USE OF CONSTRUCTION MANAGEMENT TOOLS IN THE TUNNELING PROJECT OF UHL – III (100 MW)

By

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UNDER THE GUIDANCE OF

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A Thesis submitted in partial fulfillment of the academic requirements of Post Graduate Programme in Construction Management

(PGP CMT)

JAYPEE UNIVERSITY OF INFORMATION AND TECHNOLOGY

WAKNAGHAT

DECLARATION

I declare that the research Thesis entitled "USE OF CONSTRUCTION MANAGEMENT TOOLS IN TUNNELING PROJECT OF UHL-III (100 MW)" is bonafide work carried out by me, under the guidance of Dr. A.K. Gupta. Further, I declare that this has not been previously formed the basis of award of any degree, diploma, associate-ship or other similar degrees or diplomas, and has not been submitted anywhere else.

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CERTIFICATE

This is to certify that the research Thesis entitled "USE OF CONSTRUCTION MANAGEMENT TOOLS IN TUNNELING PROJECT OF UHL-III (100 MW)" is the bonafide work of Mr. Nishant Mehra in partial fulfillment of the academic requirements of Post Graduate Programme in Construction Management (M.TECH CMT). This work is carried out by him, under my guidance and supervision.

Date: **Name of the Guide & Signature**

Dr A.K. Gupta

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GLOSSARY

ADIT: An adit**,** is an entrance to an underground tunnel, which is horizontal or nearly horizontal, by which the tunnel can be entered, drained of water and ventilated.

LEAD DISTANCE: Lead Distance is the one-sided distance travelled by a vehicle in a cycle of working. The term is used in tunnels for one short-distance travelled by dumper in process of dumping of over-burden (muck), from the excavation site to the dumping site.

PORTAL: Tunnel portals are simply the entrances and exits of the tunnel. Each tunnel would obviously have at least two and they would be located wherever the tunnel happens to be.

PENSTOCK: A penstock is a gate or intake structure that controls water flow, or enclosed pipe that delivers water to hydro turbines and sewerage systems.

SURGE SHAFT: A surge shaft is a standpipe or storage reservoir at the downstream end of a dam or tunnel to absorb sudden rises of pressure, as well as to quickly provide extra water during a drop in pressure.

MUCK: Debris or fine fragments of rock produced as a result of blasting.

HAULAGE: Transportation of muck from excavation site to dumping site.

SCALING: Removing debris manually using crow bars or rods after blasting.

ROCK BOLT: A long bolt for stabilizing rock excavations by transferring loads from the exterior into the stronger, interior rock mass, used with mesh and shot-crete.

DEWATERING: The removal of groundwater by pumping so as to artificially depress the water table and avoid the difficulties associated with construction below the water table.

ABBREVIATIONS

The following table describes the significance of various abbreviations and acronyms used throughout the thesis.

Abbreviations	Meaning
IP	Inlet Portal
OP	Outlet Portal
A1	Adit No. 1
A2	Adit No. 2
A3	Adit No. 3
TBM	Tunnel Boring Machine
PPE	Personal Protective Equipment
C/C	Centre to Centre
sqm	Square Metre (m^2)
cum	Cubic Metre (m^3)
Rm	Running Metre

ABSTRACT

Hydroelectricity is not just a cheap and clean form of energy, but also very important for the development of India to meet growing energy demands. Thus, the importance of tunnel construction is vital. Modern construction methods can drastically reduce the cost of tunnel excavation and hence money saved could be used for further development of the country. The thesis is the step in the same direction.

Certain modifications in the principles used in existing excavation of tunnels can drastically reduce the cost and time of the excavation of tunnel, thus saving considerable money. Improvements were made in the form of increasing the number of adits, improvements in the de-watering system, drilling jumbos, explosive types, excavators and dumpers and comparative analysis was done between the systems employed in the existing tunnel excavation and modified tunnel excavation.

The result is the budget of the project reduced by Rs 8,19,72,978 while the project could be completed in 2 years,1 month less . Thus, the tunneling project as a whole could be completed well before than the existing tunneling procedures , as 45% of time and resources are utilized in the excavation.

CHAPTER -1

INTRODUCTION

1.1 Introduction

1.2 History Related to the project

1.3 Need of the Study

1.4 Aim/Objectives of the project

1.5 Scope of the project

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The UHL stage-III is a 100 MW hydroelectric project, located at JoginderNagar in Distt. Mandi of Himachal Pradesh. The project is named after Uhl River, a tributary of River Beas. The project lies between longitudes of 76°43’10” to 76°48’10” East and latitudes of 31^{o} 52’15” to 31^{o}57’45” north.

It is the third hydro-electric project to be constructed at JoginderNagar and therefore it is called as Stage-III. The two other hydro projects being Shanan Power House (110MW) and Bassi Power House (60 MW). The hydrology of the area contributes to the construction of the new third project.

The project originally envisaged utilization of tail water of Uhl Satge-I (Shanan) and Uhl Stage-II (Bassi). Its capacity was 70 MW. Later more surveys were conducted to enhance the installed capacity of the project to 100 MW by adding the water of Neri and Rana Rivulets after desilting.

The whole project comprises of diversions (Neri and Rana Diversions at village Bagla), reservoir at Khuddar, 8471m long Head Race Tunnel (HRT) at Machyaal, Surge Shaft and Power House Site at village Chullah on the right bank of river Beas, where water is ultimately discharged form the Power House into River Beas.

The water would be carried through hydel channels to the Khuddar reservoir to meet the peak-load demand during the lean season. The water would further be carried to the tunnel intake through a 398 m long aqueduct over the Rana rivulet and then through a 8.27 km long tunnel to a 36.50 m high surge shaft. Two generators of 50 MW each would be installed at the power house.

In the absence of the project activity equivalent amount of power generation would have taken place in through fossil fuel dominated power generating stations. Thus the project activity will result in reduction of an average of 57,225 tonnes of CO2 per annum and a total of 572,250 tonnes of CO2 for the entire crediting period.

The project will contribute to the development of Himachal Pradesh. After the commissioning of project, the state government will receive royalty of 15% for first 12 years, 21% for next 18 years and 33% for the remaining 10 years. In addition to this 1% free power from the project would be provided for Local Area Development Fund (LADF) during the operation stage of the project, the promoters shall contribute to the Local Area Development Activities during the construction stage of the project.

LOCATION	Joginder Nagar, Distt Mandi (H P)
NEAREST RAILWAY STATION	Joginder Nagar (Narrow Gauge)
PERIOD OF CONSTRUCTION	2002-2015
ESTIMATED COST OF THE PROJECT	Rs 479 crore
OWNER/ HOST	Beas Valley Power Corporation Limited (BVPCL)
CONTRACTOR	Ajit Infrastructure Limited
INSTALLED CAPACITY	2X50 MW

Table 1.1 Salient Features of The Project

Fig 1.1 Location of Project Site

1.2 HISTORY RELATED TO THE PROJECT

In 1925, Raja Joginder Sen and Col. B. C. Batty planned a hydel power scheme near the village of Sukrahatti. A narrow-gauge railway track was laid from Pathankot to Jooginder Nagar(1,220 m) to carry the heavy machinery transported from Britain. A Haulage-way system was laid from the site of Shanan Power House to Barot, where the reservoir was constructed on Uhl river. After tunneling and piping the water over several kilometres from the river Uhl to Joginder nagar, the Shanan Power House (110MW) was built by a team of engineers headed by Colonel Batty.

Shanan Power House was the only hydroelectric project in northern India which fed undivided Punjab and Delhi. The vision of the hydel project scheme was to construct five power stations using the same water that is drawn from the Uhl river. The used water of Shanan Power House was taken through various tunnels in adjoining Siyuri Dhar, to a distance of 8 km. A reservoir was constructed at the village Chapprot that would be used for driving turbines in stage 2 of project at the base of Chapprot hill. However, the plan could not be executed following the death of Colonel Batty.

Later in 1960s, the HP State Electricity Board decided to proceed further with the plan. In 1970, another set of turbines were added at Bassi, a small village situated at the bottom of Chapprot hill and Bassi Power House (60 MW) came into existence. The construction of third stage of project, Uhl Stage III (100 MW), was inaugrated at Tullah near the Machhyal Lake and is currently under progress.

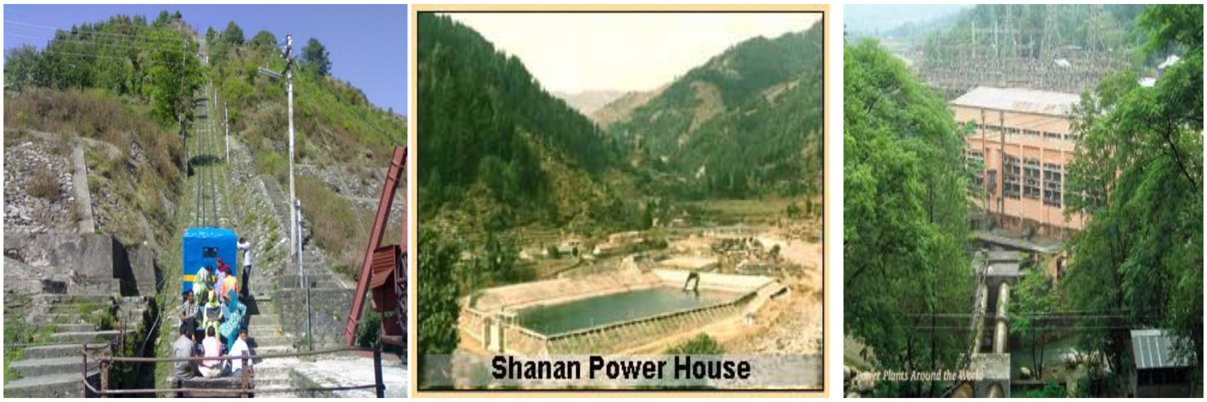

Fig 1.2 (from left to right) Haulage-way System, Shanan Power House and Bassi Power House

1.3 NEED OF THE STUDY

The need of the study is to look into those possible areas where improvement can be done using innovative techniques and practices in the project, so as to reduce the cost and the schedule of the entire project. In order to fulfill the same, information is collected regarding the various processes/ activities involved in the excavation of the tunnel and the estimated cost is found out of for the excavation of the tunnel. Thereafter, comparative analysis is made between the methods/practices used in the existing excavation module and those which could potentially improve (modified tunnel) the efficiency of the project in terms of budget and schedule. Based on such data, improvements can be made in other tunnels by using the best of practices and equipments. Also, the study provides an insight into the potential hazards during excavation and the safe working conditions in order to minimize the risks of accidents/injuries.

1.4 AIMS/OBJECTIVES OF THE PROJECT

- The primary aim of the project is to reduce the budget and schedule of the excavation of the 4.15m in dia and 8471m long Head Race Tunnel.
- Describing the phases of construction management.
- Rate Analysis of the Excavation of the Tunnel.
- Increasing the number of adits to reduce time and calculating the extra cost incurred and time reduced.

- Calculating Lead Distance to find out the number of trips for haulage machineries.
- Modifying the explosives type and comparative analysis with the explosive used actually during the excavation of tunnel.
- Improvement in the Excavator type and calculating the cycle time of an excavator.
- Improvement in the Jumbo (Drilling Machine) to achieve higher output.
- Modification in the De-watering System.
- Improvements in the capacity of Dumpers
- Describing the various hazards associated with the tunnel excavation and their control.

1.5 SCOPE OF THE PROJECT

The project focuses on the excavation of the tunnel only and construction of reservoir, penstock, power site, switchyard etc are not covered on the project. The scope of the project is therefore restricted to the excavation of Head Race Tunnel and improvement in the existing excavation module. A Comparative Analysis has been made between the existing Excavation Module, as executed actually in the site and the modified Excavation Module. The Scope of the project is not just the management of men, materials and machineries only but also the methods involved resulting in overall improvement in the schedule and budget of the project. Also special focus has been given on improving the working conditions ensuring minimum accidents or injuries resulting in the tunnel excavation.

CHAPTER - 2

LITERATURE REVIEW

2.1 Prediction of over-breaks in tunnels

2.2 Sprayed Concrete Lining in tunnels

2.3 Earned Value Analysis

2.4 Feasibility Studies for the construction of new tunnels

2.5 Early Cost Estimating of Tunnel Construction

CHAPTER 2

LITERATURE REVIEW

2.1 PREDICTION OF OVERBREAKS IN TUNNELS

(Dey, Kaushik; prediction of overbreak in underground tunnel blasting, Dhanabad, 2003)

In this paper different over-break / blast damage assessment techniques are reviewed and the most suitable blast pattern is adopted so that the over-breaks are within permissible limit in Koyna Lake Tap Tunnel which is 15m beneath a fully charged body. Instead of adopting Full Face Attack Method, the blasting was done in two rounds-First the lower part (up to spring level) and then the upper part (arch shape) in a controlled manner i.e., by limiting the maximum charge per delay. Vibration studies were conducted for both the rounds using Minimate Plus) 077 Seismographs, placed on the sidewall. The threshold limits of PPV for different degrees of rock damage are proposed from extrapolated vibration predictor equation. The actual over-break in the tunnel was measured from the tunnel profiles using a Planimeter. It was found that the percentage over-break varied from 2.45 to 16.07. The predicted over-break from extrapolated PPV measurements s compared against the measured over-break to validate the proposed blast-induced rock damage assessment model. The PPV threshold level, for incipient crack growth was found to vary from 1300 to 2000 mm/s; for crack widening from 2000 to 2800 mm/s and for over-break from 2800 to 5200 mm/s.

2.2 SPRAYED CONCRETE LINING IN TUNNELS

(Thomas, Alun; Sprayed concrete lined (SCL) tunnels, New York, 2009)

In this paper information is provided regarding the sprayed concrete lined tunnels. This term does not take into account how the tunnel was designed, the ground it was built upon or the purpose, but simply describes the lining used in the tunnels. In the 1970s shallow SCL tunnels were successfully constructed in soft ground as part of metro projects in cities such as Frankfurt and Munich. Sprayed concrete is concrete which is conveyed under pressure through a pneumatic hose or pipe and projected into place at high velocity, with simultaneous compaction. It behaves in the same general manner as concrete but the methods of construction of SCL tunnels and of placement of sprayed concrete require a different composition of the concrete and impart different characteristics to the material, compared to conventionally placed concrete. Sprayed concrete consists of water, cement and aggregate, together with various additives. On a point of nomenclature, sprayed concrete is also known as ‘shot-crete’, while ‘gunite’ normally refers to sprayed mortar, i.e. a mix with fine aggregates or sand only.

The composition of the concrete is tailored so that:

• it can be conveyed to the nozzle and sprayed with a minimum of effort.

• it will adhere to the excavated surface, support its own weight and the ground loading as it develops.

• it attains the strength and durability requirements for its purpose in the medium- to long-term.

2.3 EARNED VALUE ANALYSIS

(Nagrecha, Suketu; An introduction to the Earned Value Analysis, New York, 2002)

Earned Value Analysis is a performance Management tool used by the project managers to compare planned to the actual results. It is a better method integrating cost, schedule and scope and thus helps in determining future performance and project completion dates. It is an “early warning” program/project management tool that enables managers to identify and control problems before they become insurmountable. It allows projects to be managed better – on time, on budget. The earned-value measurement concept was first introduced to the American defense contracting community when the government issued the Department of Defence (DoD) and NASA Guide to PERT/Cost in 1963. The Schedule Variance and Cost Variance are the two main features of this concept which helps in realizing the project is on budget as well as on time. It gives a better picture than most conventional approaches taking into consideration three things, planned value, budgeted value and the actual results achieved. The budgeted value approach misses in most of the conventional approaches leading to inaccurate realization of the data.

2.4 FEASIBILITY STUDIES FOR THE CONSTRUCTION OF NEW TUNNELS

(Bruning, C; Civil engineering feasibility studies for future ring colliders at European Council for Nuclear Research, Geneva (Switzerland), 2013)

This research paper deals with the feasibility studies carried out in the proposed 80 km long tunnel to be built as an extension of CERN (European Council for Nuclear Research) project to complement LHC (Large Hadron Collider). The paper assumes the length of the tunnel to be 80 km and shall be connected to the LHC at one point and the shafts are located approximately every 10km. The shaft depths are to be kept as minimum as possible. The civil engineering feasibility studies are composed of a multitude of individual studies, e.g. civil design, geotechnical, excavation, environmental impacts, and costs, which together determine the projects' viability. Primarily, three types of rocks are predominant in the region namely, limestone, molasse and moraine. Limestone risks are mainly related to risk of water inflows during and after construction. Large inflows are dangerous, expensive and difficult to remedy. The Molasse is a relatively soft and stable rock and can lead weak zones to move apart further. Moraine risks are encountered during shaft excavation and sinking. Ground-freezing technique is employed which involves freezing the ground with a primary cooling circuit using ammonia and a secondary circuit using brine at -23°C, circulating in vertical tubes in pre-drilled holes. This frozen wall allows excavation of the shafts in dry ground conditions and also acts as a retaining wall. To prevent unwanted ground convergence and plastic deformation during tunneling an adequate support and lining is needed. Considering the long length of tunnel, Tunnel Boring machines would be handy but in case of hard rock deposits Drill & Blast shall be preferred as this would allow free access to face for grouting and dewatering. An average advance rate of 25m per day, or 150m per week is predicted. Some of the major issues covered in the Environment Impact Assessment (EIA), includes, the limestone deposits which helps in recharging the aquifers used for drinking purposes. The water should not be contaminated as per the paper. Also, proper care should be taken to have least affect on the national parks as well as the landscape. The hydrocarbon contaminated rocks should be properly disposed off. About 62 % of the proposed budget shall be used for underground construction.

2.5 EARLY COST ESTIMATING OF TUNNEL CONSTRUCTION

Petroutsatou, K., Georgopoulos, E., Lambropoulos, S., and Pantouvakis, J. (2012). Early Cost Estimating of Road Tunnel Construction Using Neural Networks. J. Constr. Eng. Manage., 138(6),679–687.

According to Burke, at each phase in the project life cycle (conception, design, realization, and operation) different levels of cost-estimating accuracy can be achieved from the detail of information available. Tunnel construction is subject to underground uncertainties and risks, and as such it is difficult to predict the final construction cost, especially at the conception phase where issues are evaluated and important design decisions are made. A system assisting in the early cost estimation of road tunnels would therefore be of great value as it would allow the quick costing of alternative and more economical solutions.

In particular, early cost estimates at the conception phase may be precise ±25%. Even at this level of accuracy, early cost estimates enable the comparison of different design alternatives at the pre-design phase and the selection of the most economical technical solution. At the same time, appropriate financing procedures can be elaborated upon at an early stage of project implementation.

CHAPTER-3

STUDY AREA PROFILE

3.1 Introduction

3.2 Salient Features of the Study Area

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  3.3.3 Highly joined Rock

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  3.5.1 Pre-construction Phase
    3.5.1.1 Conceptual Design
    3.5.1.2 Schematic Design
    3.5.1.3 Design Development
    3.5.1.4 Contract Documents
  3.5.2 Procurement Phase
  3.5.3 Construction Phase
  3.5.4 Close-out Phase

CHAPTER-3

STUDY AREA PROFILE

3.1 INTRODUCTION

The study area consists of excavation of 8471m long Head Race Tunnel, built at Machyaal, 12 km south from JoginderNagar. The site is easily approachable through link road. Since the excavation of the tunnels is a vital activity related to the construction of the Hydro-electric projects, therefore it is of utmost importance that the cost overruns and schedule of the excavation process is controlled and continuously checked. Tunnel excavation in itself comprises of multitude of tasks which have been described in the next few pages of the thesis.

3.2 SALIENT FEATURES OF THE STUDY AREA

HEAD RACE TUNNEL	
LOCATION	Machyyal, Joginder Nagar (H P)
SHAPE	Horse-Shoe
LENGTH	8471 m
BED SLOPE	0.570
ADITS	One, Length 200m
PERIOD OF CONSTRUCTION	3 years, 4 months
COST	Rs 32,32,80,330

Table 3.1 Salient Features of Study Area

Fig 3.1 Head Race Tunnel

3.3 ROCK CLASSIFICATION AND SUITABLE SUPPORT SYSTEM

The tunnel passes through alternative sequences of sand stone, clay, stone and silt stone belonging to Dharamshala and Shiwalik formation. The Geological Survey Of India (GSI) report classifies tunnelling media into three types each requiring different system of support, duly designed for seismic forces as the project area falls in the Seismic Zone V (IS : 1893-1972).
Classification and Proposed Support Systems are discussed in detail below.

3.3.1 Good Rock

17 % length of the tunnel passes through good tunnelling radii in hard and massive rock. After excavation 100mm thick shot-crete and 25mm dia 3.00m long rock bolts @ 2m C/C have been proposed.

3.3.2 Moderately Joined Rock

69 % length of the tunnel passes through moderately jointed rock. The rock is proposed to be supported by 100mm thick shot-crete and 25mm dia 3.0m long rock bolts @ 1.5m C/C spacing.

3.3.3 Highly Joined Rock

14 % length of the tunnel passes through highly jointed, sheared, fractured and faulted strata. After providing initial/immediate support by 100mm thick shot-crete, steel supports ISHB 150X150 @750mm C/C spacing have been proposed with Cement-Concrete sleepers at the extrados of ribs for crown portion.

Low pressure cement slurry is proposed to be injected for contact pack grouting to be followed by high pressure consolidation grouting.

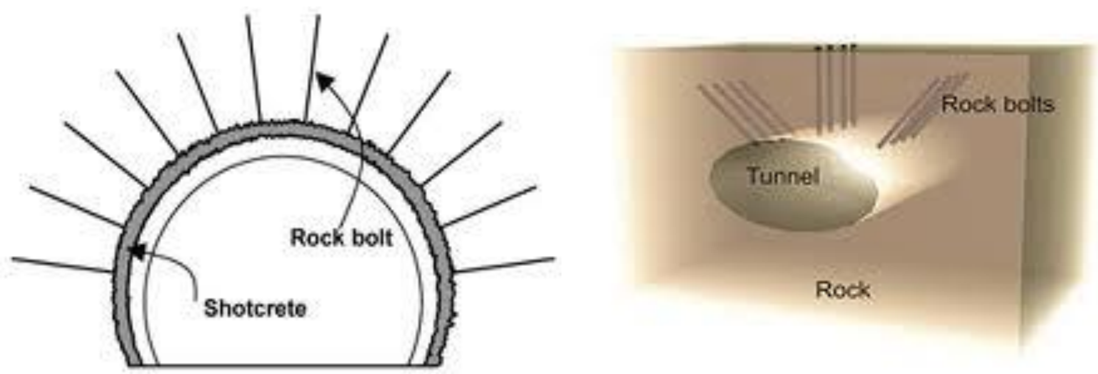

Fig 3.2 Rock Bolting and Shot-creting in tunnels

3.4 METHOD OF EXCAVATION

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

3.4.1 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.

3.4.2 Top Heading and Benching

When 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, Top Heading is excavated first- either to the full length or part length of the tunnel, and is supported simultaneously. The Benching is then removed slowly.

3.4.3 Bottom Heading And Stopping

When the rock is consistent and sound and the tunnel section is very large, this method can be easily adopted. In this method, bottom Heading is made first and the overhead slope is removed later on.

3.4.4 Drift Method

In driving a large tunnel it may be economical to drive a small tunnel called a drift or pilot tunnel prior to excavating the full face. Depending upon the nature of rock and other parameters, a drift may be excavated in the center, side bottom or top.

In Uhl Stage - III, **Top Heading Method (**also known as Underground Excavation Method**)** is adopted. This type of tunneling Method is generally recommended to the tunnels with a very small cross-sectional area. This method is derived from the Top Heading And Benching Method, but in this method the full tunnel is excavated to the whole length, while in case of the Top Heading and Benching Method top heading is excavated first- either to the full length or part length of the tunnel, also is supported simultaneously and the Benching is then removed slowly. Top Heading and Benching Method is generally recommended for tunnel with greater cross-sectional area, where tunnel's dia is greater than 8m.

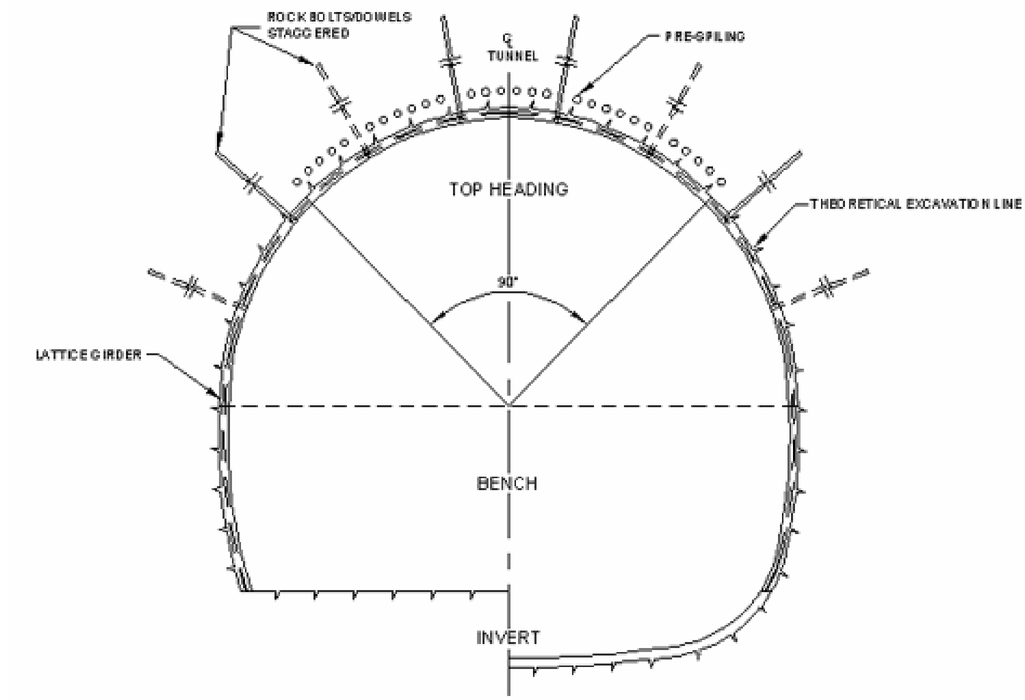

Fig 3.3 Cross section of tunnel excavation

3.5 PHASES OF CONSTRUCTION MANAGEMENT

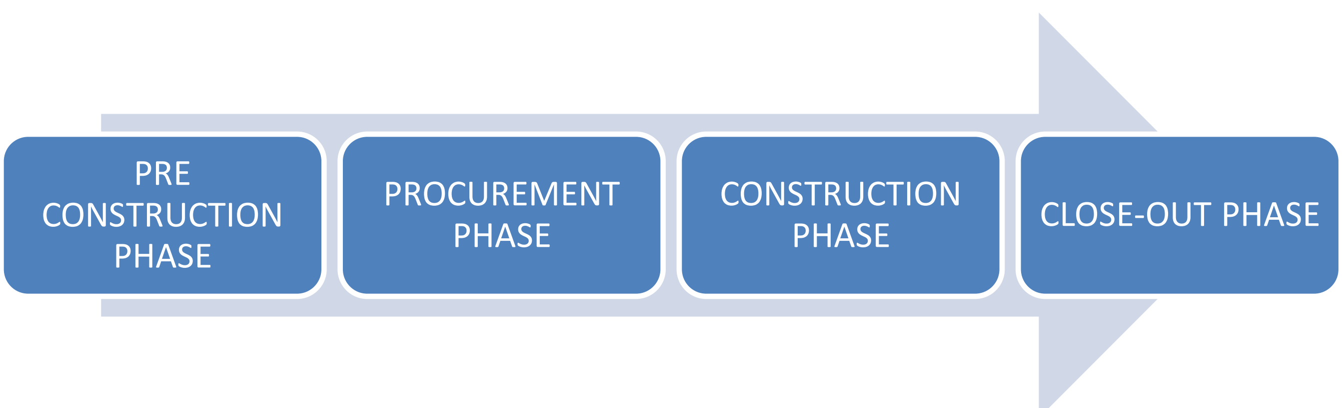

Fig 3.4 Phases of Construction Management

3.5.1 Pre-Construction Phase

The preconstruction phase of a project can be broken into conceptual planning, schematic design, design development, and contract documents.

3.5.1.1 Conceptual design

- Very important for the owner.
- During this stage the owner hires key consultants including the designer and project manager, selects the project site, and establish a conceptual estimate,schedule, and program.
- The owner must gather as much information as possible about the project.
- The most important decision is to proceed with the project or not.

3.5.1.2 Schematic design

- During this phase, the project team investigates alternate design solutions, materials and systems.
- Completion of this stage represents about 30% of the design completion for the project.

3.5.1.3 Design development

- Designing the main systems and components of the project.
- Good communication between owner, designer, and construction manager is critical during this stage because selections during this design stage affect project appearance, construction and cost.
- This stage takes the project from 30% design to 60% design.

3.5.1.4 Contract documents

- Final preparation of the documents necessary for the bid package such as the drawings, specifications, general conditions, and bill of quantities.
- All documents need to be closely reviewed by the construction manager and appropriate owner personnel to decrease conflicts, and changes.
- With the contract documents are almost complete; a detailed and complete cost estimate for the project can be done.

3.5.2 Procurement phase (Bidding and award phase)

- The project formally transits from design into construction.
- This stage begins with a public advertisement for all interested bidders or an invitation for

specific bidders.

- If the project is phased, each work package will be advertised and bid out individually.

- It is very important stage to select highly qualified contractors. It is not wise to select the under-bid contractors.

3.5.3 Construction phase

- The actual physical construction of the project stage.
- It is the time where the bulk of the owner's funds will be spent.
- It is the outcome of all previous stages (i.e., good preparation means smooth construction).
- Changes during construction may hinder the progress of the project.

The Uhl-III(100 Mw) Project is under this phase involving construction of Reservoir, Head Race Tunnel (HRT), Penstock, Power House And Switch Yard. The Scope of this Report is Limited to the Excavation of HRT only.

3.5.4 Closeout phase

- In this stage, the management team must provide documentation, shop drawings, as-built drawings, and operation manuals to the owner organization.
- The as-built drawings are the original contract drawings adjusted to reflect all the changes that occurred.
- Assessment of the project team's performance is crucial in this stage for avoiding mistakes in the future.
- Actual activity costs and durations should be recorded and compared with that was planned.

CHAPTER- 4

DATA ANALYSIS OF THE EXISTING TUNNEL

4.1 Data for the Existing Tunnel

- 4.1.1 Data
- 4.1.2 Drilling Holes
- 4.1.3 Loading Explosives and Blasting
- 4.1.4 Defuming and Scaling Loose Materials
- 4.1.5 Mucking Excavated Rock
- 4.1.6 Overall Cycle Time
- 4.1.7 Requirement of Materials
- 4.1.8 Requirement of Machinery
- 4.1.9 Requirement of Work-force
- 4.1.10 Use Rate of Materials

4.2 Rate Analysis of the Existing Tunnel

- 4.2.1 Materials
- 4.2.2 Machinery
- 4.2.3 Labor

4.3 Abstract for the Existing Tunnel

4.4 Lead Distance Calculation for the Existing Tunnel

- 4.4.1 Data
- 4.4.2 Calculating Mean Chainage
- 4.4.3 Cumulative Lead Calculation
- 4.4.4 Haulage Time Computation

4.5 Schedule and Budget Computations

4.5.1 Data

4.5.2 Excavation Time Computation

4.5.3 Budget Computation

CHAPTER- 4

DATA ANALYSIS OF THE EXISTING TUNNEL

4.1 DATA FOR THE EXISTING TUNNEL

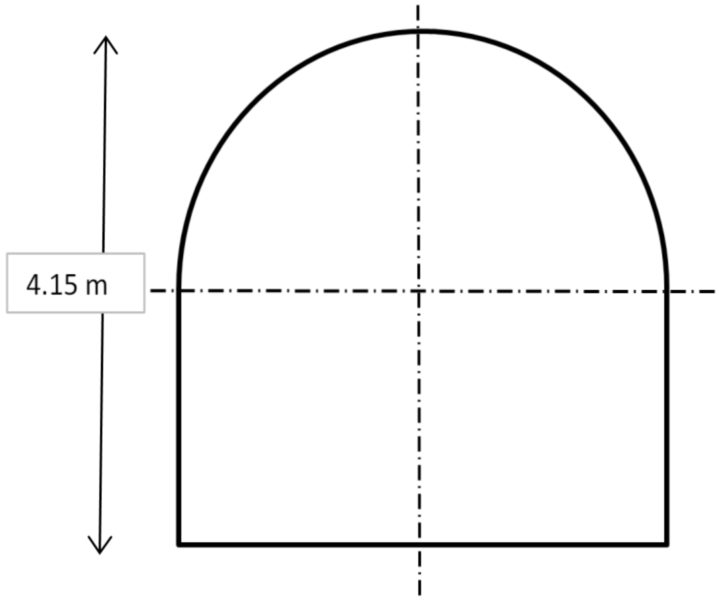

Fig 4.1 Tunnel Profile of the existing Tunnel Excavation

4.1.1 Data

Size of Tunnel	4.15 m in dia
Shape of Tunnel	Horse-shoe
Height of Tunnel	4.15 m in dia
Pay-Line Margin Assumed	0.2 m
Diameter of Tunnel Upto Pay Line For Excavation	4.55 m
Haulage of Excavated Muck	By Dumpers
Total Length of The Tunnel	8471 m

Table 4.1 Data for the existing Tunnel

4.1.2 Drilling Holes

Full Face Method Of Excavation Implemented

Area Upto Pay-Line (Sqm)	Area Of Semi-Circle + Area Of Rectangle (0.5*π*2.275*2.275)+(2.275*4.55)	
	18.48	sq.m
Cut-Holes And Erasers Spacing	500-600	mm
Trimmers Spacing	400-500	mm

Since Cross-Sectional Area is less than 45 sqm and gelatin explosive used, the number of holes for tunnel excavation will be in range of 3.5 to 4 per sqm

For Rate Analysis, 4 holes per sqm of Cross Sectional Area upto Pay Line considered.

No. of holes for full excavation	18.48*4	
	74	Nos
Depth of Holes	2	m
Extra drilling considered at 10 percent for inclined cut holes and for any secondary blasting of large fragments during mucking		
Depth of drilling for 74 holes	74*2*1.10	
	162.62	
	163	m
Average rate of drilling per hour per jack hammer	8	m
Time for 2 jack hammers with pusher leg for drilling	(163/8/2)	
	10.19	hrs
Time for 1 air compressor 15 cmm for air supply to 2 jack hammer	10.19	hrs

Time for 10 hp pump for water supply to drilling work	10.19	hrs

4.1.3 Loading Explosives And Blasting

Depth of pull per blast for 2 m deep holes	1.8	m
Quantity of in-situ excavation per blast	18.48*1.8	
	33.26	cum
Quantity of explosive small dia per blast @ 800 g per hole	74*.800	kg
	60	kg
Quantity of explosive for secondary blasting @ 5 %	0.05*60	
	3	kg
Quantity of delay detonators per blast	74	Nos
Quantity of electric detonators for secondary blasting	4	Nos
Time for drilling jumbo for loading explosives	2	hr

4.1.4 Defuming And Scaling Loose Materials

No machinery other than ventilation fans are required. For defuming adit ventilation fans are installed in duct system at about 300 m interval and are run for about 1 hour after each blast. Considering 20 hp fan 1 No. for 1 hour for defuming.

4.1.5 Mucking Excavated Rock

Quantity of muck to be removed per blast considering 40 % bulkage	1.40*33.26	
	47	cum

For 1m of pull volume of muck generated	25.87	cum
Capacity of dumper per load	3	cum
Quantity of muck per load considered under adit working conditions	2.5	cum
Number of Trips	19	trips
Loading cycle time:		
Turning / moving and spotting	1	min
Load Bucket	10	sec
Swing Loaded, capcity 0.5 cum	6	sec
Dump Bucket	2	sec
Swing Empty	5	sec
Total cycle	23	sec
Time required for 5 cycles	115	sec
Cycle time of loading dumper per load of 2.50 cum	2.5	min
Haulage cycle time:		
Running time from loading point to dump yard @ av 10 km / hr	8	min
Turning and unloading	2	min
Return trip to reversing point @ av 15 km / hr	5	min
Cycle time for haulage per load of 4.5 cum	15	min
Delpoy Dumpers	3	
Round trip cycle time of dumper	18	min
Considering Delays	20	min
	0.33	hr
Quantity of muck disposal per hour / dumper	7.5	cum
Quantity of muck disposal per hour by 3 Dumpers	22.5	cum

Time for 3 dumper for conveying muck @ 22.5 cum per trip per hour	2.07	hr
	2.1	hrs
Time for JCB and workforce for loading (Hrs)	2.1	hrs

4.1.6 Overall Cycle Time

Checking alignment and marking hole locations	2	hrs
Drilling holes	8	hrs
Loading explosive and blasting	2	hrs
Defuming and scaling loose rock fragments	2	hrs
Mucking excavated rock	2.1	hrs
Bed cleaning, support fixing, rock bolting, lighting etc (approx)	6	hrs
Total cycle of excavation per blast of 2.8 m length	22.1	hrs

4.1.7 Requirement of Materials

Explosives small diameter (60+3)	63	kg
Electric short delay detonators (74*1)	74	Nos
Electric detonators for secondary blasting (4*1)	4	Nos
Fuse coil	164	Rm

4.1.8 Requirement of Machinery

Deploy drilling jumbo for marking (1 hr) / drilling (10.19 hrs) / loading explosive (1 hr)	12.19	hrs
Deploy air compressor 15 cmm for air supply to 2 jack hammers	10.19	hrs
Deploy 2 jack hammers with pusher leg for drilling.	10.19	hrs
Deploy 10 hp pump for water supply to drilling	10.19	hrs

work.

Deploy3, 10 hp ventilation fan for defuming	1	hr
Deploy JCB 0.5 cum capacity,for loading excavated rock	2.1	hrs
Deploy 3 dumpers for conveying muck	2.1	hrs

4.1.9 Requirement of Work-Force

Surveyor for checking alignment and marking hole locations for drilling	0.5	No.
Foreman for supervising drilling of holes and other operations	1	No.
Fitter / Mechanic for extending air / water lines	2	Nos.
Blaster (Licensed)	1	No.
Helper blasting	2	Nos.
Hammerman for scaling	2	Nos.
Maistry 1 in each shift	3	Nos.
Khalasi for mucking shift	4	Nos.
Heavy mazdoor for mucking shift	4	Nos.
For other 2 shifts 1 No each shift	2	Nos.
Light mazdoor for cleaning & miscellaneous	1	No.

4.1.10 Use Rate of Materials

Cost of drill rod 2.5 m long @ Rs 6225.00 / No.	6225.00	Rs.
Life of drill rod with reconditioning	163	m
Use rate of drill rod per Rm drilling (cost / life)	38.28	Rs.
Length of air and water hose assumed	25.00	m each
Cost of 25 mm dia air hose 25 m @ Rs 165.00 / Rm	4125.00	Rs.
Life of air hose	800.00	Hrs.
Use rate of air hose per hour (cost / life)	5.16	Rs.

Cost of water hose 25 m each @ Rs 140.00 / Rm	3500.00	Rs.
Life of water hose	800.00	Hrs.
Use rate of water hose per hour (cost / life)	4.38	Rs.

4.2 RATE ANALYSIS OF THE EXISTING TUNNEL

4.2.1 Materials

S.No.	PARTICULARS	UNIT	QUANTITY	RATE IN RS.	AMOUNT IN RS.
1	Small Dia Explosives	Kg	63.00	80.00	5040.00
2	Delay Detonators	Nos	74	20.00	1478.40
3	Electric Detonators	Nos	4.00	11.00	44.00
4	Detonating Fuse Coil	Rm	164.00	9.00	1476.00
5	Use rate of drill rod 2.5 m long	Rm	163	58.33	9486.40
	Reconditioning charges @ 10%				948.64
6	Use rate of air hose	Hour	22.00	5.16	113.44
7	Use rate of water hose	Hour	22.00	4.38	96.25
8	Sundries	LS	15.00	33.00	495.00
				TOTAL Rs	19178.13
	Add for small Tools and Plants @ 1%			Rs	191.78
	Add for Contractor's Profit @ 10%			Rs	1917.81
	Add for Contractor's Overheads @ 5%			Rs	958.91
	TOTAL COST OF MATERIALS :			Rs	22246.63

Table 4.2 Rate Analysis of Materials Used in the Existing Tunnel

4.2.2 Machinery

S.No.	PARTICULARS	UNIT	QUANTITY	RATE IN RS.	AMOUNT IN RS.
1	Drilling Jumbos	Hour	12.19	338.00	4120.22
	Fuel / Energy charges	Hour	12.19	35.00	426.65
2	Air compressor 15 cmm(ele)	Hour	10.19	111.00	1130.81
	Fuel / Energy charges	Hour	10.19	671.00	6835.81
3	Jack hammer (2 x 10.19 hrs)	Hour	20.38	15.00	305.70
	Fuel / Energy charges	Hour	20.38	6.00	122.28
4	JCB 0.5 cum capacity	Hour	2.10	728.00	1528.80
	Fuel / Energy charges	Hour	2.10	750.00	1575.00
5	Dumper (3 x 2.1 hrs)	Hour	6.30	502.00	3162.60
	Fuel / Energy charges	Hour	6.30	323.00	2034.90
6	Pump 10 hp (ele) (1 x 10.19 hrs)	Hour	10.19	5.00	50.95
	Fuel / Energy charges	Hour	10.19	54.00	550.26
7	Ventilation fans 10 hp (3 x 1 hr)	Hour	3.00	6.00	18.00
	Fuel / Energy charges	Hour	3.00	107.00	321.00
8	Sundries(explosive van / magazine)	LS	15.00	33.00	495.00
				TOTAL Rs	22677.99
	Add for small Tools and Plants @ 1%			Rs	226.78
	Add for Contractor's Profit on Fuel / Energy @ 10%			Rs	1186.59
	Add for Contractor's Overheads @ 5%			Rs	1133.90
	TOTAL HIRE CHARGES OF MACHINERY :			Rs	25225.25

Table 4.3 Rate Analysis of Machinery Used in the Existing Tunnel

4.2.3 Labour

S.No.	PARTICULARS	UNIT	QUANTITY	RATE IN RS.	AMOUNT IN RS.
1	Crew for Drilling jumbo	Hour	12.19	65.40	797.23
2	Crew for Air compressor	Hour	10.19	65.00	662.19
3	Crew for Jack hammer	Hour	20.38	121.10	2468.02
4	Crew for JCB	Hour	2.00	65.00	130.00
5	Crew for Dumper	Hour	6.30	78.50	494.55
6	Crew for Pump	Hour	10.19	29.10	296.53
7	Crew for ventilation fans	Hour	3.00	10.00	30.00
8	Surveyor	Day	0.50	166.25	83.13
9	Foreman	Day	1.00	188.75	188.75
10	Fitter / Mechanic	Day	2.00	169.25	338.50
11	Blaster (Licensed)	Day	1.00	158.75	158.75
12	Helper blasting	Day	2.00	153.25	306.50
13	Hammerman	Day	2.00	157.75	315.50
14	Khalasi for mucking shift, 4 Nos	Day	4.00	157.25	629.00
15	Heavy mazdoor				
	for mucking shift 4 Nos	Day	4.00	143.75	575.00
	for other 2 shifts 1 No each shift	Day	2.00	143.75	287.50
16	Light mazdoor for cleaning & miscellaneous	Day	1.00	142.25	142.25
				TOTAL Rs	7903.39
	Add for small Tools and Plants @ 1%			Rs	79.03
	Add for Contractor's Profit @ 10%			Rs	790.34
	Add for hidden cost on Labour @ 15%			Rs	1185.51
	Add for additional hidden cost on labour @ 10%			Rs	790.34
	Add for Contractor's Overheads @ 5%			Rs	395.17
			TOTAL COST OF LABOUR :		11143.77

Table 4.4 Rate Analysis of Labour Used in the Existing Tunnel

4.3 ABSTRACT FOR THE EXISTING TUNNEL

A: COST OF MATERIALS	Rs	22246.63
B: HIRE CHARGES OF MACHINERY	Rs	25225.25
C: COST OF LABOUR	Rs	11143.77
	TOTAL	58615.66
ADD FOR AIR AND WATER LINE @ 0.50%	Rs	293.0783
ADD FOR VENTILATION @ 6.10%	Rs	3575.555
ADD FOR LIGHTING @ 1.90%	Rs	1113.697
ADD FOR ELECTRIC SUB-STATION / DEMAND CHARGES @ 3.90%	Rs	2286.011
ADD FOR OTHER ENABLING WORKS @ 1.70%	Rs	996.4661
TOTAL COST FOR 47 cum	Rs	66880.46
RATE PER cum	Rs	1436.313

Table 4.5 Abstract for the Existing Tunnel

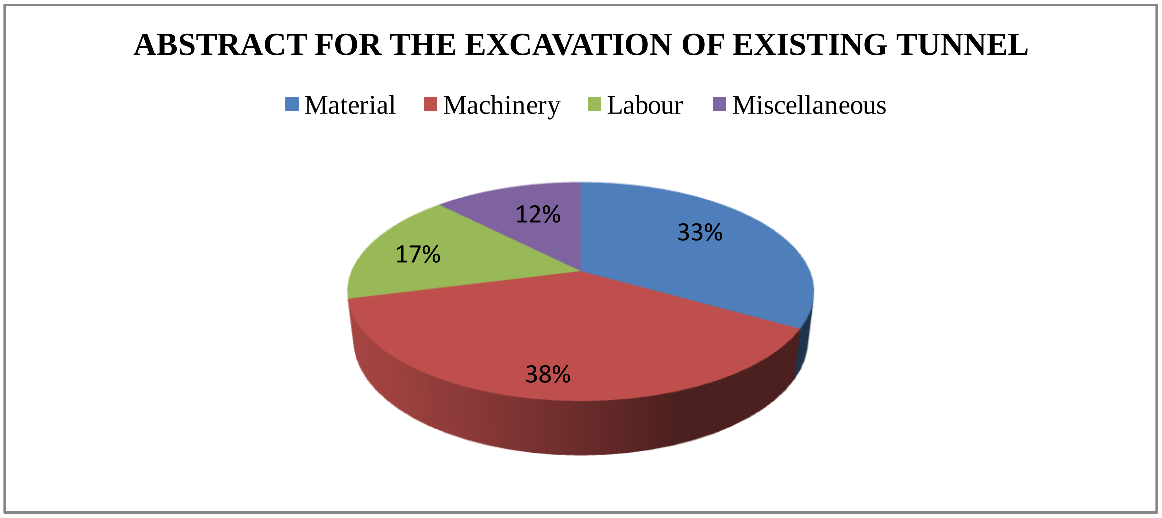

Fig 4.2 Abstract for the excavation of existing tunnel

4.4 LEAD DISTANCE CALCULATION FOR THE EXISTING TUNNEL

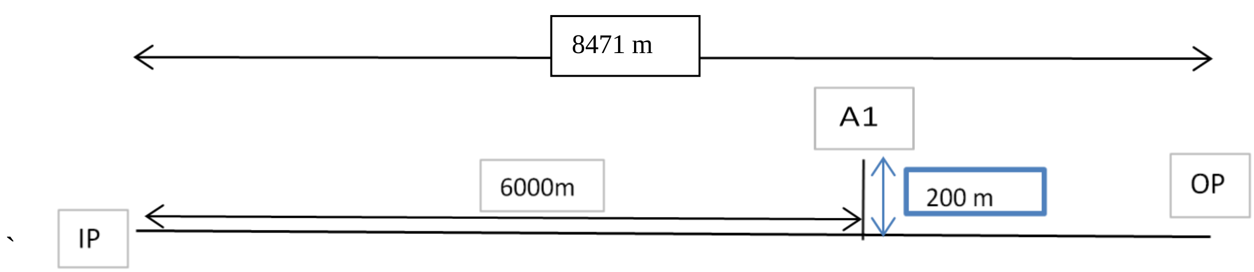

Fig 4.3 Layout of the Tunnel

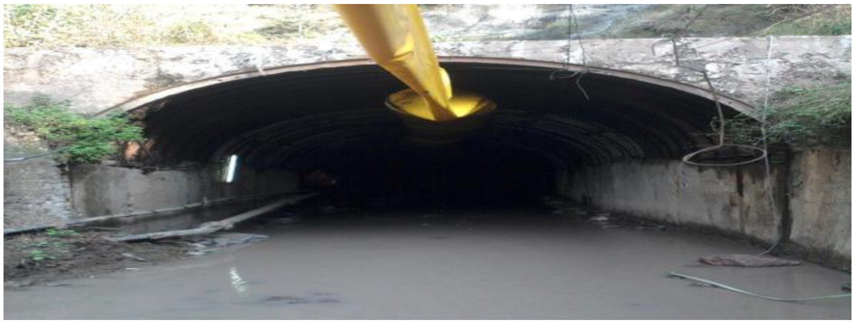

Fig 4.4 Adit at Chakhran Village

4.4.1 DATA

	DISTANCE (in m)	DISTANCE (in Km)
DISTANCE FROM INLET PORTAL IP TO OUTLET OF ADIT A1	6000	6
LENGTH OF INTERMEDIATE ADIT A1	200	0.200
DISTANCE FROM INLET PORTAL TO OUTLET PORTAL OP	8471	8.471

Table 4.6 Data for the calculating Lead Distance of the Existing Tunnel

4.4.2 CALCULATING MEAN CHAINAGE

CALCULATING MEAN CHAINAGE		
CHAINAGE	DISTANCE (in m)	DISTANCE (in Km)
CHAINAGE LENGTH IP-A1	3100	3.100
CHAINAGE LENGTH A1-OP	1335.5	1.336

Table 4.7 Calculating Mean Chainage of the Existing Tunnel

4.4.3 CUMULATIVE LEAD CALCULATION

LOCATING THE POINTS IN HEAD RACE TUNNEL(HRT)		
	DISTANCE (in m)	DISTANCE (in Km)
BETWEEN IP AND A1	2900	2.900
BETWEEN A1 AND OP	7135.5	7.136

Table 4.8 Locating Points in Head Race Tunnel of the Existing Tunnel

REDUCED DISTANCE, Km	CUMULATIVE LEAD, Km
0-2.900	4.205
2.900-6.000	5.425
6.000-7.136	0.872
7.136-8.471	0.892
	11.394

Table 4.9 Cumulative Lead Calculation of the Existing Tunnel

4.4.4 Haulage Time Computation

CALCULATING TIME REQUIRED FOR HAULAGE OF MUCK		
Average Speed to Dumping Site	10	km/hr
Average Time Required for Dumping Site	0.135 8	Hr Min
Return Speed to Excavation Site	15	km/hr
Average Time Required for Excavation Site	0.090 5	Hr Min
Total Time	13	Min

Table 4.10 Calculating Haulage Time for existing Tunnel

4.5 SCHEDULE AND BUDGET COMPUTATIONS

4.5.1 Data

Size Of Tunnel	4.15 m in dia
Shape Of Tunnel	Horse-shoe
Height Of Tunnel	4.15 m in dia
Pay-Line Margin Assumed	0.2 m
Diameter Of Tunnel Upto Pay Line For Excavation	4.55 m
Area Upto Pay-Line (Sqm)	Area Of Semi-Circle + Area Of Rectangle (0.5*π*2.275*2.275)+(2.275*4.55) 18.48 sq.m

Table 4.11 Data for Time Computation of Existing Tunnel

4.5.2 Excavation Time Computation

Depth of pull per blast for 2 m deep holes		1.8	m
Quantity of in-situ excavation per blast at			
Cycle Time of 22.1 hrs		18.48*1.8	
		33.26	cum
Quantity of muck to be removed per blast			
considering 40 % bulkage		1.40*33.26	
		47	cum
For 1m of pull volume of muck generated	47/1.8		cum
		26	cum
Volume of Muck generated for 8471m	8471*26		
		220246	cum
Considering cycle time 22.1 hrs, muck			
generated in a single day at one location		51	cum

The Excavation Work could be carried out from Inlet, outlet and One Adit

Total Muck Generated in a Single Day	51*4		
		204	cum
Time required for full excavation	220246/204		
		1080	Days
Time required for full excavation	1080/365		Years
	2 years, 350 days		
Muck generated for 200m long adit	200*26		
		5200	cum
Time Required for excavtion of Adit	5200/51		Days
		102	Days
Time Required for Excavation including			
Adit	3 years 87 days		

Considering Delays 33 Days

Total Time Required for Excavation

including Adit and Delays 3 years, 4 months

4.5.3 Budget Computation

Rate Per cum	1434	Rs per cum
Total Muck Generated, including Adit	225446	Cum
Cost incurred for the excavation of Tunnel	323280330.4	Rs
	32,32,80,331	Rs

Table 4.12 Budget Computation for the existing Tunnel

CHAPTER-5

MODIFICATIONS IN THE EXISTING EXCAVATION MODULE

5.1 Modifying the Tunnel Layout

5.1.1 Increasing the number of Adits

5.1.2 Reduction in Lead Distance

5.1.2.1 Data

5.1.2.2 Calculating Mean Chainage

5.1.2.3 Cumulative Lead Calculation

5.1.2.4 Haulage Time Computation

5.1.2.5 Lead Distance Analysis

5.2 Improvement in the De-watering System

5.2.1 Comparative Analysis of Pumps

5.3 Improvement in the Explosive Type

5.3.1 Comparative Analysis of Explosives

5.4 Improvement in the Excavator Type

5.4.1 Comparative Analysis of Excavators

5.5 Improvement in the Drilling Machine (Jumbo)

5.5.1Comparative Analysis

5.6 Improvement in the Dumper Capacity

5.6.1 Comparative Analysis of Dumpers

CHAPTER-5

MODIFICATIONS IN THE EXISTING EXCAVATION MODULE

5.1 MODIFYING THE TUNNEL LAYOUT

The existing Tunnel has been modified so as improvements could be made. No changes are made in the support systems, tunneling profile or Blasting Pattern. Improvements have been made in the methods, materials and machineries only, so as the work could be carried out without any hindrances/delays.

5.1.1 Increasing the number of adits

The number of adits have been increased from one to three, so that the work could progress at a faster rate. In the existing Tunnel Excavation, only one adit was there. Therefore, the work could progress from three locations at one point of time from inlet, outlet and adit portal. Since, the adits are now increased to three, work could be carried out from eight locations at any point of time, thus considerable improvement in the progress of the tunnel excavation. Although, three adits would have considerable implications on the financial exchequer but the cost saved due to reduction of schedule will be compensated by that. Also, increasing the number of adits would decrease the lead distance and therefore, cost is saved during each trip.

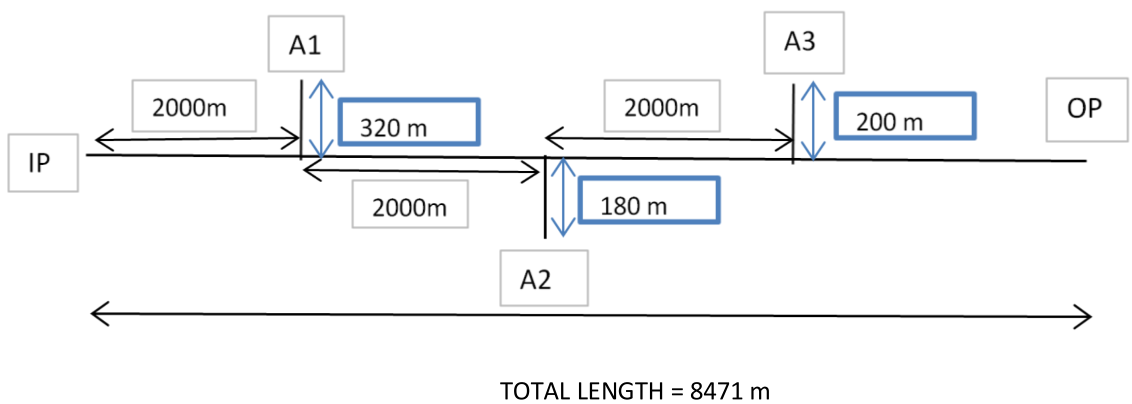

Fig 5.1 Layout of the modified Tunnel

5.1.2 Reduction in Lead Distance

5.1.2.1 Data

	DISTANCE (in m)	DISTANCE (in km)
DISTANCE FROM INLET PORTAL IP TO OUTLET OF ADIT A1	2000	2
LENGTH OF INTERMEDIATE ADIT A1	320	0.320
DISTANCE FROM INLET PORTAL IP TO OUTLET OF ADIT A2	4000	4
LENGTH OF INTERMEDIATE ADIT A2	180	0.180
DISTANCE FROM INLET PORTAL TO OUTLET OF ADIT A3	6000	6
LENGTH OF INTERMEDIATE ADIT A3	200	0.200
DISTANCE FROM INLET PORTAL TO OUTLET PORTAL OP	8471	8.471

Table 5.1 Data for the modified tunnel

5.1.2.2 Calculating Mean Chainage

CALCULATING MEAN CHAINAGE		
CHAINAGE	DISTANCE (in m)	DISTANCE (in km)
CHAINAGE LENGTH A1-A2	1250	1.250
CHAINAGE LENGTH A2-A3	1190	1.190

Table 5.2 Calculating Mean Chainage for Modified Tunnel

5.1.2.3 Cumulative Lead Calculation

LOCATING THE POINTS IN HEAD RACE TUNNEL(HRT)		
CHAINAGE LENGTH	DISTANCE (in mts)	DISTANCE (in Km)
BETWEEN A1 AND A2	2930	2.930
BETWEEN A2 AND A3	5010	5.010

Table 5.3 Locating Points in the Modified Tunnel

REDUCED DISTANCE, Km	CUMULATIVE LEAD, Km
0-2.000	2.640
2.000-2.930	0.730
2.930-4.000	0.765
4.000-5.010	0.692
5.010-6.000	0.688
6.000-8.471	3.547
	9.062

Table 5.4 Cumulative Lead Calculation for the Modified Tunnel

Cumulative Lead = 9.062/8.471 = 1.070 km

5.1.2.4 Haulage Time Computation

CALCULATING TIME REQUIRED FOR HAULAGE OF MUCK		
Average Speed to Dumping Site	10	km/hr
Average Time Required for Dumping Site	0.107 6	hr min
Return Speed to Excavation Site	15	km/hr
Average Time Required for Excavation Site	0.071 4	hr Min
Total Time	10	Min

Table 5.5 Haulage Time Computation

5.1.2.5 Lead Distance Analysis

Lead Distance calculated for the existing Tunnel with one Adit was 1.345 km, while the lead distance calculated for the modified tunnel with three Adits comes out to be 1.070 km. Therefore, for every trip from excavation site to dumping site 275m distance is saved of the haulage equipments (dumpers) in the tunnel with three adits. More than half of a kilometer, 550m to be precise, is saved to reach back to the excavation site by haulage equipments in comparison to lead distance of 1.345km with just one adit.

5.2 IMPROVEMENTS IN THE DE-WATERING SYSTEM

Proper De-watering System in a tunnel is a must not only for the proper execution but also because of the safety of the labour. De-watering System not only checks flooding of the tunnel but also provides proper and safe working conditions for the labour and machinery. Also, it enhances the safety of the tunnel by allowing entrapped water the path to be safely discharged out of the tunnel through adits and portals. Apart from that, electrical short-circuits are minimized if proper and efficient de-watering pumps are installed in the tunnel.

In the existing Tunnel, Centrifugal De-watering Pump 2 No., 20 HP and 150 cum/hr capacity were used which have been upgraded to 1 No., 75 HP and 450 cum/hr capacity , under commercial name of Viraj VDX Submerssible pump, in this thesis for achieving higher performance. Viraj Pumps have an added advantage of being light weight, compact in design and robust construction compared to the pump used in the Existing Tunnel.

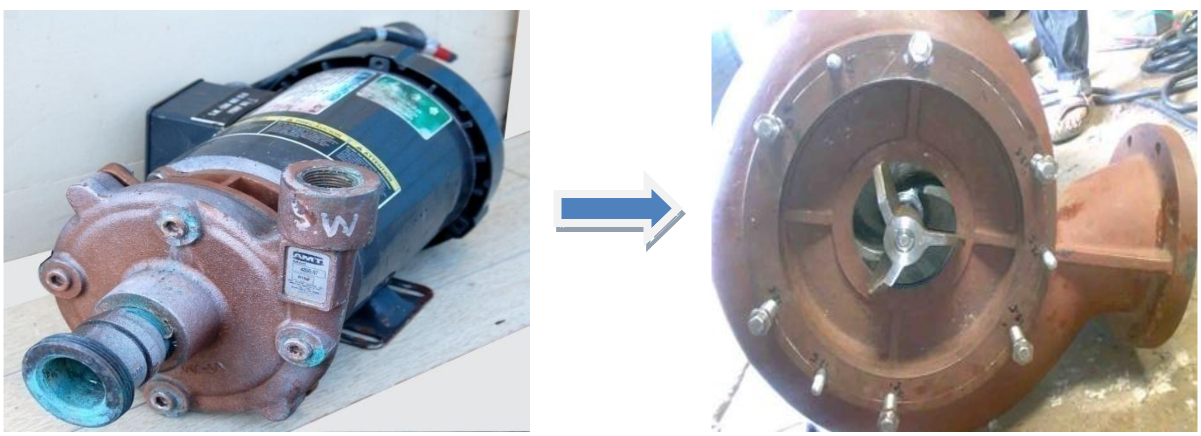

Fig 5.2 Centrifugal Pump upgraded to Viraj Submerssible Pump

5.2.1 Comparative Analysis of Pumps

CHARACTERISTICS	CENTRIFUGAL PUMP	VIRAJ VDX SUBMERSSIBLE PUMP
Thermal and Moisture Protection	No	Yes
Performance under submerged conditions	Low	High
Operation And Maintenance Costs	High	Low
Power	20 HP	75 HP
Capacity	150 cum/hr	450 cum/hr
Number of Units	2	1

Table 5.6 Comparative Analysis of Pumps

5.3 IMROVEMENT IN THE EXPLOSIVE TYPE

Drilling and blasting is an economical way of excavating long tunnels through hard rock, where digging is not possible. Explosive is a mixture of chemical compounds that can decompose violently when initiated to heat, energy, impact or friction. Choosing the best explosive is of utmost importance keeping in view the economics of the project. Slurry Explosives are new in explosives and are being used continuously in modern tunnel blasting. They are phasing out traditionally stronghold explosives such as dynamite because of more safety features and less maintenance costs.

Blasting Gelatin which was used in the Existing Tunnel Blasting has been replaced by Slurry Explosives in this thesis. Slurry is a mixture of sensitizer (Tri-nitro Toluene, Nitro-Starch), an oxidizer (nitrates and per-chlorates of ammonium, potassium and calcium), fuel (glycol, starch, sugar) and thickener (guar gum).

Slurry Explosives under commercial name of DETAGEL are used and provided by Ventrivel Explosive Pvt. Ltd.

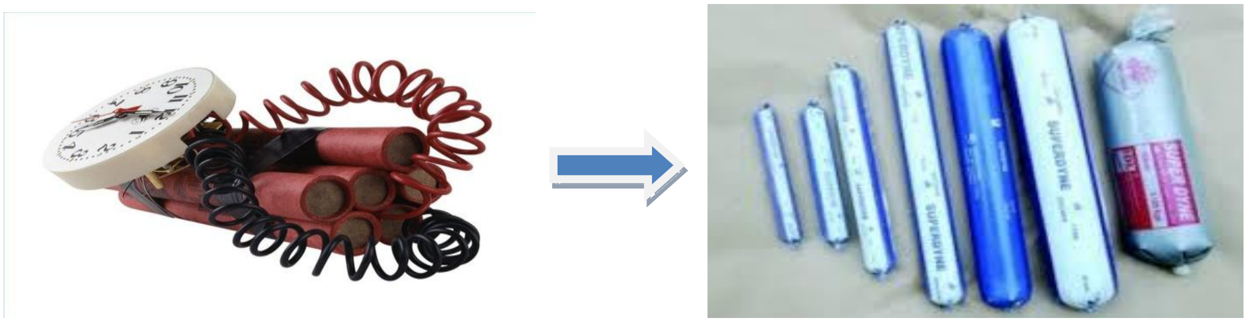

Fig 5.3 Blasting Gelatin replaced by Slurry Explosives

5.3.1 Comparative Analysis of Explosives

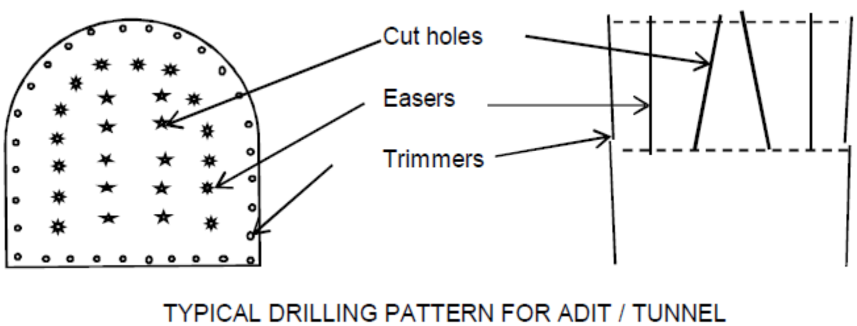

Fig 5.4 Drilling Pattern for Adits/ Tunnels

CHARACTERISTICS	BLASTING GELATIN	SLURRY EXPLOSIVES
Operating Costs	Low	Low
Maintenance Costs	High, special storage facilities needed	Low
Safety	Less Safer	Built in safety against fire, friction and impact
Water Compatibility	Less Efficient	Perform better under flooded conditions
Toxic Gases	High amount of toxic gases produced	Very less toxic gases produced
Cut Holes And Erasers Spacing	500-600 mm	650-700 mm

Trimmers Spacing	400-500 mm	500-600 mm
No. of holes for full excavation of tunnel	4 per sqm of the excavation area	3 per sqm of the excavation area
Drilling Holes	74 No.	56 No.
Rate per kg	Rs 75	Rs 85
Cost of Loading Holes with Explosives	Rs 5550	Rs 4760

Table 5.7 Comparative Analysis of Explosives

5.4 IMPROVEMENT IN THE EXCAVATOR TYPE

Excavators play an important role after blasting. They not only work as a medium to remove the muck from the blasting face out of the tunnel by loading much into the dumpers, but also help in removing the loose fragments or debris from the tunnel profile which have not come out. The capacity of the loader should be such that the dumpers are filled fast without the other dumpers' time being wasted. Therefore, in order to match the capacity of 5 cum dumpers the excavator is upgraded from TATA HITACHI 0.5 cum capacity to JCB 3DX 1 cum capacity. JCB 3DX comes with increased advantages over TATA HITACHI such as increased size of coolers, new transmission design to provide high traction forces and low fuel consumption.

Fig 5.5 Excavator 0.5cum capacity upgraded to 1 cum capacity

CHARACTERISTICS	TATA HITACHI	JCB 3DX
Loader Bucket Capacity	0.5 cum	1.0 cum
Excavator Bucket Capacity	-	0.24 cum
Brake Horse Power	50 HP	75 HP
Cycle Time (loading to unloading of muck into Dumper)	23 sec	15 sec
Performance in hot and Dusty Conditions	Moderate	High
Fuel Consumption	22-25 Lt per Hour	18-22 Lt per Hour
Muck Cleared in 2 hrs at each site	48 cum	73 cum
Operating Cost including crew	Rs 1700/ hr	Rs 3100 /hr

Table 5.8 Comparative Analysis of Excavator

5.5 IMPROVEMENT IN THE DRILLING MACHINE (JUMBO)

5.5.1 Comparative Analysis

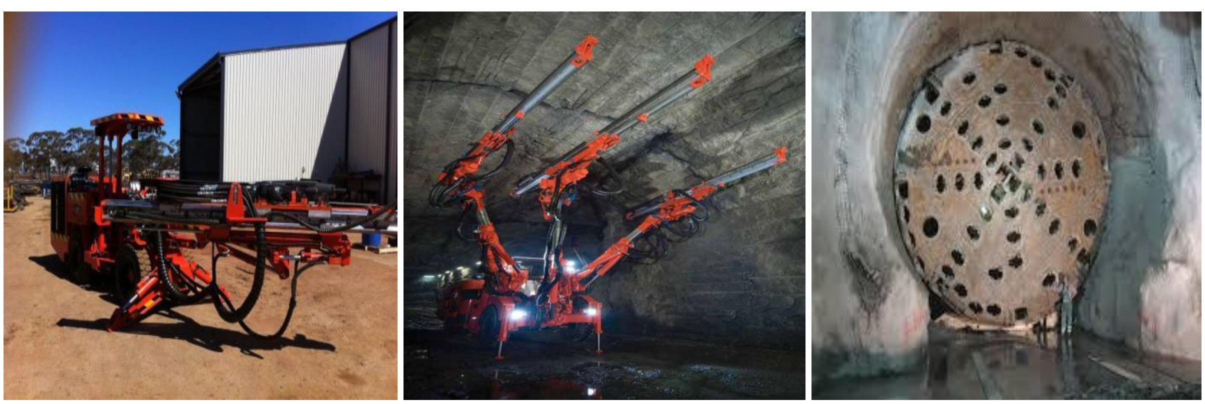

Fig 5.6 Single Boom, Multiple Boom and TBM

CHARACTERISTICS	SINGLE BOOM	THREE BOOM
Drilling	Only one hole at a time	Three holes simultaneously
Rate of Drilling 185m length per Hour	12 hrs	2 hrs
Fuel/ Energy Usages	Rs 35 per hour	Rs 125 per hour
Operation Cost	Rs 338 per hour	Rs 900 per hour
Performance	Bad	Good
Maintenance Cots	High	Very High

Table 5.9 Comparative Analysis of Single Boom And Multiple Boom (Three)

CHARACTERISTICS	TUNNEL BORING MACHINE	JUMBO
Uses	Excavation without Blasting, supporting and lining	Only for Drilling Holes
Applications	Most economical for length of tunnels exceeding 15 km	Most economical for length between 5km and 20km.
Excavating Medium	Cutter Heads	Drill Rod
Safety	Greater safety, protective shield provided	Less safer
Occupants Safety	Yes	No effect
Noise Level	High	Low
Toxic Gases	More safer, no blasting required.	Less safer, blasting required after drilling.

Advance Rate	More than 15m in a single day for 4.5 m dia tunnels	More than 5m in a single day
Re-requisite condition for advance rate	Dia of the tunnel	Number of Holes

Table 5.10 Comparative Analysis of TBM and Boomers

5.6 IMPROVEMENT IN THE CAPACITY OF DUMPERS

By increasing the drill length of the tunnel from 2m to 3m, there was also an increase in the amount of muck generated at the site. In the existing tunnel there was production of 48 cum of muck per blast while by modifying the drill length, muck generated in the modified tunnel is around 73 cum at each site. Therefore, in order to mach for the increase in muck generation the capacity of dumper is improved from 3 cum to 5 cum. However, under tunnel working conditions, it is not advisable to completely load the dumper. Therefore, 5 cum capacity truck is loaded to 4.5 cum while 3 cum capacity truck is loaded to 2.5 cum.

Fig 5.7 Capacity of Dumper upgraded from 3 cum to 5 cum

CHARACTERISTICS	3 cum CAPACITY	5 cum CAPACITY
No of dumpers deployed	3	4
Muck disposed in a single day	50 cum	130 cum
Total Number of trips for complete removal of muck from tunnel in a single day	17	26
Time required for haulage of muck and reach back at excavation site	13 min/ trip	10 min/trip

Table 5.11 Comparative Analysis of Dumpers

CHAPTER-6

RATE ANALYSIS OF THE MODIFIED TUNNEL

6.1 Data Analysis of the Modified Tunnel

6.1.1 Data

6.1.2 Drilling Holes

6.1.3 Loading Explosives and Blasting

6.1.4 Defuming and Scaling Loose Materials

6.1.5 Mucking Excavated Rock

6.1.6 Overall Cycle Time

6.1.7 Requirement of Materials

6.1.8 Requirement of Machinery

6.1.9 Requirement of Work-force

6.1.10 Use Rate of Materials

6.2 Rate Analysis of the Modified Tunnel

6.2.1 Materials

6.2.2 Machinery

6.2.3 Work-force

6.3 Abstract of the Modified Tunnel

6.4 Budget and Time Computation

6.4.1 Data

6.4.2 Time Computation

6.4.3 Budget Computation

CHAPTER-6

RATE ANALYSIS OF THE MODIFIED TUNNEL

6.1 DATA ANALYSIS OF THE MODIFIED TUNNEL

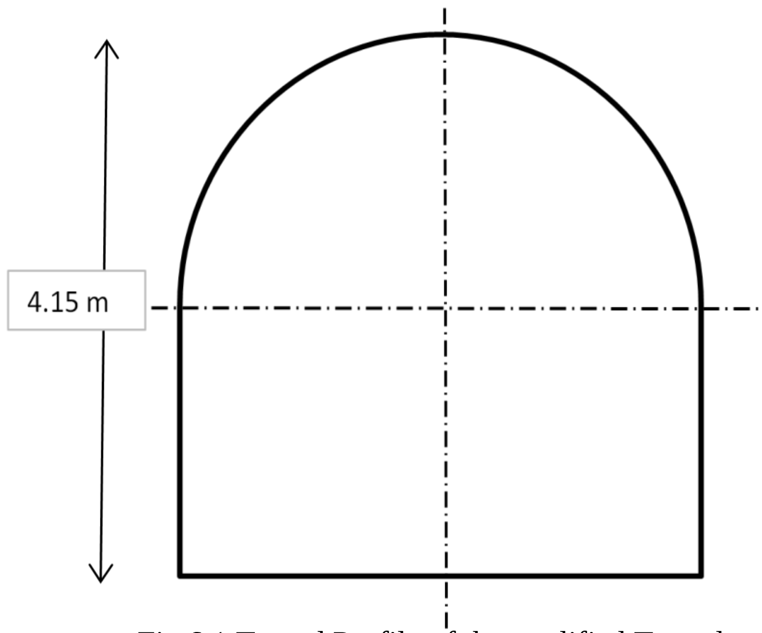

Fig 6.1 Tunnel Profile of the modified Tunnel

6.1.1 Data

Size Of Tunnel	4.15 m in dia
Shape Of Tunnel	Horse-shoe
Height Of Tunnel	4.15 m
Pay-Line Margin Assumed	0.2 m
Diameter Of Tunnel Upto Pay Line For Excavation	4.55 m
Haulage Of Excavated Muck	By Dumpers
Total Length Of The Tunnel	8471 m

Table 6.1 Data for the modified Tunnel

6.1.2 Drilling Holes

Full Face Method Of Excavation Implemented

Area Upto Pay-Line (Sqm)	Area Of Semi-Circle + Area Of Rectangle	
	(0.5*π*2.275*2.275)+(2.275*4.55)	
	18.48	
Cut-Holes And Erasers Spacing	650-700	mm
Trimmers Spacing	500-600	mm

Since Cross-Sectional Area is less than 45 sqm, the number of holes for tunnel excavation will be in range of 2.5 to 3 per sqm

For Rate Analysis, 3 holes per sqm of Cross Sectional Area upto Pay Line considered.

No. of holes for full excavation	18.48*3	
	56	Nos
Depth of Holes	3	m
Extra drilling considered at 10 percent for inclined cut holes and for any secondary blasting of large fragments during mucking		
Depth of drilling for 56 holes	56*3*1.10	
	184.8	
	185	m
Average rate of drilling per hour by Jumbo, 3 Booms	80	m
Time for Jumbo for Drilling	185/80	
	2.3125	Hrs
Time for 1 air compressor 15 cmm for air supply to Boomer	2.3125	Hrs
Time for 10 hp pump for water supply to drilling work	2.3125	Hrs

6.1.3 Loading Explosives And Blasting

Depth of pull per blast for 3 m deep holes	2.8	m
Quantity of in-situ excavation per blast	18.48*2.8	
	51.74	cum
Quantity of explosive small dia per blast @ 1.00 kg per cum	52	Kg
Quantity of explosive for secondary blasting @ 5 %	0.05*52	
	3	Kg
Quantity of delay detonators per blast	56	Nos
Quantity of electric detonators for secondary blasting	4	Nos
Time for drilling jumbo for loading explosives	1	Hr

6.1.4 Defuming And Scaling Loose Materials

No machinery other than ventilation fans are required. For defuming adit ventilation fans are installed in duct system at about 300 m interval and are run for about 1 hour after each blast.

Considering 20 hp fan 1 No. for 1 hour for defuming.

6.1.5 Mucking Excavated Rock

Quantity of muck to be removed per blast considering 40 % bulkage	1.40*51.74	
	73	cum
For 1m of pull volume of muck generated	26.07	cum
Capacity of dumper per load	5	cum
Quantity of muck per load considered under adit working conditions	4.5	cum
Number of Trips	16	Trips

Loading cycle time:

Turning / moving and spotting	1	Min
Load Bucket	6	Sec
Swing Loaded, capcity 1 cum	4	Sec
Dump Bucket	2	Sec
Swing Empty	3	Sec
Total cycle	15	Sec
Time required for 5 cycles	75	Sec
Cycle time of loading dumper per load of 4.50 cum	3	Min

Haulage cycle time:		
Running time from loading point to dump yard @ av 10 km / hr	6	Min
Turning and unloading	2	Min
Return trip to reversing point @ av 15 km / hr	4	Min
Cycle time for haulage per load of 4.5 cum	13	Min

Delpoy Dumpers	4	
Round trip cycle time of dumper	16	Min
Considering Delays	20	Min
	0.33	hr
Quantity of muck disposal per hour / dumper	13.5	cum
Quantity of muck disposal per hour by 4 Dumpers	54	cum
Time for 4 dumper for conveying muck @ 13.5 cum per trip per hour	1.35	hr
	2	hrs
Time for JCB and workforce for loading (Hrs)	2	hrs

6.1.6 Overall Cycle Time

Checking alignment and marking hole locations	1	hrs
Drilling holes	2.3125	hrs

Loading explosive and blasting	1	Hrs
Defuming and scaling loose rock fragments	1	Hrs
Mucking excavated rock	2	Hrs
Bed cleaning, support fixing, rock bolting, lighting etc (approx)	6	Hrs
Total cycle of excavation per blast of 2.8 m length	13.3125	Hrs

6.1.7 Requirement Of Materials

Explosives small diameter (52+3)	55	Kg
Electric short delay detonators (56*1)	56	Nos
Electric detonators for secondary blasting (4*1)	4	Nos
Fuse coil	186	Rm

6.1.8 Requirement Of Machinery

Deploy drilling jumbo for marking (1 hr) / drilling (2.3125 hrs) / loading explosive (1 hr)	4.3125	hrs
Deploy air compressor 15 cmm for air supply to Boomer	2.3125	hrs
Deploy 10 hp pump for water supply to drilling work.	2.3125	hrs
Deploy 20 hp ventilation fan for defuming	1	hr
Deploy JCB 1 cum capacity,for loading excavated rock	2	hrs
Deploy 1 dumper for conveying muck	2	hrs

6.1.9 Requirement Of Work-Force

Surveyor for checking alignment and marking hole locations for drilling	0.5	No.
Foreman for supervising drilling of holes and other operations	1	No.
Fitter / Mechanic for extending air / water lines	2	Nos.

Blaster (Licensed)	1	No.
Helper blasting	2	Nos.
Hammerman for scaling	2	Nos.
Maistry 1 in each shift	3	Nos.
Khalasi for mucking shift	4	Nos.
Heavy mazdoor for mucking shift	4	Nos.
For other 2 shifts 1 No each shift	2	Nos.
Light mazdoor for cleaning & miscellaneous	1	No.

6.1.10 Use Rate Of Materials

Cost of drill rod 3.5 m long @ Rs 8750.00 / No.	8750.00	Rs.
Life of drill rod with reconditioning	150.00	m
Use rate of drill rod per Rm drilling (cost / life)	58.33	Rs.
Length of air and water hose assumed	25.00	m each
Cost of 25 mm dia air hose 25 m @ Rs 165.00 / Rm	4125.00	Rs.
Life of air hose	800.00	Hrs.
Use rate of air hose per hour (cost / life)	5.16	Rs.
Cost of water hose 25 m each @ Rs 140.00 / Rm	3500.00	Rs.
Life of water hose	800.00	Hrs.
Use rate of water hose per hour (cost / life)	4.38	Rs.

6.2 RATE ANALYSIS OF THE MODIFIED TUNNEL

6.2.1 Materials

S.No.	PARTICULARS	UNIT	QUANTITY	RATE IN RS.	AMOUNT IN RS.
1	Small Dia Explosives	Kg	55.00	50.00	2750.00
2	Delay Detonators	Nos	56.00	20.00	1120.00
3	Electric Detonators	Nos	4.00	11.00	44.00
4	Detonating Fuse Coil	Rm	186.00	9.00	1674.00
5	Use rate of drill rod 3.5 m long	Rm	185.00	58.33	10791.67
	Reconditioning charges @ 10%				1079.17
6	Use rate of air hose	Hour	13.31	5.16	68.64
7	Use rate of water hose	Hour	13.31	4.38	58.24
8	Sundries	LS	15.00	33.00	495.00
				TOTAL Rs	18080.72
	Add for small Tools and Plants @ 1%			Rs	180.81
	Add for Contractor's Profit @ 10%			Rs	1808.07
	Add for Contractor's Overheads @ 5%			Rs	904.04
	TOTAL COST OF MATERIALS :			Rs	20973.63

Table 6.2 Rate Analysis of Materials used in the Modified Tunnel

6.2.2 Machinery

S.No.	PARTICULARS	UNIT	QUANTITY	RATE IN RS.	AMOUNT IN RS.
1	Drilling Jumbos	Hour	2.31	900.00	2081.25
	Fuel / Energy charges	Hour	2.31	125.00	289.06
2	Air compressor 15 cmm (ele)	Hour	2.31	111.00	256.69
	Fuel / Energy charges	Hour	2.31	671.00	1551.69
3	JCB 1 cum capacity	Hour	2.00	950.00	1900.00
	Fuel / Energy charges	Hour	2.00	1075.00	2150.00
4	Dumper (4 x 2 hrs)	Hour	8.00	620.00	4960.00
	Fuel / Energy charges	Hour	8.00	350.00	2800.00
5	Pump 10 hp (ele)	Hour	2.31	5.00	11.56
	Fuel / Energy charges	Hour	2.31	54.00	124.88
6	Ventilation fans 20 hp (1 x 1 hr)	Hour	1.00	6.00	6.00
	Fuel / Energy charges	Hour	1.00	107.00	107.00
7	Sundries(explosive van / magazine)	LS	15.00	33.00	495.00
				TOTAL Rs	15639.13

Add for small Tools and Plants @ 1%	Rs	156.39
Add for Contractor's Profit on Fuel / Energy @ 10%	Rs	1563.91
Add for Contractor's Overheads @ 5%	Rs	781.96
TOTAL HIRE CHARGES OF MACHINERY :	Rs	18141.39

Table 6.3 Rate Analysis of Machinery used in the Modified Tunnel

6.2.3 Labour

S.No.	PARTICULARS	UNIT	QUANTITY	RATE IN RS.	AMOUNT IN RS.
1	Crew for Drilling jumbo	Hour	5.00	250.00	1250.00
2	Crew for Air compressor	Hour	2.31	65.00	150.31
3	Crew for JCB	Hour	2.00	65.00	130.00
4	Crew for Dumper	Hour	2.00	78.50	157.00
5	Crew for Pump	Hour	2.31	29.10	67.29
6	Crew for ventilation fans	Hour	1.00	10.00	10.00
7	Surveyor	Day	0.50	166.25	83.13
8	Foreman	Day	1.00	188.75	188.75
9	Fitter / Mechanic	Day	2.00	169.25	338.50
10	Blaster (Licensed)	Day	1.00	158.75	158.75
11	Helper blasting	Day	2.00	153.25	306.50
12	Hammerman	Day	2.00	157.75	315.50
13	Khalasi for mucking shift, 4 Nos	Day	4.00	157.25	629.00
14	Heavy mazdoor				
	for mucking shift 4 Nos	Day	4.00	143.75	575.00
	for other 2 shifts 1 No each shift	Day	2.00	143.75	287.50
15	Light mazdoor for cleaning & miscellaneous	Day	1.00	142.25	142.25
				TOTAL Rs	4789.48
	Add for small Tools and Plants @ 1%			Rs	47.89
	Add for Contractor's Profit @ 10%			Rs	478.95
	Add for hidden cost on Labour @ 15%			Rs	718.42
	Add for additional hidden cost on labour @ 10%			Rs	478.95
	Add for Contractor's Overheads @ 5%			Rs	239.47
	TOTAL COST OF LABOUR :				6753.17

Table 6.4 Rate Analysis of Labour used in the Modified Tunnel

6.3 ABSTRACT OF THE MODIFIED TUNNEL

A: COST OF MATERIALS	Rs	20973.63
B: HIRE CHARGES OF MACHINERY	Rs	18141.39
C: COST OF LABOUR	Rs	6753.17
	TOTAL	45868.19
ADD FOR AIR AND WATER LINE @ 0.50%	Rs	229.3409
ADD FOR VENTILATION @ 6.10%	Rs	2797.959
ADD FOR LIGHTING @ 1.90%	Rs	871.4955
ADD FOR ELECTRIC SUB-STATION / DEMAND CHARGES @ 3.90%	Rs	1788.859
ADD FOR OTHER ENABLING WORKS @ 1.70%	Rs	779.7592
TOTAL COST FOR 51.74 cum	Rs	52335.60
RATE PER cum	Rs	1011.433

Table 6.5 Abstract for the Modified Tunnel

Rate per cum = Rs 1012

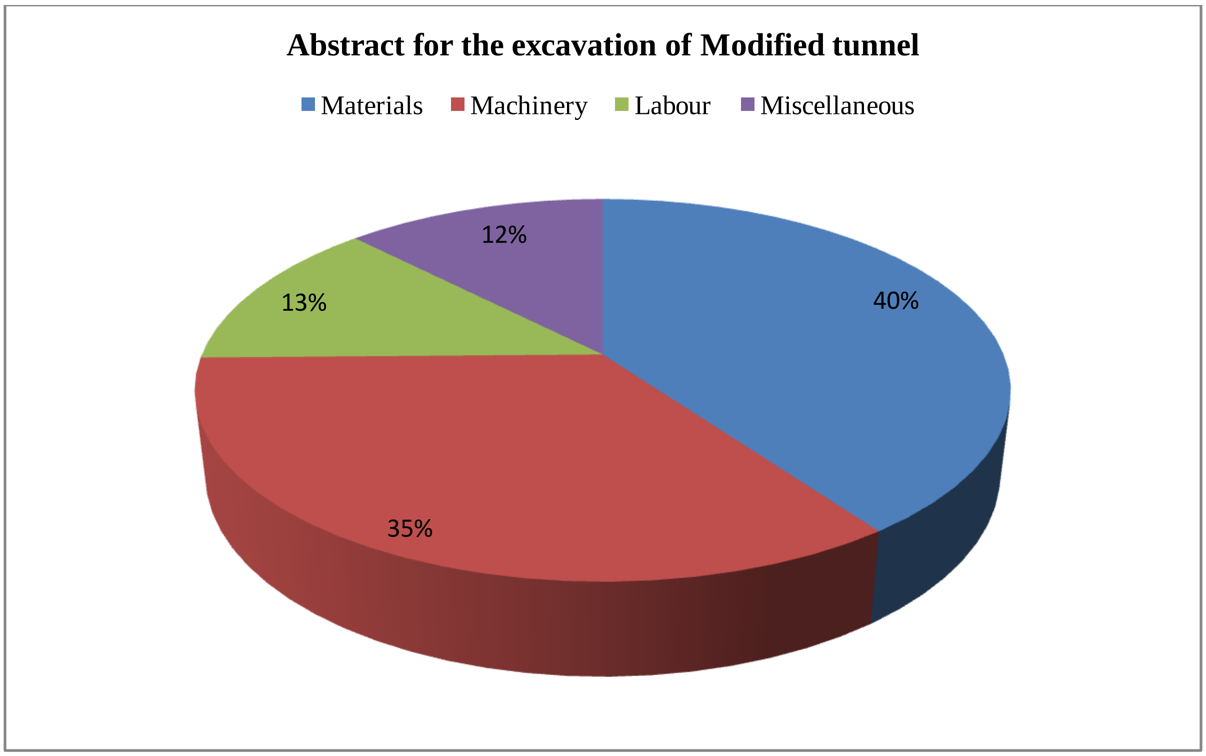

Fig 6.2 Abstract for the excavation of modified tunnel

6.4 BUDGET AND TIME COMPUTATIONS

6.4.1 Data

SIZE OF TUNNEL	4.15 m in dia
SHAPE OF TUNNEL	Horse-shoe
HEIGHT OF TUNNEL	4.15 m
PAY-LINE MARGIN ASSUMED	0.2 m
DIAMETER OF TUNNEL UPTO PAY LINE FOR EXCAVATION	4.55 m
AREA UPTO PAY-LINE (sqm)	AREA OF SEMI-CIRCLE + AREA OF RECTANGLE (0.5*π*2.275*2.275)+(2.275*4.55) 18.48 sq.m

Table 6.6 Data for Budget and Time Computation

6.4.2 Time Computation

Depth of pull per blast for 3 m deep holes	2.8	m
Quantity of in-situ excavation per blast at		
Cycle Time of 13.3125 hrs	18.48*2.8	
	51.74	cum
Quantity of muck to be removed per blast		
considering 40 % bulkage	1.40*51.74	
	72	cum
For 1m of pull volume of muck generated	72/2.8	cum
	26	cum
Volume of Muck generated for 8471m	8471*26	
	220246	cum
Considering cycle time 13.3125 hrs, muck		
generated in a single day at one location	125	cum

The Excavation Work could be carried out from Inlet, outlet and Three Adit

Total Muck Generated in a Single Day	125*8	
	1000	cum
Time required for full excavation	220246/1000	
	221	days

Muck generated for 700m length of 3 adits	700*26		
		18200	cum
Time Required for excavtion of Adit	18200/125		days
		146	days
Time Required for Excavation including Adit	1year, 02 days		
Considering Delays		28	days
Total Time Required for Excavation including Adit and Delays	1year, 1 month		

6.4.3 Budget Computation

Rate Per cum	1012	Rs per cum
Total Muck Generated, including 3 Adits	238446	cum
Cost incurred for the excavation of Tunnel	241307352	Rs
	24,13,07,352	Rs

Table 6.7 Budget Computation of the Modified tunnel

CHAPTER-7

HAZARDS AND CONTROL DURING TUNNELING OPERATION

7.1Most common Hazards

7.1.1Hazards associated with Excavation Methods

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CHAPTER-7

HAZARDS AND CONTROL DURING TUNNELING OPERATION

7.1 MOST COMMON HAZARDS

The common hazards and areas of potential risk in most, if not all, tunnels under construction are closely related to, or exacerbated by, the confines of the underground workplace. They include the following:

- tunnel stability – rock or earth falls and rock bursts
- changing conditions – strata and stress field fluctuations
- limited space and access
- level of expertise – even long-term tunnels may lack experience in certain specialized aspects or methods
- air contamination or oxygen depletion
- fire or explosion
- the use and maintenance of fixed and mobile plant
- close proximity to electrical supplies and circuits
- use of compressed air and high pressure hydraulics
- projected particles from rock breaking, drilling or cutting
- manual handling
- large scale materials handling, spoil out, and materials and equipment
- uneven surfaces
- wet or other slippery surfaces
- heights
- falling objects
- overhead seepage, ground and process water
- ground gas or water inrush
- contaminated groundwater
- reduced visibility
- loss of power, including lighting and ventilation
- noise levels

• vibration

• hazardous substances and dangerous goods.

Examples of specific hazards or risks	Example risk control measures
Manual handling, eg handling air tools, drill rods, supports, cutters, grout.	• Engineering assessment of tasks • Use mechanical equipment with automatic feed • Use lifting aids • Team lifting • Select light weight rock drills, smaller bags • Use vibration insulation on handles
Heat Stress	• Increase ventilation • More frequent rests and cool water • Cool suits • Reduce use of high heat output equipments
Noise	• Insulation of plant • Hearing Protection
Dust	• Increase face extraction ventilation • Water sprays on cutting equipment or over muck heaps and spoil conveyors

Table 7.1 Hazards and risk control measures

7.1.1Hazards associated with Excavation Methods

The site investigation, including geotechnical investigations and risk assessment, the tunnel design, access limitations and other local factors should be used to establish the appropriate excavation methods. It is usual for a number of different
excavation methods to be used on a single project. The tunnel design will usually assume particular excavation and support methods, but other methods may be used provided they are confirmed as not compromising the safety of the tunnel.

The methods of excavation should permit the designed ground support to be installed as planned, and allow for the installation of additional ground support should ground conditions be found to be worse than considered in the design.

Factors to include in determining appropriate excavation methods would include the following:

• the tunnel design, including the dimensions, shape, excavation tolerance of the excavation, and the tunnel support and lining design

• the expertise of the contractors

• available access

• the nature of the ground eg reclaimed ground

• the water table level

• historical excavation experience in the area under similar conditions

• the possibility of flooding from:

• surface run off, tidal water, rivers, dams, reservoirs, lakes or swamps

• leaking storm water drains, water mains or flooded communications conduits

• intersection of old flooded workings or an underground water-bearing structure, such as a fault, cast or perched water table

• the proximity of existing underground services, such as water mains, sewer, drainage, electricity, gas and telephone

• soil nails, rock anchors, basement underpinning, or other pre-existing ground support

• adjacent excavations eg shafts, tunnels or trenches

• other hazards, either natural or man-made, such as:

• heavy loadings, above or adjacent to the tunnel eg roadways, railway lines, buildings, rivers or planned or existing spoil stockpiles

• chemical contamination eg from past dumping or natural deposits

• the presence of methane, or other hazardous gases eg where coal seams are present or vegetation has decayed in the soil

• dynamic loads or ground vibration near an excavation, including:

• traffic (highway or rail)

• excavation equipment

• explosives.

7.1.2 Hazards associated with Hand Excavation

The use of hand methods of excavation is generally limited to small sections of work within larger projects eg a small shaft, sump or drive-in area with limited access and limited possibility for mechanisation.

Hazard areas that should be considered in greater detail include the following:

• manual handling eg additional physical lifting and activity

• falls from heights eg non mechanised access

• falling objects eg proximity to the worked face

• vibration effects on the body-use of hand tools eg rock drills or jackpicks

• impact eg air leg kick out or broken steels

• noise eg proximity to air tools and drills

• dust eg closer proximity to the face

• heat stress eg due to physical exertion.

7.1.3 Hazards associated with Machine Excavation

Most tunneling excavation is mechanized to a considerable extent, therefore, the implications of plant use are very significant in risk management, Plant use in itself presents significant hazards and risks that must be identified and controlled.

The hazard areas that should be considered in addition to, or in greater detail to, those common hazards include the following:

• moving plant and moving components on plant eg crush, nip or shear

• height eg elevated areas of plant including service access points

• restricted operator visibility and communication eg controls including audible warning sounds, hazard lights, operating lights

• ergonomics – visibility, seat belts, hand rails, seating, controls, stairs, manual handling

• locking and security mechanisms, including power isolation

• fire eg flammable liquids and materials

• high-pressure liquids or gases

• heat eg burns from localised heat sources or heat exhaustion for general heat

• air contamination eg from excavation dust or exhaust emissions

• radiation from lasers.

7.1.4 Hazards associated with Drill and Blast Methods

Drill and blast methods for tunnel construction are less widely used with the continued evolution of continuous excavation methods and the environmental impact constraints inherent in many tunnel locations. For shorter tunnels, or where ground conditions are very hard, drill and blast is often the only alternative. The drill and blast method has particular hazards that require a number of controls for the associated risks.

The hazard areas to be considered in the assessment and control of risks include the following:

- storage, transport and use of explosives
- ground support requirements
- the effect on surrounding strata and existing ground support
- drilling of faces
- firing times and prevention of access to firing areas
- clearance of blasting fumes and dust
- dealing with misfires.

7.2 HAZARDS CONTROL MEASURES

7.2.1 Portal Protection

Portal entries, if below the ground surface and not constructed with the final concrete or other permanent structure at the commencement of tunneling to provide protection, will require other support and protection.

This support will vary but should, at a minimum, include the following:

- ground support of the highwall, if any, above the portal entrance
- support of the portal brow or lip
- protection at the portal, protruding sufficiently out from the tunnel to protect persons entering or leaving the tunnel from material that might be dislodged off the high wall above the portal entrance.

A fence or other barricade should be provided above the portal to retain people and objects if there is access or work being carried out above the portal. Drainage should be provided to prevent heavy run off entering the tunnel.

Fig 7.1 Providing Steel Ribs at the portal

7.2.2 Scaling and Inspections

Inspection of the roof and walls, and scaling of loose rock, should be conducted immediately after excavation. As the effects of time can cause deterioration to rock surfaces, periodic follow-up inspection and scaling should be conducted on unlined areas. A risk assessment, with ongoing revision based on the inspection results, should be used to determine an appropriate period for initial and regular inspection and scaling. At shift changes, there should be a handover discussion to pass on information on the status of inspection and scaling, including the areas not yet inspected and the location of any identified drummy ground still in need of supporting.Scaling should take place:

• for drill and blast excavation – after every blast when the face area and spoil heap have been washed down

• for other excavation methods – at intervals as determined by the risk assessment above

• during the support cycle if more loose rock is revealed and as the support installation moves forward from supported ground

• whenever inspection reveals the possibility of loose rock on any wall or roof.

The excavation should be thoroughly washed down prior to the initial inspection. Regular inspections should continue in the unlined tunnel areas, to a schedule determined by the above risk assessment. Inspections and scaling should be conducted from supported and scaled areas. Where practical, machine scaling is preferred to hand scaling. Where hand scaling is used it should be from an elevated platform (basket).

Particular attention should be taken at breakthroughs, as the previous excavation and associated stress changes may have weakened the ground.

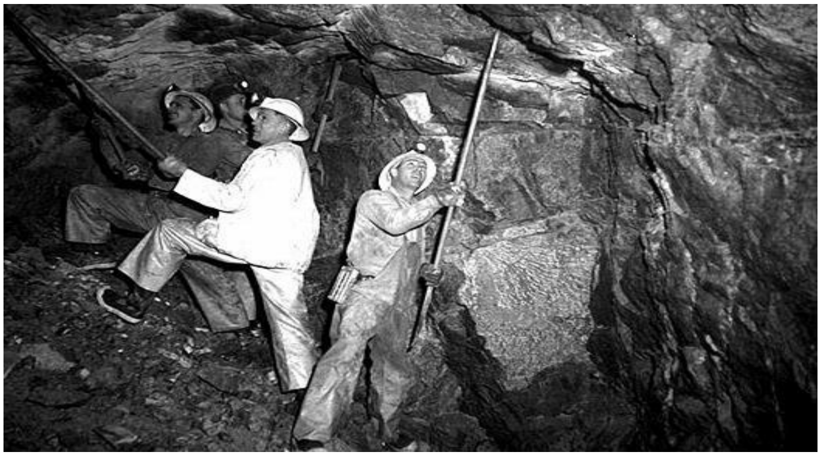

Fig 7.2 Manual Scaling of the Tunnel

7.2.3 GROUND-SUPPORT CONTROLS

Most tunnels require some form of permanent ground support. The permanent lining can be installed directly as the excavation progresses, or temporary support installed initially, followed by a permanent lining. This may be followed by the installation of a non-structural secondary lining.

It is a legal requirement that an adequate system of safety, involving shoring, earth retention equipment or other appropriate measures, is in place to control risks to health and safety arising from one or more of the following:

(a) the fall or dislodgment of earth and rock

(b) the instability of the excavation or any adjoining structure

© the inrush of water

(d) the placement of excavated material

(e) instability due to persons or plant working adjacent to the excavation.

If a system of shoring is used, the employer must ensure that an adequate supply of shoring equipment and material is provided and used to prevent a fall or dislodgment of earth, rock or other material that forms the side of or is adjacent to the excavation work.

It is also a legal requirement that an employer must ensure that adequate measures are taken in the immediate vicinity of excavation work so as to prevent the collapse of the work. In particular, an employer must ensure that no materials are placed, stacked or moved near the edge of excavation work so as to cause the collapse of the work.

Because unsupported ground is often a high risk of falling materials, all tunnels should have some form of ground support or overhead protection during the construction phase. It is usual for the planned ground support to vary throughout the project as the tunnel dimensions or ground conditions vary, and the locations of changes should be included in the design documentation.

The support actually installed as a tunnel progresses will often alter with exposure and assessment of the actual ground conditions and experience gained from the monitoring of the performance of the supports. Unless robotically installed, ground support should be installed from supported areas or using plant which provides overhead protection for the installers. The design advance and ground support system may result in the area between the last support and the face as being considered as supported. If so, this should be specified in the design.

The ground conditions should be inspected as the excavation progresses, in accordance with the inspection plan .The results from the inspections should be assessed and the ground support system reassessed, and changed if necessary, when ground conditions deteriorate from that allowed for in the design or the ground support system is not performing as designed. Similarly, changes could be made if the ground conditions are better than allowed for in the design.

Inspection and assessment of the performance of the support system and, if appropriate, changes to the specification, should be carried out by competent persons. Each ground support method or type, despite being a control for the hazards of ground conditions, has its own hazards and risks attached to the process of installation, which need to be controlled.

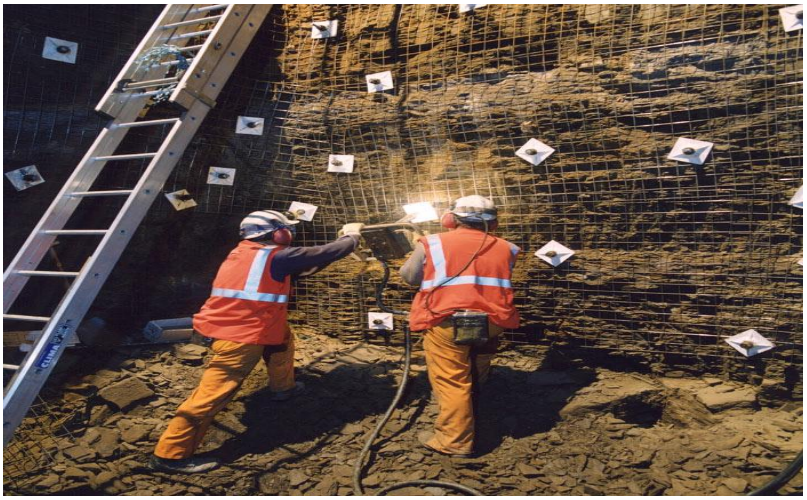

Fig 7.3 Meshing and Rock Bolting of tunnel

7.2.4 Safe Working Methods

7.2.4.1 Communication Systems

Good communication throughout the construction site is fundamental to the safety and efficiency of all aspects of a tunnel project, in particular to the passing of information and instructions, the monitoring of systems and the control of operations such as lifting; transporting persons, materials and plant; coordinating maintenance and managing emergencies. The communication system should link major workplaces, tunnel portal and face(s), or shaft top and bottom, site offices and safety critical locations on site (eg first aid room or emergency control room or dedicated mobile phone or two-way radio that is permanently attended whilst persons are underground).Means of contacting the emergency services from the site should be available and operational at all times.

A risk assessment should determine whether communication with all mobile vehicles, including personnel transporters, is required. Where electronic communication (non voice) methods are being relied upon, the point of communication reception (eg control room) should be monitored at all times by personnel who have received training in the implementation of the emergency action plan.

The communications system may need to accommodate the communication of information on a variety of safety-related items, such as machine-condition monitoring, instrumentation monitoring, atmospheric monitoring and fire alarms.

Means should be available whereby the person in charge of a workplace can communicate requirements for materials and equipment, and raise the alarm and receive instructions in the event of an emergency. The system adopted should depend on the size and length of the tunnel, the number of persons in the tunnel, the system of tunneling employed and its potential hazards, including the speed of operations.

The communication system should be independent of the tunnel power supply and installed so that destruction of one unit or the occurrence of a collapse will not interrupt the use of the other units in the system. All wiring, especially that used to transmit warnings in an emergency, should be protected. All communication cables needed to transmit warnings in an emergency should have increased integrity under emergency conditions, such as fire, water or mechanical shock, and a back up communication system should be considered for critical locations.

7.2.4.2 Personal Protective Equipment (PPE)

The use of PPE to control risks is lowest on the hierarchy of control measures. The measures at the lower levels are less effective and they require more frequent reviews of the hazards and systems of work. They should only be used when other control measures are impracticable or when a residual risk remains after implementing other controls.

7.2.4.3 Clothing For Protection

Where there is a risk that workers may be exposed to chemicals or contaminated environments, they should wear clothing for protection against chemicals that conform to the relevant Indian Standards.

7.2.4.4 Eye Protection

Dust, flying objects and sunlight are the most common sources of eye damage in excavation work. Where persons are carrying out cutting, grinding or chipping of concrete or metal, or welding they should be provided with eye protection. Eye protection should also be provided where persons carry out other work, such as carpentry or handling of chemicals, where there is a risk of eye injury.

For tunneling activities, such as rock drilling, rock cutting, concreting, service installing, steelwork and plant maintenance, the risk assessment would reasonably be expected to identify a heightened risk of eye injury, and thus require eye protection to be used at all times.

7.2.4.5 Fall-Arrest Equipment

Harnesses and other fall arrest equipment should be provided where persons are exposed to the risk of a fall when working at height. Such equipment should be selected, used and maintained in accordance with relevant codes.

7.2.4.6 Hearing Protection

Where personal hearing protection is provided it should conform with Indian Standards. Control measures including training should conform to Occupational Noise Management – Hearing Protector Program.

7.2.4.7 High Visibility Garments/Safety Reflective Vests

Persons working underground or near traffic, mobile plant or equipment under operator control, should be provided with and use high visibility garments. Such garments should be selected, used and maintained in accordance with Indian Standards. Other clothing not covered by the high visibility garment should be light colored and all garments should be selected for best contrast with the surrounding background.

7.2.4.8 Respiratory Protective Equipment

Where persons could be exposed to harmful atmospheric contaminants, such as silica dust or welding fumes, respiratory protective equipment that conforms to Indian Standards must be used (providing it is within the performance capability of the PPE).

7.2.4.9 Footwear

Persons working on tunnel construction should wear safety footwear that conforms to Indian Standards. Staff working on broken ground should wear footwear that gives ankle support and metatarsal (arch) protection.

7.2.4.10 Safety Helmets

The use of safety helmets may prevent or lessen a head injury from falling objects or a person hitting their head against something. Where there is a likelihood of persons being injured by falling objects, and overhead protection is not provided, persons must be provided with, and must use, an appropriate safety helmet. Appropriate safety helmets should also be provided and used where a person may strike their head against a fixed or protruding object, or where there is a risk of accidental head contact with electrical hazards.

7.2.4.11 Safety Gloves

Where there is a risk of hand injury, such as exposure to a harmful substance, excessive heat or cold, or to a mechanical device, hand protection appropriate to the risk should be provided and used.

7.2.4.12 Self Rescuers

Self rescuers provide the user sufficient oxygen to walk to the surface, the next cache of self rescuers or designated sealable oxygen equipped refuge. They are used in emergencies, such as fire, when the tunnel atmosphere is depleted of oxygen or has levels of contamination beyond the capacity of the respiratory protective equipment provided.

7.2.4.13 Waterproof Clothing

Waterproof clothing provided as a system of work relating to weather or site conditions should be effective and suitable for the task. Waterproof clothing should also incorporate light reflective features.

Fig 7.4 Safety requirements of tunnels

CHAPTER - 8

CONCLUSION

8.1 Abstract Comparison

8.2 Budget Comparison

8.3 Time Comparison

8.4 Inferences

CHAPTER - 8

CONCLUSION

The primary objective of the project work was to reduce the budget and time of the existing tunnel excavation. The improvements in the existing tunnel excavation module has not only reduce the time of excavation but also considerably reduce the cost of the excavation. As such the primary objective of the project has been realized. With the implementation of modern construction methods and technologies, the cost and time of the tunnel excavation can be drastically reduced. It also requires proper planning at the designing phase and controlling during the construction phase.

8.1 ABSTRACT COMPARISON

If comparison is made between the abstracts of the existing tunnel and modified tunnel per cubic metre basis, it was found that the cost of materials, machinery and men for the existing tunnel were drastically reduced by implementation of modern methods and technologies.

PARAMETERS	EXISTING TUNNEL	MODIFIED TUNNEL	OVERRUNS
Cost of Materials (per cum)	Rs 22,150.58	Rs 20,973.63	Rs 1176.95
Cost of Machinery (per cum)	Rs 25,225.25	Rs 18,141.39	Rs 7083.86
Cost of Labour (per cum)	Rs 11,143.77	Rs 6753.17	Rs 4389.83
Miscellaneous Cost (per cum)	Rs 8,251.26	Rs 6467.41	Rs 1783.85

Table 8.1 Cost Comparison of Existing Tunnel and Modified Tunnel

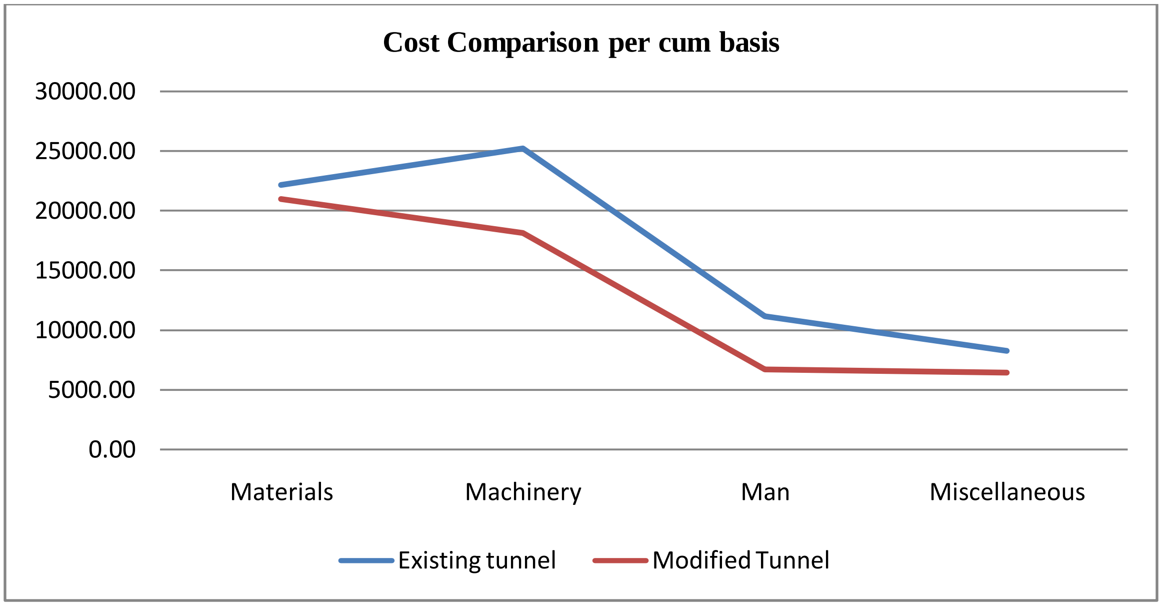

Fig 8.1 Abstract comparison of the existing and modified tunnel

8.2 BUDGET COMPARISON

The total cost of excavation for the modified tunnel was Rs 8,19,72,978 less than the existing tunnel excavation. Although there were improvements in the machineries, resulting in increased machinery operating costs, however, wise selection of resources, materials and good implementation of construction management principles had off-shoot the total cost required in the excavation of existing tunnel.

PARAMETERS	EXISTING TUNNEL	MODIFIED TUNNEL	OVERRUNS
Cost of Excavation (excluding Adit)	Rs 31,58,23,743	Rs 22,28,88,952	Rs 92934791
Cost of Excavation of Adits	Rs 74,56,587	Rs 1,84,18,400	Rs 1,09,61,813
Total Cost (including Adits)	Rs 32,32,80,330	Rs 24,13,07,352	Rs 8,19,72,978

Table 8.2 Budget comparison of Existing Tunnel and Modified Tunnel

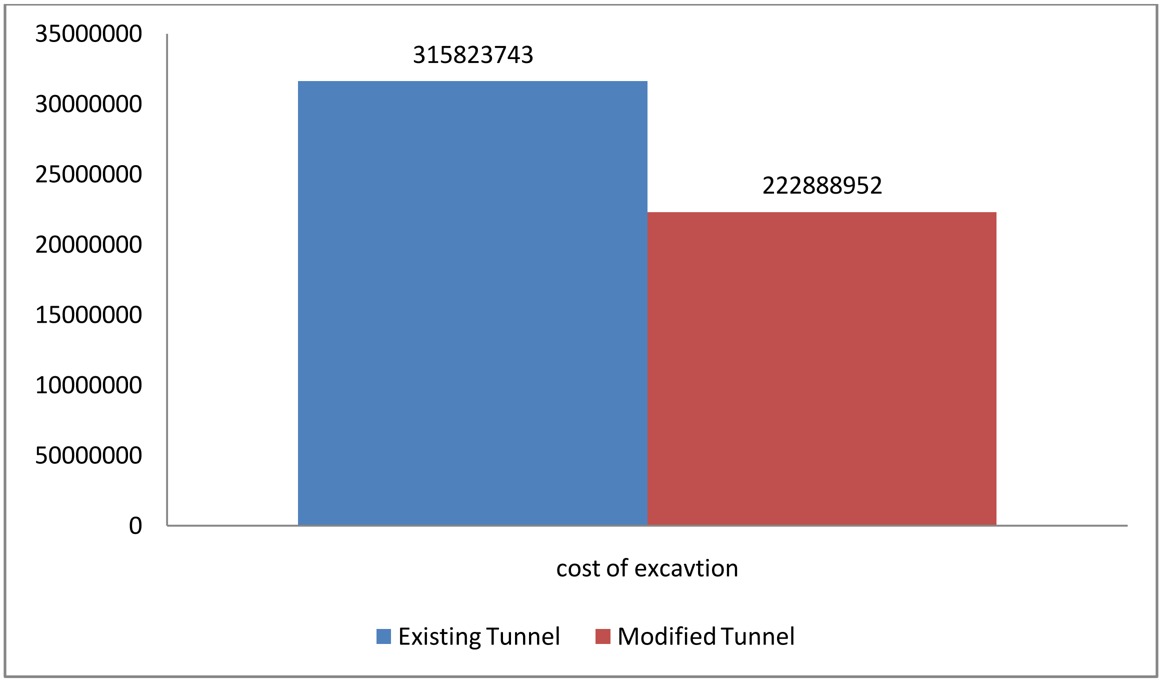

Fig 8.2 Excavation cost comparison (excluding adits) of the existing and modified tunnel

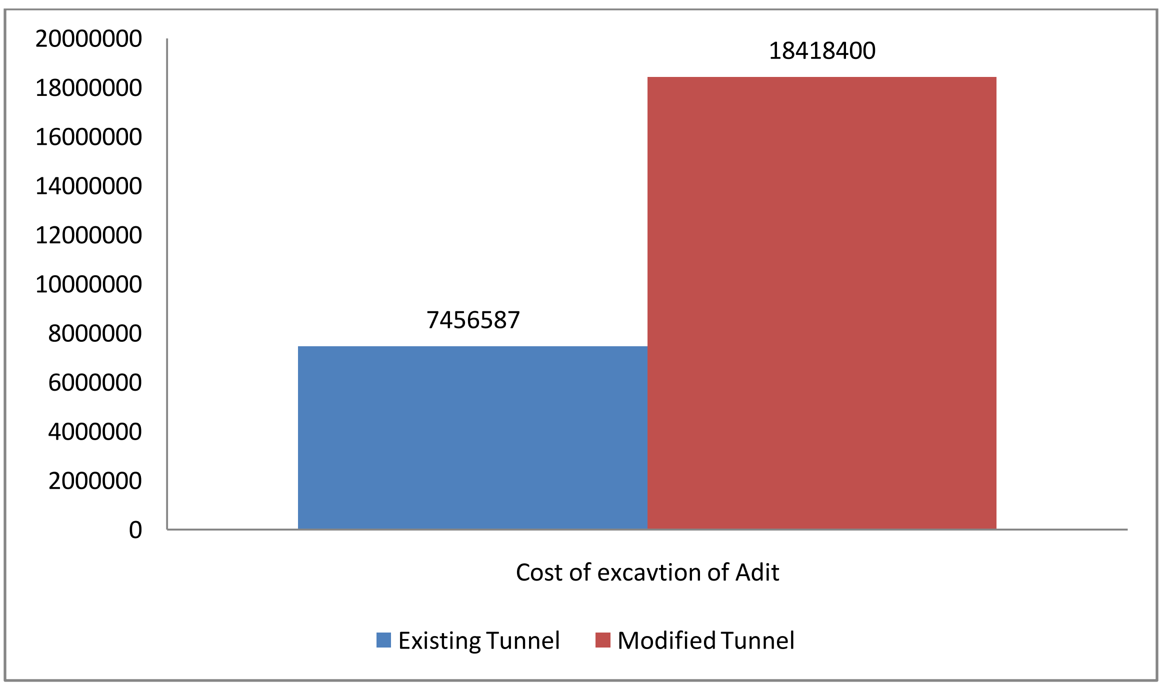

Fig 8.3 Adit cost comparison of the existing and modified tunnel

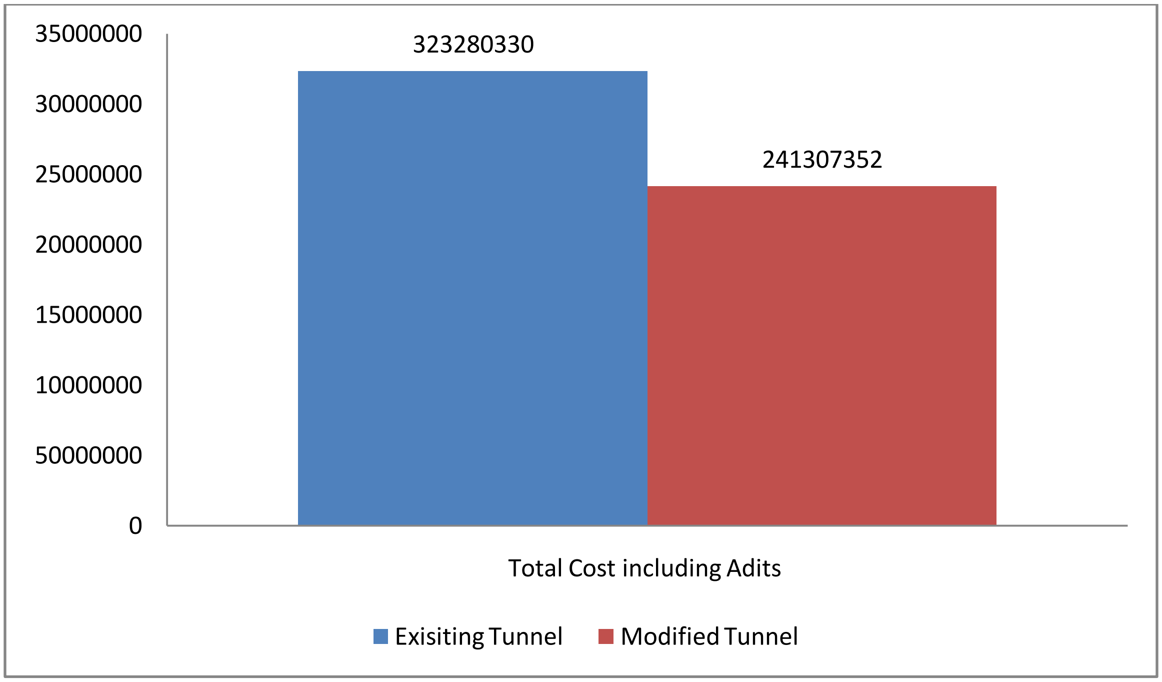

Fig 8.4 Total cost (including adits) comparison of the existing and modified tunnel

8.3 TIME COMPARISON

Time required for excavation of modified tunnel was 2 years, 1 month less than the time required for excavation of existing tunnel. The major reason for this being the increase in number of adits, providing more sites for the excavation work to be done. With 3 adits in the modified tunnel, eight possible locations were provided for the work to progress at a single day in comparison to four such locations in the existing tunnel with one adit.

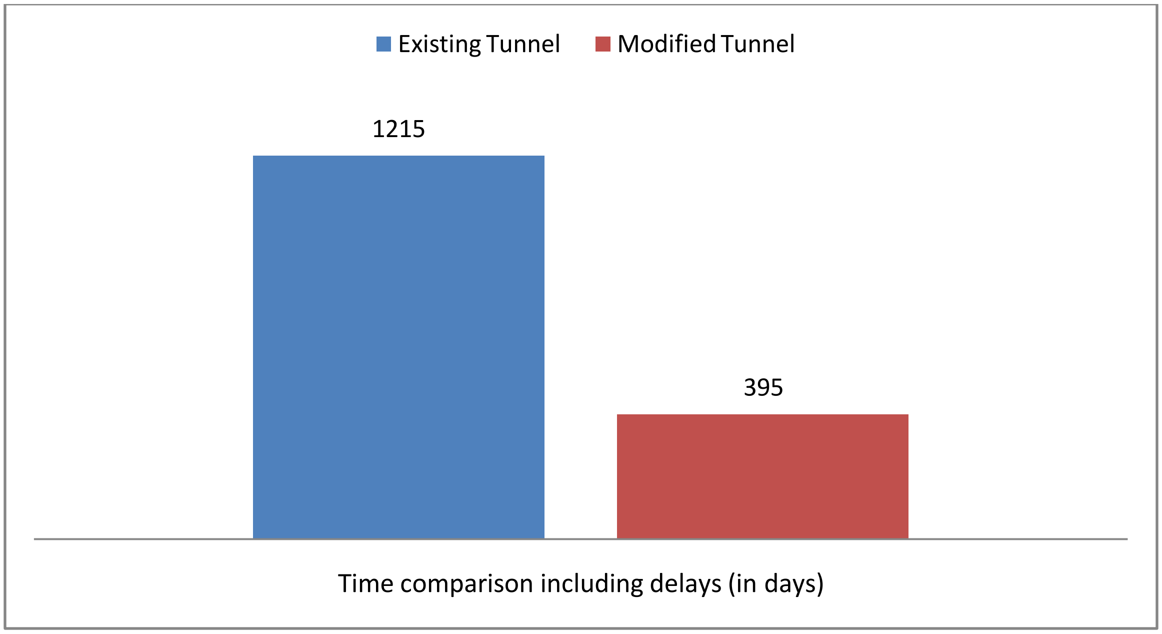

Fig 8.5 Excavation Time comparison of the existing and modified tunnel

8.4 INFERENCES

Proper use of construction management tools can drastically reduce the time and cost of the project. Construction management is not just about management of man, materials and machineries but also the methods, making it management of 4Ms. After proper improvements in the existing tunnel excavation, the budget of the project was reduced by Rs 8,19,72,978 while the project could be completed in 2 years,1 month less than the principles used in the existing excavation module

CHAPTER – 9

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