Study on the Sedimentation of Power Branch Tunnel under Turbid Water Test

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Abstract. Combined with the actual project of a hydropower station, the turbid water test is used to verify the sedimentation of the power branch tunnel under the sand discharge conditions. The results show that under the sand discharge conditions, there are different degrees of siltation outside the recirculation zone of the power branch tunnels in the bifurcation section, and the siltation form is a delta siltation form. The sedimentation volume of the power branch tunnel is related to the sediment discharge flow in the sand discharge pipe. The greater the sediment tunnel flow, the greater the sedimentation in the cecum section of the power branch tunnel when the siltation balances.

1. Introduction
Reservoir desilting is an important link to solve the problem of reservoir siltation and maintain the long-term effective storage capacity of the reservoir[1]. It has important practical significance for determining the operation method of the reservoir and developing the function of the reservoir. There have been a lot of studies on the way of sand discharge in reservoirs, and there are gravity current discharge and open flow sand discharge that rely on water flow[2,3]. Regarding the gravity current of the reservoir, Fan Jiahua conducted a more in-depth study on the gravity current observation and laboratory experiment of the Guanting Reservoir in the 1950s. According to the early production needs, it is analyzed and studied the sediment discharge characteristics of the Sanmen gorge reservoir, Qingtong gorge reservoir, Hengshan reservoir, etc. It is obtained a large number of research results which have a common understanding of the sand discharge rules of the reservoirs. These studies pay more attention to the study of the mechanism of different scouring forms of the reservoir and the study of a single sand discharge method[4]. In the actual application of the reservoir, the sand discharge includes the scouring amount of the incoming sediment and the previous silt. The amount of sediment discharged is closely related to the water level process in front of the dam, the process of water and sand flow into the reservoir, and the topography of the reservoir area[5]. It is a complex process of interaction of various factors.

The desilting tunnel and expansion project of a hydropower station is located on the left bank of the hydropower station. Its main function is to use the gravity current to directly discharge the incoming sand through the desilting tunnel during the flood season. In the non-gravity current period during the
flood season and the non-flood season, the constant flow water that keeps the entrance section "clear at the door" is used to generate electricity.

The desilting tunnel and expansion project are unique in terms of project layout and project application, and there are few related similar projects. In order to predict the hydraulic characteristics and sediment scour and silt characteristics of the water diversion system of the desilting tunnel and the power station, improve the layout of the water diversion system, and solve possible water flow and sediment problems as much as possible, it is necessary to carry out research work on the water flow and sediment model test of the water diversion power generation system. It plays an important role in ensuring the normal operation of the project and giving full play to the benefits of sand removal and power generation[6].

2. Test model

The bottom plate of the surge tank used in the model turbid water test is funnel-shaped, and the impedance hole is a round pipe with a diameter of 4.6m. The bottom of the impedance hole and the upstream gradual change section of the bottom of the surge well are connected by a broken line (1.5m*3m, 0.5m). The size of the upstream 20m transition section from the bottom of the surge tank is 12m×7m (width×height), and the top of the gate section gallery is arched. The specific layout of the surge tank is shown in Figure 1.

![Figure 1. Photo of the layout of the surge tank used in the model turbid water test.](image)

3. Test conditions

The working conditions of this turbid water test are shown in Table 1. In the turbid water test, during the siltation test, the siltation situation was observed and recorded at intervals of 10 to 30 hours, and the observation lasted until the silt deposition at the silt deposition site reached equilibrium.

In the scouring test, for the silt deposited in the cecum section of the desilting tunnel, the arc-shaped working door at the exit of the desilting tunnel opened at a normal speed (opened in about 12 minutes). Closing the power station before the sediment tunnel drain sand.

| Usage             | Conditions | Upstream/downstream water level (m) | Sediment tunnel flow(m³/s) | Sand content(kg/m³) |
|-------------------|------------|------------------------------------|---------------------------|---------------------|
| Turbid water test | 1          | 1735/1623                          | 850                       | 100~150             |
|                   | 2          | 1725/1623                          | 600                       | 95~125              |
|                   | 3          | 1735/1623                          | 600                       | 120~140             |
4. Test results
When the power station is closed and the sediment tunnel drain sand, due to the inertia of the water flow, the water flow on the left side of the sediment tunnel enters the power branch tunnel from the right side. Due to the blocking of the cecum section of the power generation branch tunnel, it returns to the sediment tunnel from the left side of the power generation branch tunnel and exists different degrees of backflow. It forms another dynamic-static water exchange area in the power branch tunnel. The water flow entering from the right side of the power branch tunnel has a certain flow rate, which can carry a certain amount of sediment. This part of the sand-laden water flow is blocked by the static water of the cecal section of the power branch tunnel. The sediment on the bottom of the pipe is concentrated. The thicker part of the pipe bottoms form delta siltation, and the thinner part can move forward with the water flow and remain suspended due to the lower settling speed. The thinner part of the sediment will continue to move downstream with the water flow. After the turbulent action of the water flows over the delta sedimentation body with the current, it will sink into the bottom of the pipe due to the reduced turbulent action of the water flow and slowly move towards the surge tank. The other part enters the sediment tunnel again in the form of backflow with the water flow, and flows out of the sediment tunnel with the water flow. Figure 2 shows the arrangement of key points of the cecum section of the sediment tunnel and the bifurcation section of the sediment tunnel to the surge tank.

![Schematic diagram](image)

Figure 2. The key points layout of the cecum section of the sediment tunnel and the branch section of the sediment tunnel to the surge tank.

Under the conditions of sand discharge, the test results are shown in Tables 2 to 3 and Figures 3 to 6. The test results show that the sedimentation of the cecum section is mainly located at point C4 of the power branch tunnel in the bifurcation section of the sand drainage tunnel (the lower boundary of the power branch tunnel in the bifurcation section) and the bend Y1-Y2 (between the surge tank and the bifurcation section). The silt body is triangular in the direction of the axis of the power generation branch tunnel. The downstream section of the delta extends directly to the vicinity of the bend, and the upstream edge of the delta extends to the vicinity of point C4 downstream of the trash rack. The vertex of the delta is the largest thickness of siltation. Before the siltation in the cecum section of the sediment tunnel reaches equilibrium, its position changes with the power generation time. With the extension of the power generation time, its position continues to move downstream until the siltation reaches equilibrium. The position after siltation balance is related to the upstream flow rate of the sediment tunnel. When the upstream flow rate is 600m$^3$/s, the sediment content of the upstream reservoir inlet is 95~140kg/m$^3$, and the maximum siltation thickness is 19.20m~26.00m downstream of the pipe section at point C4. The sedimentation longitudinal profile change process is shown in Figure 3. When the upstream flow is 850m$^3$/s, the upstream reservoir inlet sediment content is 100~150kg/m$^3$, the location of the maximum siltation thickness is 27.60m~41.20m downstream of the pipe section at point C4. The change process of the longitudinal profile of the sedimentation is shown in Figure 4.
Table 2. The location of the siltation range of the cecum section of the power branch tunnel under the sand discharge condition.

| Sand discharge conditions | The main scope of sedimentation | The siltation profile along the pipeline axis | Maximum siltation thickness position (distance from pipeline C4) |
|--------------------------|---------------------------------|--------------------------------------------|---------------------------------------------------------------|
| 1                        | Q_s=850m³/s, H_R=1735m          | C4~Y1                                       | 27.60m~41.20m                                                 |
| 2                        | Q_s=600m³/s, H_R=1725m          | C4~Y1                                       | 19.20m~26.00m                                                 |

The maximum siltation thickness position is the pipeline distance between the siltation site and C4.

Figure 3. Variation process of the longitudinal profile of the sedimentation body in the cecum section of the power branch tunnel with time under the condition of sand discharge (Condition 1: Q_s=850m³/s, H_R=1735m).

Figure 4. Variation process of the longitudinal profile of the sedimentation body in the cecum section of the power branch tunnel with time under the condition of sand discharge (Condition 2: Q_s=600m³/s, H_R=1725m).
Tests have shown that under the conditions of sand discharge, the amount of silt deposition in the cecum section of the power branch tunnel is related to the discharge flow in the sand discharge pipe. The greater the flow of the sediment tunnel, the greater the sedimentation of the cecum section of the power branch tunnel when the siltation balances. Under the desilting condition 1, the flow rate of the sediment tunnel is 850 m$^3$/s. After the siltation balance, the silt deposition in the cecum section of the power generation branch tunnel is about 1800 m$^3$. In the desilting condition 2 and 3, the flow rate of the sediment tunnel is 600 m$^3$/s. As the flow of desilting is reduced by 250 m$^3$/s, the turbulence intensity of the water level at the dynamic-static flow interface in the cecum section of the power generation branch tunnel is obviously weakened. When the siltation is balanced, the amount of sedimentation in the cecum section of the branch cave is only about 900 m$^3$.

5. Conclusion
1) Under the conditions of sand discharge, there are different degrees of siltation outside the recirculation area of the power branch tunnels in the bifurcation section, and the siltation form is also a delta siltation. With the increase of time, the siltation increases rapidly. After 3 days of continuous sand discharge, the highest silting bar surface approached the top of the pipe.

2) Under the conditions of sand discharge, the amount of silt deposition in the power branch tunnel is related to the sand discharge flow in the sand discharge pipe. The greater the flow of the sediment tunnel, the greater the siltation in the cecum section of the power branch tunnel will be when the siltation is balanced. When the upstream flow is 600 m$^3$/s, the upstream reservoir inlet has a sand content of 95 ~ 140 kg/m$^3$, and the maximum siltation thickness is located at 19.20 m ~ 26.00 m downstream of the pipe section at point C4. When the upstream flow is 850 m$^3$/s, the upstream reservoir inlet has a sand content of 100 ~ 150 kg/m$^3$, and the maximum siltation thickness is located at 27.60 m ~ 41.20 m downstream of the pipe section at point C4.

Acknowledgments
This work was financially supported by the major science and technology project of Northwest Engineering Corporation Limited, Power China. In the meantime, we express thanks to our colleagues for their help and technical support.

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