Research on Design and Application of Flap Gate in Guiyang Nanming River

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Abstract. The core section of Guiyang Nanming River suffers from river water quality deterioration, black turbidity, sediment deposition and other phenomena. The deposition is extremely serious particularly at the upstream area in front of the flap dam. It is necessary to upgrade and transform the flap dam, thereby preventing the sedimentation in the front of the dam, and improving the ecological environment of the river. The flap dam should be newly designed, and its application should be studied.

1. Basic situation of flap gate

The most widely used flap gate is the hydraulic automatic flap gate at present. Its working principle is lever balance and rotation. In particular, hydraulic automatic flap gate can reach the purpose of regulating water level by utilizing checks and balances of hydraulic and gate weight and adding a damping feedback system: when the upstream water level rise is increased, the gate starts discharge around the ‘horizontal axis’ gradually. On the contrary, when the upstream water level is decreased, the gate is gradually closed for accumulating water, thereby the upstream water level can be kept within the scope of design requirements.

Hydraulic automatic flap gate is a gate used for urban rivers which was developed by technicians from China water conservancy engineering after hardworking for more than 40 years. After the first generation of hydraulic automatic flap gate was generated in the early 1960s, it respectively underwent four development stages of discontinuous hinged flap gate (single hinge, double-hinge and multi-hinge flap gate), curve hinged flap gate, gradually-open flap gate and roller connecting rod hydraulic automatic flap gate. The third generation roller connecting rod gate has been widely used since 1982. General engineering technical personnel worked hard assiduously and experimented repeatedly especially since 1990. The fourth generation novel roller connecting rod flap gate was finally designed and developed in recent years from theory to the hydraulic model experiment, and then to engineering practice. The gate has made a qualitative leap in technical design, production process or use performance.

2. Several commonly-used gates in urban river

2.1 Hydraulic automatic flap gate with concrete structure

When the upstream water level exceeds the normal storage water level by 10-20 cm, the gate is opened automatically and gradually with the rising water level gate under the hydraulic effect. The water level is higher, the openness is larger until it is fully opened. When water flows out gradually, the water level begins to decline to the normal water level, the gate is closed completely. Starting water level with
certain height is required for the hydraulic automatic flap gate, and higher water level is required for full openness. Impurities can be clamped on the transmission mechanism during opening and closing, which can be removed under the condition of no water. Otherwise the gate can not be closed completely, and water is leaked severely. Since it is worked by completely relying on hydraulic effect, it is difficult to realize artificial adjustment of water level.

2.2 Automatic hydraulic control double-acting flap gate with concrete structure
Automatic hydraulic control double-acting flap gate with concrete structure is developed from hydraulic automatic flap gate. Namely, a hydraulic system is added on the basis of the hydraulic automatic flap gate, thereby overcoming the passive opening and closing mode of the hydraulic automatic flap gate. The gate can be opened and closed with manual interference. It is difficult for the gate to prevent impurities in water from blocking. However, since the gate can be operated by the hydraulic system, it is much easier to clean the floats, and the bottom impurities also can be cleaned easily.

2.3 Rubber dam
In rubber dam, fabric rubber is made into a seal bag, which is fixed on the weir crest. Water, oil or gas is regarded as working medium and fed into the inner chamber during work. The inner cavity is expanded to reach the purpose of water accumulation. Water is filled as working medium generally. When water should be discharged, water in the cavity should be partially or completely discharged, thereby reaching the purpose of water discharge. Though water level can be allocated manually in the rubber dam, it can be punctured and aged easily. Water level fluctuation can wear out the dam bag in operation. Rubber dam is characterized by poor durability, high cost of repair and long repair cycle. Since the high-power water pump should be opened during water filling and water discharge, the operation cost is higher.

2.4 Lift gate
Lifting equipment is utilized, such as winch, hydraulic device, screw device, etc. Water can be accumulated when the gate flap is lowered. When the gate flap is increased to the required height, water flows out from the bottom of the gate flap, thereby realizing the purpose of water discharge. The lift gate overcomes the defects of hydraulic automatic flap gate and rubber dam, water level can be allocated manually according to demand. The lift gate is durable. However, it is made of steel structures. The structure span is large, the gate thickness is high according to the requirements of design principles, the gate also should be increased to certain height, thereby avoiding impact of objects in flood. The lift gate is characterized by high steel consumption, high cost, long construction cycle, easily damaged water seal and high replacement cost. Meanwhile, it is not in line with the requirements of urban landscape. Rubber dam is vulnerable to breakage and aging with high energy consumption, high repair cost, water pollution, etc. The lift gate has investment cost problems of high cost and long construction cycle. Therefore, the majority of urban river channels are equipped with flap gates. China hydraulic automatic flap gate began in the 1950s, which became mature in the 1980s. Currently, the vast majority of the flap gates are precast with reinforced concrete in order to reduce cost and facilitate mass construction, and they are assembled for construction on site. The water retaining part of the concrete structure flap gate belongs to a reinforced concrete member. It has poor resistance to the impact of object in the river. It is difficult to restore the reinforced concrete member after being damaged. The gate is transversely moved to certain extent during opening and closing, thereby leading to severe water leakage, and even collision and blocking of neighboring gates. One end is high, and the other end is low in the gate, thereby the gate is distorted and deformed. The concrete member is damaged, even the member of the neighboring gate can be damaged. Though the concrete structure flap gate can be widely applied with own features and specific social economic foundation support, it also shows some problems that can't be overcome during application. A gate with novel structure can be used for replacing the flap gate with concrete structure.
3. Basic situation of Nanming River in Guiyang

Nanming River is a Wujiang River tributary of Yangtze River basin. It originates in Bainitian, Linka Township, Pingba County, Anshun, Guizhou. Nanming River has total length of 118km, wherein its length in Guiyang is about 100km. Its length in the urban section (from Huaxi Reservoir to Xinzhuang of Wudang District) is 36.4km. It respectively accepts Xiaohuanghua, Madi River, Xiaoche River, Shixi River, Guancheng River and other tributaries along its route, and then it is converged into Wujiang River. It is the largest river flowing through urban district of Guiyang. The built-up area of Guiyang is divided into 14 drainage zones according to the river water system. Nanming River water system accepts the drainage of 12 zones. It is the largest drainage and flood channel in the water convergence area. Therefore, Nanming River not only belongs to a ‘landscape River’, but also is regarded as the most important ‘spillway river’ in the city.

Guiyang actually strengthened river governance since the last century. River drainage facility construction, coastal landscape change and desilting, dredging and other management work are implemented continuously. Flap dams are constantly built in Nanming River core segment. The flap dams built in Nanming River core segment basically belong to hydraulic automatic flap gates with concrete structures due to historical and technical reasons. The fixed dam of the flap dam is generally higher than the riverbed. The drainage systems of Nanming River and its tributaries are preliminarily built after construction and transformation for many years. Their ability to collect and process sewage is greatly improved. The flood discharge capacity of drainage facilities and rivers is prominently improved. In recent years, urban waterlogging floods and other water dangers are not available basically. However, different river sections suffer from water quality decline, black turbidity, sediment deposition, etc. At different seasons, and the deposition is extremely serious particularly in the upstream area in front of the flap dam, the flap dam should be upgraded and transformed. Therefore, the flap dam can achieve the following ability: ① safe discharge during flood season, water surface organization of water accumulation at mean time and continuously supply of landscape water surface; ② reduction of fixed dam weir crest elevation in structure, and reduction of siltation of the channel; ③ satisfaction of unified scheduling of flood control and desilting; ④ flexible operation and easy control.

4. Design of flap gate of steel structure

4.1 Gate materials

Roller connecting rod gradually-opened flap gate is adopted. The gravity center configuration of flap gate in the same model is combined. Previous concrete panel material is replaced with steel structure material. Concrete counterweight mode is adopted at the bottom of the steel plate. Since the steel gate is mainly made of steel plates and I-shaped beams as the base material through welding. The gate is firmer, more reliable and fixed as a whole. Therefore, the overall bearing ability is stronger. In addition, the steel gate has longer service life after anti-corrosion and anti-rust treatment. Since the steel structure flap gate is made of metal material through welding, it has characteristics of the metal material itself. It is not limited in shape and specification. The steel structure flap gate door plate is made of steel plate through welding. The gate flap is sealed without gap, thereby the water retaining effect is better than that of reinforced concrete flap gate.

4.2 Hydraulic system

Electric and hydraulic flap gates can effectively improve the situation of single flap gate structure form and imperfect operation function. Actual condition of Nanming River comprehensive treatment project is combined. When the flap gate requires water accumulation, sand drainage and flood discharge functions, the gate is vertical during water accumulation, it can be opened at any angle during sand drainage and flood discharge. It is obvious that the requirements can be met by driving the flap gate by electric and hydraulic motors reservoir only.
4.3 Remote control system
It is very necessary to use remote control and participate in flood control dispatching with the improvement of the automation degree of domestic and international industrial equipment, as well as construction of smart city. The following functions are mainly realized:

1. The gate status image information is collected, monitored and transmitted on the spot or remotely. The gate state can be monitored and viewed in real time through video on the spot (operation site). The operation state of the gate can also be monitored and viewed in real time remotely through remote network video. The gate state can be monitored in real time during the whole process of gate opening and closing. The video monitoring cloud platform can be controlled on the spot or remotely.

2. Spot or remote control of hydraulic stations and gates. The gate can be opened or closed on the spot through button, command switch, etc. on the control console. The gate can be opened or closed on the interface through on-site computer (server). The gate also can be closed or opened through remote network (client).

3. Water level setting, monitoring, alarm and recording on the upstream and downstream of the gate. The water level on the upstream and downstream areas is set, monitored and alarmed by light and sound. Automatic operation of equipment beyond the water level extreme value is set on the interface. Automatic feeding function also can be canceled on the interface. Message warning alarm beyond the water level extreme value also can be set, multiple groups of client alarms can be set, and the alarm grades can be set, and the alarm statement can be recorded.

4. Hydraulic system overload, over-pressure alarm, automatic locking and reduction of operators' technical requirements. The highest pressure of the hydraulic system can be artificially set. When the system is automatically unloaded due to over-pressure, and the gate is overloaded during operation (such as: valve failure or clamp obstruction, etc.), the system is unloaded automatically, the gate is automatically stopped and locked, the system is unloaded automatically, and the gate is locked.

5. The running tension of the gate can be adjusted independently. Operation of each gate can be set separately, which should be automatically calibrated. The load (pressure) is displayed in real time, thereby ensuring no overthrow during gate operation process.

6. Automatic correction and setting of gate opening (loop opening). The opening angle of each gate can be set separately, which can be displayed in real time. The angle can be corrected automatically.

7. The system has automatic retrieval function. When the system is operated automatically beyond the water level, the water level is rapidly decreased to normal water level, some gates under automatic operation states are not operated. If the subsequent water level is increased again to the alarm water level, the non-operating gates in the automatic state can be operated. The gates with sufficient operation in originally automatic state can not be operated.

8. Remote control mode has authority protection. The operator only has the remote manual control operation authority. Only the administrator has the authority on alarm water level, gate pressure, manual/automatic selection, etc.

5. Application effect of steel structure flap gate
After four concrete hydraulic automatic flap dams on the core section of Guiyang Nanming River are transformed into steel structure automatic hydraulic controlled flap dams dams, the fixed dam elevation can be effectively reduced, which is as high as the riverbed. The sludge sedimentation can be reduced to a certain extent, thereby ensuring that most silt in the reservoir can be brought to downstream area with discharge water flows for treatment. The original concrete hydraulic automatic flap dam is transformed into a steel structure flap dam controlled by hydraulic system. It can be comprehensively opened during flood season, and water resistance effect can be reduced as far as possible, thereby ensuring discharge safety. It can be flexibly used and easily controlled, which can meet the uniform dispatching demands, such as flood control, desilting, etc.

Automatic hydraulic-controlled flap dam is additionally equipped with a hydraulic hoist control system behind the hydraulic automatic flap dam. The passive opening and closing of the hydraulic automatic flap gate can be overcome. The opening and closing of the gate can be interfered manually.
It is difficult to avoid clamping of impurities in water aiming at the gate. Since the hydraulic system can be used for controlling the gate, the floats can be cleaned easily. The lower impurities also can be cleaned easily.

The equipment undergoes two flood seasons and two dry seasons after project renovation is completed, and the equipment is put into operation. Urban river flood control effect can be effectively reached in the core section of Nanming River, and the sedimentation in front of the flap dam can be prevented.

6. Conclusion
Steel structure gate is adopted to replace concrete material gate on the basis of studying urban river flap gate materials. It is applied in the practical engineering. It is proved that urban river flap gate dam is equipped with steel structure gate instead of concrete structure gate with many advantages after operation under actual working condition in two flood seasons and drought seasons. It can be further popularized and applied.

Acknowledgments
This work was financially supported by science and technology of Guizhou Department of Water Resources (No. KT201323).

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