The DFCCIL JOURNAL

ISSUE VI, MARCH 2020

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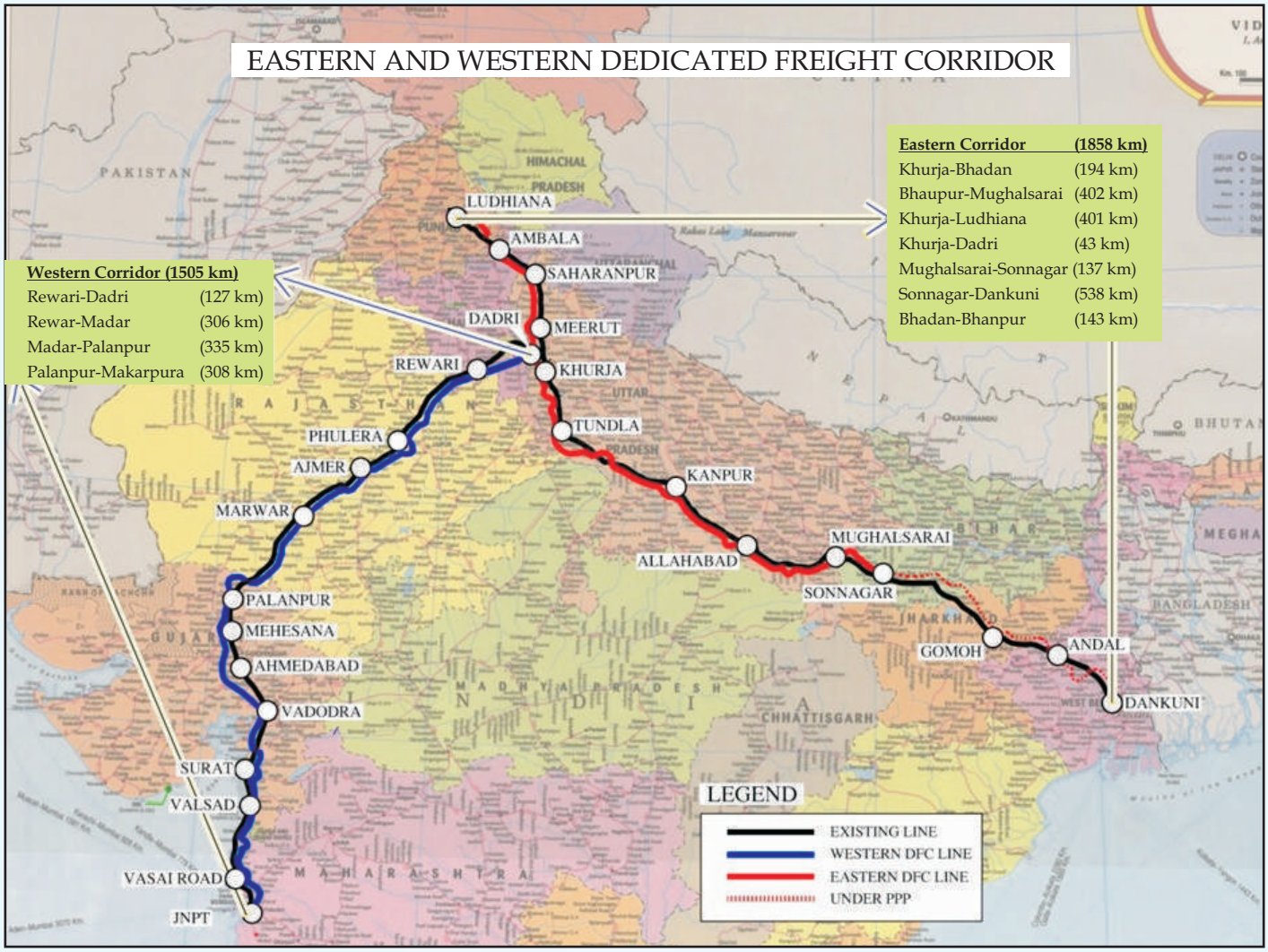

Targets

Western Corridor

SN	Sections	Targets
1	Dadri – Rewari (127 Km)	March-2021
2	Rewari – Madar (306 Km)	Commercial Trial Run started from 27.12.2019.
3	Madar – Palanpur (335 Km)	March-2020
4	Palanpur – Makarpura (308 Km)	September-2021
5	Makarpura – JNPT (430 Km)	December-2021

Eastern Corridor

SN	Sections	Targets
1	Ludhiana -Khurja (401 Km)	December-2021
2	Khurja – Bhadan (194 Km)	Commercial Trial Run started from 02.10.2019.
3	Khurja – Dadri (43 Km)	December-2020
4	Bhadan – Bhaupur (143 Km)	March-2020
5	Bhaupur – Mughalsarai (402 Km)	December-2020
6	Mughalsarai – Sonnagar (137 Km)	December-2020
7	Sonnagar – Dankuni (538 Km)	Proposed to be done through PPP

FROM THE EDITOR's DESK

Anurag Kumar Sachan
Managing Director, DFCCIL

Dear Readers,

I hope that you and your loved ones are healthy and safe. Our country has been in lockdown since March 25, 2020. During this time, keeping one of India's most ambitious infrastructure projects going is a huge responsibility on each of us. I would like to recognise and place on record, the efforts and commitments that each of you are exhibiting during this time.

After a grand success and overwhelming response to our earlier publication, I welcome the readers to this edition of The DFCCIL Journal – March 2020 – Issue-VI. In this Issue, we bring to our readers well researched & suitably illustrated (with quality Pictures & Diagrams) articles from a wide ranging subjects such as Heavy Haul Superstructure Improvements at Hot Spots with Under Sleeper Pads, Slope Erosion Control and Protection System adopted in Eastern DFCCIL Project for Railway Formation, Tunnel Construction through Arawali Hills, Rehabilitation and Resettlement of PAPs in Dahanu Taluka of Palghar District in Maharashtra, Case studies for preventing serious injuries and fatalities to enhance safety in railway projects etc. I, sincerely, hope that you would find this issue containing scholarly & insightful articles on a wide range of contemporary technical topics , satisfyingly informative.

The 14th Foundation day of Dedicated Freight Corridor Corporation of India (DFCCIL) was celebrated in New Delhi on 18 January 2020. Union Minister of Railways and Commerce & Industry Shri Piyush Goyal participated in the event and It was expressed that DFC has an impact to transform the railway sector. It is necessary to have separate tracks for freight and for passengers to ensure faster movement of both. Indian Railways has directed DFCCIL to run freight trains in convoys for maximum utilization of the path and increasing the average speed of freight trains. Dedicated Freight Corridors plays a vital role in a paradigm change in Indian Railways and asserted that DFCCIL will play a significant role in shaping the Indian economy.

DFCCIL also celebrated Sports Meet with over 330 participants drawn from Field Units and Corporate office on 14 th and 15 th February 2020. held at Karnail Singh Stadium, New Delhi. Staff of DFCCIL have participated enthusiastically in various Games such as Basketball, Badminton, Volleyball, Cricket, Chess, Carrom, Table tennis and Athletics etc.

While nature has its ways to challenge us, how we take up the challenge and find opportunities tomove forward is what defines us as individuals and eventually as an organization. In DFCCIL, the challenge of operating face to face is now being handled using audio and video conferencing on a daily basis. Every morning, our team members connect over a video conference to proactively brainstorm issues which can help the project pick up where we left off right after the lockdown period is over. In essence, the lockdown does not completely disrupt our effort.

I acknowledge, with sincere gratitude & appreciation, the warm response given to the contents of The DFCCIL Journal – March 2020 – Issue-VI, by perceptive readers.

During this tough period of lockdown due to the Pandemic of Corona, I hope that as responsible citizens stay home, stay safe and most importantly stay healthy and do not hesitate to offer a helping hand to needy once and at home as well.

Enjoy reading.

Anurag Kumar Sachan
Managing Director, DFCCIL

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Over Indian Railway Line
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Enthusiastic DFCCIL Team
Getting Ready for the Work

Back cover picture

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Atul B. Khare, CGM/Tundla/DFCCIL

Slope Erosion Control and Protection System adopted in Eastern DFCCIL Project for Railway Formation

ABSTRACT

Ministry of Railways has planned to construct Dedicated Freight Corridor covering about 3325 Route Kms on two corridors viz Eastern Corridor (EDFC) from Ludhiana (Sahnewal) to Sonenagar/Dankuni and Western Corridor (WDFC) from Jawaharlal Nehru Port, Mumbai to Tughlakabad near Delhi; with junction at Dadri. As a part of it, various civil and system works in 353 Km stretch between Bhaupur to Khurja section of EDFC, has been carried out for a double line corridor of freight trains with speed potential of 100 Kmph. Its formation has been designed for trailing load of 32.5 tonnes and an axle load of 25 tonnes. Construction of formation in this stretch involved about 75 KM of High Embankments up to 13 M height in order to provide under passes to the existing roads in detours stretches. Controlling soil erosion leading to challenges to embankment slope has remained a critical factor while designing and constructing the formation in this project. An attempt has been made to describe various methods adopted in the project for soil erosion

1. Soil Erosion

Soil erosion is the process of detachment of soil particles by erosive agents such as wind, water and gravity. Resultant loss of soil due to erosion from Railway formation has remained a matter of serious concern as the slopestability of embankments supporting permanent ways is governed by the degree of damage suffered by them due to erosion. Unchecked erosion may result in cuts, rills or gullies resulting in to slide problems.

There have been many instances where many embankments slopes, irrespective of type of soil used for their construction, have suffered a high degree of damage due to erosion from rain and runoff. Denudation of vegetation from soil slopes or the lack of vegetative cover on embankment slopes is often responsible for formation of rills and rain-cuts, eventually leading to a surficial slide or to an undermining of the edges of the Railway structure.

The embankment slope composed of silt and sand may pose the problem of the surficial erosion. The embankment slope may fail or erode or may move downward due to the following reasons.

- Heavy precipitation during the rainy season

- Improper Drainage network and steep gradient.
- Unprotected slopes without soil cover

It is, therefore, essential to take adequate measures for controlling it as well designed and constructed erosion protection measures are important factors in sustainability of any Railways system.

2. Indian Railway's Standards

Indian Railway's (RDSO) guidelines throws light on the mechanism of erosion, available erosion control systems, selection of appropriate erosion control systems, material requirement, field execution and maintenance practices. Selection of a particular erosion control system depends on specific site condition out of which; type of soil used, formation height, rainfall, velocity of water are the important considerations, however no standard yardstick can be laid down to choose a particular type of protective system.

Following suggestions have been considered while deciding the protection system.

Formation type	Height of bank/cutting	Rainfall/Velocity of water	Erosion Control system
Bank/cutting made by cohesive soil /fine grain soil (CL, CI, CH, ML, MI, MH)	Less than 6 m	Normal or less than normal (3 m/sec or less)	Vegetation shallow rooted or deep rooted
Bank/cutting made by cohesion less soil (sandy / gravely soil)	Less than 6 m	Normal or less than normal (3 m/sec or less)	Vegetation with 0.25 m to 0.30 m thick clayey soil as a cover for vegetation
Bank/cuttingmadeby By Black Cotton Soil	Less than 6 m	Normal or less than normal (3m/sec or less)	Vegetation with 0.25 m to 0.30 m thick clayey soil as a cover for vegetation
Bank/cutting (all type of soils)	More than 6 m	Normal/heavy (3 m/sec or more)	Reinforced vegetation or reinforced protection
Bank/cutting made by any type of soil and submerged /effect of wave uplift/continuous flooding	Any height	Normal/heavy (3 m/sec or more)	Boulder pitching with or without geo textiles, geo-cell up to flooded height

3. Methodology Adopted

Based on above, the formation has been divided in four type based on bank height, such as

- up to 4.5 m,
- 4.5 to 6m,
- 6 m to 10 m and
- Above 10m.

The erosion control and protection system have been identified based on height and previous experiences of specialised technology partners, which have been detailed in subsequent paragraphs.

4. Turfing with Sods up to 4.5 M Height of Formation

4.1 Material

The sod used consisted of dense, well-rooted growth of permanent turf forming grass, indigenous to the locality and practically free from weeds or other undesirable matter. At the time the sod cutting, the grass on the sod required was approximately 50 mm

and the sod used was free of debris. It is required that sod used should be as uniform as possible or so of soil covering the grass roots. The sods should be cut in rectangular strips of uniform width, not less than about 250mm x 300mm in size but not so large that it is inconvenient to handle and transport without damage. The sods should be delivered in healthy condition and be free from weed and disease.

4.2. Preparation of Earth bed

- Turfing should be done on the dressed slope as per the required slope and cross sections.
- The required slope of 1 vertical to 2 horizontal should be marked with the help of Auto Level as per approved plan and profile.
- The cutting of slope should be done with the help of excavator or grader as per applicability.
- The surface should be made free of all stones larger than 50 mm, and any other undesirable objects or materials.
- The surface of the top soil should be scarified/ loosened in a direction parallel to the alignment to a depth of about 50mm.
- Immediately prior to implanting sods, the soil should be uniformly moist to a depth of 150 mm.
- The final prepared surface should be made slightly rough to ensure a good penetration of roots into the soil.

4.3. Placing of Sods

- Sods should be delivered from a nursery, should not be allowed to dry out during the transportation period and the sods shall be planted within 24 hours of being removed from the soil.
- Sods should be laid in regular rows with staggered joints and with individual pieces closely butting against each other without any openly visible gaps or any overlaps between pieces.
- The first row of sods, where it is possible, should be laid in a straight line and starting at the bottom of the slope. Any gaps should be planted with a sod cut to the gap size or, filled with top soil.
- Sods should be suitably tamped manually to ensure a good bond with the underlying soil.
- After completion of planting, the surface should be cleaned off all excess soil, sods and any other undesirable objects or materials.
- The sods should be well-watered after planting and not be allowed to deteriorate due to lack of moisture for at least four weeks.




Fig. 1, 2, 3, 4: Different stages of sodding

5. Coir Mat with Seeds for Formation Height 4.5 m to 6m

- The slope over which GECB is proposed to be laid should be graded evenly free of depressions or projections, before installation of Geogreen blanket.
- A layer of fertile soil measuring 75-100 mm deep should be evenly spread, above the surface of the slope if the embankment soil is non-fertile. Cow dung manure mixed with organic soil conditioner is spread evenly over the prepared slope, subject to availability at site to improve the organic fertility of the soil.
- Secure the crest and toe of the blanket by burying in a trench of 300 mm deep and a 300 mm wide. Additional anchorage was achieved by installing a row of anchoring hook along the crest and toe.
- Unroll blanket down the slope in the direction of the water flow through the upper trench. The blanket should not be stretched and it should have firm contact with the soil. End of the blanket should be inserted in the toe trench before back filling of soil.
- Anchor blanket with U-hook, at least one U-hook per sq m especially on the overlapped area. Overlap the end with previous one by 75-100 mm firmly before starting a new roll. Anchor hooks on overlapped mat.
- Backfill the trench, compact the area backfilled thoroughly.
- Vegetation was developed with the help of broadcasting of selected mixed grass seeds as recommended by manufacturer as per geo-climatic and soil condition at site, these seeds should be of renewable/recyclable vegetation to provide sustainable slope stabilization.
- Seed broadcasting should be carried out in instalments and a fine layer of soil was covered before irrigation of site as per manufacturer guideline.
- Irrigated the treated slope to promote the growth of mixed grass vegetation for 3 months or till first flowering, as the treatment took place during summer/winter.
- Water supply for 100 days is mandatory to develop sustainable vegetation
- The treated site requires uninterrupted regular watering and maintenance till first flowering in absence of rain fall.
- Protect the treated slope from grazing and ensure safety and security of the site till vegetation sustains on its own.

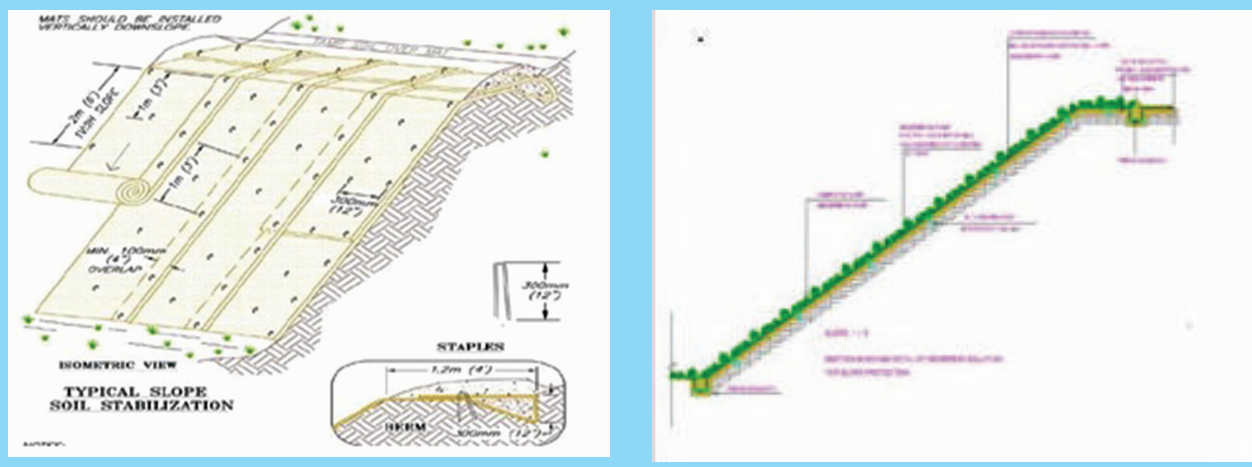

Fig. 5: Coir Mat (Schematic)

Fig. 6: Bed Preparation for Coir Mat

Fig. 7, 8, 9: Coir Mat Placement

Fig. 10 & 11: Grown up vegetation on Coir Mat

6. Coir Mat with Vetiver Grass for Formation Height 6 m to 8/10m:

- On well prepared level slope, the coconut coir net (CCM) was spread throughout the embankment slope and the same net was tightened and anchored by means of nailing in staggered manner so that it does not sleep out from it position/slopping ground.
- The coir to start at 30cm above the top of slope, fix the top of each CCM coir one staple per linear foot. Then the Vetiver root divisions, or slips, should be planted in a double or triple line to form parallel hedges across the erosion prone slope.
- Distance between consecutive hedge rows was kept 300mm.
- The slips should be planted at the beginning of the rainy season to ensure that they get full benefit of the soil moisture.
- Planting operations of Vetiver slips is similar to planting of rice seedlings.
- Regular watering was done for initial survival for a period of at least 6 months.

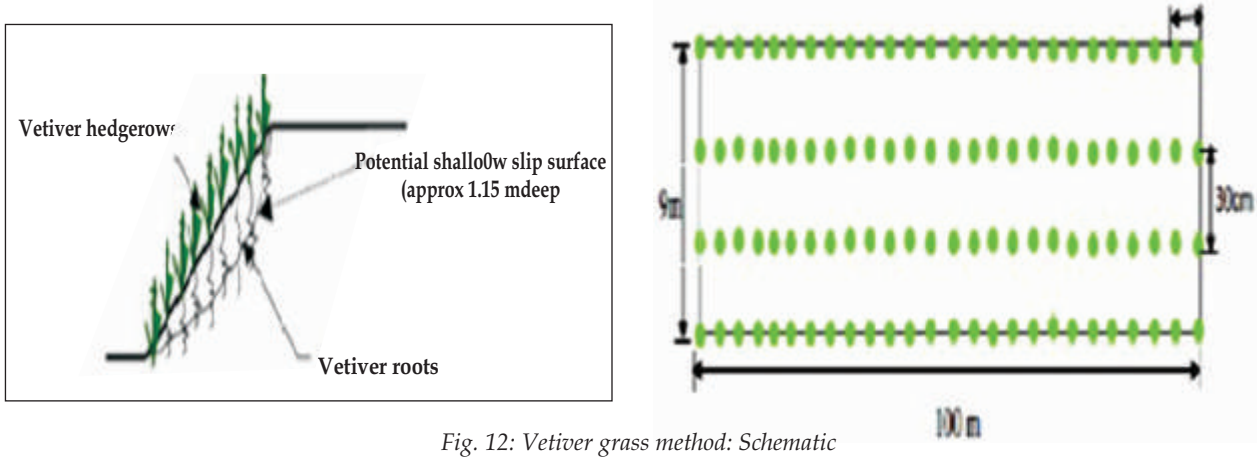

Fig. 12: Vetiver grass method: Schematic

Fig. 13 & 14: Plantation of Vetiver grass

7. Hydro-seeding for Formation Height 6/8 m to 10 m:

7.1. Hydro-seeding

Hydraulically applied, 100% biodegradable, High Performance Flexible Growth Medium (HPFGM) that is composed of 100% recycled thermally refined (within a pressure vessel) wood fibres, crimped interlocking man-made biodegradable fibres, added with mineral activators, naturally derived cross-linked biopolymers and water absorbents material was used in this method. Also, variety of grasses consisting of a mix of quick cover (for short term surface protection), and perennial grasses (for long term erosion control) or other kind of seed verities to suite with local environment has been utilised with amelioration and application of nutrients to accelerate growth of vegetation.

The HPFGM is phytosanitized, free from plastic netting, requires nocuring period and upon application it form sanintimate bond with the soil surface to create a continuous, porous, absorbent and flexible erosion resistant blanket that allows for rapid germination and accelerated plant growth.

7.2. Installation sequence

These quence followed for the construction of the Slope Stabilization System by this method is listed as below.

- Preparation of slope surface.
- Establishment and marking of location.
- Dressing of slope surface for application:
- Mixing
- Application of HECPs

7.3. Mixing and Application

Before treating the slope surface with Macflex, the slope should be neatly dressed and kept free from inorganic / toxic materials. The slope surface shall be free from any shrubs/bushes or any other vegetation (more than 10 cm in height).

MIXING: The mixing of MacFlex + Soil amendments shall be carried out as follows:

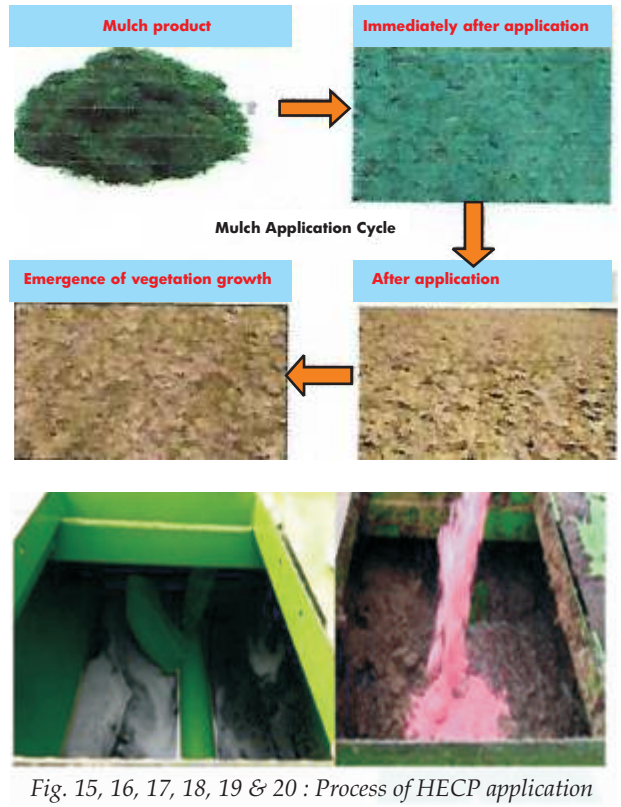

Fig. 15, 16, 17, 18, 19 & 20 : Process of HECP application

A hydro-seeding machine with mechanical agitator (Hydromulcher) is required.

- Fill 1/3 of mechanically agitated hydro Mulcher with water. Turn pump on for 15 seconds and purge and pre-wet lines. Turn pump off.
- Turn agitator on and load low density materials first (i.e. seed).
- Continue slowly filling tank with water while loading HECP and soil amendments into tank.
- Consult application and loading charts to determine number of bags to be added for desired area and application rate.
- All HECP material should be completely loaded before water level reaches 75% of the top of tank.
- Top off with water and mix until all fibre is fully broken apart and hydrated (minimum of 10 minutes — increase mixing time when applying in cold conditions). This is very important to fully activate the bonding additives and to obtain proper viscosity.

- Add fertilizer and any other remaining amendments.
- Shut off recirculation valve to minimize potential for air entrainment within the slurry.
- Slow down agitator and start applying through Hydromulcher fitted with nozzle.
- The Spraying should be done in opposite directions for maximum soil coverage.
- When the tank becomes empty the mixing and application for remaining area should be done the same way as explained above. At the end of the day the tank should be cleaned and kept ready for next day's work.

MULCHING Image

After Application

Emergency of vegetation growth

Fig. 21 &22 : Application of Mulch on surface

Fig. 23 &24 : Application of Mulch

7.4. Maintenance of Treated Surface:

- Once the Mulch has cured, water shall be applied at 12-25 mm on daily basis or as require throughout the applied areas. This is to prevent the seed drying out and dying.
- Rainfall will negate this need to additional watering.
- If wind-blown weed seed successfully germinates on the site then, the physical removal of weed species is necessary.

7.5. Assessment of Surface Stability:

The assessment of surface stability will be done in 6 months after installation which will include using soil samples, and visual assessment of all vegetative species. This will be compared to the analogue / native eco-system. Soil coverage will consist of vegetative, rock, leaf litter and debris.

7.6. Inspection and Monitoring:

- Hydro-mulched slopes will be inspected periodically for damage due to wind, water, or human disturbance. Inspecting should be carried out during seed establishment period.
- Re-seeding will be done adequately, in the areas identified with mortality.
- All damaged areas will be repaired immediately using hydro-mulching at the original specifications or straw mulch.
- Supplementary watering will be facilitated wherever required.
- Additional inspections will be scheduled during storm events / heavy rainfall
- Check for scour and sloughing will be carried out and if required, suitable repairs will be made.

8. Hydro-seeding with Jute Mat for Formation Height above 10 m:

The method used is similar to that used in Para 7 above except that in this case additional surface of Jute mat is used to provide additional stability to slope.

8.1. Jute Mat

Jute mat, an open weave biodegradable erosion control mat for erosion protection on the slope is used. It is an erosion control blanket manufactured from 100% jute fibre. The Jute Mat acts as a series of miniature check dams, thus, absorbing the force of impact and dissipating the kinetic energy of surface runoff, and thereby reducing its erosion potential. Jute Mat absorbs water up to four times its dry weight and transfers it to soil, thereby, giving full benefit of moisture for growth of vegetation. Its advantages are

- Provides immediate erosion control and high moisture containment to establish vegetation.
- Creates hospitable conditions for plant invasion and establishment.
- It also helps to strengthen the slope.
- Low installation costs
- Easy installation

Fig. 25: Typical Jute Mate

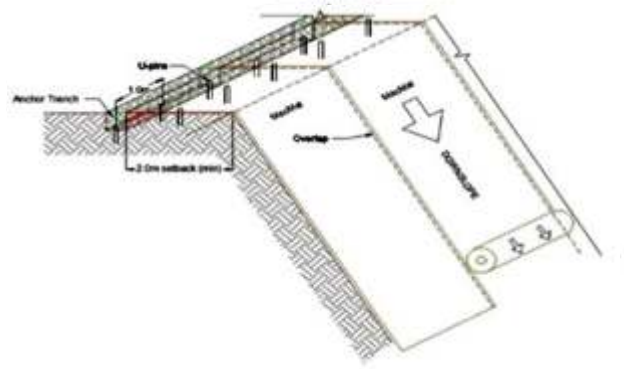

Fig. 26: Jute Mate Placement: Schematic

8.2. Installation

- Following steps used for installation of Jutem at:
- Slope should be Compacted and roughened horizontally.
- The dressed Slope should be pre-watered ensuring the minimum 3 mm of thickness of Damp water.
- HECPs were applied over the slope surface to dry over the slope surface and then installation of mat was done.
- At the crest of slope, excavate an anchor trench. Place the Jutemat roll in the trench (as possible). Secure Jutemat using wooden pegs / MS U- pins at a desired interval, wherever necessary.
- Unroll Jutem at from the top of the slope to bottom, ensuring it is placed loosely and in full contact with the in-situ stratum.
- The Mat should be in close contact with the mulch as well as soil.
- Adjacent panels of Jutemat should be overlapped if required.

Carry out the hydro-seeding as para 7.3 and 7.4 above and monitoring is required as per Para 7.6.

9. Observations:

Performance of all above measures undertaken for slope erosion control was observed during heavy monsoon and it is noted that 99% of erosion control and protection of slopes have been effective. These methods have not only reduced the cost of soil erosion control but have also contributed towards environmental protection and prevented damage due to avoidance of non-sustainable construction materials.

References

1. Guide Lines on Erosion Control and Drainage of Railway Formation, Guide Line No GE-04, February-2005, Geo-technical Engineering Directorate, Research Designs& StandardsOrganisation, Lucknow.
2. Guidelines for Application of Jute Geo-Textile in Railway Embankments and Hill Slopes No. RDSO/2007/GE:G-0008, February 200, Geo-technical EngineeringDirectorate, Research Designs & Standards Organisation, Lucknow.
3. Methodology provided by different applicators and technology partners.

Tunnel Construction in CTP-14 through Arawali Hills (NATM)

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ABSTRACT

There are several methods of Tunnel construction depending upon the Geological conditions ,presence of Ground water, Rock mass quality/Earth properties, size of Tunnel etc, The New Austrian tunnelling method (NATM), also known as the sequential excavation method (SEM) or sprayed concrete lining method , is a method of modern tunnel design and construction, NATM integrates the principles of the behaviour of rock masses under load and monitoring the performance of underground construction during construction. The NATM has often been referred to as a "design as you go" approach, by providing an optimized support based on observed ground conditions. More correctly it can be described as a "design as you monitor" approach. NATM optimized the engineering properties of underground Strata to be encountered; hence it is the most economical Tunnel construction method. The same method is being used in Tunnel construction in CTP-14 Project in the unit of CGM/Noida and the sequential construction method along with safety suggestionsare briefly discussed in this Write up.

Topography encountered

CTP-14 alignment in the unit of CGM/Noida is passing through 03 States U.P, Haryana & Rajasthan covering seven Districts in Delhi NCR (Rewari,Alwar,Mewat,Gurgaon, Palwal, Faridabad, G.B Nagar). This alignment is routed through geographically difficult terrain of Mewat& Gurgaon District of NCR through Environmentally protected Arawali hills/Reserve Forest area in a length of around 4.3 kms.

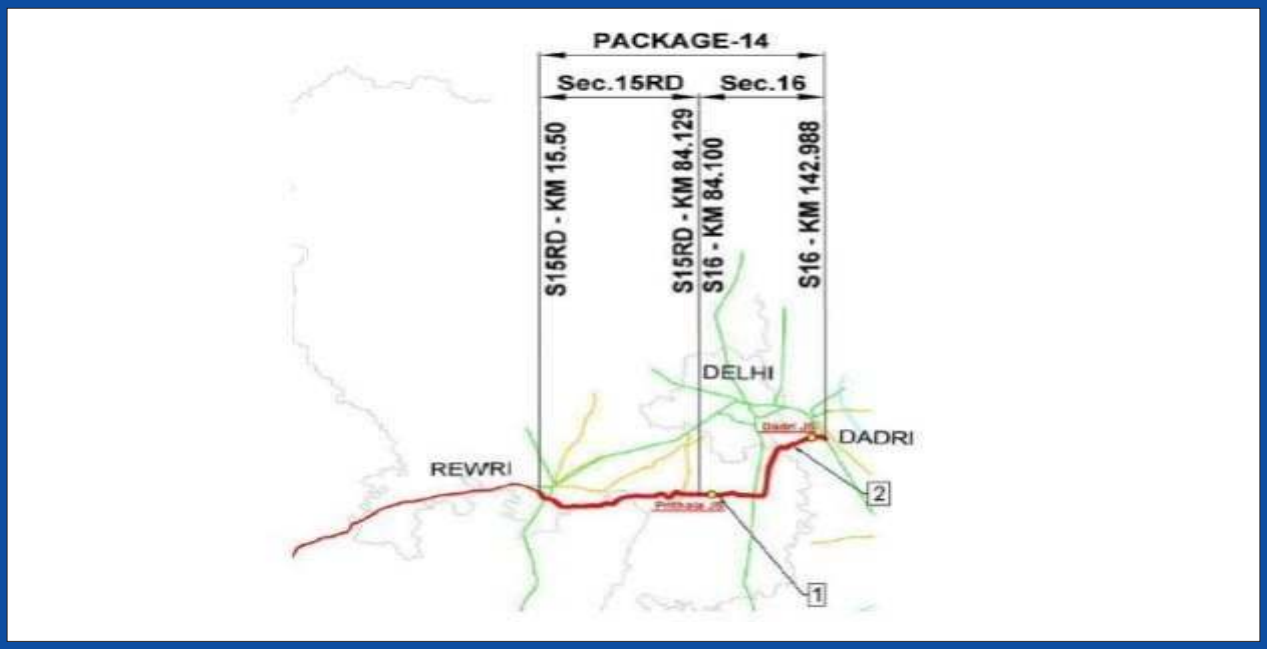

Fig-1 CTP-14 Km 15.5 to Km 142.988 (section15RD-16)

Necessity of making Tunnel

There isvertical elevation difference of 70-100 mtr existed in Natural Ground Levels in a length of 4.3 Kms on uphill & downhill side of Arawali along the proposed DFC alignment, which was impossible to negotiate with the permissible ruling gradient of 1 In 200 adopted in DFC. So this vertical difference was planned to be negotiated as below:

- 30 Mtr vertical difference is negotiated with Deep cut (depth up to 30 Mtr)
- Where depth of cut exceeded 30 Mtr, the DFC alignment is passing through the Tunnel of 1 Km length.
- 20 mtr verticaldifferencesisnegotiated through continuous downgrade achievedthrough ruling gradient of 1 in 200 in a length of 4 km along the slopes of Arawali hills.
- Remaining vertical difference is negotiated through 25 Mtr high viaduct and high embankment.

Fig-2 Google image showing Deep cut & Tunnel Portion through Arawali

Fig-3 Site Photograph showing vertical difference uphill&downhill of Arawali

Rock Strata encountered (Visual Inspections) :-

The location of Portal P1 is at DFC Chainge 65.700 Kms .The texture of the Rock in Tunnel at the location of Portal P1 is grey to brown colour, slightly weathered, strong to very strong, fractured, medium grain, hard & blocky Quartzite stone. Three plus random joints are observed near portal P1 locations in which one joint is steeply dipping. Joints are tight to slightly open in nature. The rock belongs to Delhi group of Aravalisuper group. The project site area falls in seismic zone III. P1 is covered with soil, rock and sparse vegetation cover.

Fig-4Quartzite rock near Portal-1(Rewari end) of Tunnel

Portal 2 locations at Ch. 66.700 (Dadri End),rocks encountered at portal (P2) area are grey to brown colour, slightly to un-weathered, strong to very strong, fractured, medium grain, hard & blocky Quartzite..

Fig-5 Quartzite rock near Portal-2(Dadri End) of Tunnel

Three sets of joints are observed near portal locations in which two joints are steeply dipping. Joints are tight to slightly open in nature. The rock belongs to Delhi group of Proterozoic age

Rock mass was found competent and rock mass behaviour was found likely to be stable with the potential of discontinuity controlled, gravity induced falling and sliding of blocks. Portal slopes are gentle to steep and stable

Defining of the Geological Parameters

To apply the geo-mechanics classification system, a given site is divided into a number of geological structural units in such a way that each type of rock mass present in the area is covered. The following geological parameters are determined for each structural unit:

- Uniaxial compressive strength of intact rock material (IS 8764),
- Rock quality designation [IS 11315 (part 11)],
- Spacing of discontinuities [IS 11315 (Part 2)],
- Condition of discontinuities [IS 11315 (Part 4)],
- Ground water condition [IS 11315 (Part 8)]. And
- Orientation of discontinuities [IS 1131S (Part 1)].

Geo technical investigations:-

In order to define the Geological Parameters the Tunnel length was divided in 18 segments andTotal 19 bore holes were drilled along the tunnel alignment at average distance of 50-60Mtr C/C (One bore hole at each portal location). Borehole depth was kept 3-4 mtr below the formation Level for design purposes. The Depth of bore holes varied from 36.66 mtrto56.40 mtr.14 boreholes were drilled vertically, while 05 holes were drilled at 30 degree inclination from vertical for taking the idea about rock mass distributed along the length & width of the proposed tunnel. Samples were collected during Geotechnical Investigations.

Fig-6 Photograph showing Bore holes distributed along the length of Tunnel

Figure-7 Sample collection during Geo technical investigations

Figure-8 Preparation of Rock Specimen for Testing

As per borehole data, presence of groundwater is not encountered in the entire depth of the Tunnel

Collected samples during Geotechnical investigations were sent to lab to determine the engineering geological characteristics of the rock mass using the rock mass rating (RMR) system also called geomechanics classification system. This classification can be used for estimating the unsupported span, the stand-up time or bridge action period and the support pressures of a Tunnel opening; it can also be used for selecting a method of excavation and permanent support system.

List of Rock Tests done in Lab:-

Following tests were carried out in lab on rock samples & rock specimens.

- Quantitative description of discontinuities in rock mass and rock quality.
- Unconfined compressive strength of Rock.
- Elastic modulus, poison ratio & modulus of Rock.
- Uniaxial crushing strength test.
- Bulk density & Dry density.
- Point load index in case of required sample length to diameter ratio is not available.

Design of Shape of Tunnel

On the basis of defined Rock Parameters, tunnel shape having multi-radius profile (preliminary 3-radius geometry is assumed as per the contract documents) was adopted. It results in a minimum finished width of 14.21 m and a height of 11.25 m formation level as shown in Figure.It is one of the largest Railway Tunnel in India having cross sectional area of more than 150 sqm.

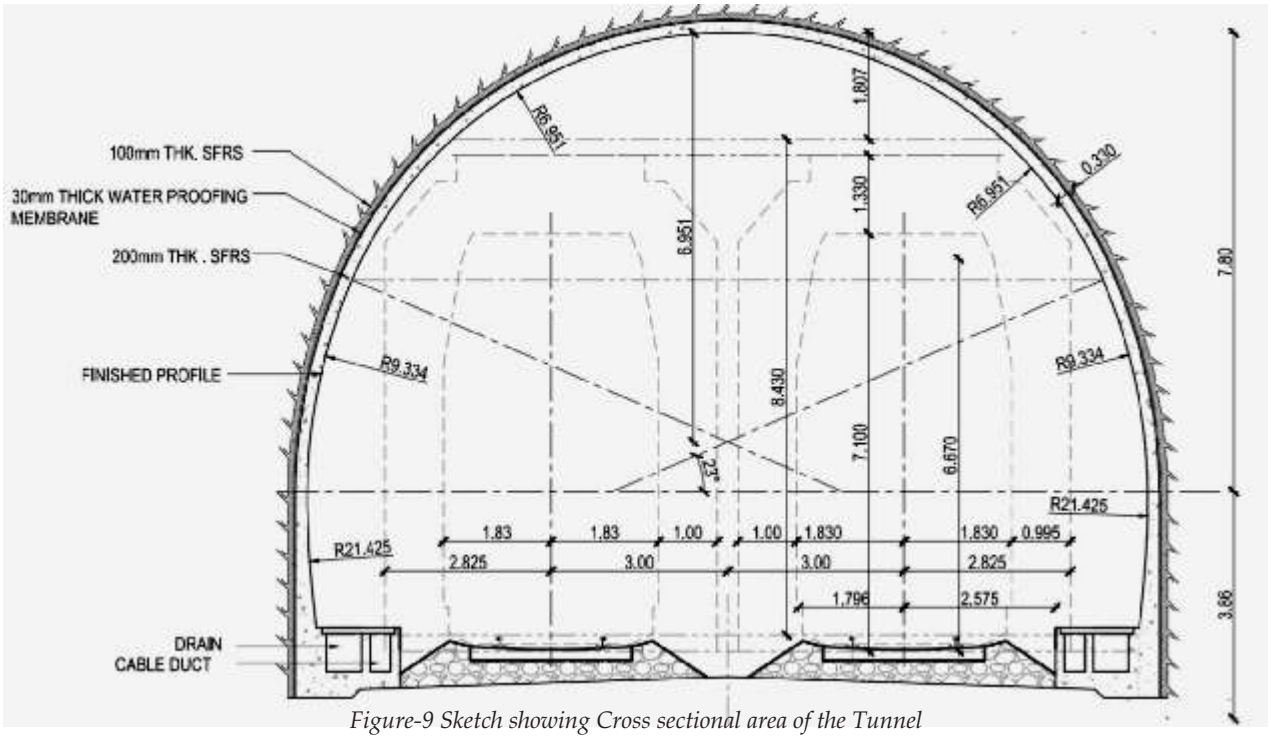

Figure-9 Sketch showing Cross sectional area of the Tunnel

Method of Tunnelling

Studies of Rock Mass properties have revealed that tunnel can be made through NATM method without much difficulty.

Principles of NATM

The NATM integrates the principles of the behaviour of rock masses under load and monitoring the performance of underground construction during construction. The NATM is not a set of specific excavation and support techniques and has often been referred to as a "design as you go" approach to tunnelling providing an optimized support based on observed ground conditions but more correctly it is a "design as you monitor" approach based on observed convergence and divergence in the lining as well as prevailing rock conditions.

There are **seven features on which NATM is based:**

Mobilization of the strength of rock mass – The method relies on the inherent strength of the surrounding rock mass being conserved as the main component of tunnel support. Primary support is directed to enable the rock to support itself.

Shotcrete protection – Loosening and excessive rock deformation must be minimised. This is achieved by applying a thin layer of shotcrete immediately after face advance.

Measurements – Every deformation of the excavation must be measured. NATM requires installation of sophisticated measurement instrumentation. It is embedded in lining, ground, and boreholes.

Flexible support – The primary lining is thin and reflects recent strata conditions. Active rather than passive support is used and the tunnel is strengthened not by a thicker concrete lining but by a flexible combination of rock bolts, wire mesh and steel ribs and Lattice Girder.

Closing of invert – Quickly closing the invert and creating a load-bearing ring is important. It is crucial in soft ground tunnels where no section of the tunnel should be left open even temporarily.

Contractual arrangements – Since the NATM is based on monitoring measurements, changes in support and construction method are possible. This is possible only if the contractual system enables those changes.

Rock mass classification determines support measures – There are several main rock classes for tunnels and corresponding support systems for each. These serve as the guidelines for tunnel reinforcement.

Based on the computation of the optimal cross section, just a thin shotcrete protection is necessary. It is applied immediately after blasting & Chipping, to create a natural load-bearing ring and therefore to minimize the rock's deformation. Additionally, geotechnical instruments are installed to measure the later deformation of excavation. Therefore a monitoring of the stress distribution within the rock is possible.

Key features

a. The strength of the ground around a tunnel is deliberately mobilized to the maximum extent possible.

b. Mobilization of ground strength is achieved by allowing controlled deformation of the ground.

c. Initial primary support is installed having load-deformation characteristics appropriate to the ground conditions, and installation is timed with respect to ground deformations.

d. Instrumentation is installed to monitor deformations in the initial support system, as well as to form the basis of varying the initial support design and the sequence of excavation.

When NATM is seen as a construction method, the key features are:

The tunnel is sequentially excavated and supported, and the excavation sequences can be varied.

The initial ground support is provided by shotcrete in combination with fibre or welded-wire fabric reinforcement, steel arches (usually lattice girders), and sometimes ground reinforcement (e.g. soil nails, spilling, Rock Bolting).

The permanent support is usually (but not always) a cast-in-place concrete lining/ SFRS

Start of Tunnelling work through NATM Method:-

Start of Construction:- As the depth of cutting was approximate 30 Mtr at both portals, so the first step was preparation of Approach through deep cut in the Rock to reach up to the face of Tunnel.

Figure-10 Excavation of approaches to reach the Portal Face Preparation for Portal

Face Preparation for Portal

After reaching to the Portalface the next step was the face preparation for development of Portal.The excavation in portal area was done in top-down benches followed by stabilizing the adjoining slopes by proper supports like rock-bolts, wire mesh and shotcrete. First layer of Short-Crete 50 mm thick was provided with suitable size of bench at every 3-4 mtr on excavated surface of portal. Rock bolts of 6 mtrlength at 3.0 mtr c/c were also provided to stich the loose rocks with the stiff rock, after applying first layer of short-crete square wire mesh(5mm dia) of size 150mmx150mmwas laid over the primary layer of short-Crete and then secondary layer of short crete was applied over the wire mesh to stabilize the face of the Portal.

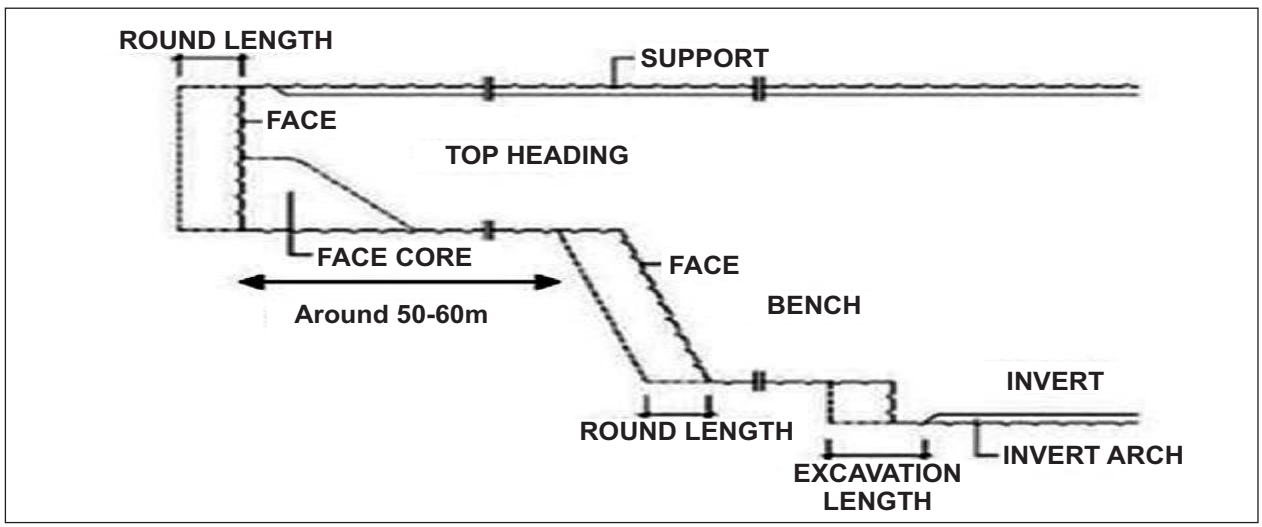

Figure-11 Top down approach for Portal development

Stages of Portal Construction

Stage-1

- Construction of ramp (1:12) to respective bench
- Excavation of respective bench by excavator and dumper combination up to spoil / overburden and later by crawler drill, Wheel loader and dumper combination for rock

Stabilization of slope by scaling, shotcreting, wire mesh and rock-bolt combination

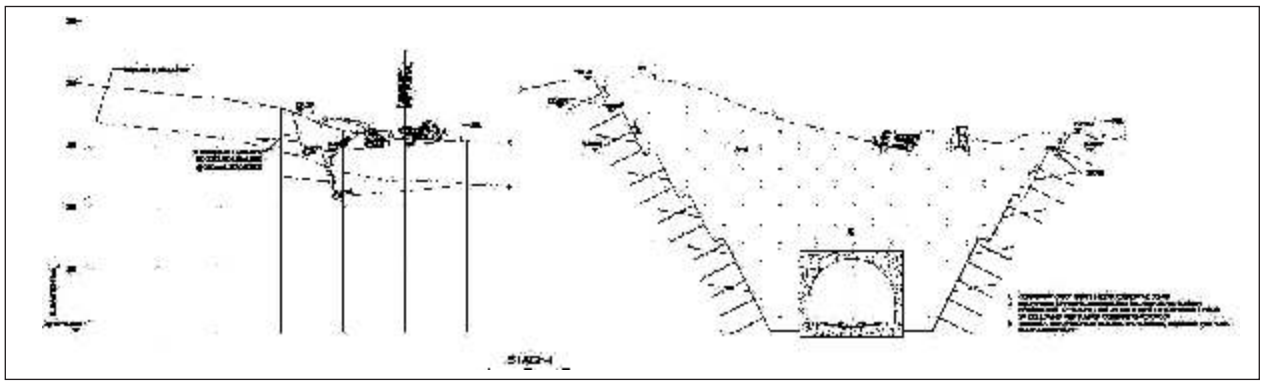

Fig-12 Stage-I of Portal Development

Stage-2

- Extension of ramp to lower benches and excavation of lower benches.
- Stabilization of slope by scaling shotcreting, wire mesh and rock-bolt combination.

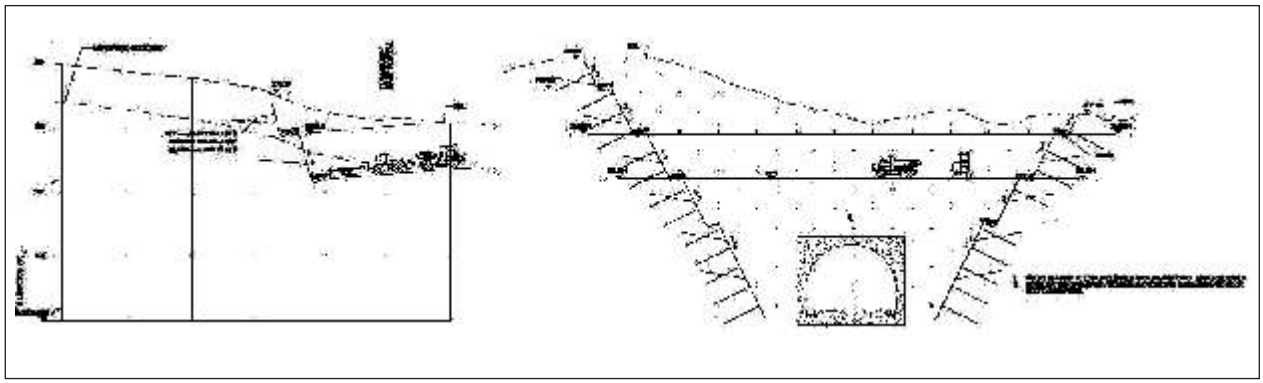

Fig-13 Stage-II of Portal Development

Stage-3

- Construction of ramp to around 3m below crown level .
- Excavation of bench using crawler drill, wheel loader and dumper combination.
- Stabilization of slope by scaling, shotcreting, wire mesh and rock bolt combination.
- Drilling of fore poling tubes
- Grouting of fore poling Tubes.

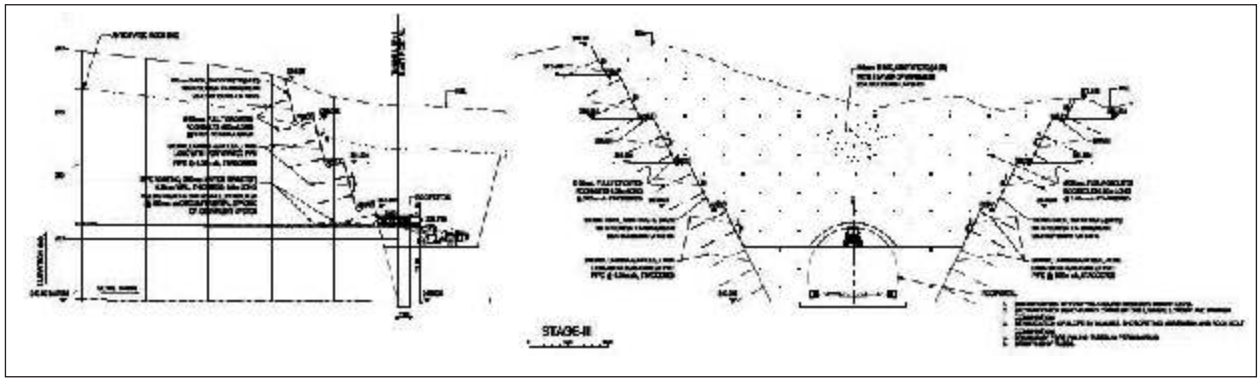

Fig-14 Stage-III of Portal Development

Fig-15Site Photograph during Stage-III of Portal Development

For poling:-For-poling are specified to supplement the arch structure in the roof and spring line regions as well as stabilization of the face and in advance of the face immediately after the excavation. The fore poling (Pipe umbrella) should extend at least 30% beyond the face of the next excavation.

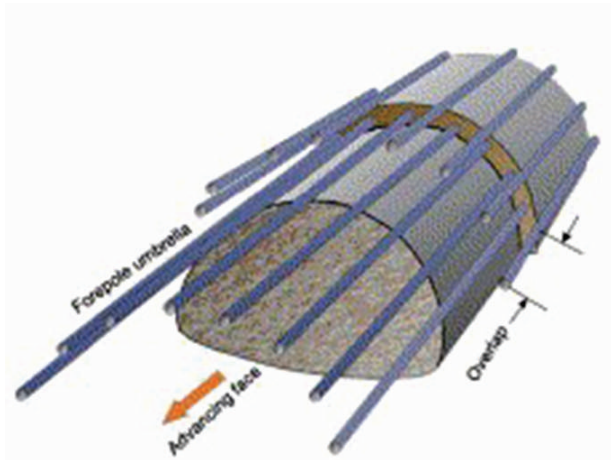

Fig-16 For poling Tubes Sketch

Hollow pipe of 38 mm dia were used for for-poling with provision of 78 mm dia sacrifice bit ahead. The sacrifice bit consisting three predrilled holes used for pressure cement grouting through the for-poles to fix them inside the rock and to make a pipe umbrella at spring level of the tunnel.

For-poling at one hand prevent over braking due to blasting beyond the proposed tunnel profile and on the other hand it protects the loose rock in spring portion to fall & thus give the stability to the face of the tunnel.

Fig-17Site Photograph after Stage-III(for poling) of Portal Development

Start of Tunnel excavation through Drill & Blast Method

It was decided to excavate the tunnel by conventional drill and blast methods, on the basis of detailed design assessment, including the optimization of the OHE, drainage, electrical cabling, etc.

Heading & Benching

Based on the excavation geometry and foreseen equipment the approximate dimension of the excavation steps was kept (Encountered Strata was found as Class-II & Class III rock).

- Top heading, with a height of approximately 7 m
- Bench, with a height of between 3 m and 4 m
- and Invert, with a depth of between 1 m and 2 m.

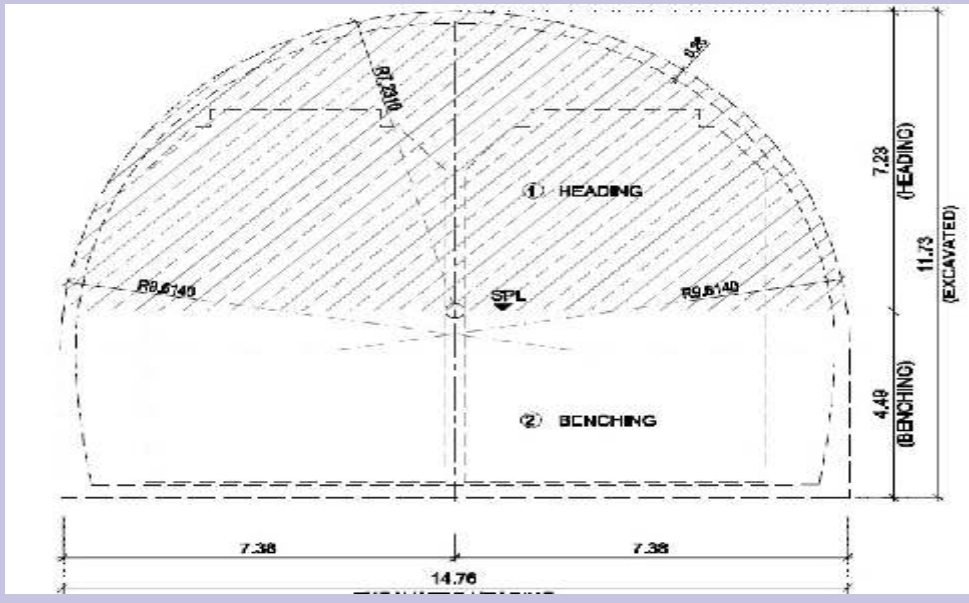

Fig-18 Sketch showing heading & benching sequence

Probe hole & Test Blasting

Probe Holes are commonly used for investigating the geology ahead.

(i) It is drilled ahead of the tunnel excavation up to 10 m to determine, in advance, the nature of the material to be excavated and the presence of water. The drilling of the probe holes included in a normal pattern of the blast holes. The length of the probe holes was kept according to the length of the expected day's excavation advance.

(ii) Based on the probe hole information, assessment of the expected material to be encountered was assessed. . Probe hole also indicates the presence of excessive water, high pressure water or geothermal conditions ahead of the excavation face, appropriate precautions weretaken to facilitate excavation and to deal with any gases or zones or weakened rock, which may be encountered.

(iii) The general sequence for each excavation sequence, were sub-divided in the following main construction steps described in the following sections.

- Profile Survey
- Face log
- Excavation (either drilling, loading and blasting)
- Ventilation (de-fuming following blasting and shotcreting)
- Spoil or muck removal
- Scaling of loose blocks
- Final mucking
- Shotcrete Sealing
- Spot bolts if required
- Installation of primary support measures
- Monitoring

Tunnel Profile survey

Prior to starting the excavation step the area will be surveyed in detail to document the previous excavation length, check the alignment and set the drilling pattern to be adopted to ensure the profile and alignment are as per requirement. Prior to drilling, the face will be surveyed and the blast hole positions will be marked on the face withpaint to enable the drill jumbo to follow the pattern.

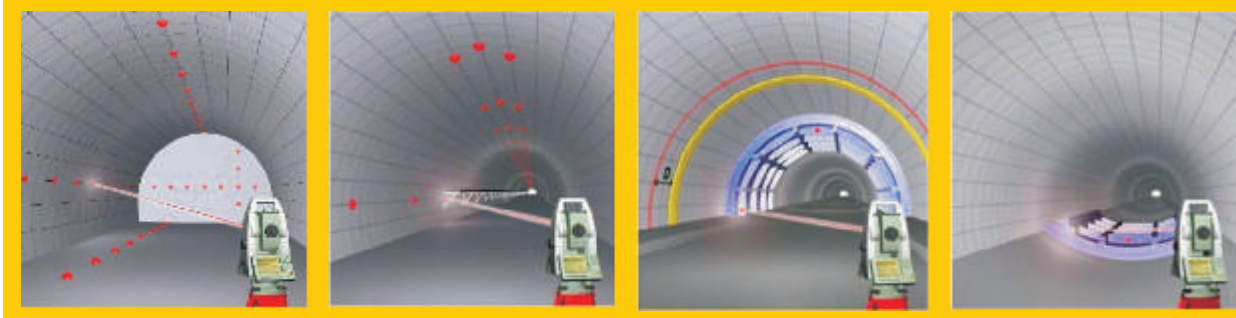

Fig-19(a),(b),(c),(d) marking of Tunnel profile over Rock before blasting

Making Rock Face mapping(Face log):- Before start of ballasting & making way in to tunnel mapping of the rock face(heading portion) was done by the Geologists who decides grading of rock mass on the basis of length of rock joints,their thickness and their distribution along the Tunnel face. The rock mapping decides the depth of charging holes & quantity of explosive for blast at the Tunnel face.

SOJITZ-L&T CONSORTIUM

Integrated contract package of civil, Building and Track Works, Electrical & Mechanical Works and Signaling & Telecommunication Works, CTP-14

CTP-14 TUNNEL

ROCK MASS RATING CALCULATION SHEET

TUNNEL :	LOCATION :	CHAINAGE :	Excavation length:	DATE/TIME :

ROCK MASS RATING SYSTEM (After Beiniawski 1989)

1. STRENGTH OF INTACT ROCK MATERIAL

Designation	UCS	STANDARD RATING
Extremely Strong	>250	15
Very Strong	100-250	12
Strong	50-100	7
Medium Strong	25-50	4
Weak	5-25	2
Very Weak	1-5	1
RATING :		

2. ROCK QUALITY DESIGNATION (RQD)

Designation	%	STANDARD RATING
Excellent Quality	90-100 %	20
Good quality	75-90 %	17
Fair Quality	50-75 %	13
Poor quality	25-50 %	8
Very poor quality	< 25 %	5
RQD =		
RATING :		

3. SPACING OF DISCONTINUITY

Description		STANDARD RATING
Very wide	> 2m	20
Wide	0.6-2m	15
Moderate	200-600mm	10
Close	60-200mm	8
Very close	< 60mm	5
RATING :		

4. CONDITION OF DISCONTINUITY

PERSISTANCE (DISCONTINUITY LENGTH)		STANDARD RATING
Very Low	< 1m	6
Low	1-3m	4
Medium	3-10m	2
High	10-20m	1
Very High	>20m	0
RATING :		

SEPARATION (APERTURE)		STANDARD RATING
Very tight joints	None	6
Tight joints	<0.1mm	5
Moderately open joints	0.1-1mm	4
Open joints	1-5mm	1
Very wide aperture	>5mm	0
RATING :		

WEATHERING	STANDARD RATING
Fresh	6
Slightly weathered	5
Moderately weathered	3
Highly weathered	1
Decomposed	0
RATING :	

ROUGHNESS DESCRIPTION	STANDARD RATING
Very rough surfaces	6
Rough Surfaces	5
Slightly rough surfaces	3
smooth surfaces	1
Slickensided surfaces	0
RATING :	

INFILLING / TECTONIC BRECCIA / GOUGE	STANDARD RATING
None	6
Hard filling<5mm	4
Hard filling>5mm	2
Soft filling<5mm	2
Soft filling>5mm	0
RATING :	

5. GROUND WATER

INFLOW per 10m of tunnel length (litres/minute) :	none	<10	10-25	25-125	>125
WATER PRESSURE (KPA)	0	<0.1	0.1-0.2	0.2-0.5	>0.5
General conditions	Dry	Damp	Wet	Dripping	Flowing
STANDARD RATING	15	10	7	4	0
RATING :					

A. BASIC RMR(1+2+3+4+5) =

B. RATING ADJUSTMENTS FOR DISCONTINUITY ORIENTATIONS	RATING
Very favourable	0
Favourable	-2
Fair	-5
Unfavourable	-10
Very Favourable	-12

ROCK MASS CLASS	ROCK MASS RATING
I Very Good	81-100
II Good	61-80
III Fair	41-60
IV Poor	21-40
V Very Poor	0-20

CORRECTED ROCK MASS RATING (A-B)

ROCK MASS CLASS :

Effect of discontinuity strike and dip orientation in tunneling

Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip 45°-90°	Drive with dip 20°-45°	Dip 45°-90°	Dip 20°-45°
Very favourable	Favourable	Very Unfavourable	Fair
Drive against dip 45°-90°	Drive Against dip 20°-45°	Dip 0°-20°	
Fair	Unfavourable	Fair	

CONTRACTOR		ENGINEER
MAPPED BY :		SIGNATURE :

Fig-20 Calculation sheet to describe Rock mass parameters after Face log

Rock Excavation(Drilling & Charging holes with Explosive, Ballasting):-

After rock mapping and deciding the rock mass classification the next step is to fix the depth of drilling of holes for charging of explosive and fixing the quantity of explosive to be used to excavate the targeted area. Trial blast was made to decide the same and accordingly the quantity of explosive to be used was fixed.

Fig-21 Photographs showing drilling & charging of holes at Tunnel face

Explosive (Description & Application):

Superpower 80 packaged emulsionsexplosive wasused for blasting. The explosive is having putty-like consistency. Products are sensitized through chemical gassing / micro-spheres / combination of both. It is a water-resistant packaged explosive. Superpower 80 is designed for priming applications and as a column explosive in surface and underground mining and general blasting. The high detonation velocity and the robust nature of Superpower 80 make it an ideal primer for the initiation of column charge.

Controlled Blasting- Important feature of NATM

Drilling and blasting is the most flexible methods of excavation and can be easily adapted to changing drift sizes, ground conditions, ground support types or other design requirements. This method is versatile and applicable to any tunnel length Disadvantages of drill and blast excavation compared to mechanical methods include:

-Higher degree of disturbance to the rock surrounding the openings, -because of this disturbance, drift conditions may be more difficult to assess for quality assurance or performance confirmation assessment.

The field tests taken during construction of tunnels provide the possibility of constructing underground openings by blasting in very complex surroundings without producing damage zone around. A design of safe blasthole patterns of underground opening to avoid rock damage demands test blast method, coupled with recording of seismic effect .Value of ground oscillation velocity is a standardized parameter for the evaluation of a damage capability. It is world-wide accepted and is included into most of world standards. The functional relationship of explosive quantity by one blasting cycle and peak velocity can be established depending of rock category excavated.

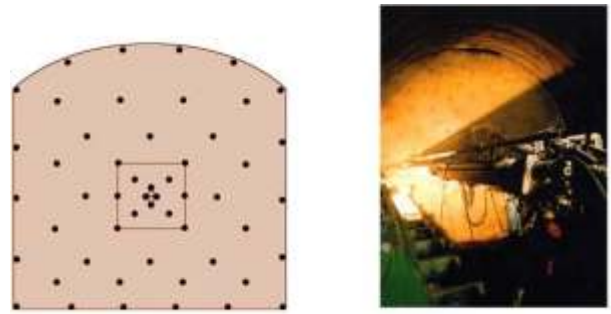

Fig-22 Sketch Showing Blasting Patter & drilling

De-fuming:-After blasting defuming was done, by sending fresh air under pressure, inside the tunnel, through the ventilation duct. This activity brings out all the poisonous gasesinside the tunnel and makes the environment breathable for the labour and equipment operators inside the Tunnel.

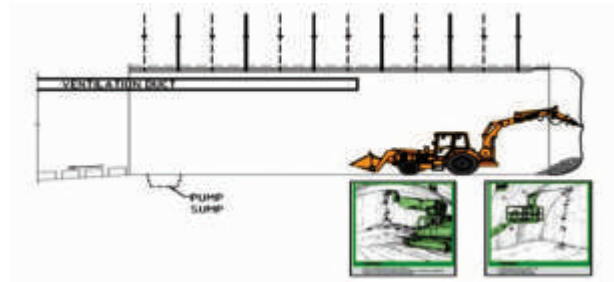

Fig-23 Sketch Showing Ventilation Duct, scaling & rock bolts at spring Level

Sprinkling Water:- After defuming, sprinkling of water was done to settle the dust released during blasting operation.

Scaling and Trimming:-

Prior to scaling the initial conditions exposed at the face was inspected to identify that the overall stability of the excavation is ensured, any water inflows or precariously poor conditions was identified and communicated to the tunnel engineer and geologist to allow preparation of any special measures required. Scaling and trimming of the blasted profile was done to remove loose rocks and ensure there is no underbreak following the blast. Scaling is usually started concurrently with the end of mucking and was performed with the excavator, Just immediate to the face, excavator with rock-breaker arrangement was used. After scaling and trimming, the excavated profile was checked by survey and geological face mapping performed to obtain the required geological and geotechnical information before application of sealing shotcrete on the freshly excavated profile.

Scaling using Scissor Platform

Scaling using Excavator

Fig-24 Photographs showing scaling & Trimming

Mucking:-

Mucking within the tunnel following the blast and scaling will be done using Loader / Excavator & Dumpers which was transported to dump-yard.

Fig-25 Mucking through Dumpers & Excavators

Providing Support systemto the excavated Rock face:- The basic principle of supporting the excavation is to optimize the geological stress of the surrounding rock mass to stabilize the tunnel. Two type of support systems were used in the Tunnel

(a) Temporary support or Primary support

- Rock bolt
- shotcrete.

Fig-26 Photograph Showing Temporary support Rock Bolt+ Shortcrete

(b) The permanent support or secondary support

- Rock bolt and shotcrete, reinforced with fibres,
- Lattice girders or steel ribs.

Shotcrete

Wet mix process was used for placing shotcrete. All materials and water without accelerators was

accurately weigh-batched and mixed to produce the shotcrete mix at the batching plant and conveyed to placement point and fed to the shotcrete equipment. The mixture is then conveyed by positive displacement/compressed air to the nozzle where air, and accelerator, is injected to increase velocity and placed without interruption on to the place. Robotic boom used for application of shotcrete. Minimum thickness of shotcrete in any one layer will be 25 mm and maximum thickness in any one layer is 150 mm depending upon rock classification. Rebound was kept minimum with proper application technics and continuously monitored.

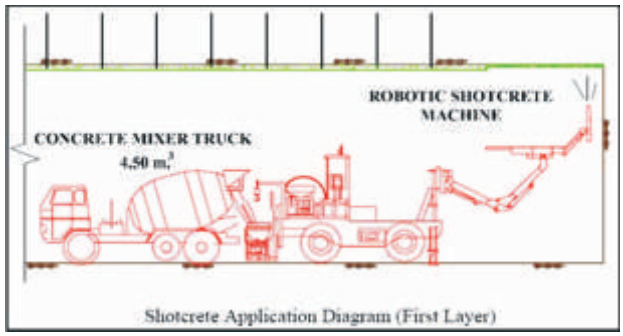

Figure-27. Set up for applying shotcrete in the fresh excavation area.

The water/cement ratio (by weight) for dry-mix shotcrete lies in the range 0.4 and is adjusted by operator to suit local conditions. The addition of steel fibres has been used to improve the toughness, durability, and shear and flexural strengths of shotcrete, and to reduce the formation of shrinkage cracks. Steel fibres are added according to the specifications of the manufacturer& Mix design proportions.

Fig- 28. Shot-creteapplication

Steel Fibre Silicious wet shortcrete

In order to solve the problem of low strength and easy cracking of shotcrete in permanent support of tunnel single shell lining, the effects of steel fiber-reinforced siliceous on mechanical properties of wet shotcrete were investigated and it was observed thatthe steel fiber-reinforced siliceous can improve splitting tensile, flexural, and shear capacity of the shotcrete, and the maximum growth rates were 77.42%, 72.73%, and 98.31%. The steel fibre plays a major role, and silica fume plays a subsidiarity role.

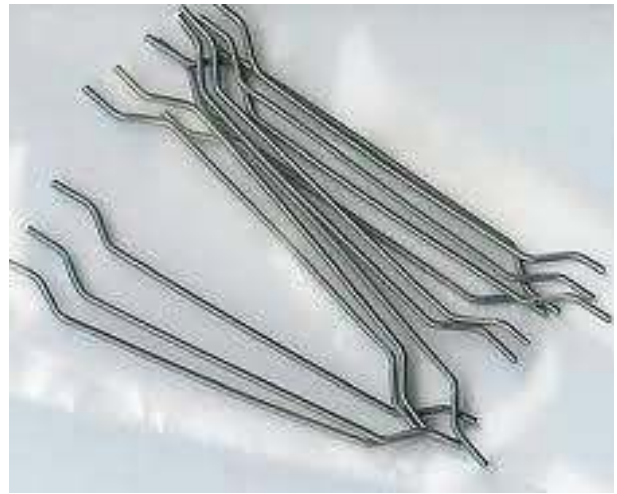

Fig-29 Steel Fibers

Steel fiber-reinforced siliceous wet shotcrete is a kind of new composite material, which is mixed with steel fiber, silica fume, and high-performance admixtures in common concrete, and the wet method is used in the spray technology. In recent years, shotcrete and cast-in-situ concrete have been widely used in tunnel support.

Fig-30 Steel Fiber Siliceous concrete

In CTP-14 Tunnel workSteel Fibre Siliceous wet shotcrete with target Strength of M-35 was used. It contains following ingredients/Cum

- OPC 53 Grade Cement -450 Kg
- Steel Fibers(StewolsShktiman) - 50 Kg
- Micro Silica(Rockfit) - 25 Kg
- Aggregate 10 MM - 791 Kg
- Sand - 871 Kg
- Admixture(MYK Armix PC-20) - 4.75 Kg
- W/C Ratio - 0.40

Rock Bolts

The main principle of bolting is to hold rock blocks in place and reinforce loose rock or fractured in- situ rock to prevent ravelling (caving), and to assist the rock mass to form its own self-supporting structure. Additionally, rock bolts help hold the shotcrete support ground in place and provide increase bonding to the ground. The length and diameter of holes for rock bolt adopted depends upon rock classification. For class B rock 25mm dia 4Mtr long Rock bolts used at c/c distance of 2.0 Mtr, while for Class C rock 5.0 Mtr long bolt used at a distance of 1.5 mtrc/c. As stipulated in Technical Specification and relevant IS Codes, diameter of drill hole for installation of rockbolt was kept minimum 1.50 times the diameter of the rock bolt. For drilling of the holes, hydraulic two boom drill jumbo was used. Rock bolts envisaged are mainly cement grouted or cement +Resin grouted.

Rock bolts were fabricated at site from reinforcing bars with requisite yield strength of 25 mm dia complying to IS: 1786. Bolts were equipped with anchor plate and a spherical hexagonal nut. Rock bolting was carried out using hydraulic two boom drill jumbo. In the resin grouted rock bolts, combination of cement & resin capsules were used& placed in the hole with the drill Jumbo. Holes were kept plugged until just prior to commencement of grouting and installation of Rock Bolt. Before grouting, each hole was thoroughly flushed and cleaned with air-water combination. Normal Portland Cement was used for the grout mixture. The grout was introduced to the end of the hole through a pipe, pipe was gradually withdrawn as the hole is filled and temporarily plugged to prevent overflow. The anchor bars/bolts will be forced in to the grout-filled hole before the initial set of the grout. After the grout achieves final setting time, the bolts were fixed with base plate and nuts tensioned gradually to the required pressure. In the resin grouted rock bolts combination of cement &resin capsules were used & placed in the hole with the drill Jumbo.

Grouted Rockbolt: can be used for temporary as well as permanent support under various rock conditions. The grout with water cement ratio (by weight) of between 0.3 and 0.35 was commonly used.

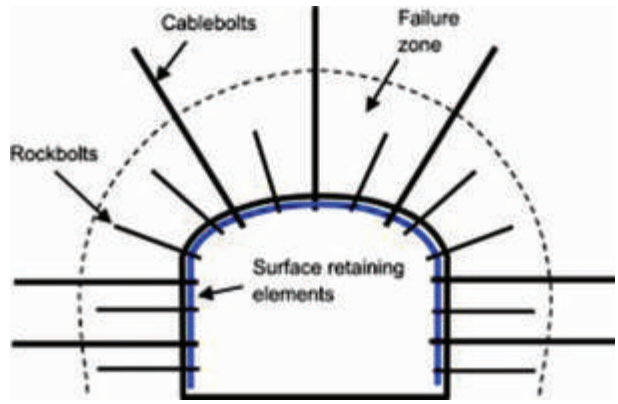

Fig-31 Sketch showing the function of Rock bolt in Rock Mass Stabilization

Lattice girders

Lattice girders or steel arches installed to maintain the designed shape of the opening and if necessary, provide early support at the working face over the length of the last excavation completed. The lattice girder mainly functions as shotcrete reinforcement and provides initial load carrying capacity during the early strength development of the shotcrete. The installation of lattice girders or steel arches prevents ground loss and improves load distribution. Lattice girders (in combination with shotcrete) also provide the excavation side foundation for forepoling bars and facilitate the placement of welded wire mesh reinforcement. Fabricated lattice girders are brought to site and fixed using hydraulic lifts ladders etc. After fixing the girders, shotcrete was sprayed over the lattice girder in uniform layers so as to enclose the

complete girders with a minimum coverage of 50 mm. Proper care was taken during fixing to ensure

- Proper positioning of the lattice girder to meet alignment and construction tolerances including making allowance for any convergence,
- Facilitate shotcrete penetration into and behind the girder, thereby minimizing the creation of projection shadows and/or voids
- Provide good-quality bonding between the steel and shotcrete, to form a composite structure acting as a continuous reinforced concrete lining,
- Protect footing connections from shotcrete when the lattice girder extends into the bench region.

Fig-33 Steel Rib support at Portal-2(Dadri End)

Steel Ribs

Structural steel sections were fabricated and bent to the required shape, size and pieces to suit the tunnel profile. Excavators and scissor platform were used for erecting the steel ribs in position at portal P1 & P2 at a distance of 0.50 Mtr C/C. The Steel rib were provided in a length of 20 mtr from the face of Portal P2 & 60 Mtr from the face of Portal P1. Ribs were Anchored on the rock and fastening of steel ribs longitudinally was done manually with access from the scissor lift platforms /staging. Lagging was placed between two steel ribs and the space behind the lagging and excavated rock face was backfilled with CC M-25 concrete.

Fig-33 Steel Rib support at Portal-2(Dadri End)

Benching:- After completion of heading portion & providing primary support to excavated face of Rock mass the benching activity was taken in hand. For ease of construction & seeing stability and standing time of Rock, it was decided to go for benching through full face method.

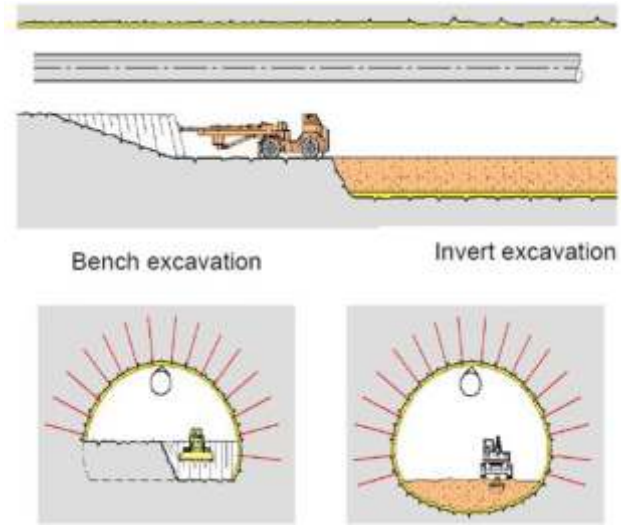

Fig-34 Sketch showing Benching activities in Tunnel

Progressing work inside Tunnel :- Further work progresses in Tunnel segment wise as explained in Figure 19 to 31. The length of the segment depends upon the Rock Mass configurations and may range from 0.50 mtr to 3.0 Mtrs. Works started from both ends after fixing Ribs for Portal development. The breakthrough of tunnel from both ends happens somewhere in the mid of Tunnel.

Fig-35 Continuous heading from Portal-2 towards Portal-1

Cycle time between two consecutive Blast in CTP-14:-

Total 17.5 Hrs cycle time is achieved in CTP-14 in Face log reading, Drilling, charging, Ballasting, defuming, scaling, Mucking, Shortcreting & Rockbolting between two successive blasting sequences.

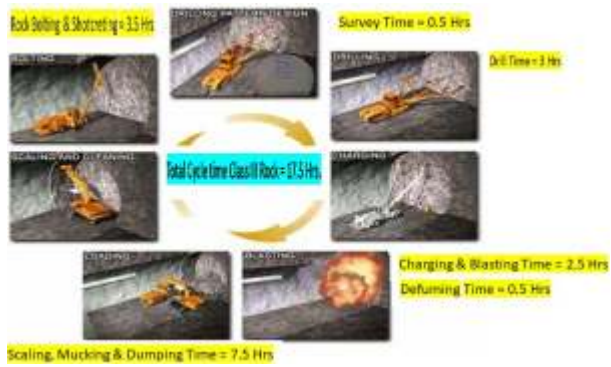

Fig-36 Figure showing sequencing & Cycle time for various activities

Dewatering System during construction phase

Through geotechnical investigation it was revealed that the Tunnel is no water Tunnel. But dewatering was required for draining the water used by the boomer during drilling operations, seeping water in rainy season and to drain out the water used for sprinkle after blasting &defuming to settle down the dust.

Dewatering was done by making sumps(collecting pits) for collecting water & to drain out the same through pipeline and centrifugal pump of appropriate capacity. Each pump shall have the capacity to ensure the full pumping duty on its own. The dewatering arrangement made and being maintained throughout the excavation period as per requirement.

The sump also act as collection pit which was provided with suitable capacity sludge pump to pump out to settling tank near to portal location. This dewatering arrangement at face was extended to another location as the face is getting advanced. This will be removed from and kept at safe distance to avoid damage by flying fragments before taking blast. The whole dewatering system will be advanced as the face advances.

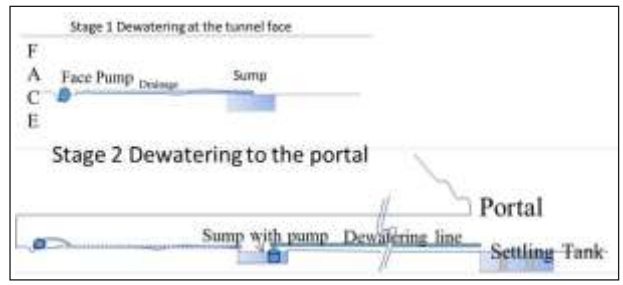

Fig-37Schematic layout of dewater system for the construction stage.

In addition to construction water and minor inflows, it may be necessary to dewater the rock mass to allow the excavation and support process to proceed. In this situation, drainage holes will be advanced from the tunnel walls aimed at intercepting the zone or structure which is contributing the water to the excavation. The collection hoses then take the water to the sump or drainage channel for transport out of the tunnel.

Rock support installation

The basic principle of supporting the excavation is to optimize the geological stress of the surrounding rock mass to stabilize the tunnel and use rock bolt and shotcrete as primary support in order to minimize the rock deformation and ensure structural stability as well as work safety. The permanent rock support would mainly consist of rock bolt and shotcrete, reinforced with fibers, and for heavier support intensities additional lattice girders or steel ribs.

The final composite support system should maximize the performance of each individual support element to result in an improved combined effect. Initial sealing of the fresh face with shotcrete may be required prior to other support installation to seal small blocks and resist loosening or spot bolting was done, wherever required to hold individual rock wedges. The primary shotcrete layer installed in the first step followed by rock bolting. Secondary support consists installation of lattice girders or ribs, the initial layer of shotcrete was applied to smooth the excavation profile, followed by the installation of the support elements. Rock bolting, depending on the design sequence, would then follow the installation of the primary shotcrete support.

Type and extent of tunnel support varied depending on the type of rock mass conditions (classification) and assessment of the ground behaviour:

Water-Proofing

Spray applied waterproofing membranes for tunnels are proprietary construction materials that are applied to the primary lining surface with spray equipment, in order to form a coating that is bonded to the concrete that can provide an effective barrier to the ingress of liquid water into the structure. These materials are most commonly formulations of reactive or water based polymers, some of which may incorporate cement compounds, and are sprayed either by hand or robotically.

A sprayed concrete lined tunnel typically comprises a sprayed concrete primary (often considered and referred to as a temporary) lining, a waterproofing membrane, and a (sprayed) concrete secondary lining (often also called the final or permanent lining). The purpose of the primary lining is to stabilise a freshly-exposed excavation and so prevent any rock or soil collapse. It is sprayed with concrete following excavation, using rapid-setting concrete applied by a spraying machine controlled by a "Nozzleman", who directs the jet of concrete onto the substrate and can stand in a safe location some distance away from the application surface. The primary lining also provides a firm substrate onto which a waterproofing membrane can be applied. Using sprayed waterproofing membranes facilitates the use of sprayed concrete for secondary linings.

Generally the membrane can be applied in one stage directly onto the concrete lining or substrate. Some membranes require first the application of a primer layer onto the substrate before application of the membrane in one or two consecutive layers. When installed between the primary and secondary concrete linings, spray applied membranes may bond to both primary and secondary linings (double-bonding) or only to one lining (single-bonding), depending on the design requirements and the product chosen. In the case of a spray applied membrane with double bonding properties, the resulting sandwich-structure (concrete-membrane-concrete) may act as a quasi-monolithic structure, depending on the bonding

Characteristics and properties of the membrane.

System water tightness comes from two key characteristics, the membrane water tightness and its bonding properties. In a bonded solution, migration of groundwater along membrane concrete interfaces cannot occur, because potential groundwater paths can be eliminated, mitigating considerably the risk of water ingress into the tunnel. Additionally, a bond between the membrane and the secondary (inner) lining can provide a further barrier against water ingress into the tunnel.

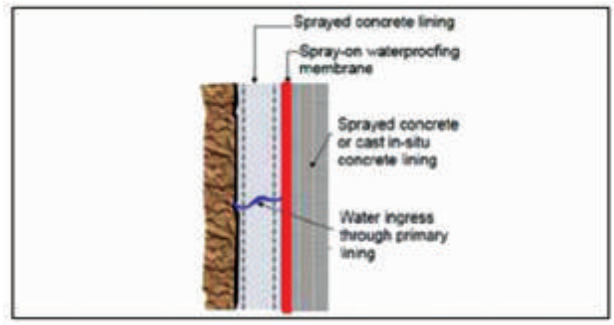

Fig-38 General layers in a spray membrane water-proofing.

Instrumentation Planning

Deformation Measurements

Instruments such as Multipoint Borehole Extensometer (MPBX) was installed in the tunnel roof and at selected

points along the tunnel walls to monitor vertical, horizontal, and longitudinal deformation components. As a minimum, the wall of each excavation (including temporary) was equipped with a device capable of measuring deformations. It is customary to install optical targets for this purpose.

Optical 3-D Displacement Monitoring (Targets (Bi-Reflex and Prisms))

Total stations with optical bi-reflex targets was used to monitor displacements in tunnel . The location of the target is measured in three dimensions and accurately determined by means of an appropriate Total Station. This data and its processing provides the most useful information for assessing the ground-support interaction (System Behaviour), assessing the adequacy of the installed support by comparing the observed and predicted displacements, allows the stabilization process due to the advancing excavation front to be monitored and any deviations to be rapidly identified allowing corrective measures to be implemented before the situation advances. 3-D Displacement monitoring is the most useful measurement during tunnelling when implemented correctly and with quality.

Tape Extensometer

The change of tunnel surface/perimeter (convergence) distance measurement is one of the most accurate measurements available and is measured with a "tape extensometer". This instrument can measure the distance between any two given points in any direction. However, in case of large tunnels it is difficult to measure the distance between two given points for heights greater than 5m, but horizontal or inclined distances up to even 20m can be measured. Two ends of the extensometer are hooked with the two anchored points/ steel studs for engaging the tape loops. A dial indicator graduated to 0.01mm measures the distance between the two anchored studs. These data provide purely a change in distance which with complex 3-D displacements can become ambiguous when not combined with optical 3-D measurements, unless complex arrays are set up with which allow the components to be determined individually.

Load Cells

During construction load cells used to measure short and long-term loads on the ribs, arches, rock bolts and cable bolts for assessing the stability of the tunnel and evaluate the performance of the support to ensure the support elements are not approaching their designed capacity for a given rock mass class, to validate the design assumptions and to determine the time of installation of permanent support. To measure increases in load on the support system, which may be due to rock movements and rock mass deformations, load cells either with or without central hole are provided on steel arches and rock bolts.

MPBX Extensometers

Multi Point Borehole Extensometers (MPBX) used as required to measure linear strains in the rock mass, due to transfer of load and the resulting deformations of the rock mass over pre-defined intervals to assess the depth of deformations into the rock mass. The heads of the MPBX extensometers should be monitored with optical 3-D displacement measurements to ensure that all the deformation is captured as it is not possible to guarantee the rock mass end of the system is not moving also.

Instrumented Rock Bolts (IB)

The strain and its conversion into load/stress along the length of a fully grouted rock bolt is never same; it varies with depth and mainly depends on the development of fractures or deformations due to transfer of load inside the rock mass as well as discrete movements along specific geological discontinuities. IB's yield one of the most important information required by the designers for optimizing the bolt's specifications and the pattern. IB's are normally installed in conjunction with other instruments including MPBX, optical targets, and load cells.

Since stress control failure are not anticipated so instrument can be judiciously used after face exposure. If any thick band of schist interbeds are encountered that shall be treated separately.

Standard requirement of instrumentation for tunnel has been given in Table below.

S. No	Instrumentation Details	Description
1	3 Point Multipoint Borehole Extensometer	3 Nos of 3 Point Multipoint Borehole Extensometer at Every 50 m.
2	Convergence Array - Optical 3-D Displacement Monitoring	7 Point Optical Convergence Array (with accuracy of 1 mm) will used at every 25m.
3	Roof Settlement Point	1-point Roof settlement point at every 50 m.
4	Load Cells	Five centre hole load cells (with accuracy 0.5%) of 250 kN capacity are used at critical locations.
5	Pressure Cells	7 Nos of Pressure cells of 100 bars (accuracy 0.25%) at each section at every 100 m.
6	Switch Box	2 Nos of Switch Box at every 100 m
7	Strain Gauge	7 Nos of Strain Gauge per section @ every 100 m.
8	Tape Extensometer	30 m long Tape extensometer at every 100 m.

Table showing Instrumentation required in Tunnel

Measurement

The data recorded was presented in graphical form as graphs facilitate the interpretation of relationships and trends of data. Readings are compared over time and with other instrument readings as well as with construction activities and changing environmental conditions. Observed trends compared with predicted trends to make an assessment of overall performance.

Data evaluation must be carried out in shortest possible time. Predicted behaviours at design stage used as a reference point from which all interpretations of the data are made. Adjustments in the original design made by feedback of the results of data evaluation during construction. The following information shall be considered when interpreting monitoring data:

1. Advance of tunnel face, bench or other data relating to the progress of the works.
2. Changes in geology encountered.
3. Rainfall and piezometric data.
4. Temperature changes when there is no systematic detection system.
5. Deformation predicted from design analyses.
6. Change or replacement of monitoring equipment during construction

Trigger value – Measurement is a part of the risk management process, and used as possible warning mechanism enabling preventive measures introduced in an acceptable time. Trigger values such as displacement, strain or pressure are determined, which determine appropriate actions in response to these values being exceeded.

When setting of trigger values, following needs to be specified:

- Procedure for passing on information.
- Allocation of responsibilities between owner, supervisor, designer, and contractor.
- Time allowed for each person to pass on information or make a decision.
- Remedial actions for dealing with foreseeable situations.

Convergence Measurement:

The monitoring of convergence is carried out with the help of pins or target plates mounted onto the tunnel wall immediately after excavation. To determine convergences, the readings between individual pins of the same cross section plotted over time. Tunnel convergence can be used in controlling tunnelling as in mathematical senses these are integrated quantities representing major local effects. Stresses, strains, and

curvatures, on the other hand, are differential quantities, the magnitude of which is significantly influenced by local effects. Displacement measurements observed at successive points so that their distribution over a sufficient area can be obtained.

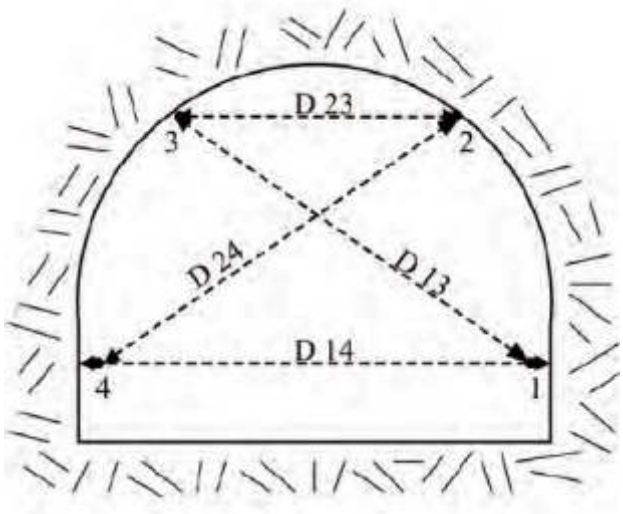

Fig-39 – General Concept of Monitoring

Absolute displacement Monitoring

The advantages of the optical 3D convergence measurement are shown in figure 38.

Fig40–Distance v/s time, convergence v/s time and convergence v/s distance

Frequency of Readings

The frequency of readings can vary according to the monitoring phases as follows:

1. Instrument installation phase – The signs of the measurement are recorded to check the numbering of the instrumented points and data channels, and to detect any anomalous behaviour.
2. Initial reading phase – The baseline readings serves as benchmark for the further measurement. It further helps to gradually improve measurement accuracy, and to validate design assumptions as early as possible.
3. Routine monitoring phase – In this phase, the reading frequency must be chosen with due consideration of the rate of change in the measured quantity and monitoring stage, i.e. active monitoring and close-out monitoring. It is to be periodically reviewed in the light of observed results. In addition, time synchronization of various data acquisition systems and consideration of seasonal variation of reading are also

The frequency of the monitoring was decided based on the following flow-chart

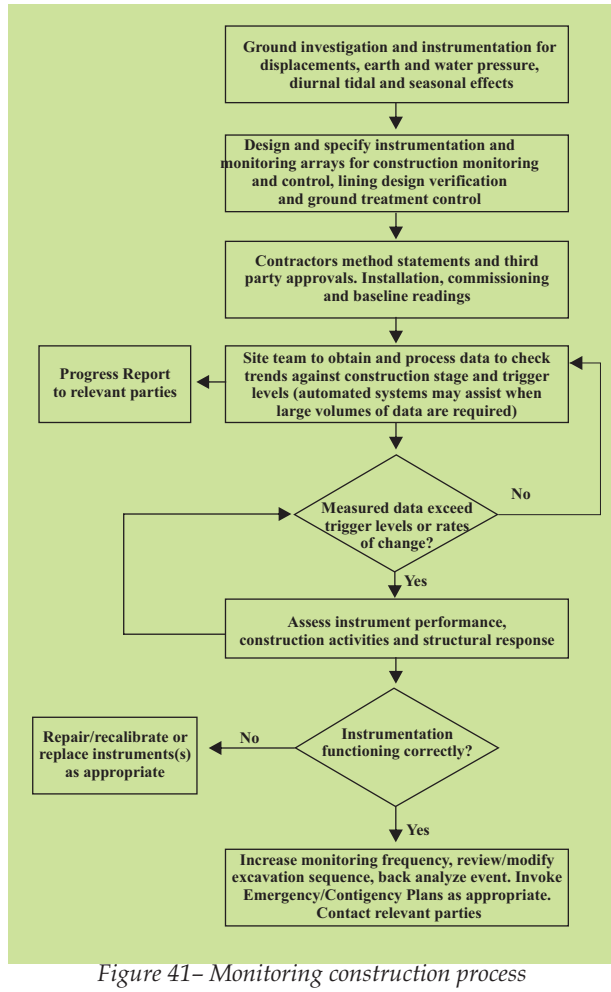

Figure 41– Monitoring construction process (Tunnel lining Design guide, 2004)

Safety issues:- In addition to routine safety precautions following specific precautions should be considered for safe & secure working

1. All employees involved in tunnelling activities goes to special training, in addition to basic site induction, specific training. It will always be given before starting of works in underground, whether as new employee or as a person new to the project.

- Possible Hazard, Risks and Health effects;
- Safe method of working;
- Site communication procedure;
- Provision at site protective equipment's; (EEBD; SCBA)
- Health and safety personnel at site;
- Emergency management systems available at site;
- Safe means of access from underground

2. Security and safe access & egress system for all tunnelling works including emergency procedures (evacuation, fire, first aid, flooding, etc.)
3. Safe operational procedures for machinery, plant and equipment
4. Where any construction worker is engaged in underground excavation in rocks and soft strata for tunnelling, such worker shall be protected by safety requirements of IS Code 4756 -1978 on 'Safety Code for Tunnelling Work' & BS-6164:2011; "Code of Practice for Health and Safety in Tunnelling in the Construction Industry".
5. Protective wear shall be provided to all the persons entering the tunnel, and arrangements are maintained for rendering prompt and adequate first-aid to the injured persons and any other facility as required by the IS Code 4756 - 1978.
6. Only the materials required for work in progress are kept inside the tunnel. All other materials are removed from inside the tunnel to keep sufficient space for emergency exit from the tunnel in case of any collapse or any other mishap inside the tunnel.
7. No flammable liquid or combustible materials are stored or kept inside the tunnel.

Ventilation:

All working area in a tunnel is provided with ventilation system to remove polluted air, gases and smoke produce by explosives, dust formed by the disintegration of rock, and exhaust gases from the diesel operated equipment. The concentration of various gases in atmosphere inside the tunnel by volume as required by the IS Code 4756-1978 shall be

- -Oxygen: not less than 19.5%
- -Carbon monoxide: not more than 0.005%
- -Carbon dioxide: not more than 0.5%
- -Nitrogen fumes: not more than 0.0005%
- -Methane: not more than 0.5% at any place inside the tunnel
- -Hydrogen sulphide: not more than 0.001%
- -Aldehyde: as formaldehyde not more than 0.0002%
- -Any other poisonous gas in harmful amounts
- In addition to the requirements given above, 2 cum of fresh air per minute shall be pumped for each brake horsepower of diesel engine used in the tunnel.
- The SLT must ensure the supply of fresh air to all underground work areas in sufficient amount to prevent any harmful accumulation of dust, vapour or gases. The SLT shall provide at least 4.25 cum of fresh air per minute per employee underground.
- Adequate lighting and battery operated emergency lights are provided or installed at all working faces or points of equipment installations. All supervisors and gang-mates are provided with cap lamps or hand torches.
- Test & measure at regular intervals likely to be after each blasting & prior to starting of work in each shift.
- Avoid re-circulation from the portal
- Extend close to the working face
- Avoid kinks
- Repair any damage immediately

Electrical Measures:

a. All electrical cable must be fire resistant and meets the requirements of BS 6164 or equivalent. An earthing cable shall be connected to the TBM and grounded outside the tunnel.

b. All junction boxes are to be fitted on fabricated stand and rubber mat, fixed on tunnel lining and must be earthed.

c. Cable and panel notification for safety precaution and symbol with painted board is provided as per requirement.

d. Armoured cable is provided for tunnel lighting purpose.

e. Tunnel lighting panels fitted on firm stands are provided at regular intervals.

f. All cables are to be laid on fabricated hooks on the opposite side of the pipe line connection with extra insulation for cable.

g. HT cable and tunnel lighting extension is carried out, as TBM advances, by the professional and qualified personnel.

h. All safety precautions are being taken into consideration during these extensions and any isolations must be suitably planned and Lock out Tag out (LOTO) system to be followed.

i. All electrical installations to be set, modified and repaired by qualified electricians; (work on high voltage network (transmission or power lines).

j. Adhere to national requirements

k. Use earth fault circuit breaker 30mA

l. Support cables and pipelines securely on brackets

m. Use appropriate fittings and coupling system

Illumination:

Good lighting contributes greatly to safety in tunnels under construction, as well as during maintenance, renovation and repair, and lighting levels should be such that any hazards on walkways and tracks can easily be seen.

Only competent electricians (ITI qualified/Govt. B licensed) are allowed to work on this tunnel light extension and repair job.

- Light all places of work and access ways
- Install special lighting at dangerous places
- Use flashing warning lights adjacent to dangerous locations
- All light fittings should be protected against ingress of water
- Check, maintain & clean lighting installations regularly
- Safety lighting system (emergency lighting)

Location	Minimum Lux Level
Walkways inside the tunnel	30 lux at walkway level
General working areas	100 lux at working surfaces
Tunnel face, excavation areas, crane lifting points	100 lux illuminated from at least two widely separated sources to avoid shadows

Table showing Level of Lighting

Maintenance

Regular maintenance, including cleaning of the luminaires, should be carried out to maintain the light output and the area lighting level. The luminaires should therefore be as easily accessible as possible.

The condition of the emergency luminaires should be regularly checked and any faults immediately rectified. The proper functioning of the emergency lighting system should be functionally tested at intervals not exceeding 3 months. Allowance should be made for

the fact that the batteries require a certain time to recharge following restoration of the supply after a prolonged power cut

Tunnel Communication:

The following equipment are used for tunnel communication:

- Telephone/ Radios
- Signal bell/ Signal by coloured lights/ Whistle/ Air horn
- CCTV (Closed circuit television).
- Equipment is required to be of a quality and standard to enable clear audible speed.
- It should be designed and to an international standard where it is robust enough to withstand any tunnel environment.
- Equipment should be always maintained and kept in good working order.
- Any fixed communication or temporary station is required to be brought forward / extended as the face is advanced.
- Suitable sound proof enclosures should be provided as necessary.
- The system should be independent of the tunnel power supply.
- It should be so installed that destruction of one unit will not interrupt the use of another units in the system.
- All wirings used to transmit warnings in an emergency should be fire-resistant and protected from water and against mechanical impact.
- Any communication Equipment used on site where BLASTING is being carried out should only be used with predetermined procedures.

Communication Signals

- Any communication signal should be distinctive sufficiently loud to avoid confusion.
- Signals to machine operators should be given by banks man only.

Audible signals

Audible signals by bell, whistle, air horn or other device should be considered for routine operations such as hoisting and lowering in a shaft, or for winch operation on an incline. Any signal should be distinctive and sufficiently loud to avoid confusion with any incidental or accidental noises.

Visual signals

The following are the standards signals given in pictorial form.

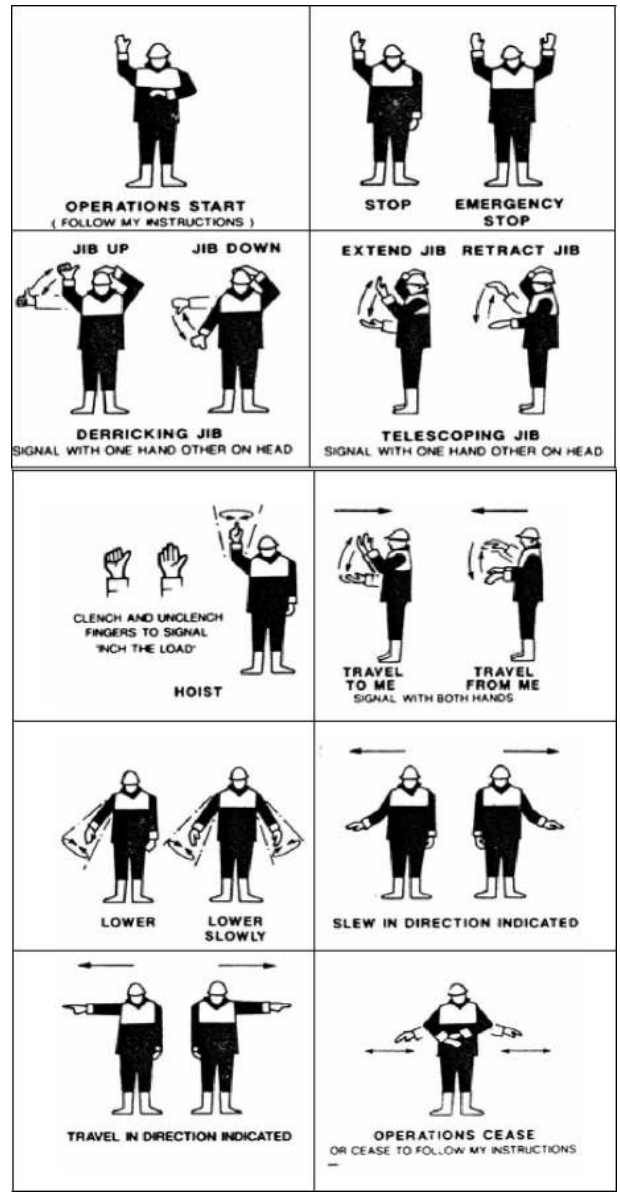

Fig-42 Various hand signals

Precautions where explosives are in use

Radio communication equipment on sites where blasting is being carried out should only beused in accordance with predetermined procedures.

All radio communications equipment that is intended to be brought on to the site should be assessed in accordance with international standard BS 6657 or equivalent for its possible hazardous effect on electro-explosive devices; this includes mobile phones and any such equipment that is a component of mobile plant coming on to site.

A system should be put in place to ensure that any equipment coming on to site that emits any electromagnetic waves is not going to affect the operation of any electrical, electronic or similar equipment on the site. Details of the frequencies and power of such equipment should be made available.

Modifications to site radio equipment should not be made without first assessing the resultant hazard and ensuring safe working in accordance with the guidance

Tunnel Entry Access:

No person can enter a Tunnel, Confined Space or Shaft without formal documented authorization. Authorization can only be granted when the person has undertaken a tunnel awareness briefing, or formal Tunnel Induction training

Person	Training	Authorisation
Worker	Tunnel Induction	Card and Hemet Sticker
Visitor	Tunnel Awareness briefing	Escorted Access permission card
Maintenance Worker	Tunnel Awareness Briefing	24hr Access Permission Card

Table showing Process flow Chart

Controlled Access/Egress:

Every access point into a Shaft Tunnel or confined space must have a controlled access point which is manned by a competent person. The competent person assigned for access/egress of persons must document, verify and authorise the access/egress of every person. Each entry point must have.

Tally Entrance Requirement

1. Access/Egress log book for the recording of ALL entry and exits of persons
2. Tag or electronic entry system which identifies individuals
3. Emergency contact list and FirstAid Equipment
4. Emergency Telephone (Wired)
5. PPE & safety devices

Safety guidelines for Drilling & Blasting

The following guidelines are set out to ensure safe execution for drilling and blasting. The guidelines do not detail specific requirements, but give consideration of the requirements for undertaking drill and blasting.

Drilling:

- Drilling area to be clear of all loose blasted material exposed with hard surface and shall be free from any debris, metallic and wooden articles etc. prior to start of drilling operation.
- Any old drill holes post pre-blast in the area shall be

checked for any presence of sockets. No drilling in the area to be started till all the old holes are checked and made free of any misfire. No drill is permitted on old holes.

- Any occurrence of hole with left out explosive shall immediately be informed to the concerned authority and competent person like shot-firer, blaster, foremen or Second class/ first class mines manager. Procedures related with handling misfires to be followed subsequently by competent person.
- Drill hole marking with required depth is to be marked in the area with white lime as per the designed drill pattern.
- Drilling operator and helper to use respiratory protection (Dust Masks), eye protection (Goggles) and ear protection (ear muff) during drilling operation.
- Dust control provisions to be implemented like covering the holes with wet gunny bag or wet drilling or selection of drill machine with dust extraction system.
- If the bench height exceeds 2m a parapet shall be provided to protect any fall. The height of parapet wall to be kept around 3ft.
- Drilling machine or tractor compressor to be subjected to inspection before deployment and ensure it to be fit and worthy of operation by P&M and SHE department before engaging on job.
- Hose pipe conveying pressurized air from compressor to the drill machine to be checked on daily basis for leakages and shall be rectified.

Charging Explosives into Drilled Holes:

The charging of explosives and placing into drilled holes requires set controls for the charging of explosives in the drilled holes:

- The diameter of the holes shall be selected according to the size of the explosive cartridge used and shall be able to accommodate the cartridge along with the shock tube and its hitch around the primer.
- Tamping shall be done only with wooden or plastic stemming rod without pointed end and exposed metal parts. The Primer must NOT be tamped.
- No holes shall be loaded except those to be fired in the immediate round of blasting. After complete charging all remaining explosives and detonators shall be returned to the explosives van for transporting back to the magazine.
- No explosives or blasting agents shall be left unattended at the blast site.
- Power lines and cables for portable electric equipment being used shall be kept at a safe distance from explosives being stored / handled / loaded into the holes.
- "Stemming" shall be done only with sticks made of wood or fibrous material. Stemming material should be of material inert to electricity.
- Shock tubes to be used should show no sign of kink/bend or compression.
- All electric detonators to be used in blasting should be checked suitably for their continuity using an Ohm-Meter. Minimum 4 EDs to be connected in series to conduct continuity test.
- Ensure all surplus explosives are in safe place and all equipment.
- All blasting cable used for connecting the blasting holes to be checked for its continuity and insulation prior to connection.
- Only charge after the whole face has been completely drilled
- Work can only be carried out under the supervision of an authorized and qualified blasting specialist

Firing:

Before firing of the explosive the following controls is to be undertaken to prevent any unauthorized persons being present and to prevent unauthorized access after firing

- Blasting timings shall to be fixed and the same shall be displayed conspicuously at all entry / exit points.

- No blasting shall be carried out before sunrise and after sunset unless and until it is controlled blasting with suitable muffling arrangements.
- Area in radius of 500 meters (blasting danger zone) of the blasting face must be cleared of all men, machineries.
- Sentries with red flags should be sent to the boundaries of the blasting danger zone at all entry points to avoid entry of any person in the danger zone.
- In addition to this Flagman should be positioned on highways / roads which pass through the danger zone so as to stop traffic from both sides during blasting operation. Necessary whistles, flags, reflective jackets shall be provided to all flagmen being engaged.
- Warning signs indicating a "blasting area" must be maintained at all approaches to the blasting area.
- Suitable blasting shelter to be provided and exploder should be operated only from the shelter.
- The blasting circuit should be checked for its continuity both before connecting the circuit to the main blasting cable and after connecting blasting cable immediately before the firing.

Blasting Signals & Controls:

The blaster must ensure that an audible signalling device, distinct from other signalling devices in the area, is used to give the following warning signals:

- At least 10 minutes prior to blasting, 12 short whistle signals must be sounded at one second intervals;
- At least 3 minutes must elapse after the last warning signal before initiating the blast;
- Following the blast and after the area has been inspected and found safe, one prolonged whistle signal of at least 10 seconds duration must be sounded, to signify that permission is granted to return to the blasting area.
- Key of the exploder should always be retained with the /shot firer / blaster or competent person designated to carry out the blast. The key should be restored to the exploder only immediately before firing the blast.
- When the movement of persons / vehicles are unavoidable with in blasting danger zone, only control blasting to be carried out.

Inspection after Blasting:

It is important that the area is inspected by the competent person before allowing any entry by workers immediately after the firing the holes, the blasting cable should be disconnected from the exploder.

- Shot firer / blaster shall wait for sufficient time to go to the blasted spot for inspection till the smoke and fumes are cleared off from blasted area.
- An inspection of the area of blasted location shall be carried out by shot firer / blaster to determine misfired holes before workers are allowed to return back to the location.
- An audible siren shall be blown to declare that blasting area is now safe for entry of men and equipment.

Safe Handling of Misfires:

It is important that if a misfire is detected the correct actions are taken and under total control of the shot firer / blaster, the following requirements are to be followed:

- If a misfire is detected, the area shall be barricaded so as to prevent entry of unauthorized persons other than person competent for handling a misfire.
- No other work should be done except that necessary to remove the hazard of the misfire and only those employees necessary to do the work should remain in the misfire location.
- No forceful attempt should be made to remove explosives from any misfired hole. The misfired holes shall be examined thoroughly and if the blasting circuit related to those misfired holes is intact. Misfired holes should be re-connected and fired.

- If the blasting circuit connecting to the misfired holes is burnt or fired, unexploded explosives shall be removed from the hole with the help of compressor or water jet. The hole thereafter shall be charged and re-blasted.
- Even after the above method if the explosives could not be taken out from the misfired hole, a hole(s) shall be drilled parallel to the misfired hole(s) keeping a distance of 300mm, charged and fired. If any explosives found in the blasting muck same to be collected and handed over to shot firer / blaster. The relieving hole shall preferably be drilled by the same drill operator who drilled misfired hole and in the presence of a shot firer/ blaster.

Conclusion:-

Given the fast-paced nature of today's tunnel construction, it is inevitable that all stakeholders will have to place greater focus on safety and quality. As budgets and time constraints take hold, project managers are forced to schedule everyone from boomers, shortcrete machines , excavators , dumpers , drilling ,ballasting use of explosives, installation of ribs and lattice girders, rock bolting activities etc tunnel water proofers and concreters in the same small space at the same time.

With trucks taking rock and spoil away from the tunnel at all hours of the day, waterproofing membrane can become a difficult task because of the airborne particles such as silica dust and diesel particulates. In fact, workers might have to wear breathing apparatus while installing membrane when previously they didn't have to.

Depending on the length of the tunnel and location, the air quality problem could be better or worse. This means project management staff will need to ensure equipment is on hand to protect workers in all cases. This safety equipment will always reduce worker mobility and increase fatigue which in itself presents additional challenges.

In fact, trucks could be removing rock and spoil at the same time as workers are inserting rock support and installation of waterproof membrane. If this cavern seems crowded, it is – and we haven't even mentioned the workers who could be pouring concrete behind that.

As such, a sense of coordination has to be created amongst the team to ensure that the Tunnel is constructed well in time by duly following all the safety and environmental parameters.

"Case Studies for Preventing Serious Injuries and Fatalities (SIFS) to Enhance Effectiveness of Construction Site Safety in Railway Projects"

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ABSTRACT

Among all industries, construction activities are considered as the most hazardous and construction safety is one of the most overlooked things during construction works. The construction work of railway projects is highly labor intensive and at the same time employs extensive use of construction equipment and machinery. Due to its critical working nature and heavy civil & track work, it requires more and more focus on the effective implementation of safety practices, development of safety culture, positive approaches towards health &safety to prevent injuries and other losses , which could occur in different levels of severity, some causing minor and major injuries with others resulting in fatality and dangerous occurrences. It is the responsibility of all level of management, project-linked staff, engineers, managers, supervisors, workers, etc. to pay special attention towards prevention of any untoward incident till the completion and commissioning of the project.

A general analysis in such large-sized construction projects on major causes that usually lead to unexpected accidents has revealed some of the key indicative factors, which relates to poor instruction by the supervisor, lack of training, lack of workers' awareness, over confidence, lack of maintenance of equipment and underestimating potential hazards and their associated risks by employees.

In order to enhance the standards of health & safety management and implementation of International & National Best Practices in railway construction projects, this paper discusses on practical safety tips and precautions through "specific case studies" for a) Construction Vehicles and Machinery, b) Welding and Cutting Operation, c) Loading and Unloading Operations, and d) Working at Height -Ladder Safety, to identify potential hazards, enhance understanding of unsafe acts & conditions, analyze the causes of accidents and suggest possible control measures for their prevention. The depth of analysis elucidated in specific case studies shall help in preventing and minimizing the occurrence of incidents and contribute to build an efficient and safe working environment/culture on all work sites of the project.

Such practice of continual improvement, knowledge and experience sharing from construction sites for dissemination of information among all stakeholders shall build the railway projects in a sustainable manner.

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INTRODUCTION

**"Preventable Accidents,
if not prevented due to our negligence,
it is nothing short of a murder"**

– Dr. S. Radhakrishnan

Accidents are unplanned and unforeseen events, which causeinjuries and losses unintentionally and unexpectedly. Every large-sized construction project is prone to accidents and at higher risk compared to other sectors. Accidents in construction works lead to severe difficulties to every stakeholder such as the Employer, Consultant, Contractor, Sub-contractor, Workers and the third party. However, accidents can be controlled by establishing proper safety management system in construction sites. All efforts should be made to continuously review the current safety management system in practice in large construction projects to establish a safe and health conscious working environment on construction sites during the entire period. Suitable control measures should be taken to ensure the compliance of all the required safety measures in an effort to prevent any accident in construction sites.

Among all other safety practices, "Case Studies" is a powerful safety training tool which provides many benefits to prevent accidents and helps in wider dissemination and sensitization. Case studies break-down the events leading up to the accident and helps to -

- Identify potential hazards;
- Understand accident causes;
- Discuss possible preventive measures;
- Determine the best methods for preventing a similar accident;
- Generalize the information learned to other safety issues in the workplace; and
- Transfer the analysis, problem-solving, and decision-making skills learned during the case study process to real situations on the job.

It is imperative in large construction projects, such as railways, to take proactive measures and precautions to prevent occurrences of accidents / incidents on the work sites that can happen as a result of carrying out routine activities. Such incidents not only affect the health and lives of the workers, but also slow down progress of the projects.

It is with this objective that a "multiple-part series of a safety training primer" is being initiated consisting of case studies to provide an effective way to identify potential hazards, enhance understanding of unsafe acts & conditions, analyze the causes of accidents and suggest possible measures for their prevention. Each case study carries an in-depth analysis in a simple and understandable manner on specific situations and real accidents / incidents scenarios on construction sites with real consequences for the people involved. This helps to expand knowledge relating to similar situations at sites for preventing cases of occurrences of serious injuries and fatalities (SIFs) resulting in enhanced site safety.

It is the responsibility of all project-linked staff, engineers, managers, supervisors, workers, etc. to pay special attention towards prevention of any untoward incident till the completion of the project.

Such construction safety training primer shall enhance awareness and knowledge among employees, engineers, field units' staff, workers, etc. of Employer, Contractors / Sub-contractors, Project Management Consultants (PMC), and other stakeholders to identify the potential risks leading to accidents / incidents / near miss cases and to implement such corrective measures which can ensure prevention of such occurrences on construction sites.

CASE STUDIES

"Accidents do not happen, but they are caused.Accidents / Incidents happen when we either don't know or under-estimate the Hazard and their associated risk, don't know the proper precautions to take for that riskor fail to take the precautions"

- Anonymous

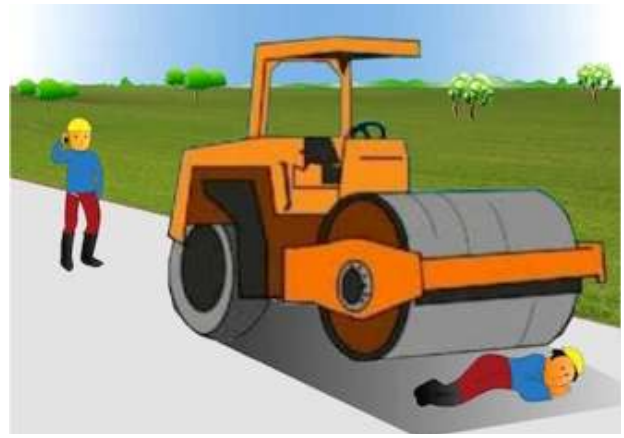
In this paper, following four case studies are discussed along with major "Safety Tips", which if diligently taken on the construction sites could result in preventing serious injuries & fatalities (SIFs) and loss of property. The situational analysis for the selected case studies have actually brought out those safety non-compliances / deficiencies, which resulted in occurrences of a particular incident. These case studies are related to safety considerations in –

1. Working Near Construction Vehicles and Machinery
2. Welding and Cutting Operation
3. Loading and Unloading Operation
4. Working at Height – Ladder Safety

CASE STUDY - 1: CONSTRUCTION WORKER HIT BY COMPACTION ROLLER

A daily wage worker engaged in weed removal work for final compaction of earth embankment for railway formation came and laid down in front of a stationary compaction roller at noon time; since there was no temporary rest shed/tree shelter/sunshade available in the vicinity. He did not foresee any danger in assuming that the operator would take care of him.

The compaction roller operator came from the other direction while talking to his supervisor on his mobile and was totally unaware. He had least imagined that a man could have been sleeping in front of the roller. He did not take any precautionary safety walk around the vehicle for checking any obstacle underneath, but directly climbed onto his seat and began to drive the vehicle forward.



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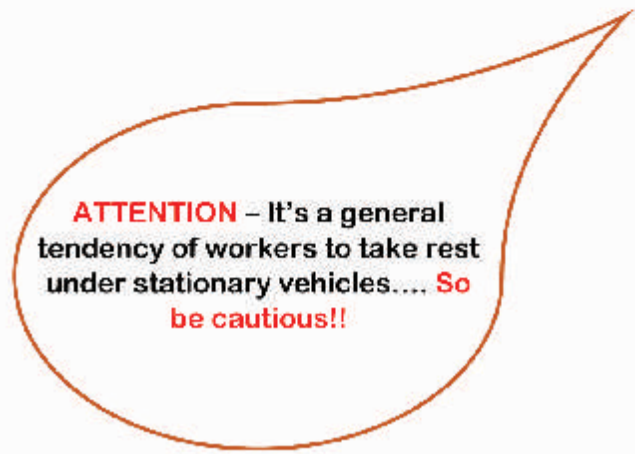
SAFETY TIPS	
Operator	☞ Whenever operator of any earth moving equipment or heavy vehicle is out of sight of his vehicle on the construction site, he should take a "*circle of safety walk*around inspection" to check for any obstruction before re-starting and moving the vehicle. ☞ Park equipment on even & secure ground & always put wheel stopper wedge while stationing the vehicle within working area. ☞ Ensure that all warning devices like horn, reverse horn, flashing lights, etc.are in working condition. ☞ Do not use 'Mobile' while sitting on the driver seat, even on stationary vehicle. ☞ Shut down the engine, remove ignition key and close the operator's cabin to avoid any unauthorized access.
Worker	☞ Always take rest or sleep under designated temporary rest shelter or shed provided on the construction site. ☞ Never walk or work or stand very close either in front or behind earth moving equipment. [DO NOT UNDERTAKE MULTIPLE WORK AT THE SAME LOCATION] ☞ Take extra precautions during foggy conditions in winter, while working close to compaction roller in operation.



Contractor's Site Engineer or Supervisor	☞ Provide regular training & daily pep talk to the operators and workers on site. ☞ Ensure adequate temporary rest sheds or shelter at work sites. ☞ Plant and Machinery In-charge shall ensure the provision and proper functioning of "Delay Start Mechanism" before permitting entry to heavy construction vehicles to the construction site. ☞ Pre-inspection check must be done regularly and before deploying any construction machinery at work site. ☞ Take extra precautions during foggy conditions in winter and engage trained signaler for the earth moving equipment. ☞ Conduct regular mock-drills on construction sites to create awareness. ☞ Display of warning sign board / stickers [➔ *resting under vehicle / equipment is prohibited*] on all earth moving equipment, as a potential for presence of such hazard of accidental rollover. ☞ No operator should be allowed to operate any construction vehicle, if he is found to be under the influence of alcohol, drug or any other intoxicating material that makes him unfit for site work. *[Always Stay ALERT! & Do Not Attribute incidents to Chance Rather Than to Behavior of Workers]*

CASE STUDY - 2: FLASHBACK FIRE DUE TO DEFECTIVE WELDING &CUTTING EQUIPMENT

A welder wearing required PPEs was entrusted with the task of cutting a metal plate using defective oxy-acetylene gas cutting/welding equipment [i.e. w/o flash back arrestor, non-return valve, etc.] BUT with proper provisions of firefighting arrangement in the vicinity & gas cylinders [oxygen & dissolved acetylene] rightly placed in a movable trolley in an upright position.

The Welder lighted an oxy-acetylene cutting torch when suddenly there was a flashback generated at the torch end and travelled towards the acetylene cylinder and caused fire. Realizing the cylinder was in a dangerous condition, he immediately informed his supervisor and responsibly at the same time prevented explosion by extinguishing the fire.


FIRE POINT


FIRE POINT


Common Unsafe Practices on Construction Sites
1
Damaged Hose
2
Cylinders Not Stored in Upright Position or not put on trolley during use
3
Fire Extinguishers Not Placed in the Vicinity of Work
4
Flash Back Arrestor, Non-Return Valve, and Regulator either not present or not in working conditions
5
Fail to Use Hose Clamps
6
Fail to Store Cylinder Away from Fire Prone Materials
REMEMBER!!!
Safe Precautions on Gas Welding / Cutting are Easy to Follow BUT Still Mostly Ignored


SAFETY TIPS
01
Beware of backfires and flashbacks and ensure proper flashback arrestors & NRV are fitted on both torch and cylinder side
02
Hose pipes and fittings should be kept in good condition and checked regularly
03
Place suitable fire extinguishers within reach
04
Regular training to be conducted on hazards associated with gas cutting / welding and their precautions
05
Pressure regulators should be fitted to cylinders in working condition
06
Safe handling of various gas cylinders are important
07
Keep gas cylinders in an upright position and secure it properly to avoid overturning
08
To avoid any damage to the valves of cylinder, they should be kept on movable trolley during work on sites
09
Utilise a fire watch person to monitor the hot work permit
10
Remove all inflammable or combustible material in the vicinity inclg rubbish, paper, etc. that could be potential fuel source of fire
11
Use Hot Work Permit System

CASE STUDY - 3: SLEEPER FELL ON WORKER DURING UNLOADING OPERATION

During unloading operation using guide ropes to lift the steel sleepers [photo inset] from the trailer, a sling man fixedthe slings on a sleeper with an F-15 crane hook. Thereafter, he put the guide rope with sling for controlling the swing of the suspended load / material.

Before the sling man could position himself to a safe place, the crane started lifting the sleeper resulting in tilting of unbalanced sleeper next to it, and the sling man could not escape himself when the sleeper suddenly turned onto its side, and ultimately it fell on him causing major injuries on his leg below the knee. He was immediately rescued by his co-workers and other site staff by manually removing the load & taken him to a nearby hospital after giving first-aid at site.


G VEHICLE
TANTRI
TANTRI
TANTRI


Workers must keep distance from the load


Never stand on truck / trailer during unloading operation

Safety Tips

1. The vibration caused by transportation must be taken into account when the unloading method is prepared / considered.
2. A sling-man should always stay at safe place when crane lifts the load. No unauthorized person should be allowed in the lifting zone.
3. All workers who sling loads must finish the course of sling works before lifting starts.
4. Unloading should start only after the stability of loads and condition of loads are confirmed.
5. All lifting operation should be under control of a competent "Lifting Supervisor".
6. All lifting appliances with a lifting capacity of more than one ton should be fitted with an 'Automatic Safe Load Indicator (ASLI)' and audible warning device.
7. All crane hooks should be fitted with operable safety latches.
8. Before commencing any lifting operation, the ground condition on which the crane is to stand should be checked in order to ensure that the load bearing capabilities are adequate.
9. All lifting gear should be stored properly and not left lying on the ground where it could be damaged.
10. All lifting gear should be visually inspected before use and if any defect is found, then it should be removed.
11. All lifting gear i.e. sling, chain, etc. should be in good condition and should be tested and certified in every six months.
12. Only trained and experienced operator, rigger and signal man should be allowed for lifting operation.
13. All lifting appliances should be inspected every three months by a competent person.

CASE STUDY - 4: WORKER FELL FROM LADDER DURING WORKING AT HEIGHT FOR WELL FOUNDATION WORK

The Contractor provided a straight ladder fabricated on construction site with ladder rungs made from reinforcement steel bar and was positioned at around 45o angle [safe angle is around 75o] but securing it at its base for ascending / descending of workmen / engineers for work at height in a hot weather condition during well foundation work for construction of special steel bridge for a railway corridor.

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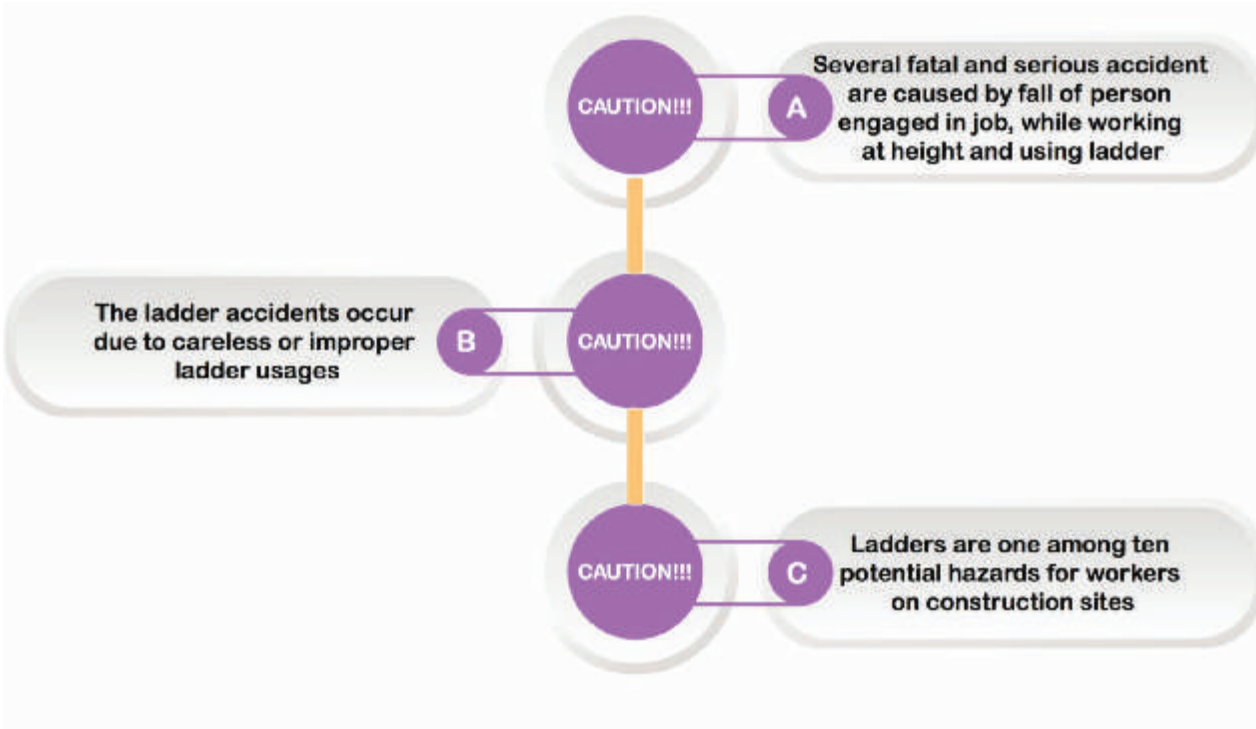
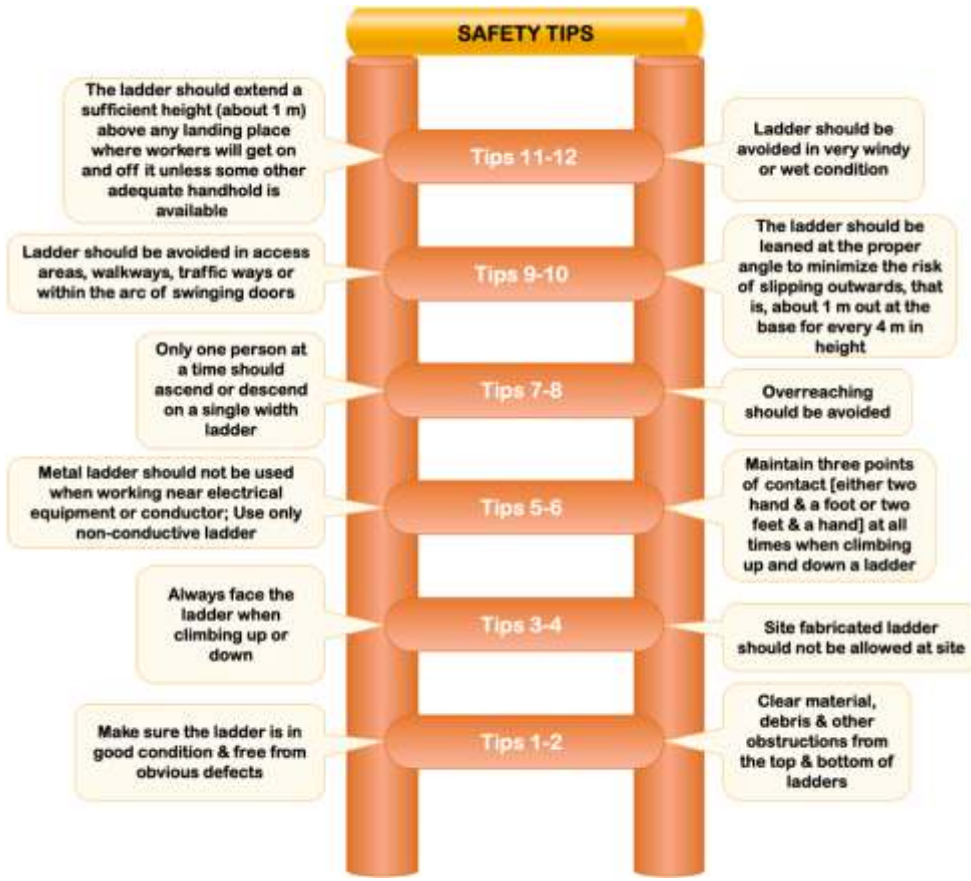
Three workers without following safe practices accessed the ladder together and started descending one after another with their backs to the ladder. While two of them got down safely, the third worker slipped and fell-down from a height causing fracture to his right shoulder.

1. Coming down a ladder is more dangerous compared to going up

2. Sliding is the main cause of fall from the straight ladders

3. Do not provide ladder rungs made from steel rebar as it causes discomfort to feet & hands & enhances slippage


CAUTION!!!
A
Several fatal and serious accident are caused by fall of person engaged in job, while working at height and using ladder
The ladder accidents occur due to careless or improper ladder usages
B
CAUTION!!!
CAUTION!!!
C
Ladders are one among ten potential hazards for workers on construction sites


SAFETY TIPS
The ladder should extend a sufficient height (about 1 m) above any landing place where workers will get on and off it unless some other adequate handhold is available
Tips 11-12
Ladder should be avoided in very windy or wet condition
Ladder should be avoided in access areas, walkways, traffic ways or within the arc of swinging doors
Tips 9-10
The ladder should be leaned at the proper angle to minimize the risk of slipping outwards, that is, about 1 m out at the base for every 4 m in height
Only one person at a time should ascend or descend on a single width ladder
Tips 7-8
Overreaching should be avoided
Metal ladder should not be used when working near electrical equipment or conductor; Use only non-conductive ladder
Tips 5-6
Maintain three points of contact [either two hand & a foot or two feet & a hand] at all times when climbing up and down a ladder
Always face the ladder when climbing up or down
Tips 3-4
Site fabricated ladder should not be allowed at site
Make sure the ladder is in good condition & free from obvious defects
Tips 1-2
Clear material, debris & other obstructions from the top & bottom of ladders

CONCLUDING REMARKS

This paper has highlighted the fact that most accidents on construction sites can be prevented by taking simple and appropriate measures or adopting Safe Working Procedures, including good housekeeping at construction sites, right man for right job, correct use of required personal protective equipment, provision of safety awareness & training, effective communication &consultation etc. If we work carefully and take appropriate safety measures, there will definitely be fewer work injury cases, and our sites will become a safe and secure place to work in.

It is also true that the severity of injuries caused by coming into contact with heavy machineries is very high and potentially fatal. However, such accidents can also be prevented as they are mostly foreseeable. It is important to first recognize the potential hazards and deal with each situation seriously. Only with such right attitude can we rectify / correct them in time to prevent another serious accident/ incident from occurring.

Through the identification of critical causes and effects of incidents in the selected four case studies in the present paper, it comes to the fact that human behaviour is identified as the main cause of construction accidents. Negligence or mistakes can happen due to uncertain circumstances. Hence, unavoidable accidents have to be expected in the construction projects. The commitment of all humans involved, from the project manager to the labourer towards good practices would enhance the safety performance in construction sites.

It is expected that different project sites shall disseminate these case studies to train people for prevention of potential accidents and injuries on construction sites.

Role of detailed Plan-Profile sheets in safe and Time bound Construction of Dedicated Freight Track Corridors in Mumbai Suburban Area

ABSTRACT

The authors through this paper intend to bring out the importance of the planning in finalization of Plan and Profile under the Western Dedicated freight Corridor in Mumbai area. New 2x25 KV double line dedicated freight corridor tracks, capable of carrying 32.5-ton axle load are proposed to be built on this stretch. The tracks are planned in heavily populated Mumbai area parallel to existing suburban networks of Central Railway within the limited ROW, many obligatory points, structures and numerous underground and over ground utilities.Taking care of the minute details during the preparation of Plan and profile has ensured that before taking up the actual execution of the planned works, the works get constructed in minimum possible time. At the same time, the removalof various utilities of different type and modifications in the existing structures is carried out beforehand. The proper detailing and planning at the Plan and profile stage can thus lead to considerable benefits in sensitive locations for fast paced construction.

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CGM
Mumbai(South)
DFCCIL

Anurag Rastogi
Dy CPM/Engg.-I/Mumbai(S),
DFCCIL

1.0 INTRODUCTION

Ministry of Railways (Govt. of India) is constructing the highly ambitious 2x25 KV electrified double line Western Dedicated Freight Corridor carrying heavy haul(HH) freight tracks for a length of about 1500 km between Mumbai and Delhi. A stretch of about 100 km in the state of Maharashtra runs parallel and close to the densely worked suburban tracks of Mumbai, along the coastal area.

In this stretch, there is severe restriction of the land due to built-up surrounding locations. On one hand, one encounters the existing railway tracks while on the other hand, there are commercial and residential structures, parallel highways etc. The stretch is thus having all the problems associated with the built-up area like a number of already constructed ROBs of low heights, numerous utilities of water, petrol & gas pipe line, electrical and telecom cables and various buildings like schools, multi-story buildings etc.

While planning the Plan and profile (P&P) of such complicated section, it has to be ensured that the surrounding structures and utilities are disturbed to the minimum, the natural drainage of the area is not affected and if affected, suitable planning is resorted to have minimal effect. The service roads and cart roads used by the local public are least affected or provided suitable alternative for access. The details to be taken care of while determining plan and profile of any section along with the methods to be adopted and detailing to be shown are beautifully presented in the RETS publication "Drawings and Estimates". The concepts of the same have been utilized while planning Plan and Profile of DFCCIL stretch under consideration.

The DFCCIL tracks have been planned with the maximum ruling gradient of 1 in 200 and maximum curvature of 2.5 degrees. Thus, the tracks cannot exactly follow the existing Railway tracks which are having ruling gradient of 1 in 100 (JNPT- PNVL) and 1 in 150 (PNVL – VASAI) and maximum curvature of 8 degrees. Alignment through detours have been adopted at places which mostly cut across heavily populated areas.

The succeeding description gives the types of factors taken into account while finalizing the plan and profile and the manner in which the various restrictions were dealt with, so as to ensure smooth execution of the work.

2.0 GENERALPROBLEMS ASSOCIATED WITH THE PLAN AND PROFILE IN THE MUMBAI SUB-URBAN

2.1 General Geography of the stretch

The area in which the double lines of the Dedicated Freight Corridor are proposed to be laid falls in the densely populated sub-urban area of Navi – Mumbai, Thane and Vasai region. The stretch is lined up with heavy built up-area in its major portion.

The lines start from JNPT and at the onset itself, near JNPT, very poor soil and high-water table is encountered. Further, since the land belongs to the JNPT and lot of oil/gas imports are there, a number of pipeline utilities in the land have been laid to the nearest tank farms. Most of these utilities are in between the existing tracks and highway.

Immediately after the JNPT area is a hillock which is accommodating the National and State highways (converted to NH now) on both sides of the Railway tracks. NHAI has already acquired land for its 8-laning work on both sides of the Railway land. This restricted land space requires lot of skills to plan and execute the laying of tracks.

A stretch of around 2 km passes through Panvel sub-urban and express yard and need to be delicately designed preventing not only any damage to Railway structures & cables but also preventing any inconvenience to passengers and staff.

Some stretch of land acquired in Kharbao area is having the state highway passing through and needs to be shifted for laying DFCCIL tracks.

Another stretch of the alignment passes through Sanjay Gandhi National Park and Tungareshwar Wildlife Sanctuary and has thus its own limitations for

protection and free passage to natural habitats of the forest.

Land acquired in some stretch in Kalyan regionhad the multi-story buildings for which necessary R&R is under process. The ROW is thus limited with very less margin for lateral shifting of the proposed tracks.

Being a built-up area, a number of Road over bridges are already constructed across the existing Central Railway line. The clearances of these ROBs are generally as per the Railway SOD (Vertical clearance of 5.85 to 6.25m and lateral clearance of 2.5 to 3.0 m). Rebuilding of ROBs in a built up area with increased vertical clearances has an impact on the acquisition of land on approaches. There are various service roads parallel to the Railway boundary and some even have come in Railway land after acquisition of land for the DFCCIL tracks.

2.2 Land Problem and R&R

The land is precious commodity in Mumbai sub-urban. The importance has increased due to coming up of numerous other projects in the area like Trans-harbour link, 8-laning of the National highway, Navi Mumbai Airport, MRTS, etc.

The land was principally acquired by Railways in 1960s. When the land record for the stretch on which DFCCIL tracks were planned to be laid, were taken from the Central Railway, it was observed that the mutation of certain stretches was not done. During the survey itself, resistance to entering those patches was noted.

The land acquisition,for additional required land for DFCCIL tracks, in this stretch was started by DFCCIL somewhere in 2010 under the Land Acquisition Act 2008 {The Railways (Amendment) Act 2008}). The acquisition continued upto 2016 i.e. even after coming of the new land acquisition Act 2013 (RFCT-LARR, 2013). Hence the major hiccup was observed when granting compensation (especially the Rehabilitation part) for the new land and Project Affected peoples (PAPs) as per new Act at locations adjacent to the old acquired land. The reason being

Fig. 1a Acquired land with PAPs

Fig.1bAlignment crossing highway and PAPs

that the Rehabilitation compensation in New Act is much more (3 to 4 times) than in Land Acquisition Act of 2008.Since any further land acquisition would have been difficult, plan and profile had to be designed in such a way so as to cause least disturbance to nearby people. Typical arrangement of P&P with PAPs is shown in Figure 1a & 1b. Solution like retaining walls, sound barriers, etc have to be used liberally.

2.3` Utilities and other hindrances

The land in JNPT area belongs to the JNPT and has been given by JNPT to Central Railway on lease. JNPT had permitted laying of numerous utilities of petroleum and gas pipe lines of IOCL, Reliance, Deepak fertilizer, BPCL, IOTCEL, ONGC and MGL in their land. The DFCCIL alignment with utilities at JNPT yard is shown in Figure.2. Besides JNPT area, the utilities of water and sewage pipelines are existing in the

municipal areas of CIDCO, Navi Mumbai, Panvel, Kalyan Bhiwandi and Vasai. A number of underground and overhead electrical utilities ranging from 11 KV to 440KV are existing throughout the land corridor. Those below 33 KV need to be made underground, while those above 33 KV are to be raised or their tower locations shifted for required horizontal or vertical clearances. This itself becomes difficult due to limited land availability.

Figure 2. JNPT area of the DFCCIL corridor

National highway or private lands are existing parallel to the land given to Railways in majority of the areas. Hence these utilities cannot be shifted out of the Railway boundary and thus need to be either protected or shifted in the Railway boundary itself so as not to affect the DFCCIL tracks.

Plan and profile had to be designed taking into account the presence of such utilities.

2.4 Existing Roads in DFCCIL acquired land

The DFCCIL tracks in the Mumbai area are passing through the highly built-up area with buildings and service roads mostly running parallel to Railway land.

The most peculiar aspect was the presence of the National highway(NH) on the land which was required for the provision of DFCCIL tracks near Gavhan phata area of CIDCO. The NH had also planned for the widening of their road from 4 lane to 8 lane. They also required the same land, as required by DFCCIL. This created a deadlock. The matter was posted on Pragati portal for the decision to be taken by the Ministry of Railways and MORTH.

Similarly, problems related to shifting of state highway in Kharbao area and Municipal road in Dombivili area were a matter of concern. Hence these required adequate care in finalizing plan and profile.

2.5 Existing ROBs with lesser horizontal and vertical clearance

The ROBs in Panvel area are built at locations where the ROB approaches are terminating into the road crossing locations and densely populated areas. It is not feasible to lift the ROBs to accommodate DFCCIL tracks.

The Shilphata ROB near Nilje was built in 2008. The horizontal clearance is even less than the required as per SOD.

Some ROBs like Gavhan phata, Vahle Dhumale &old Shil phata had vent only for accommodating IR tracks and needed to be rebuilt. The rebuilding of Gavhan phata ROB had its peculiar issue as the NH runs on both sides at a level of about 10 m above Railway tracks. Further, the laying of DFCCIL tracks gets complicated as DFCCIL tracks had to be carried around 5 m below Railway tracks causing difference in level with the adjacent NH of about 15 m.

2.6 Span configuration for RFOs

The span configuration for the RFO is decided based on the number of tracks to be crossed, existing utilities below the RFO, number of existing & future tracks, availability of ROW, skewness of the proposed RFO to the underlying tracks and other site constraints. The RFO at Kopar,if planned similar to the parallel RFO of Railways for span of 61m, was not possible as during the detailed survey it was found that bunch of cables of S&T and Electrical are passing below. These cables are for the sub-urban and main line tracks of CR. The shifting of these cables to accommodate span of 61m involved huge expenditure and a number of disconnection blocks and a new RRI tower itself, as there was no place to accommodate the replacement relay system. Further, the drainage Nallah and sewer lines near the abutment area of the RFO also created space constraints. These are shown in Figure 3 below.

Figure3. DFCCIL alignment at RFO-06

For the RFO at Kalamboli, the skew angle is of the order of 700 as the DFCCIL tracks running parallel to the CR tracks had to rise and cross them in the limited ROW on one side. Due to the presence of steel yard, the DFCCIL tracks could not be taken away for reducing the skew angle. Apart from the main line tracks, a coaching complex is also coming up, parallel to the main line, at Kalamboli. These tracks were not accounted for in the Project report and thus the earlier envisaged span arrangement was not feasible. Thus, span arrangement, crossing angle, vertical and horizontal clearances were required to be re-determined with great care and caution so as not only provide the required clearances but also not infringe with the under lying utilities. Further, no hindrance should be caused to the running tracks during the construction of the flyover for smooth execution of the DFCCIL work.

2.7 Existence of National Park – Animal passes, safety fencing

A part of the DFCCIL alignment is passing through the dense forest of the Sanjay Gandhi National Park and Tungareshwar National Park with a large of animals moving around. The forest authorities had desired to provide sufficient animal under and over passes with chain link fencing on both sides of the tracks for the full forest area.

2.8 Existence of adjacent buildings – like schools -retaining walls, sound barriers

The DFCCIL tracks have been planned with a ruling gradient of 1 in 200 with maximum curvature of 2.5 degrees. In order to meet these parameters, it had not been possible to carry the DFCCIL alignment all along the Indian Railway tracks (having ruling gradient of 1 in 100 in JNPT-PNVL Section and 1 in 150 in PNVL- Vasai road section). Hence three detours have been provided. These detours are passing through the villages. In order to avoid shifting of too many people and to keep the land acquisition cost to the minimum, bare minimum land has been acquired. This led to passing of the DFCCIL alignment adjacent to schools, residential buildings and such habitated area (Figure4).

Figure 4. DFCCIL alignment passing through habitated area

2.9 Railway passenger yard on both sides of DFCCIL corridor – Panvel

The DFCCIL track from JNPT to Vaitarna had to pass thorough the Panvel area. In this regard, various options of passing the DFCCIL tracks through the congested Panvel area were explored, including the reconstruction of various ROBs etc. Finally, the DFCCIL tracks were planned to pass between the sub-urban and main line tracks by carrying out the re-modelling work of the Panvel yard. Though this does not seem to be a good choice, as yard remodelling is not easy and takes lot of time. But with the given constraints, no other better solution could be found.

While passing the DFCCIL tracks through Panvel, not only there was a challenge of laying the tracks with constraints of Railway buildings and oil depot but also maintaining the public and staff safety wasof prime importance. There were other challenges which were to be taken into account like provision of subway for

parcel, ducts for passing the Railway signal and electrical cables, rebuilding of the pedestrian subway, proper drainage of the area, minimum disturbance to the adjoining platforms and the covering sheds without affecting passenger safety.

3.0 SOLUTIONS FOR FAST PACED CONSTRUCTION

The various problems as detailed above were delineated for each and every site. The plans and profiles for each stretch were planned in such a way that the fast paced construction is achieved in spite of the existence of all the problems as described in preceding paragraphs. Some of the steps taken for ensuring the same are detailed below:-

3.1 Ensuring adjustments in gradient with proper drainage

The general geography of the stretch was understood and the horizontal and vertical profiles were adjusted by taking care of the ROW, the amount of cut and fill and the drainage requirement of the area. The ruling gradient of the DFCCIL tracks was different (1 in 200 as compared to 1 in 100 in JNPT-PNVL and 1 in 150 in PNVL-JASAI) from the Railways. At the same time, the loading of the DFCCIL (32.5 ton axle load) is much higher than the Railways (22.5ton axle load). Hence the alignment was kept away from Railway tracks so as not to cause overlapping of the DFCCIL formation over the IR cess. Wherever the same was not feasible, retaining wall was proposed. For proper drainage between the IR and DFCCIL tracks, the longitudinal and cross drains were provided so as to avoid cutting of Railway banks during heavy rains of the Mumbai region.

3.2 Land Compensation as per RFCT-LARR 2013

In order to decide upon the issue of Rehabilitation & Resettlement (R&R), meetings were held with the Secretary (R&R) of the Maharashtra government, who decided that the compensation shall be paid for all the pending cases as per RFCT-LARR 2013. Accordingly, the proposal was made and sent to the Railway Board for approval along with the Draft Government Resolution (GR) for getting issued from the Government of Maharashtra. After lot of pursuing by the Mumbai (South) unit of DFCCIL, the GR was issued by the Government of Maharashtra paving the way for R&R.

The matter of providing the housing units to the displaced was another major hurdle. The issue was taken up with different state bodies like Kalyan & Dombivili Municipal Corporation (KDMC), Maharashtra State Road Development Corporation (MSRDC), Panvel Municipal Corporation, City and Industrial Development Corporation (CIDCO), Maharashtra Housing and Development Authority (MHADA) etc.

A total of 3215 housing units were required. KDMC alone agreed for providing more than 800 housing units in first phase and another 800 housing units in second phase. Panvel Municipal Corporation also agreed to provide housing units for people getting displaced in their area.

Some people even agreed for cash compensation in lieu of the housing units.

Thus the Plan and profile of the affected stretch could be prepared by carrying out the survey of the habituated area by persuading the people and convincing them of providing alternate accommodation and proper compensation as per RFCT-LARR 2013.

3.3 Dealing with Utilities

Depending upon the importance of the utilities, the possibility and ease of their shifting and availability of suitable land for accommodating them and the DFCCIL tracks, the plan and profile of the stretch was planned. The utilities getting affected were then classified into three different categories-

a) Utilities to be shifted along with necessary casing/protection by respective utility owner

b) Utilities to be protected (at their existing place) with suitable casing arrangement by respective utility owner

c) Utilities needing only safety precaution by Contractor for avoiding damage during execution of DFCCIL works.

Action was taken accordingly for the shifting or protection of the various utilities so that they do not

affect the execution of DFCCIL works. One such stretch in which ground improvement was to be done keeping the utilities in place is as shown in Figure 5. The stone columns which could be taken up were marked in green color and those which could not be taken up due to existence of utilities were marked red and taken up after shifting of utilities.

The work of ground improvement was meticulously planned by plotting the proposed locations of stone

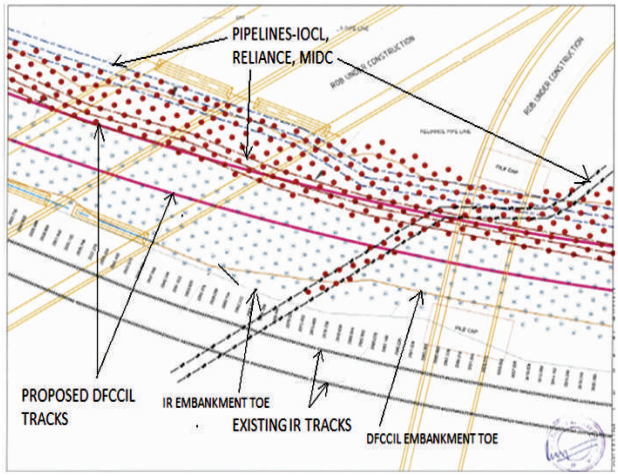

Figure 5. Work planning with utilities in place

column over the existing layout of the utility so that the work is done without affecting the utility.

3.4 Road diversions and protection walls for accommodating DFCCIL tracks

The roads coming in the alignment of the DFCCIL tracks were either accommodated by acquiring adjacent land or kept in the existing location within the Railway land by constructing retaining walls along the track.

In some areas like Dombivili (Figure 6), the service road land had to be acquired to accommodate DFCCIL tracks. In order to lay DFCCIL tracks, the retaining wall at the edge of formation (i.e. 4.0 m from the nearest track centre) was planned (to accommodate service road) to be constructed instead of going close to the Railway tracks and constructing retaining wall between Railway and DFCCIL tracks.

Figure.6. DFCCIL alignment through Dombivili

As described in para 2.4, the land was required by both NHAI & DFCCIL for work near Gavhan phata area of CIDCO. The matter was resolved by acquiring the land on the other side of NH and shifting the alignment of NHAI laterally. DFCCIL also agreed for minimum land width for laying their tracks with proper planning of the alignment. The alignment and level of DFCCIL tracks, in this area was so planned that the excavation (to the levels of around 15m below NH level) for DFCCIL tracks can be done without affecting the NH traffic and at the same time ROB is kept at such levels so that approaches could be adjusted in the available land space. The gas pipe lines of Reliance and Deepak fertiliser existing in this stretch were making the situation all the more difficult and therefore were planned to be shifted to the other side of Railway tracks. The plan and profile with the NH and pipe lines is as shown in Figure 7a & 7b below.

Figure7a. Plan and profile at Gavhan phata area

In Kharbao area, State highway land was acquired for laying the DFCCIL tracks, as there was no other alternative, the state highway was then diverted (Figure 8) to accommodate DFCCIL tracks.

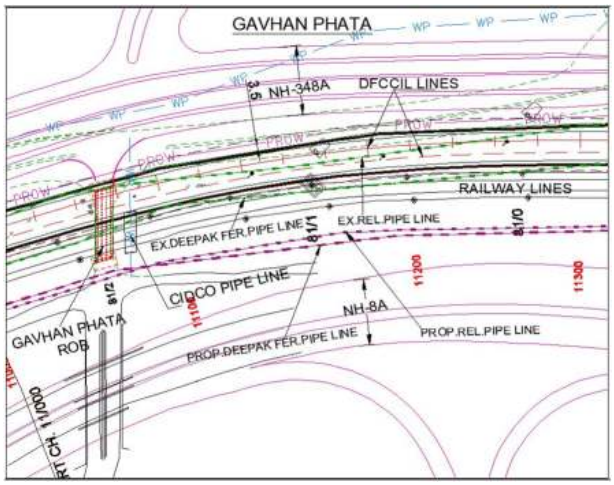

Figure7b Alignment plan at Gavhan phata

Figure 8. Diversion of state highway for tracks

3.5 Alignment below ROBs with restricted clearances

Each ROB was dealt as per its merit. The ROB in Panvel area (Figure9) had restriction on approaches and could not be lifted. Hence it was decided to lower the alignment below the ROB. Some other ROBs like near Navde, Bhiwandi etc were also not possible to be raised and the alignment was lowered to achieve the required vertical clearance for DFCCIL.

Figure.9. DFCCIL alignment through Matheran ROB

The ROB at Shil phata was relatively new and there was no point in dismantling and re-building it. Hence it was decided that DFCCIL alignment should be carried under it with condonation of SOD. Further, the plan and profile had to be designed meticulously after many site visits and picking up the details of surroundings as there were water pipe line crossing and minor bridges on approaches. The complexity can be understood from the Figure 10.

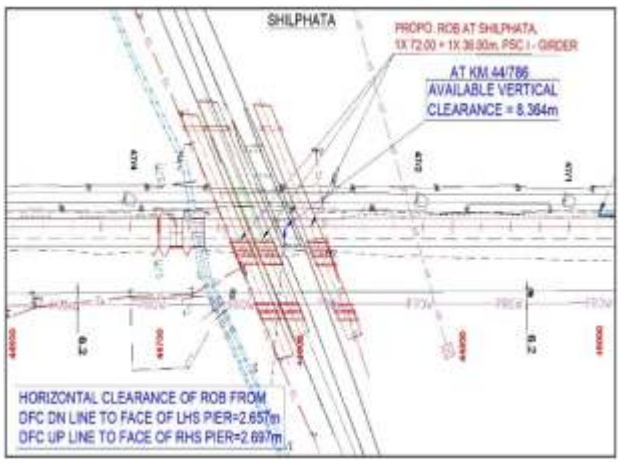

Figure 10. Plan & Profile at Shilphata ROB

For some of the ROBs like Gavhan phata, Vahle Dhumale, where vent for DFCCIL tracks was not available and the ROB is connecting the roads parallel to the DFCCIL tracks, there was no other option but to go for re-building it with increased span.

3.6 Alignment over RFOs

The alignment over RFO-06 at Kopar was straight. However, the main problem was determination of the span length. The solution to the various problems could be found after visiting the site, carrying out cross trenching to locate utilities and coordination with the various utility owners like KDMC, Railways etc. After going through rigorous detailing, it was found that instead of existing span of 61m, span of 76.2 best suits the condition with minimum disturbance to various utilities.

At Kalamboli, the RFO before rising had to pass below the Pune Expressway, rise from there parallel to the existing Central Railway tracks, take a turn and cross the Central Railway tracks. The ROW availability on the Panvel approach was very less. After detailed site inspection, span of 110.5m and 85m with a curvature of the order of 3.5 degrees could be finalized. Though this a non-standard span arrangement, but being a design-built contract, main focus was on providing hindrance and trouble-free environment for execution. This enabled achieving a maximum speed of 85 kmph. This arrangement even required modification to the existing coaching yard ESP for which CR was kind enough to agree. The finalized plan and profile showing the various infringements and utilities in the stretch is as shown in Figure 11.

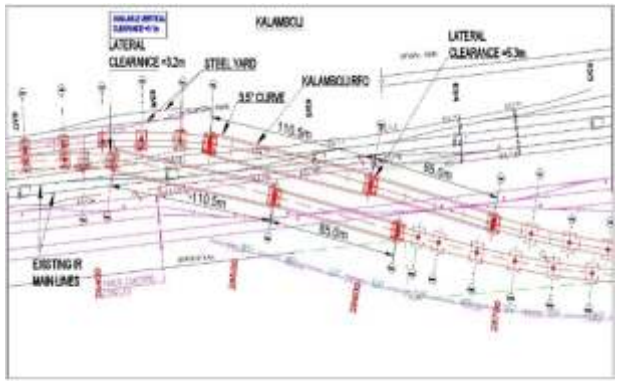

Fig 11. Plan & Profile at Kalamboli RFO

Thus, finalization of the alignment plans of the RFOs required a lot of effort and coordination with Railways without which the Plan & profile of the stretch could not have been approved.

3.7 Alignment through National park

The plan and profile through the National park had to be designed in such a way that the required all-weather animal under and overpass (Figure 12) could be provided at the designated locations. This required adjustment of plan and profile of approaches to the National park and close co-ordination with the Sanjay Gandhi National Park (SGNP)authorities.

Figure 12. Conceptual Animal overpass at SGNP

3.8 Alignment through built up areas

As already informed that in order to avoid shifting of too many people, bare minimum land was acquired. This led to the alignment coming close to the habitat structures like multi-storey buildings, schools, religious structures. In order to protect the same, the alignment was kept as away as possible from these structures. This was possible when the formation level difference between the Railway and DFCCIL tracks is less. Accordingly, the Plan and profile were designed. However, at certain locations where the same was not possible, retaining walls with sound barriers were provided.

3.9 Alignment through the Railway passenger yard

In order to finalize the alignment through the Panvel passenger yard, joint inspections were held with the Railway electrical, signal and civil departments delineating the various utilities currently passing and those planned to be provided after the yard remodelling work. Care was also taken to keep the existing facilities of parcel, passenger subway, oil

depot and Railway buildings (not being dismantled) intact to the extent possible. Another important aspect was the planning of the proper drainage not only for the DFCCIL portion but also maintaining the drainage of the existing yard leading to the DFCCIL area.Alignment was drawn up including the plotting of various utilities, drainage lines through the yard and making provisions for their safe and efficient passage. The optimum plan and profile could be finalized after a number of iterations and is shown in Figure 13a & 13b.

Figure 13a. Plan & Profile at Panvel yard

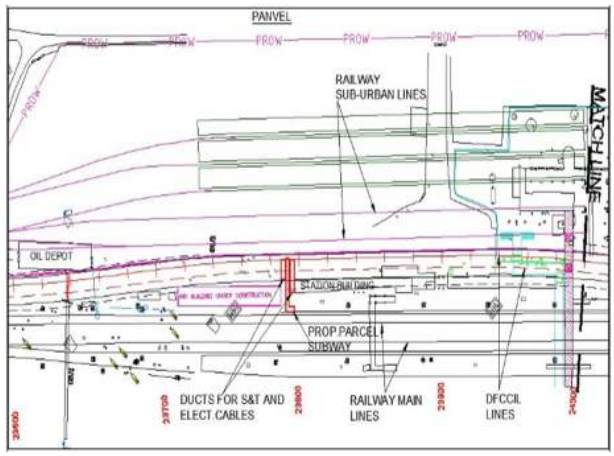

Figure 13b Utilties planning along with P&P

4.0 LIMITATIONS

The detail planning for the Plan and profile was done keeping in mind that once the scheme of execution is finalised then work can be executed at a fast pace. Even after taking all aspects into account there are certain areas in which extra care is to be taken and this may involve additional time for completing the works: The main areas of concern are:

a) The availability of limited ROW at many Deep cut locations in Kundevahal and approach to tunnel in Vasai detour. This will involve lot of rock protection works before the section is opened for traffic.

b) The passage of the alignment through the Railway passenger yard at Panvel. The work can only be done in limited hours and that too only with access through the ROW at one end only.

c) Crossing the Railway main line tracks at three locations requiring RFOs. Lot of safety issues have to be addressed before the works are taken up.

d) Passing through the built-up area requiring Rehabilitation and Resettlement of the Project affected people.

e) Dependence on the work of NHAI at Gavhan phata location for shifting their highway to the newly acquired land.

5.0 CONCLUSION

So how does detail plan and profile helps in expediting the pace of construction of a project:

a) Infringements to the adjacent Railway tracks and structures are taken care before hand.

b) The proper planning and design of the utility protection works prevents disruption of works at later stage.

c) Proper protection works for the adjacent structures and the suitable passages for the people and animals in the plan and profile leads to uninterrupted progress of work unaffected by the external agencies influence.

d) Updating Land records for the land coming under the project work during Plan and profile finalization itself ensures that alignment is completely in hindrance free land and there is no disruption of works by locals during execution.

e) Properly designed Plan and profile causes least Rehabilitation and resettlement of the project

affected people, and thus saves considerable effort in this regard.

f) Disputes with the other ongoing works, adjacent to the proposed works, are avoided by detailed planning during plan and profile finalization.

g) Proper coordination with the adjacent agencies of state government, central government and private help in making them understand the importance of our project and limitations so that they undertake their work related to our work speedily and timely.

6.0 RECOMMENDATIONS

Based on the experience gained during the designing of the plan and profile, following recommendations can be made on the importance of the detail plan and profile for the fast-paced construction: -

a) The plan and profile should keep in mind the limitation of ROW and the presence of the structures adjacent to the ROW and identify the critical locations.

b) The survey of all the existing utilities need to be done in detail by involving all the concerned utility owner from the beginning itself and understanding their limitations.

c) Proper drainage should be planned not only for the DFCCIL tracks but also the adjacent tracks and other areas so as to avoid drainage problem and disputes later on.

d) The ongoing works along the stretch parallel to the proposed tracks should be studied and proper coordination with the affected agencies is required to be made to take care of any unforeseen situations or disputes at later stages.

e) Dependence of our works on the works of others need to avoided to the extent possible by proper planning and designing the plan and profile, as it can delay the progress of planned works.

7.0 ACKNOWLEDGEMENTS

The authors are thankful to the designers of the SMEC, Tata Projects Limited and Project Management Consultancy firm OCGC and the concerned officers and staff of DFCCIL team who provided their inputs and helped to work out the optimal solution to the various problems of plan and profile.

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New Mechanized construction techniques for fast paced Construction of Railway Projects

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ABSTRACT

Dedicated freight corridor (DFC) project is the largest infrastructure project undertaken by Ministry of Railways since independence. Highly mechanized means of construction are used in execution of DFC project to complete huge quantum of work in short period of time looking to tight time lines for commissioning of the project. This paper presents an overview of new mechanized techniques that are being used in DFC project for speedy construction.

1.0 Introduction:

The golden quadrilateral of Indian Railways connecting four major metropolitan cities and its diagonals carry major chunk of freight and passenger traffic. The routes of Indian Railways falling on golden quadrilateral are highly saturated and are unable to meet the increasing transportation demand of fast growing Indian economy. This led to conceptualization of Dedicated Freight Corridor. Once completed, DFC will bring a paradigm shift in freight transport logistics in the country.

The main objective in construction of DFC is to build freight corridors that are capable of running heavy haul trains at high speed so as to enable Indian Railways to regain its market share of freight transportation by creating additional capacity and guaranteeing efficient, reliable, safe and cheaper option of freight mobility to its customer. At present two freight corridors viz. 1856 Km. long Eastern DFC from Ludhiana to Sonnagar and 1504 Km. long

Western DFC from JNPT Mumbai to Dadri are under construction. The DFC project is designed to carry

32.5 axle load and is built with higher technical standards as compared to that of existing Indian Railway standards. The quantum of work to be executed in DFC project is huge. The quantities of major items of works are given in table below:

Major Items	Unit	EDFC	WDFC	Total
Civil Works				
Formation length	RKms	1318	1504	2822
Earthwork	Lac Cum	995	1546	2541
Important Bridge	Nos.	5	43	48
Major Bridges	Nos.	149	327	476
RUBs	Nos.	784	1299	2083
RFO	Nos.	19	26	45
Minor Bridges	Nos.	1223	1921	3144
ROBs	Nos.	104	164	268
Track linking	Tkm	2549	3310	5859
Station Buildings	Nos.	64	48	112
Electrical Works				
Mast Foundation	Nos.	46019	71887	117906
Mast Erection	Nos.	37939	68671	106610
Cantilever Erection	Nos.	43376	81137	124513
Laying of catenary & contact wire each	TKM	2065	3605	5670
Traction Sub Station (TSS)	Nos.	14	25	39
S&T Works				
Laying of S&T Cable (Stations)	Km	3653	13358	17011
Laying of S&T Cable (Block Sections)	Km	8562	10795	19357

DFC is being constructed using state of the art technology. Number of new mechanized construction techniques are being used in construction of DFC project because:

(i) Infrastructure is designed for Heavy haul train operation, and

(ii) for fast paced construction

Some of the mechanized construction techniques employed in DFC project for speedy construction of different components of Rail infrastructure are presented in this paper.

2.0 Earthwork:

The total quantum of earth work to be executed in DFC project is about 25 crore cum. Nuclear moisture density gauge (NMDG) and Ev2 plate load test are employed for measurement of density and strength (bearing capacity) of compacted soil to match with the high pace of physical execution of earthwork.

2.1 NMDG

NMDG is used for measuring Field Dry Density of individual compacted layer of earthwork. The NMDG measurement equipment contains a radiation source that emits a cloud of particles and a sensor that counts the particles received back that are either reflected by the test material or pass through. By, calculating the percentage of particles that return to the sensor, the gauge is calibrated to measure the density of the test material.

The NMDG has following advantage over the convention methods of field dry density measurement:

- Portability
- Quick results at site
- Less human intervention
- Virtually Non-Destructive Testing

The time taken for one test using NMDG is about 5 to 8 minutes; whereas the conventional methods take about 20 to 30 minutes. Therefore, 80 nos. of tests can be completed in a day with NMDG as against 20 tests in conventional methods.

2.2 Ev2 Plate load test:

The Ev2 plate load test is simple solution to determine the strain moduli Ev2 and Ev1 (a figure for the bearing capacity) and the ratio Ev2/Ev1 (a figure for the compaction level). The second deformation modulus Ev2 is a very popular index of compaction standard of soil and it reflects bearing capacity of soil.

For the test, the soil is loaded and unloaded in fixed steps using a circular loading plate and a hydraulic loading device. The load plate is loaded by a hydraulic jack and kentledge or counter weight against jack is provided by any site equipment such as an excavator, roller or a loaded truck. The settlement of load plate is measured at increasing load increments.

During two loading cycles, different loads will be applied in steps to the loading plate using a hydraulic hand pump. For each loading step, the corresponding settlement of the plate is recorded. The device is equipped with an electrical force sensor to record the load and an inductive displacement gauge to determine the deflection.

A graph is then plotted of settlement against bearing pressure and will show settlement at any given load. This information is used to calculate the Modulus of Subgrade Reaction, a measure of the stiffness of the subgrade known as the K value. It is expressed as load per unit area per unit of settlement e.g. KN/m2/mm or KPa/mm. The results of the test are evaluated immediately, shown at the display, and printed with

the built-in thermo printer at the site. The test results can also be stored on a memory chipcard. Using a chipcard reader, the results can be transferred into an MS Excel sheet on a Windows-PC for further analysis.

The Ev2 plate load test has the following advantages over the conventional plate load test:

- Rugged and versatile machine
- Results of tests are calculated and displayed immediately at site
- Measurement data can be stored and printed
- Conventional load test is laborious & time taking

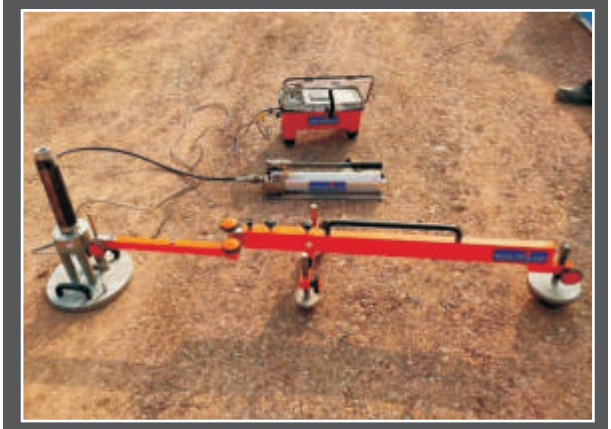

Fig. 2: EV_2 plate load test equipment

Fig. 3: Field EV_2 load test measurement

2.3 Use of Non-vibro technique for ground improvement by stone columns:

As per RDSO's report No. GE: 0014 (Guidelines and specifications for design of formation for heavy axle load), ground soil having standard penetration test "N" value less than 5 and EV2 value less than 20 MPa shall require improvement. The ground soil in patches of JNPT-Vaitarna section of western DFC parallel to Indian Railway tracks, is marine clay with poor bearing capacity. To avoid damage to adjoining track and structures due to ground vibrations generated in conventional Vibro-flotation method, ground improvement of marine clay soil in DFC is being carried out by stone columns using Non-vibro method.

In Non-vibro method of stone column construction, rig (construction assembly) is forced into ground using high torque displacing the soil in lateral directions. After the rig assembly reaches the target depth, a hydraulic cylinder opens the base of assembly and stone aggregate loaded in the upper stone bin is discharged at the base by a rotating internal stone feeding mechanism. The stone aggregates are then compacted by pressing with a rotating screw assembly. After the desired compaction level is achieved, monitored by torque value on rig's computers screen, the construction assembly is raised by rotation of screw assembly, thereby building a continuous compacted stone column.

The advantages of Non-vibro method over Vibro-flotation method in stone column construction are:

- Less ground vibrations hence likelihood of damage to the adjoining structures is minimal.
- Faster construction due to less time required in setting up of the assembly at site.
- Only two plants i.e. stone column machine assembly (Rig) & stone aggregate loader are required (no working platform is required in most of the cases) as against number of additional ancillary equipment required in conventional method like power pack, water pump etc.

- Non-vibro method does not induce liquefaction therefore can be installed with high water table without undermining problem.

3.0 Structures:

High capacity rotary pile drilling machine and slip form are being used for speedy construction of structures.

3.1 High capacity pile drilling rig:

High capacity rotary drilling machines that work on the principle of circumferential cutting (like hydraulic Rig BAUER BG-28) have been used in pile drilling in hard rocky strata in place of conventional winch and barrel method. The specifications of Hydraulic Rig BAUER BG-28 machine are:

• Maxm. drilling diameter	:	2500 mm
• Maxm. drilling depth	:	68.4 m
• Maxm. Torque	:	300 KNm
• Engine capacity	:	354 KW at 1,850 rpm

The drilling output of Hydraulic Rig BAUER BG 28 in hard strata is 2000 - 2500 mm in 22 hours as against 250 – 400 mm in conventional winch and barrel method..

Fig. 4: Hydraulic rotary pile drilling rig

3.2 Slip form for construction work.

Slip form construction technique is an alternative for conventional formwork system which helps in continuous vertical and horizontal construction. The slip form helps in continuous concrete pouring in moving formwork. The process stops only when the required length of casting is completed.

Slip form enables continuous, non-interrupted, cast-in-place "flawless" (joint less) concrete structures that have superior performance characteristics to piece wise construction using discrete form elements.

The advantages of slip form over the conventional shuttering method are:

- Easy setup
- Increase the construction pace.
- Good quality finish of concrete
- Very safe
- Approx... 40% saving in the cycle time.

Fig. 5: Concreting using slip form

4.0 Track work:

Highly mechanized means are used for handling of rails & sleepers and track linking using New Track Construction (NTC) machine to minimized damage to the track components in handling and track laying.

4.1 Mechanized track linking using NTC

Fully mechanized track linking using state of the art self-propelled crawler mounted NTC machine has been used for the first time in DFC project in India. The track laying by high performance NTC machine is done using continuous action assembly line method in which entire supply of sleepers and rails is by mechanized method. The material feeding rake of NTC machine consists of 21

Fig. 6: NTC track laying machine

BLC wagons in which 260 m. long rails, PSC sleepers and track fittings are loaded. Two concrete sleeper lifting gantries move over guide rails supported on BLC wagons and continuously supply sleepers from BLC wagons to the conveyor belt of NTC machine working in front. Since NTC machine handles 260 m. long rail panels it thereby minimizes no. of in-situ weld.

Advantages of track linking by NTC machine as compared to conventional track linking are tabulated below:

Parameters	Manual Track Linking	Mechanized Track Linking
Productivity per day	300-500m	1500-2000m
Labor Requirement	50-60	15-20
Land Requirement	Required for stacking of sleeper/	Not required
Quality/Finish	Rails Low	High

4.2 Use of Super puller for de-stressing of LWR/CWR panels

Traditionally, de-stressing has been labour intensive job and there are many constraints in manual de-stressing like low labour productivity and limited availability of time period for distressing in terms of permissible range of rail temperature. This had serious time and cost implications.

In DFC project, super puller is used for de-stressing which has not only increased the progress of de-stressing but has also enabled to carry out de-stressing of rails at any rail temperature lower than stress free temperature. Daily progress of up to de-stressing of 3.0 rail Km. can be achieved using super puller.

Fig. 7: Super puller machine for de-stressing

5.0 Electrification works:

The WDFC has the unique feature of being the world's first electrified dedicated freight corridor suitable for running of double stack containers with SOD height of 7.1 meter from the rail level and the traction contact wires at 7.54 meter height. High masts coupled with 2x25 kV AC supply system have posed several challenges in construction.

Following are some of the electrical construction activities that are being executed through mechanized means in DFC project.

5.1 Mast foundation:

In order to facilitate fast mechanized excavation of mast foundations, cylindrical foundation design has been adopted in DFC project for the first time in India. The cylindrical foundations also offer advantages of lesser space requirement thus lesser quantity of concrete and faster execution time.

Excavation of foundations has been completely mechanized with the help of deployment of different machines as given below

Type of Machine	Output per machine per day	Machine
Tractor Augers	8-12 Nos.	
Track Mounted Augers	7-8 Nos.	
RRV Auger Make: Palfinger	20-25 Nos.	

Crawler based RRV	40-50 Nos.	
Crawler based RRV Make: Tescar	15-20 Nos.	

To achieve batter quality control and fast paced construction of mast concrete foundations, RRV concrete mixtures and concrete trains are being used.:

Fig. 8: Foundation Augring by RRV Colmar

5.2 Mast/Boom erection:

Mast grabbers are used for lifting and placing masts in the foundations, thereby, resulting in very fast erection of masts. The advantages of erection by mast grabbers over conventional methods are higher productivity, better precision, safe working and no damage to galvanization coating during transportation/erection.

Fig. 9: RRV mounted Geismar mast grabber

The Geismar mast grabber has the capacity of erection of 45 masts per day as against 12 mast per day of ordinary crane.

5.3 Uses of Modular Cantiliver:

In WDFC project light-weight aluminum modular cantilever assembly, which are easy to erect and replace, have been used.

5.4 OHE Wiring and Tensioning by wiring train:

Overhead wiring trains are used for overhead laying of both contact and catenary wires and simultaneously their adjustable auto-tensioning as per the design requirements with the help of puller/tensioner. The machine is equipped with capstan unit, main guiding mast, auxiliary mast, motorized reel stands, compensators, guide rollers etc. mounted on a wagon and moves at a speed of 5kmph while working.

Fig. 10: OHE wiring train

The advantage of laying contact & catenary wire using wiring machine as compared to conventional methods are:

- No twists/kinks in laid contact wires resulting in superior quality of laying.
- Manpower requirement is less.
- The output per wiring machine is 10-12 Tkm per day as compared to 1.5 Tkm per day with manual method.

5.5 Droppering of OHE by RRV mounted vertical cradle platform:

The droppering of OHE in DFC is being carried out by vertical cradle platform (VCP) mounted on self-propelled RRVs that has higher productivity as compared to conventional method

Fig. 11: RRV mounted vertical cradle platform

6.0 Conclusions

Number of new mechanized construction techniques have been used for construction of different components of Railway Infrastructure that have improved the pace of construction. Mechanized construction has also helped in building good quality infrastructure with cost effectiveness..

Environment friendly construction and Waste management in Khurja – Dadri section of Dedicated Freight Corridor: A Sustainable Approach

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ABSTRACT

Construction of double rail line of DFCCIL from Khurja to Dadri promotes sustainable construction by incorporating environmental management system as an essential process of Construction Business. It is our endeavor to realize sustainable & responsible environment management by integrating its operation with environmental measures as business operations and environment measures are inseparable. Maintenance of Ecological Balance and a perfect environment has been of utmost importance. This project unit has implemented several Environment and Sustainability measures towards protection of environment and reduces Carbon Footprints. It includes use of LED lights to reduce energy consumption, provision of Solar Lights, use of Prefab and Precast material for site offices and welfare facilities, waste management at site, utilization of concrete waste for temporary structures, Greenbelt Development, organizing community awareness programmes and Provision of Bio-Toilet at construction sites etc.

Key words:- Environmental management system, Carbon Footprints, waste management and Greenbelt

1.0 Introduction:

The existing trunk routes of Howrah-Delhi on the Eastern Corridor and Mumbai-Delhi on the Western Corridor were highly saturated. Railways lost the share in freight traffic from 83% in 1950-51 to 35% in 2011-12. This project (ie Khurja – Dadri section) is a part of Eastern Corridor.The total length from Khurja to Dadri section is about 46 kms. The entire stretch of the project is located in the State of Uttar Pradesh and passes through two districts namely Bulandshahar and Gautam Budh Nagar. The project is certified with ISO 14001:2015 and OHSAS 18001:2007.

2.0 Sustainable method adoption:

Here in this project of Eastern Corridor of Dedicated Freight Corridor Corporation of India Limited, we have implemented several methods to make it a sustainable construction, which includes:

A. Use of Alternate Material:

The Raw Material and traditional building materials used in project affect the environment by depleting natural resources. Therefore, after approval we have made some sustainable solution to make the alternative materials available and used at site.

a) Autoclaved Aerated Concrete (AAC) Blocks are used in place of traditional brickwork. Autoclaved Aerated Concrete is a Lightweight, Load-bearing, High-insulating, Durable building product, which is produced in a wide range of sizes and strengths. AAC Blocks are around three times lighter as compared to the red bricks. AAC is a non-toxic product, which does not pollute the air, land or water. During the manufacturing process, waste from the cutting process is recycled back with raw materials and used again. During construction, there is virtually no waste generated. The energy consumed in the production process is only a fraction compared to the production of other materials. The manufacturing process emits no pollutants and creates no by-products or toxic waste products. AAC is manufactured from natural raw materials. The finished product is thrice the volume of the raw materials used, making it extremely resource-efficient and environmentally friendly.

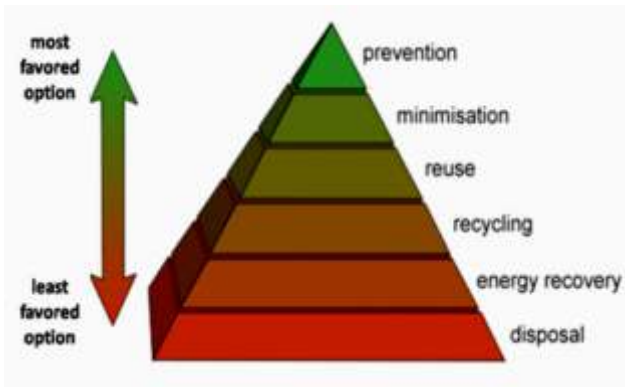
b) Steel Formwork is used in place of traditional wood shuttering. Steel formwork is environment friendly in comparison to traditional plywood formwork. It has several advantages like Very strong and able to carry heavy load, Environment Friendly, Easy to be fixed, Uniform size and surface and can be used for a very long time

B. Waste Minimization

Waste Minimization is a waste management approach that focuses on reducing the amount and toxicity of waste generated. Waste minimization techniques focus on preventing waste from ever being created, otherwise known as source reduction and recycling. These techniques can be practiced at several stages in most waste generating processes, but require careful planning, creative problem solving, changes in attitude, sometimes capital investment, and genuine commitment.

a) Wastage control of Cement at Site:

- **During Storege**
- The cement should be used on first come first used basis.
- Materials reconciliation should be done on monthly basis and not to left to be done at the end of the project.
- Proper inventory management of cement. Make use of Just in time order technique.
- During monsoon season cement, bags should be covered with polythene.
- The cement bags should be kept close together to reduce air circulation.
- The cement bags should not be hand stitched.
- Do not purchase cement bags, which are partially set due to moisture.
- Do not purchase if there are small lumps in the bags.
- Cement should be stacked in a shed, which should be dry, leak proof and moisture proof.



- Cement should be placed on wooden crates or on the planks.
- Cement from different manufacturers should be stacked separately
- **During Construction**
- If the joints of brickwork and bed thickness are more than specified, it would lead to wastage of material. So adhere to minimum thickness as specified in specifications.
- Make use of mortar, which falls down while doing brickwork by keeping jute bags adjacent to wall to carry such mortar.
- Provide proper thickness of cement plaster to walls by constructing masonry wall in plumb.
- Taking bulking of sand into account to avoid wastage of cement.

C. Material Conservation by Waste Utilization

We are working on a principle of "Waste is not a waste until we waste it" and believe that no resource can be wasted if planned accordingly..

The management of waste is a key component in a business' ability to maintain Sustainable performance. We encourage our contractors to improve our environmental efficiencies each year by eliminating waste through resource recovery practices. Many inorganic waste streams can be used to produce materials for construction.

a) Use of waste materials for making Workers Bathing Station

We have made Cement Workers Bathing Station at Batching Plantis made with waste materials. Maximum efforts have been taken care to use waste materials. All stands are made up of waste steel, soak pit is prepared by waste concrete cubes, display board is prepared on waste & discarded GI sheet etc. "Waste is not a waste until we waste it".

In addition to this, stands of site store are completely made up of waste steel. Cement Worker Bathing Station by using complete waste material is unique. Whenever any cement worker, works in Cement Godown they used to take 5 min bath for better health.

b) Waste to Wonder Park:

This is a part of Waste Management at our site and is developed at New Boraki Station Building site on REUSE Principle with following specifications:

- Pedestrian Pathway from waste tiles discarded during flooring of quarters.
- Pillars/ Delineators from waste concrete.
- Used Cold drink bottles for plantation.
- Site Induction Tree from scrap materials.
- Rejected Ballast and aggregates for beautification.

डेडीकेटेड फ्रेट कोरीडोर

Waste reused		Resource generated
	**Concrete waste:** Concrete waste generated during concreting of structures is reused for making delineators by using PVC pipes.	
	**Used cold drink bottles:** Empty cold drink bottles are collected from household of staffs through mail circulation.	
	**Metal & Wood Scrap:** Metal and wood scraps are collected from Scrap yard of our construction sites.	
	**Plants transplanted from DFCCIL RoW Land:** Plants developed at DFCCIL acquired land, which is to be developed as RoW is transplanted.	
	**Tiles:** Scrap tiles are generated during floor work / tiling of IR Quarter Dhakaur.	
	**Rejected Ballast and aggregates:** Rejected Ballast and aggregates are collected from different stacking yards.	

Responsible management of waste is an essential aspect of sustainable project. In this context, managing waste means eliminating waste where possible; minimizing waste where feasible; and reusing materials, which might otherwise become waste. Solid waste management practices have identified the reduction, recycling, and reuse of wastes as essential for sustainable management of resources.

Management of construction related waste is expensive and often presents unintended consequences. However, common sense suggests that **failure to reduce, reuse and recycle wastes is unsustainable**. It makes sense that efficient and effective elimination and minimization of waste and reuse of materials are essential aspects of construction activity.

D. Emission Control Device in DGs

This is an innovative technology to improve Ambient Air Quality with potential to reduce 80% Particulates Matter (PM) from DG Sets. The emission control device consists of heat exchanger followed by a absorbing chamber. All particulates matter collected in absorbing chamber. Whatever PM captured in device is used for INK manufacturing called POINK.

E. Rain Water Harvesting System

Rain Water Harvesting Tank has been developed at Chirsi Batching Plant with the help of Waste Drum and Waste Concrete/ aggregates.Rain Water collected in perforated drum is leached out in ground resulting recharging of ground water.

F. In situ Pollution Control

a) Use of Green Nets: In situ pollution control initiatives/arrangement using green nets to arrest pollutant at source can be seen in the photograph depicted below.

b) Haul Road Maintenance

Haul Road is properly maintained to avoid dust generation and practice for regular water sprinkling is adopted for dust suppression at site. It includes Grading, Compaction and Housekeeping of Roads.

3.0 Summary & Conclusion

We are working on this project in a very sustainable manner. Use of alternative materials for construction, waste minimization at storage and at site, Innovative waste utilization, emission control from DGs, Reuse of waste/scrap material for waste minimization, in-situ pollution control whether it is at loading area or haul road and rain water harvesting system etc are some of the key areas in which we have worked in our project to make it Eco-friendly and sustainable. Through this paper these practices are given the wide publicity so that it can be adopted elsewhere in other projects too.

Rehabilitation and Resettlement of PAPs in Dahanu Taluka of Palghar District in Maharashtra in Vaitarna – Sachin Section

An Innovative Approach

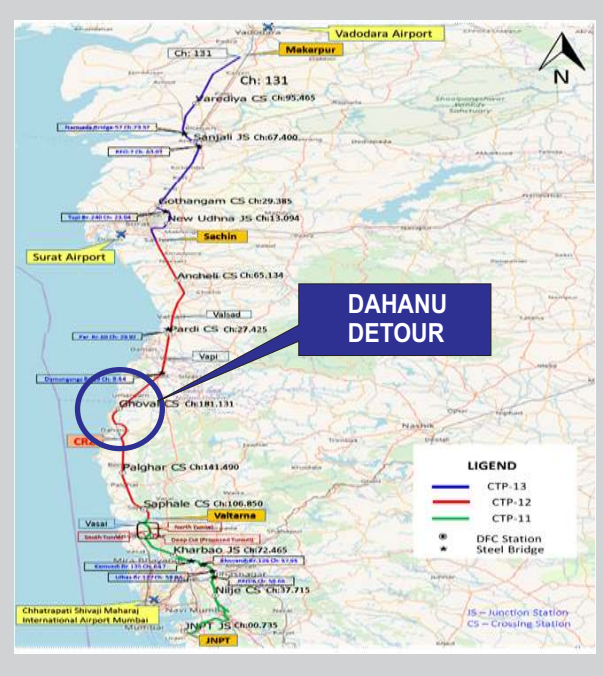
Shri Shyam Singh
CGM/North/Mumbai

Shri L. N. RAO
Dy.CPM/Engg-I

The project of Dedicated Freight Corridor in WDFC between Vaitarna – Sachin section of Western Railway passes through Dahanu Taluka of Palghar district. Maharashtra on detour alignment. This detour alignment comes under tribal and CRZ area. Before physical execution of DFC Project in this section, various clearances from different statutory bodies such as Environment, Forest, Wildlife / National Park, CRZ, ASI etc are required to be obtained. Moreover, Mumbai (North) Unit had to take additional clearance fromthe StatutoryBody, namely Dahanu Taluka Environment Protection Authority (DTEPA), constituted for safeguarding the environmental concerns of the Eco Sensitive Dahanu Taluka.

Constitution of the Dahanu Taluka Environment Protection Authority (DTEPA)

Dahanu Taluka Environment Protection Authority (DTEPA) is a statutory body of Govt. of India vide Notification No.SO884 (E) dtd.19th December 1996, as per the directions issued by Hon'ble Supreme Court of India. The Authority is empowered for safeguarding the Socio Environmental Concerns of Eco Fragile Dahanu Taluka in Palghar District of Maharashtra. The approval of DTEPA is mandatory for any development project in Dahanu Taluka and hence the clearance was necessary for DFC Project passing through this area.



Pre-rehabilitation of dis-housed persons

SR. NO	VILLAGE NAME	TOTAL STRUCTURE AS PER AWARD	WILLING FOR CASH COMPENSATION
1	Vangaon	28	28
2	Aagwan	9	9
3	Sarawli	42	41
4	Patilpada	16	16
5	Junnarpada	32	32
6	Nandare	30	30
7	Kasara	33	33
8	Waki	20	20
9	Ambewadi	14	14
10	Chikhle	2	2
	TOTAL	226	226

Proposal for clearance to DFC project in Dahanu Taluka from DTEPA

Approximately. 12.50 Kms of DFC alignment passes through 16 villages of Dahanu Taluka of Palghar district in Maharashtra.Accordingly, DFCCIL applied for the approval of DTEPA on 29.12.2010. After due deliberations, the DTEPA granted approval to the DFC Project on 02.06.2015 with13 stringentconditions including the conditions of major concerns viz. Pre-rehabilitation of dis-housed persons and Pre-forestation of 10 times the no. of trees to be cut. DFCCIL gave the commitment to the Hon'ble authority to comply with all conditions imposed by DTEPA while granting approval for the DFC project.

Compliance of the major conditions imposed by DTEPA

Pre-forestation

To comply with the condition of Pre-forestation,a sum of Rs. 3,91,36,309/- was deposited with Dy. Conservator of Forest, Dahanu, Govt. of Maharashtra for plantation of 360 mangroves and 75,548 nos. trees. Dy. Conservator of Forest, Dahanu carried out the plantation of 75,548 trees to comply with the conditions till 12.09.2017.

Total 226 PAPs in 10 villages of DAHANU taluka whose residential structures are affected due to DFC alignment have been removed.

- To comply with Pre-rehabilitation of dishoused persons, an NGO M/s. MASM-SPS was engaged by DFCCIL for implementation of Resettlement Action Plan for Development of Pre-rehabilitation scheme for dishoused persons affected in Dahanu Taluka in Vaitarna – Sachin section of Western Dedicated Freight Corridor.
- For Pre-rehabilitation of dishoused persons, the land was asked from State Govt. of Maharashtra for construction of alternate houses for PAPs as per condition of DTEPA. However, land was not made available by State Govt. of Maharashtra despite continuous follow up and thus delaying the pre rehabilitation process and affecting the ROW handing over to contractor and progress of the work.
- To find out workable solution for pre rehabilitation of PAPs before dismantling of houses and to expedite clearance of ROW for further progress of DFC project, DFCCIL field team of (North) Mumbai unit started parallel action of getting

theopinion of the PAPs for cash compensation in lieu of constructed house as per R & R policy. PAPs werealso reluctant to leave their own villages and resettleat faraway places due to following reasons:

I. Loss of livelihood within their villages.

II. Some PAPs have own Agricultural Land near their present houses.

III. To maintain their Social and Cultural relations within same village within their tribal community.

The PAPs were convinced to accept cash compensationin lieu of new houses in order to expedite the clearance of ROW in the interest of the project. All stakeholders were also taken on board to move along in this direction.

Since, the pre rehabilitation of houses was one of the conditions imposed by Hon'ble DTEPA before giving approval for the DFC project, it was prudent to discuss the proposed action of cash compensation to PAPs with Hon'ble DTEPA before going ahead with this exercise at field level.

The authority was convinced about the proposed action by DFCCIL subject to consent of PAPs and processing in most transparent manner.

Meeting with PAPs fortheir willingness for acceptance of cash compensation in lieu of new house

A meeting of PAPs in Dahanu Taluka wasconducted on 20.06.2018 as per the directives of the DTEPA. During the meeting, proposed housing plan was displayed on the board and was explained to PAPs. They were apprised that the only land identified by State Govt. of Maharashtra forrehabilitation wasalong the sea shore in the CRZ Zone and about 10 Kms from the present settlement. 189 nos PAPs immediately communicated their willingness in writing for cash compensation in lieu of a constructed house at alternate rehabilitation site.

- The willingness of the PAPs was put up for consideration of the Hon'ble Authority (DTEPA) during next Committee Meeting. The Hon'ble Authority (DTEPA) during the Committee Meeting instructed that the Cash compensation equivalent to cost of construction of new house should bepaid instead of the amount mentioned in R & R policy and Govt. of Maharashtra Gazette. Hon'ble authority also directed that this amount should be in form of a Fixed Deposit in Joint Account of Husband & Wife to ensure that money is not spent by PAPs for unwanted expenditure and is used by the PAPs for their livelihood and future family obligations. Since this was a special case not covered under existing guidelines, special approval of Corporate Office/DFCCIL was taken for payment of compensation equivalent to cost of construction house (approximately Rs. 6 Lakhs).The PAPs were paid this compensation in addition to other applicable R&R Entitlements as per guidelines such as subsistence allowance and transportation cost etc. The proposal was kept before the PAPs by Collector, Palghar for payment of compensation by asking the PAPs to open the Joint Bank A/c's in the name of Husband & Wife and to keep the cash compensation as a Fixed Term Deposit. However,most of the PAPs requested Collector, Palghar that they want cash compensation in Bank Account instead of Fixed Deposit. The report was again submitted by Collector, Palghar to Hon'ble DTEPA that most of the PAPs are not willing for Fixed Deposit and they want the compensation in cash in Bank Account instead of Fixed Deposit. PAPs gave following reasons for their choice of cash compensation in Bank Account instead of Fixed Deposit.

I. They have purchased land for construction of house and they want to repay the loan taken for purchase of such land.

II. Some have constructed incomplete houses and they want cash for completion for such constructions.

III. Most of the PAPs have immediate financial needs and they want the amount to be kept in the Joint Savings Account.

- Hon'ble DTEPA, after detailed deliberations during committee meeting and a strong recommendation of Collector/ Palghar agreed with the above arrangement as desired by PAPs with condition that whole process should be completed in transparent manner keeping all documents in record.
- Accordingly, payment of compensation is being paid to PAPs and they are allowed to take away released material from their existing houses for use in constructing new house. PAPs are also dismantling their existing houses on their own to salvage most of the material and no coercive method has been adopted by DFCCIL which has resulted into a win-win situation for both.
- The complete process of finalising the scheme and deliberations with PAPs, State govt. of Maharashtra and other stakeholders was done in most transparent manner and the meeting was also recorded on video to safeguard the interest of DFCCIL.

Pre & Post demolition of structures by PAP of Village Agwan

New houses rebuilt by the PAPs at places of their choice

The highest management of DFCCIL also took cognizance and appreciated the transparent and efficient manner in which such complex and legal issue was amicably resolved to the satisfaction of Hon'ble DTEPA, PAPs, State Govt. of Maharashtra and all stakeholders. As token of appreciation, the following team members of CGM/North /Mumbai unit involved in resolving the issue were awarded with a group cash award of Rs 1 Lakh.

1. Shri L N Rao, Dy CPM/Engg. -I
2. Shri S V Deshpande, Dy .P M/Engg.-I
3. Shri Sachin Dupare, Dy .P M/Engg.-II
4. Shri Sumit Kumar Verma, Executive/ Civil/ Dahanu
5. Shri L .B Machhi, Consultant w/u SLAO , Dahanu
6. Shri D R Dani, DPM/Fin
7. Shri. R M Barge, DPM/Fin

The efforts made by DFCCIL regarding Rehabilitation of PAPs in Dahanu Taluka in this innovative and transparent way were also appreciated by the JICA team during site visit. As desired by JICA, the whole process of such innovation and transparent execution was documented and shared with JICA for records and further appreciation to follow similar system for other projects being funded by JICA.

With this, field unit was able to clear the ROW in detour portion and hand over to contractor for further execution which was one of the most critical items being raised by the Contractor and JICA during all review meeting at the highest level in Ministry of Railways.

Accelerated Construction of Doubling Project by mechanised track laying with New Track Construction Machines adopted in Dedicated Freight Corridor

M.S. Hashmi
IRSE, Group General Manager/Western Corridor-I, DFCCIL

Abstract

As Dedicated Freight Corridor in Eastern and Western Corridor are in advance stage of construction, track laying works are progressing fast, completing track laying in first contracts of Western Dedicated Freight Corridor (Rewari – Iqbalgarh section) & Eastern Dedicated Freight Corridor (Khurja – Bhaupur section). Track is being constructed having have maximum speed potential of 100 kmph with Axle load of 25Tn over the formation and bridges designed for 32 Tn axle load.

In a first of its kind for India, Dedicated Freight Corridor Corporation of India Limited (DFCCIL) is using New Track Construction (NTC) machines to expedite track laying work on freight corridors. Machines being used on freight corridors are imported from US based firm "HARSCO" and Austria based firm "PLASSER & THEURER" and deployed on the dedicated rail freight corridors.

NTC Machines has advantage of faster laying apx 1.50 km of track per day in continuous operation with welded long panels of 250m/260m length. This Paper gives an insight to the faster track laying by NTC Machines and brings out the details pertaining to these machines and their working on Western DFC for faster construction of works in doubling /new line projects for Idian Railways.

1.0 Introduction:

NTC machines have been developed which bring substantial ease and efficiency in track construction with integrated logistic arrangements for mechanized handling, movement and laying of heavy track components like 260 m long rails and PSC sleepers. The machine provides continuous action assembly line kind of laying with high speed and accuracy. The output of the machine can comfortable be 1.5 Kms a day. These machines not only accelerate speed of construction but also help in careful handling and placement of rails and sleepers, achieving high initial quality in track laying. It is well known fact that the initial quality of track laying determines its performance and service life.

1.1 Main Components

i. Truss Frame

The NTC unit is supported at one end by a specially modified flat wagon running on the newly laid track and at the other end, by a crawler running on the ballast bed. The truss frame contains a conveyor system for carrying the sleepers down to a laying mechanism which places the sleepers on the rolled and prepared

ballast bed at a precise and predetermined spacing. This comprises of following units:

a. A conveyor system for carrying the PSC sleepers down to the sleeper laying mechanism, which places the PSC sleepers on the ballast bed at a precise and predetermined spacing.

b. Control panel

c. Crawler on which truss frame is supported in front and moves on ballast bed during working.

d.

ii. Wagons

The NTC formation has wagons carrying rails sleepers and fittings commensurate with the laying requirement for the day.

a. Power Wagon

This contains a conveyor system (where sleepers are placed by a gantry) and engine for movement during working.

b. Transition Wagon

This contains a rail pulling arrangement for pulling the rails from wagons in the rear and supplying up to front of NTC.

iii. Gantries

Two A self-propelled gantry, requiring one operator, keep supplying the sleepers to the conveyor systems. The sleeper handling flat wagons are equipped with auxiliary rails which form a continuous running rail for the gantry to move on flat bedded wagons loaded with sleepers. Pivoting extensions between the wagons allow the gantry to operate on curves. After being dropped by the gantry, the sleepers move via the via the conveyor system on to the prepared ballast bed.

iv. Rail laying/ Threading Unit

250m long rail panels are unloaded through a rail puller and laid along the prepared ballast bed (150mm to 200mm thick). NTC machine threads the rails on the sleepers through the guides located at the rear end of the unit, driving them inwards. Final placing of rails on the new sleepers is controlled by an operator who guides the rails preciously on to the sleeper seat.

1.2 Feeding rakes of NTC

Each NTC is supported by two P. Way material feeding rakes. Each rake carries P. Way material for 1.50 km track, i.e. 12 nos. of 250m rail panels, 2490 PSC sleepers & matching fastenings. Each rake comprises of 20 nos. modified BLC wagons with removable beams in between.

Modified BLC wagons have arrangements of rollers for placing 2 rail panels on each side and 8 rail panels in the centre, PSC sleepers and arrangement for movement of gantries.

Feeding material rakes are moved into/out of section using a locomotive

1.3 Specifications

HARSCO NTC

- Width - on bogie – 3.24m
- Height - 4.72m
- Working speed – 10 sleepers per minute
- Travel speed – up to 80kmph.
- Rails capable of being laid - up to 136 lbs.
- Minimum curve radius
  – Working – 144m, 12 degree
  – Travelling –97.5 m, 18 degree

PLASSER NTC

- Width - on bogie – 3.262m
- Height - 4.260m
- Working speed –10 sleepers per minute

- Travel speed – up to 100kmph.
- Rails capable of being laid –UIC60
- Minimum curve radius

  – Working radius – 230m, 7.60 degree

  –Travelling radius – 175m, 10.0 degree

1.4 Advantages

- About three times faster than manual laying.
- Mechanized flow of PSC sleepers through moving gantries.
- Placement of sleepers at pre-decided spacing.
- Capable of laying rails up to 136 lbs. and 260m long.

2.0 Sequence of working

2.1 Setting up of base depot

All the track components are stocked and transported from a well-designed Base Depot, which is essentially a yard with connection to nearest station yard of IR to facilitate bringing heavy P. Way materials like rails. On Rewari - Madar section, one base depot has been set up at Bhagega. Typical yard layout adopted has been shown on page 5 below.

25 m long rails imported from Japan are shipped to Mundra port from where these are moved on IR network in the rakes and brought into DFCCIL's base depot through connecting IR yard. The following are essential features of this base depot: -

i. Reception and dispatch lines to bring material rakes from IR.

ii. 6 nos. of overhead gantries have been provided for unloading 25 m rails from incoming rail rake.

iii. These 25m length rails are converted into 250m long panels by FB welding.

iv. Base depot also has a welding line and Mobile Flash Butt Welding unit is used to weld the 25mrails into 250m panels. A weld testing laboratory with facilities to conduct essential tests on welds like Brinell hardness test, tensile test, etc. has been provided.

v. 21 nos. of overhead gantries have been provided for loading 250m long panels in NTC

vi. 3nos. of overhead gantries have been provided for loading PSC sleepers in NTC

vii. A separate area is earmarked for stacking of sleepers in layers

viii. Lighting all along the yard length is essential as most of loading and other activities are performed during night time. Construction yard has to be in action round the clock to achieve a production of 1.5 km of skeleton track per day.

ix. Covered stores for storing track fittings, machine spares, consumable and fuel etc, are also provided in base depot

2.2 Base depot activities

Following activities are performed: -

(a) Unloading of 25m 60kg 1080 HH rails (imported from Japan) from incoming rail rakes with overhead gantries and stacking these rails at nominated places.

(b) Welding of 25m 60kg 1080 HH rails into 250m length panels by FBW plants. Welding parameters & QAP of FBW plant have been approved by RDSO in terms of para 5.6 of IR FBW manual.

(c) Loading of 12 Nos. of 250m long rail panels on NTC feeding rakes using overhead gantries. 2 Nos. of 250m long rail panels are placed on rollers on each side of wagons whereas 8 Nos. of 250m long rail panels are placed on rollers in middle of wagons. Loading of rails is completed in about 2 hours

Feeding rake of NTC

(d) Feeding rakes are then moved to sleeper stacking area and 2490 Nos. of sleepers are loaded in layers and each layer separated by wooden battens using gantries. Each layer has 40 PSC sleepers.

12.5 wagon x120 sleepers = 1500 sleepers

5.5 wagon x 160 sleepers = 880 sleepers

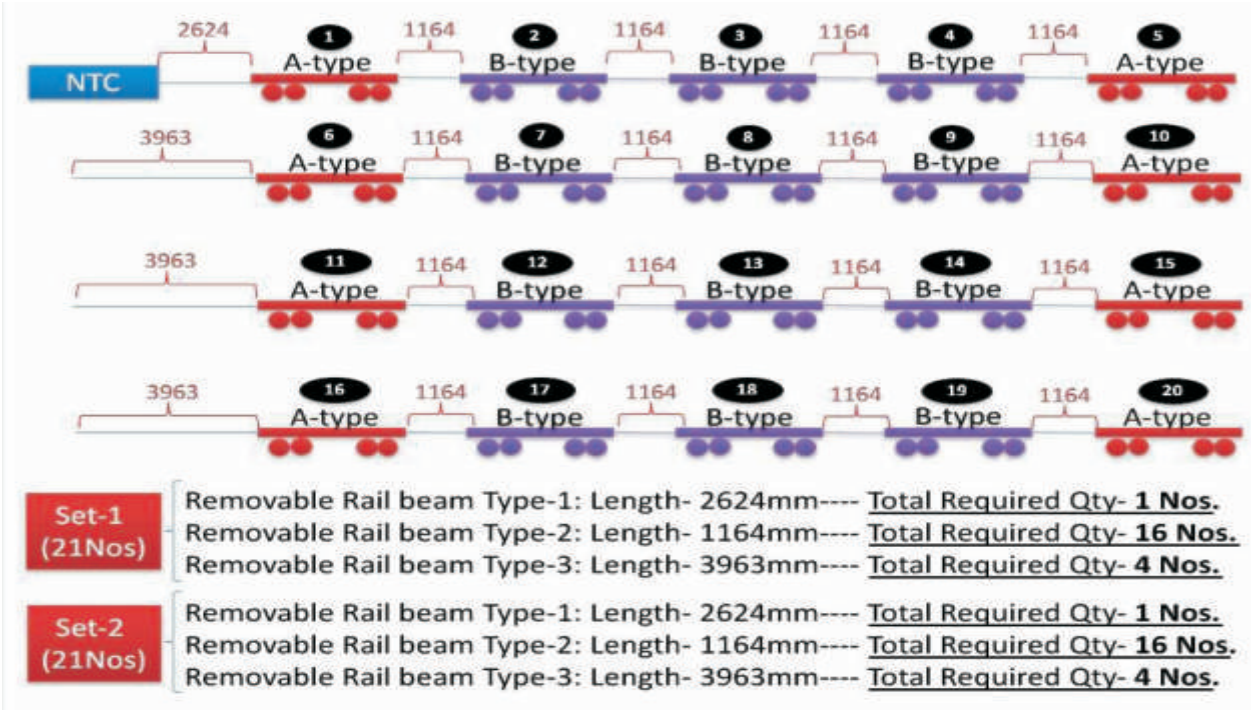
1 wagon x 110 sleepers = 110 sleepers

Total = 2490 sleepers

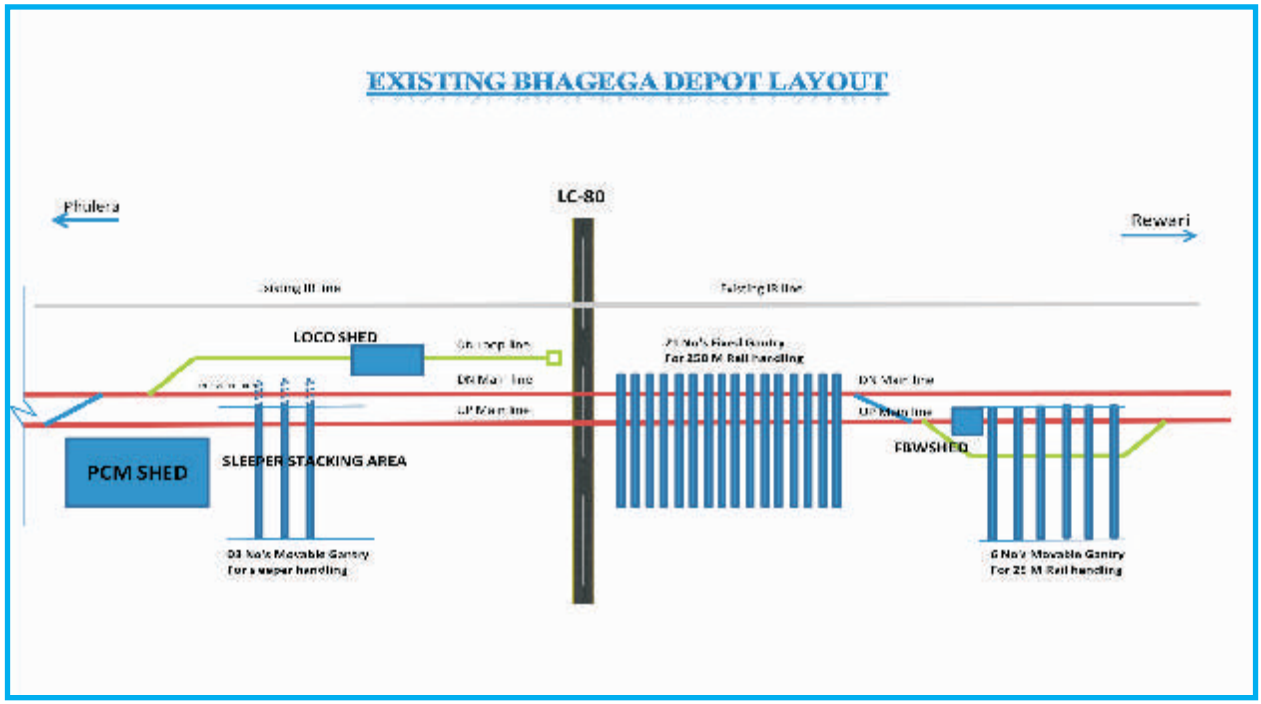
PSC sleepers are loaded in feeding rakes in about 6-8hours. Sleepers (RDSO T-7008) are

manufactured in sleeper plants set up at base depots which have been validated by RDSO. Fastenings are loaded in one wagon.

2.3 Feeding rake is than taken out of the depot and moved in section (for place of work) with locomotive at a speed of about 25kmph.



Base Depot



2.4 Field Activities

(a) Preparation of ballast bed

Ballast is spread on finished formation in required width with thickness of 150 – 200mm in two layers of 75 – 100mm thick. Each layer of ballast bed is compacted by 8-ton roller for achieving initial uniform ballast cushion of 150 – 200mm.

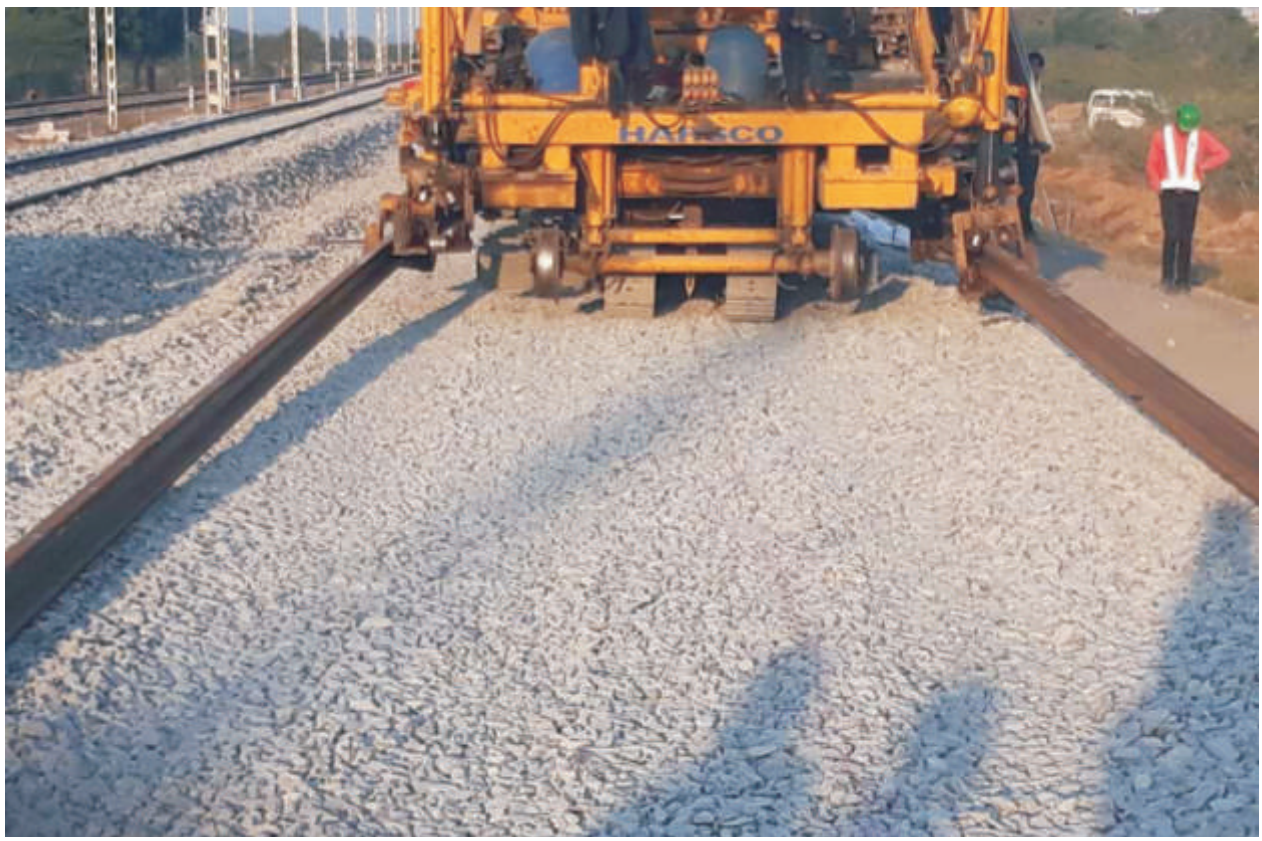
(b) Marking alignment on ballast bed

Centre line of alignment is marked on the above prepared ballast bed using lime powder for guiding the movement of NTC machine. NTC machine is moved on this centre line with a hand remote.

(c) Pulling out rail panels:

Ends of first two rail panels (250m each) in feeder rails are pulled and treaded into the roller lines on NTC machine with the rail puller arrangement in the transition wagon and these are then pulled up to the front end of NTC machine. Ends are then clamped using friction-based web clamps having eye on one end which is tied to pulling dozer. 250m long rail panels supported over rollers at evenly 6 – 10 m are then gradually lowered on the ballast bed.

Further rail panels are drawn by attaching their webs with the preceding one by using web based special friction rail clamps. Rail panels are unloaded on both sides at a lateral spacing of about 3500mm leaving space for working of NTC machine.



Ballast bed for laying the track

Pulling out rail panels

(d) PSC sleeper laying, placing CGRSP and threading rail panels:

- NTC machine is self-propelled at a speed of 15 kmph during track laying.
- Machine has an on board computer which ensures precisions in laying PSC sleepers with speed.
- Sleepers (20 no.) are picked up by moving gantries in each movement and brought up to conveyor belt and dropped there.
- CGRSP (RDSO T-7010) are installed on each sleeper by two pad operators (who sit on two chairs in the truss), who places pads on the sleepers while sleepers move on conveyor system.
- Sleeper laying mechanism lowers and drops first sleeper onto the ballast bed.
- Computer system uses the provision of first dropped sleeper as reference point and determines the locations for further sleepers dropped with the movement of machine.
- A sleeper spacer lowers down to ballast bed and adjust the sleeper dropped to the designed spacing.
- This activity continues for further sleepers dropped and adjusted to their proper location. For ensuring centreline movement, NTC machine has a pointer attached at the centre of truss beam in front end of it.
- Using hand remote control, operator ensures that pointer under truss beam remains aligned over the centre line.

(e) Provision ERC Mk-V:

After rail treading, ERC Mark V are provided manually.

(f) Check of skeleton track:

Alignment, levels and sleeper spacing are checked. Minor corrections as required are given by competent gang under competent supervisor before clipping of sleepers using ERC Mk-V (RDSO - T-5919).

(g) Feeding rake is moved back to base depot for further loading.

(h) Post NTC works: -

- Ballasting.
- Tamping
- DTS

3.0 Conclusion:

To keep pace with the ever-increasing need for transport infrastructure and match with the other modes of transport, faster construction of works is the need of the hour for Rail Infrastructure.

More than 2000 Track Km has been laid by NTC Machines in two contracts of WDFC and EDFC, where formation and structure works are complete and further works have started in other contracts as well. Track laying by NTC having inherent advantage of simultaneous laying of longer panels (250m/260m) with PSC sleepers not only helps in faster construction but also has advantage from quality considerations too as multi handing of rails and sleepers in semi mechanized (PQRS) and manual methods are avoided. As the track geometry and initial quality of laying determines the service life of track components, laying of track by NTC has been framed as the stipulated condition in all Civil and Track Contracts of DFCCIL. Adoption of these machines for track laying in Doubling and New Line works on Indian Railways would help immensely in faster completion of project.

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Heavy Haul Superstructure Improvements at Hot Spots with Under Sleeper Pads

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The following contribution presents information regarding Under Sleeper Pad(USP) technology in ballasted track and its benefits with regards to maintenance reduction in heavy haul lines. It refers to the latest findings of a coordinated system of elastic elements in railway superstructure and especially at so-called 'hot spots' like turnouts and transition zones. The state of the art finite element modelling is compared with in situ measurements and feedback from track operators.

1. Introduction

In the railway superstructure USP are primarily used for ballast protection and to improve track quality. They increase the contact area between concrete sleepers and the top ballast layer, reduce the formation of hollowness beneath sleepers and lower superstructure settlements. Next to the standard track Under Sleeper Pads can also be used to smoothen the deflections of transition zones and increase the life cycle value of all track components.

Figure 1: Padded concrete sleepers with polyurethane USP installed in track.

1. Methods

High quality superstructure systems are based on evenness and resilience and therefore a lower force excitation due to passing trains. These forces alter the track bed quality. Hollow areas below the sleepers and signs of wear on the wheel and rail surface, both of which arise over time, increase these processes as well as being the result of them. The track vibrates more and more, thereby also increasing the emissions. By tamping and adjusting, the superstructure has to be returned to its original position. The period of time this deterioration takes is largely dependent on the initial quality of the track superstructure. The creation of the conditions necessary for a good, durable line that is as inherently stable as possible should therefore be the primary goal when installing new track. In this context, evenness and resilience are important starting points for a high-quality superstructure system. Especially at higher velocities, axle loads and train frequencies, problems in the quality of the track superstructure have a great impact on the degradation, the maintenance and comfort of the passengers. Through the defined arrangement of elastic elements, such as Under Sleeper Pads, the railway track edges nearer to achieving this goal.

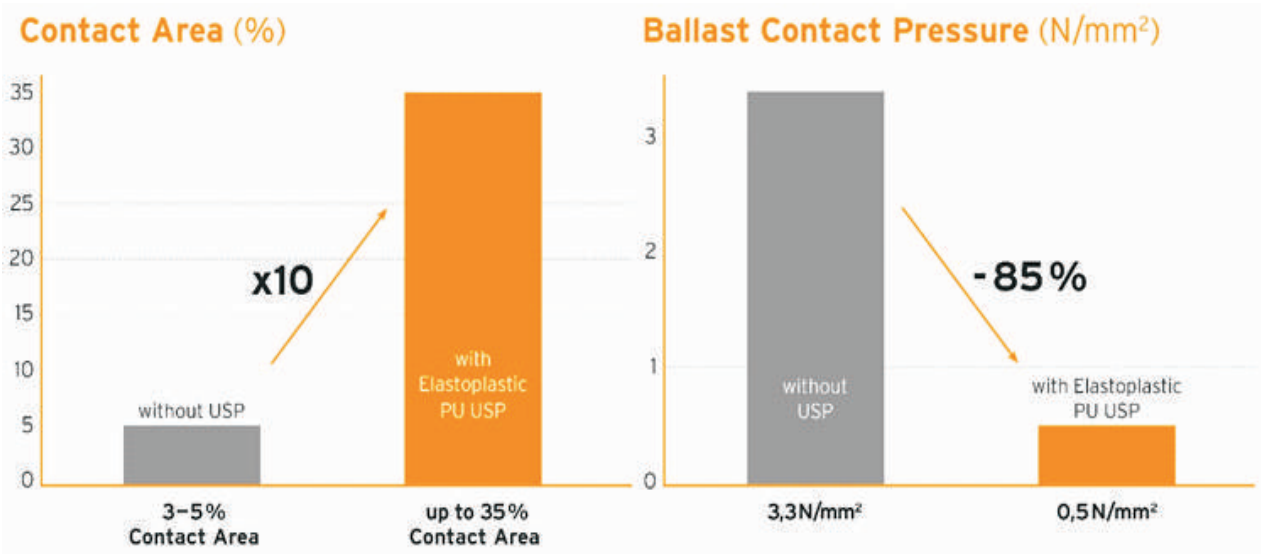
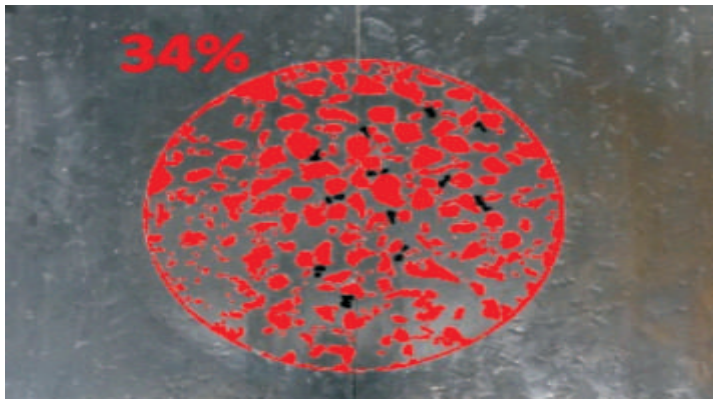


Figure 2: High contact area of elastoplastic polyurethane USP drastically reduces ballast contact pressure.

Arranging polyurethane (PU) Under Sleeper Pads beneath concrete sleepers prevents a hard impression directly on the ballast. The upper-most layer of ballast can bed into the padding material, increasing the contact area (from 2-8% without padding or EVA padding, to 30-35% with PU padding, refer to Figure 2) and thereby also avoiding excessive contact pressures. The larger ballast contact area and more even bedding lead to increased stability of the ballast bed, less track settlement and reduced wear to significant track components. Laboratory and field testing are presented showing the positive impact of the under sleeper pad on lateral resistance and settlement of the track.

Figure 3: Deflection measurements at the transition zone (top). Determining the contact area in the lab (bottom).



3. Results

With the results from open track data the next step is to have a closer look upon hot spots like transition zones between different superstructure types or turnouts. These abrupt changeovers along different superstructure constructions manifest themselves as a discontinuity in track parameters, such as deflection and bedding and result in accelerated wear of the superstructure.

The defined introduction of elastic elements into the track can drastically reduce rates of wear. Polyurethane products have been proven in the laboratory, but even more importantly: in the field. Modern simulation methods help engineers to develop an all-embracing design that takes into account the different elastic layers. A hot spot that has been optimized in terms of stiffness and settlement helps sustain track quality for longer and increases the availability of the rail network.

To extend the longevity of a hot spot the approach of optimization is as follows: dividing the hot spot into a number of sections, with the stiffness gradient minimised over a longer length. Various elastomers can be used depending on the specific function in question. Laboratory experiments and in-situ measurements round off these theoretical studies. As the aforementioned sample projects illustrate, this facilitates the targeted use of Under Sleeper Pads. Existing conflict points can even be neutralised retrospectively without having to rebuild the entire superstructure, because retrofitting of these products is also possible.

3.1 Transition zones

Transition zones can be found anywhere in a railway network where a change in superstructure build-up occurs (refer to figure 4). Very common transitions zones are:

(1) Transition from ballasted track to slab track

(2) Bridge approaches

(3) Tunnel to open track (very high difference in the stiffness of the track sections)

(4) Transition from open track to turnout and other special track work

A change in superstructure results in a sudden change in bedding modulus (stiffness), USP technology is used to smoothen this stiffness change. The length of transition zones is determined by the speed of the trains running on the line, often the "one second rule" applies: every stiffness step of the improved transition zone should have a length consistent with the distance the train travels in one second.

For a train travelling at e.g. 100kph this distance would be 28m. If the stiffness is adjusted in two steps with two different USP types, the total length of the transition zone would be 56m. The absolute minimum for reasonable transition zone length is the bogie to bogie centre distance.

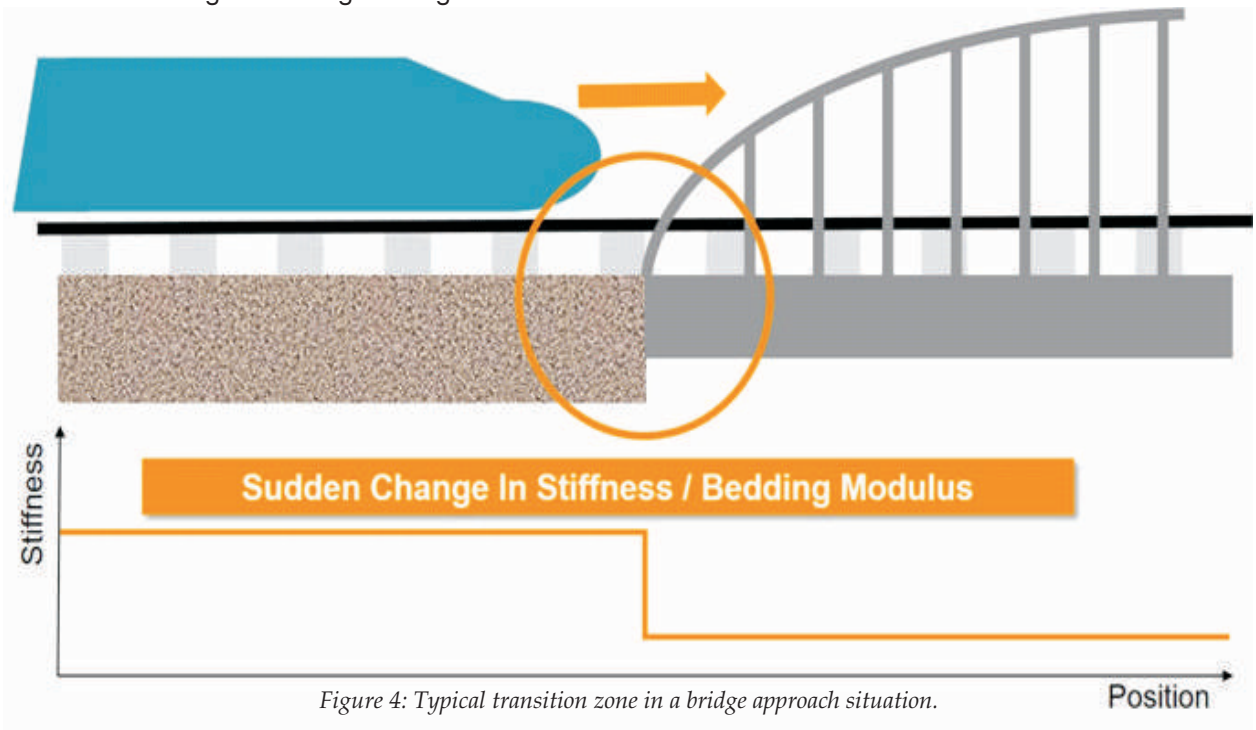


Figure 4: Typical transition zone in a bridge approach situation.

3.2 Turnouts

Compared to straight track, for which calculations are easy to conduct due to the relatively homogenous geometry with constant rail profiles and sleeper mounting surfaces, calculating elastic elements in turnouts is far more complex. The main reasons for higher effort include the varying profiles of the rails, the additional construction elements and the generally strong variations in the sleeper conditions. These parameters result in varying degrees of vertical load deflection. High-quality elastic elements, perfectly tailored to one another using modern computational methods, guarantee improved track bed quality and ensure enhanced availability of the rail network.

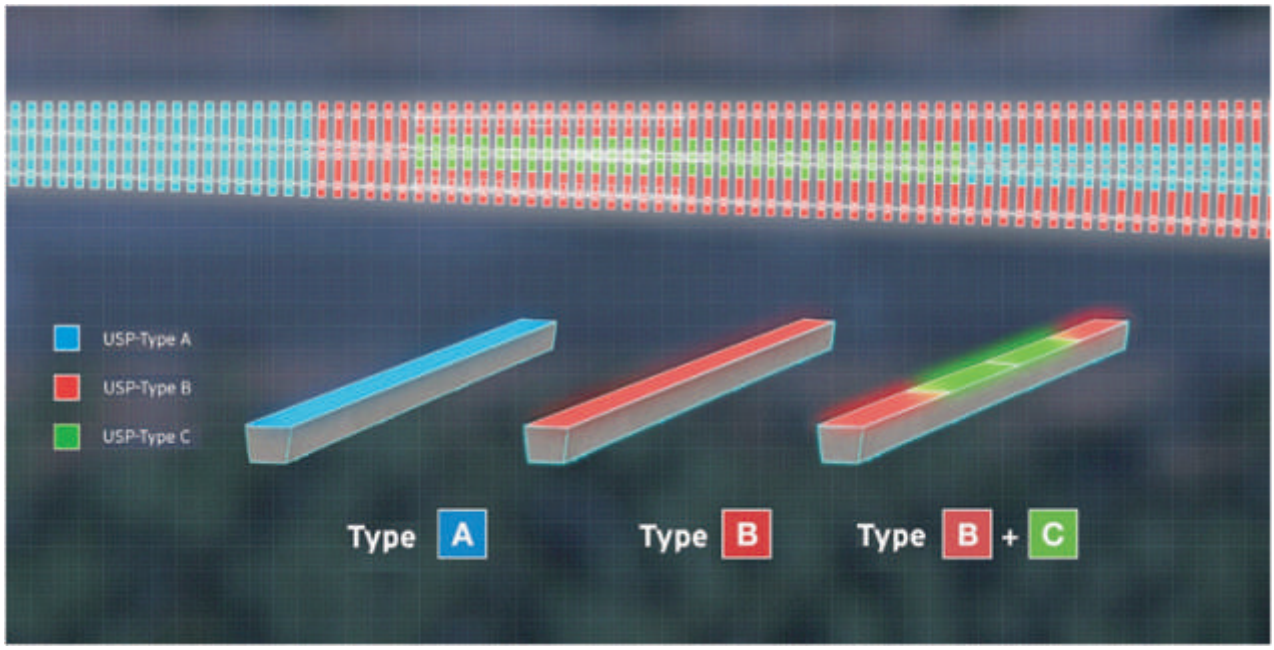


Figure 5: Using different PU USP types to optimize a turnout.

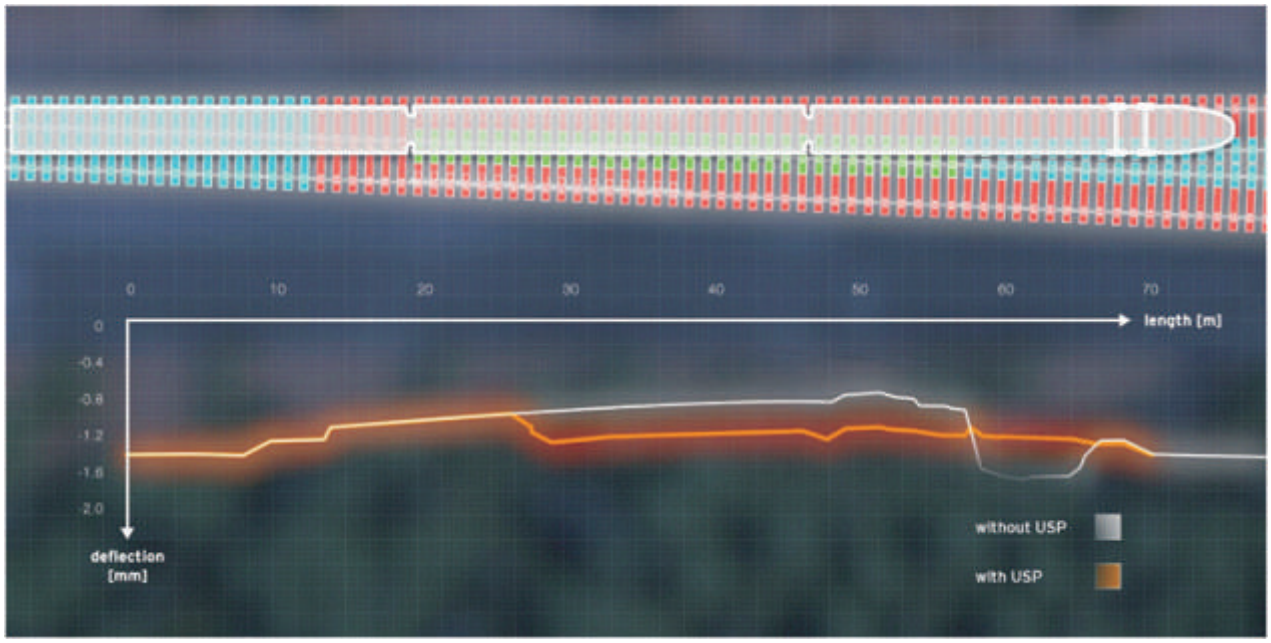


Figure 6: Smoother rail deflection due to defined elasticity introduced by PU USP.

Reference at EDFC:

One turnout in the Eastern DFC at Daud Khan is equipped with PU Under Sleeper Pads since 2019.The performance monitoring of this padded turnout is currently in progress to confirm the advantages of using PUR USP for reduced turnout maintenance. For demonstrating the benefits, the padded turnout is compared with a non-padded turnout on the same line.

The positive effects of Under Sleeper Pads have long been proven in railway tracks across the globe and PU USP are now standard components in the track superstructures of Deutsche Bahn (Germany), ÖBB (Austria), RFI (Italy), Network Rail (UK) and SNCF (France) amongst other.

Excerpt of global references in Heavy Haul:

Heavy haul operators have already successfully adopted PU USPs in their networks, significantly decreasing their track maintenance efforts.

- FMG (Australia)
- VALE, MRS (Brazil)
- DaQin Coal Line (China)
- Malmbanan (Sweden/Norway)

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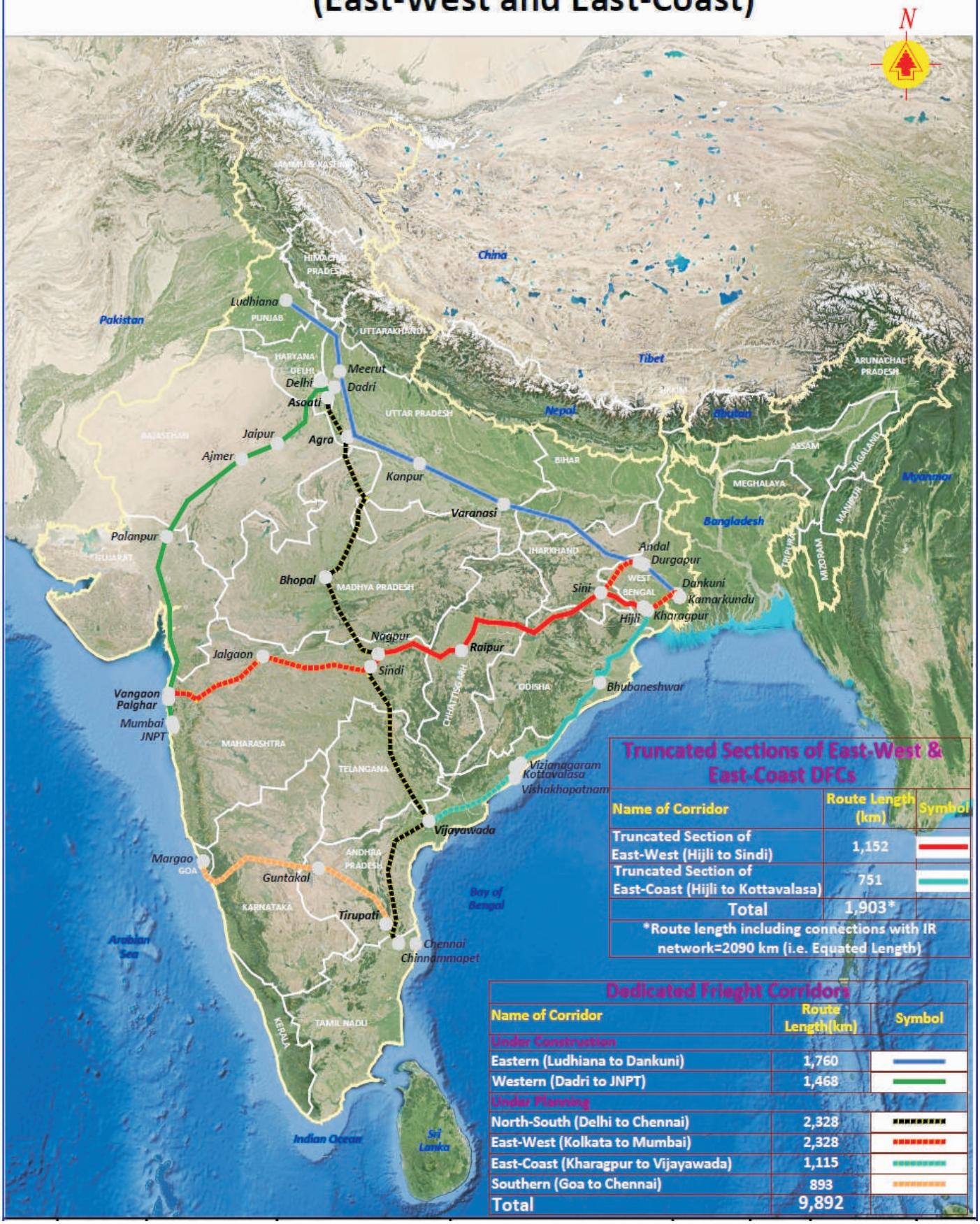
Conclusion

With the introduction of PU based Under Sleeper Pads (USP),several railway operatorshave alreadytaken a huge step towards maintenance reductions in the superstructure and therefore an efficient and sustainable railway track. With the help of laboratory and in-situ track measurements the finite element model was calibrated and is ready to improve superstructure hot spots such as transition zones, bridge approaches and turnouts. Positive feedback from railway operators around the globe proves the link between theory and reality. Long-time measurements show the importance of a good track quality and emphasize the positive effects of Under Sleeper Pads and their improved contact area.

Benefits of USP:

- Under Sleeper Pads increase tamping intervals by at least a factor of two. (60.000 cross-sections examined in the network of ÖBB, Austrian Federal Railway)
- Maintenance costs and operational hindrances are greatly reduced.
- Service life of track assets are increased by 20-30%
- Economic benefits are proven by Technical University of Graz (Austria), the world's leading experts in lifecycle management and LCC analyses.

Truncated Sections of Dedicated Freight Corridors (East-West and East-Coast)



Truncated Sections of East-West & East-Coast DFCs

Name of Corridor	Route Length (km)	Symbol
Truncated Section of East-West (Hijli to Sindi)	1,152	
Truncated Section of East-Coast (Hijli to Kottavalasa)	751	
Total	1,903*	

*Route length including connections with IR network=2090 km (i.e. Equated Length)

Dedicated Frieght Corridors

Name of Corridor	Route Length(km)	Symbol
Under Construction		
Eastern (Ludhiana to Dankuni)	1,760	
Western (Dadri to JNPT)	1,468	
Under Planning		
North-South (Delhi to Chennai)	2,328	
East-West (Kolkata to Mumbai)	2,328	
East-Coast (Kharagpur to Vijayawada)	1,115	
Southern (Goa to Chennai)	893	
Total	9,892	

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Dedicated Freight Corridor Corporation of India Limited

(भारत सरकार का उपक्रम)

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