Concrete Construction of Flood Discharge and Sand-washing Sluice Bottom Slab of Angu Hydropower Station

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Abstract. Based on the analysis of the concrete construction of the bottom slab of flood-discharge and sand-wash sluice in Angu Hydropower Station, this paper expounds the construction characteristics and difficulties, construction procedures, concrete construction of concrete stilling pool in conventional position, concrete construction of overflow and retaining wall, concrete construction methods and measures in special position, etc. Especially, the concrete stratified partition of the bottom slab of flood-discharge and sand-wash sluice and the typical partition of stilling pool have their unique features. The overflow surface concrete adopts self-designed, processed and manufactured stereotyped drawing dies. And after concreting, we use bamboo springboards and protective measures to keep warm in time. The construction scheme is reasonable in design, meets the requirements of construction progress, has no safety accidents, and achieves good construction effect. It has certain reference value for the concrete construction of bottom slab of flood discharge and sand washing sluice of similar projects.

Keywords: Sliding-form impact-resistant and wear-resistant concrete for overflow surface of keyway.

1. General situation of Engineering
Angu Hydropower Station, located in Leshan City, is the last cascade in the lower reaches of Dadu River. It is a large-scale hydropower project with the functions of power generation, flood control, shipping, irrigation and water supply. We adopt a hybrid approach to development. The normal reservoir water level is 398.00m, the total reservoir capacity is about 63.3 million m³, and the installed power station is 772MW. The main hydraulic structures are: spillway sluice, river-bed power plant, installation room, storage gate, dam section, ship lock, downstream tailrace, spillway, etc.

The sluice and dam section of the flood discharge and sand washing sluice project is 234.0m long (including 16.0m long storage gate slot section at the right end), of which 218.0m is the length of the flood discharge and sand washing sluice section, with 13 holes in total; the storage gate slot section is a concrete gravity dam with an elevation of 400.7m at the top of the dam. The flood discharge and sand-washing sluice adopts the open type of broad-crested weir with ridges, and the foundation is built with sand and pebbles. The net width of a single hole is 12.0m. A C25 (W8) concrete impervious wall is set at 0-002.42 transverse position of the dam in front of the sluice, and combined with the curtain grouting through the wall to form an impervious system.
2. Construction Characteristics and Difficulties

(1) The sluice chamber section of this project includes foundation excavation and filling construction, concrete construction and foundation treatment construction, each process needs to be interpenetrated, which increases the difficulty of site construction layout and coordination, and the potential safety hazards are more prominent.

(2) The location of 1 # and 2 # sluice chamber is restricted by many factors such as construction of cut-off wall and blasting control, and the construction conditions are complex, so it needs to be optimized.

(3) The first-line wall of left retaining wall has many variable cross-sections, relatively complex structure, large demand for composite formwork and high difficulty in quality control.

(4) The normal concrete of the bottom slab of the sluice chamber adopts four gradations. In the construction of the slope section, the construction efficiency is greatly constrained by the spacing of steel bars on the surface, and the quality of steel bar safety is difficult to guarantee.

(5) The foundation surface of the bottom slab of the sluice chamber is sandy pebble. According to the blueprint, it is necessary to reclaim the sandy pebble after excavation to a certain elevation. Because the area is the original river bed and the sandy pebble deposits naturally, it is suggested that the foundation be built directly after rolling on the original surface.

3. Concrete Construction

The concrete pouring is concentrated in June to August 2012, with an average pouring strength of about 36,000 m per month. With EX250 long arm backhoe as the main importing equipment, 4 long arm backhoes and 20 dump trucks are required to meet the strength requirements, according to the monthly production capacity of 9,000 m$^3$.

The concrete construction mainly consists of 13 holes of flood discharge and sand-washing sluice chamber, bottom slab of stilling basin and concrete retaining wall on left bank. The construction scope is from 0-012.84 to 0+212.00, and from 0+277.00 to 0+043.00, mainly including normal concrete and HF anti-erosion and wear-resistant concrete. The amount of concrete works is 265,000 m$^3$ and the steel bar system are about 4000 t. Concrete mixing is mainly produced by HZ120-2F3000 self-falling mixing station and HL240-2S3000L mandatory mixing plant. 15T and 20T dump trucks are used to transport concrete mixing to all working faces. The main way of warehousing is EX250 long arm backhoe, supplemented by crawler crane.

3.1. Construction Procedure

(1) Warehouse preparation

Before concrete pouring, the debris and soil on the foundation surface should be removed, and the position of concrete construction joints should be treated by high-pressure water flushing or chipping according to relevant quality standards. When pouring concrete, the same label cement mortar 3-5 cm thick should be laid on the surface of construction joints.

(2) Vibration of concrete

Ordinary concrete is vibrated by $\nabla$ 100 inserting vibrating rod. The time of vibrating is based on the time when concrete no longer sinks significantly, no bubbles appear and slurry flooding begins. The distance between the vibrator and the formwork is at least 1/2 of the effective radius of the vibrator, and the embedded parts such as water stoppage and reinforcing bar net should not be touched. When concrete is poured, the warehouse surface should be wet enough to avoid water accumulation. For the second-stage backfill concrete, vibration with 50 soft-axis vibrating rod is adopted, and for the surface concrete, vibration with plate vibrator is needed.

(3) Demolding and Maintenance

The template should be demolished after the concrete reaches the required strength after construction. The concrete shall be sprinkled, high pressure jet grouting and spray curing. For the HF abrasion resistant concrete, it is necessary to adopt water conservation or straw bag moisture conservation.

(4) Treatment of construction joints
After the completion of each warehouse number of horizontal construction joints, after the final setting of concrete, we use high-pressure wind or high-pressure water to flush the surface of concrete, flush the unqualified parts, and chisel the concrete surface according to the requirements of supervision engineers; for the longitudinal joints of the bottom slab of sluice dam, besides chiseling, we should also adopt "staggered joint" construction to prevent concrete from breaking.

3.2. Formwork Construction
Due to the large number of working faces and formwork work, it is difficult to construct prefabricated traffic beams, overflow slope and pier brackets. According to the structure layout and construction scheme, the following formwork types are adopted:

1) Ordinary composite steel formwork
   Mainly used for structural floor, side wall, pier foundation and other parts, 10T truck transport to the construction site, manual site assembly, fastener connection, 5 x 10 hollow square steel transverse back firmly, tie rod fixed, longitudinal fixed with 48 pipes, for the side wall and pier and other narrow warehouse surface also using butt bracing, formwork joints tight, no leakage of slurry, sufficient stiffness and strength, so as to make the whole warehouse. The formwork forms a solid whole to prevent the occurrence of such phenomena as running model and staggering platform.

2) Large planar formwork
   The flat and large concrete face of retaining wall pier is constructed with large planar formwork. The specification of bottom formwork is 2.6 x 3.0m. The large formwork must be hoisted by crawler crane for connection reinforcement by embedded bolts.

3) Molding of stilling pier and second dam slope
   The slope ratio of the back slope of the second stilling basin dam and the slope of the stilling basin is 1:2. During the construction of the slope, the combined steel formwork is used to carry out the cyclic turnover construction from bottom to top, and two steel formwork are prefabricated during the construction of the bottom concrete so as to facilitate the installation of the overturned formwork and pour it into the structural design elevation.

4) Forming drawing die for overflow surface of sluice dam
   The drawing die of overflow surface is designed and manufactured by ourselves. The slope ratio of spillway sluice is 1:4, the slope length is 43.2m, the drawing die length is 12m, the template width is 1.2m, the truss structure, and the climbing equipment is equipped with two 10T winder. The track is made of angle steel with a width of 10 cm, which is fixed on the reinforced space truss.

3.3. Construction Method
(1) Concrete construction in conventional parts
   Concrete pouring is mainly carried out by backhoe with long arms. The lower elevation storehouse number and corner parts are poured by backhoe with long arms. The storehouse number which cannot be directly covered by equipment in higher parts can also be poured by auxiliary chute or assisted by crawler crane.

(2) Concrete construction in different parts
   ① Construction of Flood Discharge and Sand-washing Sluice Floor
      The construction sequence of bottom slab of flood discharge sluice is 3~13
      Two long arm backhoes with 6.0m³ storage hopper are used in the bottom slab construction of flood discharge sluice. When the pouring layer reaches a certain height, rock ballast can be backfilled to form an unloading platform. 6 m³ storage hopper is used on both sides of the upper and lower reaches of the long arm backhoe to enter the silo, and vibration is carried out with a vibration bar of 100. The concrete is constructed by step method. The thickness of step paving is 50cm. After concrete mixing plant is mixed out, 10T (or 15T) dump truck is transported horizontally to the working face.
      The normal concrete blocks of the bottom slab of the gate chamber are grouted on both sides of the upper and lower sides of the dam with 0+42.00 as the boundary, and the size of the short side of the warehouse number is controlled within 15 meters. The key grooves are set at the joints. The concrete
The engineering scale of the warehouse is shown in Table 1. The concrete partition forms are shown in Figure 1.

**Table 1.** Scale of concrete sub-storehouse pouring for bottom slab of sluice chamber

| Concrete block Number | Elevation range | Pile Number | Maximum pouring height | Quantity (m³) | Warehousing position |
|-----------------------|----------------|-------------|------------------------|--------------|---------------------|
| Down 1#               | ▽365.50～▽368.00 | 0+62.80～0+67.00 | 2.5m | 274 | Stilling basin floor |
| Down 2#               | ▽368.00～▽370.00 | 0+59.72～0+67.00 | 2m | 392 | Stilling basin floor |
| Down 3#               | ▽370.00～▽371.28 | 0+54.36～0+67.00 | 1.28m | 486.8 | Stilling basin floor |
| Down 4#               | ▽371.16～▽372.00 | 0+48.16～0+54.36 | 1.86m | 226.13 | Down 3# |
| Down 5#               | ▽372.00～▽374.50 | 0+42.00～0+54.00 | 2.5m | 546.13 | Down 3# |
| Down 6#               | ▽371.28～▽373.28 | 0+54.36～0+67.00 | 2m | 667.83 | Stilling basin floor |
| Down 7#               | ▽372.28～▽374.5 | 0+54.36～0+60.18 | 1.22m | 137.63 | Stilling basin floor |
| Up 1#                 | ▽373.50～▽375.50 | 0+33.52～0+42.00 | 2m | 384.05 | Down 6# |
| Up 2#                 | ▽375.50～▽377.40 | 0+27.00～0+42.00 | 1.9m | 852.9 | Down 6# |
| Up 3#                 | ▽377.40～▽379.30 | 0+19.36～0+42.00 | 1.9m | 1205.48 | Upstream Floor Foundation / Down 6# |
| Up 4#                 | ▽378.00～▽380.00 | 0+11.36～0+22.2 | 2m | 606 | Upstream Floor Foundation |
| Up 5#                 | ▽379.30～▽381.20 | 0+12.36～0+35.17 | 1.9m | 986.13 | Upstream Floor Foundation / Down 6# |
| Up 6#                 | ▽381.20～▽383.00 | 0+13.50～0+27.94 | 2.0m | 551.55 | Upstream Floor Foundation |
| Up 7#                 | ▽377.00～▽379.00 | 0+01.50～0+11.36 | 2m | 571.55 | Upstream Floor Foundation |
| Up 8#                 | ▽379.00～▽381.20 | 0+01.50～0+12.36 | 2.2m | 1037 | Upstream Floor Foundation |
| Up 9#                 | ▽381.20～▽383.00 | 0+01.50～0+13.50 | 1.8m | 899 | Upstream Floor Foundation |
Fig. 1. Flood discharge sluice floor concrete layered block diagram

② Concrete construction of stilling basin, overflow and retaining wall
The stilling basin and overflow concrete are transported by 15t dump truck. The long arm backhoe is equipped with 6m³ storage hopper or crawler crane with 3.0m³ horizontal tank as auxiliary storage. The 100mm insertion vibrator is used for vibrating.

The bottom slab of stilling basin is divided into two layers according to the criterion of structural joints and the dividing line of normal concrete and HF anti-erosion and wear-resistant concrete. The typical blocks of stilling basin are divided into warehouses and the quantities of each warehouse are shown in Table 2.

Table 2. Typical block warehousing of stilling basin

| Concrete block Number | Elevation range   | Maximum pouring height | Quantity of block (m³) |
|-----------------------|-------------------|------------------------|-----------------------|
| 7#, 10#, 16#          | ▽365.50~▽367.00   | 3.0m                   | 195                   |
|                       | ▽367.00~▽368.50   | 1.5m                   | 495                   |
|                       | ▽368.50~▽369.00   | 0.5m                   | 160                   |
| 13#                   | ▽365.50~▽367.00   | 2.5m                   | 220                   |
|                       | ▽367.00~▽369.00   | 2.0m                   | 980                   |
|                       | ▽369.00~▽371.50   | 2.5m                   | 818.75                |
|                       | ▽371.50~▽374.00   | 2.5m                   | 506.25                |
|                       | ▽374.00~▽376.00   | 3.0m                   | 212.5                 |
| 19#                   | ▽361.50~▽364.50   | 3.0m                   | 180                   |
|                       | ▽364.50~▽367.00   | 2.0m                   | 380                   |
|                       | ▽367.00~▽369.00   | 2.5m                   | 640                   |
|                       | ▽369.00~▽371.00   | 2.0m                   | 355                   |
|                       | ▽371.00~▽374.00   | 3.0m                   | 181.25                |

(3) Concrete construction in special parts
① Concrete construction of overflow surface of sluice dam
The downstream surface of the sluice dam is 1:4 inclined plane, and the surface layer is thick 50cmC40HF abrasion resistant concrete. After the demolition of the portal crane, the single hole overflow surface is slipform construction, and the long arm backhoe is supplemented by chute. After the final abrasion of the abrasion resistant concrete, the spray maintenance or sand bag watering maintenance is started. The curing time is not less than 28 days.
The overflow surface of sluice dam is an important water-crossing section. After pouring and forming, protective measures should be taken in time. Bamboo springboard and thermal insulation quilt are mainly adopted.

② Construction of 1 # and 2 # Sluice Hole Cutoff-proof Wall
After 1, 2 During construction, a construction joint is set every 2-3 m, and copper sheet is embedded in the joint to stop water. With the increase of the cut-off wall, filling is carried out in time on the upper and lower sides of the cut-off wall to ensure the stability of the cast-in-place cut-off wall.

③ Construction of concrete in reserved position of portal crane
According to the design plan of construction organization, in order to meet the requirement of concrete construction strength for flood discharge and sand washing sluice dam section, an MQ900B gate crane should be installed at the elevation position of 0+042.00~0+054.36 and ▽374.5m. During the construction of concrete, after the bottom reinforcement of 0+042.00~0+054.36 blocks of the dam is installed and poured to the elevation of ▽374.5m, the crane track is pre-embedded along the axis of the dam, and the reinforcement joints of the upper and lower sides of the track are set up in accordance with the safety quality requirements of the reinforcement system, and the anti-rust treatment is carried out. After the portal crane is demolished, the concrete surface is cleaned and chiseled, the steel bar joints are de-rusted, and then the surface concrete is poured.

4. Conclusion
The floor concrete construction scheme adopted in this project is reasonable in design and achieves good results. This project satisfies the requirements of construction progress, and there is no safety accident. It provides some reference and reference value for the construction of the bottom slab of similar sluice and dam projects.

References
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