3D Wedge Analyses Carried out During DPR Stage Investigations of Pung - Dehar Silt Flushing Tunnel Project, Mandi District, H.P.

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Abstract

This paper discusses results of 3D wedge analyses carried out during DPR stage geological investigations for Pung-Dehar silt flushing tunnel project envisages construction of a 3.8m dia and ± 13.5 km long tunnel with intake nearby balancing reservoir of BSL project at Sundernagar. The silt would be flushed in river Sutlej downstream of BSL switchyard near Kangu. The tunnelling would be carried out in the sandstone and claystone/siltstone sequence of Dagshai Formation and dolomite belonging to Shali Formation in more than 90 % of the reach.

Introduction

Beas Satluj Link Project is a major inter basin project involving diversion of about 4716 m cum of Beas water to Bhakra reservoir producing 990 MW of power utilizing a drop of 320m. One of the components of this marvellous project is a balancing reservoir at Sundernagar, which is about 2.13 Km long and having maximum width of 457m. The function of balancing reservoir is to provide live storage capacity for peaking and acceptable silt free water to powerhouse. Despite a multi-pronged strategy for entrapment of and ejection of silt both at the dam and along the water conductor system, the dredging of silt from balancing reservoir has been started from 1983 onwards to have maximum live storage capacity.

Dredging operation was intensified after 1986 and is dredging out 123 ha m of silt annually accumulating in the balancing reservoir is being dredged out. This silt is being ejected in the Suketi *Khad*, which joins river Beas at Mandi. In monsoon season when there is adequate discharge this material is flushed into river Beas but in non-monsoon period this flushed silt deposits along *Khad* bed thereby creating some aquatic, environmental and agricultural problems to the local people. Pung - Dehar silt flushing tunnel project has been conceived to find a lasting solution to this problem.

Pung - Dehar silt flushing tunnel envisages construction of a 3.8m-dia and ±13.5 km long tunnel (one aqueduct to cross Alsed Khud) with intake nearby balancing reservoir of BSL project at Sundernagar. The silt would be flushed in river Sutlej downstream of BSL switchyard near Kangu. The silt-laden water would flow by gravity, utilizing a drop of more than 300m, in the tunnel with gradient in tunnel varying from 1:49 to 1:30. One construction adit is proposed at R.D. ± 6 km, which is ±500m in length.

Geology

Sandstone and claystone/siltstone belonging to Dagshai Formation are exposed in major portion (from intake to about R.D. ±11 km) of the tunnel alignment. From R.D. ±11 km to R.D. ±12.5 km grey dolomite belonging to the Shali Formation are exposed and from R.D. ±12.5 km to the tunnel outlet, river borne (terrace) material is met. The strike of the bedding is slightly askew to the tunnel

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alignment, which is not a favourable feature. The Dagshai Formation is constituted of purple and brick red claystone and siltstone with alternating beds of sandstone, which are greyish to greyish green in colour.

The major joints recorded are as follows:

i) N15°E-S15°W to N10°W-S10°E with 65°-80° dip easterly/ westerly direction. Continuity > 10m spacing 0.5m - 1.5m.

ii) N35°-50°W - S35°-50°E with 70°-80° dip due north-easterly direction. Continuity >5m spacing 0.5m - 1m.

iii) N60°-80°E - S60°-80°W with 40°-60° dip due southerly direction. Continuity < 5m spacing 0.5m.

Dolomite is grey to dark grey in colour with thin shale partings at places in it. The major joints recorded in the dolomite unit are:

i) N10°W-S10°E to N10°E-S10°W with 50°-75° dip due west. Continuity >10m spacing 0.5m - 2m.

ii) N40°-50°E - S40°-50°W with 65°-75° due northwest. Continuity > 5m spacing 0.5m-1m.

iii) N55°-75°E - S55°-75°W with 30°-55° dip due south-east direction. Continuity > 5m spacing 0.5m - 1.5m.

iv) N50°E-S50°W to N60°W-S60°E with 40°-50° dip due northern direction. Continuity > 5m, spacing 0.5m - 1.5m.

The river borne material consists of sub angular, sub rounded to rounded pebbles and cobbles embedded in silty sandy (course) to gritty matrix as observed in the exploratory edit, 30m in length at the exit portal. At places calcareous cementation is observed at the surface, which may not continue in depth as per the observations made during investigations. In the river borne material the results of excavation in the drift DR-3 is encouraging as the strata has good stand up time that drift section is smaller than tunnel section. It is inferred that this zone can be tackled by providing immediate rib supports with backfill concrete as per Terzagi's method. Advance information of the strata likely to be encountered by a probe hole would provide necessary information to tackle difficult zones like sand/ silt bands which can be tackled by using techniques like fore poling and multiple drift method.

Wedge Analysis

Wedge analysis of the possible wedges that may form during the excavation of the tunnel Shali Formation and Dagshai Formation was carried out using 'unwage' software. The wedge analysis has been done on the basis of joint data recorded during geological mapping and subsurface explorations. It is based on the following assumptions:

i) The joints are continuous and the kinematically most suitable combination of joints for wedge formation occur at one place during excavation.

ii) The cohesion along joint planes is nil and angle of internal friction is taken as 30°.

iii) The failure in the rock mass occur due to structural discontinuities.

iv) Steel capacity of bolt is 25 tonnes and anchor capacity is 10 tonnes.

v) Shear strength of shotcrete is taken as 200 tonnes/sq m in calculating the factor of safety.

vi) The density of rock is taken to be 2.7 t/ m^3.

The details of wedge analyses are as follows:

Dagshai Formation : The rocks belonging to this formation would be met in major portion of the tunnel alignment. In this the maximum possible weight calculated is 96 tonnes. It is being stabilized by 5 cm thick shotcrete and pattern bolting (25mm dia) of 2mx2m as per the preliminary support analyses carried out.

Tattapani Formation (dolomite):In this maximum weight of the wedge possible is **44** tonnes. The data is collected during the logging of the drift (DR-2) and that from surface mapping. As per the support analysis (preliminary) the wedges formed are stabilized by 5 cm thick shotcrete and pattern bolting (25mm dia) of 2m x 2m.

Conclusions

From the wedge analysis it is inferred that in rocks of Dagshai Formation and Shali Group the support of shotcrete (5 cm thick, along with wire mesh) and pattern bolting of 2m and 2.5m long rock bolts at 2m x 2m staggered spacing may be sufficient support for controlling possible wedge failures. An example of wedge analysis performed is given in figures 1 & 2. A possible 38 tonne wedge can be stabilized by 5 cm thick shotcrete and 2m long (25mm dia) grouted rock bolts at 2m x 2m spacing. However, this needs detailed analyses taking into consideration *in situ* stresses, rock mass properties, rock cover etc.

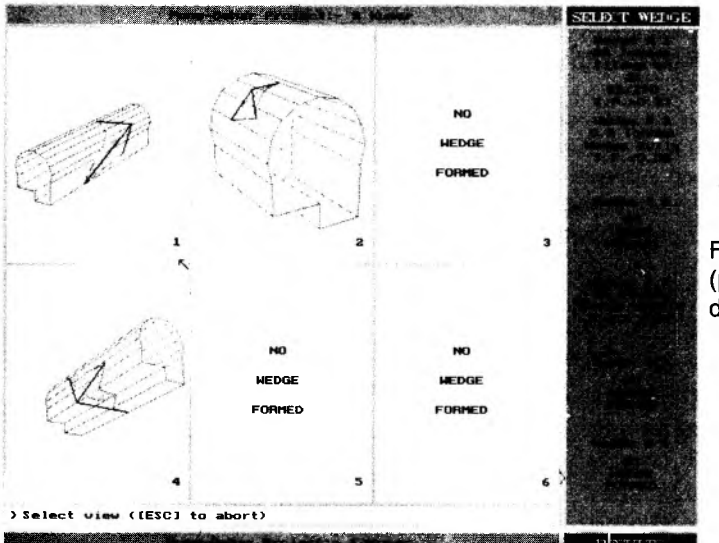

Fig. 1 Analysis depicting wedges (possible) formed in dolomite (joint data from exploratory drift)

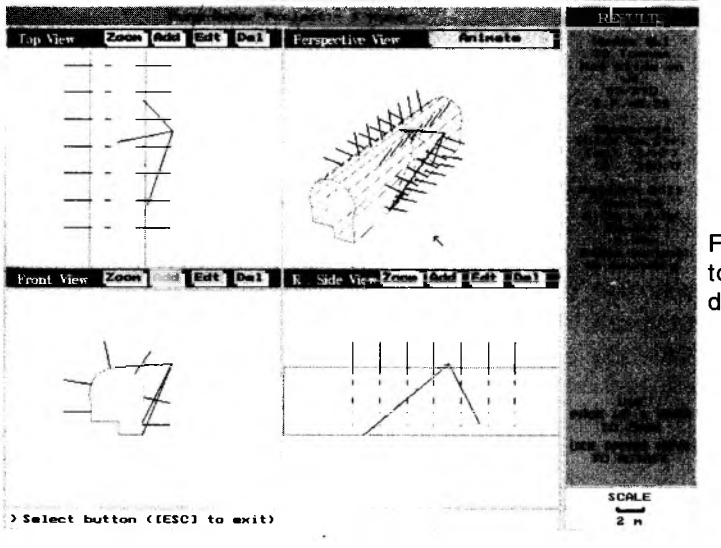

Fig. 2 Analysis of supports required to support a 38 tonne wedge in dolomite (refer Fig. 1)