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Research on Reinforcement Method of Small Span Stone Arch Bridge Main Arch

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Abstract: There are many stone arch bridges in our country, in the long time of operation, there are some diseases in the stone arch bridges. They seriously affect the normal use and capacity of the bridge and the service life of the bridge. Therefore, it is necessary to carry out maintenance and reinforcement and reconstruction to improve the load level. This paper research the several stone arch bridge upper structure reinforcement technology, analysis of the reinforcement mechanism of arch bridge, the characteristics and the applicable range of, and of these reinforcement technology were compared and analysis to on the basis of better use them for stone arch bridge reinforcement.

Keywords: Stone arch bridge; maintenance and reinforcement; Reinforcement mechanism; Construction technology

1. Introduction

The stone arch bridge is an ancient bridge, which occupies in the national bridge in the proportion accounted for about 61%. In the high mountains and deep valleys southwest area which has abundant stone, stone arch bridge is accounted for more than 90%, and it has become a scenery line of the local. But this kind of small span stone arch bridge are most in a bad state of disrepair, more or less developed diseases. If the abolition of the old bridge reconstruction not only waste of money, but hold up the traffic, and the old bridge reinforcement technology has the advantages of saving investment, shortening construction period, uninterrupted traffic which has remarkable advantages in social and economic fields.

The main arch as the main load-bearing structure, the emergence of disease causes the most serious consequences. In addition, the main arch reinforcement can significantly improve its carrying capacity, which is the focus of old bridge reinforcement.

2. Analysis of Common Diseases and the Causes of the Main Arch

2.1. The crack of arch ring

Main arch ring appears along the bridge, cross bridge to or diagonal cracks, some cracks along the mortar joint expansion, some appear in the stone arch, other throughout the mortar and the arch stone. To crack, the arch length, width and depth for different sources showed different characteristics.

Causes of crack formation are as follows: (1) the main arch overall strength insufficient; (2) construction quality causes of cracks, such as concrete mixing, transportation , sinking of support, premature release, uneven subsidence; (3) the change of the external environment caused by cracks, such as steel bar corrosion, chemical action, uneven settlement of foundation, vehicle access exceed the design load.

2.2. Arch axis deformation

Arch bridge arch axis shape will affect the distribution and size of the cross section of the internal force of the main arch. In general, the principle of selecting the arch axis is to reduce the bending moment due to the load as much as possible. The ideal arch axis is coincident with the pressure line under the load, so that in each section of arch only have axial force and without bending moment. But because the load on the bridge is not fixed, and the main arch is not only effected by the constant load and live load, but also by the temperature, shrinkage and arch foot displacement effect, which makes the design arch axis can not coincident with the pressure lines. Under the action of the above factors, the arch axis of the existing arch bridge will deviate from the original design arch axis, which will affect the force of arch bridge.

2.3. Masonry materials disease

Common diseases of masonry materials include weathering, honeycomb holes, cobalt rich crusts, deformation, surface deposition, loss, erosion, rust, powder and other, and main causes of these diseases are the natural porosity, the relative complex chemical composition, the influence of river water and the influence of the external load and the environment.

3.The Arch Reinforcement Theory

Under the action of load, the stone arch bridge not only bear the axial force generated by the load, but also bear the bending moment and shear force. Because of the shear effect is relatively small, so the structure of the stone arch bridge is a load-bearing structure of the bending members. According to the basic principle of the mechanics of materials, the formula is:

$$\sigma = \frac{N}{A} \pm \frac{M}{W}$$

In the formula:

σ : Tensile (compressive) stress of the main arch section;

N: Axial pressure of main arch cross section;

A: The main arch section area;

M: Bending moment of main arch section;

W: The bending elastic modulus on geometry of main arch section.

From the above equation, the structure stress condition of main arch stone arch bridge is determined by three factors, i.e.: the internal force produced by load (axial force and bending moment), the main arch section area and bending modulus of elasticity, the material strength of the main arch. At present, there are many ways to reinforce the stone arch bridge, which can be divided into two angles of external and internal factors. From the external cause is mainly by changing the properties of the structure, which is an increase of the main arch section and increase the intensity of the main arch, in order to improve the bearing capacity of the main arch. From the internal cause is mainly used to change the structure of the system and reduce the dead load of construction on the arch , namely, to reduce the internal force of the main arch ring and reduce the arch construction with the constant load, improving the bearing capacity of the main arch. In short, the basic principle is to reduce the tensile stress of the main arch.

4. Common Reinforcement Method

4.1. Reducing the weight of superstructure on the arch

Existing stone arch bridge mostly use abdomen building as the main body, but due to the constant weight of the construction on the arch is usually large, so the constant load occupies with a large proportion, especially the solid spandrel stone arch bridge. Therefore, it is urgent to need a kind of effective method to improve the ability of the bridge to bear the live load, that is, to reduce the proportion of constant load in the main arch.

There are ways to reduce the weight of the bridge:

a) changing the filling material or reducing the thickness of the filler on the arch

b) using reinforced concrete column instead of the gravity transverse wall on abdomen or hollowed it out

c) replacing the bulky abdominal hole arch on the main arch with a light spandrel construction

d) replacement of the ventral hole system with the light deck system

The reducing the weight of superstructure on the arch is shown as Figure 1.

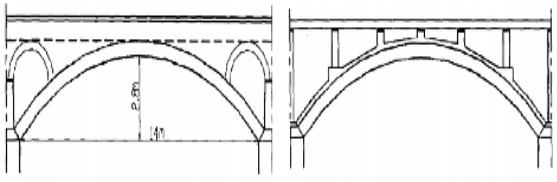

Figure 1. Reducing the weight of superstructure on the arch

The utility model has the advantages of using the original arch structure, improve the load-carrying capacity of the structure in the case of removal of the main arch ring. The disadvantage is the need to dismantle the arch filler, removing with a larger workload, and there are security risks in the process of dismantling; At the same time because of the added weight of concrete need owner arch load, its bearing potential is weakened to a certain extent; construction process also will influence the road traffic.

4.2. Bonding steel plate in the abdomen of arch

The bonding steel plate method is to use the epoxy mortar to paste the steel plate in the structure of the tensile area or weak parts, so as to form a whole with the structure. The specific method is: Firstly, cleaning the sticking surface of steel plate that is in accordance with the requirements of specifications with wire brush, then washing by cotton which is dipped in acetone. In doing this, first in the original bridge paste parts of the surface, brushing a layer of epoxy resin mortar, interval for a moment and laying a layer of epoxy resin mortar evenly in the plate, then sticking the steel plate to the original bridge paste parts, screwing the inflated screws by pressure to make the excess mortar along the edges of the plate squeezed out, so as to achieve the compactness. On the surface of tensile region or weak part of stone arch bridge component (surface for compression zone can also paste steel plate, but considering the concrete good compression performance and relatively low price, for the compression zone often used cast-in-place or strengthened reinforced concrete jet), steel plate and original structure can shaped into the overall joint force, in order to improve the stiffness and strength of the whole bridge, improving the stress state of the original structure and limiting the further development of crack, so as to achieve the purpose of strengthening and improving the bearing capacity of the bridge. The Bonding steel plate in the abdomen of arch is shown as Figure 2.

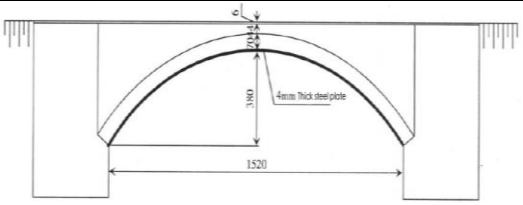

Figure 2. Bonding steel plate in the abdomen of arch

It has the advantages of no need to remove the arch construction, does not interfere the traffic and reduce the clearance under the bridge. In addition, the increase load of the original structure is very little, while the damage is relatively smaller. At the same time, construction is faster, simpler, and more economical. The disadvantage is that the quality and durability of the adhesive epoxy mortar is the main factor to the strengthening effect, and need to maintain the bonded steel plate.

4.3. Anchor grouting reinforcement technique

Firstly to implant anchor into the main arch ring so that the bolt can hang steel mesh, then spraying adding accelerator of high-strength concrete to structure surface, forming composite main arch. Close together with the new and old concrete, forming a whole, increasing the size of the original structure, and coordinate with the main arch ring deformation, share part of live load, so as to improve the bearing capacity of bridges. The advantages are that the amount of the demolition works is small, the traffic interference is low, and the construction is fast The disadvantage is that the injection of concrete in the freezing front as a load to be borne by the original structure, so that the bearing capacity of the original structure is affected; Because the span of the bridge is not large, the amount of shotcrete is limited, it will affect the quality of the injection; At the same time, due to the limited operating space, the quality of construction will also have a certain degree of impact.

4.4. Reinforced concrete casing hoop sealing technology

Along the outside of the main arch ring cast-in-place added a layer of reinforced concrete confinement layer, using "section increases, fracture mechanics and the confinement effect "three mechanism to achieve the purpose of enhancing the bearing capacity of the original bridge. In order to make the main arch force in more reasonable form, reinforced concrete hoop layer along the longitudinal direction should adopt varying section, from the cross to the foot of the arch. Sometimes for the inconvenience of top surface of arch, it also can be used L type arch rib to enhance, that is only along the side surface and the bottom surface of main arch to cast reinforced arch rib while set up a beam strengthen ties. The Reinforced concrete casing hoop sealing is shown as Figure 3.

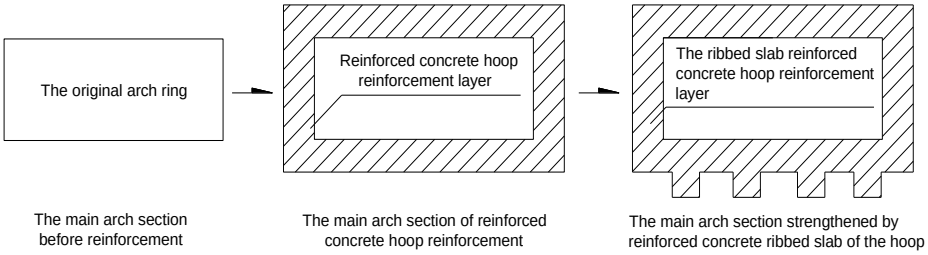

Figure 3. Reinforced concrete casing hoop sealing

The reinforcement effect is obvious, with greater strength and rigidity, weathering resistance, water erosion ability, also the strengthened main arch surface is smooth and more beautiful. The performance of confinement layer and the original arch combination is better, no durability problems, and the increase of bearing capacity is very big.

5. Conclusion

Now the main arch stone arch bridge reinforcement technology and methods commonly used are the following: reducing the weight of superstructure on the arch, bonding steel plate in the abdomen of arch, anchor grouting reinforcement technique and reinforced concrete casing hoop sealing technology. This paper from the aspects of strengthening mechanism, technical features and application scope are discussed, compared and analyzed, on this basis, in order to use them better for the reinforcement of stone arch bridge business service. And learning from each other, giving full play to the advantages and avoiding disadvantages in order to develop a more efficient and economic practical stone arch bridge reinforcement technology. For the reinforcement of the stone arch bridge, because of the factors to be considered and the problems involved are many. In the selection of reinforcement technology, the internal and external factors should be analyzed, and the technical feasibility, economic, using performance and so on ought to be fully considered. In addition, according to the actual situation of the project, to select the most reasonable reinforcement technology, also can use a variety of methods of strengthening the combination, so that the reinforcement effect to achieve optimization.

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