पश्चिम रेलवे
Western Railway

Dr. Ambedkar Nagar to Muktiyara Balwara for Existing/new detour BG line in connection with gauge conversion of existing Ratlam - Khandwa MG section of Western Railway

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Appendix – VI Construction Methodology

RITES
THE INFRASTRUCTURE PEOPLE

(A Govt. Of India Enterprise)

RITES BHAWAN

PLOT NO.1, SECTOR-29

Register of Submissions.

Document Name:	Construction Methodology Report for tunnels in Ratlam- Khandwa Section

Revision	Date	Description
R-0	19.05.2023	Construction Methodology Report for Tunnels

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1 Introduction

Western Railway (WR) is undertaking construction of gauge conversion between Dr. Ambedkar Nagar to Mukhtiyara Balwara for Ratlam Khandwa section. Railways have notified this project for fast-track execution as it is a connection between a line from South to North.

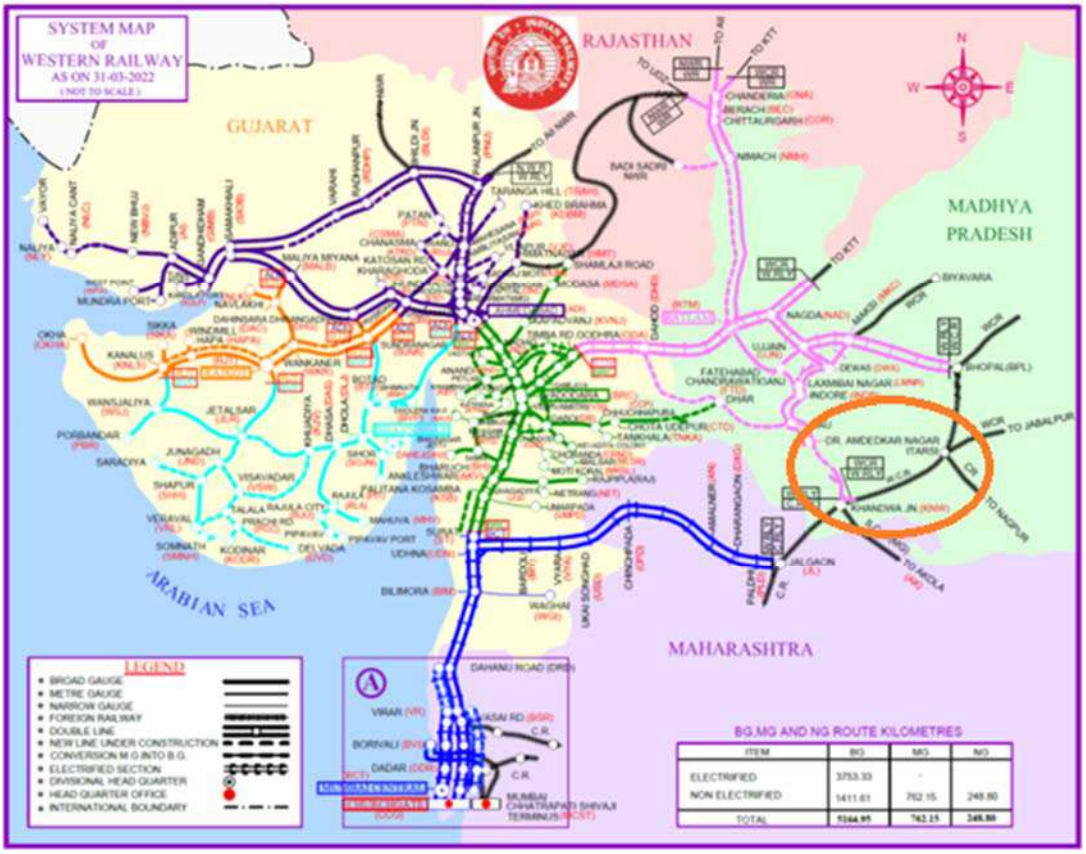


Figure 1 Location of Project

Dr. Ambedkar Nagar Station (Mhow) to Muktiyara Balwara section is about 71 km long section on Ratlam-Khandwa Gauge conversion project of Western Railway. In this connection the consultancy work for "Final Location Survey using modern survey equipment's LIDAR etc, Geological mapping and Geo Physical Survey, Soil exploration, hydraulic data collection and GAD of minor and major bridges, preparation of L-sections, preparation of land schedules for land acquisitions and digitalization of land records from Dr. Ambedkar Nagar (Excluding yard) to Muktiyara Balwara (Excluding yard) for Existing/new detour BG line in connection with gauge conversion of existing Ratlam - Khandwa MG section of Western Railway" has been entrusted to RITES vide LoA No. DYCE-C-I-IND-ENGINEERING / DADN-SWD-FLS-2 /01056930054048 dated 09.05.2022.

This report covers Construction methodology of tunnels in Ratlam-Khandwa section. The tunnels are of different lengths and requirements as per the latest RDSO and international

recommendations for safety and Health, E&M, ventilation , Quality control during construction has been covered in this report.

2 REFERENCES

I. Austrian Society for Geomechanics: Guideline for the Geotechnical Design of Underground Structures with Conventional Excavation, 2010

II. RDSO/2012/GE: G-0017 (June2012): Final Guidelines For design & Construction of tunnels 060812

III. Barton, N.R.; Lein, R.; Lende, J. (1974)." Engineering classification of rock masses for the design of tunnel support". Rock Mechanics and Rock Engineering. 6(4): 189-236.

IV. Practical Rock Engineering by Dr. Evert Hoek, 2004 ed

2.1 STANDARDS

I. Indian Railway Standard Code of Practice for Plain, Reinforced and Pre- stressed Concrete Bridge [IRS-CBC]

II. IS 456:2000 Plain and Reinforced Concrete (Fourth Revision)

III. EN 1992, Eurocode 2: Design of concrete structures, Part 1-1: General rules and rules for buildings

IV. IS 13920: 2016 Ductile Design and detailing of reinforced concrete structures subjected to seismic forces.

V. IS 1893 (Part-1): 2002 Criteria for earthquake resistant design of structures.

VI. Indian Railway Standard Code of Practice for Design of Sub-Structures and Foundations of Bridges [2013]

VII. IS 1786: 2008 High Strength Deformed Steel Bars and Wires for Concrete Reinforcement (Fourth Revision)

IS 4880 (Part-V) 1972: Code of Practice for Design of Tunnels Conveying Water – Structural Design of Concrete Lining in Soft strata and Soil.

3 GENERAL

3.1 ALIGNMENT OUTLINE

S.No.	Description/ Scope of work	Deliverables
1	Length of the section Ratlam-Khandwa	71 km
2	Number of stations	6 Stations
3	Area covered District wise & state-wise	Ratlam-Khandwa districts of MP
4	Ruling gradient adopted	1 in 150
5	Standard of Construction	BG – following SOD-2004 with latest correction slips.
6	Maximum degree of curvature	2.27° (minimum)
7	Speed potential of the line	110 Km/ph
8	Number of tunnels: Ratlam-Khandwa	21 (proposed)
9	Total tunnel length	15470 m
10	Traction:	Electrified

3.2 CHOICE OF TUNNELLING METHODOLOGY (NATM VS TBM)

The selection of excavation method, i.e., whether to go with cyclic tunnelling (NATM) or continuous drive (TBM) depends on various factors, as both the methods have their advantages and disadvantages. Therefore, depending on various conditions such as geological, financial, time constraints, accessibility etc., such selection shall be case specific and not generic. The various pro and cons of both excavation methods are described below:

Table 1 CHOICE OF TUNNELLING METHODOLOGY (NATM VS TBM)

Sr. No.	Topic	Cyclic Tunnelling (NATM)	Continuous Drive (TBM)
1	Changing Cross Section and longitudinal curves	☺ Adaptable to almost every cross section and to any turning radius	☹ Restricted to TBM cross section, turning radius is limited too
2	Changing Geology	☺ Flexible to varying geological conditions	☹ Change is geology may result in breakdown

Sr. No.	Topic	Cyclic Tunnelling (NATM)	Continuous Drive (TBM)
3	Investment Cost	 Not so high investment cost	 Heavy investment in the start to buy the machine (20-30 Million Euros/ 150-250 Cr INR)
4	Preparation Time	 A typical remote site can be ready for construction in 3-4 months	 It usually takes around 1-1.5 years. As every machine is custom built (around a year), add to it the transportation time (such heavy machine may takes months to reach a remote site) and reassembly of machine at site (around a month)
5	Familiarization Time	 As this is a standard process, the time needed for familiarization is almost negligible	 It may take 3-4 months to get familiarized with the new machine (during this period the performance may not reach peak limit)
6	More excavation faces	 Excavation can start from both ends as well and intermediate access adits simultaneously	 Only one excavation faces possible with one machine
7	Electricity Requirement	 Not so much, only needed for lighting, ventilation and pumping out water (if required)	 Very high for running the machine (3-4 MW)
8	Ventilation Requirement	 Ventilation needed to clear the dust and fumes (due to blasting), for personnel (fresh air for breathing) and for equipment (polluted air due to diesel combustion)	 Very less. No blasting, no diesel combustion, only needed for personnel
9	Performance	 Based on the geological conditions the performance can vary from 2-3 m/day to 6 m/day peak performance	 Once set in the routine TBMs can achieve 20m/day in favourable geological conditions
10	Factory Style	 The construction steps consist of lot of manual work so a limited speed could be achieved	 The construction style is more like a factory due to well designed logistics, therefore high advance

Sr. No.	Topic	Cyclic Tunnelling (NATM)	Continuous Drive (TBM)
			rate could be maintained for longer periods
11	Mechanization	 The mechanization is there (new advances coming up) but not par with continuous drive	 Completely mechanized
12	Automation	 Automation is still lacking as most of the equipment's and processes are handled manually	 Complete automation

In view of the discussions above, and considering the site conditions, in this section 90% of the tunnel's length are less then 1km and there is only one tunnel whose length is more then 3Kms i.e. Tunnel T-1 in that scenario 2 Adit's are proposed from the safety point of view and allow for efficient tunnel operations. Furthermore, only in tunnel T-1 there will be 4 faces for work and in the rest of the tunnel there will be 2 faces for work.

Detailed construction program including cycle time is provided in Volume-2 tunnelwise.

So, in our preliminary assessment that it shall be suitable to adopt NATM as design philosophy and drill and blast as primary construction methodology for tunnelling for short tunnel of length up to 5km and TBM for longer tunnels. Therefore, it is proposed to construct this tunnel with NATM.

3.3 General Construction Methodology

3.3.1 NATM

All tunnel construction will be carried out in accordance with the principles of the New Austrian Tunneling Method (NATM). The method is based on maintaining and utilizing the self-bearing capacity of the surrounding rock by using a cyclic sequence of excavation with subsequent installation of a primary support (outer lining) followed by the delayed installation of a secondary lining (inner lining). The key principle of NATM is using the surrounding rock as a part of the support system.

There are three key points of NATM: First is the application of a thin-sprayed concrete lining; **Second** is the closure of the ring as soon as possible and **third** one is systematic deformation measurement.

The construction process of new Austrian method is: 1) Line positioning; 2) drilling, loading, and blasting; 3) dust removal by ventilation; 4) anchor and steel arch support and bar-mat reinforcement; 5) Shotcreting to form the preliminary bracing; 6) building the concrete as the secondary lining.

Tunnel excavation will generally be carried out by means of drilling & blasting with drilling jumbos or by tunnel excavator. The rock support system for the drill and blast and sections will vary from place to place, depending on rock mass quality.

The primary support, which consists of shotcrete, generally reinforced by wire mesh, lattice girders (where required) and rock bolts, will provide the immediate support and stability of the excavation. The inner lining, which is made with cast-in place concrete, will provide the long-term support and durability of the tunnel.

Based on the geological-geotechnical model, a rock mass classification, and the prediction of rock classes along the tunnel sections have been developed. Specific standard support classes and their respective stabilization measures are designed to cope with all expected conditions.

A subdivision of the tunnel cross-section into top heading and bench may be required, depending upon the geology of the tunneling media.

Different excavation sequences, types and quantities of primary support elements are considered for each support class. The assignment of a tunnel section to a specific support class will be made based on the actual geotechnical conditions encountered during construction. The adjustment and refinement of the primary support, as well as its applicability for different ground conditions identified by regular face mapping, will be carried out with basis on the evaluation of the results of the geotechnical monitoring, which constitutes an essential element of the proposed construction method.

3.4 GENERAL CONSTRUCTION SEQUENCE

The general construction sequence to be applied for the Tunnels is intended as below:

- NATM excavation will start from portals, the portal with lower elevation so that during construction, water drainage is automated naturally.
- Installation of measures to prevent development of pore water pressure around tunnel lining like drain holes and weep holes.
- Concrete Lining
- Contact Grouting
- Installation of tunnel drainage
- Installation of track

Modifications to the general sequence as outlined above may be necessary to cope with site requirements and the construction time schedule.

4 DETAILED CONSTRUCTION SEQUENCE OF NATM

4.1 SITE PREPARATION

The necessary plant, equipment, materials, and supplies needed to start the work will be at the site. The necessary facilities for the construction of the Tunnel shall be established.

Power shall be provided by DG Engine generators in the absence of grid power. The capacity of the generator units shall be enough to sustain normal ventilation and dewatering in tunnel construction other than regular use of power for drilling rigs, lighting etc.

Water supply will be from natural sources in the vicinity or proximity to the area. Water will be pumped from the source to a water reservoir (RCC water tank), from which delivery and distribution lines will convey water to the tunnel, workshop, toilets, offices, and other facilities that require supply of water.

Compressed air supply will be provided by engine driven air compressors set up at the platform area. Air receiver tanks will be installed. Delivery lines will be 4-inch diameter steel pipes for the main lines, and 3-inch diameter steel pipes for the distribution line in the tunnel. A Main valve shall be installed after the air receiver tank to control or shut off compressed air supply in cases of repair or emergency. Isolation gate valves shall be installed at intervals of 60 meters also for repair and emergency purposes. However compressed air is required only for emergency purposes.

Dewatering line will be provided in down gradient face underneath of supply line to maintain the traffic ability.

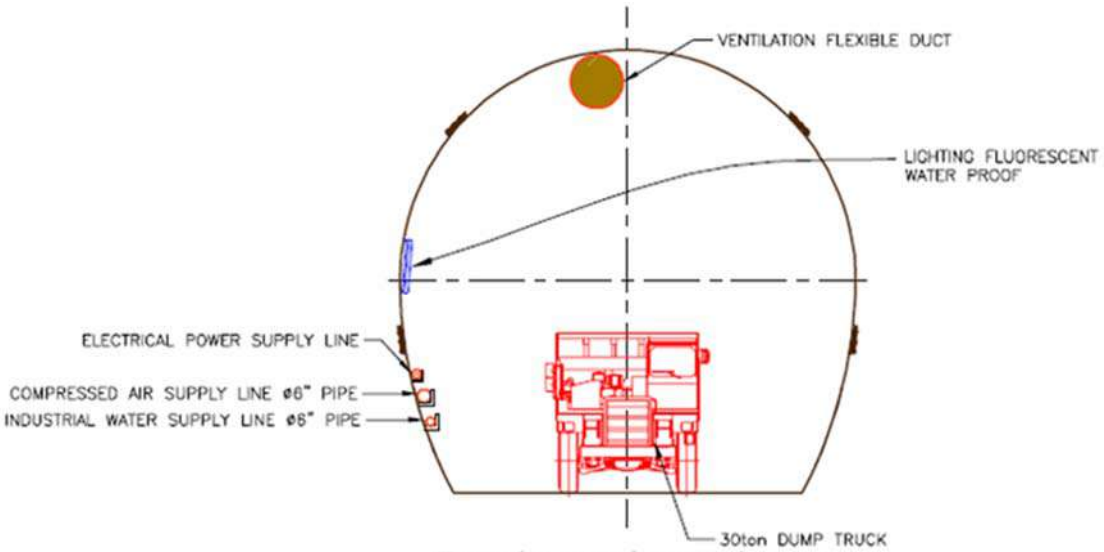


***Figure 2**: Example for Tunnel excavation supply systems*

4.2 SURVEY & SETTING OUT

The section of the Tunnel location, centerline and alignment, gradient, and elevation will be established by survey, in accordance with the design as indicated in the layout plan and cross sections of the construction drawings provided by the client.

4.3 NATM EXCAVATION

In general, round lengths for excavation are limited by the governing ground conditions and by limitations due to blasting vibrations.

Excavation shall be performed between full face and top heading and bench. Length of the top heading depends on the rock conditions.

For each standard round, the detailed construction sequence shall be as following:

Construction Sequence	Activity
1.	Installation of fore poling (if and as required) in accordance with applied support class
2.	Excavation of Round
3.	Application of sealing layer at round and face, if required, and / or installation of Swellex-/SN- or Self drilling bolts
4.	Installation of wire mesh 150/150/ 6mm; 300mm overlap in circumferential direction and 150mm in longitudinal direction
5.	Installation of lattice girder (if required)
6.	Installation of 1st layer shotcrete
7.	Installation of second layer of wire mesh 150/150/ 6mm (if required); 300mm overlap in circumferential and longitudinal direction
8.	Installation of 2nd layer shotcrete

Table 2: Construction Activities for Standard Top Heading Excavation

Tunnel excavation shall be performed between full face, and if required, between top heading and bench. For the different ground conditions five (5) Support Classes have been designed

At present it is envisaged that round lengths shall be limited as in the table below:

Ground Condition	Round Length
Very good rock mass (SC-I)	3.0 m
Good rock mass (SC-II)	2.0 m
Fair rock mass (SC-III)	2.0 m
Poor rock mass (SC-IV)	1.5 m
Very poor rock mass (SC-V)	1.5 m

Table 3: List of Round Lengths

In the Support Classes I to IV, the excavation will be done full face. In the case of Class V excavation will be done by top heading and benching.

In poor rock mass (Support Class V) the distance between top heading and bench must be decided according to the encountered geological condition. The bench excavation shall be performed for one bench round (1 round of bench excavation equals two rounds of top heading excavation).

Excavation profiles shall be determined according to the rock classification & considering the temporary support system, to obtain the optimum efficiency and accuracy of the operations. The cycle time will depend on the rock classification and support system, drilling and muck evacuation equipment.

4.4 TUNNEL EXCAVATION (DRILLING, LOADING & BLAST)

4.4.1 Drilling

Face drilling shall be done using Two/Three Boom Drill Jumbo (electrically operated). Drilling pattern to be adopted shall be decided by the Engineer In - Charge in consultation with geologist after studying the Face geology. In general, the Drill pattern adopted will be as under.

The diameter and the spacing of the blast holes shall be adapted to the actual rock conditions on site. The tunnel in charge will develop and continuously improve the blasting techniques as the work progress to obtain the best possible excavation surface after blasting. Drilling pattern to be adopted shall be decided by the tunnel in charge in consultation with geologist after studying the face geology.

Face drilling will be carried out by the skilled jumbo operator on the instruction of experienced Tunnel foreman / engineer. The foreman / engineer will guide operator for drilling as per the pattern and to the correct length and angle. Blast hole diameter will be 45 mm and the depth depending on the classification of the rock. At the perimeter, blast hole spacing (burden) of less than 700 mm (generally) shall be maintained for smooth blasting. However, in general blast hole drilling burden will be of 750 to 900 mm with one or two relief holes of 125/100 mm dia. In case of heavy seepage / ingress of water encountered during face drilling, PVC pipe of 50-mm dia shall be inserted in drilled holes to prevent collapse / blockage of holes for charging.

Exploratory / drainage hole/pressure relief holes of required dia. will be provided in heading or as directed by the Engineer In - Charge to release the water pressure. PVC pipe perforated will be inserted in the drilled hole to save the hole from collapse and to channelize the water through drainpipe.

***Figure 3**: Face drilling using Boomer/Tamrock*

4.4.2 Face Charging

After completion of face Drilling, charging of drilled holes using Explosive and Non-Electric detonators. After studying the rock geology, the quantity of Explosive to be to be charged for face will be decided by the Engineer In charge in consultation with geologist & licensed blaster. Each hole except line drilled/dummy holes will be charged as decided by the foreman/ engineer. Stemming of charged hole will be done properly, which is essential for efficient pull.

Type sequence and number of delays, delay pattern, wiring diagram for blast , size and type of hook-up lines and lead lines , type and capacity of firing source , type of condenser discharge blasting machine will be used as approved by the engineer.

Figure 4: *Face charging*

4.4.3 Blasting

After completion of charging Licensed blaster will connect all lead of detonators in series and will check the connection using Ohmmeter. After checking of all connection blasting operation will be carried out using exploder or electricity. Control blasting techniques will be used and proper care will be taken to limit the PPV (Peak particle velocity) with in permissible limits. A headcount to be done to make sure that everyone is at safe distance and no one in the blasting area.

An acoustic curtain is recommended in order to bring down the air borne noise levels. The Noise control system are consist of two different products

a) Envirotech Metal Noise barrier - The panel is to be fixed on top of the tunnel opening. The opening required is as per the cut-out of the exhaust duct.

b) Echo barrier Panels – A sandwich od 2 layers of Echo barrier with flexible arrangements in such a way that it can be vertically folded and stacked without any hindrances to existing tunnel arrangements. It will offers exceptional noise absorption and reduction with portability , durability and versatility. It is resistant to water and to extremes of temperature such as posed by humid environments and highly stringent fire regulations.

   These panels are extremely durable, high-quality waterproof PVC, of optimum mass to achieve maximum noise mitigation, also offering an impress visual finish. Echo barrier's are light weight but highly noise absorbent composite. The top portion of the barrier is needed to be fixed and should be rolled up after the blast is done. This will help ease the flow of people and vehicle inside and outside of tunnel.

Figure 5: *Blasting*

4.4.4 Defuming

This activity will be carried out immediately after the Face blast is taken. Fresh air will be pumped inside the Tunnel from outside using Ventilation system installed. Ventilation system will be designed to meet the requirement of fresh air inside tunnel; system consists of Blower fan & ducts. Blower fans are fixed outside i.e., near portal for pumping fresh air in heading through flexible duct. Following each round, the broken rock or muck pile shall be wetted down sufficiently to prevent excessive dust during mucking operations.

The blaster shall then check the condition of the blast area, particularly for misfires. If misfires are found, the blaster shall immediately treat the misfires, either by re-blasting or flushing the misfire with water to remove any explosive material remaining.

Once the area has been checked and cleared, the blaster shall give the all clear signal to resume work. In case of misfire the hole to be cleaned with copper rod and washed with water jet. In certain case if the explosive cartridge could not be removed from the misfire hole, then a hole to be drilled parallel to the misfire hole at 300 mm distance for secondary charging and blasting to remove misfire hole.

***Figure 6**: Defuming using Duct fans and connecting pipe*

4.4.5 Scaling

Scaling and trimming of the blast profile will be done to remove loose rocks resulting from the blast, and to trim any under breaks or intrusions and ensure the excavated profiles conform to the design profiles as indicated in the design drawings. Scaling and trimming will be done using a hydraulic breaker, or excavator and sometimes manually.

Figure 7: *Scaling*

4.4.6 Excavation using twin cutter/Road Header

A twin cutter/header is one of the attachments to the hydraulic excavators. It has a hydraulic motor propelled by the hydraulic circuits of the excavator and rotates cutting heads through gears. These rotating cutting heads excavate rock. The twin header/cutter scrapes the tunnel face due to the sheared nature of rock and it eliminates any risk of blasting in poor rock conditions. The main application of this type of equipment is when the rock strata encountered is of very poor nature and the rock conditions are not fit for blasting. This process of excavation becomes very handy in these types of rock as working at tunnel face becomes very easy and the safety of workers got enhanced which on the other side while using other methods remain uncertain while excavating in such rock conditions.

Figure 8: *Excavation using Twin Cutter*

4.4.7 Face mapping and 3D monitoring

Examining the types and number of joints and type of rock conditions of the obtained face is termed as geological mapping. After scaling and chipping geologist along with survey team and other supporting workers inspect the face. Geologist examines the face and prepares a face log after every pull and keeps a record of the same. Base on the actual site conditions and face log geologist decided whether designed support is enough or less or more for that section. Whereas Survey team examines if any over break is there or not and brings in the notice of the face in charge after which require measures are taken to control the over breaks.

4.4.8 Shotcreting (1st stage)

It will be carried out immediately after the scaling is over as an immediate rock support. Suitable ramp is prepared by using excavator for scaling and positioning of Shotcrete machine for Shotcrete operation. Scaling of freshly excavated surface for loose material shall be done using steel bar etc. all the loose material shall be scaled manually & by air/water jetting prior to applying shotcrete.

Figure 9: *Shotcreting immediately after taking blast*

Shotcrete mix of required grade shall be prepared in batching plant outside of Tunnel and will be transported to the discharge location through Transit Mixers. The Mix is unloaded in the Shotcrete pump from where it is conveyed to the spraying nozzle by means of positive displacement or compressed air. Skilled operator will spray initial layer of Shotcrete to the required thickness over the surface using 6 cum/hr. capacity Shotcrete machine with robot arm. During Shotcrete operation, operator will ensure that accelerator is passing at the spraying end and spraying nozzle is placed perpendicular to the surface approx. 1.5mtr away during shotcreting, which is essential to minimize wastage/rebound. Approved accelerators will be added in the shotcrete mix at the end of spraying nozzle for quick setting.

The suitable operating procedures and operations will be developed at site in order to ensure.

a) Proper thickness

b) Minimum Rebound

c) Economical use of the tunnel support system along with the rational approach of execution is done. Smooth finished surface.

d) No hollow areas in the shotcrete

e) Minimum of shrinkage cracks

f) Good adhere of shotcrete rock surface.

4.4.9 Mucking

All the scattered/spread muck of heading will be collected towards heading prior to start of mucking using the Excavator. Water will be sprinkled if required over the muck to avoid dust formation during mucking. Excavator and haulers of required capacities will be deployed during mucking operation. Preferably mucking operation will be carried out using 15/25 Ton

capacity dumpers. The excavated muck will be loaded into the Dumper by using Excavator/side dump loader. The loaded muck will be transported to the ·approved dumping yard for disposal.

Figure 10: *Mucking by Excavator*

4.4.10 Rock Supports

Once the excavated area has been scaled and trimmed, the excavation profile will be checked by survey. Under breaks will be marked and will be removed and re-excavated to the design excavation limit.

If the profiles conform to the excavation design limits, the blasted surface will be thoroughly cleaned and purged by water spray to remove loose rock fragments, dust, soil, sludge adhering to the rock surface.

The application of a sealing layer at round and at the face will be done immediately after the mucking and scaling operations if required and / or the installation of local rock bolts to secure individual blocks against rock fall.

On completion of the sealing layer and the rock bolts the first layer of wire mesh and as next step the lattice girder if any required as per the rock classification will be fixed in the tunnel. After the installation of the lattice girder the 1st layer of shotcrete will be sprayed. The next activity will be the installation of rock bolts at the sidewalls and if required the installation of the face bolts and the fore-poling for the next excavation round. Before excavation of a new round the inner layer of wire mesh will be installed if required and the 2nd layer of shotcrete will be sprayed.

1. **Rock Bolts:** Installation of rock supports to the freshly excavated rock surface will be taken up to protect the surface. The various types of rock bolts used in tunnels are as below:

a) **SN Bolts: -** SN bolts shall have a bar diameter of 25/32mm and a steel grade Fe 500. SN bolts shall have a minimum yield strength of 200 kN. Installation length shall be between 3 m to 6 m for standard applications. Bolts shall be embedded in cement mortar grout or cement paste only.

b) **Swellex Bolts:** - Self-drilling bolts shall be of type MAI or IBO with minimum yield strength of 200 kN. Installation length shall be between 6 m and 9 m for standard applications. If self-drilling bolts are used as face bolts their length shall be 9 m to allow for a sufficient overlap between following face bolting rounds. The Swellex is type of mechanical rock bolt that strengthens the rock mass through a combination of friction and mechanical interlock at the rock bolt interface. During the expansion process, the swellex bolt compress the rock surrounding the hole and adapts its shape to fit the irregularities of the borehole. Inflation of the bolt will be done with the help of water jet 300 bar pressure with help of swellex pump. The rock bolt shall be drained after inflation. Bolts shall be grouted with cement mortar grout or cement paste only

c) **Self-Drilling Bolts/Anchors: - Self Drilling bolts are used in poor conditions where effective installation of other type of rocks bolts is not possible.** Self-drilling bolts shall be of type MAI or IBO with minimum yield strength of 200 kN. Installation length shall be between 6 m and 9 m for standard applications. If self-drilling bolts are used as face bolts their length shall be 9 m to allow for a sufficient overlap between following face bolting rounds. Bolts shall be grouted with cement mortar grout or cement paste only.

d) **Fiber Glass Anchors :-** DurglassFL-Y or similar fiber glass bolts of specified diameter and tensile strength will be used for face bolting/rock bolting as per the approved. It will be used for consolidation of the heading face in poor ground conditions along with shotcrete. Bolts will be either threaded rods or self drilling bolts and it will be grouted with cementitious material or similar as per approved.

The Anti-corrosion compound will be applied to all the outer ends exposed after installation of Rock bolts . Heavy duty hexagonal nuts and Beveled washers will be used for ensuring proper contact of rock with base plate(as per specification/IS 2062).The rock bolts will be stressed, immediately after installation of Nut by torquing or jacking , by means of a regularly calibrated stressing device or by torque wrench.

Testing of rock bolt: - For SN bolts and self-drilling bolts pull out tests shall be performed. Pullout tests shall be performed not earlier than 48 hours after completion of the installation of the relevant bolt. A test shall be considered successful if a load of (yield strength / 1.15) is successfully applied without either breaking the bolt or pulling the bolt out of the borehole. The bolt type shall be acceptable if 80 % of the tests fulfil this criterion

Figure 11: *Rock bolts insertion using Boomer/Tamrock*

2. Steel Support

a) Steel Ribs/HEB140 or ISSC 140 column or equivalent Ribs/TH Ribs
Steel ribs are three-dimensional, steel frames and manufactured in compliance with the required excavation geometry of the tunnel. These are required where immediate support before shotcrete is to be installed and where lattice girder ribs becomes unstable because of lateral torsion. The subsequent ribs are interlocked with connection bars allowing for the stability during erection of the newly placed one.
TH type ribs are to be used in the worst geo-mechanical contexts. These shall be installed without locking the connection elements to let the sliding of a part of the rib on the adjacent one.

Installation of steel ribs - Installation of steel ribs to conform to the excavated shape of the tunnel. The steel ribs will divided into part for better handling and proper erection. While erection of steel ribs , the side part will be installed first in contact with the excavated rock surface which will be fixed with help of nut and bolts of the base. Once the side part of the ribs are fixed, the top part of the ribs will be erected with the help of machinery(telehandler) in way that no gap is left in

between the excavated rock surface and the ribs. It shall be embedded in shotcrete, in order to get contact between rock and steel ribs by a solid shotcrete packing which shall have a minimum cover to steel as specified.

b) **Lattice Girder:** - Lattice girders shall be installed to provide immediate support for the exposed rock mass during excavation and to serve as template for the excavation geometry. They also serve as guidance and support for fore poling and are considered as reinforcement of the shotcrete lining. Lattice girders shall be of steel grade Fe 500. Depending on the applied shotcrete thickness, the types of lattice girders as shown in Table 3 shall be installed.

Shotcrete Thickness	Lattice Girder Type	Height of Girder	Unit Weight (Kg/m)
200 and 250 mm	70/ 16/ 25	111 mm	10

Table 4 *- Lattice Girders to be applied depending on Shotcrete Lining Thickness*

All lattice girders shall be installed as close as possible to the actual achieved excavation line respectively sealing layer (if applicable) in a vicinity of approximately 30 cm to the top heading face

Figure 12: *Lattice girder erection in Tunnel*

3. **Wire mesh:** - Welded wire mesh confirming to the Technical Specifications requirement will be installed in underground tunnel surface over the first layer of Shotcrete as per the geological conditions. The wire mesh will be held in position by providing Hilti Pin I steel rod anchors. Hand drill machine will be used for drilling & fixing of anchors for holding wire mesh. The mobile scissor platform will be used as working platform for fixing of wire mesh. Additional bearing plates on the earlier anchorage shall also be provide to hold wire mesh in position for better anchorage. At least two fixation points per square meter (m^2) of support will be provided to avoid the vibrations when shotcrete is placed over wiremesh and supporting bolts , it will be covered with shotcrete to a depth of at least 50mm.The wire mesh will be overlapped to the mesh of the previous round of minimum length as specified

***Figure 13**: Installation of welded wire mesh*

4. **Shotcrete (2nd Stage):** - As soon as the wire mesh installation is completed, final layer of Shotcrete will be sprayed. Proper curing of shotcrete will be done for achieving desired strength within specified time. Shotcrete applied in the tunnels shall be of quality M25 according to Indian Standard IS456:2000. The designed shotcrete thicknesses vary according to the ground conditions between 10 and 25 cm.

Wet shotcrete mix will be applied on the excavated surface required as per the drawings. The application of shotcrete will be done by using a Robot Arm Shotcrete Pumps. After the shotcrete application the spill over shotcrete will be removed by the excavator and the face will be prepared for the next drilling.

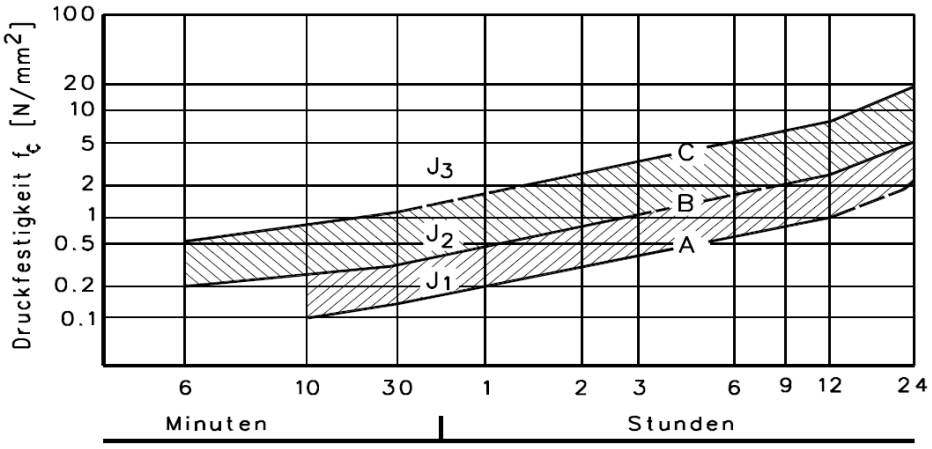
Where required due to ground conditions a sealing layer shall be applied, which is included in the required structural thickness of the shotcrete shell. Shotcrete application shall be performed in layers not exceeding an individual thickness of 200 mm.

In case of Steel Fiber Reinforced Shotcrete (SFRS), the steel fiber dosage per cubic meter of shotcrete will be 30-50kg.

Designed Shotcrete Thickness	Tentative Shotcrete Thickness
Very good rock mass	100 mm
Good/Fair rock mass	150 mm
Very poor rock mass/ Fault zone	250 mm

Figure 14: *Final layer shotcrete*

The early strength development of shotcrete shall conform to Class J2 according to the Austrian Guideline for Sprayed Shotcrete



Testing of shotcrete: - For determination of the uniaxial compressive strength and stiffness development of shotcrete short term uniaxial compression tests at various concrete ages shall be performed. Tests shall be performed at cylindrical samples with length / diameter ratio of 2:1 (200 mm height, 100 mm sample diameter) at the following shotcrete ages:

2 days, 7 days, 14 days and 28 days.

The measurement of early strength shall be done by using the Penetration needle and Hilti Shot-bolt system (or equivalent) .Samples shall be taken from cores drilled from the shotcrete lining in the tunnels.

The Engineer may from time to time request slump testing at the pump, in order to confirm that the delivered mix is with in the range of the target slump established by the trail mix.

5. **Fore poling:** In certain areas the installation of fore poling will be required to avoid the development of loosening rock zones in the crown area of the top heading. Fore poling will be installed each round from the current top heading face to provide safety for the following top heading excavation round. It shall be installed through the last lattice girder installed. Depending on the ground conditions encountered, fore poling will be performed with one of the following types:

- In ground conditions where the borehole stability can be guaranteed SN Bolts with yield strength of minimum 200 kN will be installed.
- In ground conditions where borehole instabilities are likely to occur self-drilling bolts of type R32N with yield strength of minimum 200 kN will be installed.

Fore poling length and interval of installation (to ensure sufficient overlap between adjacent rounds) will be given in the support drawings. All fore poling elements must be embedded in cement mortar.

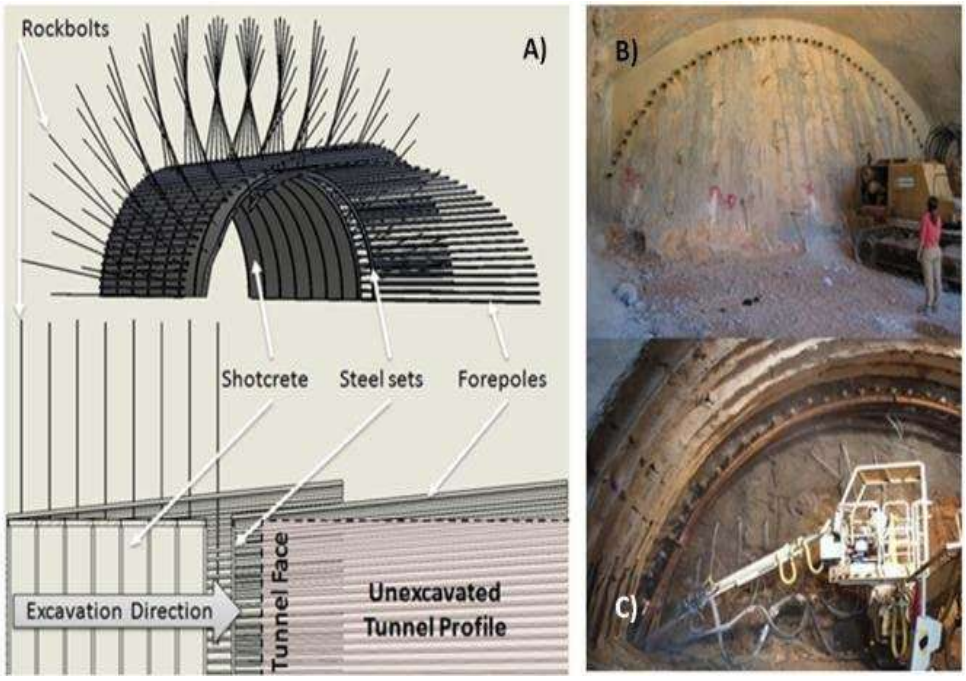


***Figure 15**: Fore poling in Tunnel*

4.4.11 Face Support Measures

Face support consists of the following measures, which shall be applied individually or in combination according to the encountered conditions and requirements.

1. Application of Face Sealing Layer

To avoid the occurrence of shallow face collapses in fractured rock masses a face sealing layer of shotcrete might be required to secure the top heading face during installation of support measures in the round closest to the face. If required, the face sealing shall be reinforced with 1 layer of wire mesh 150/150/6 mm. Face sealing layer thickness shall be between 5-10 cm, while 5 cm shall be unreinforced whereas a 5-10 cm thick layer shall be reinforced upon requirement.

2. Installation of face bolts

In addition to shotcrete sealing the installation of face bolts may be considered together with a sealing shotcrete layer. Face bolts shall be of type R32N with an installation length of 9 m. Overlap between following face bolt rounds shall be not less than 4 m. Face bolts shall be fully grouted with cement mortar grout or cement paste and be equipped with load distribution plates to provide a uniform support pressure onto the excavation face.

3. Subdivision of the top heading face in smaller "partial excavation areas"

This measure shall be taken in combination with other face support measures if face stability of the top heading cannot be maintained by other support measures in very poor ground conditions or fault zones.

The top heading face shall be subdivided into smaller areas which are excavated and supported immediately again prior to excavation of the following top heading part.

4. Drainage Measures

Tunneling is expected to be in dry and dripping/damp conditions. However, if required, during excavation several measures against water pressure and water inflow have to be taken.

5. Measures to avoid the build-up of Water Pressure on the Shotcrete Lining

To avoid the buildup of water pressure on the shotcrete lining weep holes shall be drilled through the shotcrete lining. Diameter shall be 70 or 100 mm. Depth of weep holes shall be 1.0 m. The weep holes shall be equipped with slotted PVC pipes. To avoid clogging of the PVC pipes by fines they may be wrapped in geotextile (fleece).

6. Measures to avoid Water Inflow during Excavation

Tunnel excavation shall be performed under drained conditions only.

Dewatering will be performed both from the top heading and the bench. From the top heading, drainage holes shall be drilled as required to provide for a dewatered top heading face. From the bench sidewalls, long drainage holes (up to 20 m) may be drilled, with an angle slightly outwards of the alignment to allow for a dewatering below the top heading level, in case tunneling media is water charged during monsoon season.

Water encountered in the excavation area shall be collected and diverted outside the excavation area to provide for dry working conditions and to avoid weakening of the rock mass due to water.

7. Tunnel Drainage scheme

The tunnel is designed as drained Tunnel. Reliable system for drainage and conveyance of the water will be provided in all parts of the tunnels.

As geotextile layer and a PVC or HDPE waterproofing membrane (umbrella type water-proofing) is not required for this tunnel, a provision of drainage pipes in the invert is envisage for relief of pore pressure around tunnel. Drainage pipes will be provided on both side of tunnel at spacing of 10m (average). Drainage pipe shall be perforated wrapped in geotextile and 1.5m to 2.0m in length. Pipes will discharge to drainage gutter on sides of tunnel. The pipes are being installed after contact grouting between inner liner and shotcrete lining.

Water will be discharged out of tunnel under gravity inside the drainage gutters following the tunnel gradient.

4.4.12 Concrete Lining

The inner lining will vary along the route with regard to the installed primary lining and the observed system behavior (ground-lining interaction). The inner lining will consist of high-quality cast-in situ concrete.

With regard to the possible options the following lining types are developed.

Table 5: Inner Lining Type

Lining	Application
Insitu Concrete M30 grade, t=300 mm, Side drainage, PCC overt with Face reinforcement.	Good rock conditions, dry or little water ingress which can be channeled (Grade 1 to 4)
Insitu Concrete M30 grade, t=300 mm, Side drainage, RCC overt	Soft ground, highly fractured poor rock (Grade 5)

For installation of the in-situ concrete lining a shutter will be required, and the inner lining will be installed in sections of 10 m to 12 m length. The concrete shall be cast using a travelling shutter. The shutter is transported to the correct location and then articulates itself to the correct profile. Concrete is poured through windows in the shutter to generate the required lining thickness specified in the drawings.

The shutter holds position for the required time to allow partial curing to take place and is then articulated enabling it to move onto the next location adjacent to the previous concrete pour. One set of tunneling form will have one traveler and tunnel form of standard length.

The kerb concrete will be casted ahead after having excavated / mucked the invert area. The overt section will follow at some distance then followed by Invert.

Concrete of required strength as per mix design will be mixed by batching plant and transported by transit mixer.

Concrete lining will be done in three stages.
Stage -1: - Kerb concreting
Stage -2: - Overt and side walls
Stage- 3: - Invert concrete

i. <u>Kerb concreting, padding concrete & Extension of rails</u>

Kerb concreting of approx.- 1.0 mtr. height will be done on both side of Tunnel in advance to facilitate uninterrupted Overt lining. This will be done by using collapsible shutter and tie loop arrangement. Tie loop coil (threaded) size mm x 40 mm dia. made of 8 mm M.S. Steel (M.S. Round) will be embedded in Kerb concreting at spacing of 750 mm c/c to hold the shutter by fastening tie loop with coil during overt concreting. Tie loop structure is a cone type with one end threaded and other welded with base plate. The shutter will be placed in position by fastening Tie loop with coil which is embedded in Kerb concreting.

Figure 16: *R/F and Shuttering for Kerb concrete*

ii. <u>Overt lining</u>

Overt Lining of tunnel will be carried out with gantry having two set of shutter & single traveller for Face having maximum length and for Face having smaller length will be carried out by gantry with single shutter & single traveller. For concrete lining, it is proposed to deploy collapsible type hydraulic shutters of 12 M long. Concrete from the batching plant will be transported through 6 cum capacity transit mixers which will deliver concrete directly into 30 cum/hr capacity concrete pump placed inside the tunnel. The concrete pump will be used to place the concrete behind the tunnel formwork

Figure 17: *Concrete lining using Gantry shutter*

iii. <u>Invert Lining</u>

Invert lining will follow the overt lining. Invert surface will be kept ready for concreting. Immediately after completion of overt lining, Traveller will be shifted to the second gantry. Concrete pipeline will extend to the location of placement of invert lining but without altering the location of concrete pump and concrete will be pumped for invert lining. Invert concrete will follow overt concrete and completed within 30 days after completion of overt concrete.

Concrete will be transported by transit mixing trucks to the position of the stationary concrete pump and the concrete then be delivered to the work area by concrete pump. Finishing of concrete may be done using hand screeding.

Figure 18: *Manual Invert Concrete using template system*

iv. Curing

Exposed surfaces of lining concreting shall be kept moist by means of continuous sprinkling or spraying with water.

4.4.13 Grouting

The purpose is to fill the spaces which may remain between concrete lining and the existing ground or rock by injecting grout in the crown. Before starting grouting, at least one suitability test will be performed to verify and adjust the mix design of cement mortar.

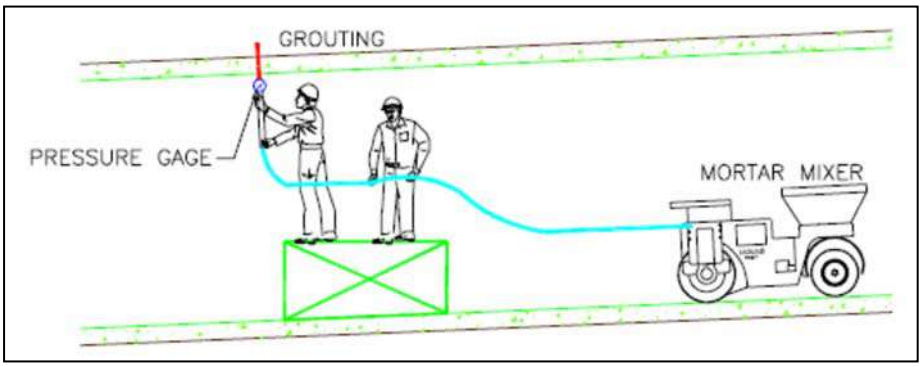


***Figure 19**: Grouting*

Contact grouting shall be performed through holes in the crown section of the inner concrete lining. These holes shall be created by installation of pipes of suitable diameter in the tunnel shutter before concreting of the lining block. The depth and spacing of grouting hole shall be as per the specification / drawing.

Each hole shall be cleaned, and a pipe sleeve with a globe valve connecting to a grout pipe will be installed. Before starting grouting, suitability tests shall be conducted to determine the correct grout mixture to be used. The cement mortar will inject into the hole by grouting pump during injection, the mixing time, grout pressure and injection flow will be recorded. After grouting completion, the valve will be closed to prevent grout backflow.

Grout in each hole will be stopped once the pressure reaches refusal pressure. Install the floodgate near the hole of injection to control the refusal pressure and to fill up a hole again after grouting. The refusal pressure is the pressure, which the absorption of mortar grout is less than 1 liter per minute per hole. The refusal pressure will be applied at 0.5 MPa for at least 10 minutes.

4.4.14 Track Laying

Components of railway track will be installed as per the standard guidelines of Indian railways

5 Dewatering provision for Tunnel

The purpose of a tunnel dewatering program can be identified due to following reasons:

a) To lower the water level so that the static compressed air pressure required to conduct mining operations is within acceptable contractual or physical limits.
b) To lower the water level to within reasonable distances of impervious layers so that the quantity of water and the pressure under which it flows into the heading do not have an adverse effect on the soils and the mining operation.

c) To lower the water level below the invert of the tunnel to eliminate interior pumping and maximize the stability of soils in the heading.

Pre-drainage methods that achieve these objectives may be performed either from within the tunnel or from the surface, depending on soil characteristics, surface conditions, and tunnel size and design.

Figure 20: Dewatering process during construction

In most tunnel dewatering applications, the choice of dewatering systems comes down to the ejector well point or the deep well installed from the surface to effect partial or complete removal of water. The choice of the dewatering tool revolves around the quantities of water to be pumped and the necessity for closely spaced pickup points.

Every effort in tunnel construction has the one basic purpose of allowing the heading to be advanced in the shortest possible time cycle consistent with safety and quality. Development of various tunneling machines, breasting techniques, spoil handling methods, and so on all have the common purpose of permitting more rapid and safe progress.

Tunnel dewatering has the same purpose. One difficulty in planning for dewatering is that the repetitive nature of the work is not completely consistent because there is a new variable in every shove, and that is the drainage characteristics of the soil. Therefore, the first step in tunnel dewatering is to understand the soils and their drainage characteristics and to provide the type of pre-drainage systems that can cope with the variation that may occur in soil drainage characteristics.

Below mentioned are methods of dewatering in general practice at site locations.

a) Deep wells

Electric submersible pumps lower the groundwater level below your tunnel. The pumps are installed in wells drilled outside the perimeter of the excavation area. This mode of dewatering is a good choice when you need to lower groundwater because of deep excavation. Deep-well dewatering is less effective in soils with low permeability, which restricts water flow. Many submersible pumps are not capable of handling the low rate of flow. In that scenario, dewatering with eductor wells is a better choice.

b) Eductor wells

Tunnels and shafts excavated in sandy or silted areas pose a challenge to dewatering projects. The most efficient way to lower the groundwater level in these conditions is by using an eductor well system, also known as an ejector system.

Water is circulated at high pressure using eductors at the base of each well. This creates a vacuum that promotes drainage. The system works on the venture principle. The wells are drilled outside the excavation area and high-pressure supply pumps at ground level maintain the vacuum. This type of dewatering solution can also help to stabilize the soil in the excavation area.

c) Wellpoints

A wellpoint tunnel and shaft dewatering option only work for excavations up to a depth of 20 feet. Lines of closely spaced, shallow wells are drilled along the perimeter of the excavation and each wellpoint is connected to a header pipe, to which a wellpoint pump is then attached. These positive displacement pumps can handle both air and water.

The wellpoint dewatering system works in stages. It can control the groundwater level only about 15 to 18 feet below the level of the wellpoint pump heads. If your tunnel excavation is deeper than that, we will have to install another ring of wellpoints at a depth equal to that of your first set.

d) Relief wells

Tunnel projects often operate with limited access and space. For example, dewatering techniques may have to be placed in the tunnel itself, while relief wells can be drilled to create an upward pathway for groundwater. As it rises into the wells, it is removed with sump pumps. Sump pumps can handle some solids while they move water. This is helpful for relief well dewatering because the wells are usually filled with sand or gravel to create a permeable path to the area where the sump pump will have access.

e) Tunnel drains

Sump pumps are also used with this system. First, small wells are drilled outward from the tunnel. Groundwater in these areas then flows into the tunnel, where it is captured by the sump pumps and removed.

Dewatering During Tunnel Construction

During the excavation ingress of water in tunnels must be controlled in order to maintain acceptable and safe conditions. Dewatering is a process by which the water will be pumped out when it enters a construction area and obstructing the construction process.

During excavation works, the probe holes are drilled in order to detect water bearing structures and weak rock, ahead of the excavation face. Probe hole will be drilled at each round, from each working face. Locations may be occasionally adapted to geological and hydro geological observations and or interpretations. When drilling is finished or when a significant water ingress is detected, the water inflow and pressure will be measured.

The design of number and capacity of pumps will be based on the estimated maximum seepage calculations and localised inflows. All the major pumps to be deployed will be electric driven and handheld pneumatic pumps if required would be used for small and localised dewatering purposes. All works during construction will be drained and kept dry and necessary precautions will be taken by providing Pumping accessories, temporary measures will be taken to control any sudden inflows water during construction as per specifications. The temporary sump pits will be provided at suitable intervals in tunnels. Temporary side drains will be provided as a channel for water to flow into sump pits.

Dewatering by gravity is planned at faced in ascending heading and for descending heading, dewatering by pumps will be used.

Water ingress into tunnel face in water saturated zone may create problem during construction stage. Therefore, it is recommended to install of one dewatering pumping arrangement at each working tunnel face. One additional dewatering pump for each tunnel shall be in place for entire excavation period of tunnel.

Permanent Groundwater Drainage

The permanent groundwater drainage of the tunnel shall consist of a main collector pipe along the entire length tunnel and lateral drainage pipe(perforated) with transversal connection pipes to the main collector pipe at regular interval along tunnel sections where major water inflow occurs.

The transversal connection pipes shall be PVC pipes with a minimum diameter as specified in drawing. The main collector pipe in the tunnels shall be virgin HDPE pipes as per design drawings. The HDPE pipe shall be confirming to I.S. 4984/ 4151 / 12786/ 13488 with necessary jointing material like mechanical connectors i.e., thread / insert joint / quick release coupler joint / compression fitting joint or flanged joint. Drainage gutters shall be located along the entire length of the tunnel at the bottom of either tunnel side wall for collecting groundwater possibly entering through the tunnel lining. The water shall be diverted into the main collector

pipe by means of transversal connection pipes. At the intersections of the main collector pipe with the transversal connection pipes maintenance manholes shall be installed. Manholes shall also be installed for the maintenance of the invert drainage. Maintenance manholes as well as the drainage gutters shall be made of concrete grade M30 according to IS 456: 2000. Inspection chamber shall be installed in the inner concrete lining for permanent maintenance (flushing) of the lateral drainage pipes as shown on the drawings.

Laying of Drain Pipe and No Fine Concrete

The lateral drainage pipes shall consist of circumferentially slotted, PVC pipes with a minimum diameter as shown in the GFC drawings. The slots shall be within the corrugated area. The width of slots shall not exceed 1.0 mm. The total area of the slots for water intake shall be more than 100 cm^2 per meter length of pipe.

All perforated HDPE pipes shall be wrapped by non-woven geotextile 500 GSM to avoid the blockage from any fine particles. No-fines porous concrete shall be used for embedment of the lateral drainage pipes and of the invert drainage pipe.

Additionally, temporary, and permanent water diversion plans have been proposed in this submission which can be reviewed or modified during construction as per site conditions.

6 Methodology for NATM Tunnels

6.1 NATM Tunnel with mechanical excavation

NATM is recommended for all tunnels, as nearly all the tunnels are identified with hard rock masses some are acquainted with weathered rock, therefore in such tunnels, mechanical excavation is proposed for tunnels with rock class IV & V. The methodology for each tunnel section has been elaborated elaborated in Volume-2 Tunnel wise.

The construction methodology for “NATM Tunnel with mechanical excavation” includes following steps:

1. Excavating the ground profile at 2V:1H as mentioned in Appendix-1 in layers of depth 2m at a time and providing steel wire net with U clamps at the slope for slope stability before each next layer of excavation.
2. Once the portal construction is complete, tunnel construction will commence.
3. Excavation sequences, enlargement of excavation profiles for allowing displacement of the surround rock mass, subdivision of headings, amount and means of rock support can be adapted rather easily and quick to the actual ground conditions encountered. Additional measures built in at the heading face (e.g. grouting, dewatering, installation of pipe roof umbrellas, shotcrete lining with yielding elements) can cope with adverse conditions in fault zones.
4. Line positioning.
5. dust removal by ventilation

6. Installing primary supports such as shotcrete and spot bolts, wherever required. The support system may vary as per the site geological conditions and on recommendation of engineering geologist.
7. building the RCC lining as the secondary lining using moveable shuttering.

6.2 NATM Tunnel with drilling and blasting

NATM is recommended for all tunnels, as nearly all the tunnels are identified with hard rock masses, drilling and controlled blasting is proposed for tunnels with rock class I, II & III. The methodology for each tunnel section has been elaborated in Volume-2 Tunnelwise.

The construction methodology for "NATM Tunnel with drilling and blasting" includes following steps:

1. Excavating the ground profile at 4V:1H as mentioned in Appendix-1 in layers of depth 2m at a time and providing steel wire net with U clamps at the slope for slope stability before each next layer of excavation.
2. Once the portal construction is complete, tunnel construction will commence.
3. Line positioning
4. drilling, loading, and controlled blasting.
5. dust removal by ventilation.
6. Installing primary supports such as shotcrete and spot bolts, wherever required. The support system may vary as per the site's geological conditions and on recommendation of engineering geologist.
7. building the RCC lining as the secondary lining using moveable shuttering.

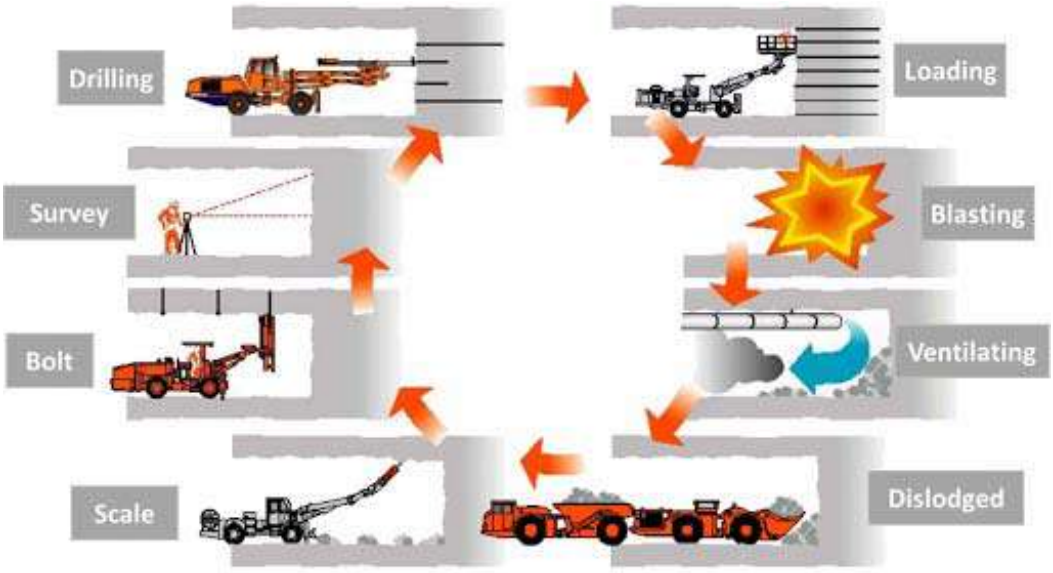


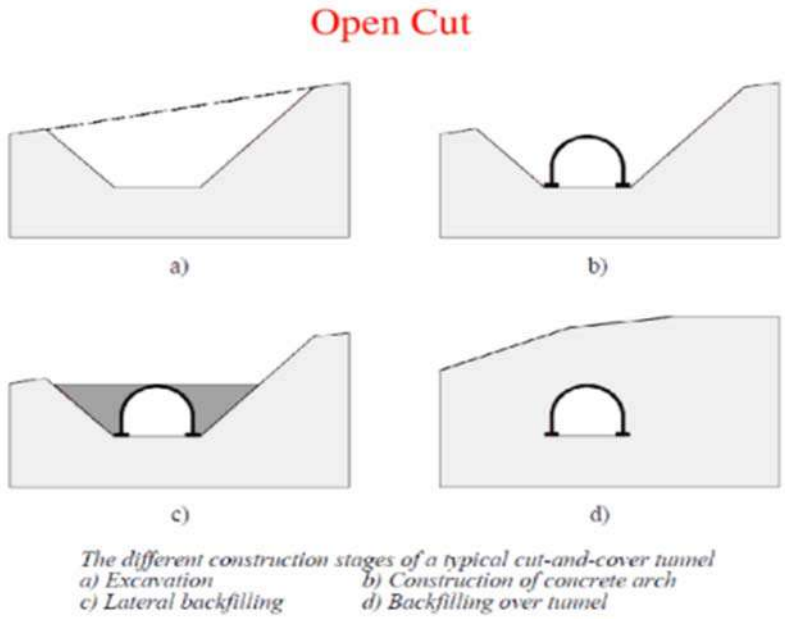
Figure 21 Construction Methodology for NATM Tunnels with mechanical excavation and drilling blasting.

6.3 NATM Tunnel with cut & cover box at the mid sections

NATM with Cut & cover box in middle is recommended for tunnels with low overburdens at mid sections along the alignment. These cut & cover boxes may also be utilized as construction phase both sides to accelerate construction activities.

The construction methodology includes following steps:

1. Excavating the ground profile as per Appendix-1 at (4V:1H/ 2V:1H) in layers of depth 2m at a time and providing steel wire net with U clamps at the slope for slope stability before each next layer of excavation.
2. Once the excavated profile is stabilized with adequate drainage arrangements, cut & cover box construction will commence.
3. First step is casting of base slabs, providing dowels for side walls, lifting the walls in shifts (as per contractor's plan) and finally providing arch (to counter compression forces and minimize bending moments) as can be seen in Figure below.
4. Lateral filling behind the walls and subsequently back filling over tunnel keeping clear cover of approximately 2m (minimum) from tunnel to reinstate ground profile to provide natural drainage over the tunnel profile.



(b)

Figure 22 Construction Methodology of Cut & Cover Method

6.4 NATM Tunnel with cut & cover box at portal portions.

The "Cut and Cover" method is encountered at tunnel portals where current earth retaining methods applied during construction are not sufficient to face small-scale and well-defined instability problems. The geotechnical concern of the "Cut and Cover" approach is to provide safe entrance to the underground project during construction and full geotechnical stability during operation. Preservation of the environment, reduced effort in lining construction and safe geotechnical conditions are the main advantages of the technique. More specifically, the "cut and cover" method is feasible and beneficial when:

• Initiation of underground excavation in weak formations with low overburden might trigger instability above the openings

• Structurally controlled wedge sliding or rock falls above the portals are expected regardless of rock mass quality

• Lateral slides due to unfavourable orientation of discontinuities and/or poor geotechnical conditions are possible.

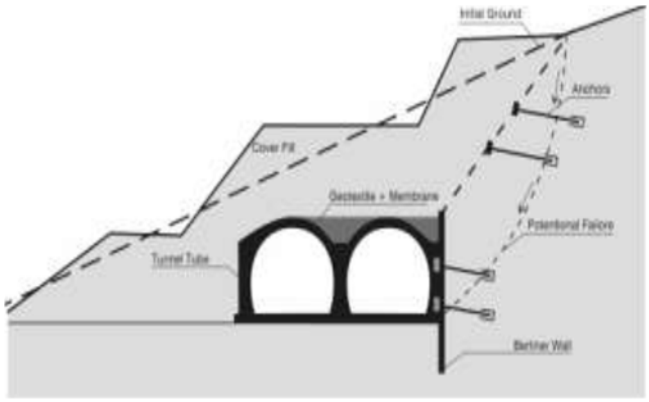


Figure 24: "Cut and Cover" tunnel along an unstable cut slope.

Construction of a tunnel portal using the "Cut and Cover" method is a two-fold project. The temporarily supported "cut" is constructed prior to underground excavations, while the permanent structure is constructed along with the final lining of the tunnel. The temporary "cut" consists of an excavation retained by a series of steel beams (pre-arches) in the "top heading" usually founded on a reinforced concrete spread footing which might also act as a pile cap if a series of piles is needed for foundation purposes. The length of the "pre-arched" section depends on the geotechnical conditions and the extent of the anticipated instabilities. The pre-arched section is shotcreted and sometimes bolted and can be partially covered to maximize stability. The final "Cut and Cover" shell is an extension of the final lining below the pre-arched area and usually extends beyond the pre-arches.

The construction methodology includes following steps:

a) Excavation for Berms and Central Portion

b) Installation of Slope Support system on side walls as per encountered geology.

c) Lean Concrete M15 PCC 100 mm thickness.

d) Reinforcement fixing for Foundation and Kicker Beam

e) Foundation and Kicker beam Casting

f) Reinforcement fixing for Overt

g) Shuttering & supporting arrangement for casting of Overt

h) Filling height near Box from both sides sequentially as per approved design drawings.

7 Conclusion

This report covers the construction methodology to be applied for the Tunnels of Ratlam-Khandwa Section. As this tunnel shall be constructed according to the New Austrian Tunneling Method, the construction methodology shall serve as basic guidelines during the execution of the works. This report shall be read in conjugation with design document (Volume-II) and design drawings (Volume – III).

पश्चिम रेलवे
Western Railway

Dr. Ambedkar Nagar to Muktiyara Balwara for Existing/new detour BG line in connection with gauge conversion of existing Ratlam - Khandwa MG section of Western Railway

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Appendix – IV Maintenance & Safety Manual

(APRIL 2023)

RITES
THE INFRASTRUCTURE PEOPLE

(A Govt. Of India Enterprise)
RITES BHAWAN
PLOT NO. 1, SECTOR-29

Register of Submissions

Document name:	Comprehensive Maintenance & Safety Manual for tunnels in Ratlam - Khandwa MG Section

Revision	Date	Description
R-0	19.05.2023	Comprehensive Maintenance & Safety Manual for tunnels in Ratlam - Khandwa MG Section

Prepared by:	Verified by:	Approved by:
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TABLE OF CONTENTS

1 Introduction

Western Railway (WR) is undertaking construction of gauge conversion between Dr. Ambedkar Nagar to Mukhtiyara Balwara for Ratlam Khandwa section. Railways have notified this project for fast-track execution as it is a connection between a line from South to North.

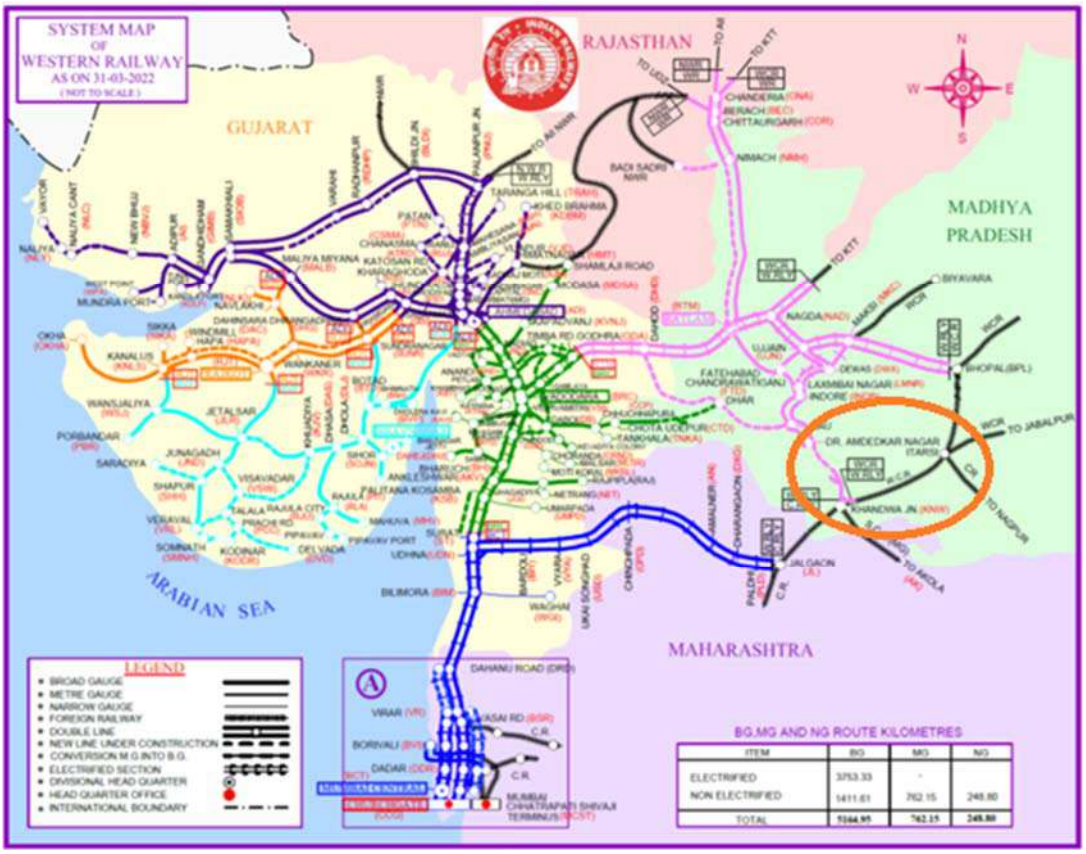

Figure 1: Location of Project

Dr. Ambedkar Nagar Station (Mhow) to Muktiyara Balwara section is about 71 km long section on Ratlam-Khandwa Gauge conversion project of Western Railway. In this connection the consultancy work for "Final Location Survey using modern survey equipments LIDAR etc, Geological mapping and Geo Physical Survey, Soil exploration, hydraulic data collection and GAD of minor and major bridges, preparation of L-sections, preparation of land schedules for land acquisitions and digitalization of land records from Dr. Ambedkar Nagar (Excluding yard) to Muktiyara Balwara (Excluding yard) for Existing/new detour BG line in connection with gauge conversion of existing Ratlam - Khandwa MG section of Western Railway" has been entrusted to RITES vide LoA No. DYCE-C-I-IND-ENGINEERING / DADN-SWD-FLS-2 /01056930054048 dated 09.05.2022.This report covers maintenance and safety manual for tunnel sections.

2 Objective of Maintenance & Safety Manual

The objective of this report is the determination of a concept and requirements for health & safety and maintenance during construction.

3 References

1. IS4756 (1978) - Safety Code for Tunneling Work
2. IS4081 (1967) - Safety Code for Blasting and Related Drilling Operations.
3. British Standard 6164 – Code of practice for safety in tunneling in the construction industry
4. Switzerland SUVA - Federal commission of coordination for work safety - Directive 6514 Code for work safety
5. U.S.A. O.S.H.A. - Occupational Safety and Health Administration 1926.800 –Safety and Health Regulations for Construction - Underground Construction
6. ITA – AITES International Tunnel Association – Working Group n.5 -Guidelines for Good Practice of Health and Safety in the construction of tunnels.

4 Maintenance

4.1Preventive maintenance

4.1.1 Maintenance specifications

The maintenance specifications will have to be issued by the Indian Railways.

4.1.2 Preventive maintenance of the track

Preventive maintenance request to ascertain the evolution of the track parameters and of its components. It includes surveillance and interventions.

- Surveillance:
  - On board surveillance using measuring /recording trains/cars which record:
    - The parameters of the geometry of the track
    - The rail defects using ultrasonic testing
  - Visual observations of equipment and track geometry undertaken during “periodic walkovers”
  - Verifications of the track undertaken during “periodic verifications” of the equipment under two types of operations:
    - Systematic preventive maintenance: verifications of key elements for safety
    - Conditional preventive maintenance: verifications which frequency depend mostly on the traffic.

- Interventions: Based on the exploitations of records obtained during the different surveillance and verifications operations

4.1.3 Surveillance

A) Inspection train:

After each interruption of commercial traffic at night and before the operation at normal speed the integrity of the system is verified by an inspection train in order to:

- Avoid the circulation of a commercial train in dangerous conditions
- Prohibit or restrain the commercial operation if any failure is detected
- Check the conditions and functioning of the systems

B) On board surveillance

It includes several types of measuring/recording operations including:

- Measuring and recording of vertical and horizontal accelerations every two weeks at the operation speed
- Measuring of the track geometry parameters 8 times a year (will be done every two weeks in the near future)
- Checking of rails defects by ultrasonic testing and recording car once a year or every 6 months depending on the traffic of the line

C) Periodic Surveillance carried out by maintenance staff

It includes:

- Surveillance walkovers in order to check the conditions of the railway equipment
- Surveillance walkovers of the surroundings to check conditions of the railway infrastructure

  - Periodic surveillance walkovers of the main tracks: during the day or at night on foot or **with lorries every 10 weeks for each track**
  - Periodic walkovers of turnouts and Rail Expansion Joints **every 5 weeks**
  - Periodic surveillance of the surroundings **every 5 weeks**
  - Particular surveillance in hot season o Particular surveillance in bad weather conditions
  - Periodic surveillance by maintenance managers by train surveys **every two weeks and on foot 4 times a year**
  - Specific surveillance of Turnouts and Rail Expansion Joints **4 times a year**
  - Manual ultrasonic testing of rails and steel parts of Turnouts/REJs **same frequency as ultrasonic car testing**

- Periodic verifications

o Turnouts : Every 6 months and every 3 years depending on elements to verify o REJs: 2 times a year (Spring and Autumn)

4.1.4 Maintenance of structures

- Current surveillance during all maintenance staff walkovers
- Periodic surveillance according to defined cycles:
  - Detailed examination of the structure every 6 years for normal /long structures
  - Detailed examination for small structures, noise barriers, every 9 years
  - Verification of the evolution of defects detected during the above surveillance every year or every 3 years

4.1.5 Maintenance of earthworks

- Current surveillance during all maintenance staff walkovers
- Periodic surveillance every 5 years maximum
- Additional surveillance to assess the evolution of defects according to records provided by a monitoring system

4.1.6 Maintenance of Overhead Catenary System (OCS)

- Walkovers every 6 weeks from the ground to detect breaking up of components, failure on return current circuit, integrity of protection devices
- Walkovers at height on platforms every year same as above and measuring of contact wire thickness
- Height of contact wire at structures, cleaning of insulators every two years
- Measurement of earthing every three years
- On board surveillance: Measuring and recording of dynamic height and offset of the catenary wire 8 times a year . Same car as track geometry

4.1.7 Maintenance of Power Supply equipment

Preventive maintenance is essential to safety and disponibility of the system.

The preventive maintenance is based on the scheduling of periodic maintenance operations activated by the overtaking of specific thresholds. The risks identified are mostly risks for the safety of personnel and risks of explosion of transformers

- Interventions and periodicity
  - A verification of the integrity of all protection devices and various switches every year
  - A functioning test of these devices every month on site and from the OCC
  - Transformers are verified every year, two years and 6 years

4.1.8 Maintenance of Signalling systems

- IXL interlocking computer : inspection every 12 months
- Track circuits: Inspection every 6 months
- Point motors: Inspection every 3 months
- Phase loops: Inspection every 12 months

- RBC: Inspection every 12 months
- Detectors of falling objects: Inspections every 6 and 12 months
  Hot box detectors: Inspection every 6 and 12 months

4.1.9 Maintenance of telecoms

- 48 Volts Power Supply: Replace the batteries every 8 years, measure every 6 months
- Telephones: Inspection every 12 months, emergency telephones every 3 months
- Data transmission network: Inspection every 12 months
- Video surveillance: Inspection every 12 months

4.1.10 Control of vegetation growth

The vegetation is necessary to protect embankments and cutting slopes but it should not provide hazards to:

- Safety of train operation (falling trees, visibility , animals,..).
- Functioning of Power Supply equipment
- Stability of earthworks
- Stability of structures
- Fencing
- Fire
- The development of vegetation create instability of rocks in cutting slopes in rocks

The table below provides frequency and types of preventive maintenance surveillance and verifications operations for main components

DRAINAGE	**Ditches**	Conditions		On foot survey	Every 5 years
	Culverts			On foot survey	Every 5 years
SURROUNDINGS		Fencing	Integrity	On foot survey	Once a year
		Vegetation	Height, growing	On foot survey	5wks
		Surroundings		On foot survey	5 wks
OCS	**All equipment**	Visual inspection		Survey at height	Once a year
		Tensioning devices, switches, cantilever		On foot survey	Every 6 wks
		Insulators cleaning,height of contact wire at bridges			Every 2 years
	OCS geometry and current capture	Dynamic behaviour		Recording car	8 times a year
		Arc detection			
		Offset and height contact			
		Wear of contact wire			
SUB-STATIONS POWER SUPPLY	**Switches**	Control	systematic		1year/5 years
	Distant operation	Control	Systematic		1year/5 years
	Transformers	Control	Systematic		1year/3 years
	Access control	Verification	Systematic		1 year
	Return current/earthing	Verification	Systematic		1 year
SIGNALLING	**IXL interlocking computer**	Inspection	Systematic		1 year
	Track circuits	Inspection	Systematic		6 months
	Point motors	Inspection	systematic		3 months
	Phase loops	Inspection	systematic		12 months
	RBC	Inspection	systematic		12 months
	Detectors of falling object	Inspection	systematic		12 months
	Hot box detectors	Inspection	systematic		12 months
TELECOMS	**48 V Power supply**	Batteries Inspection	systematic		6 months
		Batteries replacement	systematic		8 years
	Telephones	Normal telephones Inspec	systematic		12 months
		Emergency elephones Insp	Systematic		3 months
	Data transmission networ	Inspection	systematic		12 months
	Video Surveillance equip	Inspection	systematic		12 months
BUILDINGS	**Electrical equipment**				1 year
	Escalator				1 year
	Building structure				1 year

5 Safety

5.1 Contractor's safety obligation

The inspection and testing records are completed, identified, collected and kept as records. The Contractor shall be solely and completely responsible for safety conditions on the site, including the safety of all persons and property inside and adjacent to the site during the Contract. These requirements shall apply continuously for the duration of the Contract and shall not be limited to normal business hours or other time constraints, nor be reduced or diminished in any way because the Contractor is not given sole occupation of the site. The Contractor is fully responsible for the safety of workers engaged upon the Works, and of all other persons working at or visiting the site including any employees of other Contractors working within the site, and for the protection of the public in the vicinity of the site. The Contractor shall formulate and implement his Safety Plan, in accordance with the requirements defined in this report. The Contractor shall, within 30 days of the Commencement Date, submit the Contractor's Safety Plan which shall be approved by the Engineer and consequently become the Contractor's Safety Plan.

5.2 Laws & Regulations

The Contractor shall ensure that all operations carried out under the Contract shall, at all times, comply in all respects with all applicable laws and regulations, in particular with IS 4756 (1978) – "Safety Code for Tunneling Work" and IS4081 (1967) – "Safety Code for Blasting and Related Drilling Operations"

5.3 Responsibilities & Contractors safety organization

The Contractor shall designate a principal of the Contractor's organization as the Contractor´s Representative who shall be responsible and directly accountable to the Engineer in all matters concerning construction safety.

The Contractor shall provide and maintain an organizational structure of safety staff to effectively implement and manage occupational safety and health on site. Such staff shall be engaged solely in safety assurance. Responsibilities and task subdivision shall be clearly identified in the Safety Plan.

The Contractor shall within 30 days of the Commencement Date appoint a Safety Manager whose full-time duties shall be solely connected with the health & safety aspects of the Works and who shall report directly to the designated principal of the Contractor. Such an appointment shall be subject to approval by the Engineer. The Safety Manager shall be suitably qualified and experienced and have appropriate safety qualifications. He shall implement, maintain and monitor compliance with the Safety Plan and all safety procedures, and be based full time on site. The Contractor shall not commence any work on site until the Safety Manager has been appointed and commenced duties on the site and the appropriate subcontractor's safety staff are in place. The Contractor shall not remove the appointed Safety Manager without the prior written consent of the Engineer, and any replacement shall be nominated by the Contractor at the same time consent is sought. The Contractor shall provide adequate numbers of supporting staff for the Safety Manager. Such staff shall include at least one deputy safety manager, whose qualifications and experience shall be like the Safety Manager, and he shall be capable of assuming the duties and functions of the Safety Manager. He shall work full time on site and be employed solely in a safety role. The Contractor shall authorize the Safety Manager and safety staff to issue stop orders to employees of the Contractor and its subcontractors of any tier, including labor-only, to cease operations and take urgent and appropriate action to make safe the site and prevent unsafe working practices or other infringements of the Safety Plan or breach of any Applicable Laws. The Contractor shall ensure that each subcontractor of every tier, including labor-only, shall have Safety Supervisory staff who shall have appropriate experience and training. Such staff shall be responsible for implementing and maintaining the appropriate elements of the Safety Plan. They shall devote a substantial amount of their time to such duties. All subcontractors shall, always, conform to the Safety Plan. If a subcontractor has at any time more than 100 employees in direct employment on site, such subcontractor shall retain a full time Safety Manager. The Safety Manager shall have relevant experience, have

appropriate safety qualifications and shall be responsible for implementing and maintaining the subcontractor's safety plan.

If a subcontractor has at any time more than 100 employees in direct employment on site, such subcontractor shall retain a full time Safety Manager. The Safety Manager shall have relevant experience, have appropriate safety qualifications and shall be responsible for implementing and maintaining the subcontractor's safety plan.

The Health & Safety Manager is responsible for, but not limited to:

- Implementation of the measures determined in the Safety Plan
- Information and instruction of all site staff, subcontractors, and visitors on regulations and safety measures as determined in the Safety Plan.
- Performing continuous inspection of all site activities in respect of health and safety.
- Reporting, analyzing, and concluding from accidents or almost-accidents and communicating the conclusions and the related measures to all site staff, subcontractors and visitors.

5.4 Risk assessment

It is recognized that tunneling is done in an environment which is not entirely predictable and work is being executed under unfavorable working conditions. Darkness, dust and noise are factors which are unavoidable and keep the risk for health & safety at a high level. In order to formulate a specific and competent Safety Plan, the Contractor shall carry out a detailed risk assessment against the scope and nature of the contracted works and the particular site conditions. The risk assessment shall be conducted by a qualified and suitably experienced team comprising planning, design and supervisory staff led by the Safety Manager. The documentation arising from this process shall contain a comprehensive schedule of all perceived risks and the proposed elimination and mitigation measures necessary to reduce the risk to a minimum. Risk assessment documentation shall form part of the auditable safety records.

Risk Related to Design

They can be minimised or avoided by reconsidering alternative approaches under the aspects of safety.

Risk Related to Construction Sequence

They can be minimised by by reconsidering the sequence of works under the aspect of safety.

Risk Related to type and nature of Construction works.

Typical risks of underground construction works are:

1. Elevated Working Place

2. Noise
3. Dust
4. Poor Sight
5. Poor Air Quality
6. Site Traffic
7. Fire
8. Working in confined spaces,
9. Blasting and explosives
10. Excavation,
11. Rock fall or ground collapse
12. Mucking,
13. Drilling and installation of rock bolts
14. Erection of steel arches or lattice girders
15. Shotcreting
16. Steel Reinforcement works
17. Application of Waterproofing
18. Cast in place concrete works
19. Hazardous substances
20. Large and unexpected inflow of water

5.5 Safety Plan

The safety plan shall be subject to regular review against evolving legislation, the scope and programme of the Works, ambient conditions or as directed by the Engineer.

The safety plan shall contain, but not be limited to, the following elements developed to suit the works.

a) An organization chart that shall identify all full-time safety personnel and all site staff with responsibilities for safety under the Contract and the Safety Plan.

b) Details of the authority vested in the Safety Manager and his staff, which would enable them to take or instruct appropriate action, including the stoppage of activities likely to cause injury, in the event of a contravention of the Safety Plan.

c) Details of radio, or other, communication facilities necessary to enable the Safety Manager and the Contractor's Key Staff to communicate efficiently and effectively on

safety matters with the Contractor's personnel at all site workfaces and with the Engineer´s staff.

d) The means by which the Contractor shall ensure that specialist health and safety procedures proposed by sub-contractors of all levels will be reviewed and assimilated into the Contractor's Safety Plan.

e) The means by which the Contractor shall ensure that sub-contractors of all levels comply with their occupational health and safety standards and all Applicable Laws.

f) Emergency procedures that detail the organization of rescue and damage limitation teams to deal with emergency situations on site such as, but not limited to, seismic activity, fire, loss of power, typhoon, flooding, or the evacuation of a seriously injured person from a remote or difficult site location etc. The emergency procedures shall specify the equipment, it's location and the frequency of practice drills. The Contractor shall also detail how information on such services and arrangements will be made known to those at work on the site.

g) Arrangements for the training of the Contractor's entire site staff to enable them to properly undertake their health and safety responsibilities. The Contractor shall keep records of such training for health and safety audit purposes. Upon completion of their training, Contractor's site staff shall sign a copy of their assigned safety responsibilities statement which shall also be kept by the Contractor for audit purposes.

h) Arrangements for the induction and job specific health and safety training of all workers including those of sub-contractors at all level. The proposals shall include the syllabus, frequency and application of such training courses. Such training shall be conducted by suitably qualified persons and repeated at intervals of six months. All workers shall receive the agreed induction training before they can commence work on site. The ID card numbers, and names of attendees shall be kept for audit purposes.

i) Arrangements which will allow the Contractor to positively identify everyone who has successfully completed safety training. Those who cannot be identified positively shall not be allowed to work on site.

j) Arrangements to ensure that, at least once every month, all workers shall receive a toolbox talk from their immediate supervisor. Records of this activity shall be kept for audit purposes. The topic of these talks shall be decided at the site safety meeting. Guidance notes and advice on how to present the talks shall be prepared by the Contractor's Safety Manager and issued to those giving the talk.

k) Details of the quantity and specification of all necessary safe condition monitoring equipment which shall include as a minimum, but not be limited to, sound level meters and appropriate gas monitors.

l) The means and frequency by which safety facilities such as scaffolds, guardrails, working platforms, ladders and other means of access, lifting appliances, lighting, signing and guarding equipment, shall be inspected, tested and maintained. Maintenance and monitoring records for all of the aforementioned equipment e kept for audit purposes. The Contractor shall ensure that all the inspections and verifications are undertaken by qualified and competent persons.

m) Details of how the Contractor will ensure the protection of authorized visitors and the prevention of unauthorized entry to site.

n) Details of the proposed first aid provisions including medical personnel and facilities, appropriate to site conditions. This shall include arrangements for transporting the injured (ambulance, stretcher etc).

o) Details of how where and by whom, auditable health and safety related records shall be kept and maintained. In addition to these records the Safety Manager should keep a safety diary to record all safety-related activities and events on a daily basis. The diary shall be made available to the Engineer's staff on request.

p) Details of the Contractor's arrangements for site safety inspections to be conducted by the Contractor's Representative. These inspections shall take place monthly. A report of this activity, which shall include the actions taken to resolve any problems or shortcomings discovered during the inspection, shall be made available for audit purposes.

q) Terms of reference, membership and the proposed frequency of site safety meetings. These meetings shall be chaired by the Contractor's Representative.

r) A comprehensive health and safety inspection checklist for the use of the Contractor's site staff when inspecting the site. The checklist should indicate the standard to be achieved, on any aspect of health and safety, and be compiled in such a way that will allow the inspector to easily record his or her actual findings. Critical substandard Items shall be rectified on the spot and signed off as such. Noncritical substandard items that are not rectified on the spot shall be brought to the attention of the appropriate manager, via the sign off portion of the checklist, for subsequent rectification. When completed the checklist shall be kept for audit purposes.

s) Details of the internal safety audit scheme to be implemented by the Contractor on both his safety management system and the physical site conditions. The audits shall be performed, against the conditions specified in the Safety Plan at least every three Months. The audit shall include the work of sub-contractors of all levels. The documentation generated by the audit process, including score sheets, shall be made available to the Engineer for audit purposes.

t) Detailed procedures covering all health and safety aspects of the Contract as identified in course of the risk assessment and including but not limited to the following list, where they are applicable:

1. Work at height
2. Control of noise
3. Control of dust
4. Temporary illumination
5. Worker welfare and hygiene facilities
6. Traffic control and site transportation
7. Fire prevention and fire fighting
8. Working in confined spaces,
9. Blasting and explosives
10. Excavation,
11. Mucking,
12. Drilling
13. Rock bolt installation
14. Shotcrete application
15. Handheld electrical tools,
16. Temporary electrical distribution network
17. Welding/cutting operations and equipment,
18. Personal protective equipment and clothing
19. Lifting accessories (slings and shackles etc)
20. Cranes, Hoists and lifting appliances,
21. Scaffolding and work platforms,
22. Ladders,
23. Contractor's Plant, machinery and vehicles,
24. Work over water
25. Structural steel erection
26. Control of hazardous substances
27. Hot working
28. Protection from falling objects
29. Working in presence of toxic / inflammable gases

4.5.1 Revision of safety plan including procedures.

At any time a revision to the Safety Plan or any safety procedure may be required. The Contractor shall, following discussion with the Engineer, issue such revision which shall include an addition, omission or revision as applicable. The Contractor shall review, on a continuous basis, the Safety Plan and procedures and shall revise them as required in accordance with activities and experiences on site. Such revision from time to time shall enhance the standards of safety being implemented on site. Procedures shall be reviewed and new procedures issued whenever the character or extent of any activity is changed or a new activity of different nature is introduced which necessitates such revision. In addition to such revision the Contractor shall make a formal review once every 12 months on the anniversary of the Commencement Date. Such formal review, which shall take no more than

30 days, shall consider all matters pertaining to safety planning and implementation, including accident reports, inspections, audits, suggestions from meetings and other sources. Within 7 days of finishing this review the Contractor shall issue a review report to the Engineer giving the conclusions of the review and identifying the revisions to be made to the Safety Plan. Within 30 days of the issue of the review report if required, the Contractor shall submit a revised Safety Plan for consideration by the Engineer.

5.6 General health & Safety Requirements

5.6.1 Health & Safety Policy

The Contractor shall ensure that health and safety matters are given a high degree of publicity on site. Posters and signs, written in the languages understood by the workers, which draw attention to site safety, rescue, and occupational health, shall be made or obtained from appropriate sources and shall be displayed prominently in relevant areas of the site.

5.6.2 Inspection by the Safety manager

The Contractor shall regularly inspect, test and maintain all safety equipment, scaffolds, guardrails, working platforms, hoists, ladders and other means of access, lifting, lighting, signing and guarding equipment. Such inspection shall include checks on temporary works certificates, safe working procedures and personnel protection equipment. Inspection reports shall be filed for each individual inspection.

The Contractor shall establish and maintain a system for the issue of non-compliance notices by his Safety Manager in respect of safety violations and procedures for expeditiously rectifying such violations.

5.7 Emergency and Rescue Procedures, Escape Routes

The Contractor shall develop site emergency response and rescue procedures before any work commences on site, but in any event not later than two months after the Commencement Date. These procedures shall provide clear instructions to be followed in the event of an emergency, naming of responsible personnel, notification and co-operation proposals with appropriate rescue services and other authorities who would be involved, methods of evacuation, and other necessary measures.

The procedures shall be coordinated with local fire, rescue and emergency services as required.

Escape routes from all working places shall be defined in the rescue procedures. All temporary and permanent accesses (like portals, access shaft, access tunnel, etc.) shall be included as escape routes and shall be maintained in good order at any time. They shall in particular be equipped with:

- Lighting
- Ventilation independent from other ventilation
- Smoke hood deposits at regular intervals
- Emergency telephones in regular intervals
- Adequate driving surface

Emergency procedures giving full instructions and telephone numbers shall be posted at appropriate locations (in particular at emergency telephones) and in the languages in

common usage on site.
For underground works, trained rescue teams shall be designated for each working shift. These teams shall receive professional training in emergency response, rescue and first aid, particularly suited for the work at hand. Members of the rescue teams may be workers assigned to underground work or other duties.
Emergency drills including both the rescue teams and outside rescue and emergency. services shall be executed within 1 month of commencing construction on any Section and shall be repeated at no less than 6-month intervals. Where circumstances justify it, the Contractor may be required to carry out emergency drills more frequently.
The emergency and rescue procedures shall in particular but not limit to contain the following emergency cases:
• Accident with person injury
• Fire at surface facilities
• Fire underground
• Collapse of underground structures or at excavation face
Unexpected water inflow underground
In particular, for the work teams at the excavation faces an emergency procedure has to be developed for incidences, which cannot be detected at the working faces (for example: fire close to portals). An alarming system has to be installed, which cannot be set out of function. by the incident itself.
Public Convenience & Safety
All work shall be conducted so obstructions to traffic are minimized. The safety and convenience of the public and the protection of persons and property shall be provided as specified in the Contract.
Barriers, Barricades and Warning Signs -- The Contractor shall provide, erect, and maintain barriers, barricades, lights, signals, signs and other traffic control devices in accordance with the Applicable Laws and to the extent necessary to enable the Contractor to meet his obligations under the Contract.
Structural steel beams and other major structural components or heavy and potentially hazardous components shall not be lifted and/or placed over roadways, bicycle paths or walkways that are open to the public.

Personal Protective Equipment (PPE)
The Contractor shall ensure that all persons working on or visiting the site wear, at least:
• Safety (Hard) Helmet, of an approved type
• Reflective Gear
• Safety Boots (with steel inlay and steel toe cap)
Additionally, according to location and type of work, the following PPE shall be worn:
• Safety Goggles
• Ear Plugs
• Dust Protection (Face) Mask
• Working Gloves
• Waterproof Headlight
• Protective Overall
The Contractor shall assess all works areas and specify the appropriate personal protective

equipment according to the applicable Laws, standards and codes of practice. The Contractor shall ensure that subcontractor's workers of any tier, including labor-only, are issued with the specified PPE.
For self-rescue in case of fire or hazardous gases in the air, Smoke Hoods shall be provided for all personnel underground and shall have a standup time of at least 30 minutes. Smoke Hoods shall be provided in sufficient number at all working places underground, in particular at all excavation faces and at permanent deposits along escape routes.
All personal protective equipment shall be properly maintained and replaced before period of permitted use expires.
The Contractor shall ensure that all persons on site use the appropriate PPE at all times. Training in its use shall be provided where necessary. Failure to use such equipment shall be considered as conduct prejudicial to safety. The use of safety helmets on site shall be mandatory except in designated areas such as offices and canteens.

First Aid

All parts of the site where work is being carried out and all site offices shall be provided with appropriately equipped first aid kits. First aid kits shall be in sturdy weather- and dustproof. containers clearly identified in the languages in common usage on site. First Aid kits shall be. fixed in an obvious and readily accessible location.
All work sites shall have readily accessible first aid facilities fully equipped and staffed during working hours by appropriately qualified medical personnel. Such facility shall be able to provide immediate medical assistance for serious injuries, and to deal with minor injuries. The Contractor shall maintain an adequate number of personnel trained in basic first aid. Such number shall be not less than 1 trained personnel per 100 employees.

Fire Prevention and Fire Fighting

The Contractor shall establish a fire prevention strategy for all of the works under it's control and shall provide all necessary and appropriate fire fighting equipment, facilities and personnel trained in firefighting.
Firefighting equipment (fire extinguisher) shall be installed at least but not limited to at:

- Excavation faces
- Working machines and vehicles
- Workshops, offices, housing facilities
- Lining shutters
- Storage facilities of dangerous materials
- All Labour camp facilities

Additionally, hose connections to the tunnel water main shall be provided at distances of maximum 150 m. A fire hose and jet pipe shall be provided at each excavation face.
Warning systems shall be installed at all places where persons may be at risk from fire and all personnel shall be given instruction in evacuation procedures and basic firefighting.

5.8 Communication & Signs

All signs, labels, warnings, posters, and safety information directed at people working on site shall be in the languages in common usage on site. Communication regarding substandard

safety items may be verbal in the first instance to be followed by written communication, as necessary.

The Contractor shall ensure that radio or telephone communication is always available between all parts of the site and the main site offices. Such communication system shall provide a dedicated channel for use in case of emergencies involving accidents, injuries, fatalities, serious damage or dangerous occurrences. A permanent telephone line shall be installed from all excavation faces and other working areas underground to the site supervision above ground, which shall be permanently manned. Additionally, emergency telephones shall be permanently installed in the tunnels at maximum distances of 200 m, also connected to site supervision above ground.

A list with Emergency Telephone Numbers and Emergency Procedures in the languages in common usage on site shall be posted at all telephones. Site Installations and Services shall be provided by the Contractor according to the Technical Specifications. The Contractor shall submit to the Engineer a Site Installation and Services Plan in accordance with the Technical Specifications. The site shall be kept in a clean, clear and uncluttered condition, free of obstructions and hazards, at all times. All material and equipment that is not used shall be removed, particularly on access routes and walkways. All construction waste shall be removed immediately by its originator so to keep the site in good order all the time. During winter time all traffic routes shall be kept snow and ice free to allow save traffic. Lighting shall clearly and uniformly illuminate the working site. Signs shall be kept clear of obstructions and easy to read. Equipment that is damaged, dirty, not presently required in that location or not in working order shall be repaired, removed or replaced immediately. All storage of equipment and materials shall be done in a safe and controlled manner to minimize risks for others.

5.9 Blasting & Explosives

The use of explosives shall only be permitted upon approval from the relevant authorities. Storage of explosives and blasting operations shall follow permits and all. Applicable Laws and safety regulations as described in the Technical Specifications.

5.10 Ventilation

Adequate ventilation shall be provided for all underground areas in accordance with the Applicable Laws. The air quality underground shall be carried out regularly at intervals not more than 24 hours. Records of measured air quality shall be submitted to the Engineer and shall be filed in the health & safety-related documentation files.

5.11 Work over water

Where work is being carried out on, over or adjacent to water a safe system of work shall be devised to prevent persons from falling into the water. Where this cannot be achieved a suitably designed and equipped safety boat, or boats as appropriate shall be provided and used solely for rescue work. They shall be continuously manned with appropriately trained staff and be

ready to work whenever men are at risk of falling into the water. Suitable and sufficient back-up staff and equipment should be planned into the operation.

5.12 Noise

In addition to all Applicable Laws, all necessary procedures shall be established and maintained to prevent people working on site or members of the public in the area being exposed to unreasonable levels of noise. Such procedures shall include the use of noise emitting equipment and where necessary the provision of noise containment barriers and the issue of protective equipment to people working on site. Operation hours for noise generating equipments such as pile driving, drilling and other construction activities, etc. shall be according to prevailing local laws and should be avoided during night-time, especially in residential areas.

5.13 Radiation Protection

The use of radioactive substances and irradiating apparatus shall comply with the Applicable Laws. No operation involving ionizing radiation shall be carried out without the approval of the Engineer. The Contractor shall ensure that site personnel and members of the public are not exposed to radiation.

5.14 Safety meetings

The Contractor shall establish site safety meetings chaired by the Contractor's Representative. Attendance shall include the Contractor's Safety Manager and appropriate senior construction personnel. Attendance shall also include senior representatives of each of the currently active sub-contractors. These meetings shall be held at least once each month.

All such meetings and the agenda shall be notified in advance to the Engineer who may attend in person or send a representative at his discretion. Minutes of meetings shall be kept for audit purposes and forwarded to the Engineer. In course of the site safety meetings the Engineer will formally review the safety management performance of the Contractor and monitor the implementation and sufficiency of the Safety Plan. Representatives from third parties, including Statutory bodies, may be invited as necessary by the Engineer.

The Contractor shall act without delay upon decisions or recommendations as may be made during the site safety meeting on matters of health and safety. All safety related documentation including, but not limited to, permits, certificates, reports and records shall be kept on site in a readily accessible location in an auditable indexed system.

The Safety Manager shall maintain a daily site safety diary. It shall comprehensively record all matters pertaining to safety including, but not limited to, records of inspections, audits, injuries, dangerous occurrences, and safety violations. It shall be brought up to date by the end of each shift.

5.15 Non-compliance Notice System

The Contractor shall establish a system for the Safety Manager to issue non-compliance notices for safety violations and procedures for expeditiously rectifying such violations.

5.16 Reporting Adverse Events

The Contractor shall notify the Engineer immediately of any dangerous occurrence or incident that results in, or had the potential to cause, bodily injury or incapacity of any person for more than 3 days. This will include, but not be limited to, the overturning, collapse or failure of any lifting equipment or structure. Initial notification may be verbal but shall, in every event, be followed by a detailed resolution report within 5 days. The Contractor shall at the same time provide the Engineer with a copy of any statutory accident, injury or dangerous occurrence report that he submits to any Statutory Authority under the Regulations.

5.17 Monthly Safety Report

The Contractor shall submit a comprehensive safety report to the Engineer each month in an agreed format. Prior to submission, the Contractor's Representative shall endorse the report. The report shall comprehensively address all relevant aspects of occupational safety and health and shall contain certain standard forms, as agreed with the Engineer, for use in statistical analysis of the whole Project. The report should include a 3-month forward planning section in which construction issues with significant safety implication shall be discussed.

पश्चिम रेलवे
Western Railway

Dr. Ambedkar Nagar to Muktiyara Balwara for Existing/new detour BG line in connection with gauge conversion of existing Ratlam - Khandwa MG section of Western Railway

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APPENDIX –V

Quality & Assurance Plan

(MAY 2023)

RITES
THE INFRASTRUCTURE PEOPLE

A Govt. Of India Enterprise)
RITES BHAWAN
PLOT NO. 1, SECTOR-29

Register of Submissions

Document name:	Quality assurance plan for tunnels in Ratlam - Khandwa MG Section

Revision	Date	Description
R-0	19.05.2023	Quality assurance plan for tunnels in Ratlam - Khandwa MG Section

Prepared by:	Verified by:	Approved by:
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1 Introduction

Western Railway (WR) is undertaking construction of gauge conversion between Dr. Ambedkar Nagar to Mukhtiyara Balwara for Ratlam Khandwa section. Railways have notified this project for fast-track execution as it is a connection between a line from South to North.

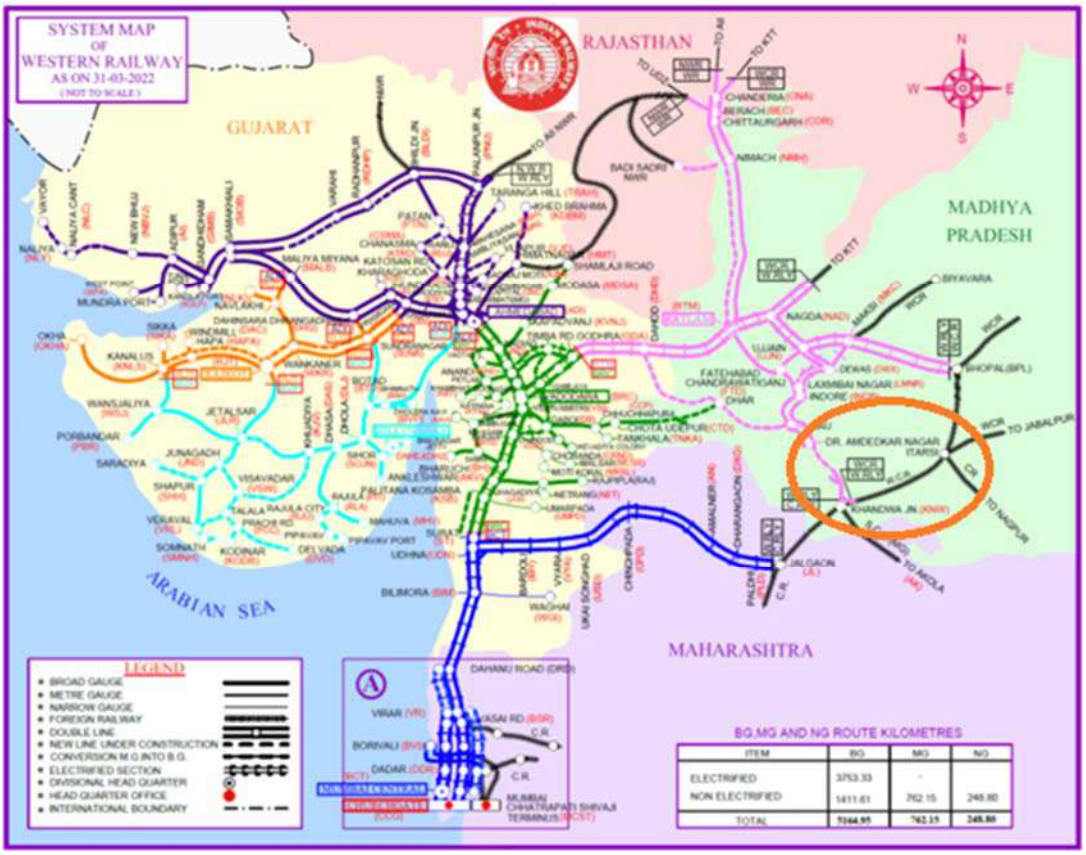


Figure 1: Location of Project

Dr. Ambedkar Nagar Station (Mhow) to Muktiyara Balwara section is about 71 km long section on Ratlam-Khandwa Gauge conversion project of Western Railway. In this connection the consultancy work for "Final Location Survey using modern survey equipments LIDAR etc, Geological mapping and Geo Physical Survey, Soil exploration, hydraulic data collection and GAD of minor and major bridges, preparation of L-sections, preparation of land schedules for land acquisitions and digitalization of land records from Dr. Ambedkar Nagar (Excluding yard) to Muktiyara Balwara (Excluding yard) for Existing/new detour BG line in connection with gauge conversion of existing Ratlam - Khandwa MG section of Western Railway" has been entrusted to RITES vide LoA No. DYCE-C-I-IND-ENGINEERING / DADN-SWD-FLS-2 /01056930054048 dated 09.05.2022.

This report covers quality assurance plans for tunneling section in Ratlam- Khandwa sections.

2 Objective of Quality Assurance Plan

The aim of this plan provides the description of Quality Assurance to be implemented to ensure that all the excavation, concreting works and the overall construction works of tunnels are in accordance with the contract requirements, specifications, drawings, and design. This procedure covers all inspection, measuring and test equipment (including testing software) used by RITES Limited to control conformity of the permanent materials used for the civil works to the specified requirements of the technical reference documentation.

3 Implementation Methods

3.1 Process Management

Process Management or Business Process Management (BPM) is the organizational discipline that provides tools and resources for analyzing, defining, optimizing, monitoring, and controlling business processes and for measuring and driving improved performance of interdependent business processes.

3.2 Process Qualification

Process qualification is the qualification of manufacturing and production processes to confirm they are able to operate at a certain standard during sustained commercial manufacturing.

3.3 QA/QC Process Qualification

The relation between the production process and the quality assurance and control is shown on Figure 4. - General Procedure for the execution and Construction of Tunnels and associated Structure and the Control of its Quality ".

Two distinct steps are distinguished for the QA/QC Concept:

1. Quality Control (QC): Quality Control is defined here as the actual inspections carried out for each activity such as laboratory works, concrete works, etc. The quality control is carried out by the person responsible for QC. The quality control is described and reported on quality records.

2. Quality Assurance (QA): Quality Assurance is defined here as the overall process of assuring the required quality of the construction of TUNNEL PROJECT. The quality assurance is carried out by QA supervisors which make sure that the quality control inspections have been carried out properly and according to this manual, and that they are reported in an acceptable manner. The quality assurance describes among other things the following:

- Where the quality control shall be carried out in the execution and construction process;
- The way of how such quality control forms are handled, communicated, reported, filed, etc.
- How non-conformities shall be dealt with; how corrective action shall be carried out;

The general inspection procedure is as follows:

1. Quality controls and inspections along the detailed instructions as per procedure should be carried out by the assigned QC persons daily or as required otherwise. The respective quality control forms should be filled in, as required, during the carrying out of the work and should be signed by the persons responsible for QC and assigned to this work.
2. The quality control forms should be sent to the respective department head which reviews the content of the forms. If a non-conformance has occurred the procedures of "Control of Non-conforming Products" should be followed.
3. The department head should forward the original quality control form to the responsible QA supervisor (see respective Organization Chart on Figure 2 1) and a copy to the technical department. He should keep a copy in his own files.
4. Technical Site Department:
    - The technical site department should review the QC forms and file a copy of them in its central QC filing archive.
    - If a non-conformance has occurred the respective item should be put on the Non- Conforming Register.
    - The technical department should make sure that the required corrective actions are carried out so that the non-conformance can be removed from the Non- Conforming Register.
5. The QA supervisor should review the QC form and signs it for acceptance. He should file the form in the QA/QC central filing archive.

The technical site department should apply with the QA supervisor if a construction activity is ready to have the final tests carried out, after making sure that all QC controls and corrective actions have been carried out. The QA supervisor should fill out the required QA forms as soon as possible. The originals of these QA forms should be filed in the central QA/QC filing archive. A copy should be sent to the technical site department.

LAYOUT OF THE ADAPTED QUALITY SYSTEM FOR TUNNELLING

STEPS FOR THE LIFETIME OF A TUNNEL ⇓

QUALITY ITEMS ⇓	General planning	Design	Financing	Procurement	Characterization	Monitoring	Construction	Approval	Claims and controversies	Operation	Maintenance	Installations	Statistics
Management responsibility	Authority and mandates for involved people												
Quality planning	Definition of procedures for the various activities and co-ordination												
Contracting	Administrative, legal and technical rules												
Control and inspections	All the tests, approval, inspections, verifications												
Document control	Issue, control and approval of documents												
Purchasing And Contractors	Control of materials and contractual works												
Non conformities	Problem definition and notifications												
Corrections and preventions	Accurate definition of problems and planning for preventive and remedial actions												
Audits	Independent check of the organization and methods												
Training and information	Internal and external education												
Data control and elaborations	Data processing of all phases; economical, statistical, technical, measurements												

Figure 1: Guidelines for a Quality Assurance Plan for Construction Works

4 Control of Inspection, Measuring & Testing Equipment

4.1 Aim

The aim of this procedure is to define the methods used by contractor for managing and calibrating inspection, measuring and test equipment used for the execution and construction of the permanent civil works and associated structures of Tunnels, with the aim of ensuring that its uncertainty is known and consistent with required measurement capability.

4.2 Scope

This procedure covers all inspection, measuring and test equipment (including testing software and comparative references) to be used by assigned contractor to control conformity of the permanent materials used for the civil works to the specified requirements of the technical reference documentation.

4.3 Responsibility

The Technical Site Department is responsible for:

- Selecting the equipment
- Having the equipment calibrated if external controls must be used
- The Quality Engineer is responsible for:
- Identifying the equipment
- Preserving the calibration documentation
- The Operator is responsible for:
- Calibrating the equipment

- Preserving and handling the equipment with care

4.4 Implementation methods

4.4.1 Equipment Selection

The selection of inspection, measuring and test equipment is to be carried out by taking into account the measurements which must be performed, and the accuracy required, as defined in the Technical Reference Documentation (Manuals, Technical Specifications, Drawings, etc).

4.4.2 Identification

All major inspection, measuring and test equipment present on the work site is recorded on the appropriate Quality Plan for Calibration of Inspection, Measuring and Test Equipment, prepared and kept up to date by the Technical Site Department.

All inspection, measuring and test devices are identified by means of a company serial/ asset number attached to them before use. For each device a "Calibration Form", prepared by contractor or from the agency that device is calibrated is compiled. This contains all the necessary information for calibration.

The "Calibration Form" shows unique identification number, thus permitting the corresponding device to be identified. Operators of inspection, measuring and test equipment ascertain that the devices are properly identified. If identification is lacking, they must inform the Technical Site Department, who verifies the cause of this and sees to it that identification is made.

4.4.3 Calibration

All major inspection, measuring and test equipment **should** undergo periodic calibration against certified standard equipment. The initial calibration frequency **should be** decided by the Technical Site Department together with the Quality Engineer and the Operator taking into account the use of the equipment and the manufacturer's instructions. The calibration frequency **should be** recorded on the "Calibration Form" of each device. The Technical Site Department **should be** responsible for calibrating all the equipment. "Calibration Form" indicates the reference documentation for performing the calibration. Calibration **could** be carried out externally or on site, each time referring to the recognized international standards. For on-site calibration in which recognized methods or manufacturers User's Manuals are not available, procedures must follow specific instructions issued by the Technical Site Department. Calibration outcome and assessment **should be** recorded on the "Calibration Form" of the respective device. If the outcome of the calibration is positive, a "Calibration Tag" is attached to the device. This indicates the calibration status and shows the calibration expiration date. Inspections, measuring and tests shall be performed exclusively with calibrated equipment within the validity period.

If inspection, measuring, and test equipment gives results which do not seem reliable, this should be reported to the Quality Engineer, who will instruct that the device in question undergoes unscheduled calibration. In the case of a negative outcome, the appropriate measures are taken.

Unscheduled calibration **should** also **be** recorded on the "Calibration Form", though in this case the "Calibration Tag" is not updated. Calibration operations **should be** carried out under environmental conditions which ensure the required accuracy.

In the case that a testing device is not used for a period longer than that between two consecutive calibrations, the phrase "not used" and the relative period must be written on the "Calibration Form". In the case that moving a device from one place to another may have compromised its calibration, the device must undergo new calibration, which is recorded on the "Calibration Form" as a note.

4.4.4 Documentation

Calibration data as well as all information which identifies equipment should be recorded on the "Calibration Forms". The "Calibration Forms" together with the relative. "Calibration Reports" issued internally to the company or by external agencies should be filed by the Quality Engineer.

Filing of documentation should be carried out in accordance with "Control of Quality Records".

4.4.5 Handling & Preservation

Inspection, measuring and test equipment **should be** preserved in such a way that it maintains its suitability and required degree of accuracy. During equipment use and handling all the necessary precautions **should be** taken to ensure its integrity (cleaning, protection from jarring, heat, etc.).

Operators are responsible for the correct handling and preservation of inspection, measuring and test equipment.

4.4.6 Measures in case Equipment is out of Calibration.

If equipment does not to meet the required standards or is out of calibration, the Quality Engineer **should** instruct the required measures for the repair or replacement. Works which were controlled with this equipment are held to be non-conforming and handled according to "Control of Non-Conforming products" in order **that the** respective departments may assess the results of the inspections, measuring and tests that were carried out.

If equipment is repaired, it is controlled and calibrated again before being used. The outcome of this operation **should be** recorded on the "Calibration Form", and a new "Calibration Tag" **should be** attached to the device. The Quality Engineer then assesses whether the previous calibration frequency is to be maintained. In the case that a change is made, the "Calibration Form" and quality plan must be updated.

4.4.7 Master Templates and Comparative Reference

Master templates and comparative references used for the purposes of control during production and test operations **should be** identified and documented in the same way as other equipment. They **should be** controlled at predetermined intervals of time. The outcome of the control **should be** recorded on the "Calibration Form".

4.4.8 Management of Standard Devices and Reference Equipment

Standard devices and reference equipment, used as standards of comparison for calibrating inspection, measuring and test equipment, **should be** periodically verified and calibrated in order to ensure congruity with national and international standards, or, in the absence of these, with the manufacturer's references. Calibration frequency Site Manager and the Quality Engineer.

Upon expiration of the period of the calibration validity, the equipment **should be** verified again or replaced.

"Calibration Reports" issued by calibration centres **should be** filed by the Quality Engineer.

5 Inspection & Test Status

5.1 Identification of Inspection and Test status

Permanent material, civil works or parts of civil works can be:

- awaiting inspection
- checked and found to be conforming checked and found to be non-conforming
- Accepted "conditionally" while awaiting completion of the inspections and tests required.

Their status is displayed by means of:

- cards, labels, stamping, paint
- storage in special marked-off areas, identified either with a "Conforming" or "Non-Conforming" sign or marked in a clear, unambiguous manner on the site plan
- Issue and completion of inspection record forms

"Conformity" should be visually identified by means of a "green" card and "Non-Conformity" by a red card, while the "Conditional" status should be shown by a white card. The "awaiting inspection" control condition should not be distinguished by a particular identification mark.

Permanent material, civil works or parts of civil works for which the test status cannot be traced, should be considered to be "awaiting inspection" and hence subjected to inspection and may have to be tested a second time.

Status identification is maintained throughout the construction phases. It is the duty of the Production/Tunnel Manager to manage the various phases ensuring that identification is always kept intact and to ensure that only civil works which have passed the required inspections and tests, or whose release has been authorized following Non-Conformity, are accepted.

5.2 Approval of Materials

All materials proposed by the **Contractor** to be used in the Project Works are to be first approved. In general, there are four types of materials to be approved.

(1) Natural Materials – materials with little or no processing except for perhaps screening for oversize and removal of unsuitable particles, etc. An example of this is soil embankment materials.

(2) Processed Materials – materials that require significant processing, including removal of unsuitable particles, crushing, screening and perhaps, blending of sizes. These materials are homogeneous, but with specified gradations.

(3) Manufactured Materials – especially homogeneous construction materials, like Portland cement and admixture that are used for blending with natural materials to obtain a concrete mix.

(4) Designed Materials – materials that involve the mixture to specific proportions of two or more different, natural, processed or manufactured materials to obtain a modified material giving a set of desired specific properties.

Approval of each of the above material types is required, however the requirements for obtaining approval of materials for each type differs slightly.

Natural materials are mined (i.e., excavated) and hence the first step, following assurance that the material is acceptable for its intended purpose, is to obtain approval for the Quarry.

Approval of the material for construction is then obtained by submittal of test results for all tests required by the Specifications (i.e., to prove that the material meets all minimum properties required).

Approval of processed materials follows that noted above for "natural" materials, except that usually the specifications are tighter (e.g. the material may also have to meet stringent gradation limits), and a greater variety of tests (and production/ storage) conditions are required to be met.

Approval of manufactured materials, based on specific Specifications requirements, is generally given in two stages.

- Initial Approval – given prior to receipt of the materials based on submittal of appropriate testing results confirmed by the manufacturer (note that claims by manufacturers, or tests etc by distributors, etc are not to be accepted).
- Final Approval – given based on initial approval plus positive results being obtained for all "acceptance" tests required by the Specifications, or as directed by the **QA Engineer**.

Approval of "designed" materials for the present Project concerns those mix designs for Portland Cement Concrete (for culverts, bridges etc). Due to the complexity of these "mixed" materials, and the plants for producing the range of materials sizes, final approval is deferred until completion of the following steps:

1. Approval of sources (generally quarries) for each of the processed material constituents to be included in the final mix design.
2. Approval of each of the individual processed materials and manufactured materials to be included in the final mix design.

3. Tentative approval of a laboratory-based mix design based on a mixture of approved materials so that the mixture meets all Specification requirements.

4. Tentative approval of a plant mix design based on proportioning of aggregate bins' materials and manufactured materials to closely approximate the proportioning of material types/ sizes finalized for the laboratory-based mix design (so that the mixture still meets the minimum Specifications requirements).

5. Based on successful laying of the mixes in accordance with the approved Methodology, conformance of the placed mix to required placing temperatures, levels and finish, etc., and conformance to quality control requirements as verified by successful testing in accordance with the Specifications, the Concessionaire's Q.A. Engineer is to give final approval of the mix design (Job Mix Formula) based on the plant mix proportions.

5.3 Revocation (Withdrawal) of Material Approvals

Following approval of the job mix formula, the PM and all field support staff shall continue to monitor both the test results of the visual characteristics of the approved mix as placed to identify at an early stage any significant change in the mix design that may adversely influence the adherence of the approved mix design to the Specifications.

A new mix design (or adjustment of the plant proportioning of materials to re-establish the approved job mix formula) will be required when it is observed that significant changes in the mix design properties are causing the mix to no longer meet all Specification requirements. In addition, a new mix design will be required when either the approval of a material source or approval of one of the materials is revoked (i.e., withdrawn). Mix /Material approved shall be revoked by the PM after due consultation with the Consultant's Q.A. Engineer. The Contractor's Q.A. Engineer shall notify in writing to the PM and the Consultant's / I C each time a new source, material and/ or mix design is either approved or the approval is revoked. This information is to be included in the Monthly Quality Control Report to be submitted with the Monthly Progress Report.

Records are to be kept by the Consultant's Q.A. Engineer/ I C giving current approvals of all Borrow Areas, Quarries (all types) and Mix Designs for all BOQ items. The current summaries are to be included as part of the Monthly Progress Report.

5.4 Sampling of Materials

All construction materials to be used in the permanent works are to be sampled jointly by the staff of Consultant's Q.A. Engineer and the Contractor prior to commencement of the Works. This includes sampling for materials to be tested for proposing approval of the material source as well as sampling of materials for approval of the individual construction materials. In both cases, and for each instance, the Contractor must give notification of a request for such sampling to the AE in advance (minimum 48 hours) by way of the Request for Inspection Form (RFI). All assistance (e.g., sampling instruments and equipment, sample bags, and labour etc) that is required for carrying out the sampling activities are to be provided by the Contractor. All sampling is to be carried out in accordance with instructions to be given by the Consultant's

Q.A. Engineer. Sampling procedures are to follow recognized guidelines of good engineering practice. These include:

- Obtaining samples from at least three areas.
- Ensuring that the sampled materials and locations are “typical” for the material to be tested.
- Ensure that all overburden etc. is removed within the stockpiles rather than from the surface (top, side or base of the stockpile) in order to avoid the collection of segregated materials.
- Ensure that enough are sampled to enable all tests to be conducted, plus additional material, to be stored for subsequent testing if required.

To ensure that each sample bag is marked/ labelled both inside and outside, giving the sample number, material type, sample location, date and number of the bag, as well as any additional information instructed by the Consultant’s Q.A. Engineer or his authorized engineer.

6 Corrective & Preventive Action

6.1 Responsibility

The Technical Site Department is responsible for:

- Determining the Corrective and Preventive Actions to be implemented following internal audits.
- Implementing the Corrective and Preventive Actions.

The Quality Engineer is responsible for:

- Making periodical analyses of the quality information and data gathered for the
- Quality System Review
- Establishing Corrective and Preventive Actions
- Assessing the effectiveness of the Actions taken by the Heads of Department checking during the closing of the "Non-Conformity Report" the effective
- Implementation of the Corrective Actions taken checking the results of these actions, Recording the Actions and filing them.

The Project Manager is responsible for:

- Taking Corrective and Preventive Actions together with the Executive Officer following the Quality System Review.

The Executive Officer is responsible for:

- Taking Corrective and Preventive Actions together with the Project Manager following the Quality System review.

6.2 Implementation method.

The Corrective and Preventive Actions taken as a result of Non-Conformities detected are documented on the “Corrective and Preventive Action Report” form. The Quality Engineer then records the Corrective and Preventive Actions in the “Corrective and Preventive Actions Register”.

The Corrective and Preventive Actions are determined by the Head of Department, their efficiency checked by the Quality Engineer. Subsequently, the actions taken are assessed by the Quality Engineer and inspected during surveillance actions. If the Quality Engineer Judges the actions to be ineffective, the Department concerned is bound to follow the recommendations made by him.

Actions following Client Complaints

The Corrective and Preventive Actions taken following Client complaints are determined by the Project Manager. The Executive Officer and Quality Engineer are notified of these actions and the latter assesses them and records them in the “Corrective and Preventive Actions Register”.

Actions following the Detection of a Non-Conformity

Corrective Actions following Non-Conformities detected on site are determined on the "Non-Conformity Report" as laid down in Procedure "Control of Non-Conforming products".

Once Non-Conformity has been resolved, the Quality Engineer checks that the Corrective Action taken has been implemented successfully.

Actions following the Periodical Quality Analysis made by the Quality Engineer

The quality information and data gathered deriving from:

- Results of internal Audits.
- Client Complaints
- Quality System review
- Quality record documents
- Quality System, process and product Non-Conformity records

On the basis of these examinations, the Quality Engineer should determine the Corrective and Preventive Actions required. After having consulted the Heads of Department involved, the Quality Engineer formalizes the Action by filling out the "Corrective and Preventive Action Report" form and by recording it in the "Corrective and Preventive Actions Register".

Actions following the Quality System Review

Before carrying out the Quality System Review, the Quality Engineer should make an analysis of Corrective and Preventive Actions, internal Audits, Client Complaints, Quality System, process and product Non-Conformities and transmits this analysis to the Project

Manager and Executive Officer to enable them, during the Quality System Review, to evaluate and determine the Corrective and Preventive Actions to be taken.

The Corrective and Preventive Actions resulting from the Quality System Review should be documented by the Quality Engineer who issues the "Corrective and Preventive Action Report" form. They should be recorded in the "Corrective and Preventive Actions Register" and transmitted to the Departments concerned to be implemented.

Checking the results of corrective and preventive actions

During the internal Audits and through surveillance actions the Quality Engineer should check the results of the Corrective and Preventive Actions in order to ascertain that:

- the time scale for their implementation has been respected.
- they have been fully implemented.
- The Quality System documents have been amended.
- The actions have been effective.

If the Corrective and Preventive Actions have had a negative outcome, they should be reviewed. These new Corrective and Preventive Actions are reported by the Quality Engineer to the Project Manager and Executive Manager.

Responsibility

The Management Board is responsible for:

- Ensuring that the internal audit is carried out periodically.
- Ensure that improvements to the quality assurance system are implemented.
- Deciding on additional internal audits if they feel that such are required.

The Executive Officer is responsible for:

- Carrying out the internal audit within the involved staff
- Implementing the proposed improvements found during the internal audit.

The Executive Officer who is responsible for the carrying out of the internal audits shall develop a system with which the quality assurance system as described in this manual shall be checked. Emphasis shall be put on the one procedure which is important at the time of the internal audit. This means e.g., that the civil works are more important at the start of the project whereas the overall organisation will become more important with time because of the interrelation between the major sub-contractors. This also means that not all procedures must be ready at the start of the project but shall be established in the course of the project so that they reflect the actual conditions at that time.

The audit shall not disturb the on-going works. Results shall be collected however if inaccuracies are observed they shall not be corrected on the spot but reported in the Auditing

Report and then be implemented through the existing QA/QC organisation.

The Auditing Report shall be prepared within 30 days after the carrying out of the internal audit. Improvements shall be implemented not later than 30 days after the Auditing Report has been made available to the responsible departments.

Additional internal audits can be carried out if the results of such an internal audit show that the quality reached is very poor and/or the quality assurance system is not followed at large. The decision to have an additional internal audit shall be taken by the management board.

7 Statistical Techniques

The Head of Department is responsible for:

- Issuing, when necessary, special Instructions for the application of the Statistical Techniques
- Documenting the reliability of the methods not defined by reference standards.

7.1 Implementation methods

For the application and control of the Statistical Techniques, refer to the standard methods laid down in the respective national or international Standards.

If no reference standard for the methods exists, the Head of Department will prepare the documentation necessary to prove the reliability of the method adopted.

To facilitate the use of Statistical Techniques and control their application, the Head of Department will, if necessary, issue special Instructions.

The Statistical Techniques designed to check:

Product characteristics, processes, Non-Conformities, mean, control cards, diagram & bar graphs. These calculations may be integrated, when necessary for the resolution of particular problems. Sampling methods which guarantee that the control is both significant and representative are used for product control.

SAMPLE INSPECTION AND TEST PLAN					
PROJECT:	Ratlam-Khandwa Section				
CLIENT:	Western Railway				
ACTIVITY: CONSTRUCTION MATERIAL FOR CONCRETE WORKS					
SL. NO.	**INSPECTION AND TESTING DESCRIPTION**	**CONTROLLING SPECIFICATION**	**VERIFYING DOCUMENT**	**FREQUNCY OF INSPECTION**	**REMARKS**
1	**CEMENT**				
a)	COMPRESSIVE STRENGTH	IS:4031 (PART 6)	MTC/ INTERNAL LAB REPORT	ONCE PER EACH WEEK	EXTERNAL LAB TEST FOR EACH 100 T
b)	INITIAL AND FINAL SETTING TIME	IS:4031 (PART 5)	MTC/ INTERNAL LAB REPORT	ONCE PER EACH WEEK	
c)	FINENESS TEST	IS:4031 (PART 1)	MTC/ INTERNAL LAB REPORT	ONCE PER EACH WEEK	
d)	SOUNDNESS TEST	IS:4031 (PART 3)	MTC/ INTERNAL LAB REPORT	ONCE PER EACH WEEK	
2	**REINFORCEMENT AND STRUCTURAL STEEL**				

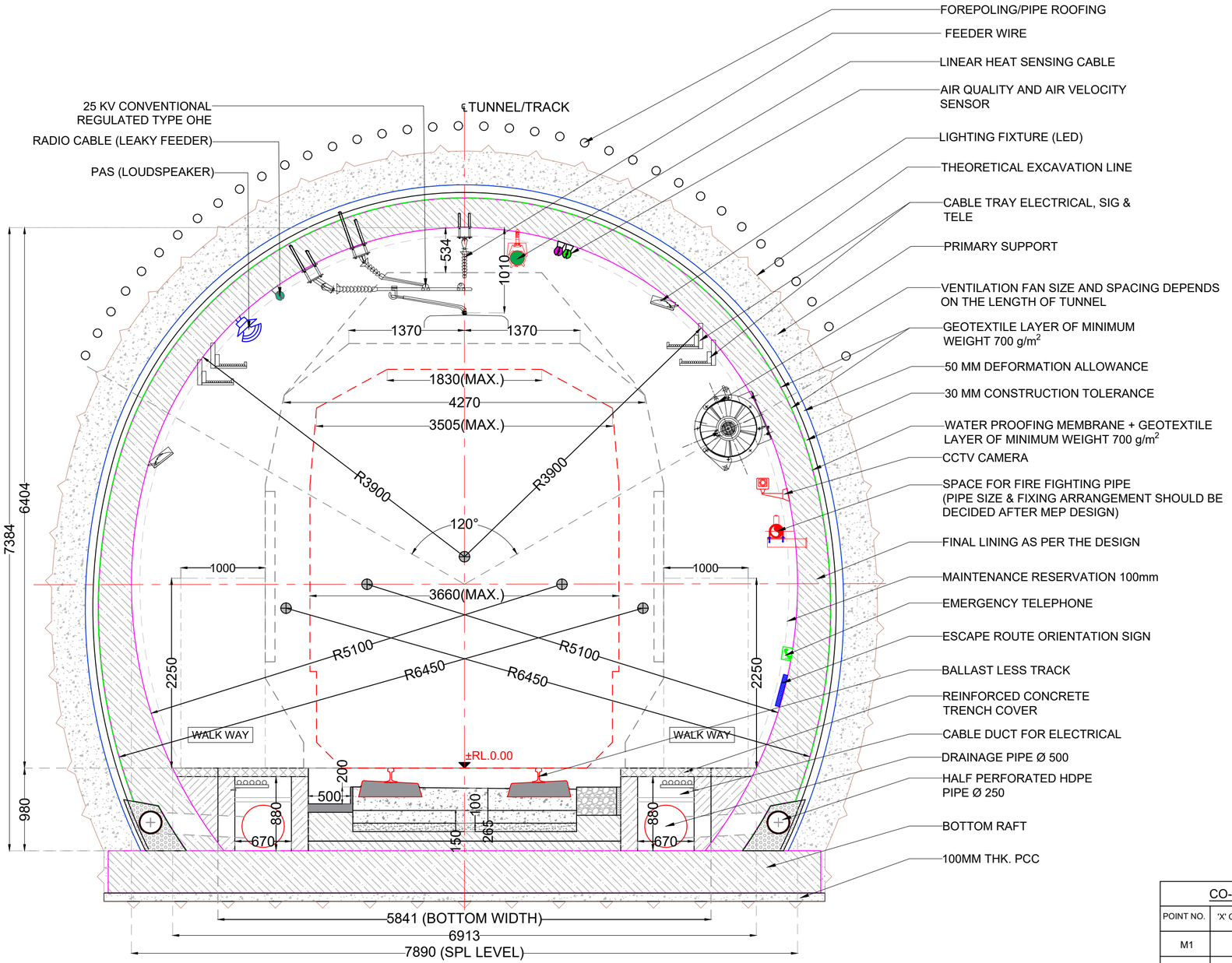
a)	ULTIMATE TENSILE STRENGTH	IS:1786, 2062	MTC/ EXTERNAL LAB REPORT	ONCE PER EACH BATCH	EXTERNAL TEST REPORT FOR EVERY 100 MT OR AS PER REQUIRED
b)	YIELD STRENGTH	IS:1786, 2062	MTC/ EXTERNAL LAB REPORT	ONCE PER EACH BATCH	
c)	PERCENTAGE OF ELONGATION TEST	IS:1786, 2062	MTC/ EXTERNAL LAB REPORT	ONCE PER EACH BATCH	
d)	BEND AND REBEND TEST	IS:1786, 2062	MTC/ EXTERNAL LAB REPORT	ONCE PER EACH BATCH	
3	**FINE AND CORASE AGGREGATE**				
a)	WATER ABSORPTION AND SPECIFIC GRAVITY	IS:2386(PART 3)	INTERNAL LAB REPORT	MONTHLY	
b)	GRADTAION ANLYSSIS	IS:2386(PART 1)	INTERNAL LAB REPORT	DAILY	
c)	SOUNDNESS TEST	IS:2386(PART 5)	INTERNAL LAB REPORT	ONCE PER EACH SOURCE	
d)	AGGREGATE IMPACT VALUE TEST	IS:2386(PART 4)	INTERNAL LAB REPORT	DAILY	
e)	AGGREGATE ABRASION VALUE	IS:2386(PART 4)	INTERNAL LAB REPORT	ONCE PER EACH SOURCE	
f)	ALKALI AGGREGATE REACTIVITY	IS:2386(PART 7)	EXTERNAL LAB REPORT	ONCE PER EACH SOURCE	
4	**WATER**				
a)	CHEMICAL TEST	TABLE 1 OF IS:456	EXTERNAL LAB REPORT	ONCE PER EACH SOURCE& EVERY 3 MONTH	
5	**CONCRETE**				
a)	WORKABILITY OF FRESH CONCRETE	IS:1199	INTERNAL LAB REPORT	ONE TEST FOR EACH BATCH OF CONCRETE	
b)	COMPRESSIVE STRENGTH	IS:516	INTERNAL LAB REPORT	AS PER IS:456	
c)	CORE STRENGTH ON HARDEN CONCRETE	IS:516	INTERNAL LAB REPORT	AS REQUIRED	
6	**CONCRETE ADMIXERS**				
a)	PHYSICAL AND CHEMICAL PROPERTIES	IS:9103	MANUFACTURE'S TEST REPORT	EACH BATCH	EXTERNAL LAB TEST FOR EACH BATCH
b)	SLUMP AND SETTING TIME	IS:9103	INTERNAL LAB REPORT	EACH BATCH	

SAMPLE QUALITY CONTROL LAB FREQUENCY

Sikarpai-Randikena TUNNEL PROJECT

S.NO	NAME OF TESTING	CONTROLLING SPECIFICATION	PARAMETER
A	**SAND & AGGREGATE**		
1	Moisture correction	IS-2386 & IS-383	Daily
2	Sieve Analysis of Ca & Fa	IS-2386 & IS-383	Daily
3	Impact Value	IS-2386 & IS-383	Daily
4	Crushing Value	IS-2386 & IS-383	Weekly

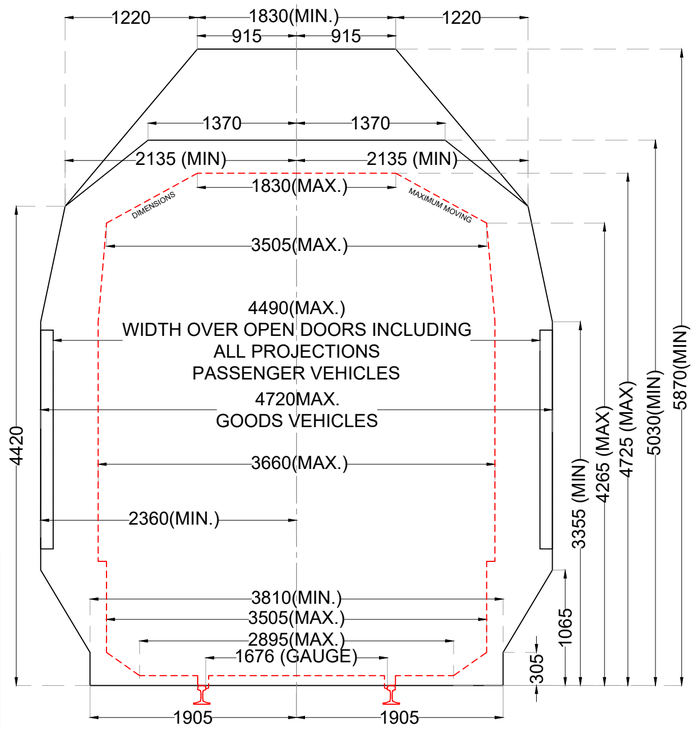
5	Flakkiness and Elongation of Aggregate	IS-2386 & IS-383	Daily
6	Specific Gravity of Ca & Fa	IS-2386 & IS-383	Monthly
7	Silt Content of Sand	IS-2386 & IS-383	Daily
8	Bulk Density of Aggregate & Sand	IS-2386 & IS-383	Weekly
B	**CEMENT**		
1	Cement setting Time Test	IS-4031	Each Week
2	Cement Cube Casting	IS-4031	Each Week
C	**ROCK BOLT**		
1	Swellex Bolt Pull Out Test		200 Nos
2	SN Bolt Pull Out Test		200 Nos
3	SDR Pull Out Test		200 Nos
D	**SHOTCRETE**		
1	Shotcrete Panel Casting (Every)		200 cum
2	Shotcrete In-Situ Core Testing (Every)		200 cum
3	Concrete Cube	IS-516	As per IS code
4	Batching Plant Calibration		3 Months
5	Needle Penetration Test(Every)		200 cum
6	Slump Test		Daily
E	**SFRS (STEEL FIBRE REINFORCEMENT SHORTCRETE)**		
1	SFRS Panel Casting		200 cum
2	SFRS In-Situ core Testing		200 cum
3	SFRS Thickness Test		200 cum
4	SFRS Cube Casting		100 cum
5	SFRS Density Test		weekly
6	Needle Penetration Test		200 cum
7	Slump Test		Daily



GAD FOR PORTAL AREA

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS AND LEVELS ARE IN METERS UNLESS OTHERWISE SPECIFIED.
2. MINIMUM EXCAVATION LINE SHALL INCLUDE DEFORMATION TOLERANCE.
3. REFER SEPARATE DRAWING FOR EXCAVATION & SUPPORT SYSTEM, TROLLEY REFUGE, LINING, REINFORCEMENT DETAILS, TUNNEL PORTALS.
4. REFER SEPARATE DRAWING FOR GEOLOGICAL SECTION, INSTRUMENTATION & MONITORING.
5. REQUIRED RING CLOSURE AT INVERT WILL BE BASED ON 3D MONITORING RESULT & GEOLOGICAL SITE CONDITIONS.
6. WORK TO BE CARRIED OUT CONFIRMING TO THE RELEVANT SPECIFICATIONS.
7. ARRANGEMENT FOR WATER DRAIN/RETAINING WALL SHOULD BE MADE AS PER SITE REQUIREMENT.
8. TUNNEL SECTION IS SUITABLE FOR ELECTRIFICATION AS PER IRSOD.
9. CURVE DETAILS, GRADIENT DETAILS ETC. ARE AS PER APPROVED L-SECTION DRAWING NO.CAO(C) CCG/E-26711-A - PTP-MKT -L-SEC & CAO(C) CCG/E - 26719 -A - PTP-MKT -L-SEC
10. REFER SEPARATE DRAWING FOR DRAINAGE ARRANGEMENT PLAN, BALLAST LESS TRACK, E&M SAFETY EQUIPMENT INSTALLATION, LIGHTING LAYOUT WITH CABLE TRAY, EARTHLING CONNECTION, OHE AND FIXING ARRANGEMENT ETC.
11. CONSTRUCTION OF TUNNEL SHALL CONFIRM TO THE LATEST RAILWAY STANDARDS, INDIAN STANDARDS OR WHERE NOT COVERED BY THESE STANDARDS, TO THE EQUIVALENT INTERNATIONAL STANDARDS.
12. SAFETY PROCEDURE AND REQUIREMENTS SHALL BE COMPLIED ALL THE TIME DURING TUNNELING TILL FINAL LINING.
13. SECONDARY SUPPORT SYSTEM SHOWN IN THE GAD IS TENTATIVE, DYCE INCHARGE SHALL DECIDE SUPPORT CLASS/CATEGORY BASED ON ENCOUNTERED GEOLOGY DURING THE WORK.
14. ALL HORIZONTAL/VERTICAL CLEARANCE ARE WITH RESPECT TO HIGHEST RAIL LEVEL (ASSUMING SE 165mm).
15. GUARD RAIL TO BE PROVIDED AS PER PARA-228(4) OF IRPWM .
16. ROAD APPROACH TO TUNNEL ENTRANCE TO BE PROVIDED FOR SAFE EGRESS OF PASSENGERS IN EMERGENCY.
17. PRIMARY SUPPORT SYSTEM (INITIAL SUPPORT SYSTEM) SHALL BE DECIDED BASED ON ENCOUNTERED GEOLOGY AND THE SAME SHALL BE PROVIDED/ INSTALLED IMMEDIATELY AFTER EXCAVATION.
18. GROUTING SHALL BE DONE AS PER PRESCRIBED SPECIFICATIONS.
19. ORIENTATION/PATTERN/LOCATION OF ROCK BOLTS MAY CHANGE AS PER ENCOUNTERED GEOLOGY.
20. THE CROSS SECTION AND SUPPORT SYSTEM MAY CHANGE DURING EXECUTION DEPENDING ON SITE CONDITION/ENCOUNTERED GEOLOGY.
21. VERIFY RAIL LEVEL, FORMATION LEVEL, INVERT LEVEL, OVERT LEVEL, GROUND LEVEL AND OTHER RELEVANT LEVELS BEFORE COMMENCEMENT OF THE WORK.
22. POTENTIAL POOR ROCK RATING, SPALLING/BURSTING GROUND CONDITIONS TO BE IDENTIFIED IMMEDIATELY & TO REINFORCE THE ZONE OF BURSTING WITH ROCK BOLTS. AS OUTLINED IN EXCAVATION SUPPORT CLASS OR AS DECIDED BY THE ENGINEER INCHARGE.
23. WORK OF SUPPORT SHALL BE COMPLETED AND INSPECTED BEFORE PROCEEDING FOR NEXT ROUND OF EXCAVATION.



STANDARD OF DIMENSIONS (BG)
SCALE 1:40
REFERENCE : SCHEDULE OF DIMENSIONS- 1676mm GAUGE

CO-ORDINATES

POINT NO.	'X' CO-ORDINATE	'Y' CO-ORDINATE
M1	0.000	+2504
M2	-1155	+2178
M3	+1155	+2178
M4	-2114	+1895
M5	2114	+1895

(THE ORIGIN OF COORDINATES IS RAIL LEVEL ±0.000)

MKD	DATE	REVISIONS
R1	04.06.2026	THE WIDTH OF THE FOOTPATH HAS BEEN INCREASED FROM 900 MM TO 1000 MM. DUE TO THIS CHANGE, THE FINISHED WIDTH OF THE TUNNEL HAS ALSO BEEN MODIFIED ACCORDINGLY
R0	26.08.2025	INITIAL SUBMISSION

PROJECT:

CONSTRUCTION OF SINGLE LINE BG TUNNEL NO.1 BETWEEN CH: 7515 TO CH: 11670, (APPROXIMATE TOTAL LENGTH 4155 M) INCLUDING ESCAPE TUNNEL (APPROXIMATE TOTAL LENGTH 4155 M) BETWEEN BADIYA (CH: 4100 M) - BEKA (CH: 14750 M) STATIONS OF DR. AMBEDKAR NAGAR (MHOW) - SANAWAD SECTION IN CONNECTION WITH RATLAM - MHOW - KHANDWA GAUGE CONVERSION PROJECT OF WESTERN RAILWAY

CLIENT:

WESTERN RAILWAY

DESIGN CONSULTANT:

BEAVER INFRA CONSULTANTS PVT. LTD.
NEW PANVEL(E) NAVI MUMBAI, INDIA-410206,
Email:-Support@beaverinfra.com

DRAWN BY	SP	
DESIGNED BY	US	
CHECKED BY	NJ	
APPROVED BY	RS	
SCALE: AS SHOWN	REV: R1	
SCALE @ A2 SIZE SHEET	SIZE: A2	

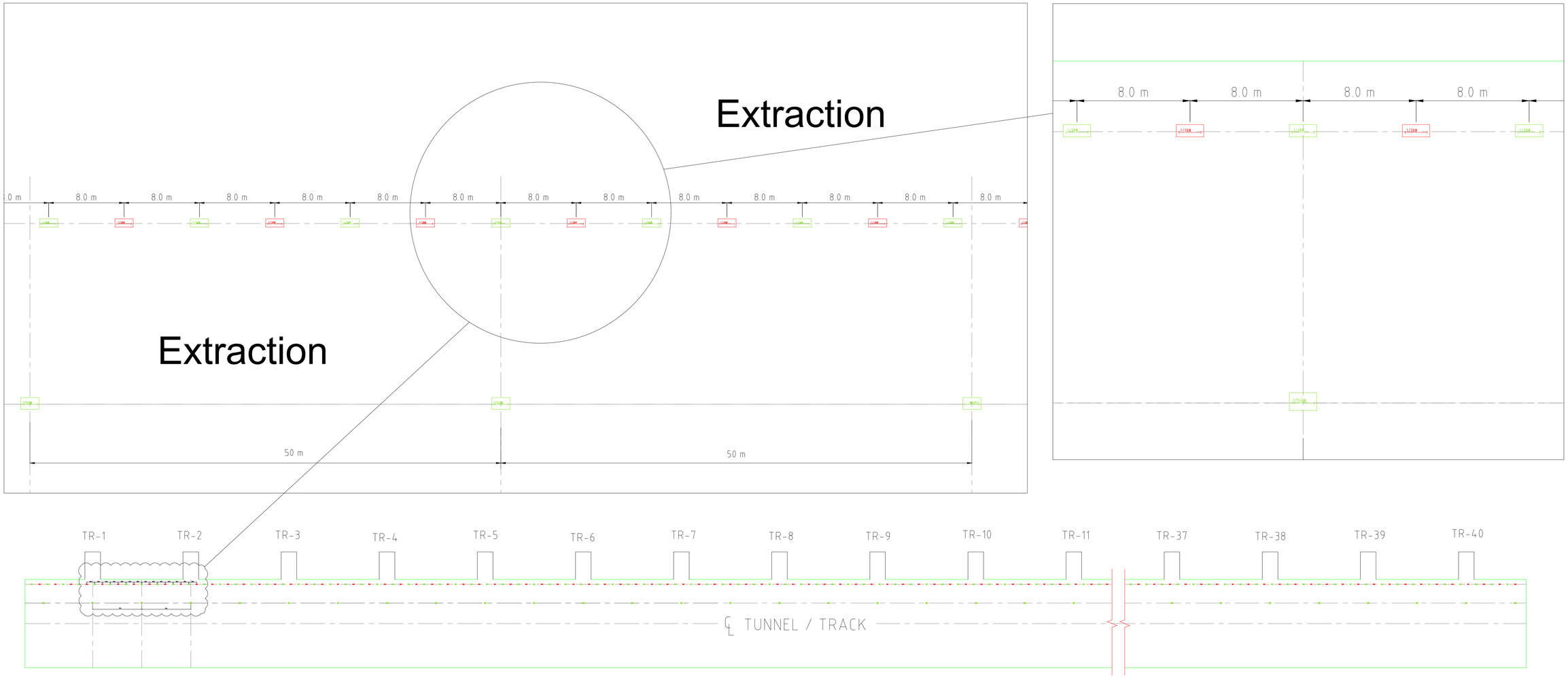
TITLE :

GENERAL ARRANGEMENT DRAWING OF PORTAL AREA - P1 (CLASS-E) CH:7+515 TO CH:7+535

MAIN TUNNEL

DWG.NO: BICPL/MHOW/WR/T1/MT/P1/01

SHEET: 01 OF 03 DATE: 04.06.2026



TYPICAL LAYOUT OF TUNNEL LIGHTING LAYOUT

Legend:

TR Trolley refuge niche

1/150W High Pressure Sodium (HPS) Lamp 150 W UPS

1/36W Flourescence lamp (asym.) 36 W NET

1/36W Flourescence lamp (asym.) 36 W UPS

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	MAY 2023

(VAKIL SAIFI)	(RISHABH GUPTA)	(JYOTSNA DIXIT)	(AMIT KUMAR)	(LALIT KUMAR)
CAD OPER./RITES LTD.	AM/RITES LTD.	DGM/RITES LTD.	SDGM/RITES LTD.	GM/RITES LTD.

REFERENCE DRAWINGS:

RITES/WR/RK/DADN-MKT/DR/P09/001 (SHEET 1 TO 3)
RITES/WR/RK/DADN-MKT/DR/P09/002 TO 009 (EXCEPT 003)

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

DADN - MKT SECTION
TYPICAL LAYOUT PLAN
TUNNEL LIGHTING LAYOUT

CE / C

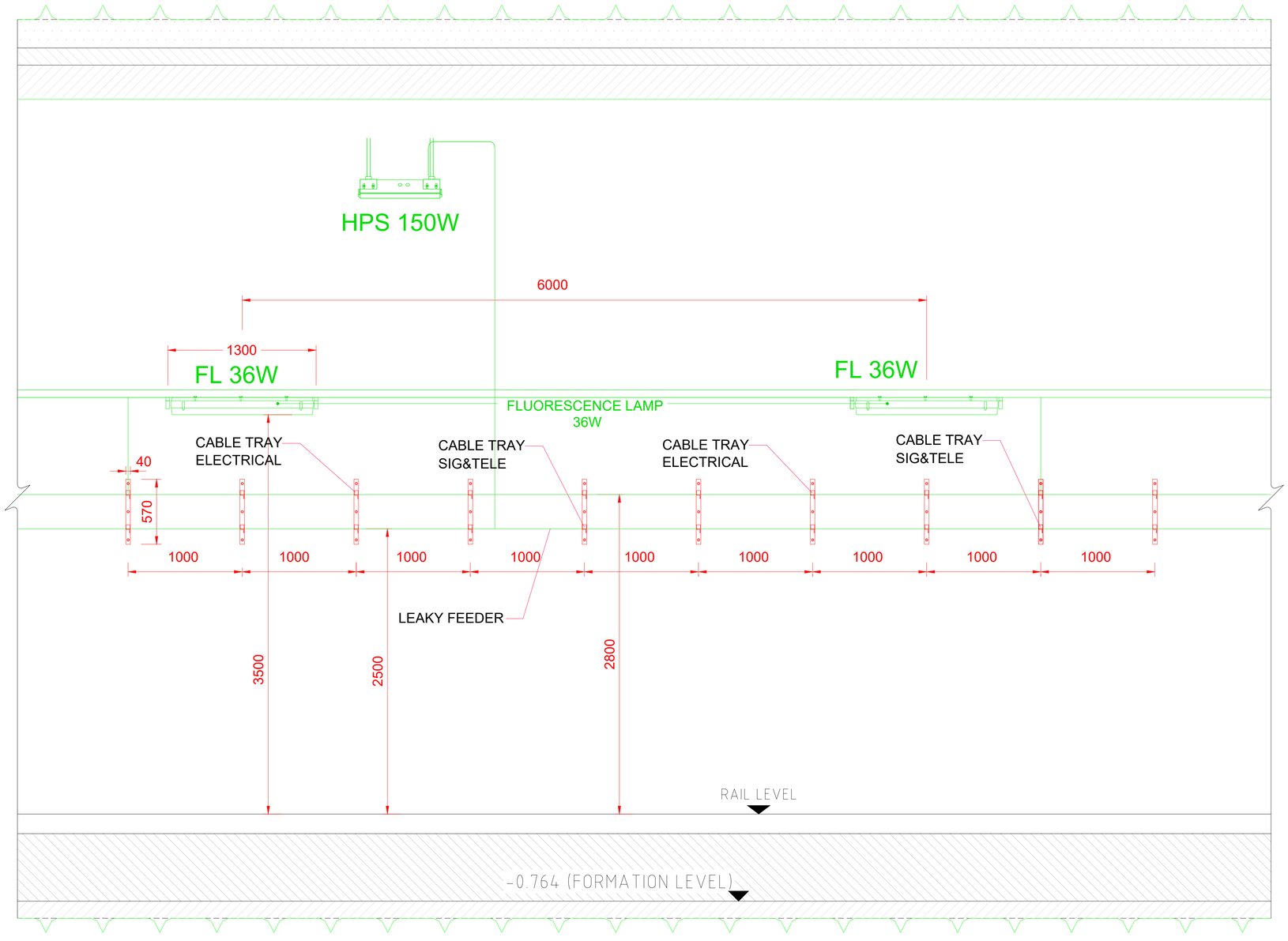
DY.CE / C

AXEN / C

Consultant RITES THE INFRASTRUCTURE PEOPLE

DATE	SCALE	SHEET NO.	REVISION
MAY 2023	N. T. S.	1 OF 1	A

DRAWING NO : RITES/WR/RK/DADN-MKT/DR/P09/003



REFERENCE DRAWINGS:

RITES/WR/RK/DADN-MKT/DR/P09/001 (SHEET 1 TO 3)
RITES/WR/RK/DADN-MKT/DR/P09/002 TO 009 (EXCEPT 004)

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	MAY 2023

(VAKIL SAIFI)	(RISHABH GUPTA)	(JYOTSNA DIXIT)	(AMIT KUMAR)	(LALIT KUMAR)
CAD OPER./RITES LTD.	AM/RITES LTD.	DGM/RITES LTD.	SDGM/RITES LTD.	GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

DADN - MKT SECTION
TYPICAL LAYOUT PLAN WITH
LIGHTING LAYOUT WITH CABLE TRAY

CE / C

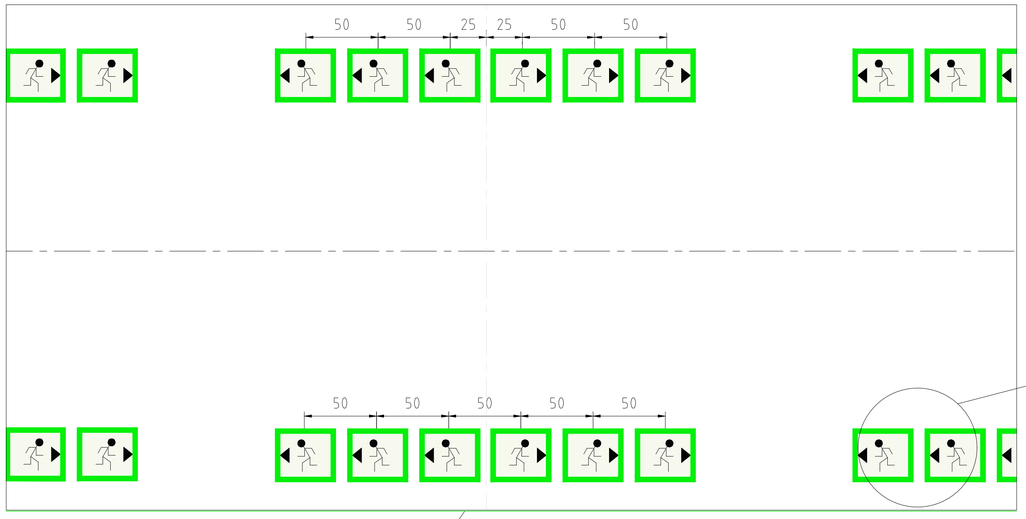
DY.CE / C

AXEN / C

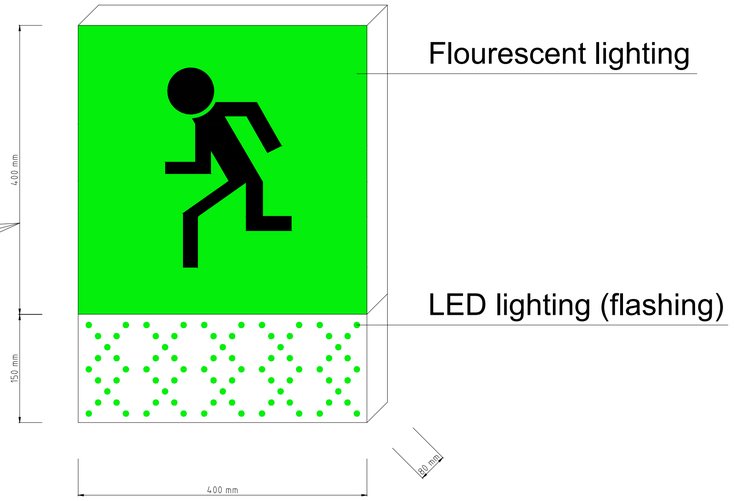
Consultant RITES THE INFRASTRUCTURE VISIBLE

DATE	SCALE	SHEET NO.	REVISION
MAY 2023	N. T. S.	1 OF 1	A

DRAWING NO : RITES/WR/RK/DADN-MKT/DR/P09/004



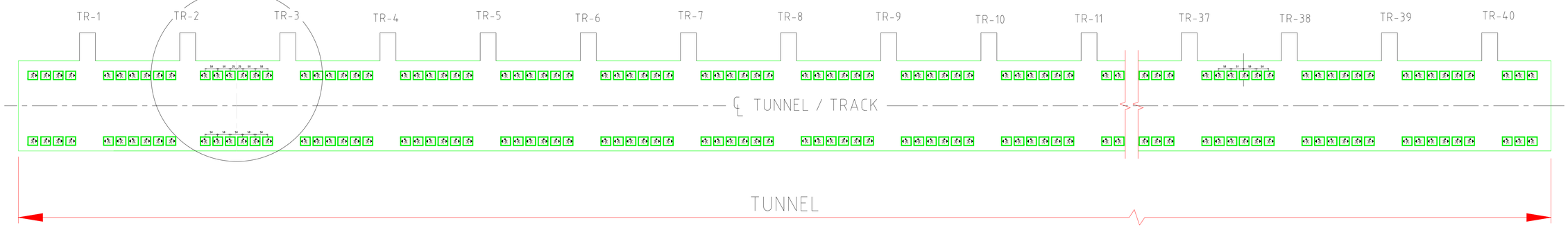
Detail



Detail

DADN

MKT



LAYOUT OF ESCAPE ROUTE SIGN

Legend:

Escape route orientation sign
flourescence lamp 36 W
with LED flash light

REFERENCE DRAWINGS:

RITES/WR/RK/DADN-MKT/DR/P09/001 (SHEET 1 TO 3)
RITES/WR/RK/DADN-MKT/DR/P09/002 TO 009 (EXCEPT 005)

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	MAY 2023

(VAKIL SAIFI)	(RISHABH GUPTA)	(JYOTSNA DIXIT)	(AMIT KUMAR)	(LALIT KUMAR)
CAD OPER./RITES LTD.	AM/RITES LTD.	DGM/RITES LTD.	SDGM/RITES LTD.	GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

DADN - MKT SECTION
TYPICAL LAYOUT PLAN
ESCAPE ROUTE ORIENTATION SIGN

CE / C

DY.CE / C

AXEN / C

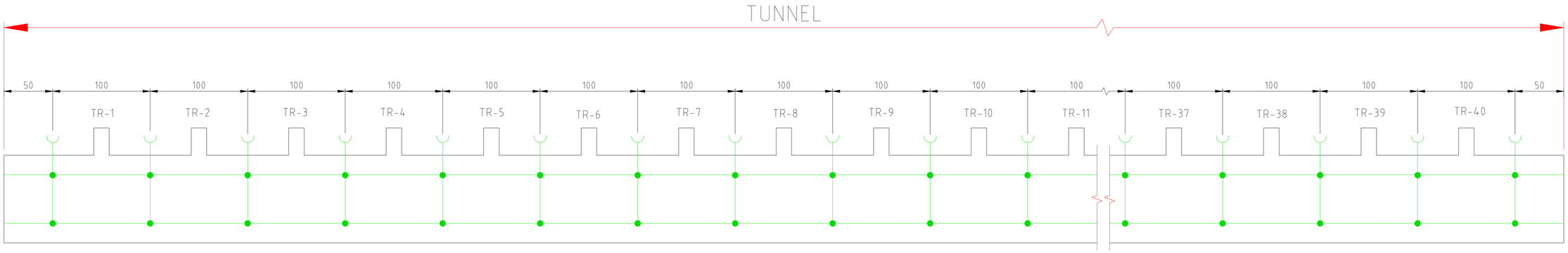
Consultant RITES THE INFRASTRUCTURE PEOPLE

DATE	SCALE	SHEET NO.	REVISION
MAY 2023	N. T. S.	1 OF 1	A

DRAWING NO : RITES/WR/RK/DADN-MKT/DR/P09/005

DADN

MKT



TYPICAL LAYOUT PLAN OF EARTHING LAYOUT

Legend:

TR	Trolley refuge niche
——	Earthing Conductor, galvanized steel, 40x6mm
•	Earthing Connection
ᛉ	Earthing Flag

WHOLE EARTHING PREPARED BY CIVIL WORKS

REFERENCE DRAWINGS:

RITES/WR/RK/DADN-MKT/DR/P09/001 (SHEET 1 TO 3)
RITES/WR/RK/DADN-MKT/DR/P09/002 TO 009 (EXCEPT 006)

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	MAY 2023

(VAKIL SAIFI)	(RISHABH GUPTA)	(JYOTSNA DIXIT)	(AMIT KUMAR)	(LALIT KUMAR)
CAD OPER./RITES LTD.	AM/RITES LTD.	DGM/RITES LTD.	SDGM/RITES LTD.	GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

DADN - MKT SECTION
TYPICAL LAYOUT PLAN
EARTHING CONNECTION

CE / C

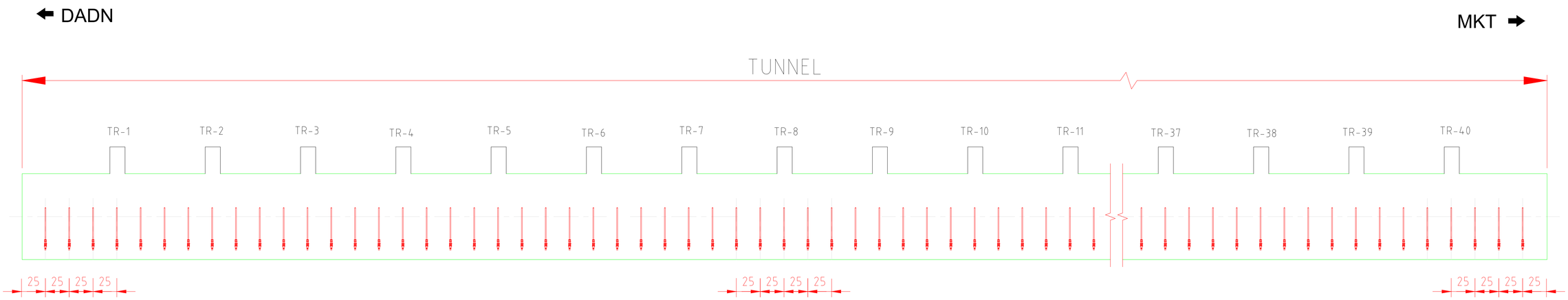
DY.CE / C

AXEN / C

Consultant RITES THE INFRASTRUCTURE PEOPLE

DATE	SCALE	SHEET NO.	REVISION
MAY 2023	N. T. S.	1 OF 1	A

DRAWING NO : RITES/WR/RK/DADN-MKT/DR/P09/006



TYPICAL LAYOUT OF PLAN OF OHE

Legend:

TR Trolley refuge niche

OHE & Fixing arrangement

REFERENCE DRAWINGS:

RITES/WR/RK/DADN-MKT/DR/P09/001 (SHEET 1 TO 3)
RITES/WR/RK/DADN-MKT/DR/P09/002 TO 009 (EXCEPT 007)

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	MAY 2023

(VAKIL SAIFI)	(RISHABH GUPTA)	(JYOTSNA DIXIT)	(AMIT KUMAR)	(LALIT KUMAR)
CAD OPER./RITES LTD.	AM/RITES LTD.	DGM/RITES LTD.	SDGM/RITES LTD.	GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

DADN - MKT SECTION
TYPICAL LAYOUT PLAN
OHE AND FIXING ARRANGEMENT

CE / C

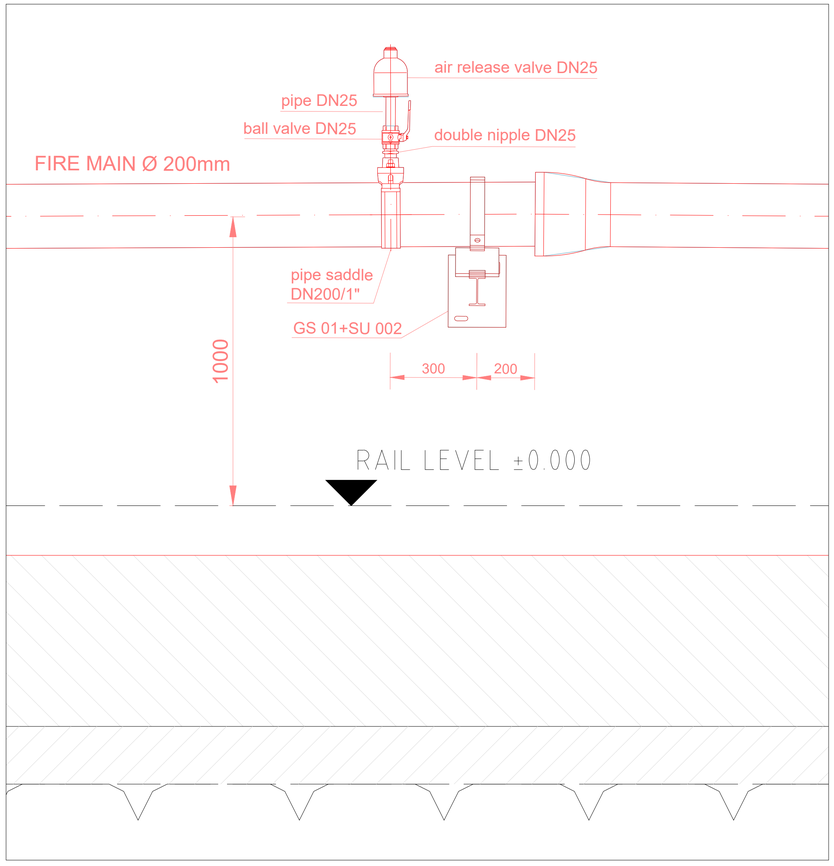
DY.CE / C

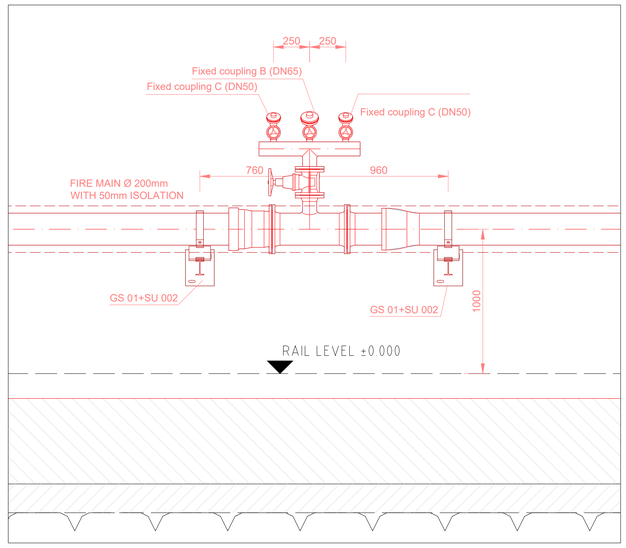
AXEN / C

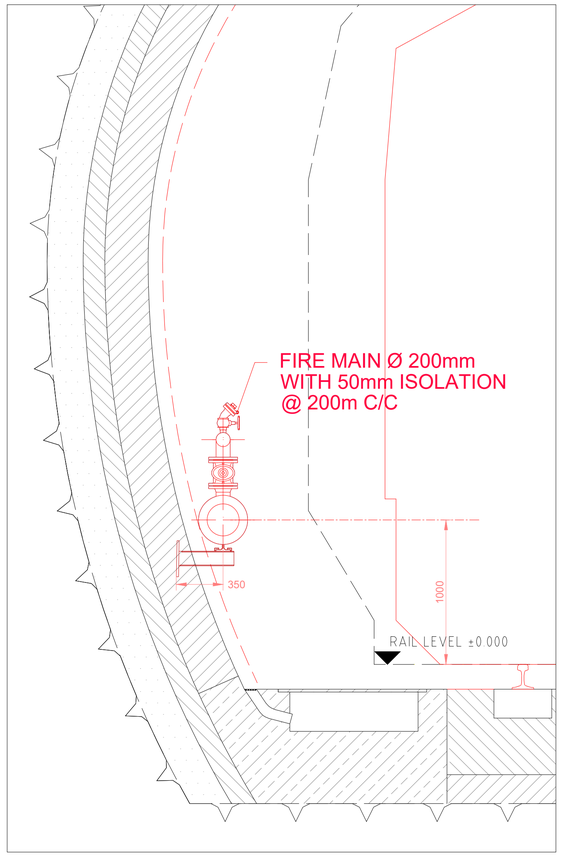
Consultant RITES THE INFRASTRUCTURE PEOPLE

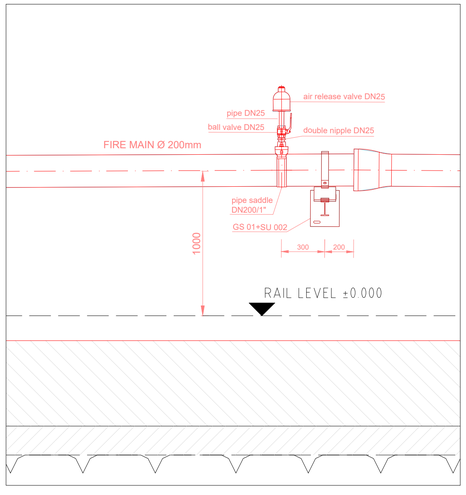
DATE	SCALE	SHEET NO.	REVISION
MAY 2023	N. T. S.	1 OF 1	A

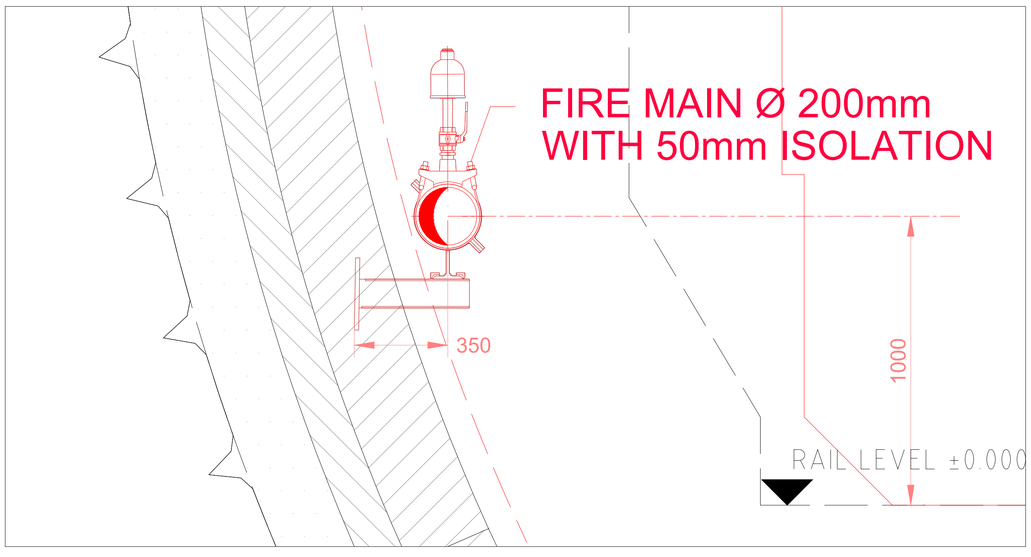
DRAWING NO : RITES/WR/RK/DADN-MKT/DR/P09/007











REFERENCE DRAWINGS:

RITES/WR/RK/DADN-MKT/DR/P09/001 (SHEET 1 TO 3)
RITES/WR/RK/DADN-MKT/DR/P09/002 TO 008
RITES/WR/RK/DADN-MKT/DR/P06/001 & 002

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	MAY 2023

(VAKIL SAIFI)	(RISHABH GUPTA)	(JYOTSNA DIXIT)	(AMIT KUMAR)	(LALIT KUMAR)
CAD OPER./RITES LTD.	AM/RITES LTD.	DGM/RITES LTD.	SDGM/RITES LTD.	GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

DADN - MKT SECTION
GENERAL ARRANGEMENT DRAWING
FIRE FIGHTING ARRANGEMENT WITH HYDRANT

CE / C

DY.CE / C

AXEN / C

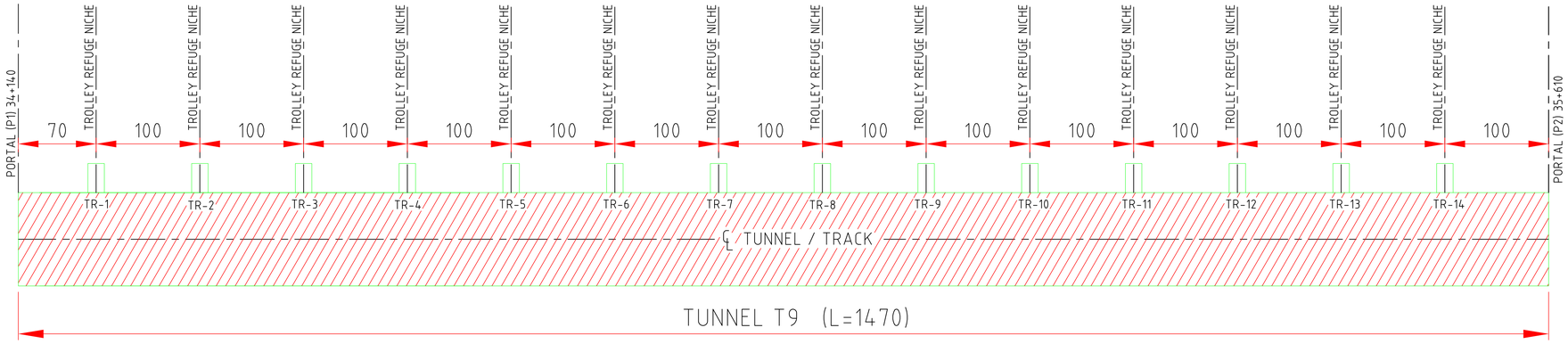
Consultant: RITES THE INFRASTRUCTURE PEOPLE

DATE	SCALE	SHEET NO.	REVISION
MAY 2023	N. T. S.	1 OF 1	A

DRAWING NO : RITES/WR/RK/DADN-MKT/DR/P09/009

← DADN

MKT →



TYPICA LAYOUT OF NICHES

N.T.S.

NOTES:

1. TROLLEY REFUGE NICHE REFER TO DRAWING NO. RITES/WR/RK/DADN-MKT/DR/P06/011
2. CHAINAGE OF NICHE LOCATION SHALL BE ADJUSTED TO THE ACTUAL LOCATION OF THE INNER LINING BLOCK ARRANGEMENT. THE AXIS OF THE NICHE SHALL BE PLACED IN THE CENTRE OF THE BLOCK.
3. IN CASE OF POOR GEOLOGY NICHES SHALL BE MOVED TO BETTER GEOLOGICAL CONDITIONS, DECISION SHALL BE MADE AT SITE BY THE ENGINEER.
4. THE INNER LINING OF NICHES SHALL CONSIST OF SHOTCRETE OR IN-SITU CONCRETE, DEPENDING ON THE APPLIED INNER LINING TYPE FOR THE MAIN TUNNEL AT THE LOCATION OF THE RESPECTIVE NICHE.

BORED TUNNEL

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	JUNE 2023

(P.K.HARIHARAN) MGR/RITES LTD.	(RISHABH GUPTA) AM/RITES LTD.	(JYOTSNA DIXIT) DGM/RITES LTD.	(AMIT KUMAR) SDGM/RITES LTD.	(LALIT KUMAR) GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

DADN - MKT SECTION
TYPICAL LAYOUT OF TROLLEY
REFUGE NICHES PLAN (T-9)

CE / C

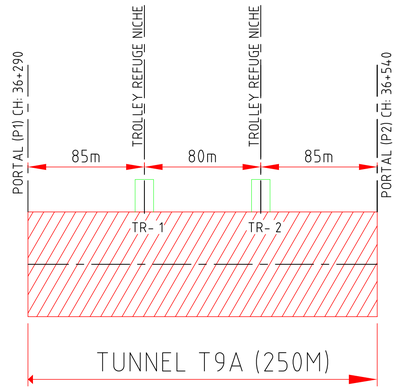
DY.CE / C

AXEN / C

Consultant	DATE	SCALE	SHEET NO.	REVISION
RITES THE INFRASTRUCTURE PEOPLE	JUNE 2023	N. T. S.	1 OF 1	A
DRAWING NO :	RITES/WR/RK/DADN-MKT/DR/T09/P01/011			

← DADN

MKT →



TYPICA LAYOUT OF NICHES

N.T.S.

NOTES:

1. TROLLEY REFUGE NICHE REFER TO DRAWING NO. RITES/WR/RK/DADN-MKT/DR/P06/011
2. CHAINAGE OF NICHE LOCATION SHALL BE ADJUSTED TO THE ACTUAL LOCATION OF THE INNER LINING BLOCK ARRANGEMENT. THE AXIS OF THE NICHE SHALL BE PLACED IN THE CENTRE OF THE BLOCK.
3. IN CASE OF POOR GEOLOGY NICHES SHALL BE MOVED TO BETTER GEOLOGICAL CONDITIONS, DECISION SHALL BE MADE AT SITE BY THE ENGINEER.
4. THE INNER LINING OF NICHES SHALL CONSIST OF SHOTCRETE OR IN-SITU CONCRETE, DEPENDING ON THE APPLIED INNER LINING TYPE FOR THE MAIN TUNNEL AT THE LOCATION OF THE RESPECTIVE NICHE.

BORED TUNNEL

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	JUNE 2023

(P.K.HARIHARAN) MGR/RITES LTD.	(RISHABH GUPTA) AM/RITES LTD.	(JYOTSNA DIXIT) DGM/RITES LTD.	(AMIT KUMAR) SDGM/RITES LTD.	(LALIT KUMAR) GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

DADN - MKT SECTION
TYPICAL LAYOUT OF TROLLEY
REFUGE NICHES PLAN (T-9A)

CE / C

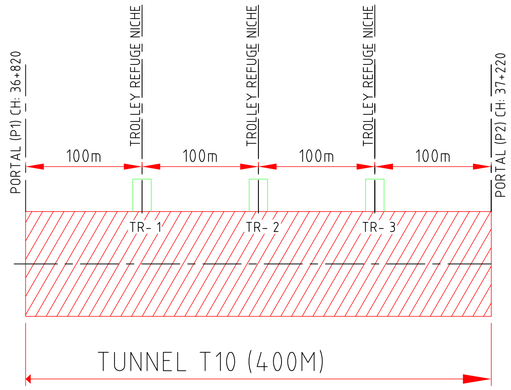
DY.CE / C

AXEN / C

Consultant	DATE	SCALE	SHEET NO.	REVISION
RITES THE INFRASTRUCTURE PEOPLE	JUNE 2023	N. T. S.	1 OF 1	A
DRAWING NO :	RITES/WR/RK/DADN-MKT/DR/T09A/P01/011			

← DADN

MKT →



TYPICA LAYOUT OF NICHES

N.T.S.

NOTES:

1. TROLLEY REFUGE NICHE REFER TO DRAWING NO. RITES/WR/RK/DADN-MKT/DR/P06/011
2. CHAINAGE OF NICHE LOCATION SHALL BE ADJUSTED TO THE ACTUAL LOCATION OF THE INNER LINING BLOCK ARRANGEMENT. THE AXIS OF THE NICHE SHALL BE PLACED IN THE CENTRE OF THE BLOCK.
3. IN CASE OF POOR GEOLOGY NICHES SHALL BE MOVED TO BETTER GEOLOGICAL CONDITIONS, DECISION SHALL BE MADE AT SITE BY THE ENGINEER.
4. THE INNER LINING OF NICHES SHALL CONSIST OF SHOTCRETE OR IN-SITU CONCRETE, DEPENDING ON THE APPLIED INNER LINING TYPE FOR THE MAIN TUNNEL AT THE LOCATION OF THE RESPECTIVE NICHE.

BORED TUNNEL

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	JUNE 2023

(P.K.HARIHARAN) MGR/RITES LTD.	(RISHABH GUPTA) AM/RITES LTD.	(JYOTSNA DIXIT) DGM/RITES LTD.	(AMIT KUMAR) SDGM/RITES LTD.	(LALIT KUMAR) GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

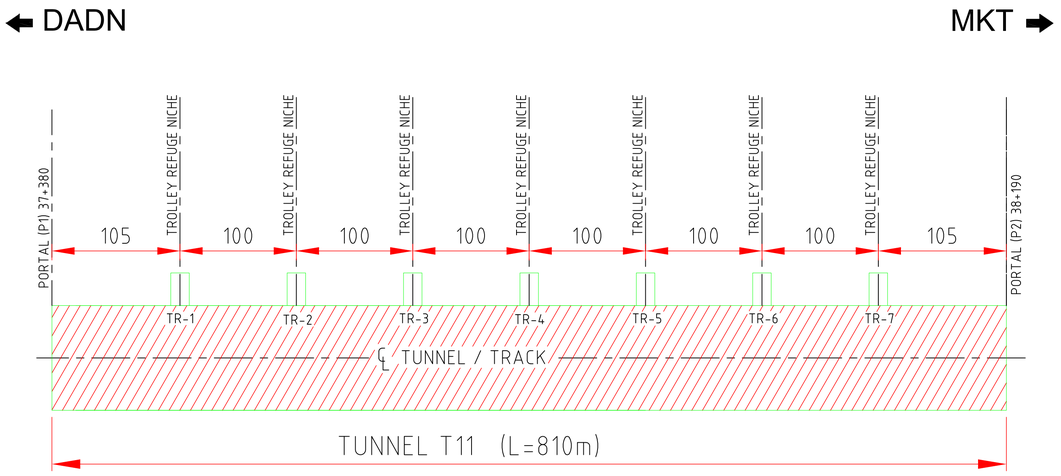
DADN - MKT SECTION
TYPICAL LAYOUT OF TROLLEY
REFUGE NICHES PLAN (T-10)

CE / C

DY.CE / C

AXEN / C

Consultant	DATE	SCALE	SHEET NO.	REVISION
RITES THE INFRASTRUCTURE PEOPLE	JUNE 2023	N. T. S.	1 OF 1	A
DRAWING NO :	RITES/WR/RK/DADN-MKT/DR/T10/P01/011			



LAYOUT OF NICHES

N.T.S.

NOTES:

1. TROLLEY REFUGE NICHE REFER TO DRAWING NO. RITES/WR/RK/DADN-MKT/DR/P06/011
2. CHAINAGE OF NICHE LOCATION SHALL BE ADJUSTED TO THE ACTUAL LOCATION OF THE INNER LINING BLOCK ARRANGEMENT. THE AXIS OF THE NICHE SHALL BE PLACED IN THE CENTRE OF THE BLOCK.
3. IN CASE OF POOR GEOLOGY NICHES SHALL BE MOVED TO BETTER GEOLOGICAL CONDITIONS, DECISION SHALL BE MADE AT SITE BY THE ENGINEER.
4. THE INNER LINING OF NICHES SHALL CONSIST OF SHOTCRETE OR IN-SITU CONCRETE, DEPENDING ON THE APPLIED INNER LINING TYPE FOR THE MAIN TUNNEL AT THE LOCATION OF THE RESPECTIVE NICHE.

BORED TUNNEL

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	JUNE 2023

(P.K.HARIHARAN) MGR/RITES LTD.	(RISHABH GUPTA) AM/RITES LTD.	(JYOTSNA DIXIT) DGM/RITES LTD.	(AMIT KUMAR) SDGM/RITES LTD.	(LALIT KUMAR) GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

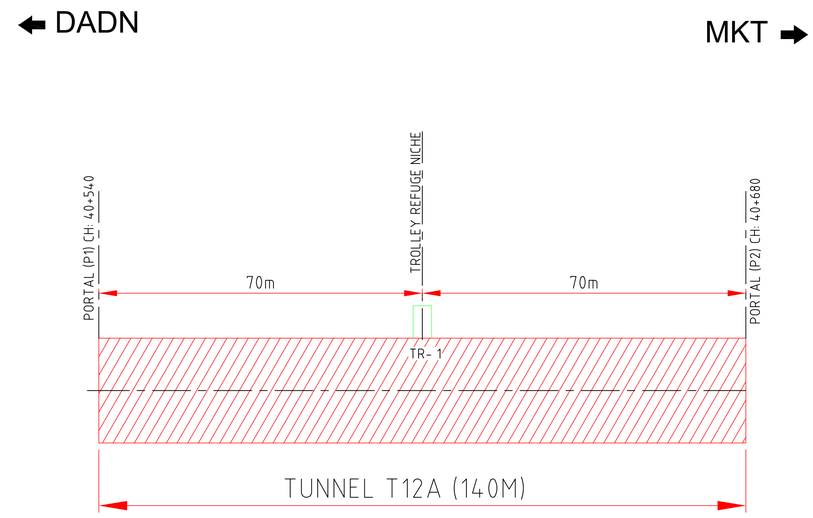
DADN - MKT SECTION
TYPICAL LAYOUT OF TROLLEY
REFUGE NICHES PLAN (T-11)

CE / C

DY.CE / C

AXEN / C

Consultant	DATE	SCALE	SHEET NO.	REVISION
RITES THE INFRASTRUCTURE PEOPLE	JUNE 2023	N. T. S.	1 OF 1	A
DRAWING NO :	RITES/WR/RK/DADN-MKT/DR/T11/P01/011			



TYPICA LAYOUT OF NICHES

N.T.S.

NOTES:

1. TROLLEY REFUGE NICHE REFER TO DRAWING NO. RITES/WR/RK/DADN-MKT/DR/P06/011
2. CHAINAGE OF NICHE LOCATION SHALL BE ADJUSTED TO THE ACTUAL LOCATION OF THE INNER LINING BLOCK ARRANGEMENT. THE AXIS OF THE NICHE SHALL BE PLACED IN THE CENTRE OF THE BLOCK.
3. IN CASE OF POOR GEOLOGY NICHES SHALL BE MOVED TO BETTER GEOLOGICAL CONDITIONS, DECISION SHALL BE MADE AT SITE BY THE ENGINEER.
4. THE INNER LINING OF NICHES SHALL CONSIST OF SHOTCRETE OR IN-SITU CONCRETE, DEPENDING ON THE APPLIED INNER LINING TYPE FOR THE MAIN TUNNEL AT THE LOCATION OF THE RESPECTIVE NICHE.

BORED TUNNEL

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	JUNE 2023

(P.K.HARIHARAN) MGR/RITES LTD.	(RISHABH GUPTA) AM/RITES LTD.	(JYOTSNA DIXIT) DGM/RITES LTD.	(AMIT KUMAR) SDGM/RITES LTD.	(LALIT KUMAR) GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

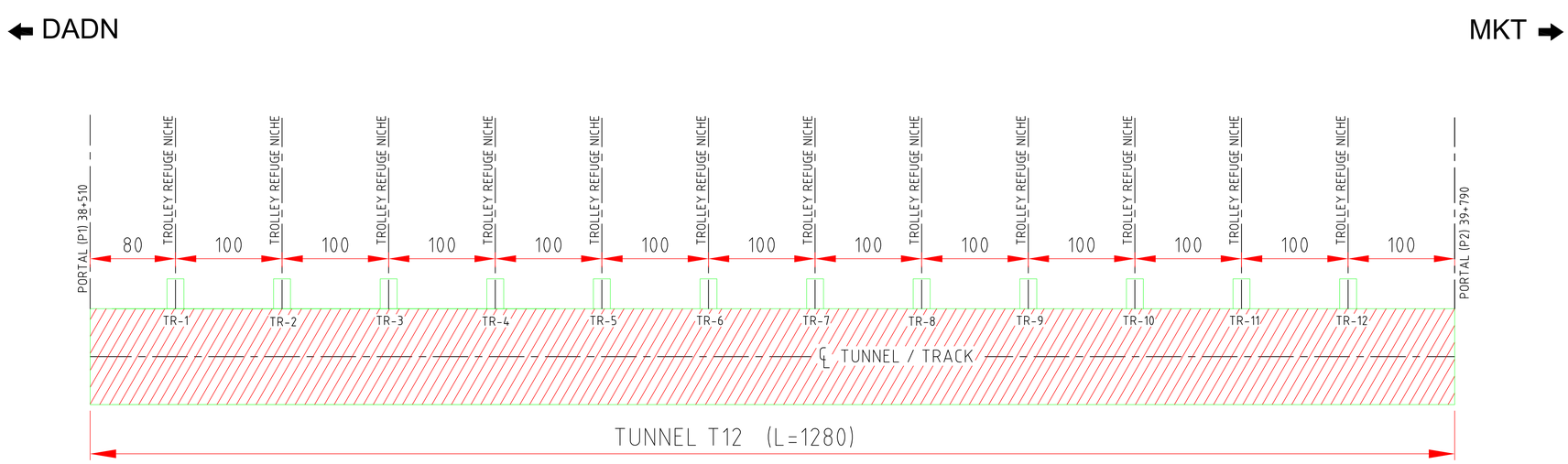
DADN - MKT SECTION
TYPICAL LAYOUT OF TROLLEY
REFUGE NICHES PLAN (T-12A)

CE / C

DY.CE / C

AXEN / C

Consultant	DATE	SCALE	SHEET NO.	REVISION
RITES THE INFRASTRUCTURE PEOPLE	JUNE 2023	N. T. S.	1 OF 1	A
DRAWING NO :	RITES/WR/RK/DADN-MKT/DR/T12A/P01/011			



TYPICA LAYOUT OF NICHES

N.T.S.

NOTES:

1. TROLLEY REFUGE NICHE REFER TO DRAWING NO. RITES/WR/RK/DADN-MKT/DR/P06/011
2. CHAINAGE OF NICHE LOCATION SHALL BE ADJUSTED TO THE ACTUAL LOCATION OF THE INNER LINING BLOCK ARRANGEMENT. THE AXIS OF THE NICHE SHALL BE PLACED IN THE CENTRE OF THE BLOCK.
3. IN CASE OF POOR GEOLOGY NICHES SHALL BE MOVED TO BETTER GEOLOGICAL CONDITIONS, DECISION SHALL BE MADE AT SITE BY THE ENGINEER.
4. THE INNER LINING OF NICHES SHALL CONSIST OF SHOTCRETE OR IN-SITU CONCRETE, DEPENDING ON THE APPLIED INNER LINING TYPE FOR THE MAIN TUNNEL AT THE LOCATION OF THE RESPECTIVE NICHE.

BORED TUNNEL

REVISION	DESCRIPTION	DATE
A	FIRST SUBMISSION	JUNE 2023

(P.K.HARIHARAN) MGR/RITES LTD.	(RISHABH GUPTA) AM/RITES LTD.	(JYOTSNA DIXIT) DGM/RITES LTD.	(AMIT KUMAR) SDGM/RITES LTD.	(LALIT KUMAR) GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

DADN - MKT SECTION
TYPICAL LAYOUT OF TROLLEY
REFUGE NICHES PLAN (T-12)

CE / C

DY.CE / C

AXEN / C

Consultant	DATE	SCALE	SHEET NO.	REVISION
RITES THE INFRASTRUCTURE PEOPLE	JUNE 2023	N. T. S.	1 OF 1	A
DRAWING NO :	RITES/WR/RK/DADN-MKT/DR/T12/P01/011			

NOTES:

1. SUPPORT CLASS LENGTH AND RCC/PCC LININGS TO BE DECIDED BY CONTRACTOR DURING CONSTRUCTION BASED ON GEOLOGY ENCOUNTERED AND RELATED DESIGN DURING CONSTRUCTION.

* LENGTH OF SC-V AT PORTAL LOCATIONS CAN BE VARIED AS PER GEOLOGY ENCOUNTERED DURING CONSTRUCTION AND CORRESPONDINGLY ADJACENT SUPPORT CLASS SHALL BE ADJUSTED ACCORDINGLY.

* SUPPORT CLASS VI HAS BEEN CONSIDERED IN QUANTITY ESTIMATION CONSIDERING UNFORESEEN GEOLOGICAL CONDITION DURING EXCAVATION .

TUNNEL T9

START OF TUNNEL PORTAL P-1 — END OF TUNNEL PORTAL P-2

	70.0	400.0	530.0	400.0	70.0
ROCK CLASS	RC - V	RC - IV	RC - III	RC - IV	RC - V
ANTICIPATED DISTRIBUTION OF SUPPORT CLASS	SC - V	SC - IV	SC - III	SC - IV	SC - V
INNER LINING TYPE	RCC	RCC	RCC	RCC	RCC
ANTICIPATED ROCK TYPES		Basalt	Basalt	Basalt	
	1470.0				

← TO KULTHANA — TO RAJPURA →

TUNNEL T9A

START OF TUNNEL PORTAL P-1 — END OF TUNNEL PORTAL P-2

	70.0	110.0	70.0
ROCK CLASS	RC - V	RC - IV	RC - V
ANTICIPATED DISTRIBUTION OF SUPPORT CLASS	SC - V	SC - IV	SC - V
INNER LINING TYPE	RCC	RCC	RCC
ANTICIPATED ROCK TYPES		Basalt	
	250.0		

← TO KULTHANA — TO RAJPURA →

TUNNEL T10

START OF TUNNEL PORTAL P-1 — END OF TUNNEL PORTAL P-2

	70.0	260.0	70.0
ROCK CLASS	RC - V	RC - IV	RC - V
ANTICIPATED DISTRIBUTION OF SUPPORT CLASS	SC - V	SC - IV	SC - V
INNER LINING TYPE	RCC	RCC	RCC
ANTICIPATED ROCK TYPES		Basalt	
	400.0		

← TO KULTHANA — TO RAJPURA →

TUNNEL T11

START OF TUNNEL PORTAL P-1 — END OF TUNNEL PORTAL P-2

	70.0	200.0	270.0	200.0	70.0
ROCK CLASS	RC - V	RC - IV	RC - III	RC - IV	RC - V
ANTICIPATED DISTRIBUTION OF SUPPORT CLASS	SC - V	SC - IV	SC - III	SC - IV	SC - V
INNER LINING TYPE	RCC	RCC	RCC	RCC	RCC
ANTICIPATED ROCK TYPES		Basalt		Basalt	
	810				

← TO KULTHANA — TO RAJPURA →

TUNNEL T12A

START OF TUNNEL PORTAL P-1 — END OF TUNNEL PORTAL P-2

	140.0
ROCK CLASS	RC - V
ANTICIPATED DISTRIBUTION OF SUPPORT CLASS	SC - V
INNER LINING TYPE	RCC
ANTICIPATED ROCK TYPES	Basalt
	140.0

← TO KULTHANA — TO RAJPURA →

TUNNEL T12

START OF TUNNEL PORTAL P-1 — END OF TUNNEL PORTAL P-2

	70.0	400.0	340.0	400.0	70.0
ROCK CLASS	RC - V	RC - IV	RC - III	RC - IV	RC - V
ANTICIPATED DISTRIBUTION OF SUPPORT CLASS	SC - V	SC - IV	SC - III	SC - IV	SC - V
INNER LINING TYPE	RCC	RCC	RCC	RCC	RCC
ANTICIPATED ROCK TYPES		Basalt	Basalt	Basalt	
	1280.0				

← TO KULTHANA — TO RAJPURA →

(P.K.HARIHARAN) MGR/RITES LTD.	(RISHABH GUPTA) JM/RITES LTD.	(JYOTSNA DIXIT) Sr.DGM/RITES LTD.	(AMIT KUMAR) JGM/RITES LTD.	(R.S. DHULL) AGM/RITES LTD.	(LALIT KUMAR) GM/RITES LTD.

WESTERN - RAILWAY

RATLAM DIVISION
CONNECTION WITH GAUGE CONVERSION
RTM - KNW PROJECT

DPR OF TUNNELS BETWEEN
DADN - MKT SECTION

DADN - MKT SECTION
TUNNEL SUPPORT SYSTEM
PRIMARY AND SECONDARY SUPPORT

CE / C

DY.CE / C

AXEN / C

Consultant: RITES THE INFRASTRUCTURE PEOPLE

DATE	SCALE	SHEET NO.	REVISION
MAY 2023	1:100	1 OF 2	A

DRAWING NO : RITES/WR/RK/DADN-MKT/DR/P02/002