The Influence of Structural and Materials on Bridge Stability and Stabilization Measures

Hao Cheng*

Civil Engineering, Shijiazhuang Tiedao University, Shijiazhuang, China

* Corresponding author Email: stdzb@stdu.edu.cn

Abstract. Bridges are now not only an auxiliary tool for travel, but it is also an important way to measure a country's comprehensive strength. Because the stability of a bridge structure is affected by a variety of professional knowledge and various aids which made by advanced technology. So whether the bridge is stable and how to be more stable are the focus of discussion. This paper mainly analyzes and summarizes the stability of the bridge from the perspective of influencing factors and structural principles, and puts forward some measures which could improve stability accordingly. It includes the most common natural factors: earthquake and flood, which need to be considered from different perspectives due to their different failure principles and structures. As for the bridge structure itself, its upper and lower structures have cracks or lack bearing capacity, resulting in uneven settlement of the foundation. The sliding and tilting of the foundation and the local voids in the foundation are all factors that endanger the stability of the bridge. As for the effects of cracks, freeze-thaw denudation, scouring and grinding, cavitation erosion, water erosion, weathering and denudation of materials, they should be considered as important factors. Moreover, the improvement of the existing technology, such as strengthening the anti-corrosion layer, waterproof layer and protective layer, are also important.

Keywords: Materials; Structure; Stabilization Measures; Bridge Stability.

1. Introduction

Bridges play an important role in a country's transportation and economic development and serve as a link and throat to connect roads. Compared with other infrastructure, the cost of the bridge is relatively higher, the investment is larger, and the social benefit is greater than others. The direct or indirect loss caused by poor stability of bridges is an important part of bridge engineering. For example, the Yingkou Xiongyue Bridge in Liaoning province collapsed on August 1, 2006. The final result of this event was that two piers collapsed, two holes of the bridge plate collapsed, and 2 holes of the bridge plate sinked. In 2009, a viaduct on Hongqi Road in Zhuzhou, Hunan province, collapsed, killing nine people, injuring 16 and damaging 24 vehicles. Therefore, stability research and bridge inspection work are an important link in bridge construction engineering, which needs to take various effective measures to ensure the quality of the project.

Bridge stability and life span are key directions in bridge design and research. The present research mainly focuses on the study of studying different natural factors affecting bridge stability and reinforcement measures. However, these studies usually aim at a single bridge and discuss its characteristics. This paper analyzes and summarizes the stability of bridges from the perspectives of mechanics, influencing factors, and structural principles, and puts forward some measures for stability accordingly.

2. Factors affecting stability

The main factors affecting the stability are natural disasters and the change in the structural system of the bridges.

2.1 Natural Disaster

Natural disasters are the most common factors that damage the stability of bridges. For example, earthquakes, floods, fires and other irresistible natural factors are also important factors threatening the stability of bridges. They can reduce the service life of the bridge, and cause corrosion and collapse of the bridge deck.

2.1.1. Earthquake

The earthquake could cause foundation failure, resulting in two kinds of damage: foundation failure caused by the damage and structural vibration caused by the damage. The latter often causes the bridge pier foundation asymmetry and different damaged components.

In the bridge structure, the impact and Influence of earthquakes on different bridge components are different, and the damage type and damage degree of the bridge are also vastly different. There are four primary causes of earthquake hazards in bridge engineering.

1) The soil mass on both sides of the bridge slips under the Influence of topography and geomorphology changes in the bridge area. The bridge structure could be damaged by soil mass, thus affecting the integrity and safety of the bridge.

2) The strong earthquake effect can cause the bridge foundation damage, the riverbed sandy soil liquefaction, and the ground surface roughness of the bridge area. Finally, the original foundation structure sinks, and the whole bridge is damaged, adversely affecting the stability and safety of the bridge's structure.

3) The internal force of the bearing bridge has a certain limit standard. If the earthquake influences the bridge's structure and material form, it cannot meet its internal force change and its existing bearing limit. It can also cause the corresponding integral stability of bridge structure damage and bridge's safety.

4) There could be a series of bridge pier damage, such as the surface of the bridge pier fracture and bridge structure exposure, bridge shape distortion, or skew. It could harm and affect the overall performance and quality of the bridge.

2.1.2. Flood

The flood not only forms a violent erosion of the pier foundation of the bridge, but in the case of carrying wood and stone, would impact the bridge causing the bridge understructure to tilt or be directly destroyed, sometimes directly washing down the entire bridge deck.

Floodwaters can wash loose, corroded soil near the piers, making the bridge unstable. After the bridge's construction, the bridge hole compresses the riverbed, which reduces the area of water passing under the bridge and increases the water velocity, so the water's sand-carrying capacity greatly increases. The water erosion causes the soil near the bridge pier to become soft, which greatly reduces its bearing capacity, so the contact point between the bridge pier and the ground could continue to rise, posing a threat to the bridge deck. At the same time, the rain with a low pH value erodes the pier, causing irreversible harm.

In addition, the drifter carried by the flood can impact bridges and make them unstable. Bridges are usually built between different terrains, so drifter mixed in the water could constantly hit the piers, causing the structure to withstand forces from different directions, eventually creating cracks. If the forces are too large, the bridges collapse.

2.1.3. Other Natural Factors

Fire is also one of the most likely disasters, and its damage to the bridge is very serious. The light could burn the surface of concrete components, resulting in concrete spalling and steel bar exposed outside. Severe situation could cause the entire lower body of the bridge to be destroyed.

2.2 Influence Of Bridge Structure And Constituent Materials

In addition to natural disasters, the stability of bridges is also affected by the structure and materials. The structures and materials could age and deform after a long time of work, and these changes may

cause defects and collapse. For example, on October 1, 2019, the Nannanao Cross-Sea Bridge in Yilan, Taiwan Province, was corroding underwater all year round, resulting in structural instability and collapses. Some bridges are very old. The trunk of a bridge carrying passenger traffic receives different forces such as gravity, pressure, deformation, and pit collapse, and eventually, the bridge collapses.

2.2.1. Structure

The structure of a bridge is a direct factor in the bridge's stability. The causes and influences of structural defects differ due to the difference in the bridge's upper and lower structures and functions.

As for superstructure, crack is the most common defect. For example, main beam or arch ring tensile cracking, damage, and bearing capacity decline. Bridge deck pavement cracks, subsidence, cracking, bridge jump car. The waterproof layer drainage function is imperfection. Water leakage phenomenon causes steel corrosion, concrete stripping. Support position is incorrect or damaged caused by tilt, wrong platform, and displacement, which causes more damage to Bridges. For instance, cracks appear in the Baoshan Bridge superstructure in Beijing, leading to the deterioration of structural stability. Therefore, when heavy objects pass by, the cracks increase and the bridge collapse.

As for the substructure, the defects and diseases of the foundation are mainly manifested. The bridge pier's insufficient bearing capacity causes the foundation's uneven settlement. The pier, abutment defects, and diseases are primarily shown as horizontal, vertical and mesh cracks, concrete falling off, void, material aging, reinforcement leakage and corrosion, structural deformation, and displacement.

2.2.2. Materials

Different materials undergo physical and chemical changes when exposed to the natural environment for a long time, leading to cracks and corrosion of the materials, thus affecting the bridge's stability.

2.2.2.1. Cracks

When the tensile stress in concrete is greater than its tensile strength, or tensile strain is greater than its ultimate tensile strain, concrete produces cracks. The first is overload cracks. When the compressive strength of the designed concrete is not enough or overload is used, local tensile stress occurs in part with high compressive stress, which often leads to local pressure crack or even local crushing. It is characterized by several short cracks in the local pressure area roughly parallel to the pressure direction.

The second is bending cracks: when the tensile stress in the tensile zone exceeds the tensile strength of concrete, bending cracks often occur. Its characteristics are as follows: transverse cracks appear from the edge of the tensile zone near the maximum bending moment section, and gradually expand to the neutral axis; At the same time, with the thread rib, the short crack happens between the cracks.

The third is mesh crack when the concrete has irregular cracks intersecting the horizontal level, called mesh crack or crack. Basically, because that concrete mixes, transport time is too long, which makes moisture evaporate and cause concrete to pour when slump falls to spend low, making concrete appear irregular net crack. In the initial stage, due to watering inadequately or encountering windy weather construction, the concrete surface becomes dry quickly, and appears plastic shrinkage state. It can produce an irregular crack in the concrete surface, and general depth is shallower.

The fourth is the crack caused by steel bars corroded in concrete. After the steel corrosion in concrete, the volume of the corrosion product would be 2~4 times larger than the original expansion, resulting in expansion stress on the surrounding concrete. When the expansion stress exceeds the tensile strength of concrete, it produces cracks, which generally develop along the length of reinforcement and the rib crack.

2.2.2.2 Concrete Carbonation and Steel Corrosion

Concrete carbonation and steel corrosion are common in bridges. Investigation shows that when carbonization depth approaches or exceeds the concrete protective layer thickness, the reinforcement

in the concrete could rust. General cracks occur in the bridge with poor concrete quality. The reinforcement corrosion degree is also serious, and smooth reinforcement cracks would be produced more than before. With reinforcement corrosion, concrete cracking, spalling, the cohesion of reinforcement and concrete would continue to lose. At the same time, the cross-sectional area of reinforcement reduces, and bearing capacity declines. These phenomena could reduce the safety strength of the structure, and then the structural damage accident may occur.

2.2.2.3 Denudation

According to different mechanisms, denudation can be divided into freeze-thaw denudation, erosion and cavitation erosion, water erosion, and weathering denudation. Different denudation causes different damage to bridges.

First is freezing-thawing denudation. Below water saturation or wet state, positive and negative temperature changes could cause the concrete structure to harden, gap water freezes expansion, dissolve relaxation, and produce fatigue stress. It could cause concrete from the outside to the inside gradually denudation damage phenomenon. The damage phenomenon of freezing-thawing denudation reduces the effective cross-sectional area of reinforced concrete structures such as piers, beams, slabs and piles. It induces steel corrosion, accelerating the aging process and declining structures' bearing capacity and stability.

Next is blunt wear and blank corrode. Empty corrode is that general expression is in the partial position on the surface of the pier that flows appear blank and rust pit, but another place is intact, corrode pit depth sometimes amount to a few centimeters. Blunt wear and corrode general area is more significant, have certain continuity. When the erosion and cavitation damage develop to a certain extent, a large area of hydraulic erosion damage may be induced.

Water denudation includes sulfate erosion, acid attack, and alkali attack. It is a common denudation phenomenon. The harm is not significant.

3. Reinforcement Technology And Measures

3.1 Materials

3.1.1. Design Of Waterproof Layer

In the areas with more rain and flood, highway bridges show different quality problems such as collapse, mainly related to ponding and rain erosion. Too much water could reduce the density of the bridge deck, then easy to leave ruts and even partial falling off of cement, exposed steel bar and other problems. Therefore, in the design of highway bridges, the design of the corresponding waterproof layer or the design of the introduction of certain waterproof factors can increase the bridge's safety. At the same time, in the design process, it should also be arched to design the bridge deck, usually should control the arched degree below 5%. It could direct water to both sides of the bridge deck, and drainage pipes and trenches could be set up on both sides to export accumulated rain water quickly .

3.1.2. Thickening Protective Layer Design

As the concrete bridge easily produces cracks, these cracks could lead to rain leakage water leakage, which leads to serious steel corrosion. To reduce and avoid this phenomenon, the most common measure is to thicken the actual protective layer of concrete. Composite materials such as reinforced concrete are often used to increase concrete pressure. Steel bars have a certain strength and concrete can be used to fill and cast hollow areas. Concrete also protects steel bars, which are often vulnerable to external corrosion, such as rust, oxidation, and chlorination. Surrounded by concrete, it could cause corrosion. It is noted that the role of the concrete also has double effects, and would significantly affect the steel in concrete components. If too much sand and stone are added to the concrete, it would seriously wear the steel bar when the concrete and steel bar appear relative displacement, or some of the chemicals mixed with them would directly corrode the steel bar, forming irreversible corrosion.

However, the common reinforced concrete would seriously damage the ecological environment, and the cost is also very high, so steel fiber concrete is gradually introduced. Steel fiber concrete refers to the concrete adding a few short steel fibers. In addition to being stronger, steel fiber is a less expensive concrete material than conventional reinforced concrete. At the same time, the compressive and tensile strength of steel fiber concrete is much greater than that of reinforced concrete. By comparing these two kinds of materials, concrete with steel fiber can reduce the number and size of crack formation, avoid the rapid crack deterioration, extend the service life of highway bridges, reduce maintenance costs, and improve the overall benefits further. Therefore, steel fiber should be popularized and applied as a new type of concrete in the design and construction of highway bridges.

3.1.3. Anticorrosive Coating Design

As a material in the main structure of highway bridges, reinforced concrete has been widely used in highway bridges. However, reinforced concrete is still severely restricted in some key places. For example, some highway bridges attached to the pier structure are a "V" or "W" shape. This method in low-lying locations often has water. If there is no professional cleaning personnel to clean up this kind of water, the water could penetrate the cracks in the concrete surface and further penetrate the inside to corrode the steel bar. To avoid this phenomenon, adding new materials could improve the construction design. For example, cementing agents such as epoxy resin is relatively mature reinforcement anti-corrosion materials. Coating this material on the surface of reinforcement to form a layer of anti-corrosion coating will play a very obvious role and reduce the probability of accidents [8-11].

3.2 Structure

3.2.1. Strengthen The Stability Of The Bridge By Changing The Structure

In order to improve the bearing capacity of the bridge, the primary method to change the structural strengthening method is to add bracing or bridge pier and stiffening beam or composite beam such as steel frame under the beam. After adding main beams, the bridge's load can be redistributed, the load in the original beam can be reduced, and the bearing capacity and stiffness of the reinforced bridge can be improved. This method is suitable for intact beam structure foundation, and the bearing capacity cannot meet the occasion's requirements.

Due to the different causes of structural stability of Bridges, this paper provides suggestions for the upper and lower parts, respectively. As for the bridge substructure, the common measures are to reinforce the bridge's foundation, increase the bridge's pile position, and replace some of the older pier. At the same time, we should pay attention to the choice of the bridge shape. For example, round or square can better withstand earthquakes, and the base material needs to be waterproof. As for bridge superstructure, it can pass to widening thickening of the upper part of the road surface to reduce the bearing capacity of per unit area. It can also use high-strength composite materials such as steel or carbon fiber paste to reinforce the road surface and reduce vehicles.

3.2.2. Strengthen The Stability Of The Bridge By Repairing The Structure And Materials

There are many kinds of bridge materials, and different materials can be repaired and strengthened differently. There are wooden, stone, reinforced concrete, steel, and concrete bridges in China. But the material of most of the bridges is reinforced concrete, because the cost of these materials is relatively low, and the application is extensive. But such materials are also prone to problems, low bending, compression performance, and cracks, especially in earthquake-prone areas. The main repair methods at present are surface plastering, grouting and pressure grouting for the treatment of these cracks.

Many roads and bridges need steel and other materials. These materials are susceptible to oxidation corrosion, which requires effective processing, such as cathodic protection, aluminized zinc layer, physical shielding, and chemical corrosion. Using these methods can better protect bridges from unprotected ones while maintaining must carry on adequate protection, preventing danger due to material oxidation corrosion.

The external adhesion reinforcement method refers to the reinforcement method that uses adhesives such as epoxy resin to paste materials such as section steel and glass fiber reinforced plastics on the outside of the structure to improve the bearing capacity of the structure. Preloading pressure to the tension zone can offset certain deadweight stress. This method is suitable for the structure with limited component size, which must greatly improve the bearing capacity.

4. Conclusion and suggestions

Increasing protection and nursing is the most effective protection method for maintaining bridges, and the quality of bridges should be guaranteed when they are built. It cannot appear to be a jerry-built situation, in accordance with the relevant provisions of the state to ensure quality and speed of construction. At the same time, the choice of materials can not violate the law of nature. It must be based on the actual situation and reasonable materials. If the quality control in the construction process of road and bridge is not strict, or there are cracks in the asphalt of road and bridge, it is easy to lead to a large range of damage phenomenon after it is put into use. The roughness of roads and bridge is an important index of engineering construction. If the roughness of the road is not well controlled during construction, the roughness of the road and bridge could decay quickly. And if the road is not smooth, it could reduce the speed, increase driving turbulence, increase impact and damage vehicles and other problems, affecting the use value of roads and bridges. Cracks and damage of asphalt on roads and bridges, large areas of cracks and damage appear soon after the operation. The reason for this situation is the quality control problems in constructing roads and bridges. Currently, pavement engineering is in pursuit of flatness, ignoring the requirements of compaction. The improper mix of materials lead to asphalt under standard, making the pavement base bearing capacity insufficient, coupled with water erosion and sunlight, which causes the pavement asphalt concrete easy to crack.

If the road surface of the bridge does not have enough strength or the strength of the soil base of the road surface is not balanced, it would lead to cracking of the cement road surface. In addition, if you choose to start this project in spring or autumn, due to the large temperature difference between day and night, the concrete pavement is very easy to lead to slab fracture under the action of stress. As long as the cement pavement of roads and bridges breaks, it would greatly affect the pavement's smoothness. In the construction of roads and bridges, the pavement cracking is caused by insufficient or uneven strength of the soil foundation of the pavement, or because the project is constructed in spring and autumn, resulting in a large temperature difference between the concrete pavement during the day and at night, resulting in a larger warpage stress resulting in the slab cracking of the pavement.

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