Advance ground improvement technology for tunneling in low cover

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Abstract

The 341km long Udhampur-Srinagar-Baramulla Railway link is under construction as a National Project in Jammu & Kashmir State. The project involves construction of series of tunnels between Udhampur and Qazigund through soft to hard rocks ranging in age from 1 to 2000 million years to Recent times which has been classified under Salkhalas/Central crystalline, Sirbon Group, Pre –Teritary (Ramsu, Muth Quartzite, Sringothyris limestone, Fenestella shales, Agglomerate slate, Panjal volcanics, Zewan, Khrew, Wuyan Formation), Murree Group, Siwalik Group and Recent to quaternary deposits. Out of these, Murree and Siwalik Groups of rocks constitute the outer Himalayan zone, where as the remaining units form the lesser Himalayas. Both outer as well as lesser Himalayas have under intense tectonic activity and besides folding and faulting, railway alignment area is crossed by three regional tectonic features which include, Main Boundary Fault (MBF), Murree and Panjal Thrust besides two local Thrusts. These structural features have disturbed rocks.

Within outer Himalayas, Murree rocks consists of alternate bands of thick clay shale/clay stone, siltstone and thin sandstone, clay shale/clay stone are soft, weathered and slide prone. As a result, most of the area along the alignment is covered with debris/slided material and rock is exposed only along the nala banks and high ridges. Between village Ind (km78.378) and Chingi nala km (100.750), most of the tunnel alignments are covered with rock debris/slided material.

In view uniform proposed grade and curve angle for the proposed railway track, it was not possible to shift the tunnel portals at suitable locations as being done for hydel or even road tunnels. As such construction of Tunnels Nos. 39,41,43,44, 45, 46 and 47 was taken up through overburden/slided material under low cover zones. This was possible only with latest ground improvement technology such as pipe fore-poling, grouting, Self Drilling Anchors (SDA) and shotcreting with wire mesh.

Methodology used to excavate some initial lengths of above tunnels through debris and low cover zones has been discussed in this paper.

1. Introduction:

Jammu & Kashmir is a border state and very important from the strategic point of view. Socio–Economic development of the state of Jammu & Kashmir has been vital for government of India. Therefore construction of Railway line connecting Jammu with Kashmir and Baramulla has been taken up as national project. The 138 km long Railway line section between Katra & Qazigund consists of 76 tunnels, 62 major bridges and two Special Bridges, 132 minor bridges and 9 Railway Stations. To expedite the construction of the railway line, the ministry of railway had entrusted Konkan Railway Corporation Limited to take up the Katra –Laole (km 30-km120) and rest of section i.e. Laole to Qazigund to Baramulla to M/S IRCON.

After the construction of approach and feeder roads, Konkan Railway Corporation Ltd, has take up the construction of tunnels 1 to 12 (km 30 to km 62) and in Sangaldan area from T-39 to T-47 (km 88 to km 100.676). Tunnels 1 to 5 have been excavated through

Sirbon dolomite which is generally closely jointed, fractured and sheared. Due to jointing and fracturing, heavy- sub surface water was recorded. As a result tunnel progress remained slow.

Tunnels 6 to 12 and tunnels 39 to 47 are being excavated through Murree rocks consisting of alternate bands of thick clay stone /Siltstone and minor Sand stone. Due to the presence of three thrusts i.e.; Sangalkundi, Murree and Saldar Thrust, Murree rocks in the Sangaldan area are more disturbed and slide prone. Almost all Tunnels (39 to 47) are either located within thick slope wash/slided material or cultivated fields which have been formed after the sliding of the hill slopes.

After finalization of alignment in this area, excavation of Sangaldan station Yard proposed between km 92.735& km 93.210 & tunnel 43 proposed between km 94.232 km 95.903 was taken up. Subsequently excavation for open cut and cut & covers section proposed between tunnel-42 & tunnel-43 i.e.; between km 93.759 and km 94.150 was taken up. Though the cutting varies from 5 to 12 m in height partly in overburden and partly in Murree rocks but after heavy and continuous rains a major slide developed. The head of the slide was 200m above the centre of the alignment and toe was 167m below. The 230m long Sangaldan Gool road located above the alignment was shifted down slope by about 50m. The 28 houses and 26 shops located along both sides of the road were washed away and buried under the slide debris. Similarly 5-12m deep trench made for open cut & cut & cover section was also bodly shifted down slope by about 50m. In view of the above developments, keeping the tunnel portals locations within thick overburden was not desirable. Hence, all the tunnel portals were shifted within low cover where minimum cutting is evolved. To avoid the development of slide or reactivation of old slide, provision of the consolidation grouting, anchoring the ground surface and concrete cladding was provided before the start of the tunnel excavation. A brief description of such portions of tunnels has been given in the following paragraphs.

Tunnel – 39:

The 745m long tunnel is located between km 87.450 and km 88.180. Execution of the tunnel was taken up from P-2 side portal through rock debris consisting o f compact clay and boulder derived from the Murree rocks. Top cover above the tunnel from P-2 side varies from 1D to 2D for a length of 55m. Earlier the Portal was kept at km 88.160 but it was apprehended that cut slopes for open cut may not remain stable during excavation. To avoid frequent slope failure problems, it was decided to excavate the tunnel without disturbing the hill slopes.

After constructing false portal for a length of 10m, an umbrella of pipe fore-poling with pre-grouting was created for a length of 6m. The tunnel excavation was done for a length of 4m.and 2m kept as overlap. Excavated tunnel length shotcreted with 50mm.supported with steel ribs 0.50m apart were erected and back filled with concrete, there after 6m deep SDA were provided & grouted. The above process was repeated till 71m tunnel excavation is completed without wastage of time.

Tunnel-40/ 41:

Some portion of the tunnel-41 was located around the head of the active spra slide. To improve the stability of the tunnel alignment of T-40 & T-41 were modified resulting combining the tunnel- 40 & 41. After combining these tunnels, the tunnel length has become 3.840kms. Even after shifting the alignment, P-1 portal remained critical along the hill slope made up of partly slope wash material and partly rock. About 35m tunnel length was excavated partly cut & cover and partly half tunnel. During the excavation for cut & cover and half tunnel, 6m deep S.T.D where provided towards hill side and grouted. To improve the stability of the tunnel, 9m deep anchors in three rows are recommended at the invert level to stitch the tunnel with the ground.

Tunnel-43:

The 1671m long tunnel has been located between km 94.232 & km 95.903. P-1 portal of tunnel is located in Murree rocks but P-2 portal of tunnel is located in overburden. Earlier, P-2 portal of tunnel was located around km 95.76m in slope wash material. But presence of steep nala across the alignment just before the portal and excavation through slope wash material, it was not advisable to keep the portal around km 95.760. Hence portal location was shifted to Km 95.903. Cover above the tunnel varies from 7m to 35m. Before the excavation of the tunnel following strengthening measures were adopted.

- Provided proper slope cuts & berms above the tunnel portal.
- RCC Concrete cladding along the berms & cut slopes.
- 6 to 9m deep S.D.A
- Consolidation grouting.
- Removal of big boulders from nala bed.
- Anchoring along the nala bed.
- Concreting along the nala bed to avoid collapsing of nala bed due to low cover.
- Provided 10m long false portal.
- Creation of an umbrella of 6m long pipe fore-poling spaced 30 to 50mm.
- Grouting through pipe fore-poling.
- Excavation of tunnel for a length of 1m to 1.5m
- 50mm shotcreting.
- 6 to 9m deep SDA with grouting.
- Erection of steel ribs 150 x 150 ISHB at 0.50m C /C.
- Back fill concreting.
- Channellsing where needed.

With this methodology, 4m tunnel length was excavated out of 6m strengthened portion and 2m left for overlapping & the process was repeated. With this methodology about 225.50m tunnel length was excavated without any problem & wastage of time. Tunnel has been completed in July 2010.

Tunnel-44:

About 876m long tunnel is under construction between Km 96.543 & Km 97.419.Both the portal of the tunnel are located in overburden/ slided material. Like P2 of T43, here also a steep nala located before proposed P1 portal. Hence to avoid failure of cut slopes, tunnel portal was kept at km 96.498 instead of km 96.543. The cover above the tunnel varies from 3 to 31m. Before the excavation of the tunnel, nala bed & top area was strengthen as done for P2 portal of T43 & same tunneling methodology was adopted as done for T43 (P2). With this methodology 141m tunnel length was excavated in overburden with top cover varies from 3m to 35m.

2. Combing of tunnels 44 and 45:

P2 side of tunnel-44 & P1 side of tunnel-45, are located along high hill slope made up of thick slope wash /slided material & partly rock above a deep nala. The space between T44 (P2) & T45 (P1) is 161m in length where open cutting & one bridge was proposed. To reach up to portals & bridge locations, feeder roads were needed which could have destabilized the hill slopes before the construction of portals & bridge. In view of the above apprehension of major failures during the construction of feeder roads & open excavation, it was decided to combine the tunnels-44 & 45 to avoid the construction of feeder roads & tunnel portals.

The top cover above 161m tunnel length varies from 8m-13m. Most of the area above the tunnel portal is made up of slope wash material .In view of the experienced & confidence gained during the construction of T43 (P2 Side) & T -44 from P1 side, it was decided to combine tunnels 44 & 45 & took up the construction from P2 side of tunnel-45 with following methodology.

- Cement Grouting. About 2 month before starting the tunnel excavation ,three rows of cement grouting ,one at the center of the tunnel & other two rows one each side of center line of tunnel at 5m apart. Side holes were drilled & grouted up to formation level whereas central hole, one meter below the crown level.
- Creation of an umbrella with pipe fore-poling spaced at 30mm to 50mm apart for a length of 6m.
- Consolidation grouting through fore poling pipes.
- Controlled blasting with restricted pull of 1m.
- 50mm SFRS instead of plain shot Crete.
- Erection of steel ribs at 1.50m apart.
- Back filling with concrete.
- 6m – 9m deep anchors at 1.50m apart with grouting
- Consolidation grouting.

With this methodology 130m out of 161m length tunneling in low cover has been completed till September end without any problem & wastage of any extra time. Besides avoiding instability of the area, a lot of money & time has been saved needed for the construction of feeder roads, bridges & tunnel portals.

Tunnel– 46:

The 582m long tunnel-46 located between Km 98.346 and Km 98.976 is under construction. Except P2 portal area where Muree rocks are exposed, the entire tunnel alignment is covered with slope wash material & cultivated fields.P1 portal was proposed within slump side. The width of the slide zone is 70m. The toe of the slide is located in the nala bed i.e.; 50m below the portal area.

Since the railway alignment cannot be changed frequently hence design engineer proposed the portal at km 98.400 with in the center of the slide zone with 3m wide berms after every 15m height with anchors & RCC cladding. But from geotechnical view point it was not possible to control the reactivation of slide during excavation of these berms & slope cuts .To avoid reactivation of slide zone & wastage of time & money, it was decided to shift the portal location around km 8.346 without providing any berms & slope cuts. The cover above the tunnel from P1 portal to a distance of 13.50 m varies from 2m to 5m & onward 5m to 33m.

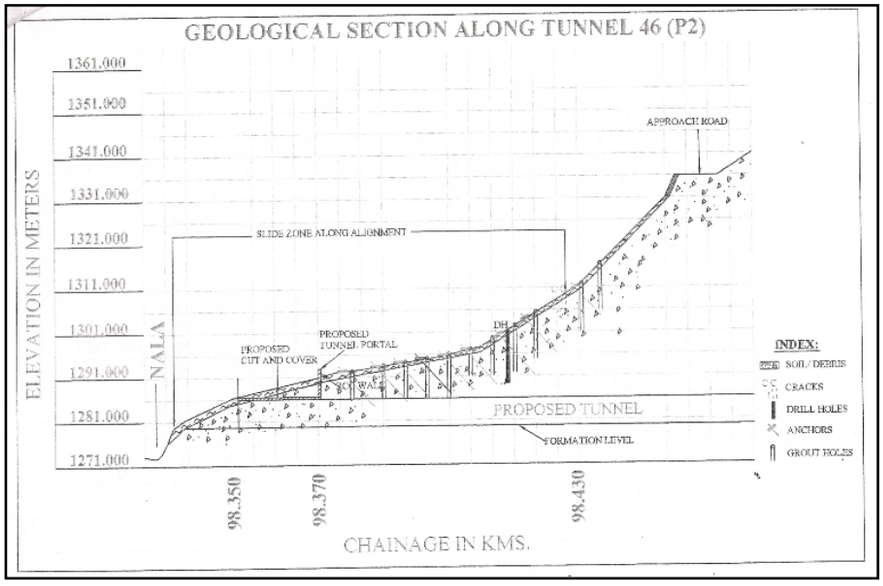

Figure 1 Geological Section along tunnel 46 (P2)

To stabilize the slide area, following remedial measures have been provided.

- Consolidation grouting from the surface along alignment.
- Anchoring the ground along the alignment.
- Cutting the ground /feeder road up to bench level of the tunnel.
- Provision of S.D.A on both sides of the proposed tunnel portal.
- Pipe fore-poling with grout for a length 6m at 0.30m to 0.50m spacing.
- Erection of false portal.
- Excavation of tunnel for a length of 1m.
- Erection of steel 150 x 150 ISHB steel ribs at 0.50m apart.
- Backfilling with concrete.
- Consolidation grouting.

After excavating the tunnel for about 50m length, feeder road was lowered at rail formation level.

RCC Cladding was provided on both sides of the tunnel portal to avoid the reactivation of slide. Though during tunneling there was a stress on shotcrete layer & cracks developed along the slope cut but after providing RCC cladding, area has become stable now.

With the above methodology 227m tunnel length has been excavated. Of this 94m in slided material. During tunneling a cavity of 5m x 3.5 x 3.5 had formed which was tackled by providing channels & backfilling with concrete and grouting

Tunnel – 47:

A 1548m long tunnel -47 is proposed between Km 99.122 & Km 100.675. After constructing 10m long false portal, about 15 m length of the tunnel from P1 Portal side where top cover of soft ground was less than 1D has been excavated by providing umbrella of pipe fore-poling.

3. Conclusion:

It has been the practice of the planner; design Engineer & Engineering Geologist to locate the tunnel portal at stable& safe place with at least 2 to 3 D top as well as lateral rock cover. Now on the basis of experience gained by the construction of series of tunnels located within soft & unstable ground along Katra-Qazigund Railway line section of USBRL Project, it is recommended that with latest ground improvement technology *viz.,* Pipe fore-poling, self-drilled anchors, shotcrete, grouting etc, now it is possible to construct tunnel portal in soft ground even with 2m top cover of soft ground. Tunneling in loose ground conditions is generally based in the load transfer along the current unsupported crown & side wall. Pre-reinforcement as an improvement of the rock mass reduces the over stressing in the face area. The anchors installed sub-horizontally-longitudinally around the tunnel periphery are forming an arc in the rock mass & act as in situ support placed ahead of the excavation. However each difficult zone area shall need a different approach which is worked out by detailed discussions in each case.