Research on Water Cooling Optimization of Temperature Control for High RCC Dam

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Abstract—In the mid- to late-stage construction of Roller Compacted Concrete (RCC) dams, once the concrete pouring breaks away from foundation constraint zone, the existing temperature control criteria and measures still have room for optimization. This paper takes a RCC dam under construction as research object and focuses on the feasibility of cancelling or simplifying water cooling measure to control concrete temperature, in order to ensure construction quality while shortening construction period and saving investment. Our research object is roller compacted concrete (RCC) dams, once the concrete pouring breaks away from foundation constraint zone, the existing temperature control criteria and measures still have room for optimization. This paper takes a RCC dam under construction as research object and focuses on the feasibility of cancelling or simplifying water cooling measure to control concrete temperature, in order to ensure construction quality while shortening construction period and saving investment.

Keywords—roller compacted concrete; optimization of temperature control; anti-cracking temperature control; and simulation calculation

I. INTRODUCTION

Anti-cracking temperature control is indispensable throughout every stage of a dam construction. Therefore, it is important to carry out systematic analysis at design stage of such issues as selection of quality concrete, characteristics test, setting temperature control criteria and temperature control measures. This helps propose specific requirements on selection of materials, temperature control criteria, corresponding measures and construction technologies to meet the needs of anti-cracking temperature control and guide the on-site construction. Because concrete temperature control is a complex issue involving multiple disciplines such as meteorology, hydrology, materials, construction and structure. Despite the research efforts made at the design stage, there exist much difference between design conditions and actual conditions, which may lead to the risk of concrete cracking under certain conditions. What’s more, given the construction conditions, technology and management levels at the construction stage, there could also be differences between design and actual construction. Therefore, it is very necessary to use tracking and simulation means to simulate and estimate by using monitored data as per actual progress and temperature control measures as real as possible. Based on that, sensitiveness analysis of parameters of design, progress and temperature control proposals need to be carried out to optimize design. In the mid- to late-stage construction of Roller Compacted Concrete dams, once the concrete pouring breaks away from foundation constraint zone, the existing temperature control criteria and measures still have room for optimization. This paper takes a RCC dam under construction as research object and focuses on the feasibility of cancelling or simplifying water cooling measure to control concrete temperature, in order to ensure construction quality while shortening construction period and saving investment.

II. RESEARCH OBJECT AND TASKS

This paper takes the section No. 12 of a RCC gravity dam as the research object. Actual pouring progress is adopted for poured concrete, while designed progress is adopted for unpoured concrete in the upper part breaking away from foundation constraint zone. Taking into different pouring location in different seasons, the paper is intended to determine whether temperature control by canceling or simplifying water cooling is feasible, find out the general rules of temperature stress under the two conditions, and further optimize temperature control measures. The main contents include basic parameters of thermodynamics; analysis of boundary initial conditions; calculation of reservoir water temperature value; inverse analysis of key parameters of thermodynamics, simulation and analysis of temperature stress without water cooling, and optimizing water cooling measure by widening the gap between water-cooling pipes.

III. COMPUTATION MODEL AND SCHEME

A. Computation Model and Conditions

The Figure 1(a) & Figure 1(b) show the computation model of the Section 12 of a dam with bottom width over 100m. To optimize the water cooling required in the temperature control design, the typical Section 12 of the dam is selected for research. Considering the noticeable temperature gradient at the dam surface, relatively thinner elements than usual are designed with meshes becoming thinner from outer to inner circle. Meanwhile, to simulate the process of layered pouring, 0.5m is taken as the element thickness along the vertical direction when calculating...
Hexahedral mesh isoparametric element is adopted for dividing meshes.

(a) Material zoning model for finite elements computation of the Dam Section

(b) Meshing for finite elements computation of the Dam Section

FIGURE I. COMPUTATION MODEL

B. Computation Scheme and Conditions

Computation scheme and conditions are shown in Table 1. The concrete pouring progress by June 15th, 2016 was computed by taking actual pouring quantity and pouring temperature for poured concrete and taking designed progress and temperature for unpoured concrete respectively.

<table>
<thead>
<tr>
<th>Serial no. of working condition</th>
<th>Pouring temperature</th>
<th>Cooling measures</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working condition 1</td>
<td>By mid of June, 2016, took actual pouring temperature for poured concrete and follow the required temperature control for unpoured concrete.</td>
<td>By mid of June, 2016, followed actual cooling measures for poured concrete and eliminate water cooling for unpoured concrete.</td>
<td>Thermodynamic parameters were subject to feedback simulation results while for unpoured concrete, cooled water was made at 12°C, and cooled water flow was made at 1.2m³/h.</td>
</tr>
<tr>
<td>Working condition 2</td>
<td>Ditto</td>
<td>By mid of June, 2016, follow actual cooling measures for poured concrete and the gap between pipes was widened from 1.5m per layer to 3m for unpoured concrete.</td>
<td>Ditto.</td>
</tr>
</tbody>
</table>

The constrained boundary of the computation model has foundation bottom and sides to constrain each other, foundation initial temperature is determined by combining measured and simulated results.

IV. COMPUTATION RESULTS

A. Computation Results without Water Cooling

Looking at the temperature nephogram and the temperature hydrograph of the dam, when no water cooling is provided, the maximum temperature of RII concrete zone may reach 35°C at the elevation of 1503m-1540m inside the Dam while the maximum temperature of RIII concrete zone may reach 33°C; the maximum temperature at top RII zone may reach 39°C due to higher pouring temperature. All of the maximum temperature occurs in the zones poured in summer, as shown in Figure 2. Overall speaking, when no water cooling measure is used, the internal temperature of the dam would exceed designed temperature, and the internal stress safety coefficient of RII and RIII concrete zones is larger than 2.0. At the elevation of 1501m, safety margin is slightly inadequate due to the layer temperature difference at the transition zone between water cooling and no-water cooling, as shown in Figure 3. The surface stress safety coefficient is 1.6 at the elevation of 1585.5m, as shown in Figure 4, which falls short of design requirements.

FIGURE II. ENVELOP DIAGRAM OF MIDDLE-PLANE TEMPERATURE OF DAM SECTION 12
B. Computation for Simplifying Water-cooling Measures

This computation is to explore the feasibility of laying water cooling pipes by widening their gap from 1.5m to 3m, taking into account pouring at different locations and seasons on the precondition of strictly controlling the pouring temperature. The computation results show that, with the pipe gap widened, the maximum temperature in the RII and RIII concrete zones (third and fourth sub-zones) inside the dam can be controlled at no higher than 31°C in summer and 28°C in winter. The maximum temperature of rolled impervious layer RIV concrete at the elevation of 1503m-1540m in the upstream can get to 33°C while the maximum temperature of rolled impervious layer RV concrete can get to 35°C near the top. By widening pipe gap, the maximum temperature of the rolled concrete inside the dam can be controlled within the design temperature. Because the rolled impervious layer concrete has no separate zone for concrete temperature control, it needs to enhance control of pouring temperature and increase water flow in order to control the maximum temperature within the design specification in the rolled impervious layer concrete in the upstream. Both internal and surface stresses of rolled concrete in RII and RIII zones have safety coefficient larger than 2.0. Generally speaking, for concrete in non-contraint zones, the option of widening water-cooling pipe gap can ensure that the dam stress meets the requirement and it is feasible.

V. SUMMARY

Based on the requirements by the principle and the design needs, the paper is intended to optimize the water-cooling temperature control over the RII and RIII rolled concrete.
breaking away from foundation constraint zone. The optimization is by increasing the gap between water pipes as much as possible while taking into account pouring at different locations and seasons on the precondition of strictly controlling the pouring temperature, so as to explore the possibility of widening pipe gap or canceling water cooling. The simulation computation takes Section 12 of Dam in typical riverbed as research object, using actual poured progress for poured concrete and designed progress for unpoured concrete, so as to find out the general rules of temperature stress and thus further optimize temperature control. Generally speaking, in case of using water cooling, the maximum temperature of the dam section exceeds the designed temperature, which results in the internal and surface stresses in some parts failing to meet the design requirement. Therefore, the option of water cooling is not feasible. If the horizontal gap between water-cooling pipe is widened from 1.5m to 3m, the maximum temperature, internal and surface stresses all can meet the design requirements. Thus, the option of widening pipe gap is feasible. But because the rolled impervious layer concrete has no separate zone for concrete temperature control, it needs to enhance control of pouring temperature and increase water flow in order to control the maximum temperature within the design specification in the rolled impervious layer concrete in the upstream. For concrete in this zone, temperature control should be enhanced and pipe gap can remain unchanged. In addition, it is suggested to do well in surface protection, insulation and maintenance, and provide accurate forecast and warning of rainfalls and cold wave. By doing so, the effect of single-point rainstorm and cold wave can be minimized. Furthermore, be sure to ensure the continuous pouring for the dam sections. Continuous pouring between dam sections should also be guaranteed to avoid cracking caused by excessive temperature difference between layers due to long-time interval. In case that long-time interval cannot be avoided, specific analysis and demonstration is needed.

ACKNOWLEDGEMENTS

The research was supported by the National Key Research and Development Project of China (Grant NO. 2016YFB0201000, 2018YFC0406700, 2016YFC0401608), The research was supported by the National Natural Science Foundation of China (Grant NO.51579252, 51779277, 51439005, 51578544), the Special Scientific Research Project of the China Institute of Water Resources and Hydropower Research (Grant NO. SS0145B392016, SS0145B612017), the Special Scientific Research Project of the State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin and the Special Scientific Research Project of the China Institute of Water Resources and Hydropower Research (Grant NO. 2015TS05, 2016ZY10). Huaxin Group Science and Technology Project (HNKJ16-H16).

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