Application of CFRP Reinforcement Technology in Culvert Pipe

Dan Li1,*, Yuebo Li2
1Wuhan University of Engineering Science, Wuhan, China
2Kunming University, Kunming, China

*Corresponding author e-mail: 125281883@qq.com

Abstract. This paper put forward analysis and design for a worn drain pipe reinforced by CFRP. In engineering practice, it can solve the absent problems.

1. Preface
Structural reinforcement is often necessary not only for the existing structure, but also for the structure under construction. This is because the structure under construction (or newly built structure) will be damaged, cracked and other diseases due to a variety of reasons. At the same time, it will change the load and modify the design due to the actual requirements. Therefore, it is necessary to reinforce the original structure.

When a high-rise building in Wenzhou was built to the 8th floor, many cracks appeared in the beams, columns and shear walls of the 5th floor; after the completion of the construction of a high-rise building in Guangzhou, the design of the 10th floor was modified and the load was increased; the tunnel lining of a highway section in Yunnan Province was damaged due to the landslide and the load was increased. This kind of situation puts forward new problems for structural reinforcement. It is the main work for the structural reinforcement workers to solve the above problems to carry out structural analysis and failure mechanism analysis, reinforcement design and reinforcement treatment.

In view of the damage of the drainage culvert pipe under a tailings dam in the construction process, this paper puts forward the structural analysis opinions, carries on the reinforcement design, organizes the implementation of the reinforcement project, and checks the effect after reinforcement, which has a good reference and reference value for similar problems.

2. Project overview
The project is located in Saishitang ranch, Xinghai County, Hainan Tibetan Autonomous Prefecture, Qinghai Province, belonging to Saishitang copper mine. The altitude is 3350-3750m. The tailings dam of copper mine is a directional blasting dam, which is located in the west fork of nongmugou in the mining area. The initial dam height is 39.61m, and the length of the drainage structure - culvert under the dam (reinforced concrete structure) is 470m. The inner diameter of the pipe (two specifications) is 1200mm between 6 # - 8 #, and 1500mm below 6 #. The wall thickness is 300 mm. The culvert pipe is divided into types and reinforced by sections. Generally, Φ10, Φ12, Φ14 (spacing 100 to 300 mm) are provided longitudinally, and φ8 @ 200 and φ10 @ 200 are provided circumferentially.
After the completion of directional blasting, the pile meets the design requirements to form the dam body, but the culvert pipe is damaged in different degrees due to the impact of soil mass. The brief description is as follows:

1) The culvert pipe collapses in the middle of the dam body, with a length of about 8.0m;
2) According to the water outlet at the head of culvert pipe under the dam, the culvert pipe structure with a depth of 0-95.0m has not been damaged, the concrete protective layer on the inner surface of culvert pipe between 95.0m-106.0m has fallen off, the reinforcement has collapsed and exposed, and the damaged area is 11.0m long and 0.5m wide.
3) The depth is 108.6m-126.8m, the concrete protective layer on the inner surface of culvert pipe falls off, the reinforcement collapses and is exposed, the total length is 18.2m, and the widest part is 0.3m.
4) When the culvert pipe is 132.0m deep, there is a 1.5m long and 0.5m wide hole at the top of the right slope. The concrete falls off, and the reinforcement mesh is seriously deformed into a basket shape, with the deformation size of 500mm. The external sand and soil enter the pipe. At the same time, the reinforcement under the left slope is also exposed and severely deformed.
5) There is horizontal shear dislocation of some pipe sections, the dislocation is about 0.3m away from the bottom of the pipe, the length runs through the whole pipe section (6m), the dislocation value is about 200mm, in the form of steps, and the steel bars also yield and bend into steps.
6) Some pipe walls also have cracks.

3. Reinforcement design scheme

3.1. Design basis
1) Survey and inspection report of damage;
2) Cecs 25: 90, standard of China Engineering Construction Standardization Association, technical code for strengthening of concrete structures;
3) Standard of China Engineering Construction Standardization Association technical code for strengthening and repairing concrete structure with carbon fiber sheet.

3.2. Design scheme of reinforcement technology
The preliminary design of reinforcement is based on the damage of different pipe sections of culvert.
1) Reinforcement of culvert pipe where the protective layer of reinforcement falls off and reinforcement collapses.

![Figure 1. Preliminary design plan of reinforcement 1.](image)

For the falling part of the protective layer, the steel bar shall be derusted first, and then the resin mortar shall be used for repair to the original thickness of the protective layer; Stick a layer of carbon...
fiber along the damaged section, 1000mm wide. For anchoring, the length shall be 1 m beyond both ends of the damaged area; Paste a layer of glass fiber around (Fig. 1).

2) Reinforcement of culvert pipe at 132M depth

Fill the soil material into the pipe in the reverse direction into the hole, and compact the soil material outside the pipe (if necessary, transport the clay for filling) until it does not collapse and can be used as the external form of Backfill Concrete; Reset the deformed steel bars, increase the reinforcement (welding) on the basis of the original reinforcement, and remove the rust; Clean the damaged concrete; Pour concrete of one grade higher than the pipe wall strength at the broken hole; After formwork removal, a layer of 1500mm wide and 2500mm long carbon fiber (l200-c) shall be stuck inside the pipe; In the damaged part of the lower left corner, the resin mortar is used as the protective layer of the reinforcement, and then a layer of 1500mm wide and 17m long carbon fiber (l200-c) is pasted; A layer of carbon fiber (l200-c) with a width of 500mm shall be glued to each section with a spacing of 300mm along the axis of the pipe for reinforcement. (Fig. 2)

3) Repair scheme for destructive dislocation of culvert pipe body

Chisel and clean the damaged and misplaced places; Grout and seal the cracks at the dislocation position, and then repair and restore the concave and uneven parts; continuously paste the steel plate with a thickness of 3mm and a width of 150 mm, and after the steel plate is stable, fully stick a layer of l200-c carbon fiber (Fig. 3).
4) Repair plan of pipe wall crack
   All cracks with a joint width greater than 0.3mm shall be sealed or poured with special structural glue to protect the internal reinforcement of the pipe wall.

4. Mechanical analysis of reinforcement

4.1. Calculation results of glass fiber cloth model in reinforced concrete pipe
After calculation, the internal water pressure bearing limit value of the carbon fiber cloth model attached to the reinforced concrete pipe is 0.59mpa, at this time, the reinforced concrete Mises stress value is $0.509 \times 10^{-4} \sim 0.228 \times 10^{-3}mpa$, and the carbon fiber Mises stress value is $1556mpa$, as shown in Fig. 4 and Fig. 5 (in which, the carbon fiber stress at the boundary of Fig. 5 is more affected by the stress concentration, so the calculated carbon fiber Mises stress is at the stress continuity point in the figure Is the calculation result).

![Figure 4. Stress diagram of reinforced concrete unit](image)

![Figure 5. Stress diagram of carbon fiber unit](image)

4.2. Calculation results of glass fiber cloth model in reinforced concrete pipe
After calculation, the bearing limit value of internal water pressure of reinforced concrete pipe with glass fiber cloth model is 0.61mpa, at this time, the maximum reinforced concrete Mises stress value is $0.128 \times 10^{-4} \sim 0.526 \times 10^{-4}mpa$, and the glass fiber Mises stress value is $398.371mpa$, as shown in Table 1, Fig. 6 and Fig. 7 (in which, the glass fiber stress at the boundary of Fig. 7 is relatively large under the influence of stress concentration, so the calculated glass fiber Mises stress is The continuous stress in the figure is the calculation result).

![Figure 6. Stress diagram of reinforced concrete unit](image)

![Figure 7. Stress diagram of glass fiber unit](image)
Table 1. Model calculation results.

| Working condition       | Structural type                      | Position                                      | Results           |
|-------------------------|--------------------------------------|-----------------------------------------------|-------------------|
| Uniform internal water  | Concrete culvert pipe                | Ultimate internal water pressure              | 0.35MPa           |
|                         |                                      | Ultimate stress of reinforced concrete        | 1.989 MPa         |
|                         | Reinforced concrete culvert pipe with carbon fiber cloth inside | Ultimate internal water pressure              | 0.59MPa           |
|                         |                                      | Ultimate stress of reinforced concrete        | 0.228×10^-3 MPa   |
|                         |                                      | Mises stress of carbon fiber                  | 1556 MPa          |
|                         | Reinforced concrete culvert pipe with glass fiber cloth inside | Ultimate internal water pressure              | 0.61MPa           |
|                         |                                      | Ultimate stress of reinforced concrete        | 0.526×10^-4 MPa   |
|                         |                                      | Mises stress of carbon fiber                  | 398.371MPa        |

5. Conclusion

The results show that:

1) Compared with the original concrete pipe, the internal water pressure bearing limit value of carbon fiber reinforced concrete pipe is increased by 68.6%, and that of glass fiber reinforced concrete pipe is increased by 74.3%.

2) The main stress components after reinforced concrete pipe are carbon fiber cloth and glass fiber cloth.

3) Carbon fiber and glass fiber have not reached their respective yield strength in the process of stress, which shows that the concrete culvert pipe strengthened by carbon fiber and glass fiber has a large safety reserve.

4) The ideal elastic-plastic element is used to simulate the concrete, carbon fiber and glass fiber materials in the finite element calculation. However, due to the material quality, construction technology and other reasons in the actual engineering application, the mechanical properties of materials have certain discreteness, so when the finite element calculation is applied to the engineering, the constitutive relationship of materials needs to be modified.

The reinforcement project has been completed and fully meets the structural requirements.

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