CONTROL OBSERVATIONS DURING CONSTRUCTION OF AN ARCH DAM

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For systematic monitoring of the Mansur Eddahbi dam* on the Draa River in Morocco, control and measuring devices, 885 in all (Fig. 1), were installed in the structure. A large number of these (temperature, linear displacement, and pressure gauges) were used for monitoring during construction the temperature regime of the concrete, amount of opening of the intersectional joints, condition of the joints along the concrete-rock contact, and effectiveness of the grout curtain. All observations were carried out by a specially created group of seven specialists following a developed program.

Monitoring of the Temperature Regime of the Concrete in the Dam during Construction. The dam was constructed in a region with a hot climate. The mean daily temperatures during the hot months (June-August) in the construction period reached +35°C with an absolute maximum of 43°C and of the cold months (December-February) +4-5°C with an absolute minimum of -3°C.

The arch dam, 70 m high with a crest length between abutments of 232 m, is divided by joints into individual sections. The concrete was placed by buckets. The maximum size of the concreting blocks in plan, limited by the dimensions of the section were, in the arch 15 x 15 m and in the abutments, 15 x 20 m. The blocks were 1.0 m high in the near-rock zone (height of zone 8-10 m) and in the remaining part, 1.5 m. The concrete was placed in 50-cm-thick layers in the direction from the upstream face of the block toward the downstream face.

The concrete composition was cement 200 kg; gravel of size 20 mm, 380 kg; 20-40 mm, 240 kg; 40-80 mm, 530 kg; sand 0-5 mm, 560 kg; water, 116 kg. Cement with the following thermophysical characteristics was used:

<table>
<thead>
<tr>
<th>Age, days</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat liberated of cement, kcal/kg</td>
<td>51.0</td>
<td>62.5</td>
<td>67.5</td>
<td>70.0</td>
<td>71.5</td>
<td>72.0</td>
<td>74.0</td>
</tr>
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</table>

With respect to heat liberation this cement considerably surpassed the cement to be used according to the design.

To provide crack resistance in the concrete the maximum temperature of the concrete of the blocks of the near-rock zone could not exceed +32°C and above the near-rock zone +36-38°C. The break in concreting the blocks was limited to 4-7 days according to the conditions of the construction time.

Calculations showed that for the composition of the concrete used and specific heat liberation of the cement the rise in temperature of the concrete during exothermic heating under adiabatic conditions is about +25°C. On the basis of this, for the 1.5-m-high blocks the temperature of the concrete mix at which the concrete could not cool was Tc,m = 38°C - 25°C = 13°C. For the pipe cooling system used, the design requirements with respect to the allowable limit of exothermic heating of the concrete under the climatic conditions of the construction site could be maintained at a temperature of the concrete mix not greater than +25°C.

A system of cooling the aggregate and cement was introduced to obtain a concrete mix with a guaranteed temperature (sprinkling the aggregate at the storage sites by water cooled to +16-18°C by means of a cooling tower, ventilating the wet aggregate with air by fans from the transport gallery, delivery of cold water (+2-3°C) for mixing

* Construction was carried out during 1969-1972 according to the design of the All-Union Planning, Surveying and Research Institute (Gidroproekt). The design philosophy of the dam was presented in the journal "Gidrotekhnicheskoe Stroitel'stvo," No. 10 (1974).

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Fig. 1. Layout of the control and measuring devices in the dam. 1) Linear-deformation gauges; 2) linear-displacement gauges; 3) string temperature gauges; 4) pressure gauges in concrete; 5) piezometers; 6) direct plumb; 7) commutators; 8) pressure gauges in rock; 9) route of cable.

The temperature of the concrete in the blocks was reduced by means of coils through which circulated water cooled to +10-13°C obtained from a cooling plant with an output of 330,000 kcal/h. The coils of 25-mm-diameter thin-walled metal tubes were placed every 1-1.5 m in plan in one or two rows over the height of the block, depending on its height, initial temperature of the concrete mix, and temperature of the concrete of the underlying block. In installing the coils in one row they were placed directly on the subjacent block. If it was necessary to install a second row, the coils were fastened to support rods at a height of 50 cm (block height 1 m) or 75 cm (block height 1.5 m) from the surface of the subjacent block. The coils were connected to the main collectors, which were protected by heat insulation and equipped with valves. The cooling plant provided circulating water at a rate of 0.45-0.5 liter/sec.

The high rate of concrete placement (6-9 m/month) required an efficient control system.