Construction Technical Measures of Consolidation Grouting

1 Work Items
1.1 Compilation basis and instruction
   1) Foundation treatment specification during detailed design

2 Construction General Layout
2.1 Construction layout of air, water and power
   The air, water and power for construction are pipe linked to the operation platform from system main pipeline to the construction side. Of which the water for construction is pipe linked directly from the system water supply pipeline by 2" rubber hose, and the air for construction is pipe linked directly from the system air supply pipeline by 2" rubber hose, and the power for construction is linked to the operation platform directly from the system electric distribution cabinet by 50mm² cable.

2.2 Construction layout of slurry system
   1) Layout of slurry station
      The slurry system is arranged in the suitable area near the construction side. And the temporary slurry station of the slurry system is set up by the scaffold, and mixed by the high-speed slurry making machine. And the temporary slurry station should be set in the suitable area of both the concrete gravity dam and the spillway construction area, and the cement platform area of the slurry station should be 25m², while the cement storage of each slurry station should be 50t. And according to the change of the construction site, we should set up 2 transportable temporary slurry stations for convenient construction.

   2) Slurry transportation
      Each slurry station is equipped with a 3SNS grouting pump, which transports the slurry to the
grouting pump near the operation platform for grouting operation, and its capacity of transporting the slurry is 4000L/h.

3) Slurry making

(1) Slurry is made by the high-speed mixer produced by Yichang Black Whirlwind machinery plant, and the production is 4000L/h.

(2) The slurry making material shall be measured in accordance with the standard mixture ratio, and the measurement error shall be less than 5%.

(3) All kinds of slurry should be stirred evenly.

(4) The mixing time of the pure cement slurry is: no less than 3min for an ordinary mixer, and no less than 30s for a high-speed mixer.

(5) It should be no more than 4h from the start to the end when sieving the slurry before use.

(6) Mix the fine cement slurry and the stable slurry, add the water reducing agent and use a high-speed mixer. And the stirring time is determined by experiment. It should be less than 2h from the start making the fine cement slurry to the end.

3 Grouting Material and Grouting Equipment

3.1 Grouting material

Grouting material mainly consists of cement, water, admixture, additive (in case), etc., and it shall be in accordance with the related quality standard of materials of each present batch of cement, admixture, admixture, etc., and enclose the quality certificate of the factory.

1) Cement

(1) The cement for consolidation grouting is OPC42.5 cement.

(2) The cement for grouting shall be in accordance with the quality standard, and do not use the damp agglomerated cement. The cement is placed in a special warehouse according to the different varieties, strength grade, factory batch number, bags, etc., which is in order to prevent the cement from metamorphosing because of the improper storage.

(3) During the course of grouting construction, we should conduct the sampling inspection of cement in its strength, fineness, setting time, etc..

2) Water

The temperature of the water for slurry making should be no more than 40°C.

3) Admixture (in case)

According to the need, the cement slurry could be mixed with admixture like sand, clay, fly ash,
water glass, etc.. The incorporation amount should be determined by experiment.

4) Additive (in case)

According to the need, the cement slurry could be mixed with accelerator, water reducing agent and stabilizer. And the optimal dosage of additive should be determined by laboratory test and field grouting test. In addition, all the additives that can be dissolved in water should be added in the water state.

3.2 Choose drill-hole grouting equipment

1) The drill-hole operation of the consolidation grouting construction is drilled with the hydraulic drill, and the inspection hole uses the geological drilling rig for construction, and the grouting uses the 3SNS grouting pump for construction.

2) The machine in the slurry station is the NJ-400 type high speed mixer with small size and strong production capacity.

4 Grouting Test

1) Choose a representative section as the productive grouting test area according to the building layout and geological conditions of the project, .

2) Select layout, depth, grouting section, grouting pressure and other test parameters of the inspection hole according to the grouting engineering construction layout and requirement.

3) The grouting experiment should be conducted in accordance with the approved grouting construction procedures and methods in the grouting experiment area, and master the features of rock grouting in the project area, and inspect the validity of grouting measures. Furthermore, categorize and analyze the experiment data of per unit water absorption rate and ash consumption amount of each drill-hole and inspection hole, so as to obtain the reasonable grouting procedure, the good grouting technique and the high effective grouting parameter.

5 Construction of Consolidation Grouting

The consolidation grouting part of this project includes the concrete gravity dam and the spillway section. The consolidation grouting hole is drilled with the hydraulic drill, and the inspection hole is drilled with the geological drilling rig, and the grouting uses the 3SNS pump for construction.

5.1 Drill-hole

1) The consolidation grouting hole is drilled with the hydraulic drill in the hole appointed by the construction drawing.

2) The location, depth, diameter, direction and so on of the consolidation grouting hole should be
drilled with the requirement of the construction drawing, and the diameter of the grouting hole should be more than 50mm.

3) Ensure the accurate direction of the hole while drilling, and make sure that the slope of the hole meets the requirement.

4) In the process of drilling, we should record the abnormal situations in detail and report to the general manager in time. Such as meeting the change in rock stratum and lithology, drilling out, hole collapse, drill speed variation, backwater discoloration, dehydration, water gushing, etc.

5) After the completion of drilling, carry out to the next step when the inspection is accepted.

5.2 Drill-hole wash

1) Drill-hole wash should be conducted after the completion of drilling the grouting hole. First, bring in large amount of water through air&water linkage or a catheter, then wash in a way from the bottom to the surface of the hole. And the fissuring wash method should be determined by the grouting experiment according to different geological conditions.

2) When conducting the fissuring irrigating, the water pressure should be 80% of the grouting pressure, and 1MPa should be used when the pressure is more than 1MPa, and ends after 10min when the water is clear.

3) After the grouting hole(section) finishes the fissuring wash, the hole(section) should do the grouting operation immediately and continuously, and it should conduct the fissuring wash again before grouting if the time interval is more than 24 hours for some reason.

5.3 Water pressure test

1) The water pressure test is carried out after the fissuring wash, and it is tested in a “simple water pressure” way.

2) Simple water pressure test should be conducted after or during the fissuring irrigation, and the pressure should be 80% of the grouting pressure, and no more than 1 MPa, and the water pressure should be 20 minutes, and record the water pressure amount every 5min, then choose the final amount as the result, which is expressed with permeable rate.

5.4 Grouting

1) Grouting method

(1) The consolidation grouting should be conducted in accordance with the principle of the sequence and the density. The different rows of the grouting holes and the different holes of the same row can be divided into two sequences construction, and also can be sequenced only by row but not hole or otherwise the opposite.

(2) When using the top-down section grouting method, we should use the grouting packer to block at
0.5m above the top of each grouting section to prevent leakage. As for the hole section without watering of the orifice, it can be uncondensed after grouting. But it should be condensed in the complex areas like fault and fracture zone, and the time should be determined according to the geological conditions and design requirements.

3) The consolidation grouting hole of this project is deep to 5m into the rock, and it conducts a first grouting method.

4) It records the parameters like grouting pressure, amount and so on by a grouting automatic recorder.

5) After grouting, we should close it for condensation towards the grouting hole that carries a outflow slurry or up-back slurry. And it should be condensed in the complex geological condition areas like fault and fracture zone, and the time should be determined according to the geological conditions and design requirements.

2) Grouting pressure and water cement ratio

The pressure of the consolidation grouting of this project is supposed to be 0.3MPa, and the final number shall be determined by the grouting experiment. And the grouting pressure and injection rate should be strictly controlled during the grouting.

The water cement ratio of the consolidation grouting slurry can be conducted by four levels including 2:1, 1:1, 0.8:1 and 0.5:1, to be specific, the ratio of open the grouting slurry can be 2:1. And the grouting slurry is transformed from dilute to concentrated. And when the grouting pressure remains constant and the injection rate decreases, or when the injection rate remains constant while the grouting pressure continues to rise, the water cement ratio should not changed. And it can also use a single ratio of stable slurry if it is demonstrated feasible through grouting experiment.

3) Slurry transforming standard

When using multi-stage water cement ratio, the principle of the slurry is as follows:

1) When the grouting pressure remains constant and the injection rate decreases, or when the injection rate remains constant and the grouting pressure continues to rise, the water cement ratio shall not be changed.

2) When the injection amount of a single ratio slurry has reached more than 300L, or the grouting time has reached 30min, while the grouting pressure and injection rate are not significantly changed, it should be replaced by a concentrated grouting slurry;

3) When the injection rate is more than 30L/min, it can leapfrog to concentration according to the specific circumstances of construction.

In the process of grouting, when the grouting pressure or the injection rate suddenly changes a lot, we should immediately identify the reason and take corresponding measures.

4) Grouting finishing standard

When consolidation grouting is under the maximum designed pressure, it should finish after 30min continuously grouting while the injection rate is no more than 1L/min. And if it is not able to reach the finish standard for a long period, we should report to all participants to work out a solution together..

5) Hole sealing
The method to close the consolidation grouting hole is the "pipe grouting hole sealing method" or the "full grouting hole sealing method".

To the consolidation grouting hole constructed by the citation (buried) pipe method, it should use the 0.5:1 concentrated slurry instead of the dilute slurry in the hole after the grouting reaches the designed finish standard, and when the slurry pipe drains the 0.5:1 concentrated slurry, we should conduct the hole sealing, close the grouting and seal the hole.

5.5 Grouting quality inspection

The method of the quality inspection of the consolidation grouting project is the drilling water pressure test. And the inspected number of the holes in the single point water pressure test should not be less than 5% of the total number of grouting holes.

6 Eliminating Measures of Waste Residue, Slurry and Water

In the process of each parts of the construction side, set up the temporary sump in the lower construction site and around slurry stations, so the construction sewage could precipitate here and be drained into the sedimentation tank with the pump, and then be concentrated drained after precipitation, and clean up the sediment and waste slurry, etc. at any time, at last, transport them to the designated place. As for the grouting area without cover weight, the surface residue will be backhoe loaded and transported to the designated place after cleaned up by hammer.

7 Schedule plan

Foundation consolidation grouting construction of concrete gravity dam GD1 started on November 23, 2015, completed on January 6, 2016.

SP1 Foundation consolidation Grouting construction of the spillway started on September 1, 2015, completed on October 31, 2015.

SP2 Foundation consolidation Grouting construction of the spillway started on July 20, 2015, completed on September 21, 2015.


Because of the range and type of final Grouting is not finalized, the above construction period is estimated, when using consolidation grouting without cover weight, will occupy different parts of linear time, specific time determined by the final grouting location, scope and number.

8 Resource input

8.1 Construction labor force input

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8.2 Main construction equipment

Main construction equipment
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9 Quality control measures

1) Strengthen the quality education of all construction personnel and enhance their quality awareness.

2) Establish a reward and punishment system, rewarding good and punishing bad.

3) Experienced professional engineers are responsible for the construction of the project, establish a sound quality assurance system and "3-inspection " system, which means initial inspection by the shift or team, re-inspection by quality inspector of the operation shop or team and final inspection by full-time inspectors seized.

4) Accept supervision and guidance by the internal supervisor. The procedure is not finished, the next step shall not be start, insure each process to meet the quality requirements.

5) From technology and procedure to control quality, from point, drilling, borehole flushing, water pressure test grout sealing, strictly control the quality of each procedure, and establishing the quality management system of prevention first, correct is complementary.

6) In the process of drilling, the direction of the hole should be strictly controlled, and measures should be taken in time if there appears a deflection of the hole, and we should ensure the depth of drill-hole, at the same time, the residue in the bottom of the hole should meet the requirements of the standards. While in the process of grouting, we should strictly control the slurry ratio, grouting pressure, grouting time, etc., and we shall contact both the internal supervisor and the designer in time when there is a special situation, and record in the original record.

7) During the grouting process, strictly control the water pressure and the filling pressure

8) Grouting material shall meet the quality requirements, all kinds of cement must have factory certification and inspection reports. Grouting material should be fresh cement, the lumped cement forbid to use. The cement in the factory more than three months shall not be used.

9) Grouting machine shall be maintained and service timely to ensure it is in good working order in the construction process, and avoid effecting on the project quality.

10 Construction safety, environmental control measures

During the construction, set the safety and environment department, arrangement full-time personnel for safety and environmental protection management.

10.1 Safety assurances
1) Safety education and pre-post operating procedure training for newly recruited personnel.

2) In order to ensure the smooth progress of drilling and Grouting in the construction, we shall set 2 safety personnel to daily check on the construction site. Detect security defects or risks, are processed in a timely manner.

3) The helmet, overalls, safety shoes should meet the safety requirements of the job. To strictly compliance with safety rules and labor discipline.

4) Construction materials should be piled up steady, not be placed on the verge, and do not impede the movement and handling. Objects disassembly, the remaining material must be cleaned up and removed in a timely, and prohibited throwing and discarding objects up and down. Within the field of operation, where any objects may fall, there must be removed or fixed to prevent falling hurts.

5) Drilling frame and drilling rig must be fixed before drilling. When drilling speed too fast, the recorder and operator should not close to the shaft and belts.

6) Grouting machine operator should not close turning belt and running bearings.

7) Personnel involved in the construction of drilling and grouting, and the recorder shall not have long hair.

8) Grouting, slurry transportation should check piping is intact, if possible, the event of a breakdown, must be put on the well pipe, then start grouting.

9) Workers must be carried out according to the rules in the construction, operation against rules is strictly prohibited.

10.2 Production and environmental protection measures

1) Set up identity signs, safety warning signs in all major works

2) Pay attention to protect the surrounding environment, not disposal disorderly garbage and construction waste.

3) Handle construction waste water properly, then discharged it into river.

4) Construction noise should be controlled in specified range.

5) Pay attention to water the construction road, keep it clean and sanitary.