THE CONSTRUCTION TECHNOLOGY AND QUALITY CONTROL METHOD OF MEROVE EARTH CORE ROCKFILL DAM

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Abstract: The Merove hydropower station sits on the Nile river in the north of Sudan. The power capacity is 1250 MW. The dam is about 9.6km long, including three kinds of dam, which are concrete face rock-fill dam, gravity dam and earth core rockfill dam. Among them, the earth core rockfill dam locates on the main riverbed and has 841m long, 65m height. The construction and quality control of the core area of the earth core rockfill dam is the key and difficult point of backfilling. This paper discusses about the construction technology and quality control method of the four kinds of clay material locating in the core area, which composing by high plasticity clay, common clay, clay with gypsum and low plasticity clay. This paper also presents the construction technology and quality control in the special area, such as the area where the clay and concrete connect together. And, we timely adjust the construction method according to the large test sample results. It has been found that those methods can make the backfilling go on wheels and have significant effect to improve quality, and also provide reference for the similar project.

Key words: Merove earth core rockfill dam; clay; construction technology; quality control

1 Project introduction

The Merove hydropower station, 400Km away from the capital city Khartoum, sits on the Nile river in the north province of the republic of the Sudan. The project that has a power capacity of 1250MW is the second biggest hydropower station after the Aswan in Egypt on the Nile river. Its main work is supply power and irrigation.

The civil work involves a dam across the river and power plant. From the left bank to the right bank the dam include left bank dyke, left bank irrigation outlet, left bank concrete face rockfill dam(CFRD, about 1450m length), left bank earth core rockfill dam(ECRD, about 841m length, 65m height),concrete gravity dam with power plant(about 300m length), concrete gravity dam with spillway(154m length), concrete gravity dam without spillway, right bank CFRD(about 4364m length, maximum 52m height), right bank irrigation outlet and left bank dyke. The dam with a full supply water level 300m and dead storage level 285m has a 67m maximum height.

2 The main construction technique and quality control requirement

The backfilling clay material in the dam should follow the design grading requirement and other guide line. Before start backfilling, analyzing the clay material resource, exploiting the clay material within the approve area and allowance excavation depth.

(2) The site compaction test and construction controlling parameters. Before we have done the compaction test, analyzing the clay’s plastic, optimization moisture content,
friction angle, cohesion, dispersion, grading and so on. During the construction period, we also make lots of test for the above parameters. The backfilling thickness, compaction passes, quantity of sprinkle water should follow the construction parameters requirement. At the same time controlling the weight of compaction equipment, force of vibration, frequency of vibration reach the method statement requirement. The different material should strictly follow the compaction equipment deciding by the compaction test. Enhancing the quality control in the area the big machine can not reach and the different materials joint together in order to make sure the quality meets the design requirement and avoid the defect happening.

2.2 The main quality target

The ECRD of the Merove dam locates on the original river bed with deep loose sand. The key of the construction quality is controlling settlement, seepage and stability. The dam sits on the edge of the Sahara Desert with high temperature, high evaporation, arid weather and less rainfall, so the moisture control becomes an importance factor. The goal of the quality control during the construction is every procedure of the work should be strictly supervised and the dam satisfies the design requirement and function.

3 Dam body zone and material

3.1 Dam body zone

The ECRD with dam crest elevation 304m, dam crest width 10m, the lowest foundation elevation 240m has upstream 1:2 slope and downstream1:1.8 slope. The typical cross section of the ECRD is perpendicularity clay core dam. The central is perpendicularity clay cut off wall, beside of which is filter material and rock fill dam shell. The ECRD clay cut off wall has top elevation 300m and top width 4m. The upstream and downstream slope of the clay cut off wall is 1:0.25. It is low plastic clay material above 293m. There is clay material between 293m and 255m, beside of which it is 2m width clay with 4% gypsum. To reduce the force on the top of the concrete cut off wall, there is 4m high plastic clay. The cross section of the dam is shown in the attached drawing no. 1. Zone 1 material is clay. Zone 1.1 material is clay adding 4% gypsum. Zone 1B is low plastic clay. Zone 22 is high plastic clay. Zone 13L is clay blending with sand that is come from the cover material of raw clay yard. Zone 2 is fine sand. Zone 3 is coarse sand. Zone 3A is fine rock. Zone 4 is coarse rock. Zone 8 is rip rap. Zone 9 is slop finish with rock.

![Figure 1](image)

The ECRD of Merove dam typical section
3.2 The dam backfilling material

All the zone 1, zone 1B, zone 1.1 clay material come from the borrow area L. The raw clay is transported to clay batching plant after exploitation. The clay can be used as backfilling material after sieving, modifying moisture content, curing, taking test sample.

The clay material less than 0.075mm diameter occupies over 40% in the zone 1B. The liquid index less than 50%. The plastic index more than 15%. The content of the organic should less than 1%. The 85% of clay sample on the site should show dispersion. The infiltration of the clay material after compaction should less than 10^-7m/s. The clay has 22° friction angle and 15KN/m2 cohesion. The average dry density is 98% of optimization dry density. The minimum dry density is 86% of optimization dry density. According to the trail compaction, the moisture content should over the optimization moisture content by 2%. The site moisture content should around the optimization MC by -1% ~ +3%. The optimization moisture content is decided by laboratory standard proctor test. After curing for 1 to 2 days and doing proctor test, pinhole test, double hydrometer test, consolidation test, determination of Atterberg limits test, organic matters test, the eligible material can start use. The total volume of zone 1 clay material is 522629 m3.

The zone 1.1 clay material is the zone 1 material adding 4% of gypsum. Moisture content should control within -1% ~ 3% of optimization moisture content. The zone 1.1 material occupies 213666m3. It is nearly the same with the zone 1 material, but with very strictly on dispersion requirement. Many double hydrometer tests and pinhole tests show it has no dispersion. The zone 1.1 material meets the quality requirement.

Zone 22 material is high plastic clay with low elastic modulus, high plastic and high moisture content. It is made of 80% Nile river silt blending with 20% bentonite and water. The zone 22 material locating on the top of the concrete cut off wall and connecting with clay material, has a function of reducing the vertical force on the concrete cut off wall. The zone 22 area has a 407m length, 4m width, 3m width on the bottom and 5m on the top. The total volume is 7932m3. The plastic index of zone 22 material should more than 50%, reaches 60% is better. The moisture content of zone 22 stockpile should between 1% and 4% around the optimization moisture content.

After curing one day and the laboratory shows the material is eligibility, the material can be use as backfilling material. Above 263.4m, first the whole clay cross section backfill by zone 1 material until 1m exceeds the zone 22, then getting agreement by engineer and setting the boundary of zone 22. Second excavating the zone 22 area. The zone 22 material placing thickness is 35cm. After sprinkling water and scarify, we can start filling. In order to make sure the connection between zone 22 material and zone 1 material, the side wall of trench for zone 22 must be wet. After placing the material finish using 12T smooth roller runs 2 passes without vibration and 4 passes with vibration and taking test sample. Every stockpile should take proctor test to decide maximum dry density and optimization moisture content. The dry density degree on the site should between 90%MDD and 95%MDD. The average dry density degree should more than 92.5%MDD.

The zone 22 material is high plastic material with PI>50%. If it is exposed to the sun, the surface will quickly change. In addition the climate is hot and drought, the backfilling must be very quickly (placing and
compacting within 30 minutes). The working area should strictly control and the 12T roller must be ready before start working. Before starting next layer, sprinkling water and scarify on previous layer is necessary within 30 minutes. If something stop the work, water tank on the site or use plastic film to seal the previous layer is necessary.

Zone 1B material is low plastic clay, which has 30%~40% clay with less than 0.075mm diameter, 15% ~ 20% plastic index and 10-7m/s infiltration after compaction. The stockpile moisture content is 2% over optimization moisture content, -1% ~ +3% around optimization moisture content is acceptable. The minimum dry density degree is 97%. The average dry density degree should more than 99%.

Before any layer start, sprinkling water on the acceptance previous layer and waiting for 15 minutes for pervasion is required. Sprinkling water again after scarify to make the previous layer surface moisture content around 5%. After engineer approved, using qualify stockpile to fill. Each clay material construction parameter could be seen in the table 1.

<table>
<thead>
<tr>
<th>Material type</th>
<th>Guideline for material</th>
<th>Compaction requirement</th>
<th>Density degree</th>
<th>Compaction passes</th>
<th>equipment</th>
<th>Overlap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1, zone 1.1</td>
<td>( D_{0.075} &gt; 40% ), LL &gt; 50%, PI &gt; 15%, K &lt; 10^{-7} m/s )</td>
<td>(+2%~+4%)</td>
<td>average &gt; 97%</td>
<td>-2</td>
<td>19tPF</td>
<td>0.3m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0%~+2%)</td>
<td>average &gt; 98%</td>
<td>-2</td>
<td>19tPF</td>
<td>0.3m</td>
</tr>
<tr>
<td>Zone 1B</td>
<td>30% &lt; ( D_{0.075} &lt; 45% ), 13% &lt; PI &lt; 25% , K &lt; 10^{-7} m/s</td>
<td>Special area (-2%~+2%)</td>
<td>average &gt; 99%</td>
<td>-2</td>
<td>19tPF</td>
<td>0.3m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal area (-2%~+2%)</td>
<td>average &gt; 99%</td>
<td>-2</td>
<td>19tPF</td>
<td>0.3m</td>
</tr>
<tr>
<td>Zone 22</td>
<td>PI &gt; 50%</td>
<td>(+1%~+4%)</td>
<td>Average &gt; 90% MDD, max&lt;95% MDD</td>
<td>-2 + +4</td>
<td>12t SR</td>
<td>1m</td>
</tr>
</tbody>
</table>

4. The key point of construction and quality control

(1) Taking test sample. To make sure each material reach the technical specifications requirement, we have done trail compaction and many test regarding to the character of clay material that will be used. On the site the frequency of taking test is very high. Many kinds of test sample have been taken. During backfilling every section and every time working have test records, including compaction degree, moisture content, void ratio and so on. Every kind of clay material is the key objective of taking sample. The frequency of taking test sample could be seen in attached table 2. In addition the frequency of taking test sample should be enhanced in special area. In order to make sure the quality in special area, every layer should take test sample. Deep scarify and adding water or deep scarify and solarization are the methods of modifying moisture content and density degree for unqualified working. Then recompaction and taking test sample is required. When this happen, we should analyse the reason of failure and change the stockpile if necessary.

Table 2    The frequency of taking test sample

<table>
<thead>
<tr>
<th>Material zone</th>
<th>Content of testing</th>
<th>Testing frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>Water content(borrow pit)</td>
<td>One testing for every 500m$^3$ fill</td>
</tr>
<tr>
<td></td>
<td>Complete particle size distribution(borrow pit)</td>
<td>One testing for every 10000m$^3$ fill</td>
</tr>
<tr>
<td></td>
<td>degree of dispersion (borrow pit)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>In-situ dry density(fill)</td>
<td>One testing for every 500m$^3$ fill</td>
</tr>
<tr>
<td></td>
<td>Water content(fill)</td>
<td>One testing for every 2000m$^3$ fill</td>
</tr>
<tr>
<td></td>
<td>Atterberg limit(fill)</td>
<td>One testing for every 5 000m$^3$ fill</td>
</tr>
<tr>
<td></td>
<td>Standard Proctor density and optimum water content(fill)</td>
<td>One testing for every 10000m$^3$ fill</td>
</tr>
<tr>
<td></td>
<td>Permeability(fill)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Triaxial shear strength</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Direct shear strength</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Organic impurities</td>
<td></td>
</tr>
</tbody>
</table>

(2) The dam locates in the torrid zone with drought climate, high temperature, 70 degrees centigrade on the ground and obvious evaporation. How to guarantee the quality in high temperature climate becomes a key point when we organize the work and control the quality. During backfilling, the moisture content should be higher than the optimization moisture content by 1%~3%. The water tank must be ready on the site at any time. Curing the finished layer uses water tank is also important. Every day there are 3 hours without works afternoon. Using smooth roller to seal the unfinished working place must be applied to stop evaporation and control the quality before the morning work finish.

(3) Below 293m, there is 2m clay with 4% gypsum every side of the clay. It is very difficult during construction and very slowly by common method. The backfilling method is preparing the whole area with zone 1 in the same working place, than sprinkling, scarifying and setting the boundary of zone 1.1. First backing the middle area zone 1 and leaving the zone 1.1 material. Second, leveling the surface of the clay and cleaning the area of zone 1.1. After this finish, using 25T truck dump the zone 1.1 material and bulldozer shaping the surface. It is very efficiency to compact and take sample together. Because the gypsum containing in the zone 1.1 have action with concrete, we should avoid to contacting zone
1.1 material with concrete.

(4) As shown in the attached drawing, the high plastic material sits on the top of concrete cut off wall. The method is backfilling first, then excavating the area for the zone 22. Because the trench for the zone 22 is only 5m width and the moisture content is high, the bulldozer is not easy to work. We use truck directly dump the material into the trench for the zone 22, and using excavator levels the material. Because of the drought climate and the high plastic index of zone 22, before starting working the water tank and smooth roller must be ready on the site. Within one hour compaction and take test sample must be finished. Enhance curing is necessary for finished layer. To avoid deep crack, plastic film should be applied if we have long time without work for the next layer.

The same clay material at different location have different requirement. For example the moisture content of clay near the concrete structure should be high than the optimization moisture content by 4%. Disqualification material can not be used. The clay above 295m should have plastic index less than 20%. In order to control the density degree and moisture content, the optimization density degree and optimization moisture content must be known by taking proctor test.

There are many kinds of material with different function and different construction requirement. At the margin of the clay area the big equipment is difficult to apply. This area is the key point of quality control. We must concentrate our attention to this area to make sure the joint line between different material follow the design and avoid less compaction. The test sample in special area must strictly control by the requirement.

(6) For special area near concrete structure, backfilling lay thickness should be half of the normal area (15cm thickness). The moisture and the plastic index should be higher than other area. The frequency of taking test sample and the compaction standard also modifies. The temporary road across the clay area must be removed until 30cm bellow the temporary road surface. Deep scarify and recompaction should be used in this area. The next layer road across the clay must be 30m away from the old one.

(7) In order to exercise a control over each procedure during construction to meet the requirement of contract and Engineer, quality control team will be established by Project Management, comprising technology & quality department, laboratory and site construction section, and will be staffed with professional test and inspection engineer. Construction team subordinate to site construction section will be staffed with quality inspector to exercise joint control over quality. Under the leadership of quality control team, quality management will be fully implemented. Prior to construction, professional engineer will give technology interpretation to construction team chief technician in terms of construction procedure, method and quality assuring method to get team member understand quality control essentials for strict control in construction. During construction different material may be use at the same time. A person will be assigned full-time for directing unloading. Plate shall be put up on the vehicle indicating the loadings to avoid the wrong dumping.

5 Conclusion

During the backfilling of ECRD of Merove dam in the republic of the Sudan, By strictly quality control, sufficient laboratory inspect, implementing the standard with engineer and enhancing detail area control from material transportation, placing, compaction and so on,
the dam backfilling obtains favourable result and makes a good example for the same dam construction in the future.

References
