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Local Erosion Mechanism and Protection Measures of Bridge Piers

Shuangping Liu*
Chongqing Jiaotong University, Chongqing, 400074, China
*Corresponding Author

Abstract

The pier is the supporting structure of the bridge, and its role is pivotal, and we must pay attention to the related problems of the pier. Therefore, this paper discusses the local erosion mechanism of bridge piers, summarizes the influencing factors of erosion, and finally sorts out the ideal protection measures for bridge piers, which basically solves the problem of local erosion of bridge piers that bridges deal with at present.

Keywords

Bridge Pier; Local Scour; Mechanism; Factors; Measures.

1. Introduction

After the bridge was built, in addition to the natural evolution of the riverbed, there was also river bed erosion caused by the disturbance of water flow and sediment movement by the piers, which were intertwined and carried out at the same time, and the washing process was very complex. In order to facilitate research and calculation, the maximum erosion depth of the pier is often divided into three independent parts: natural evolution caused by washout, general erosion and local erosion, and it is assumed that they occur sequentially. Due to the water flow impact and eddy action generated by the blocking flow of the bridge pier, a three-dimensional boundary layer is separated around the pier, resulting in a local water flow with high turbulence and high flow velocity characteristics, causing vortex and propagation and development downstream, resulting in a large bed shear force, and the local riverbed deformation formed around the pier is called the local erosion of the bridge pier [1].

According to statistics, most of the destruction of bridges is caused by water erosion, which not only has a huge impact on social security and economic development, but also has a huge hidden danger to people's life safety.

2. Mechanism

2.1. Study of Water Flow Structure

At present, scholars at home and abroad have generally believed that the water flow structure around the pier mainly includes four parts: the falling water flow in front of the pier, the horseshoe-shaped vortex around the pier, the boundary separation layer on the side of the pier and the tail vortex behind the pier.

Zhang Xinyan et al. [2] experiments show that due to the water blocking effect of the pier, part of the water flow in front of the pier passes around the pier, and part of it is dispersed into water flow in different directions up and down, resulting in dispersion of flow direction and velocity, and decrease of longitudinal flow velocity. In the part of the sink that is not affected by the piers, the water flow does not change significantly, and the original flow rate and flow direction are maintained. The lateral flow velocity is strongly turbulent around the pier, and the flow velocity distribution is disorderly, that is, the water flows around the pier on the left

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and right sides in front of the pier. These phenomena are obvious in the bottom flow rate, while the surface flow rate is different, as the observation fault develops downstream, the lateral surface flow velocity gradually increases, which is caused by the intervention of the pier and the decrease of the water cross-section. In general, the intervention of the pier changed the original water flow characteristics of the cross-flow section, and the flow velocity and flow direction changed.

Ren Yanfan et al. [3] model test observations show that the flow velocity distribution of the upstream section of the bridge pier is uniform. When the water enters the front of the pier, the streamline begins to separate, forming a certain range of low flow velocity area behind the pier, the water flow is turbulent, the flow state is very disordered, and the flow direction swings uncertainly, but the downstream flow velocity distribution of the pier is still symmetrical along the pier axis. When the water flow is hindered by the pier, the water surface in front of the pier produces a water phenomenon, forming a high Δh rush in front of the pier, and after the water flows through the pier head, it forms a horseshoe-shaped vortex close to both sides of the pier, and the water surface in the vortex is reduced to the lowest point (the point is in the upstream part of the bridge axis).

2.2. Study on the Evolution Process of Local Scouring Pits

Under the action of constant flow, the pier forward near the water flow and the downward pressure water flow to form a "pile through water flow", the pile water flow in front of the near water column pile flow velocity is the largest, vortex and sand lifting is the most serious, when the water flow shear stress is greater than the critical shear stress when the sediment starts, the sediment around the pile begins to start, part of it is taken to the downstream cover area to form a sand ridge, the other part of the sediment is taken away by the mainstream, the range of the scouring pit is formed soon after the start of scouring and tends to stabilize in a short time. With the passage of time, the volume of downstream silt volume is gradually increasing, resulting in increased resistance, gradually weakening of sand transport capacity, coupled with the gradual increase of the scouring depth and range of the erosion pit, making it more and more difficult to transport the sediment in the pit out of the pit, and only local adjustments are made in the scrubbing pit until the equilibrium scouring depth is reached.

Early research results generally believe that the bottom bed sediment begins to start, spin, take away from the original position, behind the silt pile group, thereby further changing the boundary conditions of water flow sediment movement, intensifying the disturbance of the water flow field, producing more complex and more numerous vortices, further intensifying the movement of sediment starting, spinning, taking away and dredging, etc., when the sediment erosion and dredging reach a dynamic equilibrium state, the bridge pier local erosion pit is formed.

3. Factors

3.1. Water Flow Factor

3.1.1. Velocity of Flow

Many scholars at home and abroad have studied the influencing factors of local erosion of bridge piers, and it is generally believed that there are clean water flushing and moving bed flushing. When the near flow velocity of the upper parade is less than the starting flow velocity of sediment, at this time, the local erosion pit of the pier has no upstream sand replenishment, which is called clear water washout; When the near-flow velocity is greater than the sediment starts flow velocity, the scour pit can get sand replenishment, which is called moving bed scouring.

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The view that "under clean water erosion conditions, the depth of local erosion increases in a straight line with the increase of near-flow velocity", while under moving bed erosion conditions, researchers hold different views. Wang Shunyi et al. [4] experimental results show that the maximum depth of local erosion increases with the increase of near-water depth. Ma Kui [1] believes that a large amount of sediment on the bed surface is started, and the sand is replenished in the erosion pit, and the change of the erosion depth with the increase of the flow rate is greatly weakened.

3.1.2. Depth

It is generally believed that when the approximate water depth is small, the local maximum depth increases with the increase of water depth, and when the water depth increases further, the local maximum depth and water depth are almost irrelevant.

3.1.3. The Water Flows at an Angle

The angle of water flow, that is, the angle between the direction of water flow and the circumference of the pier. Zhang Yingjie et al. [5] believe that the larger the angle between the bridge foundation and the water flow, the stronger the erosion effect on the waterfront surface.

3.2. Sediment Factor

The particle size, gradation, and relative roughness of the bed material all have an impact on the local erosion depth. For riverbeds of single materials, riverbeds can be divided into gravel beds, clayey soil riverbeds and sandy beds according to the particle size of the bedding material.

The equilibrium scouring depth of the gravel bed increased with the decrease of gravel particle size. For uniform gravel beds, the time required to reach the scouring equilibrium state increases with the increase of gravel particle size, and for uneven gravel, the time decreases with the increase of the geometric standard deviation of sediment particles. The size, density, disturbance degree, dry bulk density, etc. of the clay bed of the cohesive soil will affect the degree of erosion, and its effect should be investigated and studied for a long time.

Zhao Kai [6] sorted out according to the size of the particle and obtained that "the smaller the particle size, the easier it is for the sediment to start, and the greater the depth of the erosion pit, but when the particle size is small to a certain extent, the stickiness between the sediment begins to play a role, so that the depth of the erosion pit is smaller".

3.3. Pier Factor

The shape of the pier and the size of the pier also affect the time to reach the erosion equilibrium, which is one of the important factors affecting local scouring. Generally speaking, the longer the pier and the wider the pier, the deeper the local erosion generated at the pier head, because the length of the bridge and the width of the bridge reflect the compression degree of the structure to the water flow, the greater the compression, the greater the change of the water flow structure caused by the structure directly blocking the water flow caused by the structure, and the greater the effect of forming a strong vortex and river channel sediment around the pier head, the greater the erosion depth caused.

4. Measures

4.1. Principle of Erosion Protection

The principle of preventing local erosion of bridge piers is very simple and considers it from two directions. The first is to increase the anti-impact ability of the riverbed around the piers, so that the piers are more resistant to water erosion; The second is to reduce the energy of water erosion, so that the piers are washed by the water flow less.

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4.2. Erosion Protection Methods

4.2.1. Sacrificial Pile Protection Methods

A series of small-diameter piles are arranged upstream on the basis of the piers, and when the water flows over, it will first encounter the piles, so that the water flow rate is reduced and the energy is attenuated, so that the washing effect of the water flow on the piers is reduced, which plays a protective role.

Liang Fayun and Wang Chen [7] used the wave flow trough for model experiment, compared the erosion process of single pile, tandem double pile, side-by-side double pile and double row of four piles when there is sacrificial pile protection, and analyzed and studied the protection mechanism and dynamic evolution process, and obtained important conclusions: "sacrificial pile can effectively reduce the local erosion around the pier", "The existence of sacrificial pile makes the time required for piles to reach the flushing equilibrium state is also greatly shortened", ". The sacrificial piles laid in front of the pile foundation can still effectively reduce the erosion of the entire pile foundation."

4.2.2. Rock Throwing Protection Methods

The protective layer of rock throwing around the river bed around the pier is designed to enhance the erosion resistance of the soil around the pier, on the one hand, it increases the water flow force required for the sediment winding start, and on the other hand, its rough stones slow down the bottom water flow to a certain extent, thereby protecting the pier.

Yang Xin and Liang Fayun [8] concluded through case analysis: "Due to the loose granularity of the rock-throwing particles, the bed sand is easily taken away by the water flow from the gap between the rock-throwing particles, resulting in the embedded failure of the rock-throwing layer under the condition of moving bed, and the evasion measures of layered design, rock-throwing grouting, or wrapping the rock-throwing group with a net pocket can be adopted, in order to avoid excessive water pressure on the rock-throwing layer, the group should not be too large, so as to ensure the proper permeability of the rock-throwing layer."

4.2.3. Artificial Grass Protection Methods

After planting artificial grass in the river, it will produce a damming phenomenon and form a wake area behind the grass, resulting in a loss of flow rate, which can also play a protective role.

Yang Shaopeng and Shibing [9] preliminarily studied the influence of the arrangement density of several artificial grasses on the washing depth according to the model scale, and selected the appropriate arrangement density from the perspective of economy and construction, and carried out a series of experiments, which showed that when flushed with clean water, the combination of the protective ring and artificial grass could completely disappear the scouring, and the washing depth could be reduced by more than 40% under the condition of moving bed scouring.

5. Conclusion

The water blocking effect of the pier causes a sharp change in the water flow around the pier, resulting in the formation of local erosion pits, and the mechanism of the perimeter flow field under different water flow conditions needs to be further studied. Nowadays, the local erosion research of single pier is more common and mature, but the situation of multiple piers is more common in actual engineering, and it is necessary to approach the actual direction and study the situation of multiple piers thoroughly.

Bridges have gradually begun to develop into mountains and oceans, and we need to study the impact of tides, mudslides and other factors on bridge piers.

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