Foundation Problems and Remedial Measures for Power House and Four Diversion Tunnels of Gangrel Hydro Electric Project Across Mahanadi River Dhamtari, District Chattisgarh

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Abstract

The Gangrel Hydel Project with an installed capacity of 4 x 2.5 MW has been constructed on the left bank of the existing Gangrel dam across Mahanadi River. The foundations of the power house and the tuunel media of four diversion tunnels are formed of quartzitic sandstone. The contact of the sandstone and the underlying pink granite gneiss has been established below the power house foundations. The power house of 13.5 m x 36 m dimensions has been completed. Artesian flowing water conditions were observed during the excavation of the power house site. Anchors have been provided and grouting was recommended to seal the openings and make the foundation impermeable and monolithic.

Four diversion/tunnels aggregating to a total length of 182.4 m were examined and studied. Fresh rock has been encountered in all the tunnels except some minor seepage problems both at the inlet and outlet portals. The Rock Mass Rating (RMR) as per geomechanics classification has been done and this works out to > 60% and > 80% relegating to RMR Class II – Good and Class I – very good. Based on these values Resin Coated Rock bolts of 3 m depth at a spacing 2m C-C have been provided. Shotcrete with wire mesh for smooth flow of water was suggested and has since been implemented. The project was completed before schedule time frame. Remedial measures and treatment of the power house, tunnels, upstream and downstream portals have been executed. The paper discusses in detail the problems encountered and remedial measures accorded.

Introduction

A 30 m high and 1800 m long composite dam has been constructed across the Mahanadi River at Gangrel for augmentation of water supply to Bhilai Steel Plant and to provide irrigation in Raipur district. Geological investigations were started in 1968-69 and the project was completed in the year 1978. A 454 m long masonry dam located on the left bank has been founded on the coarse grained sandstone and grit underlain by basement granites.

An important geotechnical feature is the presence of weathering and clay infillings along the horizontal bedding planes noted during the construction stage. In situ tests for the seams gave an average value of Phi = 22.5 degrees and C = 0.33 kg / Sq cm. A five meter thick apron has been provided at the toe of the dam. Consolidation grouting has been done up to 10 m depth with grout holes spaced at 3 meter C/C as part of treatment of the foundations.

The Gangrel HE project was taken up for construction by M/s SEW Construction Ltd; Hyderabad (A.P) on a turnkey basis for the Chattisgrah State Electricity Board, Raipur since May 2002. It is located on the left bank from RD 214 to RD 250 m of non-overflow masonry dam section where good rock

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forms the foundations of the power house as well as tunnelling media for the proposed tunnels. The Power House consists of 4 units of 2.5 MW each. The power house is spread in an area of 13.5 m x 36 m and there are 4 diversion tunnels of horseshoe shape, each of 45.6 m length. This Mahanadi River waters are supplied to Raipur City, the capital of the Chattisgrah State.

Salient engineering features

The power dam extends from RD 214 m to R.D.250 m (Non overflow – masonry dam) and has since been completed along with the main Irrigation component and penstocks of size 2200 mm diameter along with the head regulator and trash racks installed.

Location :

State : Chattisgrah

District : Dhamtari

River : Mahanadi

Length of the river upto site dam : 115 km

Width of river at dam site : 488 m

Project site : Near village Gangrel 7 km south of Rudri Village or 14 km south of Dhamtari Dam.

Hydrology :

Catechment area : 3670 Sq.km.

By Dudhawa Reservoir : 625 Sq km.

By Murumsilli Reservoir : 486 Sq.km

Independent : 2559 Sq. km

Rainfall :

Annual Rainfall:

Maximum : 2286 mm

Minimum : 841 mm

Average : 1430 mm

Monsoon Rainfall :

Maximum : 1910 mm

Minimum : 792 mm

Average : 1282 mm

Floods :

Maximum observed at Dam Site (1976) : 16000 Cumecs

Design Floods : 23500 Cumecs

Moderate Design Flood (spillway) 17230 Cumecs

Reservoir Storage Capacity : Gross storage at RL 348.00 m : 909.32 m .Cum

Dead Storage at RL 336.2 m : 43.60 M Cum

Live storage at FRL – 348.70 m : 765.70 M. Cum

Water spread area at FRL 348.70 : 9540 ha

Principal Levels:

Lowest river bed level : 322.47 m

Penstock level U/S of power dam : 322.325 m

Crest of spillway : 338.70 m

MWL: 350.70 m

Flood Lift : 12.00 m

Top of dam : 352.00 m

Masonry Dam – Spillway straight gravity : 252.25 m

Radial Crest Gates : 14 No: 15 m x10 m Hydro Power:

4 Nos. penstocks of 2.2 m diameters with installed capacity Hydro Power : 4 units of 2.5 MW (10 MW)

Geological set up of the gangrel dam

The Gangrel dam site is located on the Archeaen gnessies, Cuddapah Quartzitic sandstone, quartz granulites and instrusive granite (Post Cuddapah). This has been examined by different officers of Geological Survey India since 1968–69 onwards. Detailed subsurface explorations by drilling, number of drill holes have established the foundation grade rocks. The study of drill

holes have proved shearing of granite in the river bed portion. The percolation tests have been conducted to study water tightness of the joint openings in order to finalize the grouting treatment to be adopted at the dam site.

Geology of the foundations of the power house

The foundations of the power house (1- 4 blocks) were been examined during the construction. There are four units; each one is located in fresh, hard, well – bedded, grey to greenish layers of Quartzitic sandstones. The power house wall will provide toe support to the already constructed dam. Foundations of each block have been laid on fresh and hard rock as accepted for laying concrete (Fig.1).

The consolidation grouting carried out appears to have strengthened the rock below the foundation grade as required to withstand the load and vibrations of the power house. A total of 487 bags of cement have been consumed for grouting of the foundation in

Fig. 1. Photo showing the power house foundation blocks 1-4 under construction

order to make the foundations impermeable, tight and monolithic. Anchors have been provided throughout the blocks 1 to 4 with spacing at 2.5 m C-C and to a depth of 2.5 m. The Block diagram (Fig.2) shows the thickness of quartzitic sandstone above the contact with granite (Basement rock) in the sump pit (3 m x 2 m x 2.1 m) in Unit IV of Power House. Each block was excavated where sandstone contact with granite as basement rock has been established as unconformity.

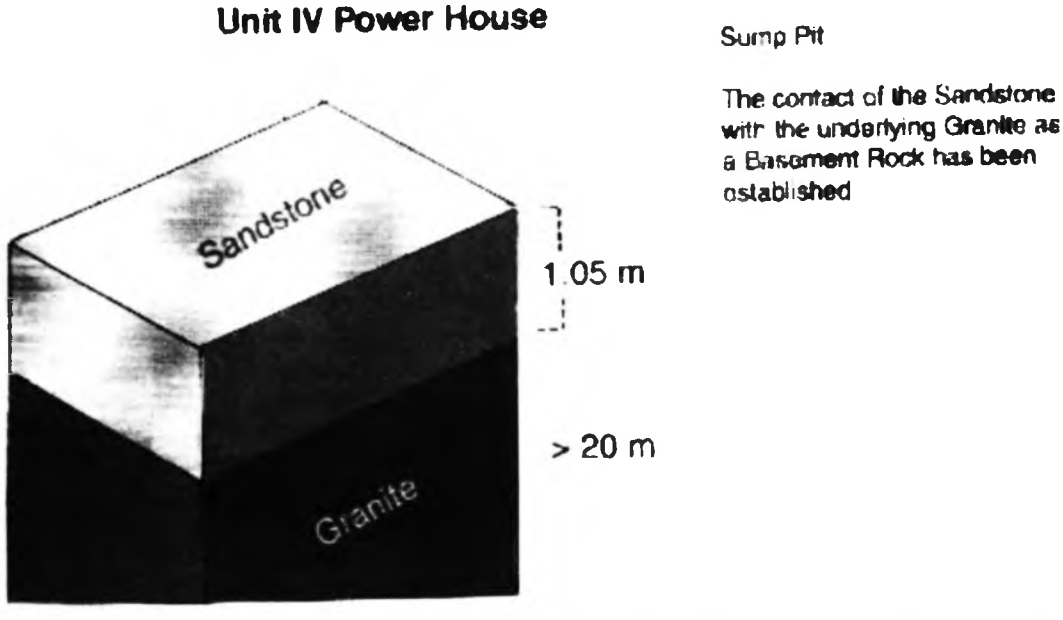

Fig. 2. Block diagram showing 1.05 m thick sandstone over the granites forming foundations of Power House

Table 1: Grout holes with grout consuption

HOLE NOS.	LOCATION RD (m)	LOCATION RL (m)	DIAMETER OF HOLES IN (mm)	DEPTH OF HOLES DRILLED (m)	HEAD OF WATER (Kg/ cm²)	TEMPERATURE OF WATER (°C)	WATER COLOUR	TOT OF CEMENT BAGS	WATER CEMENT RATIO
1	246.65 d/s 30.15 m	316.6	57	1.5	1.5	26	Grouted Grey white to yellowish brown	89	1:5 & 1:1
2	232.25 d/s 31.4 m	316.36	57	1.5	1.5	26	-	165	1:5 & 1:1 1:1
3	248.4 d/s 33.4 m	316.44	57	1.2	-	26.5	Gray to clear	113	1:5 1:1
4	220.05	316.61	57	2.4	-	27	yellow brown	120	1:1 1:5 1:1

The contact zone is found to be tight with fresh and hard sandstone of 1.05m established in the sump pit excavated. Shallow holes of 1.5 m depth drilled as part of explorations for anchors in the foundations revealed the artesian conditions with water flowing from the holes, under a head of 1.5 kg/ sq cm. The discharge observed is about 40 liters per minute.

Fig 3: Artesian well showing flowing water of coloumn of 12 m above the top of the borehole in the foundations of the power house site.

Grouting of the foundations

The grouting was carried out after washing and cleaning the holes to the depth drilled by air and water jets. The grouting has proved effective to control the leakage/water flow. The grouting has ensured the effectiveness of consolidation of foundations to the depth drilled and grouted. The concreting process of foundations of the power house has been carried out after grouting was completed. Test holes indicate the foundations to be impermeable with complete reduction of the water seepage and water flowing conditions. Anchors have been provided in blocks 1 to 4 to a depth of 2 m and spaced at 2.5 m C-C. Details of Grout Roles with grout consumption is given in Table-1.

Geological setting for the tunnels at the inlet and outlet portals

The excavation of the tunnels has been started as per the recommendation of CMRI, Nagpur. The method adopted was Drill-Blast-Method (DBM). The rock of tunnel media in general is of good quality and the tunnel route runs across the strike of the beds. The thickness of the beds is generally 0.50 m to 0.90 m at the crown and these are expected to be self-supporting. The rock bolts and shotcrete for the tunnel have been provided as per the design. Broken and loose rock has been removed before shotcreting work was undertaken.

The four tunnels are 5500 mm x 1950 mm in dimension. The tunnels have encountered along the route, fresh, hard, fine grained and greenish coloured quartzitic sandstone beds. Water seepage at the crown has been noted. The geomechanical properties of the rock mass at the tunnel grade have been worked out on the basis of the joint spacing and orientation and spacing with respect to the structure and over all geological competency of the rock mass. The fresh sandstones intercalated with 6-10 cm siltstone beds encountered in the tunnelling fall under RMR-Class-I of Very Good. The joint pattern (after Deere 1963) indicate that it falls in the

category of moderately close to close and the rocks are therefore considered self supporting as it has been observed . The Rock Mass rating has been computed to be of > 80 relegating to RMR Class I- Very Good. This when interpreted amounts to 20 years of stand-up period for a span of 15 m. The rock formations encountered in the tunnelling are therefore considered as very good tunnelling media and self supporting.

Geotechnical evaluation and treatment of the diversion tunnels

TUNNEL – I

The total length of Tunnel- I from upstream portal to downstream portal is 45.5 m. The tunnel excavations were started 13th Nov 2002 and completed on 26th Jan 2003.

The dimensions of the Horse shoe shape tunnels are 5100 x 3350 mm. The spacing of the joints and the nature of the joints were studied from both the portals. Slight surface seepage was noticed at the portal faces. The thickness of the beds varies from 40 – 80 cm but small layers of siltstone varying in thickness from 8 cm to 15 cm were observed. The inter layers of siltstone and sandstone beds are uniform and contact is tight. In the initial stretch of 6 m iron stained, yellowish coloured, vertical to steeply dipping joints are noticed. The rock in general is fresh, hard and good to fairly good.

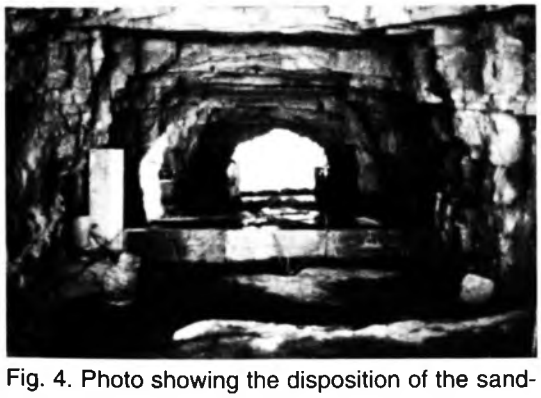

Fig. 4. Photo showing the disposition of the sandstones at the downstream portal of Tunnel I

These sandstone beds are seen extending in the side walls of the tunnel. At the crown thick sandstone beds varying in thickness from 50 cm – 70 cm were noticed which have been provided with the rock bolts by drilling vertical / steep angled holes towards the roof of the tunnel so that maximum beds above the crown of the tunnel as well as along the spring line are tied. The bedding dip is shallow (5º to 7º). The attitude of the beds and the orientation of discontinuities, spacing and nature of joints are noted. The joint patterns observed during construction stage are:

1. NW – SE dip vertical
2. North – South dip vertical, slightly iron stained at the crown.
3. NNE – SSW dip 80º towards WNW
4. NE - SW dip 80º towards SE
5. East – West dip 7º towards Northerly

The joints are tight, fresh, and spaced at about 0.40 m to 0.60 m. Minor shear zones have been observed near the side walls of the tunnel, where rock bolts have been provided confining them to the overlying beds of hard sandstone. The type , nature of the sandstone beds appear to be self-supporting as the thick beds occur in the crown. The Rock Mass rating has been computed to be of > 80 relegating to RMR Class I- Very Good. This when interpreted, amounts to 20 years of stand-up period for a span of 15 m. The rock formations encountered in the tunnelling are therefore considered as very good tunnelling media and self supporting.

The tunnel was excavated across the strike of sandstone beds. The layered beds can be seen at the crown, which have been made monolithic, uniform by providing Resin Coated Rock Bolts.

TUNNEL – II:

It has been excavated for the full length of 45.6 m. The excavation was started in mid Nov 2002 and completed on 29th Jan 2003. The crown height is 3.7 m to 1.9 m at 28 m

Fig. 5. Photo showing the downstream portal of the tunnels I, II, III & IV

completed on 10th feb 2003. The total length of the tunnel is 45.6 m. It has encountered well bedded, hard, fresh and greyish to slightly iron stained, yellowish coloured quartzitic sandstone. The stained zone is about 6 m in length. Minor hard siltstone bed of thickness 10 cm to 13 cm has been noted. The siltstone layers continue and extend in all the Tunnels- I to IV. The joints are tight, with slightly rough surface and at places showing undulating surface along the joint

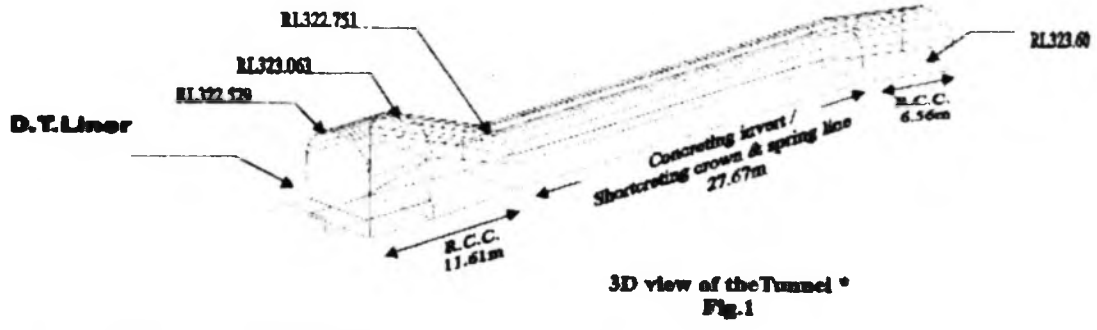

Fig. 6. Showing the 3D view of the tunnels and the treatment provided.

length. The joint spacing and the nature of joints have been studied and examined. These are same as in Tunnel –I, as all the four tunnels are excavated in the same formations (Fig. nos. 5 & 6).

The geotechnical evaluation and treatment accorded are identical as in Tunnel-I.

TUNNEL - III

The total length 45.6 m has been excavated. The date of starting was 15th Nov 2002 and was completed on 30th Jan 2003. It has encountered grayish colourd, fine grained and well bedded sandstone with a dip of 5º to 7º towards N.N.W as in Tunnel-I.

The geotechnical evaluation and treatment accorded are identical as in Tunnel-I.

TUNNEL – IV

It was started on 19th Nov 2002 and was planes.

The geotechnical evaluation and treatment accorded are identical as in Tunnel-I.

The downstream vertical has been mapped geologically demarcating the quartzitic sandstone and siltstone beds (Fig. 7). Four geological sections were taken along the central lines of the four tunnels and thicknesses of these beds are given in Table-2. The thickness of beds ranges from 0.25 m to 1.75 m except siltstone which is of the order of 0.03 to 0.06 m in thickness. The quartzitic sandstone beds are gray to yellowish in colour, fine to medium grained in texture, thick-bedded and hard with iron staining at places.

The thicknesses of quartzitic sandstone beds in metres on the downstream vertical Face above the Downstream portals of the Tunnels – I to IV.

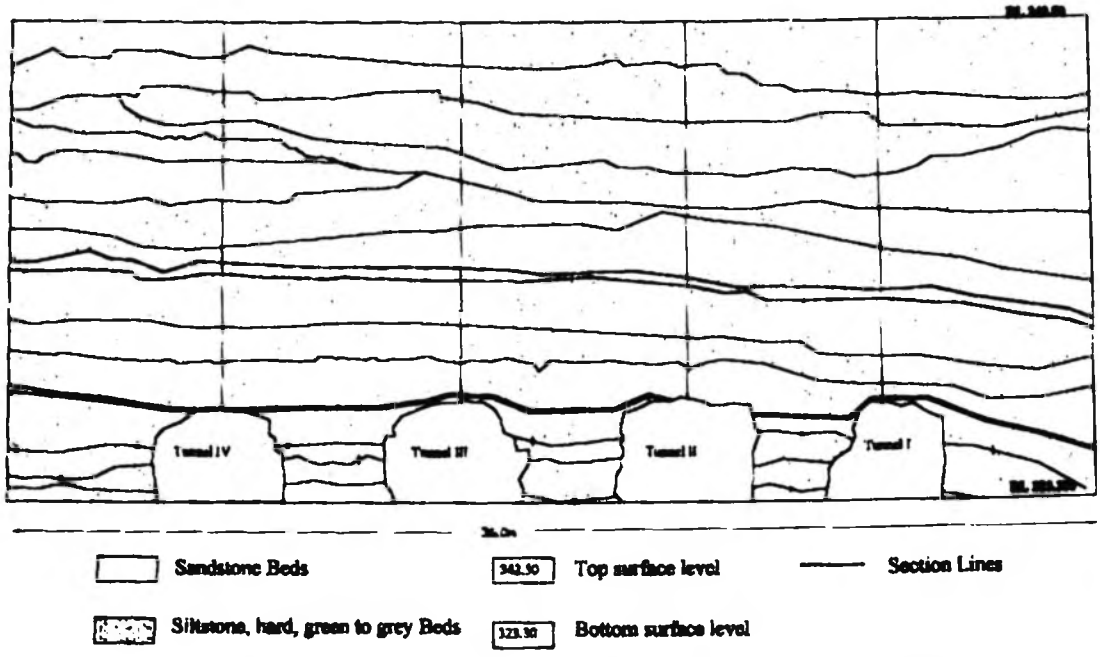

Fig. 7: Geological log of the downstream portal faces of tunnel I- IV showing the thickening and thinning of beds and the section lines.

Tail race channel

The general rock condition of the Tail Race Channel , the foundation grade level is good.It comprise Greenish gray to yellowish coloured, fine grained quartzitic sandstones. These sandstones show iron staining at places. These sandstones show very gentle dips.The joints are spaced 0.50 to 1 m and are mostly vertical with a variation to steeply dipping. The bottom level of the Tailrace channel is at RL 323.60 m. The side slopes of the Tailrace channel have been provided with short-crete up to RL 342.50 m.

Concluding remarks

Quartzitic sandstone of about 1.05 m underlain by granites forms the foundations at levels of RL 314 m - 316 m of the power house with four units; each with installed capacity of 2.5 MW under the Gangrel HE project. This lies between RD 214 m and RD 250 m of Gangrel dam. .The power house pit of 13.5 x 36 m is located in 19 m deep cut.

Artesian conditions were observed at 12 m head of water. Treatment by cement grouting was done with total consumption of 487 bags to make the power house foundations impermeable and it completely reduced the water seepage.

Anchors have been provided in blocks 1- 4 spaced at 2.5 m C-C and to a depth of 2.5 m. In the power house unit IV, a sump pit of 3 m x 2 m x 2.1 m was excavated, where sandstone contact with granite was exposed. The contact appears to be unconformity and found to be tight.

The surface geological mapping and geological sections have been carried out both at inlet and outlet portal faces and the rock conditions studied in a 19 m deep cut on both sides of the inlet and outlet tunnels. The details of the tunnels and the treatment accorded have been discussed in the paper in detail. The portal faces of both upstream and downstream are found to be stable. However shot-creting was recommended to avoid rock fall hazard at the face of a 19 m deep cut.

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