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Research on Reinforcement of Tunnel Lining for Beneath the Stadium

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Abstract: Highway tunnel of beneath the stadium was put into use. It will lead to deterioration and reduce the carrying capacity of the structural material for the impact of geological conditions and terrain conditions and weather conditions and other factors. With the passage of time, most tunnel structure safety, applicability and durability of the early greatly reduced because of the structure of the aging, degradation, and lack of maintenance for a long time. Facing the task of highway tunnel repair reinforcement, steel belt reinforcement technology is convenient and high efficiency and good durability and the advantages of small perturbation, which is expected to be applied in tunnel lining reinforcement.

Keywords: Beneath the stadium; Tunnel structure; Maintenance; Steel belt reinforcement

1. Introduction

In the middle of the 60's in twentieth Century, the technology of strengthening the steel sheet was first appeared in South Africa and France. After about half a century, the technology of steel reinforced by the technology has been widely used in bridge engineering, water conservancy projects and industrial and civil construction. Many countries have already compiled the relevant design codes or regulations, which provide a powerful basis for the popularization and application of the technology and the healthy development of the technology. However, due to the reinforcing member affected by the complexity of mechanism and failure modes of the diversity, foreign scholars of bonded steel plate reinforcement technology in-depth research has been carried out, in order to further improve the bonding steel plate strengthening design theory.

In China, the first successful application of structural glue to the structure of steel reinforcement is in 1978. In our country, French company J Besim first adopted STADUR-31 building structure glue for some concrete beam of steel bonded reinforcement. In 1981, the Institute of Dalian, Chinese Academy of Sciences developed our own architectural structure JGN-1 and JGN- II. The development of the sticky steel technology in China has played a great role in promoting.

The technology of strengthening lining is a new type of tunnel strengthening technology. The technology is attached importance to highway maintenance department because of its convenient construction and no damage to the original structure. At present, the paste in the strengthening of reinforced concrete structure has reached a considerable level. It has been widely used in building, bridge repair and reinforcement, and achieved considerable economic benefits. However, the research in this field is still in its infancy, and the research is small and the system is not, and the research in tunnel is lagging behind. Based on the crack of the highway tunnel lining in the stadium, the paper uses the steel plate to paste reinforcement method. The selection and proportion of materials were determined. The reinforcement mechanism, lining cracking and lining stability were analyzed, and the key points and quality control of tunnel repair were put forward.

2. Paste steel reinforcement method and composition

The reinforcing method of steel plate bonding is the tension or weak spot of the steel plate and the steel plate in the concrete structure by using epoxy resin series adhesive. It can improve the bearing capacity of the lining, and a strengthening method of reinforcing effect. The main advantages of this method are: The structure of the original structure that is not destroyed basically; No change in structure size; In the short term can complete the reinforcement project, after the maintenance 3D, then can open the transportation; Economic application, the cost is not high. The following aspects should be noted in the following aspects of strengthening the lining by strengthening the steel plate and reinforcing the reinforcement method.

2.1. Adhesive

Epoxy resin material has strong strength and corrosion resistance, anti permeability, and can be bonded with concrete and other materials, which is a good repair material. General selection of epoxy resin adhesive, it has good bonding strength with the "glue" in the world.

2.2. Material selection and matching

(1) Epoxy
As the basic liquid, it is a kind of epoxy group in molecular chain. It is of high chemical stability and good construction operation. It is the general term of polymer condensation.
(2) Curing agent
Generally choose ethylenediamine. The epoxy resin itself is a molecular structure of the line. Therefore, we must add curing agent to form cross-linked structure formation. The structure is an insoluble and insoluble solid with good properties. Accelerate curing, shorten the process time. The dosage decreases with the increase of temperature.
(3) Toughening
Generally choose two butyl ester. The epoxy resin is brittle and added to the toughening agent. It can improve the impact toughness and improve the cold resistance and vibration resistance, and increase its anti stripping strength and decrease the shrinkage rate. But it cannot be used too much, the general control in the 20% ~ 15%, otherwise it will reduce the mechanical strength of the adhesive.
(4) Packing
Generally choose cement. Cement can change the surface hardness, increase the cooling effect and prevent the flow glue and easy for construction operation. The main purpose is to improve the hardness and compressive properties. It should choose the new production of cement.
(5) Ratio
Epoxy resin, ethylenediamine, two butyl ester, cement ratio is shown in Table 1.

Table 1. The ratio of schedule

Material name	Epoxy resin	Ethylenediamine	two buty ester	Cement
Quantity of use	100g	8-10g	20-25g	400g

3. Strengthening Mechanism

In this paper, the adhesive with good adhesive properties is used to take the technology and technology of adhesive bonding. Depending on the adhesive force of the adhesive, the plate is closely glued to the weak part of the component, and the pressure curing makes it a structure whole. Under the action of the external force, the steel plate and the member can coordinate each other in common deformation and joint force [1].
Because of the increase of the overall stiffness of the member, the mechanical performance is improved, and the bending resistance and shear resistance of the strengthened member are improved. The service life of the member is prolonged, and it has good antiseptic effect.

3.1. Strength checking

The strength of the lining structure of the tunnel is checked at present, and the calculation method of the reinforced concrete rectangle section eccentric compression member is adopted. The magnitude of the eccentricity affects the structure directly [2].
When the eccentricity of the E is smaller, 0<e<0.17h. The section is in the compression condition, when the compressive stress is higher than the concrete compressive strength, and the concrete performance is the compression damage.
When the eccentricity of E is increased, 0.17h<e<0.3H. Because of the increase of eccentricity, the distance of the section is increased, and the tension stress is the tension stress of one edge. That is, the concrete cracks in the tension zone, but the damage form of the cross section of the cross section is still under the compressive edge compressive stress, which is more than the compressive strength of concrete. The concrete occurs crushing damage.
When the eccentricity is e>0.3h, the side of the cross section is pressed and the other side is pulled. With the increasing of the tensile stress and tension crack expanding, the compression surface area decreased. The failure mode of the cross section is close to the failure state of the flexural member.
(1) The basic assumptions
Lining structure is generally bending members, according to bridges and other structures of bonded carbon fiber sheet. By bending of the design and calculation of the following assumptions:
a. The steel belt only carries the load bearing capacity under the live load, so it can calculate the stress state according to the corresponding elastic modulus ratio;
b. Flat section assumption;
c. Regardless of the tensile strength of concrete;
d. The ultimate strain of concrete is $\varepsilon_{cu} = 0.0033$, the ultimate strain of ordinary steel is $\varepsilon_s = 0.01$.
(2) Normal stress calculation
According to the principle of structure design, the equilibrium equations are calculated in the allowable stress method: $\sum x = 0$; $\sum M = 0$.
(3) Normal section strength calculation
According to the structural design principle, the ultimate load bearing capacity of the section is calculated, and the ultimate load carrying capacity of the section is M_u, and it satisfies the $M_J \le M_u$.

3.2. Cracks develop analytical methods

(1) Determining the occurrence of cracks
Whether the crack appears can be determined by the formula of the crack resistance [3]. For general tunnel lining, the formula for the crack resistance of the reinforced concrete eccentric compression member is:

$$N_{cr} = \frac{\gamma f_{tk} A_0}{\frac{e_0 \bullet A_0}{W_0} - 1}$$

For the tunnel lining after steel belt reinforcement, the formula for the crack resistance of eccentric compression member is:

$$N_{cr} = \frac{\gamma f_{tk} A_n}{\frac{e_0 \bullet A_n}{W_0} - 1}$$

(2) Cracks sectional stiffness reduction

After the crack appears, the concrete is out of work, and the concrete area of effective compressive stress is reduced. The concrete and compressive steel are gradually shifted from elastic to plastic, and the load deflection curve slope decreases, and the compressive rigidity and bending rigidity of the lining section are decreased.

In the structural analysis, the compressive stiffness is determined by EA, and section height of the lining structure is h0, and the crack section of the lining section is highly denoted as x, the compression stiffness is the reduction factor:

$$\alpha = x / h_0$$

The bending rigidity is determined by EI, and the change of bending rigidity can be realized by changing the inertia moment I value. The reduction coefficient of the inertia moment I of the lining section of the stress stage and the improvement of the inertia moment I of the steel tape at each stage of the lining section are shown in Table 2.

Table 2. The reduction coefficient of lining section moment of inertia and the strip increase of section moment of inertia

The value of inertia moment I	$N < N_{cr}$	$N_{cr} < N < N_y$	$N_y < N < N_u$
I reduction factor	0.85	1/4-1/2	1/10-1/20
I coefficient of enhancement	3%	25%	100%

(3) Lining section strength checking

In order to ensure the safety of the lining structure, it is needed to calculate the strength after calculating the structural internal force [4]. The strength safety factor K should be introduced when the section strength of the component is calculated at the failure stage. That is:

$$k = \frac{N_{Jixian}}{N} \geq K_{Gui}$$

For the lining area without steel belt reinforcement, the strength of the bearing capacity formula of the ultimate section of the reinforced concrete eccentric member is checked.

Big bias damage:

$$N = f_c bx + f_y' A_s' - f_y A_s$$

$$N \bullet e = f_c bx\left(h_0 - \frac{x}{2}\right) + f_y' A_s' \left(h_0 - a'\right)$$

Small bias damage:

$$N = f_c bx + f_y' A_s' - \sigma_s A_s$$

$$N \bullet e = f_c bx\left(h_0 - \frac{x}{2}\right) + f_y' A_s' \left(h_0 - a'\right)$$

For the steel tape reinforced concrete lining section, the strength of the reinforced concrete eccentric load is calculated by the calculation formula of the ultimate bearing capacity of the reinforced concrete eccentric member.

Big bias damage:

$$N = f_c bx + f_y' A_s' - f_y A_s - E_{cf} \varepsilon_{cf} A_{cf}$$

$$N \bullet e = f_c bx\left(h_0 - \frac{x}{2}\right) + f_y' A_s' \left(h_0 - a'\right) + E_{cf} \varepsilon_{cf} A_{cf} \left(h - h_0\right)$$

Small bias damage:

$$N = f_c bx + f_y' A_s' - \sigma_s A_s - E_{cf} \varepsilon_{cf} A_{cf}$$

$$N \bullet e = f_c bx\left(h_0 - \frac{x}{2}\right) + f_y' A_s' \left(h_0 - a'\right) + E_{cf} \varepsilon_{cf} A_{cf} \left(h - h_0\right)$$

Limit state ($\varepsilon_{cf} = [\varepsilon_{cf}]$):

$$N = f_c bx + f_y' A_s' - f_y A_s - E_{cf} [\varepsilon_{cf}] A_{cf}$$

$$N \bullet e = f_c bx\left(h_0 - \frac{x}{2}\right) + f_y' A_s' \left(h_0 - a'\right) + E_{cf} [\varepsilon_{cf}] A_{cf} \left(h - h_0\right)$$

4. Lining cracking analysis

The cracks caused by the lining structure of the tunnel are the comprehensive reflection of the load bearing process and the change of the internal force state of the lining. The cause of the crack is closely related to the structural form of the lining, the size and distribution of the rock pressure, the distribution, construction method, engineering quality and building material factors [5]. The investigation and analysis of the cracks in the existing lining can help to determine the cause of the cracks more accurately, and adopt the reasonable structure of the lining.

The crack is divided into tension, tension and shear crack according to mechanics. The edge of the crack is crushing. In severe cases, the surface compression zone will produce scaly debris peeling off block, pressure, band splitting phenomena such as crisp. Irregular crack development direction, closed or unclosed ring, oblique direction and transverse direction and longitudinal and cross split; The edge of pull crack is neat, roughly along the longitudinal tunnel development. But there are also oblique crack. The depth of the radial and crack width decreases gradually with the depth of the crack depth. Severe tension rupture is often accompanied by dislocation; The width of the shear crack is generally the same as the

depth of the surface; The lining of the lining has a wrong movement along the crack direction; Shear fracture and crack or fracture often have a close relationship.

The scale of the crack includes the number of cracks, the spacing, the length, the width, the depth, etc.. The size of its size directly reflects the damage of the lining. Japan and other countries often conduct a structure of the important indicators of health levels. Through some research and summary, we can establish the quantitative evaluation index of lining damage in China.

5. Lining stability analysis

When the arch part appear some small width of tensile cracks and cracking of lining section compression stress has not yet reached the ultimate compressive strength and cross section of plastic hinge, and arch still has certain strength reserve. This situation should be effective with steel strip reinforcement. When the arch section inner appear fracturing fracture or width larger crack, and outer concrete may also have been crushed, and cross-section of the effective cross section is reduced greatly, and produce larger local compression deformation. At this point, if the cracks appear more than two, or while the wall is also moving at the same time, and the lining has basically lost stability. This kind of situation by changing the arch or steel reinforcement for concrete analysis: when the lining appear shearing and along the shear crack surface displacement, and structure has lost stability should not be used to strip reinforcement scheme; For improve the strength and tensile strength of structure seismic complete lining, carbon fiber reinforcement [6] and steel with reinforcement is worthy of serious consideration.

6. Patch points and quality control

First, the crack of the tunnel is repaired and the crack is repaired and then pasted with steel plate, so as to meet the design requirements of the joint force between the steel plate and the concrete [7] belongs to technical strong work. The effect of the strengthening of the steel is mainly on the bond construction quality. When reinforcing steel plate, the surface of the steel plate should be smooth and straight, and the contact between the steel plate and the lining surface is made of epoxy adhesive. The sticking steel plate should be blasting and paste before cleaning with acetone dry.

Before the steel plate, the contact parts of the lining concrete surface should be cut to 2 ~ 3 mm. Then, the surface of the compressed air is used to remove the surface dust, and the surface of acetone is rubbed with acetone. The lining and steel plate surface should keep dry, it is found that the surface dry wet timely application of fan. When the steel plate is pasted, the adhesive should be filled with the paste, and the adhesive should not stay void.. The glue liquid of the edge of the secretion should be cleaned in time, and the appearance of the liquid is clean.

When construction besides should follow the technological requirements and pay attention to the following:

1) The construction time ZL-JGN [8] structural adhesive after the completion of the preparation. After the configuration of good structure adhesive, it must be finished before its beginning to finish coating, fixed and other items [9];

2) The extent of concrete surface. The concrete surface must be carefully polished and remove the deterioration of parts of the surface of the concrete structure layer until his complete;

3) Close degree of plate fixation. In the fixed plate, the concrete member must be fully affixed, at least to the sides of the steel plate and the adhesive agent, leaving no gap;

4) In order to guarantee the quality of the glued steel, each procedure shall have a professional control and inspection, and the acceptance shall have the acceptance. For example, bear the brunt of the as related inspection record, fill in the treatment of primary single concealed, strict inspection for steel grinding condition, welding quality, acetone brushing situation, the full degree of structural adhesive, structural adhesive proportion and so on. This is to avoid the quality problems such as hollowing irremediable. Such as quality problems, timely rework to reduce the loss.

7. Conclusion

(1) At present, the reinforcement of highway tunnel lining repair technology is still backward, and urgently need to be in the new materials and new technology adoption intensify research;

(2) Highway tunnel lining cracking analysis is the foundation of highway tunnel lining reinforcement;

(3)Simple technological equipment, easy operation, wide application;

(4)Fill the fast, efficient, reliable quality, the effect is obvious;

(5)The results show that the crack lining can improve the structure's load and the load carrying capacity of the structure. So in engineering practice, when the cracks and damage of highway tunnel occur, we should adopt the reinforcement measures as soon as possible and strengthen the structure and improve the structure system security.

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