Concrete Crack Control Technology for Face of Rock-fill Dam in Plateau Cold Regions

Sinohydro Corporation Engineering Bureau 15 Co., Ltd
He Xiaoxiong

[Abstract]: Put forward an effective technical method for anti-cracking of concrete-faced of rock-fill dam in plateau cold regions and a new thought for solving the anti-cracking problem of concrete-faced, and can be recommended in the similar engineering.

[Key words]: plateau, rock-fill dam, concrete-faced, crack control

1. Project overview
Jishi Gorge Hydropower Station, locating at the outfall of Jishi Gorge of the Yellow River’s mainstream in Xunhua County, Qinghai Province, is a key water-control project mainly engaging in electricity generation with a consideration of comprehensive utilization such as irrigation and flood prevention. Its main body building is a concrete-faced rock-fill dam, with a crest elevation of 1,861m, the maximum dam height of 103m, total overall length of 325m, the width of dam crest of 10m; and a 5.2m-high “L-shaped” concrete wave wall is set up on the upstream side of the dam crest, with a scale of 1:1.5 for the upstream dam slope and 1:1.4 for the downstream dam slope.
The place where the Jishi Gorge Dam is located and its upstream have a plateau semi-arid climate with dry climatic condition and low rainfall; the highest temperature is 38.2℃ and the lowest temperature is -19.9℃ of many years; the maximum wind speed of each month for many years is 24m/s and the average wind speed is 3.1m/s; and the rain capacity of many years averages 266.2mm and the yearly evaporation capacity of many years averages 2,131.4mm.
With large day-night temperature difference and dry climate due to the location of Qinghai Jishi Gorge Hydropower Station in the plateau cold region, crack control of concrete-faced of rock-fill dam is the technological difficulty in project construction and also the significant link of construction quality assurance. In view of the crack concrete-faced of the similar projects in the same region that have been completed, to reduce the cracks of the concrete-faced of Jishi Dam in
construction and ensure the construction quality, monographic studies have been carried out on the anti-cracking problems of concrete-faced in plateau cold region, and good results are achieved.

2. General thought
Concrete cracks are caused by many reasons. But the causes for large-area and thin concrete-faced in the plateau cold regions are mostly the shrinkage, temperature difference between inside and outside the concrete, property and quality of concrete raw materials and construction quality. The prevention of concrete cracks in construction mainly focuses on researches of the following aspects:

2.1 Concrete raw materials have a great influence on the concrete crack control, thus, the concrete raw materials that are conducive to crack control and the cement with low heat of hydration are chosen so as to lower the adiabatic temperature rise inside the concrete and to reduce the temperature cracking of concrete.

2.2 Additive is a significant means to change properties of concrete. Adoption of additives with a good anti-cracking ability can effectively improve the deformation property and anti-cracking ability of concrete.

2.3 The larger concrete slump will cause a larger concrete shrinkage. The deformation due to concrete shrinkage is far greater than the deformation by ultimate extension of concrete. Lower the ex-machine slump of concrete mixture and reduce the cracks caused by concrete shrinkage.

2.4 Favorable workability is the key to ensure the concrete construction quality. According to the experimental study, concrete mix ratio with good peaceability, anti-separability and uniformity can reduce the generation of cracks of concrete-faced; concrete with good workability can also prevent or reduce the construction cold joints caused by unsmooth construction or other factors. Studies on crack control shall ensure the favorable workability of concrete.

2.5 Larger temperature difference between inside and outside concrete will make the cracking easier. Internal temperature due to cement hydration in initial pouring of concrete will go up rapidly. Control the curing water temperature whilst enhancing normal curing according to the value of concrete adiabatic temperature rise provided by laboratory tests to prevent cracks caused by large temperature difference between curing water and inside concrete.

2.6 Improve construction technology and methods to effectively reduce the concrete cracks.

3. Technical measures
3.1 Selection of raw materials making for crack control of concrete-faced

3.1.1 Choose the moderate heat cement with favorable mineral component and chemical, physical and mechanical properties. The indicators of cement shall meet the national standard and its expansibility and alkalinity shall also be valued.

3.1.2 Blend of Grade I fly ash can bring down the water consumption per cubic concrete, hence reducing the cement content per cubic concrete. Increase the content of fly ash as much as possible and control the internal temperature rise on the premise of the code requirements and design objectives are met to reduce cracks caused by temperature variation.

3.1.3 The water absorption and sediment percentage of gravel aggregate have a great influence on the shrinkage and tensile property of concrete. On condition that the quality of gravel aggregate is guaranteed, scientifically choose the gravel aggregate mix ratio and sand ratio according to the practical situation of the local gravel aggregate to make the concrete well workable.

3.1.4 Loss of slump of concrete mixture lessens as well as the water consumption per cubic concrete by replacing the naphthalene-based superplasticizer with polycarboxylene based superplasticizer for reaching the purpose of reducing the cementitious material consumption per cubic concrete. Conduct contrast tests between anti-cracking compacting enhancing agent and shrinkage reducing agent. By analyzing the test results, the compacting enhancing agent with good deformation property is adopted to reduce cracks of concrete-faced.

3.2 Experimental study on the mix ratio of concrete-faced with good anti-cracking ability and concrete performance

3.2.1 Lower the warehousing slump of concrete

On condition that the concrete workability is satisfied, reduce the ex-machine slump of concrete as much as possible so as to decrease the cementitious material consumption in concrete mixture, lower the adiabatic temperature rise of concrete and reduce concrete cracks caused by shrinkage. For that purpose, polycarboxylic additives and compacting agents are used to make the effect of liquefaction by vibrating the concrete mixture better and ensure the quality of concrete pouring on condition of smaller slump and reduce the shrinkage crack of concrete. The laboratory test on the concrete-faced of Jishi Gorge finally determines the ex-machine slump of concrete within 2cm~4cm.

3.2.2 Improve the deformation property of concrete

Enhancement of tensile strength and deformation property of concrete is one of the dominant
factors to control the generation of cracks. According to the previous experience of construction of concrete-faced, blending of appropriate additives may effectively enhance the deformation property of concrete.

According to the data presentation, the compressive strength of concrete slightly reduces after the blending of compacting enhancing agents, while the tensile strength increases, elastic modulus of concrete decreases and deformation property improves substantially. Elastic modulus of the concrete in which the compacting agent is added decreases and the ultimate extension increases drastically. Comparing with the additive 1 without compacting agents, the ultimate extension of additive 1 with compacting agents increases by 22.6% on condition of 3 days, 14.0% on condition of 7 days and 13.6% on the condition of 28 days; Comparing with Additive 2 without compacting agents, the ultimate extension of Additive 2 with compacting agents increases by 19.1% on condition of 3 days, 10.9% on condition of 7 days and 12.6% on condition of 28 days.

Shrinkage and autogenous volume deformation of concrete blending with compacting agents drop substantially. Shrinkage: Additive 1 decreases by 18.6% and Additive 2 decreases by 17.6% on condition of 28 days; autogenous volume deformation: Additive 1 drops by 35.9% and Additive 2 decreases by 44.1% on condition of 28 days, and Additive 1 decreases by 22.7% and Additive 2 decreases by 31.8% on condition of 60 days.

3.3 Site Construction
3.3.1 Good dam body filling quality and full presedimentation before pouring of concrete-faced are two important ways to prevent concrete-faced from cracking.

(1) Compaction quality of dam body filling is an important factor to prevent face from cracking. During construction of the Jishi Gorge, pay attention to rock filling quality to ensure that the sedimentation deformation of dam will not lead to face crack.

(2) To keep sedimentation of dam in steady condition before pouring of concrete-faced, 6 months are scheduled for sedimentation. Besides, to accelerate sedimentation rate of dam body during construction period for the purpose of earlier making the sedimentation stable, in accordance with the features of the Jishi Gorge Dam, soaking treatment is taken for dam body lower than EL 1785 before face construction, and the soaking height is 25m. Before soaking, dam sedimentation is 1.57mm/d, while in the soaking treatment, is 6.9mm/d, which is 4.5 times of the rate before. Dam sedimentation is obvious and make sure the pouring of concrete-faced is carried out in the condition that dam body sedimentation is almost steady.
After construction of face and before impoundment, there is no change of instrument for separation of concrete-faced embedded in concrete-faced of Storehouse 11, and it is tending towards stability; instrument for separation of concrete-faced embedded in concrete-faced of Storehouse 21 changes, but the value is as low as about 0.001cm. After impoundment, add counterweight to Storehouse 11 to cause sedimentation and thus having the instrument changed, but the value is as low as about 0.001cm; dam body sedimentation in early stage of Storehouse 21 is stable, instrument for separation of concrete-faced changes after impoundment, but the value is as low as about 0.001cm.

3.3.2 Concrete mixing station shall be built on the top of dam to shorten transportation distance of concrete and change concrete transportation method.

3.3.3 Adopt patented product to pave concrete for storehouse to improve quality and speed of paving concrete.

During construction of this Project, new concrete-faced construction method and new pouring template are researched, thus forming a patented construction method, through which the concrete pavement of face is even and compact, and pouring fast and the crack caused by uneven shrinkage is reduced.

3.3.4 Control internal and external temperature differences through warm water curing

According to relevant information, internal and external temperature differences of concrete shall not exceed 20°C. According to the test result of indoor adiabatic temperature rise, final adiabatic temperature rise of general concrete-faced is over 30°C and some even over 35°C. When pouring concrete, cover it timely and strictly control curing water temperature to keep the temperature differences between concrete-faced and internal concrete under 20°C, in order to prevent crack caused by great internal and external temperature differences. Adiabatic temperature rise in laboratory test in 7 days is 26.9 – 29.3°C. During construction period (April to May of 2010), local temperature is 2°C—18°C and the natural temperature of river water is 1 °C— 2 °C. According to different temperatures, heat the warm water for curing concrete-faced to make the internal and external temperature difference lower than 20°C and the effect turns out to be good. Curing water for the Jishi Gorge’s concrete-faced is boiled to 25°C by boiler for concrete curing.

4 Application effect

This technical method is applied in Qinghai Jishi Gorge Hydropower Station Project and the
result turns out to be good on preventing concrete-faced from cracking. This technical method is scientific, reliable and successful. Comparing the crack of concrete-faced of Qinghai Jishi Gorge Hydropower Station with similar projects in the same climate environment, the crack of the former is 90% less than others, and it also reduces expense on crack treatment in later period and guarantees the operation safety of dam.

After site survey, the number of cracks of concrete-faced of the Jishi Gorge Hydropower Station is 71 by June 2010. See detail information about the crack in table 1.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Summary sheet of face crack examination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack type</td>
<td>Classification</td>
</tr>
<tr>
<td>Block I</td>
<td>F5, F13, F15, F17, F27, F33, F21, F23, F25, F29</td>
</tr>
<tr>
<td>Block II</td>
<td>F6, F10, F12, F16, F18, F22, F24, F26, F28, F32</td>
</tr>
<tr>
<td>Shanxi Yellow River additive + compacting agent</td>
<td>F15, F16, F17, F23, F25, F28, F33</td>
</tr>
<tr>
<td>Jiangsu Bote additive + compacting agent</td>
<td>F10, F17, F21, F22, F27, F29, F6, F12, F24, F26, F32</td>
</tr>
<tr>
<td>Crack width &gt; 0.2㎜</td>
<td>4 in total</td>
</tr>
<tr>
<td>Crack width &gt; 0.1㎜ and ≤0.2㎜</td>
<td>54 in total</td>
</tr>
<tr>
<td>Crack width ≤0.1㎜</td>
<td>13 in total</td>
</tr>
<tr>
<td>Total number of cracks</td>
<td>71</td>
</tr>
</tbody>
</table>