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Construction Methodology of Twin Tunnel at Chirwa Ghat - A Review

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Abstract: *The paper describes the details of construction stages for the twin tunnels, particularly highlighting the challenges encountered during the construction of large diameter tunnels, also tackling the same, by providing rock supporting systems designed in accordance with Barton's Q system, along with NATM/ Observation method.*

I. GENERAL

Tunnel can be defined as underground passages constructed for the purpose of transportation connection between two points. Construction activities inside a tunnel are required to be carried out in restricted space. Due to space restrictions and for working underground, specially designed plant and equipment are required along with adequate artificial ventilation and lighting arrangements the tunnel construction operations are carried out in a 'Time cycle' consists of following activities;

- A. Surveying and Profile marking
- B. Advancing the face by appropriate excavation methods
- C. Drilling, Loading, Charging & Firing Operations.
- D. De-fuming (after blasting) and scaling
- E. Mucking including disposal
- F. Plotting of excavated profile and geological mapping
- G. Support Installation – temporary and/or permanent

II. SCOPE

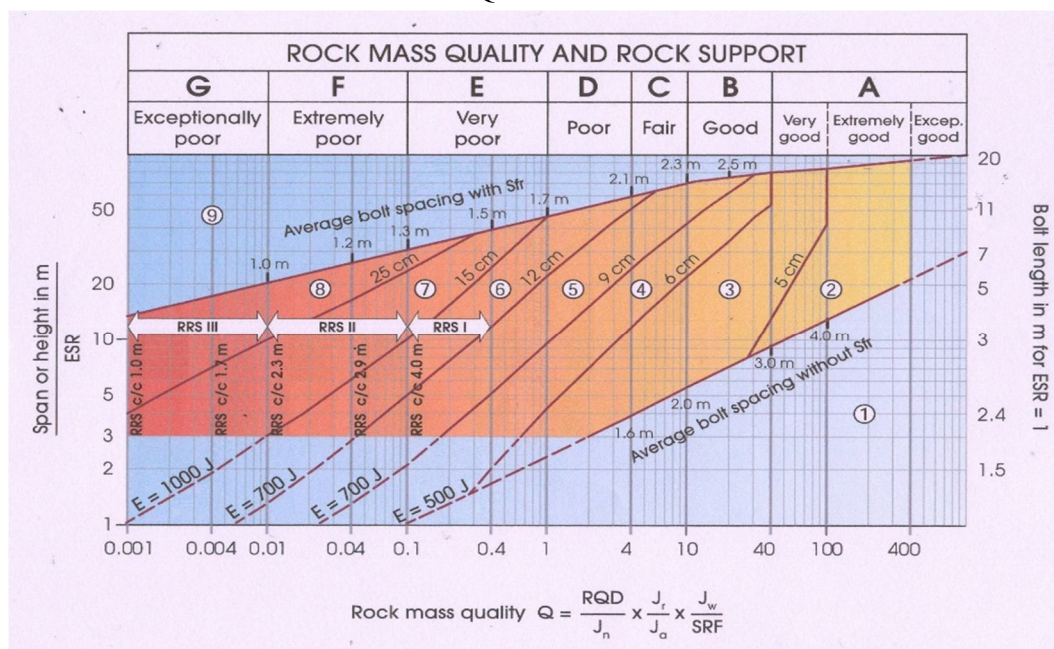
The twin tunnel on NH-8, excavated in quartzarenite rock type. Phyllite and schist are also encountered in bands. The RMR value in major portion of the tunnel length is ranging 30 to 60 and found good as far as the blast ability of the rock mass is concerned. Length of LHS and RHS tunnel is 490 and 410 m respectively. The shape is D-Shape and finished dia. is 14.50m. Based on the geological report of the twin tunnel a typical blast design was prepared for excavation, using conventional technique of drill and blast method, and NATM (New Austrian tunneling method). Observation Method was also used to achieve greater overall economy without compromising safety. The method may be described as "learn-as-you-go". The concept of controlled blasting is, applied to tunnels for following advantages:

- A. Minimizing and reduction in over breaks
- B. Less damage to peripheral rock
- C. Reduced requirement of support system
- D. Reduced requirement of scaling
- E. Safer tunnel operation in general.
- F. Heading and benching & secondly by multi-drifting.
- G. Appropriate instrumentation - multi-point borehole extensometers or studs and tape extensometers.
- H. Monitoring frequency, adopted depending upon convergence observed

III. DEVELOPMENT of PORTAL @ NATHDWARA & UDAIPUR – END

- A. Excavation near portal zones.
- B. Disposal of excavated material – recycled and reused.
- C. Stabilization of benches, Side & Back Slopes.
- D. Special treatments for rock/soil stabilization e.g. Shotcrete, wire mesh, rock bolts, toe walls, etc. For safe working above portals
- E. As per Design, consultant and/or Geologist and in accordance with the geological conditions
- F. As per geological conditions at site effective arrangement made, peripheral/ catch water/storm water drain, for collection of surface water and its drainage

ROCK MASS QUALITY and ROCK SUPPRT



IV. TUNNEL EXCAVATION - MULTIPLE HEADING METHOD

- Approved blast/pattern designs for multiple heading and benching along with loading, charging and firing sequence, decided by geologist.
- In multi-heading method of rock excavation whole cross section divided and advanced in four sections that includes three parts in top heading and one part of bottom benching.
- The fore poling with 32mm dia.TMT bars, and 6/8m long drilled in periphery of tunnel profile and suitable spacing of 0.50mc/c, with upward inclination of 5-10degree, as decided by geologist
- Further repeated up to portal zone and the same fore poling pattern was followed, if poor strata encountered during tunneling. Subsequently the top heading shall be advanced in three stages which include Centre pilot excavation of 45.31 m² and widening in the remaining rock portion which forms 24.52 m² in both the sides.
- Whereas, the benching of bottom 3.5 m shall be maintained same in both the method of excavation. Adequate safety precautions shall be taken during drilling holes, storage and use of explosive, firing, shooting with fuse, etc, in accordance with relevant IS codes and guidelines.

V. HEADING and BENCHING

- Approved controlled blast pattern/ designs for heading and benching along with loading, charging and firing sequences, decided by geologist
- Pattern worked out considering the nature of rock encountered during tunneling the geological investigation.
- Total cross-sectional -149 m². Tunnel excavated by top heading and benching methods. Top 7.75 m excavated in heading and remaining portion in benching
- Top heading of 7.75 m works out to be approx. 94 m². Burn cut/V-cut /diamond cut, blast designs using five set of reamer holes/empty holes of dia. 76 or 102 mm recommended.
- Total charge – 275Kg and maximum charge per delay of the heading round 40 kg respectively. Emulsion explosive of strength 80% used in conjunction with non-electric (NONEL) long delay detonators for blasting.
- Heading blast round carried out & blasted with powder factor of approx. 1.0-1.2 kg/m³. The progress of the face -approx. 2.4 to 3.1 m in each round with depth of hole 3.2/3.3 m.
- Approx. 3.5 m bottom portion of the tunnel taken as in benching with vertical/horizontal holes.
- Total charge- 156.8 and maximum charge per delay in benching- approx.19.2 kg respectively. Powder factor of the benching portion - average 0.64 kg/m³.

VI. VENTILATION

- A. Ventilation was carried out in tunnels to make the working space safe, for workmen by keeping the air fresh and by eliminating harmful and obnoxious dust, explosive fumes, exhaust from the plant & equipment, particularly diesel operated and other gases.
- B. Mechanical ventilation was adopted, wherever necessary to force the air in or exhaust the air out from the working face to the portal through ducts. Externally located fans operate in forced ventilation and induced ventilation modes to supply air through rigid or flexible ducts. Intermediate booster fans shall also be provided to improve the supply of fresh air.
- C. Normally, the minimum fresh air requirement considered in tunneling shall, 4.25 cum./min/man and 2.0 cum/min/BHP for plant and equipment. However, it may be modified as per size and shape of the tunnel.

VII. TREATMENT of SHEAR ZONES

- A. The Shear zones at four places, were encountered during tunneling & three places in portal development zone, tackled and treated effectively, in consultation with geologist/project team.
- B. The mean Q-value may be determined, taking into consideration the breadth of weak/shear zone. The strike direction (θ) and thickness of weak zone (b) in relation to the tunnel axis is important for the stability of the tunnel. Special spot rock bolting system shall be provided for supporting the weak shear zone. A typical treatment of a thinner shear zone, which is thicker than 50 cm. First, the gouge was cleaned out to the desired extent.
- C. Secondly, the rock bolts were installed across the shear zone and connected with the chain link wire mesh. Finally, this “dental” excavation shall be back filled with steel fiber reinforced shotcrete.
- D. In wide shear zone (>1 m), reinforcement was placed before shotcrete so that the reinforced shotcrete lining could withstand the heavy support pressure.
- E. Adequate safety precautions were taken during the treatment of shear zone.

VIII. INSTALLATION of TEMPORARY and PERMANENT SUPPORTS

- 1) Provision of tunnel supports becomes necessary when exposed periphery of a tunnel is not capable of standing own its own, as time passes. The support system was designed strong enough to carry the ultimate loads.
- 2) The temporary support systems was installed within the standup time for the safety of workmen. The following temporary and permanent rock supports, was provided to portal zone, and beyond portal zone, as per drawing/design/geologist.

A. Support For Portal Zone

- 1) The slopes above portal are critical to the construction of a tunnel hence, stabilized before excavating the tunnel/underground excavations.
- 2) Excavation methods shall include blasting and controlled blasting to control the damage from ground vibrations.
- 3) Since the portal region is critical for tunneling due to presence of low rock covers and Poor ground conditions.
- 4) The rock mass pre-reinforced well ahead of advancing Face by forming a protective fore pole umbrella.
- 5) The for poles in arch portions, of 32 mm dia.TMT bars,6/8m long and spaced at 0.5 to 1.0m c/c as per site conditions.
- 6) An overlap of 25% of the fore pole length between successive fore poles, were considered, up to 15/30/45m of tunnel advance at the portal.
- 7) An integrated support system provided, comprising of steel rib along with the rock bolts and SFRS, for the portal zone of tunnel.
- 8) It was realized that for efficient and safe tunneling supports installed as soon as possible after exposing the face and well within the standup time. The sequence of providing support as mentioned further.

B. Steel Fiber Reinforced Shotcrete (Sfrs M-25, Wet Shotcrete)

- 1) Before applying the SFRS, all loose rocks was scaled out and washed. So that shotcrete is forced into open joints, fissures, seams and irregularities in the rock surface and act as the binding for subsequent layers to attain the design thickness.
- 2) Shotcrete was transported by transit mixer; from the batching plant to site and delivered into the hopper of the shotcrete spraying machine and pumped to the nozzle. An initial sealing layer of 50 mm thick, was applied by Shotcrete spraying machine, over exposed periphery of a tunnel, just after the de-fuming, to give it an immediate support and to prevent dilation of the exposed surface and to extend its stand-up time.

- 3) Spraying shotcrete starts from the bottom and moves the nozzle in small circles working its way up. Care was taken to avoid applying fresh materials on top of rebound or over sprayed Shotcrete. It is essential that the air supply on top of rebound or over sprayed Shotcrete.
- 4) It is essential that the air supply is consistent and has sufficient capacity to ensure the delivery of a steady and uninterrupted stream of high velocity shotcrete to the rock surface.
- 5) Applying the second layer of shotcrete does not affect the compressive strength development of the first layer.
- 6) This also make the area safe for further operation of rock bolting. The balance thickness of 150 mm thick SFRS shall be applied after the rock bolting. Curing of shotcrete done for a min. 7 days.



Construction Stages of Tunnel

C. Rock Bolting

- 1) The rock bolts are the active type of support & improve the inherent strength of the rock mass which acts as the reinforced arch.
- 2) The 25 mm dia. TMT bar, Rock bolts, 4.5 m long at 1.5 m c/c spacing, for poor rock having Q value 0.2 to 1.0 and 2.5 m c/c spacing, for rock having Q value 1.0 to 10.0, were provided to stitch together layers of jointed and blocky formations.
- 3) The face plate of rock bolt was 10 mm thick MS plate of 150x150 mm size with 32 mm hole at center, and spherical hexagonal nut
- 4) The Rock bolts were installed systematically as per drawing, by hydraulic rock drill mounted on hydraulic boom for drilling and a basket mounted on a telescopic hydraulic boom.
- 5) The rock bolts provided, were full column grouted with cement/resin capsule. The rock bolts of 25 mm dia, un-tensioned were inserted into the hole over the specified length so that bolt is completely surrounded by grout.

The rock bolts were tested @ 2% for pull out capacity of about 15 tons. The pull-out test of rock bolting was conducted in accordance with provision of relevant codes.

D. Steel Rib (Permanent Support)

- 1) The steel rib of ISHB 200 at 0.75 m c/c spacing in a length of 15 m from the face of tunnel was provided.
- 2) The steel rib was fabricated as per the profile, mentioned in drawing/design. The complete steel rib set, consist of 2 nos. vertical post, 2 nos wall plate and 3 nos arch segment, were fabricated, assembled at site, jointed and erected in position.
- 3) The 2 nos vertical post is placed in position over 100 mm thick PCC M-15 and anchored in the rock by 2 nos 25 mm dia. TMT bar rock anchors.
- 4) The wall beam was placed and jointed over the vertical post. The 2 nos arch segment were placed and jointed over the wall beam with the MS bolts with Nut & washer. Finally,

- 5) The third arch segment was jointed either side with the other arch segment, to complete the erection of a steel rib set. The 16 mm dia. Tie rods, bracing @ 1.0 M c/c staggered, were provided for the fixing the steel rib set in proper position
- 6) The same process was repeated for the erection of another sets of steel ribs and after erection of all steel rib sets,
- 7) The final alignment (transverse and longitudinal) with respect to center line /axis of the tunnel was checked and verified in accordance with the design/drawing, Subsequently,
- 8) The steel lagging was fixed & welded in position to provide protection falling rock or spalls and to receive and transfer loads to the rib sets.

IX. TUNNEL LINING (PERMANENT SUPPORT)

- 1) The RCC lining M-25, 300 mm thick in tunnel lengths and 350 thick in portal zone, provided as the final and permanent support for the tunnel.
- 2) The reinforcement for the RCC lining was done, in accordance with the design/drawing. The tunnel lining was carried out in two stages namely invert and overt lining.

A. Invert Lining (Wall Starter+Kerb)

- 1) Once the tunnel excavation including heading and benching, was completed about 100m length, then the kerb lining /side wall activity, shall be carried out by maintaining a minimum gap of about 50m from the tunnel face till the drilling and blasting operations.
- 2) The conventional fixed steel shutters/formwork, were used for the wall starter and Kerb. The concreting in the vertical shutters was placed and compacted by using immersion type of vibrator.
- 3) Subsequently, the overt lining took place by mobilizing, the erection of hydraulically operated, mobile gantry shutters (3 Nos./6 m long).

B. Overt Lining

- 1) Once the wall starter and Kerb lining is completed about 30m both sides, the Overt lining was started. The overt lining activity was carried out by maintaining a minimum gap of about 50m from the tunnel face till the drilling and blasting operation.
- 2) The conventional fixed steel shutters/formwork shall be used for the wall starter and kerb. The concreting in the vertical shutters were placed and compacted. Rail mounted telescopic (hydraulically operated), movable gantry shutters of 6m length were used for the concreting of overt lining.
- 3) The concrete was supplied from batching plant through transit mixers, to concrete pump and thereby, it was pumped in the formwork through the windows, provided in the formwork at appropriate levels. The placing of the concrete was done in evenly to maintain equal pressure on both the wings of formwork.
- 4) The crown was filled through the slick line, running along the top of formwork. The slick line was deeply buried in the concrete at all times and withdraw from the formwork gradually as the placement proceeds.
- 5) The concrete spouts were provided alternately. The concrete in gantry shutters were compacted using in built shutter vibrators, fitted at appropriate location.

X. GROUTING

- A. Grouting was carried out to fill discontinuities in the rock by a suitable material so as to improve the stability of the tunnel, or to reduce its impermeability, or to improve the properties of rock.
- B. Since tunnel is excavated in poor ground condition, arising from various reasons such as poor-quality rock, low strength rock, sheared rock, excessive ground water, poor behavior due to very high stresses, low cover area, etc, pre-grouting also done a useful technique.
- C. The grout mix used for backfill grout is normally consist of cement, sand, and water in the proportion of 1:1:1 by weight. However, it may be suitably modified as per the site requirement. The following types of grout technique are used in tunneling as per the site situation, with the consent of geologist:
- D. Consolidation grouting-carried out to consolidate the poor rock mass.
- E. Water control grouting-carried out to mainly, to reduce the excessive ground water flows.
- F. Contact grouting-carried out after the installation of a lining to fill up the gaps between the outer surface of the lining and the excavated periphery.

XI. FALSE PORTAL - RCC (NATHDWARA/UDAIPUR END)

- A. The RCC M-25 false portal were provided on both end before the main portal on each side for safety reason as per specific site requirement.
- B. The construction of RCC M-25 false portal was of suitable lengths as per approved design and drawing. The geometric dimension of the portals is the same as the main tunnel.

XII. LIGHTING in TUNNEL

- A. The system of lighting designed flexible enough to permit it operates during its operation at night. The tunnel lighting system generally requires, two-day time lighting levels,
- B. one for the entrance zone comprising of threshold and transition sections, and another normal day zone for interior zone.
- C. Night lighting was designed to avoid flicker and glare and the same illumination level maintained throughout the entire length.
- D. Lighting in the tunnel normally follow the luminance level as mentioned below for safe visibility during day light hours.
 - 1) Open area -1000 cd/Sq.m(natural day light)
 - 2) Threshold zone-500 cd/Sq.m
 - 3) Transition zone- 150 cd/sq.m
 - 4) Interior zone- 20 cd/Sq.m

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