Execution of a Long Tunnel Without any Mishap - Case of Bansagar Tunnel, Madhya Pradesh

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Abstract

A 5.0m dia and 2.045km long horse shoe shaped, lined tunnel has been constructed at the end of Bansagar Feeder Channel across flat topped Kaimur Range in Sidhi District of M.P. The scheme envisages diversion of 46.46 cumec water from Bansagar Reservoir to Adh Nala, a natural carrier to Mirzapur, for augmenting the existing irrigation system in Allahabad District through Meja Reservoir.

The tunnel has been excavated in rocks of Kaimur Group of Vindhyan Supergroup. Gently dipping jointed sandstone dominates the tunnel alignment. Shale and thinly interbedded sandstone and shale are limited to some sections. The strata dip gently. The rock is traversed by three joint sets, few thin shears and faults, not exceeding 50cm thickness. The Q-value for the rockmass ranges between 0.8 and 73.88. The design supports include 25ϕ 1.75m rock bolts center to center staggered both ways above spring level with 50mm thick shotcrete.

The geological investigations indicated problems of crown collapse due to the dominant and persistent major basal sets of bedding joints. This was contained by way of systematic rock bolting in crown region, irrespective of rockmass class.

The measures proved effective and the entire tunnel has been excavated without any mishap. This long tunnel may be considered to be one of the rarest major underground structures completed without any problem.

Introduction

A 5.0m dia and 2.045km long horse shoe shaped, lined tunnel (Photo-1) has been constructed at the end of 68.860km long Bansagar Feeder Channel across flat topped Kaimur Range in Sidhi District M.P. This scheme of Irrigation Department, Government of Uttar Pradesh, envisages diversion of 46.46 cumec water from Bansagar Reservoir in Madhya Pradesh to Adh/Adwa Nala, a natural carrier to Mirzapur for further distribution of water for irrigation in Allahabad district in Uttar Pradesh through Meja Reservoir (Fig-1). The Inlet portal of the tunnel (Photo -2) is located in village Sudwar and outlet portal (Photo-3) at village Hardi in District Sidhi, Madhya Pradesh. A 900m long open Channel has been constructed between outlet portal and the Adh Nala.

The pre-construction geological assessment of the tunnel was carried out by geological mapping, geological logging of five drill holes totaling 417 m depth and 50m long drift at the tunnel grade on the inlet portal side (Kumar and Kandpal, 1990; Srivastava, 2000; Srivastava, 2003 & 2004)). Two alternatives of the tunnel alignment were studied. Alternative -I was dropped because of the location of the Transmission Tower of Power Grid at the inlet portal site of this alternative and Alternative -II due to design considerations at the outlet end. Finally, a third alignment, located between the two earlier discussed alignments was Chosen for the construction

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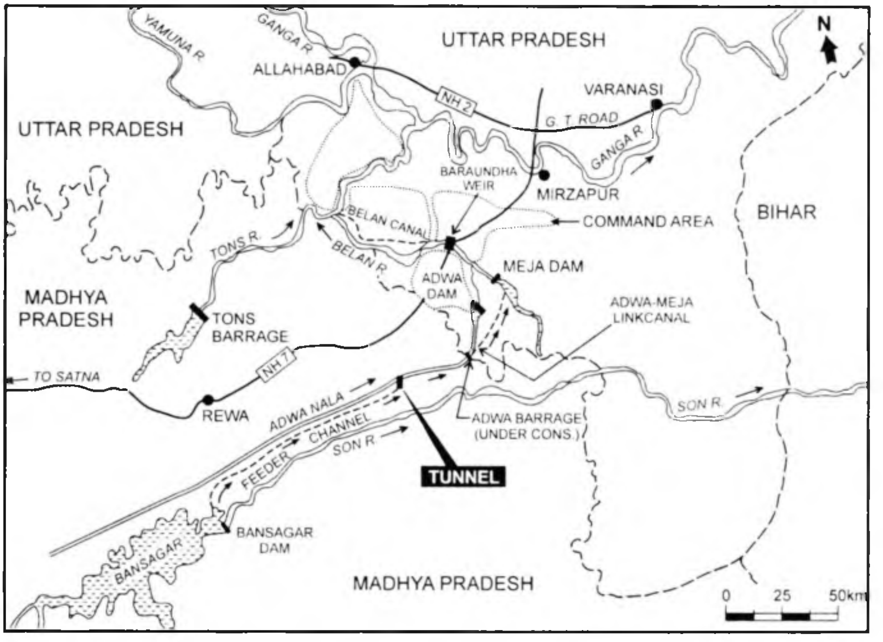

Fig. 1: Layout of Bansagar Feeder Channel Scheme and Location of Feeder Tunnel.

(Fig-2). During construction, 3 D geological logging of the tunnel on 1:200 scale was carried out. Besides this, Q-values for the rockmass was determined and the support systems were recommended from time to time.

Geology

The rocks exposed along the tunnel alignment belong to Kaimur Group of Vindhyan Supergroup comprising sandstone, shale and thinly interbedded sandstone and shale (Fig -2)). The strata dip N320°-355°/ 04° -12°, i.e. along the tunnel alignment in downstream direction. The variation in dip amount is because of warping due to inter-layering of competent and incompetent strata. Besides bedding joints, other prominent joint sets dip steeply (>80°) in N140°-175°, N060°-080° and N180° directions. The joints are widely spaced (>1m) in sandstone but are closely spaced (0.10-0.30m) in shale and thinly interbedded sandstone and shale. Few thin shear zones and a fault zone have been encountered during excavation of the tunnel.

Photo 1 : 5.0m dia and 2.045 km long Bansagar Feeder Tunnel

Rockmass Characteristics and Support System

The tunnel has been excavated mostly through jointed sandstone. Shale and thinly interbedded sandstone and shale are limited to few sections. On the basis of Q-Values (Barton et.al 1974), the rockmass was divided into five different Rockmass Classes (Table –1) by the Central Water Commission, New Delhi, through its design drawings of the tunnel. The design support was recommended for each class.

In view of the dominance and persistence of

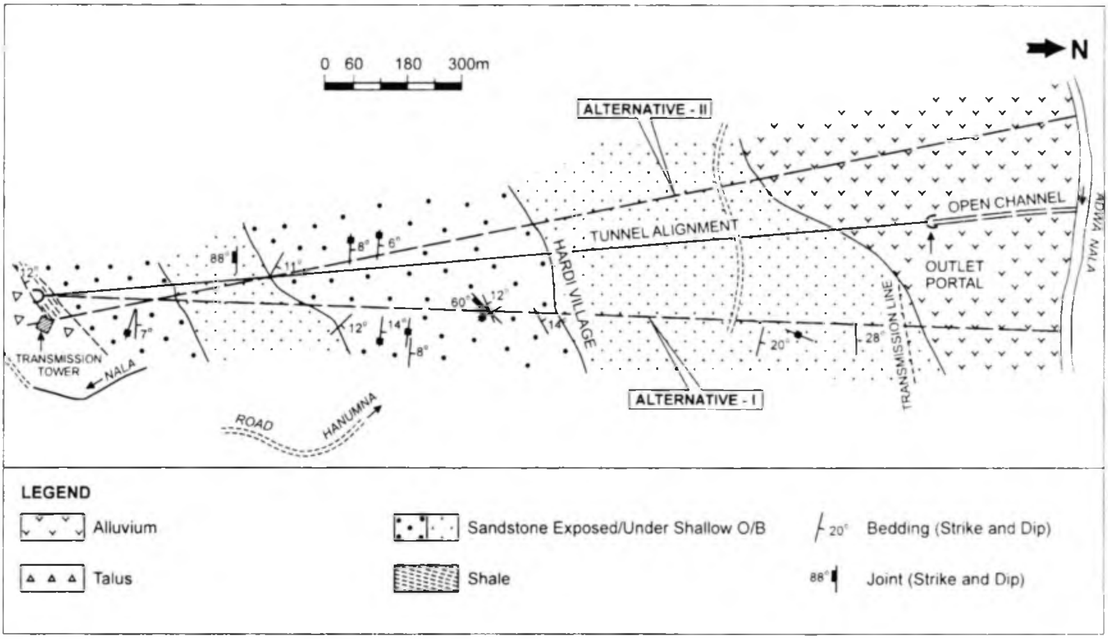

Fig. 2: Layout and Geological map of Bansagar Feeder Tunnel.

the basal set of joints, in combination with other sub-vertical sets, instability due to slabbing was apprehended at crown level. It was, therefore, decided to provide rock bolting in the crown portion immediately after excavation as per the design criterion for Class II rock (Good), irrespective of the actual Rockmass Class (Anon, 2005). This included staggered bolts to a maximum of three numbers in one cross section. The bolting comprised 25Ö rock bolts 3500mm long @ 1750m C/C staggered both ways.

Tunnelling Conditions

The major part of the tunnel (88.8 % of its entire length) has been excavated through good to very good quality of rockmass and rest 12% through fair to very poor (Paikray and Srivastava 2005 and Srivastava 2005). The sandstone falls in good to very good rockmass class whereas shale and shear/ fault zones in poor to very poor category. Thinly interbedded sandstone and shale are of fair rockmass quality. A major shale band of about 28m thickness is exposed at inlet portal itself. Besides this, other geological problems encountered during tunnel excavation included presence of very poor quality of rockmass at the inlet portal site and flooding of tunnel because of free flow of water from the shear zone at Ch.m 1043.

The very poor quality of rockmass at inlet portal was mitigated by way for providing steel ribs as per the portal design.

Table 1: Rockmass classification and Design Support.

Sl.No.	Rockmass Class	Q-Values	Design Support
1	Very Poor	0.1-1.0	ISHB 150 @ 500mm C/C; 25Φ spot rock bolts 3500mm long; 100mm thick shotcrete.
2	Poor	1.0- 4.0	ISHB 150 @ 600mm C/C; 25Φ rock bolts 3500mm long @ 1500m C/C; 75 mm thick shotcrete.
3	Fair	4.0- 10.0	25Φ rock bolts 3500mm long @ 1750m C/C staggered both ways with 50mm thick shotcrete.
4	Good	10.0 - 40.0	25Φ rock bolts 3500mm long @ 1750m C/C staggered both ways with local application of 50mm thick shotcrete.
5	Very Good	40.0 - 100.0	25Φ rock bolts 3500mm long (where ever required) or local application of 50mm thick shotcrete (where ever required).

Table-2: Classification of excavated rockmass.

Sl. No.	Tunnelling Media	RQD (%)	No. of Joint sets (Jn)	Joint Roughness (Jr)	Joint Alteration (Ja)	Joint water (Jw)	Stress Reduction Factor (SRF)	Q-Value	Rock-mass Class
1.	Shear zones in Shale	20	3 (9)	Rough, irregular, Planar (1.5)	Unaltered joint wall, Surface staining (1)	Medium inflow, Dripping (0.66)	Weakness zones containing clay (2.5)	0.879	Very Poor
2.	Shear zones / Fault in Sandstone	50-60	2+ random -3 (6-9)	Slickensided, undulating (1.5)	Slightly altered (2)	Moist (1)	Weakness zones containing clay (2.5)	1.9-4.4	Poor - Fair
3.	Shale	20	3 (9)	Rough, irregular, Planar (1.5)	Unaltered joint wall, Surface staining (1)	Medium inflow, Dripping (0.66)	Weakness zones containing clay (2.5)	0.879	Very Poor
4.	Thinly inter-bedded sandstone and shale	63-72	2+ random -3 (6-9)	Rough, Irregular (3)	Altered joint wall, Clay coating (2-3)	Moist, wet (1)	Weakness zones containing disintegrated shaly material (2.5)	3.6-7.0	Poor-Fair
5	Sandstone	75-100	2+random (6)	Rough, Irregular (3)	Unaltered Joint walls (1)	Dry-Moist	Low stress (1)	10.5-73.8	Good –Very Good

Thin shear zones of 10-50cm thickness have been encountered in the tunnel at Ch.m 25.8, 629, 690, 711, 743 and 1043 from inlet portal (Fig. 3). A gougy, steeply dipping fault with a throw of about 1m was intersected at Ch. m 1690 (Deva, 2005). The rock on either side of the fault also appeared fractured in about 15m zone along the tunnel alignment.

Photo 2: Inlet Portal of the Bansagar Feeder Tunnel.

Subsurface water in the tunnel has not been much. However, wet and dripping conditions prevailed. In particular, some rock bolts were found profusely seeping that was interpreted to be due to the bolt holes intersecting water charged, gently dipping bedding joints (Deva, 2005). Free flow of water leading to temporary flooding of the tunnel was recorded through a major steeply dipping shear zone at Ch. m 1043 that got reduced considerably in a short time. The flooding was handled through enhanced pumping capacity. The rock condition at the heading was sound. The seepage, interpreted to be from a perched water body, was routed through a steeply SSE (u/s) dipping shear zone that was intersected on the left side.

A uniform stabilisation approach had been designed for the entire 115m long stretch of the open box-cut at the Outlet (Photo 3). The treatment comprised 5m long, 25mm dia torque steel rock bolts @ 1.5m C/C

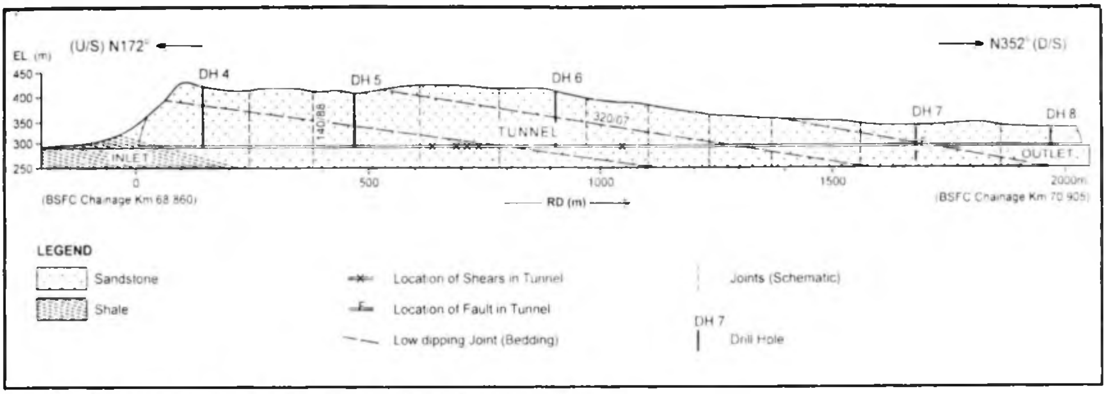

Fig. 3: Geological section along Bansagar Feeder Tunnel.

staggered, inclined 10°-20° in to the slope face, followed by wire mesh reinforced shotcrete of 50mm thickness. 75mm dia weep holes of perforated pipes, filled with pea-gravel, were being provided @ 5m C/C staggered. Seepage through these holes was proposed to be drained through contour drains on respective berms. It was, however, found that there was no provision for channelising seepage through individual weep holes that may lead to deterioration of the slope face – both technically as well as aesthetically. It was, therefore, advised to provide appropriate guided drainage from the weep holes to the contour drains (Deva, 2006).

The rockmass classes for the excavated media were determined on the basis of Q-Values and are summarized in Table-2.

In general, the tunnel was excavated for 1.3 % in Class-1 rockmass, 3.1 % in Class-2, 6.8 % in Class-3, 43.3 % in Class-4 and 45.5 % in Class-5.

Conclusions

The designed supports, that were modified with the design-as-you-go approach, have been found generally adequate in the execution of the Bansagar Feeder Tunnel. In particular, the decision of providing rock bolts in the rockfall prone, basal jointed, crown portion is interpreted to have been a sound judgment. The overall excavation and support measures, in general, proved effective and the entire tunnel has been excavated without any major problem or suspension of works for long durations. This long tunnel may even be considered as a case of major underground structures executed without any mishap.

Photo 3: Outlet Portal of the Bansagar Feeder Tunnel.

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