discusses the local erosion mechanism, the evolution process, and influencing factors and protective measures. Due to the complexity of the pier local erosion phenomenon and the inherent limitations of traditional protection engineering measures itself, there has not been a sufficient theoretical basis and proved to be completely effective protection method, thus the new pier local erosion protection engineering measures and the combination of traditional protection effect of further research is very important practical significance.

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