National Highways of Infrastructure Development Corporation Ltd

CONSTRUCTION OF CHISOPANI TRAFFIC TUNNEL AT KM 67.24 ON NH-10 IN EAST DIST., SIKKIM

VOLUME-I: MAIN REPORT

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MINISTRY OF ROAD, TRANSPORT & HIGHWAYS
GOVERNMENT OF INDIA
NHIDCL

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CONSTRUCTION OF CHISOPANI TRAFFIC TUNNEL AT KM 67.24 ON NH-10 IN EAST DIST., SIKKIM

Name of Road :NH-10 within Sikkim

VOLUME -I : MAIN REPORT

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EXECUTIVE SUMMARY

1. INTRODUCTION

Sikkim is the youngest and small hill state of India having an area of 7096 Sq.km and lies between 27° to 28° north latitude and 88° to 80° east longitudes. The altitude above mean sea level varies from 213 m in the south to over 8500 m in the North West. It is surrounded by important mountain ranges. The chola range of mountains on its east forms the watershed between it and Bhutan on one side and Chumbi valley of Tibet on the other. It is bordered on the west by Nepal, on the north by Tibet, on the east by Bhutan and the south by Darjeeling district of West Bengal. Sikkim is drained by number of perennial rivers. Three main river systems are Teesta, Rangpo and Rangit. Rangpo River joins Teesta River just near the border between Sikkim and West Bengal at Rangpo. Climate of the study area is of Tropical Monsoon type, with moderate to hot summer, long rainy season and a short spell of cold weather. The maximum and minimum temperatures are 37.4°c and 7.8°c respectively. Maximum and minimum humidity at 8.30 hrs and 17.30 hrs are 89.74% and 58.19% respectively. The total annual rainfall is around 3200 mm.

NH 10, originating from junction of NH -27 & Hill cart Road at Siliguri and terminate at Burtuk , Gangtok , Sikkim . This is an important NH and life line for the Defense/ Civilians of the Sikkim & Darjeeling District in West Bangal for their social and economic development. This route is also one of important international trade route via Nathula pass in between two Giants of Asia.

2. PROJECT BACKGROUND

NHIDCL has been assigned the work by the Ministry of Road Transport & Highways, Govt. of India for Construction of Additional Tunnel adjacent to the existing Tunnel Chisopani Traffic Tunnel at Km 67.24 on NH-10 in East Distt., Sikkim.

NHIDCL has awarded the contract vide LOA letter No. NHIDCL/DPR/Sikkim/Rangpo Bridge –Chisopani Tunnel/2015 dated 23rd May 2016 to CM Engineering and Solution, Gurgaon for detailed investigations, costing and preparation of Technical Schedules of EPC documents.

3. PROJECT ROAD

The alignment of project road passes through south west to North east (Chisopani in East district) direction. The whole length of the project road will be in fresh cutting of mountainous as steep terrain with broken contours. The alignment of the project road traverses through natural forest and virgin land of thick undergrowth of evergreen bushes and creeping plants.

a) Land use

The proposed project is likely to cover an area of 1.0 Ha of land which open forest area.

4. OBJECTIVE OF THE PROJECT AND SCOPE

a) Objective of the project :

There is an existing tunnel at Km 67.24 of Sevoke Gangtok Section of NH-10 having length 62.0 m & carriage way width of 4.25 m .The existing tunnel entry point is blind curve and

exit point is very narrow road with very steep hill on both sides resulting in frequent traffic jams. At present only one way traffic (unidirectional) can pass through this tunnel. The widening of existing tunnel is not possible. The Defense vehicle movement towards China Border is also catered by this stretch of NH-10.Thus it is proposed to construct new tunnel parallel to this tunnel or construct an open cut Highway

b) The Scope of the Project

The scope of consultancy work of new 2 - lane with formation width of 12 m, including construction of cross drainage works at required locations, Tunnel at Chisopani and will cover the followings:

ROADS AND TUNNEL

- Suggest option alignments of the road, bridges and tunnel may be proposed
- Lay down the principles of design of the highway and pavement.
- Carryout survey and investigations.
- Gather information of the stretches of the highway which are flood prone, accident prone, any obligatory point which may help in designing of highway & enhancing safety.
- Digging test pits atleast 1 m below the lowest pavement layer. Conduct soil tests as per relevant IRC standards.
- Collect information about hydrology i.e. catchments characteristics, rainfall stream channel characteristics, design discharge, waterway, scour depth etc., for all cross drainage works and bridges.
- Carry out geotechnical investigation and sub surface exploration at the locations of each abutments/pier for the bridges and suggest hydraulic and structural design of the bridges.
- Examine the need of bye pass re-alignment for congested places.
- Carry out topographical survey and geo technical investigations.
- Decide location of portals of each tunnel.
- Detail design of portal and cut & cover section.
- Detail design of support system with steel ribs and alternative design.
- Design of retaining wall at portal/cut & cover section location.
- Drainage system inside the tunnels.
- Detail report on geological covering
- Preparation of cost estimates.
- Prepare suitable number of bid packages including cost estimates & bid documents as per MORT & H's standard documents.

c) Detailed project report consisting of the following:

- Conduct surveys of the existing alignment and collect inventory data.

- Conduct detailed reconnaissance survey and collect relevant data as well as the remote sensing data.
- Conduct detailed topographical, geotechnical / geological, hydrological and environmental surveys on selected alignment.
- Carry out detailed survey for construction materials
- Preparation of detail alignment drawings and geometric designs and prepare cost estimates
- Detailed design of Tunnels
- Analyse various alternatives and recommend the most appropriate for detailed design.
- Prepare Detailed Project Reports covering the following :
  - Main Report
  - Design Report
  - Investigation Report
  - Cost Estimate
  - DPR Drawing
  - Land Acquisition

5. ENGINEERING SURVEYS AND INVESTIGATIONS

Detailed engineering surveys and investigation have been carried out along the selected alignment of the project road and major findings are as given below:

a) Terrain:

The alignment of the project road passes through mountainous and steep terrain exceeding 30 % ground slope across the alignment.

b) Rainfall:

The proposed road is in heavy rainfall area. Monsoon period is between May to September when construction work is practically impossible.

c) Topographical Survey:

The topographical survey was conducted with Total Station and Auto Level Bench Marks were established at every kilometer and cross-section levels were recorded at 20m intervals in straight portions in general and at closer intervals at curves and where required. Temporary Bench Marks were established at every kilometer, reference pillars consisting cement concrete pillars with central nail point have been fixed at every 200 m to 250 m intervals .The topo survey information was then translated into digitized topographical map using suitable mapping software.

d) Alignment & Road Design:

The general alignment of the road under this project is as:

From Km 67/04 to Km 67/46
New-alignment : 420 m
Road is designed for 2-Lane (12.00 m roadway with 7.00 m carriageway).

Gradient, being the most important parameter, has been the guiding factor. Ruling gradient (less than 5.0%) has been achieved while the maximum gradient being 3.7% at few selected stretch.

e) Soil:

The soil along the alignment of the project is fairly homogenous in nature and character. Soil types vary from silty clay to sandy clay of medium plasticity, plasticity index varying from 7 to 18.The soaked CBR value ranges from 5 to 7.

f) Construction Material and Stones:

Construction materials for GSB, Cross drainage & Masonry R/Wall etc. works, will be available at local quarry within the project corridor and WMM, DBM & BC material from Teesta River & Tunnel excavated mug within the project corridor .Water Absorption and AIV of these quarries are within the limit of the Ministry's Specifications. Bitumen, steel and cement will have to be taken from Siliguri.

6. SALIENT FEATURES OF THE PROJECT

Salient features based on design are as below:

• Length of Project Road Sector 420 m
• The road has a ROW of 24.00 m at open area
• The formation width is 12.0 m
• The Highway is designed for 2-lane carriageway of 7.0 m width.
• The Highway is designed with flexible pavement
• Paved shoulders of 2.50m are provided on both sides of road
• All structures are matching to two lane NH roadway standard.
• Drains : Lined Drain.
• Landslide : No.
• Tunnels – 1 Nos
• Items for Road Safety and Road Furniture are provided.

a) Cross Section Elements:

The design standards of relevant Indian Roads Congress for Roads and Bridges are adopted for cross section designs of the project road. The earlier items of construction may involve construction of the road formation, cross-drainage works including construction of major bridges for 2-lane standard and protection works. The later stage of the construction will cover the construction of Pavement for double lane with paved shoulder (7.00 m wide) NH standard. The proposed cross section element with dimensions is shown in table below:

Sl.No.	Design elements	Dimensions
1	Roadway width	
	At roads and culverts*	12.00 m & 10.80m
	At Tunnel**	7.50m
2	Carriageway width	7.00 m
3	Cross slopes/Camber at straight reaches	2.5%

**Roadway width is inclusive of side drain and parapet wall/crash barrier (IRC SP: 48)*
***Roadway width is exclusive of kerbs*

b) Road Geometry:

The project corridor passes through steep and mountainous terrain. The design speed adopted is 30km/hour (IRC SP: 48). Along the proposed alignment, there will be no hair-pin bend. However minimum design speed has been considered on technical grounds.

e) Pavement Design

It is based upon CVD-464, CBR-9%, Traffic msa -10, Design period – 15 years, VDF-1.5, Annual Growth of traffic rate 7.5% and Design speed 30.00 Km/h. However the proposed pavement composition is based on CBR-9% and msa -20.
Pavement composition is designed as under:

Proposed pavement.

BC	:	40 mm
DBM	:	60 mm
WMM in 2-layers	:	250mm
GSB in 2-layers	:	250 mm
Total	:	600 mm

f) Shoulder Design

The carriageway width of 7m and paved shoulder width of 1.5 m on each side shall have the same pavement as the carriageway. The remaining 1.0m on each side shall be used to accommodate side drain on hill side or parapet/soft shoulder on valley side. In the hill side, depending on the total width of side drain, there is a small width remaining between the wall of side drain and paved shoulder, therefore it is also paved to avoid erosion by surface water

g) Slope Protection works:
Adequate Protective structures are proposed for retaining of cut/fill slopes to ensure stability of the road formation at locations where required. The proposed type and length of each structure are shown in the table below:

S.N	Side	Length in m	Height in m	Barak Type of structure	Proposal
1	Singtam Side	100.0	3.0	RRM Breast wall	New
2	Gangtok Side	50.0	3.0	RRM Breast wall	New

h) Drainage Design

Pavement Drainage includes camber / cross fall of 2.50%.
Slope 3.5 % has been considered for drainage of shoulders.
Drainage: PCC side drain is to be provided in 170 m on

i) Road Sign, Markings and Furniture
The project design includes Information Signs, Route Marker Signs & road marking are provided.

7. TRAFFIC SURVEY, ANALYSIS & FORECAST

This is to assess the capacity requirements, pavement design, identify present and likely future traffic conditions and to have provisions for future improvements.

From traffic volume counts the following observations are made,

Location	Average daily traffic intensity (PCU)	Average daily traffic intensity (CVD)	peak Hour Traffic Nos/PCU	Peak Hour Traffic ratio in %	Time of Peak Traffic
Rangpo to Singtam	4594	1815	1530/3341.50	8.43	9-10

(i) There are large numbers of Cars, bus and Two wheelers using the road (77.08%).

(ii) Traffic is dominated by the passenger vehicles (cars and two wheelers).

(iii) The heavy vehicle traffic (22.92%) as compared to the passenger traffic (77.02%).

Capacity analysis is fundamental to the planning, design and operation of roads and provides among other things the basis for determining the carriageway width to be provided at any point in a road network with respect to the volume and composition of traffic. It is also a valuable tool for evaluation of the investments needed for future road construction and improvements and for working out priorities between competing Projects. The NH road has been considered for two lanes.

- Therefore, No of commercial vehicles per day for design taking into consideration 7.5% per annum growth rate and a pavement life of 25 years
- After 25 years design life PCU per day : 28015
- Design road capacity (Service volume) for hill road for high curvature (above 200 degrees per Km) for 2 lane ,greater than 7000 PCU
- Hence existing road need to be upgrade for 2 lane standard

Based on traffic counting existing roads need to be upgrade for 4 Lane standards. However Widening of existing NH-10 (Rangpo to Ranipool) from 2 lane to 4 lane is not possible due terrain condition and huge habitation along Highway. Along with that there

is already one project preparation is going under PWD Sikkim for Alternate Highway from Melli – Singtam-Ranipool on opposite bank of existing road. Therefore instant project is considered for 2 Lane only.

8.0 ROAD TUNNELS IN PROJECT AREA

Road tunnels are feasible alternatives to cross through physical barriers such as steep mountains/vertical cliff, existing tunnels, existing roadways; rail lines etc. In addition road tunnels are viable means to minimize potential environmental impact such as traffic congestion, Pedestrian movement, air quality, noise pollution or visual intrusion to protect areas of special culture or historical values, private properties etc.

There are three main shapes of highway tunnels i.e. rectangular, circular and horse shoe shape. The geometrical configuration of tunnel should accommodate all potential vehicles that are expected to use the roads leading to the tunnel including over height vehicles such as military vehicles, if needed. The tunnels are generally equipped with various systems such as ventilation, lighting, communication, fire life safety, traffic operation and control system.

Good knowledge of the expected geological conditions is essential for proper planning of a tunnel alignment and its shape. Geotechnical issues such as soil or rock properties, ground water regime, ground cover over tunnel, presence of underground utilities and obstructions such as boulders or buried objects should be taken into consideration while fixing tunnel alignment. Construction of portals and its long term maintenance is very important and their locations are made based on safety consideration. The portals should be as close to the face of the rock as practically constructive.

The geometrical design of road tunnel is based on design speed, shoulder width, tunnel width, horizontal and vertical alignments, grade, stopping sight distance, super elevation, horizontal & vertical clearances. Maximum effective grade should not exceed 4%, although grades upto 6% have been used where necessary. The horizontal curve radii should be as large as possible but not less than 250-300 m, super elevation should preferably be in the range of 1% to 6%. The vertical clearance should be selected as economical as possible and should be consistent with the vehicle size. General consideration is that the minimum vertical distance to be 5.0 m on highway. The desirable distance from curb to curb and wall to wall should be 11.7 m and 13.2 m respectively. Sidewalks are required in road tunnels to provide emergency egress and access by maintenance personnel. It has been recommended that raised sidewalks or curbs with a minimum width of 0.7 m or wider beyond the shoulder area. Drainage must be provided in tunnels to deal with surface water as well as water seepage. The ventilation system of a tunnel operates to maintain air quality levels for short terms exposure within the tunnel. It is determined using two primary criteria (i) handling of noxious emissions from vehicles using the tunnel (ii) handling of smoke during a fire. A longitudinal ventilation system introduces air into, or removes air from a tunnel, with the longitudinal flow of traffic by using a jet fan system of high velocities at a limited number of points. Lighting in tunnels

assists the driver in identifying hazards or disabled vehicles within the tunnel while at a sufficient distance to safely react or stop.

During the surface mapping of the project area, the outcrop rock was classified by Geologist as (i) Phyllites (ii) Phyllites quartzite (iii) Fine grained quartzite interbedded with thin phyllitic bands. The general strike has been observed to be N80° to S80° W with dip ranging from 35° to 65°. On the basis of study of surface geology of the area, 5 sets of joints have been observed and rock is exposed of low grade Metamorphic. The analytical design of the tunnel has been carried out based on Q system of rock tunneling & RMR (Rock Mass Rating) system. It was estimated that rock encountered during excavation may varies from fair rock to very poor rock. The section of the road tunnel and its support system are shown in Drawing Volume.

During the surfacing mapping survey, the location of portals of each tunnel (Inlet & Outlet) has also been decided. Based on the profile of the area, design was carried out. The section of the portal & support system shown in Drawing Volume

Underground construction is a series of individual activities that must be completed before the subsequent activities can start. For tunnels that employ drilling and blasting to create the tunnel opening, the series is drill, load, short, muck and support. Each round is drilled a certain length or depth using a pre-engineered drill pattern. Once the drilling is done the explosives are loaded into the drill holes and wired up. The equipment and crews are then pulled back a safe distance from the loaded face and the blast is shot. Exhaust gasses produced by the explosives are removed from the face and fresh air is sent to the heading area. After around 30 minutes, the crews are brought back into the area to scale or knock down any loose rock and remove the excavated material or muck. Once the muck is removed the initial tunnel support is installed to make the excavated opening stable and safe. The next round can be started and all these activities are to repeat. In the end final lining consist of cast –in-place concrete is provided.

The ventilation system of a tunnel operates to maintain acceptable air quality level within the tunnel. The design is driven either by fire/safety consideration or by air quality. A longitudinal ventilation system introduces air into or removes air from the tunnel roadways at the portals, thus creating a longitudinal flow of air with in the roadway, with discharge at the existing portal. Longitudinal ventilation is created with a series of axial fans mounted at the ceiling level of the tunnel. They are used to introduce air into the tunnel roadway at the portals, thus creating a longitudinal flow of air within the roadway with discharge at the tunnel portals. The fans, due to the effects of high velocity discharge, induce a longitudinal airflow through the tunnel.
The lighting requirements of a tunnel are totally different by day and by night. At night the problem is relatively simple and consists in providing luminance level on lit routes inside the tunnel at least equal to those outside the tunnel. The design of lighting during daytime is particularly critical because of human visual system. The driver outside the tunnel cannot simultaneously perceive details on the road under lighting levels existing in a highly illuminated exterior and a relatively dark interior. When the visual system can

adapt to rapid reduction in ambient illumination such as that produced when passing from daylight into the darkness of a tunnel these adjustments are not instantaneous. The adaptation process takes a certain time, depending on the amplitude of the reduction, the greater the difference, the lighting level outside and that inside the tunnel.
It is practical to distinguish different zones in the tunnel in order to determine the longitudinal lighting level at daytime lighting i.e. the access zone, the threshold zone, the transition zone, the interior zone and the exit zone.
Safety in the event of a fire is of paramount importance in a tunnel. The catastrophe consequence of the tunnel fires not only resulted in loss of life, property but also concerns of the lack of fire life safety protection in the road tunnels. Minimum fire protection requirements are based on tunnel length. Where tunnel length is 350 m and where the maximum distance from any point within the tunnel to an area of safety exceeds 175m, all safety measures are taken.
Tunnel ventilation installed in road tunnel is an important element of fire protection. Jet fan units are axial type fans with direct drive motors designed to deliver a wide range of thrust capabilities in both the forward and reverse direction. The thrust produced is governed by size, blade angle and brake horse power. However it's required in proposed tunnel.

The stand pipe system for firefighting shall be a Class – I" automatic Wet" type system. It contain water at all times that is attached to a water supply capable of supplying the system demand at all times and that requires no action other than opening lose value to provide water at lose connections. 150 mm main waterline shall be laid on one side of the walkway of tunnel wherein stand pipe system shall be installed at an interval of 80 m. The required flow rate for the stand pipe system shall be 1920 l/minute. It shall be connected to a reliable water supply storage tank which is capable of supplying the system demand for a minimum of 1 hour. However it's required in proposed tunnel.

Emergency exits leading from the tunnel environment is considered to be a safe and effective means for getting motorists out of a road tunnel in case of a severe fire emergency. The spacing of the exits may vary based on time and capacity requirements, however a spacing of 300m is typical, Evacuating motorist from tunnel is the use of cross passage ways. Cross passage ways are used to connect adjacent parallel tunnel of smaller size i.e. 2m2.5m. Cross passage ways are also used by emergency responders for quick access to the site of a fire event. Exit signage is required in the tunnel. Maintaining the minimum required luminance for the signs and a constant supply of power is important because most motorists will immediately look for an exit sign once the vehicle is stopped in a fire event.

Road tunnels require a dependable power supply and a flexible power distribution system that will provide maximum reliability and power continuity for tunnel ventilation, lighting and water pumping etc. Minimum illumination level is to be maintained without interruption. During the daytime, when vehicle do not have their headlights on, a sudden loss of all tunnel illumination can cause driver confusion and result in an accident.

In order to provide reliability and continuity, diversity is needed in the power distribution system so that an alternate power source is available upon failure of the normal power source. The tunnel lighting can be provided from alternate source of emergency i.e. solar power voltalic calls.

For the two service system, two services from separate and independent sources of the power are needed. The primary power source i.e. sub-station is existing near Singtam site. The power line can be drawn from sub-station to provide the necessary power required for the tunnels. The secondary source is anticipated to come from Alternate source of generic i.e. solar power voltalic cell.

The electric power shall be required of the order of 5KW. The limitations of solar power system are the following:

- During continuous rainfall days or in cloudy weather conditions, the array cannot be charged. Under such situation main power supply from sub-station shall be restored.
- Shadow free area is necessary for installation of array.

9.0 METHOD OF TUNNEL

Drill and Blast

This tunneling method involves the use of explosives. Drilling rigs are used to bore blast holes on the proposed tunnel surface to a designated depth for blasting. Explosives and timed detonators are then placed in the blast holes. Once blasting is carried out, waste rocks and soils are transported out of the tunnel before further blasting. Most tunneling construction in rock involves ground that is somewhere between two extreme conditions of hard rock and soft ground. Hence adequate structural support measures are required when adopting this method for tunneling.

Sequential Excavation Method

This method is also known as the New Austrian Tunneling Method (NATM). The excavation location of a proposed tunnel is divided into segments first. The segments are then mined sequentially with supports. Some mining equipments such as road headers and backhoes are commonly used for the tunnel excavation. The ground for excavation must be fully dry for applying the NATM and ground dewatering is also an essential process before the excavation. Another process relates to the ground modifications such as grouting, and ground freezing is also common with this method in order to stabilize the soil for tunneling. This method is relatively slow but is found useful in areas where existing structures such as sewer or subway could not be relocate.

Basic principles of NATM

- Maximize the inherent resistance of the rock mass, allowing for deformation in a way that the rock becomes its own support.
- The application of a thin layer of shotcrete to prevent a greater deformation of the rock mass

- Systematic measuring and assessment of any tunnel movements, in order to provide any relevant additional support measures
- Flexible support with active elements that combine bolts, steel mesh and shotcrete

In view of above it is suggested and recommended that DBM method is suitable for proposed tunnel project

- õ As length of tunnel is short.
- õ Equipment used in NATM is general used in mining field. Therefore it may not be possible to procurement for small project.
- õ From the field study it is found that seepage of water through exposed face of hill, which is not suitable NATM method of tunneling.
- õ From the geological study and surface mapping it is found that rock strata is non homogeneous.
- õ Nearby our project already completed /ongoing hydro power projects DBM method of tunneling had adopted.

10.0 ENVIRONMENTAL IMPACT ASSESSMENT

The proposed road from Km 67.04 to Km 67.46 in Sikkim will serve East Sikkim. The preliminary Environmental Impact Assessment does not envisage any Negative Impact. The preliminary study suggests numerous beneficial impacts on the environment.

As there is new alignment that passes through forest areas, there are no endanger species both in plants and animals, the project will not attract the provision of Forest (Conservation) Act 1980 vide Govt. of India. Ministry of Environment & Forest No. 4-1/97-FC Dt. 18.2.1998.

Nevertheless, all possible measures will be taken to mitigate any adverse environmental impact the project may cause to the environment.

The air pollution due to emission/effluents from the construction machineries will also be negligible. The stream pollution due to spillage from the construction machineries will also be negligible. As the construction work involves widening of existing road formation, no adverse effect will occur on aquatic life system.

11.0 LAND ACQUISITION PLANS AND FOREST CLEARANCE

a) Land Acquisition Plans

The alignment passes through open forest lands.

b) Forest Clearance

The Sikkim State Forest authorities conducted a detailed survey of the alignment and the following is the findings of that survey:

1) That the proposed road alignment does not form part of National Park, wild life sanctuary, biosphere reserve, tiger reserve, elephant corridor, etc.
(2) No rare/endangered/unique species of flora and fauna are found in the area.
(3) No protected archeological/heritage site /defense establishment or any other important monument is located in the area.
(4) The requirement of forest land as proposed by the user agency is unavoidable and barest minimum for the project. No alternative for the project exists.
(5) No work in violation of the Forest Act has been carried out.

The proposed project is likely to cover an area of 1.0 Ha of land which open forest area

After due verification and assessment, the Estimate for Net Present Value and Compensatory Afforestation is already framed by the concerned Environment and Forest Department. Process for obtaining forest clearance is in the hand of the concerned authority of Government of Sikkim which already submitted

12.0 MATERIALS, LABOURS AND CONSTRUCTION EQUIPMENTS:

a) Materials:

The rock deposits are available along or the vicinity of the project road alignment. Besides, cobbles, pebbles and sand deposits are available in the rivers or streams crossing the main alignment. Construction materials for GSB, Cross drainage & Masonry R/Wall etc. works, will be available at local quarry within the project corridor and WMM, DBM & BC material from Teesta River & Tunnel excavated mug within the project corridor can also possible for use in construction material .Water Absorption and AIV of these quarries are within the limit of the Ministry's Specifications. Bitumen, steel and cement will have to be taken from Siliguri.

b) Labour:

Local labourers skilled & unskilled are available in plenty. However, where required, imported labourers will also be engaged for road construction works. Since the area is malaria infested, medical assistance with qualified practitioners will be required during the execution of the project. Comparatively higher wages (from the National average) and incentives have to be paid to labourers for the work. It is envisaged that equipment / machine-intensive method would be adopted for proposed construction works.

c) Equipments:

Heavy Machineries like Bull dozers, Excavators, Loaders, Air compressors, Vibratory / Static Road Rollers, Wet-mix plants, Electric generator sets, Motor Graders, Tractor–Rotavators, Hot/batch-mix plants, Paver-finishers, etc. as required for the execution of the work will be arranged by the contractor executing the project.

13.0 UNIT RATES AND COST ESTIMATES:

The cost estimate for the proposed construction work has been based on the quantities worked out from the design drawings.

a) Unit Rate:

The unit rates for arriving at cost of different components of works are based on Sikkim PWD Schedule of Rates 2012 (for National Highways). However WPI from 2012 to Oct-2018 (100% to 121.70%) is included in the project cost to bring the current rate of project cost for those items of works which are not available in the SOR, separate Analysis of Rates have been carried out and incorporated in this DPR.

- Bitumen (60-70 grade) (Ex-Singtam) (Basic rate = Rs 32340/ MT +transportation from Barauni to Singtam (462Km xRs.11) Rs.5082= Rs 37422)
- Emulsion (Ex-Singtam) (Basic rate = Rs 26140/ MT +transportation from Haldia to Singtam (740Km xRs.11) Rs.8140= Rs 34280)
- Cement (53 grade) (Ex-Singtam) (Basic rate = Rs 6160/ MT +transportation from Guwahati to Singtam (=510Km xRs.6.7) Rs.3417= Rs 9577)
- Cold twisted bars (HYSD Fe 500 Bars)(Basic rate = Rs 48559/ MT +transportation from Siliguri to Singtam (90Km xRs.6.7) Rs.603= Rs 49162)
- Sand & Aggregate from Teesta River.

However rate analysis for Tunnel item is carried out separately. During analysis of unit rates an overhead component of 20% has been considered to account for the establishment cost and cost of financing to the contractor. In addition, a contractor's profit of 10% has been included. In all cases, fully mechanised construction techniques have been assumed.

b) Project cost:

The total Project cost for Civil construction works and other allied charges is **Rs. 36.36 Cr**. and the details of cost breakup is given in the general abstract of cost in the DPR.

14.0 IMPLEMENTATION SCHEDULE

(a) Contract packaging :

The whole project is divided into single packages as given below.

Package No	Package description		Length (km)	Cost (Rs in cr.)	Remarks
	From	To			
1	67+04	67+46	0.42	36.36	This package have access both end

b) Procurement / Implementation Strategies:

The general conditions of Contract will be as per Standard Bidding Document of Ministry of Shipping, Road Transport and Highways, Government of India, works.

c) Phasing of Construction:

The total cost of the project is Rs 35.86 Cr. which covers costs for formation work, Slope protection and cross drainage works, construction of bridges and pavement works. Construction period of 24 months has been proposed, considering the quantum of activities to be performed including mobilization period needed and four intervening rainy seasons in between.

The project is proposed for commencement during the financial year 2018-2019 with target completion by the year end of 2020-2021. Since the project will be executed through a period of two years there will be cost escalation during the period of construction. Considering the rate of price escalation at an average rate of 10% per annum compounded annually after the initial year, the cost of construction and physical and financial phasing of the project is given in the table below:

Sr.No	Year	Cumulative Physical Target (%)	Cumulative Cost (Rs in crores)
1	2018 -19	15	5.4
2	2019 - 20	80	28.7
3	2020 - 21	100	36.36

15.0 TENDER DOCUMENTS:

a) General Conditions of Contract:

The general conditions of Contract will be as per Standard Bidding Document of Ministry of Shipping, Road Transport and Highways, Government of India, works.

b) Technical Specifications:

The Technical Specifications shall be the "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS" FIFTH REVISION 2013, of the Ministry of Road Transport and Highways, Government of India.

c) Project Drawings:

The Project Drawings as produced in Volume – III of this Detailed Project Report.

Proposed Alignment Shown in Red colour

CHAPTER - 1

INTRODUCTION

1.1 INTRODUCTION

Sikkim is the youngest and small hill state of India having an area of 7096 Sq.km and lies between 27° to 28° north latitude and 88° to 80° east longitudes. The altitude above mean sea level varies from 213 m in the south to over 8500 m in the North West. It is surrounded by important mountain ranges. The chola range of mountains on its east forms the watershed between it and Bhutan on one side and Chumbi valley of Tibet on the other. It is bordered on the west by Nepal, on the north by Tibet, on the east by Bhutan and the south by Darjeeling district of West Bengal. Sikkim is drained by number of perennial rivers. Three main river systems are Teesta, Rangpo and Rangit. Rangpo River joins Teesta River just near the border between Sikkim and West Bengal at Rangpo. Climate of the study area is of Tropical Monsoon type, with moderate to hot summer, long rainy season and a short spell of cold weather. The maximum and minimum temperatures are 37.4°c and 7.8°c respectively. Maximum and minimum humidity at 8.30 hrs and 17.30 hrs are 89.74% and 58.19% respectively. The total annual rainfall is around 3200 mm.

NH 10, originating from junction of NH -27 & Hill cart Road at Siliguri and terminate at Burtuk , Gangtok , Sikkim . This is an important NH and life line for the Defense/ Civilians of the Sikkim & Darjeeling District in West Bangal for their social and economic development. This route is also one of important international trade route via Nathula pass in between two Giants of Asia.

1.2 BACKGROUND

NHIDCL has been assigned the work by the Ministry of Road Transport & Highways, Govt. of India for Construction of Additional Tunnel adjacent to the existing Tunnel Chisopani Traffic Tunnel at Km 67.24 on NH-10 in East Distt., Sikkim.

NHIDCL has awarded the contract vide LOA letter No. NHIDCL/DPR/Sikkim/Rangpo Bridge –Chisopani Tunnel/2015 dated 23rd May 2016 to CM Engineering and Solution, Gurgaon for detailed investigations, costing and preparation of Technical Schedules of EPC documents.

1.3 OBJECTIVE OF THE PROJECT

There is an existing tunnel at Km 67.24 of Sevoke Gangtok Section of NH-10 having length 62.0 m & carriage way width of 4.25 m .The existing tunnel entry point is blind curve and exit point is very narrow road with very steep hill on both sides resulting in frequent traffic jams. At present only one way traffic (unidirectional) can pass through this tunnel. The widening of existing tunnel is not possible. The Defense vehicle movement towards China Border is also catered by this stretch of NH-10.Thus it is proposed to construct new tunnel parallel to this tunnel or construct an open cut Highway

1.4 SCOPE OF WORK

The Scope of Work is specified in Para 2 of the Terms of Reference. The phases of implementation are highlighted as under:

- **Stage-I (Preliminary Stage)-Providing three options each for location**
- **Stage-II (Investigation report and GAD)**
- **Stage-III (Technical Schedules design and drawings)**
- **Stage-IV (Review of Environmental Study Report & Land Acquisition Plans)**

CHAPTER – 02

RECONNAISSANCE SURVEY

2.1 REVIEW OF DATA & DOCUMENTS

The Team identified the data, documents and information requiring study and review. In addition, the data is procured and collected about likely constraints in execution of the project like existence of structures along the road, which would require interaction with the local authorities for their relocation and removal. The data as collected has been studied and reviewed.

The teams made in depth study of data/information, as available, about the project sites. The inter alias includes:

- Topographical sheets, geological and meteorological maps etc.
- Detailed of on – going works.
- Details of works already proposed on the project road.
- Study reports/ investigation reports of specialized agencies for trouble spots/ other problems on the project site.

2.2 FURTHER STUDIES & INVESTIGATIONS

Based on this study/review, the team has identified the data and investigation gaps, so that, further data collection and investigations, as required, are carried out during the detailed surveys and investigations proposed for the project.

2.3 GROUND RECONNAISSANCE:

In addition to the discussion and study of maps, report and available data, the consultant conducted the ground reconnaissance and general survey of the proposed bridges and tunnel sites. It included:

(a) Data Collection
(b) Compilation of salient feature
(c) Evaluation of bridge and tunnel condition
(d) Major problems on the proposed bridge site & tunnel site / approach, if any

2.4 LOCATION SURVEY

General

Based on the reconnaissance survey of the bridge & tunnel by the consultant staff, the location study is summarized in the matrix as attached.
The data collected helps the consultants to appreciate the requirement of the project, the challenges to be faces on the ground and the thrust area to be covered in the study, engineering and design of the project bridge.
We carried out the following studies as part of the Preliminary Stage (Siting of the proposed bridge and tunnel alignment / orientation)

- Location
- General physical feature
- Geophysical features
- Hydrological features

- Environmental
- Derivation

THE DATA OF LOCATION STUDY ARE AS UNDER:

Location study of Chisopani Tunnel at 67.24 Km of NH - 10		
Sn	**Study Item**	**Location Study**
1	Proposed Tunnel	Tunnel (Double Lane)
2	Location	Chisopani , Singtam
3	Topography of the area	Hilly
4	Existing facility	Existing lane Single
5	Tunnel requirement	Permanent Tunnel
6	Geometric approach	Curve at starting & Straight at end
7	Traffic	Very High
8	Terrain and soil condition	Hilly
9	Geology	Rock types of the area are mostly Phyllite - Quartzite intercalations and they have been traversed by Quartzite veins.
10	Cliff & Gorges	Deep Gorge
11	Drainage characteristic	Perennial stream
12	Veg. Extent	Very high
13	Temperature	30°C Daytime
14	Rainfall	3200 mm per year
15	Snowfall	Nil
16	Wind direction / Velocity	Moderate
17	Visibility	Clear
18	Exposure to sun	Sunny
19	History of Cloud burst	No cloud burst
20	Ecology	Natural and undisturbed
21	Slope stability of approaches	Stable

2.4.1 PROBLEMS AND CHALLENGES AREAS

Based on the ground study, reconnaissance survey and the data collected from PWD Sikkim & BRO, the consultants have gained appreciation of the technical and project management problems and have insight of the challenge areas of the project. In addition, each project road sector has its own local challenges. The general appreciation of the thrust areas is described in the following paragraphs.

Approach to the tunnel site: Presently all types of vehicle passing through the existing single lane tunnel.

Plantation: There is little growth of vegetations on both sides of the bridge and very high vegetation growth on both sides of tunnel

Sand and stones for Bridge & Tunnel construction: Good quality sand is available in the Teesta River. Good quality stones have been identified in the vicinity of the proposed bridge & Tunnel

site. Alternatively, the good quality stone can be transported from identified quarries. While extracting stones from concrete works, the quality materials should be selectively chosen.

Water: Generally, water available in the area has been found suitable for use in the bridge & tunnel construction work.

Work force: Most of the local people are engaged in agriculture. Bridge & Tunnel construction requires tradesmen of sort, skilled labourers and unskilled labourers. Manpower may need to be brought from other part of the country. It requires planning and organization for recruitment, training, induction and maintenance including provision of campage, food supplies, medical welfare activities, etc. Independent facilities are necessitated to cater for the increased workforce**.**

Contractor: Though small supply of Contractor are available in Sikkim, the bulk of the requirement is initially to be augmented from outside. The stone crushers have to be installed for meeting the project requirement for major bridge.

Approach road for tunnel

Based on the reconnaissance survey, review of the available data and the desk study, we have arrived at the conclusion that widening of existing tunnel is not possible. Therefore we need to realign the existing stretch of the road either by complete new alignment or by new two lane tunnel.

CHAPTER – 03
ENGINEERING SURVEYS AND INVESTIGATIONS

3.1 TOPOGRAPHICAL SURVEY

Objective

The Topographical Survey was carried out to map the topographical features of the approach road, existing tunnel location & proposed alignment. It is aimed at preparation of the Base map of the area, to facilitate review of alignment layout and preparation of plan for the proposed alignment.

The objectives of the survey were:

- The alignment should meet the geometric standards, particularly the gradients and curvature.
- It should be as directional as possible i.e. least distance.
- It should facilitate smooth traffic dispersal.
- It should avoid acquisition of commercial and residential establishments.
- It should avoid costly land acquisition.
- It should be environment friendly.
- Enable a definitive influence to be made for the profile of the approach road.
- Enable quantity estimate to be prepared.
- Provide record of work that will serve maintenance planning needs.
- Surveyed corridor is suitably extended for overall view of the area.

Resource Input

The detailed survey is carried out using Total Station. Other Survey equipment may also be used. The work of verification is carried out by deploying survey Expert and survey Assistant along with the Tunnel Engineer and Geologist.

Control Points

For mapping we have the control points as follows:

PILLAR-G1	**(X=650578.994**	**Y=3014042.997**	**Z= 470.996)**
PILLAR-G2	**(X=650594.161**	**Y=3014048.522**	**Z= 471.480)**
PILLAR-G3	**(X=650889.110**	**Y=3014429.117**	**Z= 472.770)**
PILLAR-G4	**(X=650896.408**	**Y=3014445.098**	**Z= 473.225)**
P=K1	**(X=650505.302**	**Y=3014337.846**	**Z= 656.701)**
P=K2	**(X=650507.591**	**Y=3014318.487**	**Z= 655.433)**

3.2 GEO – TECH ASSESSMENT SURVEY

General

It include general enquiry, foundation inspection, analysis of available data and historical background in order to make assessment and geo – technical behavior of the design parameters. The activities involved under the task are as under:

- Location study
- Conduct analysis of design operation
- Select Option
- Working out soil investigation requirement
- Define parameter, level of investigation and deliveries
- Assess requirement of bore holes
- Organize drilling of the bore holes
- Prepare characteristic and test on samples

Location Study

- The official inspection indicates that ample possibility of rock formation at both end of the portal.
- The out crop of rock of Gangtok side shows possibility of good rock formation.

Requirement of sub – soil investigation

- Soil investigation up to the rock level and depth to meet codal requirement.
- Sub – soil is carried out by a own firm
- The drilling of the bore hole carried out to meet the Codal requirement
- The soil characteristic have based on test of samples

On the basis of field investigation following field observation have been made

Rock types of the area are mostly Phyllite - Quartzite intercalations and they have been traversed by Quartzite veins at places of thickness varying from a mm to 6-7 cm. Due to shearing at places these Quartz veins have taken lampzoidal shape . At inlet portion Quartzite content is more, at places it is 70% or more whereas near outlet portion Quartzite contents more and going upto 70-75.

The general trend of rock type is N30W-S30E to N50W-S50E however it has been observed to swing either way due to structural deformation .Mostly they are dipping 30-60 degree in N-E direction N-S, E-W shears also have noted. Four sets of prominent joints have been observed of which bedding Joint is most prominent. At places they are filled with siliceous material. Other joints are N-S, W45E, S45W, E-W with varying dips.

3.3 MATERIAL ASSESSMENT SURVEY

General

- Soil and materials survey is carried out for resource input for the construction activity
- Good quality sand is available.
- Approved stone is available.
- Alternatively, good quality stone can be transported from other areas

- Water is available in the area

3.4 INITIAL ENVIRONMENTAL EXAMINATION

General

Initial environment screening has been carried out in accordance with government of India Guidelines, as applicable.

- The Consultant carried out the preliminary environmental screening to assess the direct and induced impacts due to the project
- The Consultant ensured to document baseline conditions relevant to the project with the objectives to established the benchmarks
- The Consultants assessed the potential significant impacts and identify the mitigate measures to address these impact adequately
- The Consultants carried out the analysis incorporating environmental concerns. This would include with and without scenario and modification incorporated in the proposed project due to environment considerations

Special Features of the Project

- Name of the Project : Construction of 2 lane Tunnel adjacent to Existing tunnel at Chisopani
- Length of the Tunnel : Approximately 250 m.
- Location : On NH-10 at Km 67+230
- Nature of terrain : Hilly
- Nature of Soil : Hard rock and on surface soil or soil mix with soil and rock

The Project

The project is for the construction of the bridge. The project is for bridging the gap in the road on the existing route alignment

Present Facility

Presently there is existing steel truss bridge at this location

Environmental grading

Factors affecting environmental resources and values and their IEE grading level is given in the Table given below

Beneficial Impact of the Bridge Project

The project will have several beneficial impacts as given in the table attached

Negative impact

We do not contemplate any negative impact of this project on the environmental aspect

INITIAL ENVIRONMENTAL EXAMINATION (IEE)

Actions affecting environmental resources and values		Recommended feasible mitigate measures	IEE grading (suggestive)
(A)	**Environmental Impacts Due to Project Location**		
(i)	Disruption to Hydrology	There will be no disruption to flow of stream	D1
(ii)	Resettlement	No resettlement involved	-
(iii)	Environmental aesthetics degradation	Care shall be taken to avoid/ minimize effect	D1
(iv)	Inequitable locations for rural roads	Cross roads suitable clubbed for access to the road. For the purpose, suitable connectors are planned and under implementation NHIDCL	D1
(v)	Loss of terrestrial ecology including forest and wildlife	Not involved	-
(vi)	Loss of swamp ecology	Not involved	-
(B)	**Impacts during construction phase**		
(i)	Site runoff from cut and fill area	Suitable measures to be adopted during construction	D1
(ii)	Safety of works from accidents	All safety measures to be incorporated in tender document	D1
(iii)	Slum creation hazards	Appropriate planning for housing of construction workers to be made	D1
(iv)	Cultural difference hazards	It is to be avoided and public learning be made and considered	-
(v)	Escape of hazardous materials	Strict monitoring the movement of hazardous materials	D1
(vi)	Escape of air pollution (including dusts)	Suitable measures to be adopted to prevent/ minimize	D1
(vii)	Noise and vibrations	Effects shall be assessed and measures taken based on significance	D1
(viii)	Quarrying hazards(including use of explosives)	Appropriate planning operation of blasting and use of operating quarries	D1
(ix)	Disruption of utilities along route	Not involved	
(x)	Disruption of traffic along route	Alternative	
(C)	**Impacts from Project Operations**		
(i)	Noise disturbance	Not involved	D1
(ii)	Vibration disturbance	Appropriate planning and post construction monitoring may be made	D1
(iii)	Air Pollution	Appropriate planning and post construction monitoring will be made	D1
(iv)	Continuing erosion	Protective vegetation and other methods shall be adopted	D1
(v)	Highway runoff contamination	Appropriate planning and post construction monitoring to take care	D1
(vi)	Highway spills of hazardous materials	Appropriate spills control program and post construction monitoring to take care	D1
(vii)	Escape of sanitary wastes	Appropriate planning/ post construction monitoring to be considered	D1
(viii)	Congestion at access/ exit points	Not involved	-
(ix)	Inadequate highway maintenance	Not involved	-

Note IEE grading Scale:
D1 - Not significant
D2 - Small significant effects
D3 - Moderate significant effect
D4 - Major significant effect

Beneficial Impacts of Project

- Employment opportunity to people
- Enhancement of local industry, agriculture and handicrafts
- Income from visitors and taxes
- Enhancement of rural development through quick and easy transportation of building materials
- Transporting, processing and marketing of agricultural products
- Opening up of opportunities for new occupations
- Approach to quick services and safety
- Improved quality of life for people and so on

CHAPTER – 04
OPTION STUDY OF ALIGNMENT

General

In order to carry out the option study of alignment near the existing tunnel site, as widening of existing tunnel is not possible, we have carried out survey of the possible locations and the influence area.

The objective of the Route alignment study is to determine various alternative alignment options and to identify relative acceptable and preferable alignment. With a view to appreciate the feasibility and relative strength, weakness of the alternative proposals marked on the topo sheets, and site evaluation of the same have been carried out. This was manifested through identifying the problems, shortcomings along with probable route.

CRITICAL FACTORS IN ALIGNMENT SELECTION

The critical factors to be considered in the selection of the alignment are as follows:

- The alignment should meet the geometric standards, particularly the gradients and curvature.
- It should avoid acquisition of commercial and residential establishments.
- It should avoid costly land acquisition.
- It should be as directional as possible, i.e. least distance.
- It should facilitate smooth traffic dispersal.
- It should be environment friendly.
- It should have minimum provision of structures.

During the detailed topographical survey, the trace-cut has been marked on the ground and survey details have been obtained on the trace-cut. However, in hard rock and hazardous areas the trace-cut is serving as reference line only.

THE METHODOLOGY ADOPTED IS DESCRIBED AS FOLLOWS :

Step – 1: Contour Map Study

Contour sheets are very important for fixing the alignment of the road and to design the road geometric, particularly in the hill road. Based on the contours, approximate alignment options have been studied taking into account the level difference between take-off and the terminal points. This exercise was done with a view to have an approximate understanding of the alignment options. The alignment marked on the contour sheets are planned to achieve the required length

Step-2: Satellite image study

Satellite image is very useful for fixing of the new alignment. Satellite image gives three dimension picture of the project area. Based on the contours, clear view of water channel & terrain condition, approximate alignment option has been studied. This exercise was done with a view to have a better understanding of the alignment option.

Step-3: Fly Level Survey

After the detailed study of the contour sheets and the available data, fly level survey of the entire road was carried out by using Auto Levels and the support instruments in order to generate the

road profile. The gradients of various alignment options were generated in the shape of strip plan showing gradient of proposed road

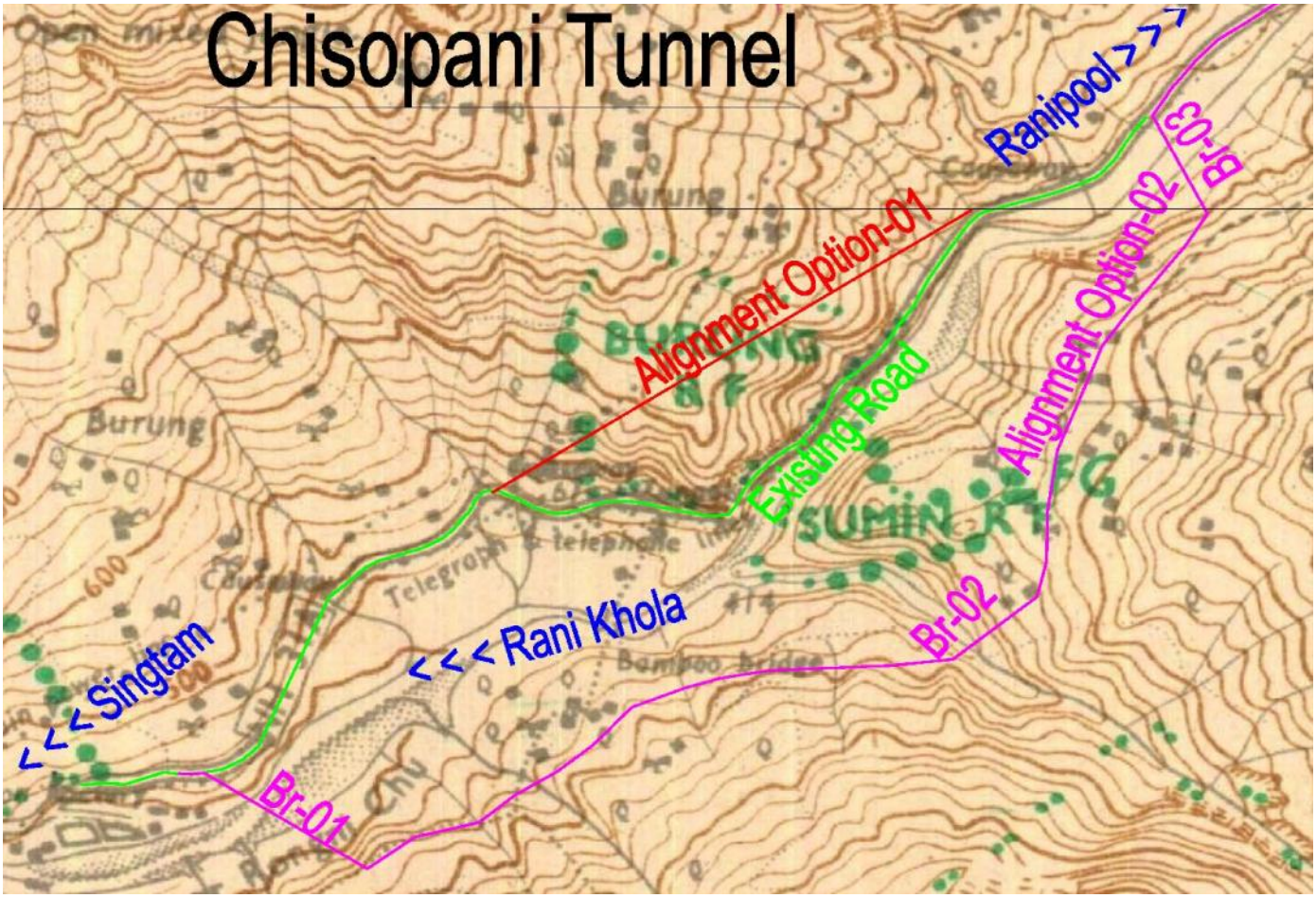
ALIGNMENT OPTIONS

Two (2) alignment options have been studies. The details of each option is given below

S/N.	Option-1	Option-2
1	Take of Point 90m backward from existing tunnel inlet & merging point 200 m away from existing tunnel outlet.	Take of point 850 m backward from existing tunnel inlet & merging point 350 m away from existing tunnel outlet.
2	Proposed alignment on RHS of the Ranikhola.	Proposed alignment on LHS of the Ranikhola
3	Proposed alignment passing through New tunnel parallel to the existing tunnel.	Proposed alignment cross the Ranikhola at two places i.e. one at starting of the alignment & other at end of the alignment.
4	Proposed alignment Length 400 m including 250 m tunnel	Proposed alignment length is 2.4 Km including 3 Nos of bridges. Length of Br. No-01 -70m, Br.No.-02-50m & Br.No.-03 -07m.
5		Proposed alignment needs three Nos of bridges. Two bridges over the Ranikhola & one bridge over Rongou Khola.
6	Entire stretch passing through the Burung Reserve forest.	About 70% of proposed alignment passing through the built-up area , cultivated portion and remaining passing through Sumin reserve forest
7	Proposed alignment needs forest clearance. Forest land required about 1.0 Ha.	Proposed alignment needs private Land acquisition and forest clearance. Proposed alignment needs about 6.5 Ha private lands & 0.50 Ha forest land.
8	Proposed alignment having better road geometry & shorten the length of road.	Proposed alignment geometry is comparatively poor than option-01 & lengthen the length of existing road.

Select option:

Option no: 1 – Tunnel


Chisopani Tunnel
Ranipool
Alignment Option-01
Existing Road
Alignment Option-02
Br-03
Br-02
Br-01
Rani Khola
Singtam
Burung
SUMIN

CHAPTER-05

PLANNING AND GEOMETRICAL CONFIGURATION OF HIGHWAY TUNNEL

5.1 INTRODUCTION

Road tunnels are feasible alternatives to cross through physical barriers such as mountains, existing tunnels, existing roadways, rail lines etc. In addition, road tunnels are viable means to minimize excessive length of road particularly in hilly areas apart from potential environmental impact such as traffic congestion, pedestrian movement, air quality, noise pollution, or visual intrusion to protect areas of special cultural or historical value such as places of worship, forts or palaces or private properties or for other sustainability reasons such as to avoid the impact on natural habitat or reduce disturbance to surface land. It should be noted that the life expectancy of tunnels are significantly longer than those of other facilities.

There are three main shapes of highway tunnels i.e rectangular, circular and horse shoe. The shape of the tunnel is largely dependent on the method used to construct the tunnel and the ground conditions i.e. rectangular tunnels are often constructed by cut and cover method. Circular tunnels are constructed by using either tunnel boring machine (TBM) or by conventional method of drill and blast in rock. Horse shoe configuration tunnels are constructed using drill and blast in rock or by following sequential excavation method (New Austrian Tunnelling Method).

Road tunnels are generally lined with concrete and internal finished surfaces. Rock reinforcement is often needed. Rock reinforcement for initial support includes the use of rock bolts, un-tensioned steel dowels or tensioned steel bolts. To prevent small fragments of rock from spalling, wiremesh, shotcrete or a thin concrete lining is generally used. Shotcrete is often used as initial lining prior to installation of final lining. Segmental linings are generally made of cast iron, steel or concrete. The walls and the ceilings often receive a finish surface while the roadway is often paved with asphalt pavement.
The tunnels are generally equipped with various systems such as ventilation, lighting, communication, fire fighting system and life safety, drainage, traffic operation and control systems etc.

Generally, the tunnel geometrical configuration should accommodate all potential vehicles that is expected to use the roads leading to the tunnel including over height vehicles such as military vehicles. Road tunnels should have atleast the same traffic capacity as that of surface roads. Studies suggest that in tunnels where traffic is controlled, if traffic is more than that in uncontrolled surface road suggesting that a

reduction in the number of lanes inside the tunnel may be warranted. However, traffic will slow down, if the lane width is less than standards and may strike with tunnel walls if insufficient lateral clearance is provided inside the tunnel. Also, very low ceilings give an impression of speed and tend to slow the traffic flow. Therefore, it is important to provide adequate lane width and height in the tunnel comparable to those of approach road.

5.2 Geological Investigations

Geological and Geotechnical investigations are critical for proper planning of a tunnel. Selection of the alignment cross section and construction methods is influenced by the geological and geotechnical conditions, as well as the site constraints. Good knowledge of the expected geological conditions is essential. The impact of geological features on the tunnel alignment is the presence of active or inactive faults. During the planning phase, it is necessary to avoid crossing a fault zone and preferred to avoid being in a close proximity of any active fault. Geotechnical issues such as soil or rock properties, ground water regime, ground cover over tunnel, presence of underground utilities and obstructions such as boulders or buried objects should be taken into consideration while fixing tunnel alignment. Tunnel alignment is sometimes changed based on the results of the geotechnical to minimize construction cost or to the reduce risks. The profile can also be adjusted to improve constructability or accommodate construction technologies as long as the road geometrical requirements are not compromised.

It is necessary that the geotechnical investigations may start as early as possible during the initial planning phase of the project. The investigations should address not just the soil and rock properties but also their anticipated behaviuors during excavation. For example in sequential excavation or New Austrian Tunneling Method (NATM), ground standup time is critical for its success.

5.3 Environmental Friendly

Road tunnels are more environmental friendly than other surface facilities. Air quality would be improved because traffic generated pollutants are captured and disposed off away from the public. Similarly, noise would be reduced and visual aesthetic and land use would be improved.

5.4 Ground Water Control

A dry tunnel provides a safer and friendlier environment and significantly reduces operational and maintenance cost. Advancement in tunnelling technology in the last few decades in general and in the water proofing field in particular have facilitated the implementation of strict water infiltration criteria and the ability to build dry tunnel. Tunnel water proofing system is used to prevent ground water inflow into

an underground opening. This system is commonly installed between an initial tunnel support (initial lining) and the final support (permanent lining).

There are two basic types of water proofing system, drained (open) and un-drained (closed), open water proofing systems allows ground water inflow into a tunnel drainage system. The tunnel vault area is equipped with a water proofing system forming an umbrella like protection that drains the water seeping towards the cavity around the arch into a drainage system that is located at the bottom of the tunnel sidewalls and in the tunnel invert. The open system is commonly used in rock tunnels where water infiltration rates are low.

Closed water proofing system (closed system) extend around the entire tunnel perimeter and aim at excluding the ground water from flowing into the tunnel drainage system completely. Thus, no ground water drainage is provided. The secondary linings, therefore, have to be designed for full hydrostatic water pressures. These systems are often applied in permeable soils where ground water discharge into the tunnels would be significant.

5.5 Tunnel Portals

Construction of portals and its long term maintenance is very important & their locations are made based on safety consideration. Portals are located such that they satisfy environmental and air quality requirements as well as the geometrical configuration of the tunnel & hill slopes. At portals, it may be necessary to extend the dividing wall between traffic travelling in opposite directions to reduce recirculation of pollutants from the exit tunnel into the entry tunnel. If possible, portals should be oriented to avoid drivers being blinded by the rising or setting of the Sun. Special lighting requirements at the portal are needed to address the 'black hole' effect. In mountain tunnels, the portals should be as close to the face of the mountain as practically constructible.

5.6 Design Process

The basic process used in the design of a road tunnel is:

i) Functional requirements including design life and durability requirements.
ii) Investigations and analyses of the geological & geotechnical data.
iii) Determination of the most appropriate method of tunnelling.
iv) Appropriate initial and final ground support and lining system critical for the tunnel design, considering both ground conditions and proposed method of construction.
v) Establishing tunnel alignment, profile and cross section.
vi) Preparation of project document including planning, construction method schedule, specifications, estimate and geotechnical report.

5.7 Fire Protection & Life Safety Requirements

The fire protection and life safety requirements for road tunnels are as follows:

(i) Fire Protection: Stand pipe, fire hydrants, water supply, portable fire extinguisher, fixed water-base fire fighting system etc.

(ii) Tunnel Drainage System

Good design anticipates drainage needs. Usually sump-pump systems are provided at the portals and low points. Roadway drainage throughout the tunnel using drain inlets and drainage pipes should be provided. The drainage system should be designed to deal with surface drainage as well as any ground water infiltration into the tunnel. Other areas of tunnels, such as ventilation ducts and potential location for leakage should have provision for drainage.

(iii) Emergency Egress

Emergency egress for persons using the tunnel should be provided at regular intervals. Exists should be clearly marked and the spacing of exists into escape routes should not exceed 300 m. The emergency egress walk ways should be a minimum 1.2 m wide and should be protected from incoming traffic. Signage indicating both direction and distance to the nearest escape door should be mounted at one of the emergency walk ways and be visible in an emergency.

(iv) Emergency Ventilation, Lighting and Communication

An emergency ventilation system should be provided to control smoke and to provide fresh air for the evacuation of passengers. The emergency ventilation system is often the normal ventilation system operated at higher speeds. The fans should be connected to an emergency power source in case of failure of primary power.

The risk of fire spreading through power cable ducts should be eliminated by dividing cable ducts into fire proof sections. Placing cables in ducts using fire proof cables where applicable and other preventative measures be adopted.

Emergency telephones should be provided in the tunnels and connected to the emergency power supply. When such a telephone is used, the location of the caller should be identified both at the control centre and by a warning light visible to rescuing personnel. Telephones should be provided at cross passage doors and emergency exits. Communication system should give the travelling public the possibility of summoning help and receiving instructions and ensuring coordinated rescue. Systems should raise the alarm quickly and reliably when unusual operating conditions or emergency situations arise.

5.8 Geometrical Configuration of Road Tunnel

The geometrical design of road tunnel is based on design speed, shoulder width, tunnel width, horizontal and vertical alignments, grade, stopping sight distance, cross slope, super elevation, horizontal and vertical clearances. In addition to the above design standards, the geometrical design for road tunnels should also consider tunnel systems such as fire fighting & life safety elements, fire detection and protection , ventilation, lighting, traffic control, drainage, escape route, communication etc.

5.8.1 Maximum Grade

Maximum effective grades in main roadway tunnels preferably should not exceed 4%, although grades upto 6% have been used where necessary. Long or steep uphill grades may result in a need for climbing lane for heavy vehicles. However for economic and ventilation reasons, climbing lane should be avoided within tunnels.

5.8.2 Horizontal Curve

The horizontal alignment for a road tunnel should be as short as practical and maintain as much of the tunnel length on tangent as possible, which will limit the numbers of curves, minimize the length and improve operating efficiency. When horizontal curves are needed, the minimum acceptable horizontal radii should consider traffic speed, sight distances and super elevation provided. In general, for planning purpose, the curve radii should be as large as possible and not less than 250-300 meters.

5.8.3 Super Elevation

Super elevation which is the rise in the road way surface elevation from the inside to the outside edge of the road, should preferably be in the range 1% to 6%.

5.8.4 Sight and Braking Distance

Sight and braking distance cannot be relaxed in tunnels. On horizontal and vertical curves, it may be necessary to widen the tunnel locally to meet the requirements.
Sufficient stopping distance should be made available for drivers to stop their vehicles when faced with an unexpected obstruction in the carriage way. The stopping sight distance as recommended is given below:

Speed (km/h)	Safe Stopping Distance (m)
20	20
25	25
30	30
35	40
40	45
50	60
60	90
70	120

5.8.5 Travel Clearance

The clearance should consider vehicle height, vehicle mounting on curbs, construction tolerances, structural settlement, ventilation equipment, lighting etc. The vertical clearance should be selected as economical as possible & should be consistent with the vehicle size. General recommendation is that the minimum vertical clearance to be maintained of the order of 5.5 m for highways. The minimum clearance for two lane tunnel from curb to curb and wall to wall should not be less than 7.5 m and 9.0 m respectively. The desirable distance for curb to curb and wall to wall may be 7.5 m and 12.0 m respectively.

The vertical clearance shall also take into consideration for future resurfacing of the roadways. Although it is recommended in roadways tunnels only after the previous surface has been removed, it is resurfaced once without removal of the old pavement.

5.8.6 Travel Lane and Shoulder

For planning and design purposes, each lane width within a road tunnel should not be less than 3.75 m. It is preferable to carry the full left and right shoulder widths of the approach freeway through the tunnel. It is suggested for unidirectional road tunnels that the right shoulder be 1.2 m and left shoulder be atleast 0.6m. Sometimes shoulder are eliminated and replaced by barriers.

5.8.7 Side Walks/Emergency Egress Walkway

Although pedestrians are not permitted in road tunnels, sidewalks are required in road tunnels to provide emergency egress and access by maintenance personnel. It has been recommended that raised sidewalks or curbs with a minimum width of 0.7 m or wider beyond the shoulder area are desirable to be used as an emergency egress and that to a raised barrier to prevent the overhang of vehicles from damaging the wall finish of the tunnel.

5.8.8 Tunnel Drainage

Road tunnels must be equipped with a drainage system consisting of pipes, channels, sump/ pump, oil/water separators and control system for the safe and reliable collection, storage, separation and disposal of liquid/ effluent from the tunnels that might otherwise collect together.

Drainage must be provided in tunnels to deal with surface water as well as water leakage. For the safety reason, PVC, fibre glass pipes or other combustible materials should not be used. Sumps and pumps should be located at low points of a tunnel and at portals to handle water that might otherwise flow into the tunnel.

5.8.9 Ventilation Requirement

The ventilation system of a tunnel operates to maintain air quality levels for short terms exposure within the tunnel. The design may be driven either by fire/safety

considerations or by air quality; which one governs depends upon many factors including traffic, size and length of tunnel and any special features such as underground interchanges. It is determined using two primary criteria (i) handling of noxious emissions from vehicles using the tunnel (ii) handling of smoke during a fire. The two main ventilation system options for tunnels are longitudinal ventilation and transverse ventilation.

A longitudinal ventilation system introduces air into, or removes air from a tunnel, with the longitudinal flow of traffic at a limited number of points. It can be sub-classified as either using a jet fan system or a central fan system with a high velocity nozzle. Generally, it includes a series of axial, high velocity jet fans mounted at the ceiling level to induce a longitudinal air flow through the length of tunnel.

A transverse ventilation system can be either a full or semi full transverse type. With full transverse ventilation, air supply ducts are located above, below or to the side of the tunnel and inject fresh air at regular interval. Exhaust ducts are located above or to the side of the tunnel and remove air and contaminants. With semi transverse ventilation, the supply duct is eliminated with its "duties" taken over by the traffic opening.

5.8.10 Lighting Requirement

Lighting in tunnels assists the driver in identifying hazards or disabled vehicles within the tunnel while at a sufficient distance to safely react or stop. High light levels (portal light zone) are usually required at the beginning of the tunnel during the day time to compensate for the 'Black Hole Effect' that occurs by the tunnel structure shadowing the roadway. These high light levels will be used only during day time. Tunnel light fixtures are usually located in the ceiling or mounted on the walls near the ceiling.

For improved safety during a fire, it is suggested that strobe lights be placed to identify exit routes. If used, they should be placed around exit doors, especially at lower levels which might then be under the smoke level. The strobe lights would be activated only during tunnel fires.

5.8.11 Portals and Approach

Tunnel portals may require special design considerations. Portal sites need to be located in stable ground with sufficient space. Orientation of the portals should avoid, if possible direct East and West to avoid blinding sunlight. Ameliorating measures should be taken where drivers might otherwise be blinded by the rising or setting sun. A central dividing wall sometimes is extended some distance out from the portal to prevent re-circulation of polluted air.

CHAPTER-6

CLASSIFICATION OF ROCK MASS OF TUNNELS

6.1 BACKGROUND

The surface geological mapping was carried out around Inlet and outlet of tunnel. It is inferred that the area exposes predominantly low grade metamorphic rocks which are represented by phylitic rocks with minor quartzite. On the basis of the field observations, the rocks of the area can be geologically classified as:

(a) Phyllites

(b) Phylitic quartzite

(c) Fine grained quartzite

(d) Occasional Mylonitic quartzite interbedded with thin phyllitic bands

The general trend of the formation is N-S to NW-SE with dips of 45^o – 50^o in E and NE direction. The rocks are highly jointed. All the important joints are described in the chapter on geology of the Project. Based on the laboratory testing of rock samples, the compressive strength of phyllite is < 50 MPa whereas compressive strength of phyllitic quartzite is < 100 MPa.

Rock mass classification is vital in the design of tunnels, underground cavities and similar structures. It has become a customary and practice to follow Norwagian experiences as they have case histories of about 200 tunnels and caverns constructed in various terrains. In the Himalays, the tectonic settings are different and the rocks are entirely in different geological settings.

6.2 Classification Method of Rock Mass

The rock mass classification is used to obtain a general rating of rock mass quality and classification of drill ability and blastabity and estimate the rock supports.

Two commonly used methods are:

(a) RMR method (Rock Mass Rating)

(b) Q method (Rock Mass Quality)

6.3 RMR Method

It was developed by Bienianwski in 1973 and it involves six parameters. The parameters are:

(i) Uniaxial compressive strength of intact rock material

(ii) Rock quality designation (RQD)

(iii) Joint or Discontinuity spacing

(iv) Joint condition

(v) Ground water condition

(vi) Orientation of Joint or Discontinuity

6.3.1 Uniaxial Compressive Strength of intact rock material

The strength of the intact rock material is obtained from rock cores in accordance with site conditions. The rating based on Uniaxial compressive strength is given in Table 6.1 – Annexure I.

6.3.2 Rock Quality Designation (RQD)

Rock quality designation (RQD) is percentage of rock cores (equal to or more than 10 cm) in one metre of drill run. The details of rating is given in Table 6.2 – Annexure I.

6.3.3 Joint or Discontinuity Spacing

The term discontinuity covers joints, bedding or foliation, shear zones, minor faults. The details of rating is given in Table 6.3 – Annexure I.

6.3.4 Joint Condition

This parameter includes roughness of discontinuity surfaces, their separation, length or continuity, weathering of the wall rock or the planes of weakness and infilling (gorge) material. The details of rating are given in Table 6.4 – Annexure I.

6.3.5 Ground Water Condition

In the case of tunnels, the rate of inflow of ground water in litres per minute per 10m length of tunnel is determined to assess the general condition as dry, damp, wet, dripping and flowing. The ratings as per the water condition is given in Table 6.5 – Annexure – I.

6.3.6 Orientation of Joints or Discontinuity

Orientation of discontinuity means the strike and dip of discontinuities. The strike is recorded with reference to magnetic north. The dip angle is the angle between the horizontal and the discontinuity plane taken in a direction in which the plane dips. The value of dip and strike are recorded. To facilitate a decision whether or not the strike and dip are favourable, reference is made in Table 6.6 & 6.7 – Annexure I.

6.4 Q Method (Rock Mass Quality)

Barton at the Norwegian Geotechnical Institute (NGI) originally proposed the Q-system of rock mass classification on the basis of about 200 case histories of tunnels and caverns. He has defined the rock mass quality "Q" by the following factors:

$$Q = \frac{RQD}{Jn} \times \frac{Jr}{Ja} \times \frac{Jw}{SRF}$$

RQD = Rock quality designation

Jn = Joint set number

Jr = Joint roughness number

Ja = Joint alteration number

Jw = Joint Water reduction factor

SRF = Stress reduction factor

6.4.1 Rock Quality Designation (RQD)

The RQD value in percentage is also the rating of RQD for the Q-system. The RQD value of core recovery has been in the range of 25-50%. The details of rating are given in Table 6.1 – Annexure II.

6.4.2 Joint Set Number (Jn)

The parameter Jn, representing the number of Joint sets, is often affected by foliations, schistocity, slaty cleavages or beddings. The ratings are given in Table 6.2 – Annexure II.

6.4.3 Joint Roughness Number (Jr) and Joint Alteration Number (Ja)

The parameters Jr and Ja are given in Table 6.3 & 6.4 – Annexure II respectively represent roughness and degree of alteration of joint walls or filling material. The parameters Jr and Ja are obtained for the weakest critical joint set or clay filled discontinuity in a given zone.

6.4.4 Joint Water Reduction Factor (Jw)

The parameter Jw is given in Table 4.5 – Annexure II is a measure of water pressure which has an adverse effect on the shear strength of Joints. Water in addition may cause softening and possible wash out in the case of clay filled joints.

6.4.5 Stress Reduction Factor (SRF)

The parameter SRF is given in Table 4.6 – Annexure II is a measure of loosening pressure in the case of an excavation through shear zones and clay bearing rock masses.

6.5 CLASSIFICATION OF ROCK AT TUNNELS

On the basis of RMR classification, the rating has been assessed in case of phyllite ad phyllitic quartzite rock occurred at all the tunnel site. The details are given as below:

S. No.	Reference	Parameters	Rating	
			Phyllite	**Phyllitic Quartzite**
1.	Table 6.1 – Annexure I	Uniaxial Compressive strength of Intact rock	4	7
2.	Table 6.2 – Annexure I	Rock Quality designation	8	8
3.	Table 6.3 – Annexure I	Joint or discontinuity spacing	8	8
4.	Table 6.4 – Annexure I	Joint Condition	20	20
5.	Table 6.5 – Annexure I	Ground Water Condition	10	10
6.	Table 6.6 & Table 6.7 – Annexure I	Orientation of Joints or discontinuities	-5	-5
		Total Rating	**45**	**48**

On the basis of RMR values for a given engineering structure, the rock mass is classified into five classes.

Rock Mass Rating (RMR)	Classification of Rock Mass
100-81	Very good
80-61	Good
60-41	Fair
40-21	Poor
<20	Very Poor

In our case the RMR of Phyllite and Phyllitic Quartzite lies in the range of 41-60. Therefore, Fair rock conditions may prevail based on RMR classification.

On the basis of **Q-method classification**, the rating has been assessed and details are given as below:

S. No.	Reference	Parameters	Rating	
			Phyllite rock	**Phyllite Quartzite rock**
1.	Table 6.1 – Annexure II	Rock Quality Designation (RQD)	40	50
2.	Table 6.2 – Annexure II	Joint Set Number (Jn)	15	15
3.	Table 6.3 – Annexure II	Joint roughness number (Jr)	2	2
4.	Table 6.4 – Annexure II	Joint alteration number (Ja)	3	3
5.	Table 6.5 - Annexure II	Joint Water reduction factor	1	1
6.	Table 6.6 – Annexure II	Stress Reduction Factor (SRF)	5	5

Putting the above values in the equation :

$$Q = \frac{RQD}{Jn} \times \frac{Jr}{Ja} \times \frac{Jw}{SRF}$$

In case of Phyllite

$$Q = \frac{40}{15} \times \frac{2}{3} \times \frac{1}{5}$$
$$= 0.35$$

In case of Phylitic Quartzite

$$Q = \frac{50}{15} \times \frac{2}{3} \times \frac{1}{5}$$
$$= 0.44$$

On the basis of Q-method for a given engineering structure, the rock mass is classified into six classes:

Q	Classification
0.01 - 0.1	Extremely Poor
0.1 - 1	Very Poor
1 - 4	Poor
4 - 10	Fair
10 - 40	Good
40 - 100	Very good

In our case, Q value is assessed as 0.35 and 0.44 for phyllite and phylitie quartzite respectively. Therefore, very poor type rock mass prevail at the project site based on Q-system.

6.6 CONCLUSION

On the basis of surface mapping and lithology of the area near the portals of tunnel, it is summerised that the area is mainly occupied by phyllites with 15-30% of phylitic quartzite and quartzite veins. Area has been subjected to deformation which has resulted in development of folding and shearing. Five to six sets of structural discontinuities have been observed of which bedding and foliation are mostly

predominant and are very closely spaced. Thin shears of few cms to a maximum of 1.5m thickness have been observed. They need proper treatment during tunnel excavations. Since the area is part of one of the youngest Himalayan events with incidences of Earthquakes and landslides occurring at present days as well.

Rock mass of the project can be categorized from average to very poor. Hence all the precautionary measures are recommended to be taken during course of tunnel excavations. The most commonly used rock support methods are, shotcreting, rock bolting, steel ribs, concrete lining, and grouting.

Rock Mass Rating (RMR)

Annexure – I

Table 6.1 Strength of intact rock material

Qualitative Description	Compressive strength (MPa)	Point load strength (MPa)	Rating
Exceptionally strong	> 250	8	15
Very strong	100-250	4-8	12
Strong	50-100	2-4	7
Average	25-50	1-2	4
Weak	5-25	Use of uniaxial compressive strength is preferred	2
Very weak	1-5	As above	1
Extremely weak	<1	As above	0

Table 6.2 Rock quality designation, RQD

Qualitative Description	RQD	Rating
Excellent	90-100	20
Good	75-90	17
Fair	50-75	13
Poor	25-50	8
Very Poor	<25	3

Table 6.3 Spacing of discontinuities

Description	Spacing (m)	Rating
Very wide	>2	20
Wide	0.6-2	15
Moderate	0.2-0.6	10
Close	0.06-0.2	8
Very Close	<0.06	5

Table 6.4 Condition of discontinuities

Description	Joint separation (mm)	Rating
Very rough and unweathered, wall rock tight and discontinuous, no separation	0	30
Rough and slightly weathered, wall rock surface separation <1mm	<1	25
Slightly rough and moderately to highly weathered, wall rock surface separation <1mm	<1	20
Slickensided wall rock surface or 1-5mm thick gouge or 1-5 mm wide continuous discontinuity	1-5	10
5 mm thick soft gouge, 5 mm wide continuous discontinuity	>5	0

Table 6.5 Ground water condition

Inflow per 10 m tunnel length (liter/min.)	None	<10	10-25	25-125	>125
Ratio of Joint water pressure to major principal stress	0	0-0.1	0.1-0.2	0.2-0.5	>0.5
General description	Completely dry	Damp	Wet	Dripping	Flowing
Rating	15	10	7	4	0

Table 6.6 Assessment of joint orientation effect on tunnels (dips are apparent dips along tunnel axis)

Strike perpendicular to tunnel axis				Strike parallel to tunnel axis		Irrespective of strike
Drive with dip		Drive against dip				
Dip 45°-90°	Dip 20°-45°	Dip 45°-90°	Dip 20° -45°	Dip 20°-45°	Dip 45°-90°	Dip 0°-20°
Very favorable	Favorable	Fair	Unfavorable	Fair	Very unfavorable	Fair

Table 6.7 Adjustment for joint orientation

Joint orientation assessment for	Very favorable	Favorable	Fair	Unfavorable	Very unfavorable
Tunnels	0	-2	-5	-10	-12
Raft foundation	0	-2	-7	-15	-25
Slopes	0	-5	-25	-50	-60

Rock Mass Quality Rating (Q)

Annexure – II

Table 6.1 Rock quality designation RQD

Condition	RQD
A. Very poor	0-25
B. Poor	25-50
C. Fair	50-75
D. Good	75-90
E. Excellent	90-100

Table 6.2 Joint set number J_n

Condition	J_n
A. Massive, no or few joints	0.5-1.0
B. One joint set	2
C. One joint set plus random	3
D. Two joint sets	4
E. Two joint sets plus random	6
F. Three joint sets	9
G. Four or more joint sets, random, heavily jointed, "sugar cube", etc.	15
J. Crushed rock, earthlike	20

Table 6.3 Joint roughness number J_r

Condition	J_r
(a) Rock wall contact and	
(b) Rock wall contact before 10 cm shear	
A. Discontinuous joint	4
B. Rough or irregular, undulating	3
C. Smooth, undulating	2.0
D. Slickensided, undulating	1.5
E. Rough or irregular, planar	1.5
F. Smooth, planar	1.0
G. Slickensided, planar (c) No rock wall contact when sheared	0.5
H. Zone containing clay minerals thick enough to prevent rock wall contact	1.0
I. Sandy, gravelly or crushed zone thick enough to prevent rock wall contact	1.0

Table 6.4 Joint alteration number J_a

Condition		Aprox (degree)	J_a
(a)	Rock wall contact (No mineral filling, only coating)		
A.	Tightly healed, hard, non-softening, impermeable filling, i.e., quartz or epidote		0.75
B.	Unaltered joint walls, surface staining only	25-35	1.0
C.	Slightly altered joint walls. Non-softening mineral coatings, sandy particles, clay-free disintegrated rock, etc.	25-30	2.0
D.	Silty or sandy clay coatings, small clay fraction (non-softening)	20-25	3.0
E. (b)	Softening or low friction clay mineral coatings, i.e., kaolinite, mica. Also chlorite, talc, gypsum and graphite, etc. and small quantities of swelling clays (Discontinuous coatings, 1-2 mm or less in thickness) Rock wall contact before 10 cm shear (Thin mineral fillings)	8-16	4.0
F.	Sandy particles, clay-free disintegrated rock, etc.	25-30	4.0
G.	Strongly over-consolidated, non-softening clay mineral fillings (continuous, <5 mm in thickness)	16-24	6.0
H.	Medium or low over-consolidation, softening, clay mineral fillings (continuous, <5 mm in thickness)	12-16	8.0
J.	Swelling clay fillings, i.e., montmorillonite (continuous, <5 mm in thickness). Value of J_a depends on percent of swelling clay-size particles, and access to water, etc.	6-12	8-12
(c)	No rock wall contact when sheared (Thick mineral fillings) K,L,M, Zones or bands of disintegrated or crushed rock and clay (see G,H,J for description of clay condition)	6-24	6,8 or 8-12
N.	Zones or bands of silty or sandy clay, small clay fraction (non-softening)	-	5
O,P, R.	Thick, continuous zones or bands of clay (see G,H, J for description of clay condition)	6-24	10,13 or 13-20

Table 6.5 Joint water reduction factor J_w

Condition		Aprox, water pressure (MPa)	J_w
A.	Dry excavations or minor inflow, i.e., 5l/min locally	<0.1	1
B.	Medium inflow or pressure, occasional out-wash of joint fillings	01-0.25	0.66
C.	Large inflow or high pressure in competent rock with unfilled joints	0.25-1.0	0.5
D.	Large inflow or high pressure, considerable out-wash of joint fillings	0.25-1.0	0.33
E.	Exceptionally high inflow or water pressure at blasting, decaying with time	>1.0	0.2-0.1
F.	Exceptionally high inflow or water pressure continuing without noticeable decay	>1.0	0.1-0.05

Table 6.6 Stress reduction factor SRF

Condition		SRF
a)	Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated	
A.	Multiple occurrence of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock (any depth)	10.0
B.	Single-weakness zones containing clay or chemically disintegrated rock (depth of excavation <50m)	5.0
C.	Single-weakness zones containing clay or chemically disintegrated rock (depth of excavation >50m)	2.5
D.	Multiple-shear zones in competent rock (clay-free), loose surrounding rock (any depth)	7.5
E.	Single-shear zones in competent rock (clay-free) (dept of excavation < 50m)	5.0
F.	Single-shear zones in competent rock (clay-free) (depth of excavation >50m)	2.5
G.	Loose, open joints, heavily jointed or “sugar cube”, etc. (any depth)	5.0

CHAPTER-07

GEOLOGY OF CHISOPANI HIGHWAY TUNNELS

7.1 INTRODUCTION

NHIDCL has been assigned the work by the Ministry of Road Transport & Highways, Govt. of India for Construction of Additional Tunnel at Chisopani on uphill side at Km 67.24 on NH-10 in East Distt., Sikkim.

	Length of tunnel	**:**	**230 m**
i)	Length of Inlet Portal	:	10 m
ii)	Length of outlet Portal	:	10 m

The description of physiography, regional geology and geology at the proposed tunnels are given below:

7.2 PHYSIOGRAPHY

Sikkim is the small hill state having an area of 7096 Sq.Km. The Chola range of mountains on its east forms the watershed between Sikkim and Bhutan on one side and Chumbi valley of Tibet on the other. The well-known Singalila ridge is of the great Himalayas peaks. Sikkim is drained by number of perennial rivers. However, the two main river systems are Teesta and Rangit. Rangit river joins Teesta river near the border between Sikkim and West Bengal at Melli. It is worth mentioning that the Kanchenjunga, third highest peak in the world towering at 8550 metres is in Sikkim. However, in the area under study the highest peak is 650 m, located in the north of proposed tunnel.

The Himalayan belt has been subdivided into four linear East-West trending zones. These are the Outer, Lesser or Sub-Himalaya, Great Himalaya and Tethys Himalaya. The area under study falls into the lesser or Sub-Himalayan region.

7.3 REGIONAL GEOLOGY

The tectono-stratigraphic units of Sikkim Himalaya and its vicinity have been carried by intricate deformations and Himalayan tectonic activity. The high grade Darjeeling gneissic rocks physically rest over the low grade metamorphic rocks like the Daling phyllites, slates and quartzites, considered as allochthonous pre-cambrian rocks thrusted over the para-autochthonous Buxa, Gondwana group of rocks, which in turn have thrusted over the Siwalik molasse of Neogenic age in the sub-Himalaya, south of Darjeeling along the Main Boundary Fault, the trace of which is seen along Kali Jhora between Sevoke and Teesta Bazar on the Siliguri-Gangtok National Highway, NH 10. The pre-Siwalik thrust sheets have been refolded into East-West Synforms (Darjeeling Klippe) south of Great Rangit (Badi Rangit) River and antiforms (Rangit Window), having north-south bending axial culmination along the Teesta valley and the corresponding depression along the Dharamgarh-Kanchenjunga axis.

The median unit of para-autochthonous zone comprising the low-grade metamorphic rocks of Buxa and Gondwana group rocks are exposed through a tectonic window at a lower erosional level towards the core of antiform near the confluence of Ramam and Rangit river (which is in the adjacent western part of this study area). Number of Geologists have worked in this area and a Tectonic succession of Sikkim-Darjeeling Himalaya (modified after Sinha Roy and Bhattacharya, G.S.I. Special Publication No. 22,1974) is reproduced below:

TECTONIC SUCCESSION OF SIKKIM-DARJEELING HIMALAYA

North Tethys	Trans-Axial Chhollamo Series Tectogene Lachi Series	Area
Great Himalaya	--------Thrust---------- Mt. Everest Limestone Everest pelitic Group --------- Trans Axial Thrust------- Kanchenjunga gneiss with Chungthang Formation and acid intrusive	North Sikkim Chhollamo Series Lachi Series Central Sikkim
	--------- Central Crystalline Thrust or MCT----------	
	Daling-Darjeeling Group with Buxa Group and Gondwana Group in Tectonic Window	Southern Sikkim & Darjeeling Hills
Lesser Himalaya Or Sub-Himalaya	- Daling Thrust (Window Thrust)-- Autoch - Buxa Group thonous ----Thrust---- To para-Autoch - Gondwana Group thonous	Darjeeling Hills
	--------- Main Boundary Fault----------	
Outer Himalaya	Siwalik Group	Darjeeling Foot Hills

7.4 SEISMICITY

The Sikkim is located in Zone IV according to Seismic Zoning Map of India (Fig 1). The Main Boundary Thrust (MBT) and Main Central Thrust (MCT) cross the state (Dasgupta et.al.2008). Due to continuous thrusting of Indo-Australian Plate against the Eurasian Plate, Sikkim has been a moderately active seismic region in the historical times (De and Kayal 2003, Nath et.al.2006). Some significant earthquakes which have shaken the region in the last 30 years include the 19 November, 1980 Sikkim earthquake of M_W 6.0, 21 August 1988 Bihar-Nepal earthquake of M_W 6.5, 14 February 2006 earthquake of M_W 5.3 and 18 September 2011 earthquake of M_W 6.9 (www.usgs.gov).

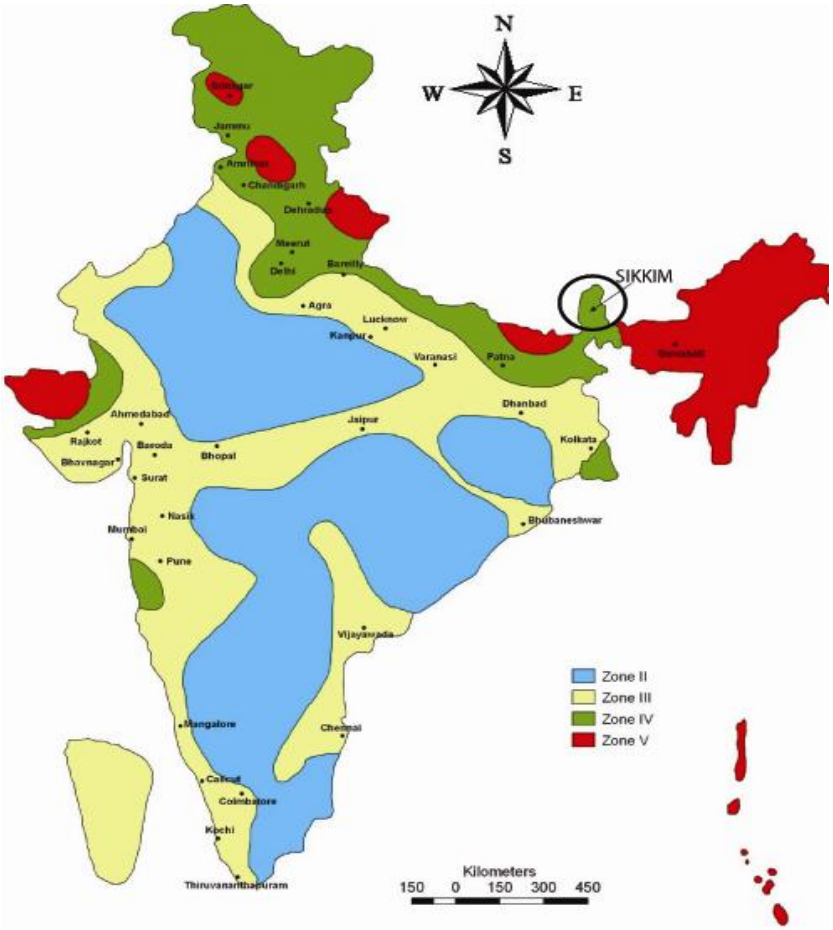


Fig-1: Seismic zoning map of India showing location of Sikkim in zone IV (BIS 2011, New Delhi)

7.5 LOCAL GEOLOGY

The youngest river borne sediments in form of sand, silt and clay can be easily observed along the main Teesta river besides its tributaries. Pebbles, gravels and boulders of assorted size from few cm to a maximum of 1 m – 2m dia are observed along Teesta river and its tributaries namely Rani Khola & Rangpo Khola etc. High assorting of fine to coarse grained constituents are indicative of turbulent velocity during peak rainy season. River terraces of different regimes are also found to be present in the project area.

Hill slopes are often occupied by scree and talus material at places where the country rock is weathered. The regional geological set up as well as the visible lithology indicates that the area studied is dominantly a phyllitic terrain wherein presence of quartzite bands and a mix of phyllites and quartzites are invariably observed. It has been possible to delineate the rock mass characterizing phyllites, phyllitic quartzite and quartzite along with weathered soil cover and rock debris with thick vegetal covers. Thickness of quartzite band varies from few cm to a maximum of 6 m, however in totality phyllite quartzite ratio is almost 70:30. In regional geological set up; these lithounits belong to Daling Group of rocks.

Structurally the lithounits exhibit primary bedding (So) foliation plane (S_1), deformations (folding), shears, silckensides, joints etc. Displacement of a few centimetre within a single silica band had been observed but its continuity is not confirmed. In the upstream of Rani

Khola, at a place far away from the inlet portal of Tunnel, a highly disturbed outcrop of rock mass (phyllitic quartzite and schistose quartzite), containing surfacial oxidation has been observed where pulverized and crushed material of powdery nature are profusely present. But continuation of it has not been confirmed. This is probably a highly crushed zone where shearing is of extensive order. The primary bedding (So) is observed only in phyllitic rock where colour bandings are prominent, it is not found in quartzites.

It has been observed that in majority of the cases joint surfaces are found with no infilling. It is probably because of the fact that the material present therein might have been subjected to atmospheric activities such as rains. Thin to thick shears are invariably associated in phylitic rock. Some shears are also observed along other joints and at acute and obtuse angle as well. Quartzite bands either thin or thick are in general devoid of sheared material. Occurrence of groundwater either in form of seepage water driplets or oozing out are not observed in the area.

7.6 Geology around Proposed Tunnels

During the comparative study of different options for the proposed ,it was also imperative to finalise the orientation of tunnel/tunnels sites, their respective portals. Since these tunnels are basically traffic tunnels, so it is desired to keep their diameter around 11.698 m and shape would be horse shoe. The 11.698 m dia tunnel would suitably house the side drains, traffic lights, requirements and pavements apart from the 2 lane road. While selecting the alignment sites for these tunnels; due care has been taken for both lateral and vertical covers. It has been seen that, in no case lateral cover is less than 4 'D' (Diameter of tunnel) and for attaining a vertical cover of at least 3 to 5 'D' at the tunnel location has been given on the section/profile. The Tunnel is aligned along N51^{o}E (Singtam side) – S51^{o}W (Ranipool side) .

Geology Around Tunnel

In order to unravel the lithological disposition, geological data including structural details were collected from 69 (CH1 to CH76) locations marked with the help of Total Station . The altitude covered falls within range from EL 460.00 m to 655.0 m. The main lithounits are phyllite, quartzite and phyllite with thin bands of quartzite.

Rock types of the area are mostly Phyllite - Quartzite intercalations and they have been traversed by Quartzite veins at places of thickness varying from a mm to 6-7 cm. Due to shearing at places these Quartz veins have taken lampzoidal shape . At inlet portion Quartzite content is more, at places it is 70% or more whereas near outlet portion Quartzite contents more and going upto 70-75.

The general trend of rock type is N30W-S30E to N50W-S50E however it has been observed to swing either way due to structural deformation .Mostly they are dipping 30-60 degree in N-E direction N-S, E-W shears also have noted. Four sets of prominent joints have been observed of which bedding Joint is most prominent. At places they are filled with siliceous material. Other joints are N-S, W45E, S45W, E-W with varying dips.

This swing is indicative of effective deformation (folding) in this part. Variation in strike of joints (Jo) and variation in dip amount are preserved in foliation. Occurrences of sheared material particularly clayey gouge are often observed along the foliation plane of phyllites.

This foliation joint is more persistent. Other sets of joints are also noticed and recorded. An attempt has been made to plot the orientation of joints at the Tunnel

Since the joint data have been recorded from a wider area and in majority of the cases the outcrops and their adjoining areas are disturbed, a deviation in joint surfaces is found due to structural disturbance.

7.7 CONCLUSION

Tunnel is aligned along N51^{o} E-S67^{o} W . It is proposed to have at least 11.698 m dia tunnel of horse shoe shape which would conveniently house the requisite infrastructures of a traffic tunnel. At this stage, it is also suggested that the tunnel should be excavated through heading and benching method.

The tunnelling media would be phyllite, phyllite with quartzite or phyllite with silica intercalations and quartzites.

CHAPTER 08

SEQUENCE OF CONSTRUCTION OF TUNNELS

8.1 GENERAL

Tunnels can be driven through any material in nature, but the methods used and costs differ radically. Thus, the method used in tunneling in soil, soft sediments or crushed whethered rock depends mainly on the bridge action period of the material above the roof of the tunnel and the position of water table, whereas the method used for tunneling through hard, intact rock requiring little or no supports depends upon the strength condition and of rock. Because of the great longitudinal extent of the work, different kinds of situations are encountered, which have to be tackled for maximum economy during tunnel excavation and supported accordingly.

Underground construction is a series of individual activities that must be completed before the subsequent activities can start. This series of unique activities are then repeated until the operation is complete. For tunnels that employ drilling and blasting to create the tunnel opening, the series is "drill, load, shoot, muck and support". Each round is drilled a certain length or depth using a pre-engineered drill pattern. Once the drilling is done the explosives are loaded into the drill holes and "wired up". The equipment and crews are then pulled back at a safe distance from the loaded face and then the blast is "shot". Exhaust gasses produced by the explosives are removed from the face and fresh air is sent to the heading area. After around 30 minutes, the crews are allowed back into the area to scale or knock down any loose rock and remove the excavated material or muck. Once the muck is removed, the initial tunnel support is installed to make the excavated opening stable and safe for the crew to work beneath. The cycle is completed and the tunnel has been advanced some distance. The next round can be started when all of these activities have been fully undertaken and completed.

8.2 PRECISION SURVEY AND SETTING OUT

The precision survey and setting out of the tunnel alignment shall consist of transferring the obligatory points like portal points from topographical maps to the actual site of construction. This is carried out either by "Direct setting out" or by "Triangulation". In the mountainous regions it is an extremely rare possibility that both the ends of the tunnels will be visible from each other and hence "triangulation" has to be invariably adopted for setting out the alignment.

8.2.1 Location of Portals

A tunnel portal is the face from where a tunnel starts or ends. Its location is decided with reference to the vertical and lateral rock cover. The minimum cover with which tunnel can be started depends upon the type and structure of rock, size and shape of tunnel.

8.3 METHODS OF TUNNELLING

The methods of excavating the faces of a tunnel depends upon the size and shape of the tunnel, the rock characteristics, the equipment available, the support system envisaged for the tunnel. Following are the methods commonly adopted.

8.3.1 Full Face Attack

In this method, the entire cross-sectional area of the tunnel to be excavated is attacked simultaneously. This method is generally recommended for small size tunnels and tunnels in good rock conditions where major rock falls are not anticipated.

8.3.2 Top Heading and Benching

Where the tunnel has a very large cross sectional area or where the rock is not of good quality, the top heading and benching method is generally recommended. In this method, a top heading is excavated first either to full section or part section of the tunnel, and is supported simultaneously. The benching is then removed slowly.

8.3.3 Bottom Heading and Stopping

Where the rock is consistent and sound and the tunnel section is very large, this method can be easily adopted. In this method a bottom heading is made first and over head stope is removed later on.

8.4 SEQUENCE OF OPERATIONS FOR CONSTRUCTION OF TUNNELS

After the tunnel alignment has been marked on the site and portals constructed the actual tunneling operations starts. The sequence of operations for construction of tunnels using the conventional drilling and blasting method are as under:

(a) Setting up of drilling jumbos and drilling of holes

(b) Loading the drill holes with explosives and blasting of holes

(c) Defuming and ventilation of the tunnel

(d) Checking the misfires

(e) Scaling the loose material

(f) Removal of the muck

(g) Shotcrete and Rock bolting

(h) Erection of support system

(i) Concrete Lining

8.4.1 Setting Up and Drilling

Holes on rock face are drilled by using pneumatically operated drills in conjunction with pneumatic pushers etc. mounted on drilling jumbos. The pattern of drilling and the number of drill holes is governed by the strength of rock, size and shape of tunnel, strength of explosives and the fragmentation of rock required so as to make it suitable for muck removal. As a thumb rule, one drill hole 4 to 5 m^2 of face area may be provided. Diametre of the drill hole may be kept atleast 6 mm more than the diameter of the explosives cartridge.

Generally, three types of drill holes are provided in any drilling pattern i.e.cut holes, easers and trimmers. The cut holes are usually provided in the centre of the round about 15 to 30cm deeper than the other holes and are drilled converging towards the centre of the face with the idea of producing an initial cone or wedge as a free face for breaking off succeeding holes. The other holes, namely the easers and trimmers are placed around the cut holes and are fired in that order so as to induce a perfact fracture with minimum overbreak.

The most commonly used pattern of drilling is the "horizontal wedge cut". In this pattern holes are placed symmetrically with respect to the vertical centre line of the section. The drill holes are horizontal and the angle towards the working face is large and therefore it is easy to drill.

8.4.2 Loading and Blasting

Explosives used in blasting are generally made of gelatin in varying percentage depending upon the strength of rock to be blasted. Before loading is started, each hole is blown out with a high pressure air jet to remove loose cuttings and water. The explosive, which is available in the form of cartridges ranging from 25mm to 63mm in diameter and 200 mm to 245mm in length is then inserted in the hole and tamped firmly in place taking care to prevent breaking of detonator lead wires. Finally, the remainder of the hole not occupied by explosives is filled with an inert material (like mixture of clay and sand) and tightly tamped. The holes are then blasted from a safe distance.

8.4.3 Defuming and Ventilation

The tunnel is allowed to defume and all foul gases and dust particles are driven out by blowing fresh air into the tunnel through blower.

8.4.4 Checking Misfires

Immediately after the tunnel has been defumed and ventilated, the blasted face is checked carefully for any misfires. For this an experienced and competent Foreman enters the tunnel, removes the rock carefully and makes sure that all cartridges have been fired.

8.4.5 Scaling the Loose Material

After the checking of misfires is over, workers enter the tunnel and remove all loose material by the use of crow bars.

8.4.6 Mucking

The composite earthfill material is removed as a result of blasting which is carried out from site by tippers, dumpers or mine cars, as the case may be.

Depending upon the "bridge action period" or the "stand up time" of the excavated rock, efforts are made to install the supports and to make the temporary face ready for the next sequence of operation.

8.5 TUNNEL SUPPORTS

When an underground opening is made, it generally becomes necessary to install supports to hold the rock which has a tendency to drop out of the roof of the opening.

8.5.1 Need for Tunnel Support

The necessity of tunnel support arises from the fact that the excavated rock has a tendency to drop out of the roof of the tunnel. The time which the loosened rock takes to drop out and the amount of rock expected to fall depend upon the "bridge action period" of the rock. The bridge action period "tb" is defined as the time which elapses between blasting and the beginning of collapse of the unsupported roof. It may range from a few hours to a few weeks. The bridge action period for cohesionless sand or completely crushed rock is almost zero.

However, if to happens to be quite large, one should not misunderstand that the tunnel needs no support because of the fact that the rock loads go on developing for weeks and months together after the tunneling operations are over.

The restraint on the development of rock loads by the provision of supports can be easily understood from Fig 8.1. In this figure, the unit load at the crown of the support is plotted on the ordinate, while the time is plotted along the abscissa. As soon as the excavation is made, a small amount of unit load (Ho) develops at the crown of the tunnel. The support which is designed for the maximum probable load (Hmax) is

installed within the bridge action period. At this instant, the load acting over the support is because of wedge action alone. The job of tunnel supporting does not end with the provision of a support alone. It should also be ensured that the support is immediately and carefully back packed with concrete. Care should be taken to fill up all the gaps between the excavated surface and the rib. This should then be followed by pressure grouting and contact grouting to seal all the interstices left in the concrete. The importance of a careful back packing could be judged by having a look at the load versus time curve shown in Fig. 8.1. It will be seen that the ultimate load developed at the crown of the support is much lesser for a carefully back packed tunnel than a poorly back packed one. It would also be seen from the figure that if the cavity is left unsupported, H goes on increasing to such an extent that it exceeds the crushing strength of the rock and at that stage the crown caves in resulting in dome formation.

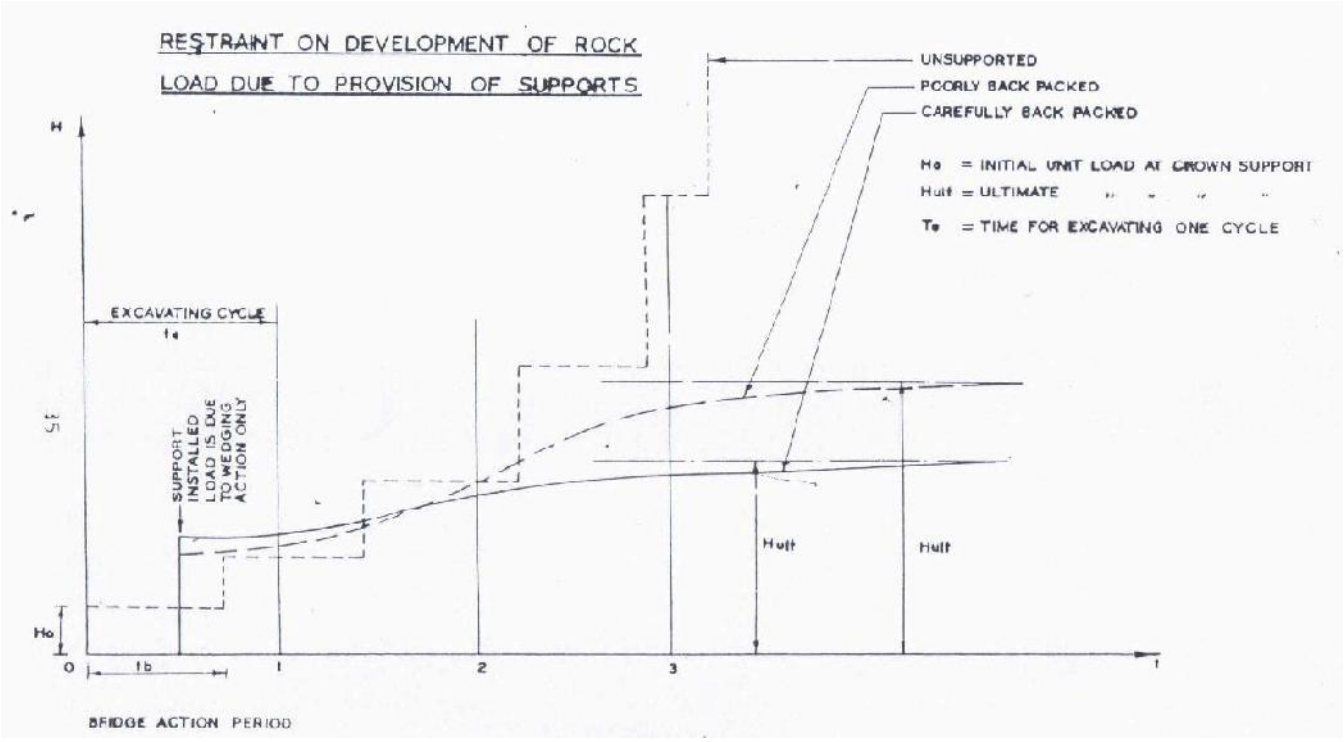


Fig -8.1

8.5.2 Reinforced Support System/Temporary Support

8.5.2.1 Shotcrete

Shotcrete for tunnel support may be used as a thin skin type reinforcement to protect and support zones of fractured, cushed, disintegrated or spalling rocks and to preserve and prevent further deterioration caused by the action of water or atmosphere or the effects of time. Details are given below:

(a) All loose rock pieces shall be scaled out and the rock surface shall be washed by water jet before applying shotcrete.

(b) Shocrete is forced into open joints, fissures, seams and irregularities in the rock surface.

(c) Initially a 25mm thick shotcrete is sprayed immediately after the excavation.

(d) Shotcrete's adhesions to the rock surface and its own shear strength provide a considerable resistance to the fall of loose rock blocks from the roof of a tunnel.

The thickness of shotcrete required depends upon the type of rock, the extent of stratification and/or joints, blockiness and also the size of tunnel. The thickness may normally range from 50 to 150 mm.

The drawback of normal shotcrete is that it is rather weak in tensile, flexural and impact resistance strength. These mechanical properties are improved by the addition of steel fibers. Steel fibers are made into various shapes to increase their bonding intimacy with the shotcrete. Steel fibers make up between 0.5 to 2 percent of the total volume of mix (1.5 to 6 percent by weight).

8.5.2.2 Rock Bolts

Rock bolts are the active type of support and improve the inherent strength of the rock mass which acts as the reinforced rock arch. Rock bolts consists of a steel bar inserted in a hole drilled into the rock. The end away from the rock surface has a device which permits it to firmly anchor in the hole. The projecting end is fitted with a plate which bears against the rock surface. The bolt is placed in tension between the anchor and the plate, thereby exerting a compressive force on the rock between the ends of the bolt.

The rock bolts in common use are the following:

(a) Slot and Wedge type
(b) Expansion Anchorage Type
(c) Grouted Type

The most commonly used bolts are the expansion anchorage type. However, the slot and wedge type can also be used except in soft rock. Epoxy type resins for anchoring the bolts are also being used particularly in water bearing strata.

The rock bolts if properly installed have the following effects :

(a) A zone of compressions is created in the rock around the excavation by the tension in the bolts.

(b) The compressed material between the ends of the bolts tends to expand laterally. At this tendency is restrained by the rock outside the bolted areas, compressive forces are induced at right angles to the direction of the rock bolts.

(c) The deformation of the surface of the excavation is restrained i.e. the rock at and near the surface is prevented from moving in towards the cavity, particularly if the bolts are placed very soon after blasting. In other words, the interaction of the rock bolts when installed in an appropriate pattern prevents the dilation of the surface of excavation which otherwise would take place as a result of the relaxation of the original stress and strain around the opening.

It is generally agreed that pattern bolting should be preferred over spot bolting because unknown conditions behind the surface of an excavation may be more critical than those visible at the surface.

8.5.2.3 Steel Support

The use of steel sets along with shotcrete and rock bolts could be used as temporary supports. The special advantage of using these are that psychologically it looks more stable. It provides the connection between anchorage points and the weak rock and therefore increased the bearing capacity of the support system.

Rock tunnel support system of steel can be classified into the following types :

(a) Continuous ribs
(b) Rib and post
(c) Rib and wall plate
(d) Rib, wall plate and post

(a) Continuous Ribs

This type can be erected more rapidly than the other types and is generally recommended for use in rocks whose bridge action period is long enough to permit the removal of gases and mucking.

(b) Rib and Post

This type is generally recommended for use in tunnels where, excavated tunnel roof joins the side walls at an angle instead of a smooth curve. It may also be used in large tunnels, such as double track-rail road or two lane highway tunnels to keep the size of the rib segments within handling and transporting limitations.

(c) Rib and Wall Plate

This type is generally recommended for use in tunnels with large cross sections with high straight sides through good rock where it is possible to support the wall plate by pins and where the strata below the wall plate does not require support.

(d) Rib, Wall Plate and Post

This type of support permits post spacing to be different from the rib spacing and is generally recommended for use in tunnels with high vertical sides. Invert strut may be used in addition, where mild side pressures are encountered.

In addition to this, steel support needs to be properly packed by following arrangements:

(e) Blocking

If an underground opening is provided with a tight, back-packed lagging, the rock loads act uniformly on the entire rib. However, in most instances, the rock loads are transferred to the ribs by a relatively small number of blocks which are inserted between the rock and the outside of the ribs. These blocks could be of timber or precast concrete. The places where these blocks bear on the ribs are known as blocking points.

(f) Lagging

Where rock excavation is made in such conditions that rock falls or spalling occurs, it will be hazardous and dangerous to the workers inside the tunnel. In such cases, the space between two successive ribs is gapped by providing steel, timber or precast concrete lagging slabs. Another function of lagging is to provide a convenient surface against which to place back packing is placed and to serve as an outside form for concreting between the ribs and the rock.

(g) Back-Packing

The type of back packing and its function depends on the rock condition. In dry tunnels through jointed rock, packing is only used to fill large cavities produced by excessive over breaks. In broken, crushed or decomposed rock, it plays an important function that of restraining the development of rock loads. Where considerable rock loads are expected, concrete back packing is always recommended.

8 .5.3 Concrete Lining

The traditional final lining consists of cast-in-place concrete at a thickness of generally 250 mm to 300 mm for two lane road tunnels. Initial ground support is installed in the tunnel as the tunnel is excavated and can take any form from steel ribs and laggings. While the lining may generally remain unreinforced, structural design considerations will dictate the need for and amount of reinforcement.

To ensure a contact between the initial and final linings, contact grouting is performed as early as the final lining has achieved its 28 day design strength. With this grouting the

contact is established between the initial lining and final tunnel support. Any deterioration or weakening of the initial support will leads to an increased loading of the final support by the increment not being supported by the initial lining. The loads can be directly transferred radically due to the direct contact between initial and final linings.

Cast-in-place final concrete linings are frequently installed in pour lengths not exceeding 10 metres. This restriction is important to limit surface cracking in general and becomes mandatory if unreinforced concrete linings are used. A 10 metre long section in a two lane highway tunnel is also practical in terms of form work installation and sequencing and duration of concrete placement. Adjacent concrete pours feature construction joints that are true lining separators designed as contraction joints.

8.6 Construction Methods Comparison

8.6.1 Drill and Blast

This tunnelling method involves the use of explosives. Drilling rigs are used to bore blast holes on the proposed tunnel surface to a designated depth for blasting. Explosives and timed detonators are then placed in the blast holes. Once blasting is carried out, waste rocks and soils are transported out of the tunnel before further blasting. Most tunneling construction in rock involves ground that is somewhere between two extreme conditions of hard rock and soft ground. Hence adequate structural support measures are required when adopting this method for tunnelling. Compared with NATM, blasting generally results in higher but lesser duration of vibration levels. A temporary magazine site is often needed for overnight storage of explosives.

Drilling and blasting works as follows:

- A number of holes are drilled into the rock, which are then filled with explosive.
- Detonating the explosive will cause the rock to collapse and thus lengthen the tunnel.
- Rubbles are removed and new tunnel surface are reinforced.
- Repeating these steps will eventually result in a tunnel.

The positions and depths of the holes (and the amount of explosive each hole receives) are determined by a carefully constructed pattern, which, together with the correct timing of the individual explosions, will guarantee that the tunnel will have an approximately circular cross-section.

Advantages

- Suitable for all type strata.
- Its flexibility, mobility, and low capital cost constitute real advantages in many situations, such as those involving short lengths of tunnel or low rates of advance.

Disadvantages

- There is a high risk of over breaking the tunnel profile and damaging the surrounding rock

- High levels of noise and vibration make this unsuitable for an urban area.

Main characteristics

- Tunnel Lining – Sprayed Concrete / Rock Bolts / No lining
- Typical Performance – 0.1m to 1m per day. Actual performance and costs will depend on ground conditions and tunnel diameter

8.6.2 Sequential Excavation Method

This method is also known as the New Austrian Tunneling Method (NATM). The excavation location of a proposed tunnel is divided into segments first. The segments are then mined sequentially with supports. Some mining equipments such as road headers and backhoes are commonly used for the tunnel excavation. The ground for excavation must be fully dry for applying the NATM and ground dewatering is also an essential process before the excavation. Another process relates to the ground modifications such as grouting, and ground freezing is also common with this method in order to stabilize the soil for tunneling. This method is relatively slow but is found useful in areas where existing structures such as sewer or subway could not be relocate

NATM involves lining the walls of an excavated tunnel with wire mesh, then spraying them with quick-drying concrete. The main idea is to use the geological stress of the surrounding soil mass to stabilize the tunnel itself.

Advantages

- Eliminates the need for using some expensive TBM equipment during excavation
- Suitable for a wide range of geometry (shafts, junctions, non-circular tunnels and tunnels with variable shapes)

Disadvantages

- Its suitability diminishes in softer ground, which can subside when excavated
- Not suitable below water table in highly permeable soils

Main characteristics

- Tunnel Lining – Sprayed Concrete
- Typical Performance - 1m to 3m per day. Actual performance and costs will depend on ground conditions and tunnel diameter

8.6.3 Environmental Benefits and Dis-benefits

Selection of the techniques to be adopted for construction of a tunnel section shall take into account the nature of the substrata and the levels of the tunnel involved. A summary of the environmental benefits and dis-benefits associated with the construction methods is presented in the table below.

Tunnel Construction Methods	Environmental Benefits and Dis-benefits (on relative terms)
Drill and blast	Benefits:

Tunnel Construction Methods	Environmental Benefits and Dis-benefits (on relative terms)
	• Potential environmental impacts in terms of noise, dust and visual on sensitive receives are significantly reduced and are restricted to those located near the tunnel portal; • Compared with the cut-and-cover approach, quantity of C&D materials generated would be much reduced; • Compared with the cut-and-cover approach, disturbance to local traffic and associated environmental impacts would be much reduced; • Blasting would significantly reduce the duration of vibration, though the vibration level would be higher compared with bored tunneling; Dis-benefits: • Potential hazard associated with establishment of a temporary magazine site for overnight storage of explosives shall be addressed through avoiding populated areas in the site selection process.
Sequential Excavation Method	Benefits: • Similar to the drill-and-blast and bored tunnelling methods, only localised potential environmental impacts would be generated; Dis-benefits: • As the method is relatively slow, duration of potential environmental impacts would be longer than that of the other methods.

CHAPTER-09

VENTILATION, LIGHTING AND FIRE SAFETY REQUIREMENTS

9.1 VENTILATION OF TUNNEL

The ventilation system of a tunnel operates to maintain acceptable air quality level for short term exposure within the tunnel. The design may be driven either by fire/ safety consideration or by air quality, which one governs depends upon many factors including traffic size and length of tunnel. Air quality monitoring points may be provided and ventilation should be adjusted based on traffic volume to accommodate the required air quality.

The two main ventilation systems are used for tunnels i.e. longitudinal ventilation and transverse ventilation. Longitudinal ventilation system introduces air into, or removes air from a road tunnel, with the longitudinal flow of traffic at a limited number of points such as a ventilation shaft or a portal. It can be sub-classified as either using a jet or a central fan system with a high velocity (saccardo) nozzle. Generally, it includes a series of axial, high velocity jet fans mounted at the ceiling level of the tunnel to induce a longitudinal air flow through the length of the tunnel. In transverse ventilation, air supply ducts are located above/below or to the side of the tunnels and inject fresh air into the tunnel at regular interval. Exhaust ducts are located above or to the side of the tunnel. Generally longitudinal ventilation is preferred.

9.1.1 LONGITUDINAL VENTILATION

A longitudinal ventilation system introduces air into or removers air from the tunnel at the portals, thus creating a longitudinal flow of air within the tunnel, with discharge at the existing portal.

9.1.2 Jet Fans

Longitudinal Ventilation is created with a series of axial fans mounted at the ceiling level of the tunnel. They are used to introduce air into the tunnel at the portals, thus creating a longitudinal flow of air within the roadway with discharge at the tunnel portals. The fans, due to the effects of the high velocity discharge, induce a longitudinal airflow through the length of the tunnel.

During normal tunnel operations, the jet fans operate to induce flow through the tunnel by pushing vitiated air through one end of the tunnel while introducing fresh air into the other end. Above a certain threshold of vehicle density and vehicle speed, the tunnel will be self ventilating due to the piston effect of vehicles and will not require fan operation. Carbon monoxide sensors installed in the tunnels will automatically regulate

the start/stop operation of the ventilation fans. During a fire, the jet fans operate similar to normal operation. They are sized to push smoke and hot gases in the direction of traffic movement and out of the tunnel.

Jet fans are typically spaced at 80-200 m intervals depending upon the length of the tunnel. The interval is based on the distance between fans necessary to dissipate the discharge velocity from the fan before the air stream impacts the adjacent fans. The interval between fans provides sufficient distance for an efficient transfer of momentum from the jet fan to the surrounding air stream. At each interval, one or two fans as per the design are mounted in the tunnel to provide a uniform distribution of air from the fan discharge to the tunnel cross-section.

Jet fan unit are axial type fans with direct drive motors designed to deliver a wide range of thrust capabilities in both the forward and reverse direction. The thrust produced is governed by size, blade angle and brake horsepower. Jet fans units are typically 0.8-1.6 m in diameter with thrust in the range of 1100-2250 Newton at rated motor power 30-55KW. Sound attenuators are provided at both ends of the fan motor unit for noise control. A range of different type of jet fans is given below in the Table 9.1.

Table 9.1 Different types of Jet Fan for Quick Selection

Diameter	**Type**	**Thrust N**	**Vol. flow Rate m3/S**	**Outlet speed m/s**	**Related Motor Power KW**
800	Uni-Directional GT	1200	23.0	45.8	45.0
800	Reversible GR	1100	22.0	43.8	45.0
1000	Uni-Directional GT	1120	27.8	35.4	30.0
1000	Reversible GR	1000	26.2	33.4	30.0
1120	Uni-Directional GT	1350	34.2	34.7	37.0
1120	Reversible GR	1280	33.8	33.3	37.0
1250	Uni-Directional GT	1700	42.8	34.9	45.0
1250	Reversible GR	1600	41.3	33.8	45.0
1600	Uni-Directional GT	2250	63.0	31.3	55.0
1600	Reversible GR	1990	59.4	29.5	55.0

Proposed Chisopani Tunnel length is 250 m including both sides of portal, therefore Ventilation system is not required.

9.2 LIGHTING OF ROAD TUNNELS

The requirements for lighting installation of a tunnel are influenced by several critical factors which determine visibility. These conditions are eminently variable and involve characteristics of the vehicle driver including his ability, age and personal habits, the physical conditions of the road, access to and the length of the tunnel, atmospheric conditions, traffic density, volume, speed and type of vehicles in transit. Additional considerations include the contribution of lighting to the architectural aspect of the tunnel opening with regard to visual guidance, comfort and the overall maintenance of the installation.

The minimum day time and night time lighting requirements is to ensure visibility conditions such that the user may travel through tunnel equally well during day or night at a given design speed. It should provide safety, comfort and confidence at a level not lower than those that exist at the same time along the access roads to the tunnel.

The photometric characteristics of the lighting installation of a tunnel which define the quality of the lighting system are as follows :

- The luminance level of the road and of the lower part of the tunnel walls.
- The uniformity and distribution of the luminance of the road surface and of the walls.
- The limitation of glare produced by the light sources.
- The limitation of the flicker effect.
- The level of visibility of possible obstacles.
- The visual guidance.

The lighting requirements of a tunnel are totally different for day and night. At night the problem is relatively simple and consists in providing luminance level on lit routes inside the tunnel at least equal to those outside the tunnel. The design of the lighting during daytime is particularly critical because of the human visual system. The driver outside the tunnel cannot simultaneously perceive details on the road under lighting levels existing in a highly illuminated exterior and a relatively dark interior. When the visual system can adapt to rapid reduction in ambient illumination such as that produced when passing from daylight into the darkness of a tunnel, these adjustments are not instantaneous. The adaptation process takes a certain time, depending on the amplitude of the reduction, the greater the difference, the longer the adaption time. For a given speed, this means that the greater the difference between the lighting level outside and that inside the tunnel, the longer will be the distance over which the visual system of the driver has to adopt.

It is practical to distinguish different zones in the tunnel in order to determine the longitudinal lighting level at daytime lighting: The access zone, the threshold zone, the transition zone, the interior zone and the exit zone.

Access Zone: The part of the open road immediately outside (in front of) the tunnel portal, covering the distance over which an approaching driver must be able to see into the tunnel. The access zone begins at the stopping distance point ahead of the portal.

Threshold Zone: The first part of the tunnel, directly after entering the portal. The total length of threshold zone must be at least equal to the stopping distance. Over the first half of the distance, the luminance level must be equal to Lth_1- 325cd/m^2. It is recommended that from half the stopping distance onwards the lighting level may gradually and linearly decrease to a value, at the end of the threshold zone, equal to 0.4 Lth_1 i.e. Lth_2 from 325cd/m^2 to 130cd/m^2. The gradual reduction over the last half of the threshold zone may be in steps.

Transition Zone: A zone of diminished light level down stream of the threshold zone to enable gradual adaptation to the interior tunnel lighting level. The length of this zone is based on the minimum time needed for a motorist's eye to adapt to the darker tunnel interior. The average luminance levels should decrease smoothly from 130cd/m^2 to 4cd/m^2 through the transition zone.

Interior Zone: The interior zone is the portion of the tunnel where the driver's vision has adapted to a low luminance. The interior of the tunnel should be illuminated to a level of 4cd/m^2.

Exit Zone: The exit zone should be illuminated in the same way as the access zone of the tunnel. The 150m length of road (access/exit zone) at both side of the tunnel shall be illuminated with LED type street lighting fixtures on poles.

Emergency lighting shall be provided. Luminaries with 2X28W T5 lamps with battery back up for 2 hours (minimum) shall be used for emergency lighting. These lights will normally remain in "off" condition and shall come into operation automatically during emergency i.e. in case of failure of original installed light fittings in the respective zones.

Traffic signal shall be provided in "Red" & "Green" at the entrance of tunnel from both ends with local switch for selecting between "Red" and "Green". This signal will generally remain "Green" and manually "Red" signal shall be operated.

9.3 FIRE LIFE SAFETY REQUIREMENTS IN THE TUNNEL

Safety in the event of a fire is of paramount importance in a tunnel. The catastrophic consequence of the tunnel fires not only resulted in loss of life, property but also concerns of the lack of fire life safety protection in the road tunnels. Minimum fire protection requirements are based on tunnel length. Where tunnel length is 350 m and where the maximum distance from any point within the tunnel to an area of safety

exceeds 175 m, all safety measures shall be taken. The following are the fire protection and life safety requirements for road tunnels:

(a) Tunnel ventilation installed in road tunnel is an important element of fire protection. The details are given under Para 9.1 as above.

(b) Fire Protection

(i) Stand pipe system, hose connection etc.
(ii) Water Supply and Storage
(iii) Tunnel Drainage
(iv) Emergency Egress & Communication

(b) Fire Protection

(i) Stand Pipe System

The stand pipe system shall be a class I "automatic wet" type system. It contain water at all times that is attached to a water supply which is capable of supplying the system demand at all times and that requires no action other than opening a hose to provide water at hose connections.

150 mm main water line shall be laid on one side of the walkway wherein approximately. stand pipe system shall be installed at an interval of 80 m. It provides 63 mm hose connection to supply water for use by fire department. Each independent stand pipe system shall have minimum of two fire department connections that are remotely located from each other.

The required flow rate for the stand pipe system shall be 1920 l/minute. It shall be connected to a reliable water supply storage tank which is capable of supplying the system demand for a minimum of 1 hour.

Hydraulically designed stand pipe system shall be designed to provide the water flow rate required at a minimum residual pressure of 100psi (=7kg/cm^2) at the outlet of the hydraulically 63 mm hose connection upto end. Hose connection shall have 63 mm external threads and shall be equipped with caps to protect hose threads. Hose connection shall be spaced so that no location on the protected roadway is more then 45 m from the hose connection. Hose connection spacing shall not exceed 80 m.

(ii) Water Supply and Storage

The water supply required at the hose connection end for a minimum of 1hr. (one hour) at the rate of 1920 l/minute i.e. 1,15,200 or 115.2 cubic metre.

(iii) Tunnel Drainage

Drainage is needed inside the tunnels to remove water and other liquids introduced during fire fighting, washing of tunnel interiors, flushing of pavements and water dripping from vehicle during rainy season. Water will drain from the roadway into

drainage inlets along each side of the tunnel. Inlets will be connected to longitudinal drain provided in concrete below the walkway leading to the portal of the tunnel. Near the portal, covered trench culvert shall be constructed to pass the discharge. Closed spaced drain inlets are preferred as they help to prevent propagation of fire by burning fuel in case of serious accident.

(iv) Emergency Exit

Emergency exits leading from the tunnel environment is considered to be a safe and effective means for getting motorists out of a road tunnel in case of a severe fire emergency. The spacing of the exits may vary based on time and capacity requirements, however a spacing of 300 m is generally provided. Evacuating motorist from tunnel is by the use of cross passage ways. Cross passage ways are used to connect adjacent parallel tunnel of smaller size of 2.0m x 2.5m. Cross passage ways are also used by emergency responders for quick access to the site of a fire event. It is important that these cross passage ways doors remain closed and latched at all times and should be maintained properly. Exit signage is required in the tunnel. Maintaining the minimum required luminance for the signs and a constant supply of power is important because most motorists will immediately look for an exit sign once the vehicle is stopped in a fire event. However in proposed Chisopani Tunnel emergency exit is not required as total length is less than 350 m.

v) Emergency Communication:

Emergency telephones should be provided in the tunnels and connected to the emergency power supply. When such a telephone is used, the location of the caller should be identified both at the control centre and personnel by a warning light visible to rescuing personal. Telephones shall be provided at suitable places such as near the portals and at emergency exists. Communication system should give the traveling public the possibility of summoning help and receiving instructions and should ensure co-ordinate rescue. Systems should raise the alarm quickly and reliably when unusual operating conditions or emergency situations arise. However in proposed Chisopani Tunnel emergency communication is not required as total length is less than 350 m.

CHAPTER 10

ELECTRIC & SOLAR POWER SUPPLY FOR THE TUNNELS

10.0 GENERAL

Road tunnels require a dependable power supply and a flexible power distribution system that will provide maximum reliability and power continuity for tunnel ventilation, lighting, signals, and communication systems, Minimum illumination levels must be maintained without interruption. During the daytime, when vehicle do not have their headlights on, a sudden loss of all tunnel illumination can cause driver confusion and result in an accident. However, brief interruption of the power to the ventilation system can be tolerated.

In order to provide reliability and continuity, diversity is needed in the power distribution system so that an alternate power source is available upon failure of the normal power source. The tunnel lighting (exclusive of Jet Fans & electric pumps) can be provided from Alternate source of energy i.e. Solar Power voltalic cells.

For the two-service system, two services from separate and independent sources of the utility's power are needed. The primary power source i.e. sub-station is existing near Singtam site. The power line can be drawn from sub-station to provide the necessary power required for the tunnels. The secondary source is anticipated to come from Alternate source of energy i.e. Solar Power Voltalic cells.

10.1 LOAD

The peak lighting load will occur during daylight hours due to the higher level of illumination required in the threshold and transition zones. The lighting load will be reduced at night when only minimum lighting will be needed throughout the tunnel.

The peak ventilation load will occur during a fire in the tunnel. Under normal conditions, the maximum load will occur with peak traffic in one tunnel and normal traffic in the other. The power requirement during off-peak hours without traffic congestion is reduced due to the piston effect of vehicles moving through the tunnel.

The electric power will be required as details given below:

Tunnel

(a)	Lighting	5 KW
		5 KW

10.2 Alternate Source of Energy – Solar Power Plant

10.2.1 Main Features and advantages of Solar Photovoltaic Power plant are:

- Safe and easy to install
- Free from noise, smoke and pollution
- Requires very little attention
- Possible to expand to System in future
- Elegant and efficient luminaries
- Highly advanced charge controller
- Longer battery life ensured
- Adequate protections and indications
- Silent operation
- High reliability
- No fuel dependence

10.2.2 The solar power plant shall consist of the following:

(a) SPV Array & support structure

(b) Power conditioning unit

(c) Wires, cables & other items

(a) SPV Array

The SPV (Solar Photovoltaic) array shall consist of suitable number of modules wired in series – parallel configuration. The modules shall be fixed on corrosion resistant M.S Structures. The SPV module has suitable number of crystalline silicon solar cells connected in series and hermetically glass on top and suitable lamination material on back using state of the art technology. The laminates are framed using anodized aluminum channels. A terminal block is fixed on the frames for taking the electrical output. The SPV array shall be grouted on Galvanized M.S support structure.

Support Structures

The modules will be mounted on support structures fabricated from drawn steel. The structures will be hot dip galvanized to make them non-corrosive and long lasting.

(b) Power Conditioning Unit

The Power Conditioning Unit (PCU) provides AC Power to the tunnel with an objective to reduce the dependency on conventional power.

The power conditioning unit mainly comprises of MPPT, and an inverter.

The high efficiency inverter converts the DC power available from the Array into AC, by incorporating IGBT devices for power conversion. The microprocessor controlled inverter incorporates pulse which modulation (PWM) technology and incorporates all the desired features.

(c) Junction Boxes

The junction boxes shall be just vermin and water proof with high degree of protection. The junction boxes will have suitable cable entry points fitted with cable glands of appropriate sizes for both incoming and outgoing cables.

10.2.3 Tunnel lighting can be provided from the solar power plant installed separately for each tunnel. The requirement is given as below:

Tunnel – I (lighting) : 5 kW

Shadow free area of 75 m^2 is required for installing array of 20 kW

The limitations of solar power system are the following:

1. During continuous rainfall days or in cloudy weather conditions, the array can not be charged. Under such situation main power supply from sub-station shall be restored.

2. Shadow free area is necessary for installation of array.

CHAPTER 11

QUANTITIES AND PROJECT COSTS

11.1 General

The present consultancy assignment envisages preparation of Detailed Project Report for Chisopani within the territory of Sikkim in order to connect Gangtok from Singtam

This volume of the Detailed Project deals with the rate analysis of various items of work. The items of work for which rate analysis has been carried out are based on detailed engineering design of roads, structures & Tunnel.

11.2 Estimation of Quantities

In arriving at the quantities, the following items of civil works have been computed for the total length of the road :

- Earthwork Works
- Slope Protection Works
- Tunnel Works
- Pavement Works
- Road appurtenances

Detailed estimate of quantities and costs are presented in "Volume – II: Cost Estimate" of the report. Methodology followed for various items are based on Technical Specifications of Ministry of Road Transport and Highways (MoRTH) for material laying, its quality, measurements, etc. and it has been illustrated in brief in the subsequent paragraphs.

Earthwork: Earthwork quantities in cutting and small quantities of filling are calculated by highway design software Mx-Road for the entire length of the project road. The formation cutting consists of earth cutting to get a formation width of double lane standard. Through cutting has also been proposed in some locations especially in curves where the existing alignment has been followed to ease the curves while going round spurs. Embankment s has also been proposed at some stretches.

The classification of soil in cutting has been made in three categories :

Soil : includes ordinary soil, hard, soil mixed with boulder

Ordinary Rock not requiring blasting

Hard Rock requiring blasting.

Locations along the road alignment passing along the above given three were noted down during field surveys and total quantities of earthwork in cutting has been worked out accordingly.

Slope Protection Works: Quantities for retaining walls, breast walls, parapet walls, toe walls, etc. has been worked out based on the design proposals. Gabion walls have also been proposed at specified locations and quantities have been worked out.

Tunnel: Quantities of various items have been worked out based on details engineering and analysis of survey and geological data.

Pavement: The provision for pavement includes different layers of sub-base, base, and surfacing course as appropriate throughout the whole stretch of the road.

- Granular Sub-base (GSB): 250mm thick sub-base layer of crushed stone aggregate has been proposed. The sub-base course has been extended up to full width of the formation.
- Extra quantities for widening at curves, major and minor junction locations are calculated separately and final quantities are worked out.
- Wet Mix Macadam Base (WMM): 250mm thick base layer of Wet Mix Macadam is proposed for 10.0m width.
- Dense Bituminous Macadam of 60 mm thick and 40mm thick of Bituminous Concrete as surfacing course has been proposed.

Junctions Improvement: This item includes quantities of kerbs, railings, median etc. at the location of junctions. Other items of road works have been included under the respective items of works. The cost for junctions includes the cost for at grade junctions, which need improvement along the highway.

Traffic Signs and Markings: Proper traffic signs were selected at required locations along the project corridor and special signs at tailgates were designed. It is reviewed considering the traffic and pedestrian safety and the number of traffic signs shall be minimum and modified if required. Centre line and edge markings required from safety point of view were considered in the quantity estimate.

Drainage and Protection works: Provision under this sub-head has been made for surface, subsurface roadside drains and open Transverse drains on the shoulder. This item covers for unlined, open lined and covered drains.

Project Facilities: provision under this sub head has been made for Truck lay-bye & Bus bays with Bus Shelters based on Manual of Standards & Specifications of two laning, IRC:SP:84-2009.

Miscellaneous Items: Lump sum amounts for cross utility ducts and Planting of trees by the road side (Avenue trees) has been provided and drainage chutes in cement concrete & stone pitching at outfalls/escapes for drainage in high embankment location.

Other Charges: Other charges include Centages for the civil works are taken as follow:

- Contingency = 2.8%
- Construction Supervision Charge = 3.0%
- Maintenance for 10 Years = (5x0.25%+5x0.5%)=3.75%
- Escalation for 2 Years = 2 x 5.0% =10.0%
- Agency (NHIDCL) Charge = 3.0 %

11.3 Unit Rates

The unit rates for arriving at cost of different components of works are based on Sikkim PWD Schedule of Rates 2012 (for National Highways). For those items of works which are not available in the SOR, separate Analysis of Rates have been carried out and incorporated in this DPR. The following considerations have been made with regard to the basic inputs of rate analysis:

- Material
- Labour
- Machineries

- **Material**

The sources of material are as follows:

- Bitumen : Barauni,Bihar to Singtam , Sikkim
- Emulsion : Haldia, West Bengal to Singtam ,Sikkim
- Steel : Siliguri, West Bengal to Singtam , Sikkim
- Cement : Guwahati, Assam to Singtam ,Sikkim
- Borrow Soil : Borrow areas along the project
- Aggregates : Teesta River bed Material /Quarry in Project Corridor
- GSB : Teesta River bed Material in Project Corridor
- Course Sand : Teesta River bed Material in Project Corridor
- Fine Sand : Teesta River bed Material in Project Corridor

✓ Bitumen (60-70 grade) (Ex-Singtam) (Basic rate = Rs 32340/ MT +transportation from Barauni to Singtam (462Km xRs.11) Rs.5082= Rs 37422)

✓ Emulsion (Ex-Singtam) (Basic rate = Rs 26140/ MT +transportation from Haldia to Singtam (740Km xRs.11) Rs.8140= Rs 34280)

✓ Cement (53 grade) (Ex-Singtam) (Basic rate = Rs 6160/ MT +transportation from Guwahati to Singtam (=510Km xRs.6.7) Rs.3417= Rs 9577)

✓ Cold twisted bars (HYSD Fe 500 Bars)(Basic rate = Rs 48559/ MT +transportation from Siliguri to Singtam (90Km xRs.6.7) Rs.603= Rs 49162)

✓ Sand & Aggregate from Teesta River.

One Hot Mix Plant has been proposed to be erected at mid of the project road during construction. An Avg. lead of 5.0 km has been assumed form the HMP. The lead considerations for the different materials are as follows:

- Bitumen : 10.0 km to the Hot Mix Plant
- Emulsion : 10.0 km to the Hot Mix Plant
- Steel : 10.0 km from market to site
- Cement : 10.0 km from market to site
- Borrow Soil : 5 km from the site
- Aggregates : 20 km to the HMP
- GSB : 20 km to the HMP
- Coarse Sand : 20 km to the HMP
- Fine Sand : 20 km to HMP

- **Labour:** Labour rates for rate analysis have been based on Schedule of Rates (SOR) -2012 of Sikkim PWD
- **Machineries:** The rates of machineries have been taken Schedule of Rates (SOR) - 2012 of Sikkim PWD

  Project cost estimate is prepared based on SOR-2012; however WPI from 2012 to Oct-2018 (100% to 121.70%) is included in the project cost to bring the current rate of project cost.

  In proposed project cost is also included 12% of GST,

  As SOR -2012 is already built-up with 6 % of Taxes like Vat, Excise therefore input item 6.0% of taxes excluded and to bring the input items tax free.

The rates of skilled and unskilled workers for tunnel have been taken from present rates of market. The basic rates of plant and machineries have been collected from the manufacturer along with taxes, salvage value, economic life and fuel consumption.

During analysis of unit rates an overhead component of 20% has been considered to account for the establishment cost and cost of financing to the contractor. In addition, a contractor's profit of 10% has been included. In all cases, fully mechanised construction techniques have been assumed.

Construction Cost Items

For construction of project road, the cost items include various elements, which added together, will give the total cost. The elements of the cost considered for the project are under the following major heads :

* Site Clearance
* Earthwork
* Pavement Works
* Slope Protection Works
* Tunnel Works
* Miscellaneous Works
* Provisional Sum

Based on the unit rate of various items as per rates adopted as mentioned earlier and quantities calculated, a detailed cost estimate has been prepared under the above mentioned major heads.
