Nonlinear Analysis for Steel Lined Reinforced Concrete Penstock

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Abstract—Steel lined reinforced concrete penstock is commonly used as a hydraulic structure in recent years. Because of the complex structure of the penstock, so far no design specification can follow at home and abroad. In this paper, general finite element calculation software is used to conduct nonlinear analysis, the stress of the steel liner with the increased internal pressure variation elastoplastic distribution of outsourcing concrete and the development law of joints cracked concrete for the penstock of Yisa River Station II. Analysis shows that, the steel lined reinforced concrete penstock design of the I I Hydropower of Yi Sa river is reasonable, pressure piping structure will not crack occurred in the design load, the structure meet the strength requirements, the deformation values of pressure pipelines is small and meet the stiffness requirements. The design of structural is economical, safe and reliable.

Keywords- Steel lined reinforced concrete; Penstock; Nonlinear analysis; Stress distribution; Analysis section.

I. SUMMARY

Yisa River Station II is located in Yuanjiang County, Yunnan Province, and the total installed capacity is 25MW. Plant water flow is 3.6 m³/s and the biggest work stress of pressure pipeline is 994 m water head. Most of the catch-water pipeline is out steel tube structure, but the end of main pipeline uses steel lined reinforced concrete pipe structure, and the steel pipe radius is 1.0m. The designed internal pressure of pipe is 9.94MPa, and the depth of internal steel lining of pressure pipe is 22mm. It uses steel plate 16MnR, and the elasticity modulus is 210GPa, the yield strength 330MPa. The depth of outsourcing of reinforced concrete is 0.4m, and the upside of it is thick wall cylinder, the central angle of it is 210°, and the downside is the connection of the flat base and the foundation. Its strength grade of concrete is C25, and the grade of rebar is II. Tangent modulus of elasticity is 200GPa, and the Poisson's ratio is 0.25[1], yield strength of it 310MPa, the secant Young's modulus 20GPa, and two layers of reinforcement is used at the ring. The diameter of the inlayer is 28mm and the number is 9, and the outer layer’s is 22mm and the number is 8[2].
III.

IV. STRUCTURAL ANALYSIS OF PRESSURE PIPE

A. Analysis of the Section

When using the three-dimensional nonlinear finite element analysis of the steel lined and reinforced concrete penstock from the Yi Shahe river hydropower station, we should remove the cross section shown in Fig. 3.
B Process Analysis of Cracking

The results show that with the increase in the water pressure, pressure piping structure mainly has the following stages:

1. \(0 < P \leq 10.134\text{MPa}\). The internal water pressure entirely is born by the steel-lined, but the concrete does not work because in the water pressure at the inner steel liner radial displacement has not filled the gap of 0.55mm, which is that the steel liner and the concrete do not completely contact so that all the internal forces completely are composed by the steel. When \(P = 10.134\text{MPa}\), the gap between the steel liner and the concrete full contact, then if we continue to increase the pressure on this situation, the internal forces will pass through the spring element to transfer the surrounding concrete with together working by the concrete and steel liners.

2. In the situation of stress between 10.134MPa and 13MPa with about 45 degree angle, the local fractures appear in the interior of the concrete. But the fractures in this situation is only small part of it and don’t develop cracked stripes.

3. In the situation of stress between 13MPa and 17MPa, the first cracked fractures appear in the surface of concrete located in 45 degree angle as well as the first cracked stripe. At the same time, the buckling of concrete enters the part plastic state.

4. In the situation of stress between 17MPa and 19MPa, at the top of concrete pipe during 45 and 135 degree angle, many fractures appear. Those fractures are cracked fractures. At the same time, the concrete enter the fully plastic state and already have been broken without capacity of bearing internal water pressure. The stress of 19MPa is the ultimate bearing capacity of steel liner and concrete joint bearing.

C Stress Analysis

At the given water pressure the pipe circumferential stress behind the dam and the surrounding concrete pressure are shown in Fig. 4 to Fig. 7.

As can be seen from Fig. 4 to Fig. 7, the value of circumferential stress in the steel liner is gradually increased with the increase of the inside water pressure, the maximum stress on the surrounding concrete extend outward from the inner surface, which is mainly due to cracking of the concrete, inner stress is gradually released, the maximum stress gradually extended to the outer ring.
V. CONCLUSION

In summary, the steel lined reinforced concrete penstock design of the II Hydropower of Yi Sa river is reasonable, pressure piping structure will not crack occurred in the design load, the structure meet the strength requirements, the deformation values of pressure pipelines is small and meet the stiffness requirements. The design of structural is economical, safe and reliable.

REFERENCES


