Finite Element Simulation Calculation of Reinforced Concrete Precast Inverted Siphon

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Abstract—Inverted siphon is a common conveyance structure, in order to have a clear understanding for stress and deformation distribution of inverted siphon structure, researching mechanical characteristics of inverted siphon structure. Precast inverted siphon has advantage of quick construction speed, easy control of construction quality, etc. This paper adopts the universal finite element calculating software to simulate and calculate precast inverted siphon, and gets stress and deformation distribution of inverted siphon under the most unfavorable conditions, and provides beneficial reference to the design and application for the reinforced concrete precast inverted siphon project. The results showed that, Liziwan inverted siphon engineering adopts precast inverted siphon is safe and economic, in the construction and operating process, inverted siphon's stress and deformation values are smaller, the stress and deformation values can meet engineering requirements.

Keywords-Precast inverted siphon; Finite element method; Simulation calculation; Circumferential stress; Deformation distribution.

I. INTRODUCTION

Liziwan inverted siphon project is located at Dongfeng lateral canal in the Meishan county, Sichuan province, its controlled basin area is 10000 mu. Inverted siphon pipe is reinforced concrete precast pipe, concrete strength grade is C25, reinforced strength grade is II, length of each pipe is 1 m, effective length is 0.9 m. Concrete strength grade of concrete lining at the bottom of pipe is C20, pipe laying on the soil base that is heavy clay at horizontal section and sandy soil at slope section[1]. Inverted siphon pipe is single round pipe, inner diameter is 0.8 m, wall thickness is 0.1 m, design discharge is 1.0 m^3/s, velocity is 1.99 m/s, design head is 18.4 m, head loss is 2.0 m, minimum head is 17.2 m, total length is 196.5 m.

II. STRUCTURAL CALCULATION MODEL

A Material Parameters.

Liziwan inverted siphon project adopts reinforced concrete precast tube structure, thickness of concrete lining at the bottom of pipe is 0.3 m, concrete strength grade of inverted siphon pipe and concrete lining is C20, elastic modulus of concrete is 25.5 GPa, poisson's ratio of concrete is 0.167, bulk density is 25 kN/m^3. Reinforced strength grade is II, elastic modulus of concrete is 200 GPa, poisson's ratio of concrete is 0.28[2-4]. Soil base at horizontal section simulated in the calculation model is heavy clay[5-7], compression modulus is 22 MPa, poisson's ratio of concrete is 0.30.

B Calculation Model.

When establishing structural finite element calculation model for inverted siphon, we uses eight node isoparametric brick element SOLID65 to simulate inverted siphon pipe and concrete lining, this element is the special element to simulate concrete or rock, can set volume reinforcement ratio of concrete structure in all directions or anisotropic properties of rock[8]. We uses eight node isoparametric brick element SOLID45 to simulate foundation[9]. The calculation model simulates and calculates Liziwan inverted siphon project at horizontal section, simulation range is 59 m along the flow direction, 20 m at the transverse that is perpendicular to the flow of water, 19 m at the vertical that is perpendicular to the flow of water, finite element calculation model shows in the Fig .1.

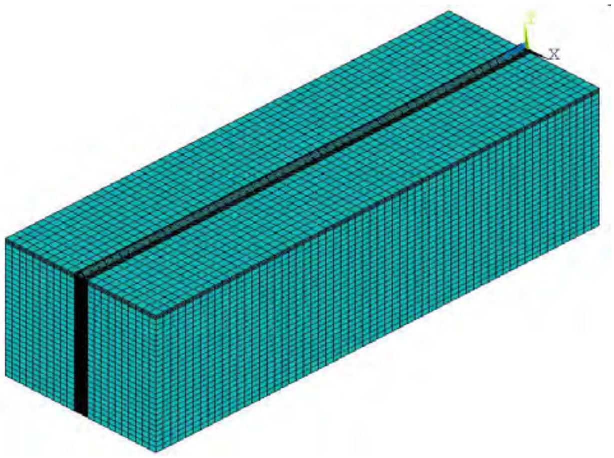

Figure 1. Finite element calculation model of inverted siphon

C Calculation Cases.

Liziwan inverted siphon project, design head at horizontal section is 18.4 m, minimum head is 17.2 m. Simulation calculation mainly considers the following 3 kinds of calculation cases[10]: case 1, dead weight of inverted siphon (construction case); case 2, dead weight and minimum head 17.2 m (operation case); case 3, dead weight and design head 18.4 m (operation case).

III. ANALYSIS OF CALCULATION RESULTS

A Stress Analysis.

Through simulation analysis to the Liziwan inverted sipho at horizontal section in the process of construction and operation, under case 1 maximum hoop tensile stress of inverted sipho is 0.11 MPa, that appears at top of inverted sipho's middle section at horizontal section, maximum hoop compressive stress is 0.16 MPa, that appears at bottom of inverted sipho's middle section at horizontal section. Under case 2, maximum hoop tensile stress of inverted sipho is 0.86 MPa, that appears at top of inverted sipho's middle section at horizontal section, maximum hoop compressive stress is 0.05 MPa, that appears at bottom of inverted sipho's middle section at horizontal section. Under case 3, maximum hoop tensile stress of inverted sipho is 0.92 MPa, that appears at top of inverted sipho's middle section at horizontal section, hoop compressive stress does not appear. Fig .2 and Fig .3 respectively shows the first and the third principal stress contour map of inverted sipho's middle section at horizontal section under case 3.

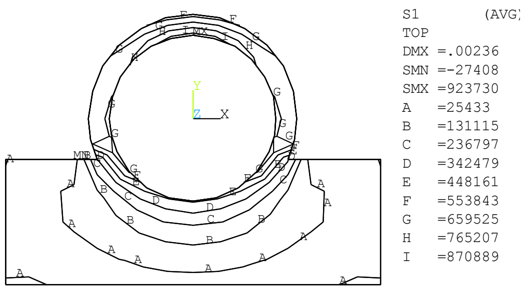

Figure 2. The first principal stress contour map of inverted sipho (Pa)

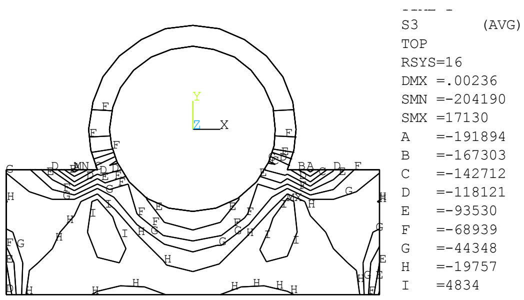

Figure 3. The third principal stress contour map of inverted sipho (Pa)

As can be seen from the Fig .2, the maximum first principal stress of inverted sipho appears at top of inverted sipho's middle section at horizontal section, this is mainly due to the stiffness on the top of inverted siphon pipe is small, water pressure causes large tensile stress on the top of pipe, the first principal stress decreases from the inner surface to outside surface at the bottom of pipe. As can be seen from the Fig .3, the third principal stress of inverted sipho's middle section at horizontal section is compressive stress basically, and on the border of inverted siphon and concrete lining stress distribution is more complicated, change dramatically, this is mainly because the angle on the border causes the stress concentration phenomenon. When Construction, the angle on the border can be erased or reserve expansion joint that can reduce the stress concentration problem.

B Deformation Analysis.

Deformation analysis results show that under case 1 maximum radial displacement outward of inverted siphon is 2.02 mm, that appears at bottom of inverted sipho's middle section at horizontal section, maximum radial displacement inward is 2.02 mm, that appears at top of inverted sipho's middle section at horizontal section. Under this case inverted siphon is uniform subsidence, this is mainly inverted siphon dead weight cause foundation's heavy clay is compressed and produce displacement. Under case 2 maximum radial displacement outward of inverted siphon is 2.35 mm, that appears at bottom of inverted sipho's middle section at horizontal section, maximum radial displacement inward is 2.34 mm, that appears at top of inverted sipho's middle section at horizontal section. Under case 3 maximum radial displacement outward of inverted siphon is 2.36 mm, that appears at bottom of inverted sipho's middle section at horizontal section, maximum radial displacement inward is 2.34 mm, that appears at top of inverted sipho's middle section at horizontal section. Fig .4 and Fig .5 respectively shows radial displacement nephogram of inverted siphon under case 1 and case 3.

As can be seen from the Fig .4 and Fig .5, under 2 kind case, radial displacement value is close, distribution is same, displacement is basically vertical subsidence displacement, overall subsidence displacement is around 2 mm.

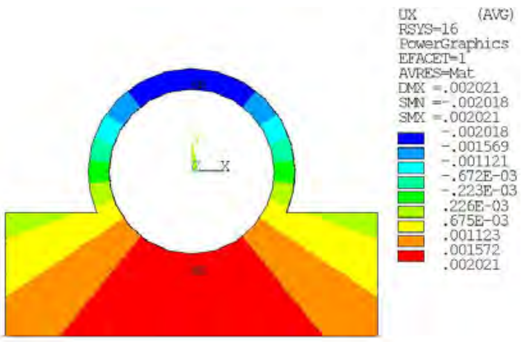

Figure 4. Radial displacement nephogram of inverted siphon under case 1 (m)

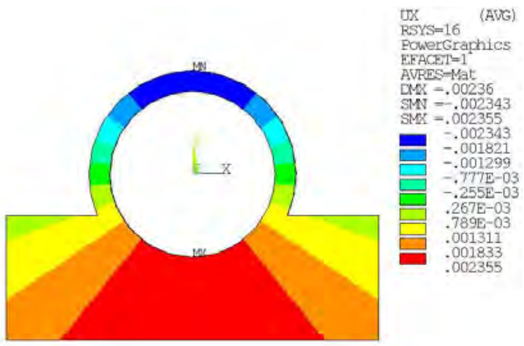

Figure 5. Radial displacement nephogram of inverted siphon under case 3 (m)

IV. CONCLUSION

Above results analysis shows that Liziwan inverted siphon project using precast reinforced concrete pipe structure is safe and economic, stress and deformation value of inverted siphon during construction and operation period is small and can meet the engineering requirement.

REFERENCES

[1] Xiaopei Sun,Xiaoling Wang,Ruirui Sun et al. Numerical Simulation for Water Conveyance of Inverted Siphon [C]. Advances in civil engineering II.2013:2407-2410.

[2] SL191-2008. Design Code for Hydraulic Concrete Structure[S]. China Water Conservancy and Hydropower Press, 2008.

[3] Juan Li,Zhenwei Mu,Lin Li et al. Numerical Simulation and Model Test on Hydraulic Characteristics of Long-Distance Inverted Siphon [C]. Advances in Hydrology and Hydraulic Engineering.2012:1112-1116.

[4] Cheng Zibing,Wang Feng,Yan Wei et al. Experimental study on inverted siphon channel in South-to-North water diversion project [C]. Advances in hydraulic physical modeling and field investigation technology.2011:685-689.

[5] Guangxin Li. Advanced Soil Mechanics [M]. Tsinghua University Press, 2005.

[6] Wenliang Ma,Weifang Zou. Three-dimensional finite element analysis of trench-buried inverted siphon structure [C]. 2012 7th International Conference on System of Systems Engineering. 2012 :380-382.

[7] Lun-Yan Wang,Lei Guo. Analysis on Concrete's Measures for Qin river Inverted-Siphons in winter [C]. Proceedings of the third international conference on modelling and simulation. vol. 2, Modelling and simulation in engineering.2010:70-73.

[8] Jianjing Jiang, Xinzheng Lu, Lieping Ye. Finite Element Analysis of Concrete Structures [M]. Tsinghua University Press, 2004.

[9] Xucheng Wang. Finite Element Method [M]. Tsinghua University Press, 2003.

[10] Huiying Li, Wenduo Tian, Haixin Yan. Inverted Siphons [M]. China Water Conservancy and Hydropower Press, 2006.