

Construction of three RCC dams forming part of the Ghatghar Pumped Storage Project in India

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SYNOPSIS

The 250-MW Ghatghar Pumped Storage Scheme, now nearing completion near Mumbai in India, has three roller-compacted concrete (RCC) dams forming the Upper and Lower reservoirs. The level difference between the two reservoirs is 410 m. The two dams forming the Upper reservoir were constructed first and were useful precursors to the 84-m high dam impounding the Lower reservoir.

The Lower dam was built over two seasons with a halt for the 2005 monsoon when there is heavy rain – 640 mm fell at the site in eight hours on 28 June 2005; on the same day 940 mm fell in Mumbai – in total 7,200 mm rain fell in just over four months during the monsoon.

This paper describes the construction of the dams and also the thermal analyses used to choose the optimum placing temperatures.

GENERAL

The Ghatghar Pumped Storage Scheme, now nearing completion about 100 km north-east of Mumbai, has an underground power house in a cavern measuring 123 x 23 x 46 m in which there are two 125-MW pump/turbines. There is also a separate cavern housing the transformers.

The Upper reservoir is retained by the Upper dam, which is 15 m high, 495 m long and has a volume of 32,000 m³, and the Saddle dam, which is

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12 m high, 250 m long and has a volume of 12,500 m³. Both are RCC dams.

The Lower reservoir is retained by a single RCC dam that will be 84 m high, 415 m long and will have a total volume of 656,827 m³. The total cost of the Lower dam is \$ 35.6 million. This implies a cost of \$ 54 per m³ for the dam structure.

SADDLE DAM

The Saddle dam, which was constructed first, was considered to be a large full-scale trial for the Upper dam. RCCs with several different mixture proportions were tried in this dam. The Portland cement content varied between 88 and 98 kg/m³ and the low-lime flyash content between 142 and 152 kg/m³. The specified maximum placing temperature was 28 °C, although the actual maximum placing temperature was only circa 24 °C, and the joint spacing was 25 m. The dam was constructed in two halves, the first half, the Left-Hand Side (LHS), between 9 March and 23 March 2003 and the second half, the Right-Hand Side (RHS), between 21 April and 9 May. To date the dam is free of any detrimental cracking and has no seepage (see Figure 1).



Figure 1: Downstream face of Saddle dam

UPPER DAM

The Upper dam has a central spillway with five overtoppable radial gates measuring 12 m long by 3 m high. The remainder of the dam is constructed of RCC the great majority of which contained 88 kg/m^3 of Portland cement and 132 kg/m^3 of flyash.

The placement of RCC started just before the 2003 monsoon. At the time the joint spacing was 25 m and the specified maximum placing temperature was 28°C (although the majority of the RCC had a placing temperature below 25°C). The RCC was placed in two sections either side of the central spillway. The lower section of the RHS was placed between 19 and 23 May 2003 and the lower section of the LHS between 1 and 10 June. In both cases the volume of RCC placed was a relatively low proportion of the total volume. During the placements the ambient temperatures were high with maximum temperatures well over 40°C .

During the 2003 monsoon, some uncontrolled cracks were found between the contraction joints in both sections of the dam that had been placed in May and June. Some thermocouples had been placed in these sections and it was found that the adiabatic temperature rise was circa 25°C rather than the 17°C that had been used in the design. A preliminary thermal study was therefore undertaken and this showed that with the new data, the Factor of Safety against cracking in the Upper Dam was close to unity while that for the Saddle dam was in excess of 1.5. Using these data the joint spacing in the Upper dam for the second season was halved to 12.5 m while the maximum allowable placing temperature was maintained at 28°C . The remainder of the LHS was placed between 26 November and 20 December 2003 and the RHS between 2 and 16 January 2004. No further uncontrolled cracks have been found in the upper sections of the dam (other than those propagated from the lower sections of the dam). Figure 2 shows the Upper dam and reservoir.

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Figure 2: Upper dam and drawn-down reservoir

LOWER DAM

The Lower dam has an upstream face sloping at 0.141:1 (H:V) and a stepped downstream face sloping at 0.782:1. The central 58 m of the crest is a free overflow spillway. The crest width in the non-overflow sections is 8.0 m.

In the same way as the Upper dam, the Lower dam was constructed over two seasons, either side of the 2005 monsoon. The RCC placement started on 14 December 2004. The mixture proportions initially were the same as the Upper dam (i.e. 88 + 132) but this was changed to 75 kg/m³ of Portland cement and 155 kg/m³ of flyash at the beginning of February 2005. As the volume of each layer of RCC was too great to be placed within the limits for a 'hot' joint (for which there is negligible treatment), the dam was spilt into two halves. One half was raised circa 3.6 m, the plant was then transferred to the other half of the dam (using a 1.8-m high mobile ramp (see Figure 3)) and then the second half was raised 3.6 m. The first season was completed on 31 May 2005 by which time 235,500 m³ of RCC had been placed.

Placement for the second season commenced on 14 November 2005 and, at the time of writing, it is expected that the RCC placement will be completed – there is 421,250 m³ of RCC to be placed in this season – in the second half of May 2006. Figure 4 shows the RCC placement on 20 January 2006; the escarpment on top of which is the Upper reservoir can clearly be seen in the background.



Figure 3: Plant being moved from one side of the ‘split placement’ to the other

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Figure 4: Ghatghar Lower dam under construction on 20 January 2006

THERMAL STUDY

To confirm the assumptions made during the preliminary Thermal Study, it was decided to carry out a full thermal stress analysis for the Lower dam. This analysis was started at the end of the first season (December 2004 to May 2005) when the dam was already 27 m high and when the contraction joint spacing had already been chosen to be 15 m. The main purpose of the analyses was to determine a suitable maximum placing temperature for the second season (November 2005 to May 2006).

The modelling technique was a more sophisticated version of that employed on the Khlong Ma Dua dam in Thailand (Cordell, 2002) and at various other RCC Dams such as Platanovryssi dam in Greece (Kolonias et al, 1989) and New Victoria dam in Australia (Hinks et al, 1991). As at Khlong Ma Dua it was planned to build the Lower dam using the 'split-placement' methodology so there was a need for separate models for the LHS and RHS of the placement as well as for the spillway and non-spillway sections.

The temperature analyses, as well as the stress analyses, were carried out using ANSYS since this program now offers all of the facilities built into the program DAMHOT which has been used on previous occasions (Hinks and Copley, 1995). The use of a single program offers considerable advantages in that it is easy to transfer data between the temperature and stress modules.

Because thermocouple readings were available from the Lower dam's first season there were ample data available to check the calibration of the

temperature model. In the event it was found that predicted temperatures were generally close to those measured in the dam (see Figure 5).

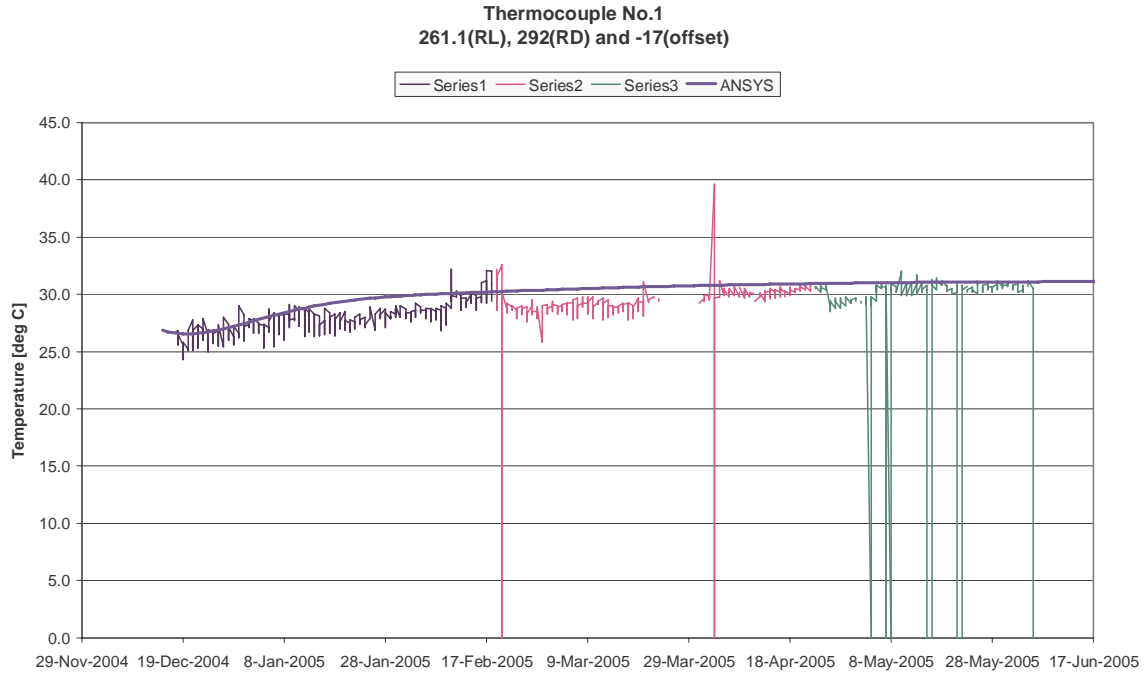


Figure 5: Comparison between predicted and measured temperatures in the Lower dam at Ghatghar

It had originally been intended to construct the spillway crest in conventional concrete at the end of May 2006. However the thermal stress analyses showed excessive stresses in the RCC immediately beneath the conventional concrete so it was decided to defer the construction of the spillway sill until the cooler weather in November 2006.

The conclusion of the thermal analyses was that it would be safe to increase the placing temperature from 22 °C (as used during the first season) to 25 °C. This increase was expected to produce a cost saving of \$500,000 to \$600,000. In the event, the maximum placing temperature was relaxed to 23.5 °C for the first few months of the second season (November to February) when the temperatures on the site are not particularly high (less than 35 °C) and it is possible that it will be further relaxed to 25 °C for the last few months of the second season (when the temperatures are rather higher (up to 45 °C)).

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