Scheduling and Cost Estimation of Underground Work in Hydroelectric Project

A Thesis

Submitted in partial fulfilment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

IN

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With specialization in

CONSTRUCTION MANAGEMENT

Under the supervision of

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to

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CERTIFICATE

This is to certify that the work which is being presented in the project title **"Scheduling and Cost Estimation of Undergroun work in Hydroelectric Project"** in partial fulfilment of the requirements for the award of the degree of Master of technology in Civil Engineering with specialization in **"Construction Management"** and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Irshad Ahmad(**Enrollment no. 152601**)** M.Tech Construction Management during a period from **July 2016 to May 2017** under the supervision of **Mr. Santu Kar** Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

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Date: Irshad Ahmad

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ABBREVIATIONS

RHP	Ratle Hydroelectric Project
HE	Hydroelectric Energy
DT	Diversion Tunnel
PS	Pressure Shaft
TRT	Tailrace Tunnel
TBM	Tunnel Boaring Machine

ABSTRACT

The construction of tunnel is important for different purposes. They can be constructed for railways, roadways, pedestrian footways and can be built in hard rock, soft ground, river bed and are also used to convey Hydro electric power, water stream, or as a sewer. The construction of Diversion Tunnel, Pressure Shaft, and Tailrace Tunnel to convey water is considered in this project. To identify different activities and their cycle time is calculated. Scheduling for different activity is carried out with the help of Primavera Software which is shown at result page. Cost Estimation in Diversion Tunnel, Pressure Shaft, and Tailrace Tunnel is also calculated.

Excavation in heading and benching, Rock bolt support work, lining work is considered for cycle time and cost estimation calculation in DT, PS, and TRT. Excavation is carried out by two methods drill and blast method, and by Roadheader. Cost estimation is also carried out by two methods. The comparison of two methods adopted for excavation work and cost estimation has been carried out

Keywords: Heading, Benching, Cycle time, Lining, Rock Bolts, Diversion Tunnel, Pressure Shaft, Tailrace Tunnel.

CHAPTER 1

INTRODUCTION

1.1 General

The proposed Ratle Hydroelectric Project, in Kishtwar tehsil of Doda District of Jammu and Kashmir, is located downstream of the Dulhsti power house which is in advance stage of construction on Chenab river as identified by Central Electricity Authority in their ranking studies. The Chenab River originates at Chandra flows westerly till it meets Bichlari on the right bank and flows continuously up to Akhnoor travels 584 Km and experience total drop of 5430 m. The project envisages harnessing the hydro-power potential of the river from EL 1000 m to EL 887 m. A concrete gravity dam is proposed across the river just downstream of the Ratle village (Latitude 330 14' 50.15" N, Longitude 750 46' 47.17" E) and an underground power house with an installed capacity of 4X140 MW is proposed near Juddi village (Latitude 330 09' 02" N, Longitude 750 45' 00" E) both in Doda District. The scheme will generate 2483.37 GHz in a 90% dependable year and 2614.38 GHz in a 50% dependable year. The tariff from the project at present day cost would be Rs. 1.22/- KWh (Levelised) The nearest rail head to the project site is Jammu which is about 260 km from dam site is 15 Km South West of Kishtwar. Kishtwar is a important tehsil head quarter of Doda district of Jammu Province and is connected to Jammu (and Srinagar) via Batote an important place on Jammu Srinagar National Highway 1A.

Two nos. of Diversion Tunnel has to be constructed in order to divert the Chenab river water flow during Dam construction. Diversion Tunnels are having 11.0 m finished diameter circular shaped with the slope of 1:94 for DT-1 and 1:102 for DT-2. Invert bottom finished levels at Inlet and Outlet portals are EL926 and EL921 respectively for both the tunnels. Construction work for Diversion tunnels has to be carried out from Inlet and Outlet ends. Diversion Tunnel works includes excavation by conventional method like drilling and blasting or by Roadheader or as directed by Engineer In-charge.

Diversion tunnels are common in the construction of dams. When a dam is built, a tunnel is bored in order to divert water away from the dam construction site so that it essentially bypasses it, hence the term diversion tunnel.

1.2 Need of the study of project

1. The need of the study of project is to identify different activities of hydroelectric project construction work in a proper sequence from start to finish work.
2. To be able to have a clear understanding and knowledge of hydroelectric project construction activities in a sequential order.
3. Study of different component in hydroelectric project.

1.3 Objective of the project

1. To find out different activities involved and to prepare construction schedule of different underground structures of the Hydroelectric project using drill blast method and mechanical excavation method.
2. To estimate the cost of underground work in hydroelectric project. The excavation in DT, PS, and TRT as well as estimation of cost has been carried out and their comparison in excavation as well as in cost is done.
3. To compare the excavation method by drill & blast and mechanical excavation as well in their cost.

1.4 Project methodology

The first step of the research consists of gathering information about activities and resources used in tunnelling construction. This is mainly done by means of a literature study. In order to identify the main variables of tunnelling construction a deterministic model is constructed. The deterministic model is used to help to understand the processes involved in tunnelling construction, and identify the model variables for which information needs to be collected data about model parameters, probability distributions of time durations of activities, resources and the relationships between model's parameters are examined.

The last step analysing the results. A sensitivity analysis is carried out on real tunnelling case studies, to identify and analyse the most critical tunnelling variables affecting productivity of tunnelling construction processes. Critical variables are the variables that have major impact on productivity (and cost) of tunnelling construction. On the basis of the results produced, the 'best' excavation method regarding a real tunnelling project is determined also, a comparison will be made between the road header and drill and blast excavation methods. These analyses are done based on productivity (in terms of tunnel advance rate) and cost.

The project methodology described can be graphically represented as shown

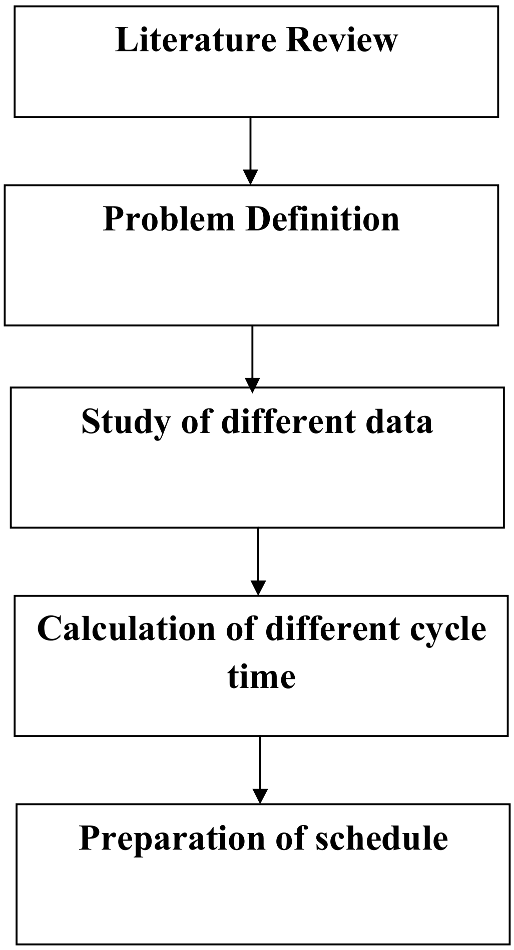


Fig 1.1 Project methodology

CHAPTER 2

LITERATURE REVIEW

2.1 General

From the extensive literature study, it can be observed that the about 26% of energy is contributed by hydropower to India. For India, the total capacity is more than 2 Lakh MW and so holds the 5th position for electricity generation in the world

2.2 Hydro power plants

Hydro power can be classified as: large hydro power, medium hydro power, Small hydro Power. These are classified according to the power generation capacity.

Large hydro power >100 MW

Medium hydro power: 30-100 MW

Small hydro power: 1-30MW

2.3 Mechanism

The water is stored behind a dam. This reservoir is located very high as, "height of a reservoir decide the force of water flowing to the turbine. Since the height increase the potential energy of water at the reservoir also increase. The gate controls the water flowing into the plants. Depending on the load demand the water is allowed into the turbine. The water flowing from the control gate has both potential and kinetic energy. The water flow through to the turbine through the penstock which is designed to transport water from intake to turbine without any cavitations problem. The water further increases in the penstock due to the height. The height of water at the water reservoir and amount of water into the penstock determine the total power generation by a hydro plant. Then water then allowed into the turbine generator unit. The water strikes the blade of the turbine and the potential and kinetic energy of water is converted to the rotational energy which drives the blades of the turbine. The shaft of the turbine which is enclosed inside a generator start to rotate due to the rotating blades. This rotating shaft produces alternating current in the coils of the generator. This rotating shaft inside the generation is responsible for the production of magnetic field which is further converted to the electrical energy by electromagnetic field mechanism. Thus shaft connecting the turbine and generator plays a vital role here. Thus, hydroelectric power plants produce electricity from the energy of water. This electric is the transfer to the grid".

2.4 Processes of tunnel construction

Before a tunnelling construction project can be analysed. It is important to define the tunnelling system. Decisions have to be made, "concerning the modality of excavation (e.g. drill and blast, road-header), the material handling process, and the tunnel support system. In this chapter the various activities related to the tunnelling construction process will be explored. The purpose of this literature study is to get a general overview of the different construction processes involved in tunnelling, and the interaction of the various processes in the context of tunnelling construction.

In the first paragraph the focus will be on the main excavation methods, namely drill and blast, and road-header".

2.5 Excavation methods

At present, "drill and blast and TBM tunnelling can be considered the most common excavation methods used in tunnelling. One of the differences between the use of TBM or drill and blast is that the performance (rate of advance) for drill and blast is lower in most cases. The total labour cost using drill and blast-method is higher, but the investment cost is lower than TBM technology (relatively low capital cost for equipment). According to Girmscheid and Schexnayder, drill and blast technology is cost efficient when the length of the tunnel to be excavated is less than three kilometres. The cost efficiency decreases as tunnel length increases. Comparing both methods there are also other significant differences. Tunnel excavation using TBM requires a predetermined tunnel diameter, which can be excavated accurately. Using drill and blast the cross section can be created to any shape".

2.5.1 Drill and blast method

The drill and blast process is a cyclic operation; each round consists of four successive operations, namely: drill, blast, muck and installation of primary support. The drilling operation consists of, "drilling a series of small blast holes in the tunnel face, by a so called "drill jumbo". The number of holes and location are dependent of the type and condition of the rock, the type of explosive and the blasting technique used. After all the required holes are drilled, they will be loaded with explosives. Once the explosives are loaded in the blast holes, the tunnel face is cleared and the explosives are detonated.

Tunnelling construction involves three main processes, namely excavation, dirt removal and tunnel support. The construction of a tunnel (using TBM) begins with the excavation and liner support of the vertical shaft".

2.5.2 Roadheader

Road-header machines (partial-face tunneling machine) were," initially developed for the coal mining industry, but are increasingly being used in rock tunneling. The machine consists of a rotating cutting head mounted at the end of the boom to a crawler frame. This crawler frame contains a power system, a muck gathering system, and a conveyor that transports the muck to the back of the machine. The muck is then loaded into the muck handling system and hauled out of the tunnel. Road-headers can achieve a better advance rate than the drill and blast-method, but significant lower than the tunnel boring machine. The advantages of this method are similar to the TBM method, such as continuous operation, limited non-productive time, and quality of the tunnel opening.
However, road-headers are more flexible than the tunnel boring machine, because they can be applied to various types, shapes, and sizes of underground excavation Tunneling construction using road-headers involves three main processes, namely: excavation, dirt removal and tunnel support. Excavation is done using road-header for a certain amount of time. In order to start the next process the road-header is pulled back. The removal of dirt from the face of the tunnel can be done by using a conveyor belt, trucks or trains. After

the road-header has excavated for a certain amount of time it gets pulled back, so that scaling and the installation of mechanical bolts can start. Subsequently installation of initial support is done. This operation involves installation of wire mesh or shotcrete at their designed location

The main difference between conventional mechanized drill and blast was given by G.germchied (2002) and TBM tunneling is related to the process cycle and operational continuity. A TBM drive requires a predetermined fixed tunnel diameter. Such a circular profile can be excavated with a high degree of accuracy by the TBM. However, with drill and blast methods the tunnel cross section can be created to any required shape and, most importantly, the tunnel shape can be changed along the length of the drive. The diameter of a circular cross section can be increased or decreased as required, or a circular section can be changed to a horseshoe form when necessary. However, in the most unfavorable drill and blast case, there can be blasting over break amounting to 10–25% of the design cross-sectional area. This material must be removed and the space may possibility have to be refilled. With drill and blast, considerably more temporary ground support work must be undertaken at the face and in the excavation area than is usually the case for a TBM excavation".

2.6 Drilling technology

For achieving the, "required tunnel section and for optimal fragmentation of the rock, accurate drilling is an important prerequisite. Drilling critically impacts blast performance. The drilling cycle includes the positioning of the jumbo, checking that the proper drilling pattern is employed to match the position along the tunnel length station location, positioning the drilling arms booms, and drilling the holes. The latest generation of jumbo drills with two or three booms can attain high production in semi or fully automatic robotic operation. The positioning of the drill jumbo is accomplished manually by means of a tunnel laser, but the drilling pattern for the appropriate location is produced via computer-aided design to the jumbo's process control computer. On the basis of the jumbo positioning data, the on-board computer calculates the positions for the drilling booms and the specific drill pattern horizontal, angle, depth, and spacing. This can all be done in either a semi or fully automatic mode".

2.7 Blast technology

Three factors influence developments in, "tunnel blasting technology safe handling of explosives reduction of accidental detonation risk reduction in toxicity post blast gases, nitrous oxides, and carbon monoxide and rapid and straightforward loading/charging of the bore holes".

2.8 Mucking technology

Mucking denotes the gathering together of, "material from where it has been deposited after the blast. The size of the individual rock fragments and the volume excavated per length of advance are essential criteria for selecting a mucking process. Muck haulage can be undertaken via mucking trains, belt conveyors, or dumpers".

2.9 Tunnel ground support technology

Tunnel rock supports are, "installed in one, two, or three stages depending on the type of tunnel cross section in the face area in the excavation area; and in the rear area. Bolting operations i.e. drilling, placing, and prestressing of the rock bolts are in most cases completely automated. Two types of rock bolting are utilized:

System bolting pattern: This means rock bolts are installed according to a systematical predetermined pattern spacing that depends on the rock support class; and

Local bolting of single fracture blocks: This refers to the means used for holding back and preventing the falling of fractured rock".

CHAPTER

3 WORK DONE

3.1 Equipment required

Two boom drill jumbo, Dumpers, Excavators, Loaders, Shotcrete machine, Concrete pump, Gantry with shutter Hydra crane, Batching plant, Scissor Lift, etc.

3.2 Excavation

3.2.1 Open excavation

This work shall consist of excavation by mechanical means in all types of strata, in rock by blasting or line drilling using pneumatic equipment and expanding agents, chiselling including dressing to final line, level, grades including hauling of excavated materials to site, also disposal of unsuitable cut materials in specified manner.

3.2.2 Job procedure

Rock excavation by blasting includes all solid rock in place which cannot be removed until loosened by blasting, barring or wedging, removal of all boulders or detached pieces of solid rock larger than 1 cum in volume, as well as any existing structural foundation made of concrete or masonry placed in mortar which cannot be removed during common excavation or by ripping.

The blasting operations shall be prepared or made by the competent and experienced personnel and workmen who are thoroughly acquainted with details of handling explosives and blasting operations.

Diameter and spacing of blast holes shall be constantly adapted to the actual site conditions. The charge holes shall be drilled by using jack hammer drill. All the excavated rock shall be removed from the bench toe before the next shot.

If a misfire is due to a defective detonator or dynamite the whole quantity or box from the defective article was taken must be thoroughly inspected.

Blasting shall be carried out in fixed hours as ordered in writing by the Engineer and kept known to the people, public and authorities in the vicinity sufficiently in advance.

Red flags shall be displayed in all directions during blasting operations. People except those who actually light the fuse shall be prohibited from the area and all persons including workmen shall be excluded from the flagged area at least 10 minutes before firing, a warning alarm or siren sounded for this purpose.

3.3 Underground excavation

3.3.1 Job procedure

1. The underground excavation of Diversion Tunnel will be carried out in 2 stages namely Heading: Excavation of top arch shaped area of Diversion Tunnel and providing required support systems
2. Benching: Excavation of bottom area of Diversion Tunnel
3. Drill holes shall be cleaned for dust & rock cutting by air flushing before charging.
4. After charging operation, Mining Engineer/ Shift In-charge along with Engineer In-charge shall note down charge concentration per hole, positioning of delay detonators, and capacity of blasting device in prescribed format.
5. Dewatering of seepage water shall be removed to avoid water logging in the tunnel

3.4 Blasting pattern

Drilling and blasting pattern i.e. the number of holes; depth of holes, quantity, quality and distribution of explosives shall be decided as to suit the rock conditions encountered.

Drilling and Blasting shall be carried out as per the pattern proposed and approved by Engineer In-charge and shall be changed or modified as per the rock conditions encountered.

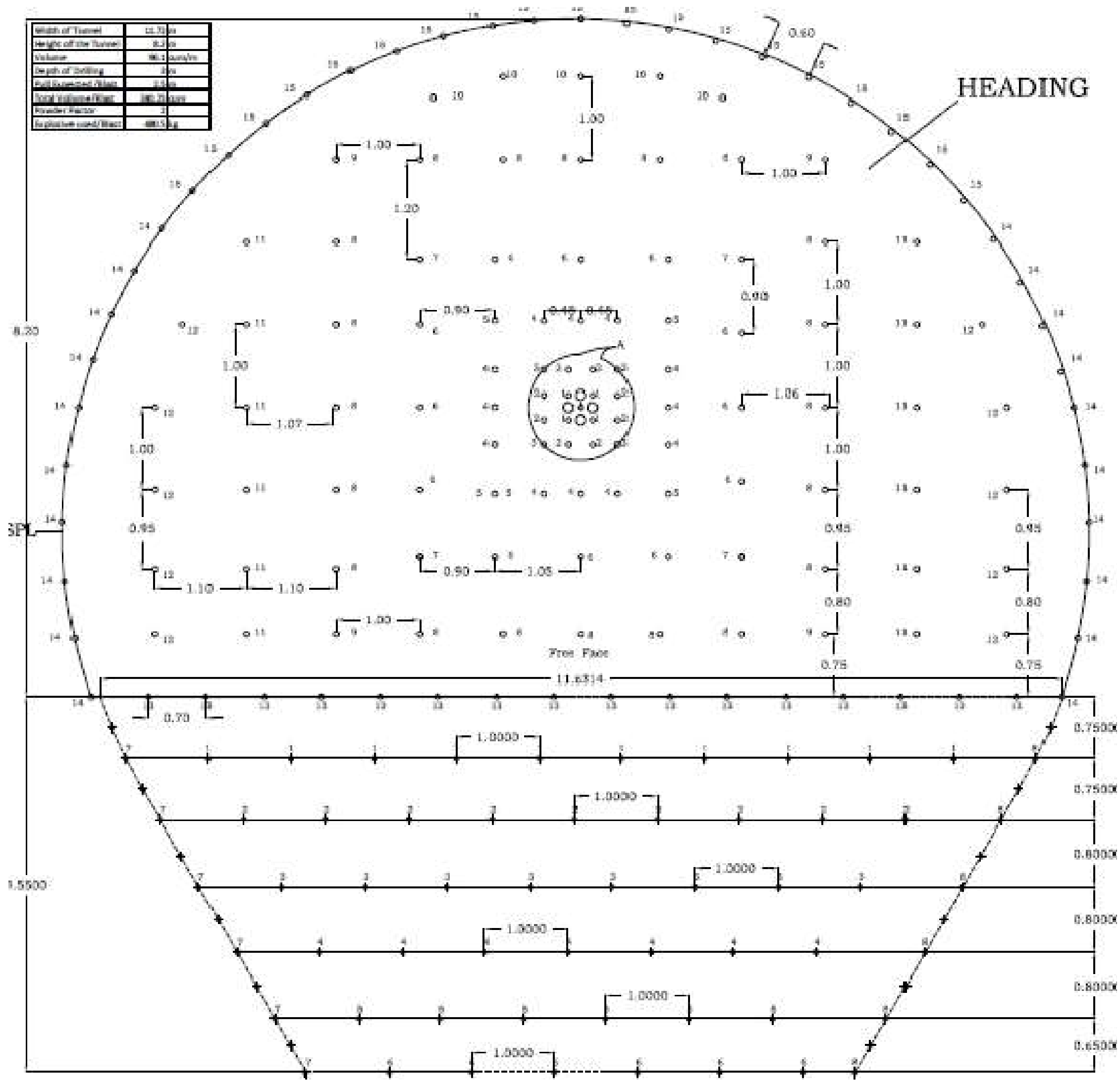


Fig 3.1 Drilling Pattern

Fig 3.2 Charging explosive

Open excavation time at Inlet portal = $\frac{\text{Excavated Quantity}}{\text{Excavator productivity} \times \text{working hour in a day}}$

$= \frac{85764 \text{ m}^3}{50 \text{ m}^3 \text{ per hour} \times 24 \text{ hour}}$

= 55 days

Open excavation time at Outlet portal = $\frac{\text{Excavated Quantity}}{\text{Excavator productivity} \times \text{working hour in a day}}$

$= \frac{40427 \text{ m}^3}{50 \text{ m}^3 \text{ per hour} \times 24 \text{ hour}}$

= 28 days

No. of Dumpers required:

Cycle time of dumpers= (Hauling + Tipping + Turning + Loading)

Loading time = no of bucket required to fill a bucket × time taken by a loader in a single bucket to fill dumper = 7×1.2 = 8.4 minute

Time for hauling = $(\frac{\text{dumping yard distance}}{\text{avg.speed of dumper truck}})$ × time per hour = $(\frac{2\times4}{20})$ ×60min = 24 minute

Turning time= 4 minute

Tipping time = 1 minute

Total cycle time = (8.4+24+4+1) minute = 37.4 min

No. of dumpers required = $\frac{\text{Cycle time}}{\text{Loading time}}$

= $\frac{37.4}{8.4}$ = 4.45 =5 nos. dumper

Table 3.1 Major Quantities

S.N	Description	Location	Quantity	Unit
1	Open Excavation	Inlet Portl	85764	cum
2	Concrete	Inlet Portl	10601	cum
3	Open Excavation	Outlet Portal	40427	cum
4	Concrete	Outlet Portal	152	cum
5	Heading	DT - 1	42042	cum
6	Benching	DT - 1	21595	cum
7	Concrete lining	DT - 1	11798	cum
8	Heading	DT - 2	49134	cum
9	Benching	DT - 2	25237	cum
10	Concrete lining	DT - 2	13635	cum

3.5 Heading in Diversion tunnel

Heading excavation will be carried out by Drilling & Blasting methodology. Heading work will be carried out continuously in a cyclic process along with the supporting work. Types of supporting work will depend on the rock classes encountered.

Sequence of operation in tunnel excavation without rib supporting:

1. Profile marking by surveyor
2. Drilling by Two boom drill jumbo
3. Charging & blasting by professional blaster
4. Mucking by wheel loader and dumpers
5. Scaling/Trimming to the required excavation line
6. Supporting by Steel Fiber Reinforced Shotcrete
7. Fixing of Rock Bolts
8. Extension of ventilation duct

Sequence of operation in tunnel excavation with rib supporting

1. Profile marking by surveyor

2. Drilling by Two boom drill jumbo
3. Charging & blasting by professional blaster
4. Mucking by wheel loader and dumpers
5. Scaling/Trimming to the required excavation line
6. Supporting by Steel Fiber Reinforced Shotcrete
7. Fixing of Rock Bolts
8. Supporting by steel Ribs
9. Precast RCC lagging fixing
10. Back fill concreting
11. Extension ventilation duct

EXCAVATION BY DRILL & BLAST METHOD

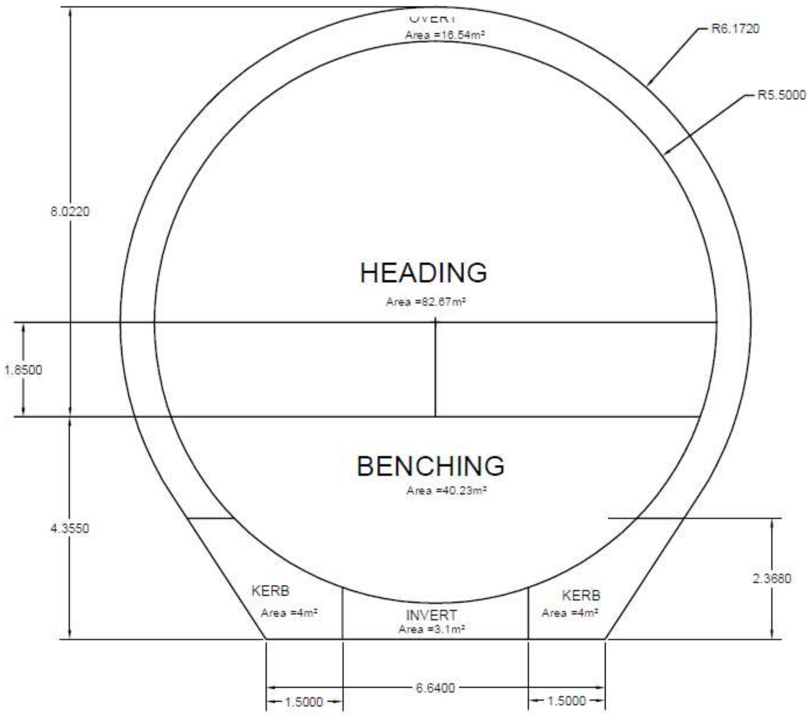


Fig 3.3 Cross-sectional view of Diversion Tunnel

3.6 Cycle time calculation for different activities for heading work of DT by Drill & Blast method

1^{st} Activity: Survey - 0.5 hours

2^{nd}. Activity: Time required for drilling

$= \frac{\text{Tot drilling length}}{\text{length per hour achieved by drilled jumbo}} = \frac{\text{no of drill holes} \times \text{length of each hole}}{\text{length per hour achieved by drilled jumbo}} = \frac{165\times3.2}{100\text{m/hr}}$

= 5.0 hours

3^{rd}. Activity: Charging = 1.0 hour

4^{th}.Activity: Blasting & Defuming = 0.5 hours

5^{th}. Activity: Time required for Mucking = $\frac{\text{Mucking Quantity}}{\text{productivity of loader}}$

Excavated quantity = c/s area of tunnel × length of drill = $(\frac{\pi\times d^2}{4})$×length of drill

$= \frac{\pi\times8.0225^2}{4} \times 3 = 151.6458\ \boldsymbol{m^3}$

Mucking quantity = 151.6458 × 1.2 (20 % as over-break quantity)

= $182.0m^3$ (mucking quantity will be more than the excavated quantity because there wil be some voids in the quantity)

Time required for mucking quantity = $\frac{\text{Mucking quantity}}{\text{Productivity of loader}} = \frac{182\ m^3}{65m^3}$ per hour = 3.0 hour

6^{th}. Activity: Scaling time – 1.0 hours

7^{th}. Activity: Time required for shotcreting = $\frac{\text{Quantityty of shotcrete}}{\text{productivity of shotcret machine}}$

Quantity of shotcrete = Circumference of tunnel × thickness of shotcrete × length per cycle

1. For Good Rock Shotcreting (5 cm) = 2πr×5cm×3m

   = 2π×4.01125×0.05×3

   = 3.7805 m^3×(1.1) (10% as rebound)

= 4.1585 m^3

Time required for shotcreting = $\frac{\text{quantity of shotcrete}}{\text{productivity of shotcrete machine}} = \frac{4.1585m^3}{6m^3\ per\ hour}$ = 0.5 hour

2. For Fair Rock Shotcreting (10 cm) = 2π×4.01125×0.1×3

= 7.5610 m^3 ×(1.1) (10% as rebound)

=8.3171m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete machine}} = \frac{8.3171\text{m}^3}{6\text{m}^3\text{ per hour}}$ = 1.0 hour

3. For Poor Rock Shotcreting (15 cm) = 2π×4.01125×0.15×3

= 11.4315 m^3 ×(1.1) (10% as rebound)

= 12.4756m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete machine}} = \frac{12.4756\text{m}^3}{6\text{m}^3\text{ per hour}}$ = 2.0 hour

4. For Very Poor Rock Shotcreting (20 cm) = 2π×4.01125×0.2×3

= 15.1220 m^3 ×(1.1) (10% as rebound)

=16.6342m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete machine}} = \frac{16.634\quad ^3}{6\text{m}^3\text{ per hour}}$ = 2.5 hour

8th. Activity: Rock bolt drilling & fixing Time :

1. For Good & Fair Rock:

Circumference of circle = 2πr

= $(\frac{2\pi r}{distance\ of\ two\ rock\ bolt} + 1) \times 2 = (\frac{2\times\pi\times4.011}{2.3} + 1)\times2$

= 24 no. in 3m stretch of tunnel

Total drilling length of Rock bolt= Total nos. of rock bolt × length of each rock bolt

= 24×3m = 72 m

Time required for drilling = $\frac{\text{total drilling leng}}{\text{productivity of drill jumbo}} = \frac{\text{72m}}{\text{100m per hour}}$ = 1.0 hour

Time required for fixing & grouting = (no. of rock bolt) × (time required for each rock bolt)

= 24× 3min = 72 min = 1.0 hours

Total rock bolt drilling fixing time = (1+1) hour = 2.0 hour

2. For Poor & Very Poor Rock:

Circumference of circle = $2\pi r$

$$= \left(\frac{2\pi r}{distance\ of\ two\ rock\ bolt} + 1\right) \times 2 = \left(\frac{2\times\pi\times4.011}{1.7} + 1\right)\times2$$

= 32 no. in 3m stretch of tunnel

Total drilling length of Rock bolt= Total nos. of rock bolt × length of each rock bolt

= 32×3m = 96 m

Time required for drilling = $\frac{\text{total drilling length}}{\text{productivity of drill jumbo}} = \frac{\text{96m}}{\text{100m per hour}}$ = 1.5 hours

Time required for fixing & grouting = (no. of rock bolt) × (time required for each rock bolt)

= 32 × 3min = 96 minute = 1.5 hours

Total rock bolt drilling fixing time = (1.5+1.5) hour = 3.0 hour

3.7 Cycle time for heading in Diversion tunnel

3m pull length per cycle to be considered for heading without rib and 1.5 m pull length to be considered for heading with rib.

3.7.1 Cycle time for heading without rib support in DT

Excavation without rib support is considered as 90% of total excavation in Diversion tunnels.

Table 3.2 Cycle time for heading without rib support in DT

S.N	Description	Quantity	Units
1	Pull length	3	m
2	Heading c/s area	82.67	sqm
3	Excavation	248.01	cum
4	Survey	0.5	Hours
5	Drilling	5	Hours
6	Chrging	1	Hours
7	Blasting&defuming	1	Hours
8	Mucking	3	Hours
9	Scaling	1	Hours
11	shotcreting	1	Hours
12	Rockbolt drilling & fixing	2	Hours
	Total cycle time for 3m pull length	14.5	Hours

3.7.2 Cycle time for heading with rib support in DT

Excavation with rib support is considered as 10 % of total excavation in Diversion tunnels.

Table 3.3 Cycle time for heading with rib support in DT

S.N	Description	Quantity	Units
1	Pull Length	1.5	m
2	Heading c/s area	82.67	sqm
3	Excavation	124.005	cum
4	Survey	0.5	Hours
5	Drilling	5	Hours
6	Charging	1	Hours
7	Blasting&defuming	1	Hours
8	Mucking	3	Hours
9	Scaling	1	Hours
10	Shotcreting	2.5	Hours
11	Rockbolt drilling & fixing	3	Hours
12	Rib erection	3	Hours
13	Lagging fixing	3	Hours
14	Stopper fixing&Back fill concrete	4	Hours
	Total cycle time per 1.5m pull length	**27**	Hours
	Total cycle time per 3m pull length	54	Hours

Time Schedule:

Among the total excavation 90 % is considered as without rib support and 10 % as with rib support.

Weighted average cycle time = (14.5 × 0.9) + (54×0.1) = 18.45 hours per 3m pull length

Progress per month = $\frac{26(\text{working day per month})\times 22(\text{working hours per day})\times 3\text{m}(\text{pull length})}{18.45\ (\text{weighted cycle time in hours})}$

= 93 m per month

Time required for completion of heading work = $\frac{\text{Length of Diversion tunnel}-1}{\text{Work progress per month}}$ = $\frac{472}{93\text{ m per month}}$

= 5.0 month = 150 Days

Time required for completion of heading work = $\frac{\text{Length of Diversion tunnel}-2}{\text{Work progress per month}}$ = $\frac{552}{93\text{ m per month}}$

= 6.0 month = 180 Days

3.8 Benching in Diversion tunnel

Benching work will be started on completion of heading work. It will be carried out continuously in a cyclic process using Drilling & Blasting method. Sequences of works are same as mentioned in “Heading” except that no Rock Bolt support is required in Benching work and supporting works are required in both side faces.

3.9 Cycle time calculation for benching in Diversion tunnels by Drill & Blast method

1st. Activity: Surveying time – 0.5 hours

2nd. Activity: Drilling time

$= \frac{\text{Total drilling length}}{\text{length per hour achieved by drilled jumbo}} = \frac{(\text{no of drill holes})\times(\text{length of each hole})}{\text{length per hour achieved by drill jumbo}} = \frac{81\times 3.2}{100}$

= 2.5 hour

3rd.Activity: Charging time = 0.5 hour

4th. Activity: Blasting & Defuming = 0.5 hours

5th. Activity: Mucking time = $\frac{\text{Mucking quantity}}{\text{productivity of loader}}$

Mucking quantity = C/S area of tunnel × length of drill

= $(\frac{\pi\times d^2}{4})$×drill length = $(\frac{\pi\times 4.3225^2}{4})$ ×3m = 41.4690 m^3

Mucking Qty = 41.4690 × 1.2 (20 % as over-break quantity)

= 52.8277m^3 (mucking qty will be more than the excavated quantity because there will be some voids in the quantity)

Time required for mucking quantity= $\frac{\text{Mucking quantity}}{\text{Productivity of loader}} = \frac{52.8277\ m^3}{65m^3}$ per hour = 1.0 hour

6th. Activity: Scaling time = 0.5 hour

7th.Activity: Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcret machine}}$

Quantity of shotcrete = Circumference of tunnel × thickness of shotcrete × length per cycle

1. For Good Rock Shotcreting (5 cm) = 2πr×5cm×3m = 2π×2.16125×0.05×3

   = 2.0369 m^3×(1.1) (10% as rebound)

   = 2.2406 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete machine}} = \frac{2.2406m^3}{6m^3\ per\ hour}$ = 0.5 hours

2. For Fair Rock Shotcreting (10 cm) = 2π×2.16125×0.1×3

   = 4.0738 m^3 ×(1.1) (10% as rebound)

   = 4.4812m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete machine}} = \frac{4.4812\text{m}^3}{6\text{m}^3\text{ per hour}}$ = 0.5 hours

3. For Poor Rock Shotcreting (15 cm) = 2π×2.16125×0.15×3

   = 6.1107 m^3 ×(1.1) (10% as rebound)

   = 6.7218m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete machine}} = \frac{6.7218\text{m}^3}{6\text{m}^3\text{ per hour}}$ = 1.0 hour

4. For Very Poor Rock Shotcreting (20 cm) = $2\pi \times 2.16125 \times 0.2 \times 3$

= 8.1477 m^3 ×(1.1) (10% as rebound)

= $8.9624 m^3$

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete machine}} = \frac{8.9624\text{m}^3}{6\text{m}^3 \text{ per hour}}$ = 1.5 hours

3.9.1 Cycle time for benching without rib support in DT

Table 3.4 Cycle time for benching without rib support in DT

S.N	Description	Quantity	Units
1	Pull Length	3	m
2	Benching c/s area	40.23	sqm
3	Excavation	120.69	cum
4	Survey	0.5	Hours
5	Drilling	2.5	Hours
6	Charging	0.5	Hours
7	Blasting&defuming	0.5	Hours
8	Mucking	1	Hours
9	Scaling	0.5	Hours
11	Shotcreting	0.5	Hours
12	Total cycle time for 3m pull length	6	Hours

3.9.2 Cycle time for benching with rib support in DT

Table 3.5 Cycle time for benching in DT with rib support

S.N	Description	Quantity	Units
1	Pull length	1.5	m
2	Benching c/s area	40.23	sqm
3	Excavation	60.435	cum
4	Survey	0.5	Hours
5	Drilling	2.5	Hours
6	Chrging	0.5	Hours
7	Blasting&defuming	0.5	Hours
8	Mucking	1	Hours
9	Scaling	0.5	Hours
10	Shotcreting	1.5	Hours
11	Rib erection	2	Hours
12	Lagging fixing	**1**	Hours
13	Backfill concreting	**1**	Hours
	Total cycle time for 1.5m pull length	11	Hours
	Total cycle time for 3m pull length	22	Hours

Time Schedule:

Weighted average cycle time = (6.0×0.9) + (22×0.1) = 8.50 hours per 3m pull

Progress per month = $\frac{(26(\text{working day per month}) \times 22(\text{working hours per day}) \times 3\text{m pull length})}{8.50(\text{weighted average cycle time in hours})}$

= 202 m per month

Time required for Completion of benching work = $\frac{\text{Tunnel length} - 1}{\text{progress per month}}$

= $\frac{472}{202}$ = 2.33 month= 70 days

Time required for Completion of benching work = $\frac{\text{Tunnel length} - 2}{\text{progress per month}}$

= $\frac{552}{202}$ = 2.73 month= 82 days

3.10 Rock support work in Diversion tunnels

Rock support works in the tunnel shall be provided as given in the construction drawings in accordance to the rock classification given by the geologists and as per the directions of Engineer in Charge. The Rock Supports are classified depending upon the amount of hindrance it poses for the advancement of excavation work. The details of support system for each class of excavation are given below

For excavation in Good, Fair and Poor rock, support work shall consist of a Shotcrete layer of 5 cm, 10 cm and 15 cm thick respectively, sprayed in layers, followed by fixing of rock bolts. This shall consist of 25mm diameter, 4 m for Good and Fair Rock and 5.0 meter long rock bolts for Poor Rock to be fixed in staggered manner as mentioned in approved drawings.

For excavation in Very Poor rock, support work shall consist of a shotcrete layer of 20 cm thick, sprayed. The spacing of rock bolt support, in case of good & fair rock is 2.30 m and in the case of poor & very poor rock 1.70 m.

Fig 3.4 Rock Bolt supporting

3.11 Concrete lining in Diversion tunnel

Concrete lining of tunnel will be taken up when the Heading and Benching excavation of the Diversion tunnel will be completed. Concrete lining for overt will be carried out using 15 m gantry equipped with 2 shutters and 1 traveller. The concrete lining of Diversion tunnel will commence from Inlet end.

Concrete lining of the tunnel will be carried out in three stages:

1. Kerb Lining
2. Invert Lining
3. Overt Lining

3.11.1 Cycle time in kerb lining in Diversion tunnel

1. Surface cleaning should be done before Kerb concreting.
2. Kerb concreting will commence parallel to benching excavation with 1 month lag.
3. Kerb shutters with requisite anchoring in the rock will be used for kerb concreting.

Kerb lining area = 4.0 m^2

Concrete quantity in 15 m length = 2×4 m^2×15m =120m^3

The rate of concrete for 2 agitator truck with 50 min per hour working: 3.5m^3per hour

Time for placing the concrete = $\frac{concrete\ Quantity}{concrete\ quantity\ in\ one\ truck \times working\ hour} = \frac{120m^3}{3.5 \times 22} = 1.5$ hours

Shutter panel- 1 (15m length):

Table 3.6 Shutter panel - 1 in Kerb lining in DT

S.N	Description	Quantity	Units
1	Kerb shutter	1.5	Hours
2	Shutter alignment	1	Hours
3	Concreting	1.5	Hours
4	Concrete setting	20	Hours
5	De- shuttering	1	Hours
6	Miscellaneous	1.5	Hours
	Total cycle time for 15m panel	26.5	Hours

Shutter panel – 2 (15m length):

Table 3.7 Shutter panel – 2 in Kerb lining in DT

S.N	Description	Quantity	Units
1	Kerb shutter	1.5	Hours
2	Shutter alignment	1	Hours
3	Concreting	1.5	Hours
4	Concrete setting	20	Hours
5	De- shuttering	1	Hours
6	Miscellaneous	1.5	Hours
	Total cycle time for 15m panel	26.5	Hours

Time Schedule:

Cycle time for 30m Kerb lining = 53 Hours

Progress per month =

$$= \frac{26(\text{working day per month}) \times 22(\text{working hours per day}) \times 30\text{m (length of lining in cycle)}}{53(\text{weighted average cycle time in hours})}$$

= 323.77 m per month

Kerb lining time = $\frac{\text{Length of the tunnel}-1}{\text{working progress per month}} = \frac{472\text{m}}{323.77\text{ m per month}}$ = 1.5 month

= 45 days

Kerb lining time = $\frac{\text{Length of the tunnel}-1}{\text{working progress per month}} = \frac{552\text{m}}{323.77\text{ m per month}}$ = 1.7 month

= 52 days

3.11.2 Cycle time in invert lining in Diversion tunnel

1. Invert lining will be done using the invert template.
2. It will be carried out parallel to the overt concreting with a time lag of 1 month.

Invert lining area = 3.1 m^2

Concrete quantity in 15 m length = 3.1 m^2×15m =46.5m^3

The rate of concrete for 2 agitator truck with 50 min per hour working: 3.5m^3per hour

Time for placing the concrete = $\frac{concrete\ Quantity}{concrete\ quantity\ in\ one\ truck \times working\ hour} = \frac{46.5m^3}{3.5 \times 22} = 0.5$ hours

Table 3.8 Shutter panel – 1 in Invert lining in DT

S.N	Description	Quantity	Hours
1	Invert template	1.5	Hours
2	Invert template alignment	1	Hours
3	Concreting	0.5	Hours
4	Concrete setting	20	Hours
5	De-shuttering	1	Hours
6	Miscellaneous	2	Hours
	Total cycle time for 15m panel	26	Hours

Table 3.9 Shutter panel – 2 in Invert lining in DT

S.N	Description	Quantity	Hours
1	Invert template	1.5	Hours
2	Invert template alignment	1	Hours
3	Concreting	0.5	Hours
4	Concrete setting	20	Hours
5	De-shuttering	1	Hours
6	Miscellaneous	2	Hours
	Total cycle time for 15m panel	26	Hours

Time Schedule:

Cycle time for 30m Invert concreting = 52 Hours

Progress per month =

$$\frac{26(\text{working day per month}) \times 22(\text{working hours per day}) \times 30\text{m (length of lining in cycle)}}{52(\text{weighted average cycle time in hours})}$$

= 330 m per month

Invert lining time = $\frac{\text{Length of the tunnel}-1}{\text{working progress per month}} = \frac{472\text{m}}{330\text{m per month}}$ = 1.5 month = 45 days

Invert lining time = $\frac{\text{Length of the tunnel}-2}{\text{working progress per month}} = \frac{552\text{m}}{330\text{m per month}}$ = 1.67 month = 50 days

3.11.3 Cycle time for overt lining in Diversion tunnel

1. Overt lining will be carried out using gantry with traveller.
2. Gantry will be erected after completion of benching excavation.
3. After Gantry erection, overt lining will commence.
4. Traveller will be moving on rails fixed on kerb concrete.
5. Shutter will be fixed to the kerb concrete to avoid uplifting due to concreting.
6. Shutter will be properly aligned by adjusting hydraulic jacks.
7. Pneumatic vibrator will be used for regular distribution and compactness.
8. Concreting in the 2nd shutter position will be carried out parallel to the concrete setting in 1st shutter position and will continue in the cyclic manner.

Fig 3.5 Overt Lining

Shutter panel -1 (15 m length):

Overt lining area = 16.54 m^2

Concrete quantity in 15 m length = 16.54 m^2×15m = 248.1m^3

The rate of concrete for 2 agitator truck with 50 min per hour working: 3.5m^3per hour

Time for placing the concrete = $\frac{concrete\ Quantity}{concrete\ quantity\ in\ one\ truck \times working\ hour} = \frac{248.1m^3}{3.5\times22} = 3.5$ hours

Table 3.10 Shutter panel -1 in Overt Lining in DT

S.N	Description	Quantity	Units
1	Rail fixing	2	Hours
2	Shutter shifting	3	Hours
3	Shutter alignment	3	Hours
4	Bulk had fixing	2	Hours
5	Concreting	3.5	Hours
6	Concrete setting	20	Hours
7	De- shuttering	2	Hours
8	Miscellaneous	3	Hours
	Total cycle time for 15m panel	**38.5**	Hours

Table 3.11 Shutter panel -2 in overt lining in DT

S.N	Description	Quantity	Units
1	Rail fixing	2	Hours
2	Shutter shifting	3	Hours
3	Shutter alignment	3	Hours
4	Bulk had fixing	2	Hours
5	Concreting	3.5	Hours
6	Concrete setting	20	Hours
7	De- shuttering	2	Hours
8	Miscellaneous	3	Hours
	Total cycle time for 15m panel	**38.5**	Hours

Time Schedule:

Cycle time for 30m Overt lining = 77 Hours

Progress per month =

$$\frac{26(\text{working day per month}) \times 22(\text{working hours per day}) \times 30\text{m (length of lining in cycle)}}{77(\text{weighted average cycle time in hours})}$$

= 222 m per month

Overt lining time = $\frac{\text{Length of the tunnel}-1}{\text{working progress per month}} = \frac{472\text{m}}{222 \quad \text{per month}}$ = 2 month = 60 days

Overt lining time = $\frac{\text{Length of the tunnel}-2}{\text{working progress per month}} = \frac{552\text{m}}{222\text{m per month}}$ = 2.5 month = 75 days

Table 3.12 Length of DT- 1 in different rock conditions

Diversion Tunnel-1 (472 m)					
		Good(15%)	Fair(60%)	Poor(15%)	V.Poor(10%)
		70.8 m	283.2 m	70.8 m	47.2 m
	Inlet	35.4 m	141.6 m	35.4 m	23.6 m
	Outlet	35.4 m	141.6 m	35.4 m	23.6 m

Time duration for different rock conditions:

Table 3.13 Time Duration in DT - 1

Activity	Source	Good	Fair	Poor	V.Poor	Total days
Heading	Inlet	11	45	11	8	75
Heading	Outlet	11	45	11	8	75
Benching	Inlet	5	21	5	3	34
Benching	Outlet	5	21	5	3	34
Invert lining	Inlet	3	13	3	2	21
Invert lining	Outlet	3	13	3	2	21
Kerb lining	Inlet	3	13	3	3	22
Kerb lining	Outlet	3	13	3	3	22
Overt lining	Inlet	15	19	15	3	52
Overt lining	Outlet	15	19	15	3	52

Length in DT- 2 for different rock conditions:

Table 3.14 Length of DT – 2

Diversion Tunnel -2 (552 m)					
	Source	Good(15%)	Fair(60%)	Poor(15%)	V.Poor(10%
		82.8 m	331.2 m	82.8 m	55.2 m
	Inlet	41.4 m	165.6 m	41.4 m	27.6 m
	Outlet	41.4 m	165.6 m	41.4 m	27.6 m

Time duration for different rock conditions:

Table 3.15 Time duration in DT- 2

Activity	Source	Good	Fair	Poor	V.Poor	Total Days
Heading	Inlet	14	55	14	9	88
Heading	Outlet	14	55	14	9	88
Benching	Inlet	6	24	6	4	40
Benching	Outlet	6	24	6	4	40
Invert lining	Inlet	4	15	4	2	25
Invert lining	Outlet	4	15	4	2	25
Kerb lining	Inlet	4	15	4	2	25
Kerb lining	Outlet	4	15	4	2	25
Overt lining	Inlet	5	23	5	4	37
Overt lining	Outlet	5	23	5	4	37

Table 3.16 Activities duration for Diversion Tunnel

RHP - DT		Classic WBS Layout					28-Apr-17 18:47
Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
RHP - DT		223	223	0%	15-May-17	22-Nov-17	0
A1000	Mobilisation	30	30	0%	15-May-17	08-Jun-17	0
DT Portal		55	55	0%	08-Jun-17	26-Jul-17	0
A1020	Dt portal outlet	28	28	0%	08-Jun-17	03-Jul-17	9
A1130	Dt portal inlet	55	55	0%	08-Jun-17	26-Jul-17	0
DIVERSION TUNNEL 1		169	169	0%	21-Jun-17	14-Nov-17	9
A1030	Heading Inlet	75	75	0%	21-Jun-17	24-Aug-17	9
A1080	Heading outlet	75	75	0%	21-Jun-17	24-Aug-17	9
A1040	Benching Inlet	34	34	0%	24-Aug-17	22-Sep-17	9
A1090	Benching outlet	34	34	0%	24-Aug-17	22-Sep-17	9
A1060	Kerb inlet	22	22	0%	12-Sep-17	29-Sep-17	9
A1110	kerb outlet	22	22	0%	12-Sep-17	29-Sep-17	9
A1070	Overt inlet	52	52	0%	29-Sep-17	14-Nov-17	9
A1120	overt outlet	52	52	0%	29-Sep-17	14-Nov-17	9
A1050	Invert Inlet	21	21	0%	18-Oct-17	03-Nov-17	20
A1100	Invert Outlet	21	21	0%	18-Oct-17	03-Nov-17	20
DIVERSION TUNNEL 2		178	178	0%	21-Jun-17	22-Nov-17	0
A1170	Heading Inlet	88	88	0%	21-Jun-17	05-Sep-17	0
A1220	Heading outlet	88	88	0%	03-Jul-17	15-Sep-17	55
A1230	Benching outlet	40	40	0%	20-Jul-17	23-Aug-17	55
A1250	kerb outlet	25	25	0%	07-Aug-17	28-Aug-17	55
A1260	overt outlet	37	37	0%	28-Aug-17	28-Sep-17	55
A1180	Benching Inlet	40	40	0%	05-Sep-17	10-Oct-17	0
A1240	Invert Outlet	25	25	0%	14-Sep-17	05-Oct-17	55
A1200	Kerb inlet	25	25	0%	22-Sep-17	13-Oct-17	0
A1210	Overt inlet	37	37	0%	13-Oct-17	15-Nov-17	0
A1190	Invert Inlet	25	25	0%	31-Oct-17	22-Nov-17	0

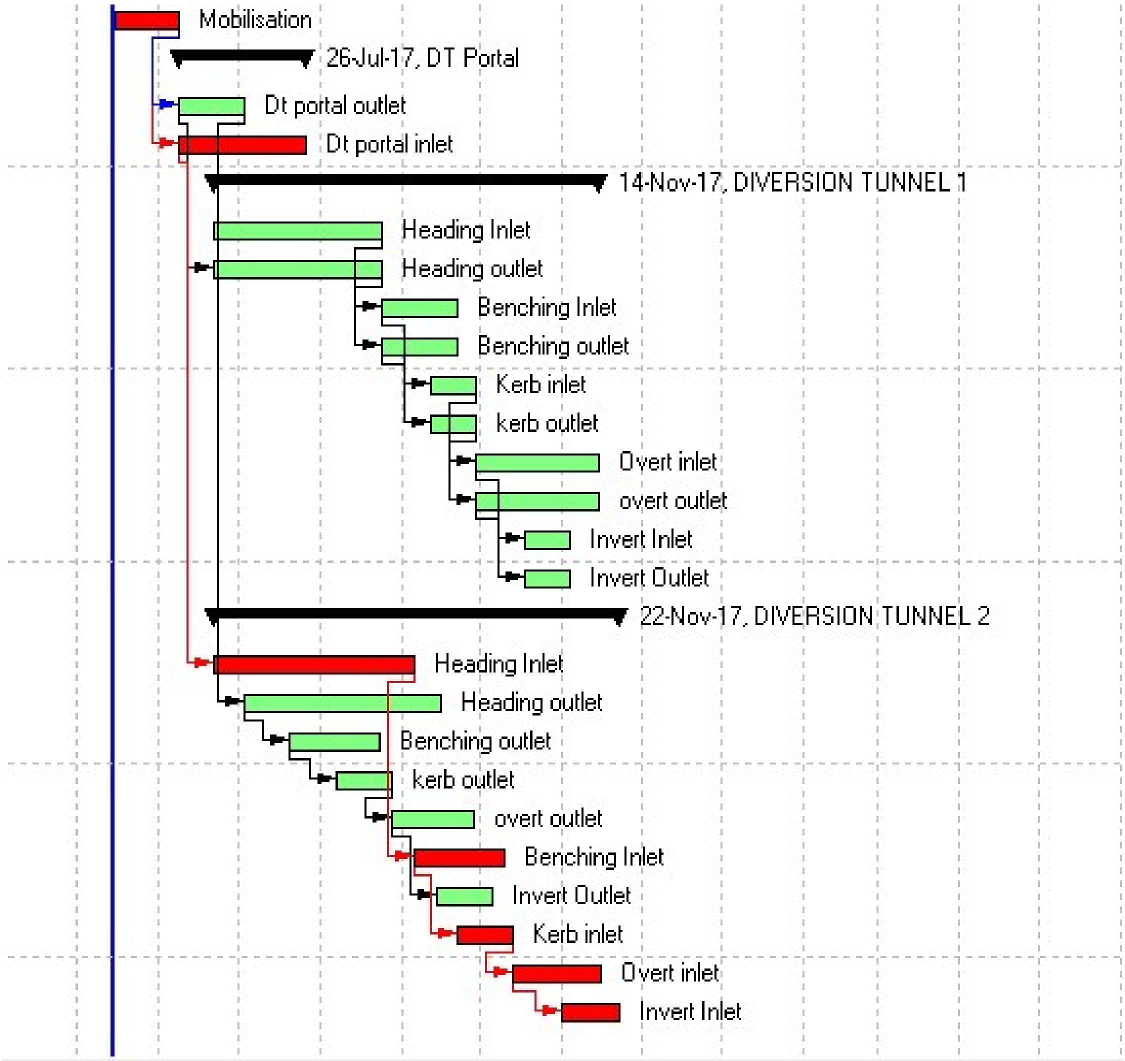


Fig 3.6 Network diagram of Diversion Tunnel in case of Drill & Blast method

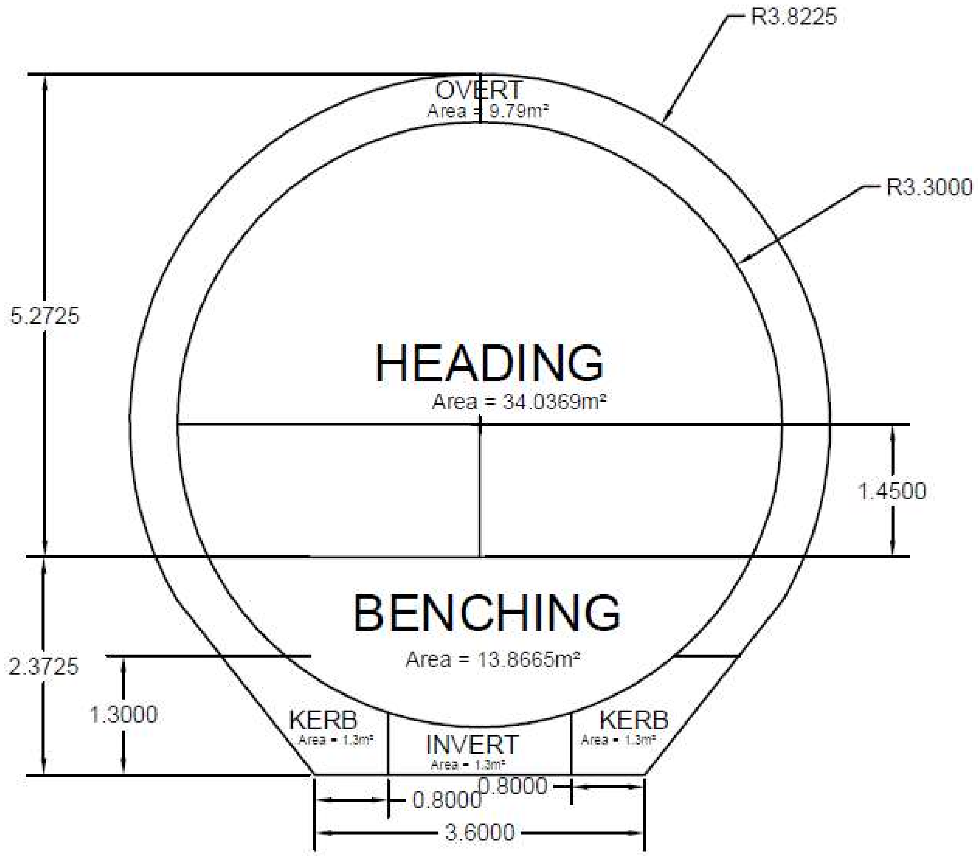


Fig 3.7 Cross-sectional view of Pressure shaft

3.12 Cycle time calculation for different activities for heading work of Pressure shaft by Drill & Blast method

1st Activity: Survey - 0.5 hours

2nd. Activity: Time required for drilling

$$= \frac{\text{Total drilling length}}{\text{length per hour achieved by drilled jumbo}} = \frac{\text{no of holes} \times \text{length of each hole}}{\text{length per hour achieved by drilled jumbo}} = \frac{68 \times 3.2}{100\text{m/hr}}$$

= 2.0 hours

3rd. Activity: Charging = 0.5 hour

4th.Activity: Blasting & Defuming = 0.5 hours

5th. Activity: Time required for Mucking = $\frac{\text{Mucking Quantity}}{\text{productivity of loader}}$

Mucking quantity = Cross-sectionl area of tunnel×length of drill = $(\frac{\pi \times d^2}{4})$×length of drill

$= \frac{\pi \times 5.2725^2}{4} \times 3 = 65.5004\ \boldsymbol{m^3}$

= Mucking Quantity = 65.5004 × 1.2 (20 % as over-break quantity)

= 78.6005m^3 (mucking quantity will be more than the excavated quantity because there wil be some voids in the quantity)

Time required for mucking quantity = $\frac{\text{Mucking Quantity}}{\text{Productivity of loader}} = \frac{78.6005\ m^3}{65m^3}$ per hour = 1.5 hour

6th. Activity: Scaling time – 0.5 hours

7th. Activity: Time required for shotcreting = $\frac{\text{Quantityty of shotcrete}}{\text{productivity of shotcret machine}}$

Quantity of shotcrete = Circumference of tunnel × thickness of shotcrete × length per cycle

1. For Good Rock Shotcreting (5 cm) = 2πr×5cm×3m

 = 2π×2.6362×0.05×3

 = 2.4845 m^3× (1.1) (10% as rebound)

 = 2.7330 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{2.7330\ m^3}{6m^3\ per\ hour}$ = 0.5 hour

2. For Fair Rock Shotcreting (10 cm) = 2π×2.6362×0.1×3

 = 4.9691 m^3 ×(1.1) (10% as rebound)

 = 5.4660 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{5.4660\ \text{m}^3}{6\text{m}^3\ \text{per hour}}$ = 1.0 hour

3. For Poor Rock Shotcreting (15 cm) = 2π×2.6362×0.15×3

 = 7.4536 m^3 ×(1.1) (10% as rebound)

 = 8.1990 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{8.1990\text{m}^3}{6\text{m}^3\ \text{per hour}}$ = 1.5 hour

4. For Very Poor Rock Shotcreting (20 cm) = 2π×2.6362×0.2×3

$= 9.9382\ m^3 \times(1.1)$ (10% as rebound)

$= 10.9320\ m^3$

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{10.9320\text{m}^3}{6\text{m}^3 \text{ per hour}}$ = 2.0 hour

8th. Activity: **Rock bolt drilling & fixing:**

1. **For Good & Fair Rock:**

Circumference of circle = 2πr

$= (\frac{2\pi r}{distance\ of\ two\ rock\ bolt} + 1) \times 2 = (\frac{2\times\pi\times2.6362}{2.3} + 1)\times2$

= 17 no. in 3m stretch of tunnel

Total drilling length of Rock bolt= Total nos. of rock bolt × length of each rock bolt

= 17×3m = 51 m

Time required for drilling = $\frac{\text{total drilling length}}{\text{productivity of drill jumbo}} = \frac{51\text{ m}}{100\text{m per hour}}$ = 0.5 hour

Time required for fixing & grouting = (no. of rock bolt) × (time required for each rock bolt)

= 17× 3min = 51 minute = 1.0 hours

Total rock bolt drilling fixing time = (0.5+1) hour = 1.5 hour

2. **For Poor & V. Poor Rock:**

Circumference of circle = 2πr

$= (\frac{2\pi r}{distance\ of\ two\ rock\ bolt} + 1) \times 2 = (\frac{2\times\pi\times2.6362}{1.7} + 1)\times2$

= 22 no. in 3m stretch of tunnel

Total drilling length of Rock bolt= Total nos. of rock bolt × length of each rock bolt

= 22×3m = 66 m

Time required for drilling = $\frac{\text{total drilling length}}{\text{productivity of drill jumbo}} = \frac{66\text{ m}}{100\text{m per hour}}$ = 0.5 hours

Time required for fixing & grouting = (no. of rock bolt) × (time required for each rock bolt)

= 22 × 3min = 66 minute = 1.0 hours

Total rock bolt drilling fixing time = (0.5+1.0) hour = 1.5 hour

3.13 Cycle time for heading in Pressure shaft

3m pull length per cycle to be considered for heading without rib support and 1.5 m pull length to be considered for heading with rib support.

3.13.1 Cycle time for heading without rib support in Pressure shaft

Excavation without rib support is considered as 90% of total excavation in Pressure shaft.

Table 3.17 Cycle time for heading without rib support in PS

S.N	Description	Quantity	Units
1	Pull length	3	m
2	Heading c/s area	34.0369	sqm
3	Excavation	102.11	cum
4	Survey	0.5	Hours
5	Drilling	2	Hours
6	Chrging	0.5	Hours
7	Blasting&defuming	0.5	Hours
8	Mucking	1	Hours
9	Scaling	0.5	Hours
10	shotcreting	1	Hours
11	Rockbolt drilling & fixing	1.5	Hours
	Total cycle time for 3m pull length	7.5	Hours

3.13.2 Cycle time for heading with rib support in Pressure shaft

Excavation with rib support is considered as 10 % of total excavation in Pressure Shaft.

Table 3.18 Cycle time for heading with rib support in PS

S.N	Description	Quantity	Units
1	Pull Length	1.5	m
2	Heading c/s area	34.0369	sum
3	Excavation	51.05	cum
4	Survey	0.5	Hours
5	Drilling	2	Hours
6	Charging	0.5	Hours
7	Blasting&defuming	0.5	Hours
8	Mucking	1.5	Hours
9	Scaling	0.5	Hours
10	Shotcreting	2	Hours
11	Rockbolt drilling & fixing	1.5	Hours
12	Rib erection	2	Hours
13	Lagging fixing	2.5	Hours
14	Stopper fixing&Back fill concrete	2.5	Hours
	Total cycle time per 1.5m pull length	**16**	Hours
	Total cycle time per 3m pull length	32	Hours

Time Schedule:

Among the total excavation 90 % is considered as without rib supporting and 10 % as with rib supporting

Weighted average cycle time = (7.5 × 0.9) + (32×0.1) = 10.0 hours per 3m pull length

Progress per month = $\frac{(26(\text{working day per month}) \times 22(\text{working hours per day}) \times 3\text{m pull length})}{10.0\ (\text{weighted cycle time in hours})}$

= 171.6m per month

Time required for completion of heading work = $\frac{\text{Length of Pressure Shaft}}{\text{Work progress per month}}$

$= \frac{(211+197+184+172=764\text{ m})}{(171.6\text{ m per month})}$ = 4.5 month = 135 days

3.14 Cycle time calculation for different activities for benching work in Pressure shaft by Drill & Blast method

1st. Activity: Surveying time – 0.5 hours

2nt. Activity: Drilling time

$= \frac{\text{Total drilling length}}{\text{length per hour achieved by drilled jumbo}} = \frac{(\text{no of drill holes}) \times (\text{length of each hole})}{\text{length per hour achieved by drill jumbo}} = \frac{28\times3.2}{100}$

= 1.0 hour

3rd.Activity: Charging time = 0.5 hour

4th. Activity: Blasting & Defuming = 0.5 hours

5th. Activity: Mucking time = $\frac{\text{Mucking quantity}}{\text{productivity of loader}}$

Mucking quantity = Cross-sectional area of tunnel × length of drill

= $(\frac{\pi \times d^2}{4})$×drill length = $(\frac{\pi \times 2.3725^2}{4})$ ×3 m = 13.2624 m^3

Mucking quantity = 13.2624 × 1.2 (20 % as over-break quantity)

= 15.9149 m^3 (mucking quantity will be more than the excavated quantity because there wil be some voids in the quantity)

Time required for mucking quantity= $\frac{\text{Mucking quantity}}{\text{Productivity of loader}} = \frac{15.9149\ m^3}{65 m^3}$ per hour = 0.5 hour

6th. Activity: Scaling time = 0.5 hour

7th.Activity: Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcret machine}}$

Quantity of shotcrete = Circumference of tunnel × thickness of shotcrete × length per cycle

1. For Good Rock Shotcreting (5 cm) = 2πr×5cm×3m

   = 2π×1.1862×0.05×3

   = 1.1179 m^3× (1.1) (10% as rebound)

   = 1.2297 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{1.2297 m^3}{6 m^3\ per\ hour}$ = 0.5 hours

2. For Fair Rock Shotcreting (10 cm) = 2π×1.1862×0.1×3

   = 2.2359 m^3 ×(1.1) (10% as rebound)

   = 2.4595 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{2.4595\ \text{m}^3}{6\text{m}^3\ \text{per hour}}$ = 0.5 hours

3. For Poor Rock Shotcreting (15 cm) = 2π×1.1862×0.15×3

= 3.3539 m^3 ×(1.1) (10% as rebound)

= 3.6892 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{3.6892\ \text{m}^3}{6\text{m}^3\ \text{per hour}}$ = 0.5 hour

4. For Very Poor Rock Shotcreting (20 cm) = 2π×1.1862×0.2×3

= 4.718 m^3 ×(1.1) (10% as rebound)

= 4.9190 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{4.9190\ \text{m}^3}{6\text{m}^3\ \text{per hour}}$ = 1.0 hours

3.15 Cycle time for benching without rib support in Pressure shaft

Table 3.19 Cycle time for benching without rib support in PS

S.N	Description	Quantity	Units
1	Pull Length	3	m
2	Benching c/s area	13.8665	sqm
3	Excavation	41.5995	cum
4	Survey	0.5	Hours
5	Drilling	1	Hours
6	Charging	0.5	Hours
7	Blasting&defuming	0.5	Hours
8	Mucking	0.5	Hours
9	Scaling	0.5	Hours
10	Shotcreting	**0.5**	Hours
11	Total cycle time for 3m pull length	4	Hours

3.15.1 Cycle time for benching with rib support in Pressure shaft

Table 3.20 Cycle time for benching with rib support in PS

S.N	Description	Quantity	Units
1	Pull length	1.5	m
2	Benching c/s area	13.8665	sqm
3	Excavation	20.79	cum
4	Survey	0.5	Hours
5	Drilling	1	Hours
6	Charging	0.5	Hours
7	Blasting&defuming	0.5	Hours
8	Mucking	0.5	Hours
9	Scaling	0.5	Hours
11	Shotcreting	1	Hours
12	Rib erection	2	Hours
13	Lagging fixing	**1**	Hours
14	Backfill concreting	**1**	Hours
	Total cycle time for 1.5m pull length	8.5	Hours
	Total cycle time for 3m pull length	17	Hours

Time Schedule:

Among the total excavation 90 % is considered as without rib supporting and 10 % as with rib supporting

Weighted average cycle time = (4.0 × 0.9) + (17×0.1) = 5.3 hours per 3m pull length

Progress per month = $\frac{26(\text{working day per month})\times 22(\text{working hours per day})\times 3\text{m(pull length)}}{5.3m^3\ /hour}$

= 323 m per month

Time required for completion of Benching work = $\frac{\text{Length of Pressure Shaft}}{\text{Work progress per month}}$

= $\frac{(211+197+184+17\ \ )}{(323\text{ m per month})}$

= 2.5 month = 75 days

3.16 Cycle time in kerb lining in Pressure shaft:

Kerb lining area = 1.3 m^2

Concrete quantity in 15 m length = 2×1.3 m^2×15m =39 m^3

The rate of concrete for 2 agitator truck with 50 min per hour working: 3.5m^3per hour

Time for placing the concrete = $\frac{concrete\ Quantity}{concrete\ quantity\ in\ one\ truck \times working\ hou} = \frac{39\ m^3}{3.5\times 22}$ = 0.5 hours

Shutter panel – 1 (15 m length):

Table 3.21 Cycle time in kerb lining in Shutter panel – 1 in PS

S.N	Description	Quantity	Units
1	Kerb shutter	1	Hours
2	Shutter alignment	1	Hours
3	Concreting	0.5	Hours
4	Concrete setting	20	Hours
5	De- shuttering	1	Hours
6	Miscellaneous	1.5	Hours
	Total cycle time for 15m panel	25	Hours

Shutter panel – 2 (15 m length):

Table 3.22 Cycle time in kerb lining in Shutter panel – 2 in PS

S.N	Description	Quantity	Units
1	Kerb shutter	1	Hours
2	Shutter alignment	1	Hours
3	Concreting	0.5	Hours
4	Concrete setting	20	Hours
5	De- shuttering	1	Hours
6	Miscellaneous	1.5	Hours
	Total cycle time for 15m panel	25	Hours

Time Schedule:

Cycle time for 30m Kerb concreting = 50 Hours

Progress per month = $\frac{26(\text{working day per month}) \times 22(\text{working hours per day}) \times 30\text{m (length of lining in cycle)}}{50(\text{weighted average cycle time in hours})}$

= 343.5 m per month

Kerb lining time = $\frac{\text{Length of the pressure shaft}}{\text{working progress per month}} = \frac{(211+197+184+172)\text{m}}{343.5\text{m per month}}$ = 2.5 month = 75 day

3.17 Cycle time in invert lining in Pressure shaft

Invert lining area = 1.3 m^2

Concrete quantity in 15 m length = 1.3 m^2×15m =19.5m^3

The rate of concrete for 2 agitator truck with 50 min per hour working: 3.5m^3per hour

Time for placing the concrete = $\frac{concrete\ Quantity}{concrete\ quantity\ in\ one\ truck \times working\ hour} = \frac{19.5m^3}{3.5\times22} = 0.5$ hours

Shutter panel – 1 (15m length):

Table 3.23 Cycle time in invert lining for shutter panel – 1 in PS

S.N	Description	Quantity	Hours
1	Invert template	1.5	Hours
2	Invert template alignment	1	Hours
3	Concreting	0.5	Hours
4	Concrete setting	20	Hours
5	De-shuttering	1	Hours
6	Miscellaneous	2	Hours
	Total cycle time for 15m panel	26	Hours

Shutter panel – 2 (15m length):

Table 3.24 Cycle time in invert lining for shutter panel – 2 in PS

S.N	Description	Quantity	Hours
1	Invert template	1.5	Hours
2	Invert template alignment	1	Hours
3	Concreting	0.5	Hours
4	Concrete setting	20	Hours
5	De-shuttering	1	Hours
6	Miscellaneous	2	Hours
	Total cycle time for 15m panel	26	Hours

Time Schedule:

Cycle time for 30m Invert lining = 52 Hours

Progress per month = $\frac{26(\text{working day per month}) \times 22(\text{working hours per day}) \times 30\text{m (length of lining in cycle)}}{52(\text{weighted average cycle time in hours})}$

= 330 m per month

Invert lining time = $\frac{\text{Length of the tunnel}-1}{\text{working progress per month}} = \frac{(211+197+184+\quad)\text{m}}{330\text{m per month}}$ = 2.5 month = 75 days

3.18 Cycle time in invert lining in Pressure shaft

Overt lining area = 9.79 m^2

Concrete quantity in 15 m length = 9.79 m^2×15m = 146.5 m^3

The rate of concrete for 2 agitator truck with 50 min per hour working: 3.5m^3per hour

Time for placing the concrete = $\frac{concrete\ Quantity}{concrete\ quantity\ in\ one\ truck \times working\ hour} = \frac{146.5\ m^3}{3.5\times22}$ = 2.0 hours

Shutter panel – 1(15m length):

Table 3.25 Cycle time in overt lining for shutter panel – 1 in PS

S.N	Description	Quantity	Units
1	Rail fixing	2	Hours
2	Shutter shifting	3	Hours
3	Shutter alignment	3	Hours
4	Bulk had fixing	2	Hours
5	Concreting	2	Hours
6	Concrete setting	20	Hours
7	De- shuttering	2	Hours
8	Miscellaneous	3	Hours
	Total cycle time for 15m pannel	**37**	Hours

Shutter panel – 2 (15m length):

Table 3.26 Cycle time in overt lining for shutter panel – 2 in PS

S.N	Description	Quantity	Units
1	Rail fixing	2	Hours
2	Shutter shifting	3	Hours
3	Shutter alignment	3	Hours
4	Bulk had fixing	2	Hours
5	Concreting	2	Hours
6	Concrete setting	20	Hours
7	De- shuttering	2	Hours
8	Miscellaneous	3	Hours
	Total cycle time for 15m pannel	**37**	Hours

Time Schedule:

Cycle time for 30m Overt lining = 74 Hours

Progress per month = $\frac{26(\text{working day per month}) \times 22(\text{working hours per day}) \times 30\text{m (length of lining in cycle)}}{74(\text{weighted average cycle time in hours})}$

= 232 m per month

Overt lining time = $\frac{\text{Length of the pressure shaft}}{\text{working progress per month}} = \frac{(211+197+184+172)\text{m}}{232\text{m per month}}$ = 3.29 month = 100 days

Length in Pressure Shaft for different rock conditions:

Table 3.27 Length in Pressure Shaft for different rock conditions

	Good Rock(15%)	Fair Rock(60%)	Poor Rock(15%)	V.Poor Rock(10%)
Pressure Shaft -1 211 m - Length	31.65 m	126.6 m	31.65 m	21.1 m
Pressure Shaft -2 197 m - Length	29.55 m	118.2 m	29.55 m	19.7 m
Pressure Shaft -3 184 m - Length	27.6 m	110.4 m	27.6 m	18.4 m
Pressure Shaft -4 172 m - Length	25.8 m	103.2 m	25.8 m	17.2 m

Table 3.28 Duration in Days for different rock conditions in PS – 1

Pressure Shaft - 1	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	6	23	6	4	39
Benching	3	12	3	2	20
Kerb	8	11	8	2	29
Overt	8	11	8	2	29
Invert	8	16	8	3	35

Table 3.29 Duration in Days for different rock conditions in PS – 2

Pressure Shaft - 2	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	5	22	5	4	33
Benching	3	11	3	2	19
Kerb	2	11	2	1	16
Overt	2	11	2	1	16
Invert	4	15	4	2	25

Table 3.30 Duration in Days for different rock conditions in PS – 3

Pressure Shaft -3	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	2	20	2	1	25
Benching	2	11	2	1	16
Kerb	2	10	2	1	15
Overt	2	10	2	1	15
Invert	4	14	4	2	24

Table 3.31 Duration in Days for different rock conditions in PS – 4

Pressure Shaft -4	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	4	19	4	3	30
Benching	2	10	2	1	15
Kerb	2	9	2	1	14
Overt	2	9	2	1	14
Invert	3	13	3	2	21

Table 3.32 Activities details of Pressure shaft for Drill & Blast method

RHP- PS		Classic WBS Layout					28-Apr-17 18:49
Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
RHP- PS		137	137	0%	15-May-17	08-Sep-17	0
ps1		137	137	0%	15-May-17	08-Sep-17	0
A1030	Heading	39	39	0%	15-May-17	15-Jun-17	0
A1040	Benching	20	20	0%	16-Jun-17	04-Jul-17	0
A1060	Kerb	29	29	0%	04-Jul-17	28-Jul-17	0
A1070	Overt	35	35	0%	28-Jul-17	28-Aug-17	0
A1050	Invert	29	29	0%	15-Aug-17	08-Sep-17	0
ps2		113	113	0%	15-May-17	18-Aug-17	24
A11	Heading	36	36	0%	15-May-17	14-Jun-17	24
A11	Benching	19	19	0%	14-Jun-17	29-Jun-17	24
A12	Kerb	16	16	0%	30-Jun-17	14-Jul-17	24
A12	Overt	25	25	0%	14-Jul-17	04-Aug-17	24
A11	Invert	16	16	0%	04-Aug-17	18-Aug-17	24
ps-3		98	98	0%	15-May-17	07-Aug-17	39
A	Heading	24	24	0%	15-May-17	02-Jun-17	36
A	kerb	15	15	0%	15-May-17	26-May-17	87
A	overt	24	24	0%	26-May-17	15-Jun-17	87
A	Invert	15	15	0%	13-Jun-17	26-Jun-17	87
A	Benching	16	16	0%	14-Jun-17	27-Jun-17	24
ps4		98	98	0%	15-May-17	07-Aug-17	39
	Heading	30	30	0%	15-May-17	08-Jun-17	39
	Benching	15	15	0%	08-Jun-17	21-Jun-17	39
	kerb	14	14	0%	26-Jun-17	07-Jul-17	39
	overt	21	21	0%	07-Jul-17	26-Jul-17	39
	Invert	14	14	0%	25-Jul-17	07-Aug-17	39

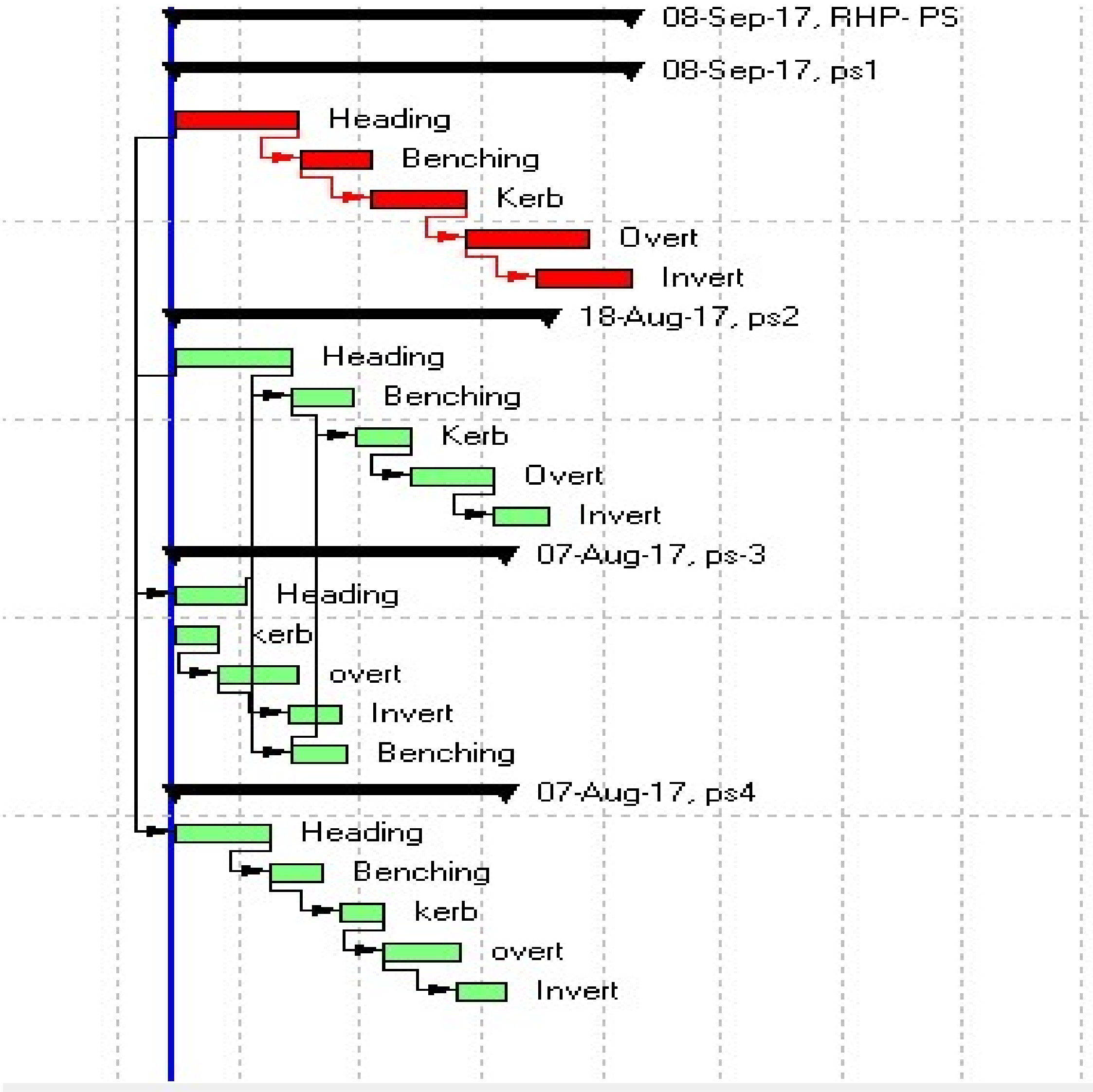


Fig 3.8 Network diagram of Pressure shaft in case of Drill & Blast method

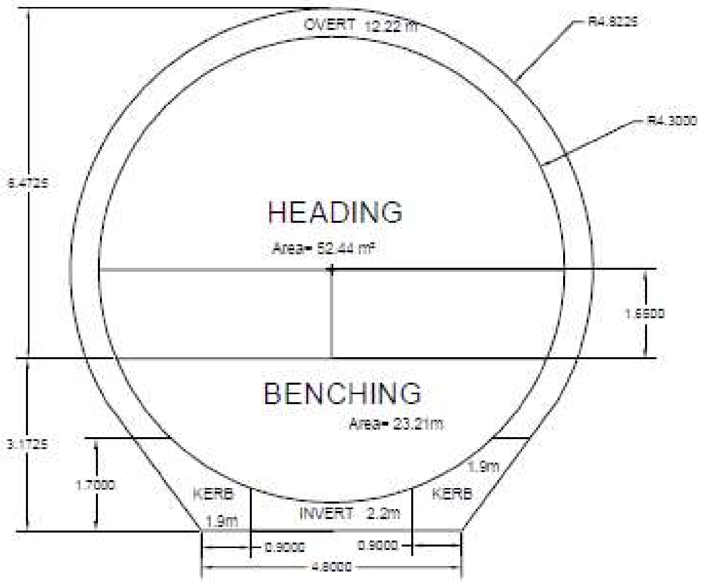


Fig 3.9 Cross-sectional view of Tailrace Tunnel

3.19 Cycle time calculation for different activities for heading work of Tailrace tunnel by Drill & Blast method

1st Activity: Survey - 0.5 hours

2nd. Activity: Time required for drilling

$= \frac{\text{Total drilling length}}{\text{length per hour achieved by drilled jumbo}} = \frac{\text{no of holes} \times \text{length of each hole}}{\text{length per hour achieved by drilled jumbo}} = \frac{105 \times 3.2}{100\text{m/hr}}$

= 3.5 hours

3rd. Activity: Charging = 0.5 hour

4th.Activity: Blasting & Defuming = 0.5 hours

5th. Activity: Time required for Mucking = $\frac{\text{Mucking Quantity}}{\text{productivity of loader}}$

Excavated quantity = $\frac{\text{C/S area of tunnel}}{\text{length of drill}} = (\frac{\pi \times d^2}{4}) \times$length of drill

$= \frac{\pi \times 6.4725^2}{4} \times 3 = 98.7086\ \boldsymbol{m^3}$

= Mucking Quantity = 98.7086 × 1.2 (20 % as over-break quantity)

= 118.4503 m^3 (mucking quantity will be more than the excavated quantity because there wil be some voids in the quantity)

Time required for mucking quantity = $\frac{\text{Mucking Qty}}{\text{Productivity of loader}} = \frac{118.4503\ m^3}{65m^3}$ per hour = 2.0 hour

6^{th}. Activity: Scaling time – 0.5 hours

7^{th}. Activity: Time required for shotcreting = $\frac{\text{Quantityty of shotcrete}}{\text{productivity of shotcret machine}}$

Quantityty of shotcrete = Circumference of tunnel × thickness of shotcrete × length per cycle

1. For Good Rock Shotcreting (5 cm) = 2πr×5cm×3m

   = 2π×3.2362×0.05×3

   = 3.05 m^3×(1.1) (10% as rebound)

   = 3.3550 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{3.3550\ m^3}{6m^3\ per\ hour}$ = 0.5 hour

2. For Fair Rock Shotcreting (10 cm) = 2π×3.2362×0.1×3

   = 6.1000 m^3 ×(1.1) (10% as rebound)

   = 6.7101 m^3

Time required for shotcreting = $\frac{\text{Qty of shotcrete}}{\text{productivity of shotcrete}} = \frac{6.7101\ \text{m}^3}{6\text{m}^3 \text{ per hour}}$ = 1.0 hour

3. For Poor Rock Shotcreting (15 cm) = 2π×3.2362×0.15×3

   = 9.1501 m^3 ×(1.1) (10% as rebound)

   = 10.0651 m^3

Time required for shotcreting = $\frac{\text{Qty of shotcrete}}{\text{productivity of shotcrete}} = \frac{10.0651\ \text{m}^3}{6\text{m}^3 \text{ per hour}}$ = 1.5 hour

4. For Very Poor Rock Shotcreting (20 cm) = 2π×3.2362×0.2×3

   = 9.9382 m^3 ×(1.1) (10% as rebound)

   = 12.2001 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{12.2001\ \text{m}^3}{6\text{m}^3 \text{ per hour}}$ = 2.0 hour

8th. Activity: **Rock bolt drilling & fixing:**

1. **For Good & Fair Rock:**

Circumference of circle = 2πr

$= (\frac{2\pi r}{distance\ of\ two\ rock\ bolt} + 1) \times 2 = (\frac{2\times\pi\times3.2362}{2.3} + 1)\times2$

= 20 no. in 3m stretch of tunnel

Total drilling length of Rock bolt= Total nos. of rock bolt × length of each rock bolt

= 20×3m = 60 m

Time required for drilling = $\frac{\text{total drilling length}}{\text{productivity of drill jumbo}} = \frac{\text{60 m}}{\text{100 per hour}}$ = 0.5 hour

Time required for fixing & grouting = (no. of rock bolt) × (time required for each rock bolt)

= 20× 3min = 60 minute = 1.0 hours

Total rock bolt drilling fixing time = (0.5+1) hour = 1.5 hour

2. **For Poor & Very Poor Rock:**

Circumference of circle = 2πr

$= (\frac{2\pi r}{distance\ of\ two\ rock\ bolt} + 1) \times 2 = (\frac{2\times\pi\times3.2362}{1.7} + 1)\times2$

= 26 no. in 3m stretch of tunnel

Total drilling length of Rock bolt= Total nos. of rock bolt × length of each rock bolt

= 26×3m = 78 m

Time required for drilling = $\frac{\text{total drilling length}}{\text{productivity of drill jumbo}} = \frac{\text{78 m}}{\text{100m per hour}}$ = 1.0 hours

Time required for fixing & grouting = (no. of rock bolt) × (time required for each rock bolt)

= 26 × 3min = 78 minute = 1.0 hours

Total rock bolt drilling fixing time = (1.0+1.0) hour = 2.0 hour

3.20 Cycle time for heading in Tailrace tunnel

3m pull length per cycle to be considered for heading without rib and 1.5 m pull length to be considered for heading with rib

3.20.1 Cycle time for heading without rib support of Tailrace tunnel

Table 3.33 cycle time for heading without rib support of TRT

S.N	Description	Quantity	Units
1	Pull length	3	m
2	Heading c/s area	52.44	sqm
3	Excavation	157.32	cum
4	Survey	0.5	Hours
5	Drilling	3.5	Hours
6	Charging	0.5	Hours
7	Blasting&defuming	0.5	Hours
8	Mucking	2	Hours
9	Scaling	0.5	Hours
10	shotcreting	1	Hours
11	Rockbolt drilling & fixing	1.5	Hours
	Total cycle time for 3m pull length	10	Hours

3.20.2 Cycle time for heading with rib support of Tailrace tunnel

Table 3.34 Cycle time for heading with rib support of TRT

S.N	Description	Quantity	Units
1	Pull Length	1.5	m
2	Heading c/s area	52.44	sum
3	Excavation	78.66	cum
4	Survey	0.5	Hours
5	Drilling	3.5	Hours
6	Charging	0.5	Hours
7	Blasting&defuming	0.5	Hours
8	Mucking	2	Hours
9	Scaling	0.5	Hours
10	Shotcreting	2	Hours
11	Rockbolt drilling & fixing	2	Hours
12	Rib erection	2.5	Hours
13	Lagging fixing	2	Hours
14	Stopper fixing&Back fill concrete	3	Hours
	Total cycle time per 1.5m pull length	**19**	Hours
	Total cycle time per 3m pull length	38	Hours

Time Schedule:

Among the total excavation 90 % is considered as without rib supporting and 10 % as with rib supporting

Weighted average cycle time = (10.0 × 0.9) + (38×0.1) = 13 hours per 3m pull length

Progress per month = $\frac{(26(\text{working day per month}) \times 22(\text{working hours per day}) \times 3\text{m pull length})}{13.0(\text{weighted cycle time in hours})}$

= 132 m per month

Time required for completion of Heading work = $\frac{\text{Length of Tail Race Tunnel}}{\text{Work progress per month}}$

= $\frac{(502+490+475+460)\text{ m}}{(132\text{ m per month})}$

= 14.5 month = 435 days

3.21 Cycle time calculation for benching of Tailrace tunnel by Drill & Blast method

1st. Activity: Surveying time – 0.5 hours

2nt. Activity: Drilling time

$= \frac{\text{Total drilling length}}{\text{length per hour achieved by drilled jumbo}} = \frac{(\text{no of drill holes}) \times (\text{length of each hole})}{\text{length per hour achieved by drill jumbo}} = \frac{47\times3.2}{100}$

= 1.5 hour

3rd.Activity: Charging time = 0.5 hour

4th. Activity: Blasting & Defuming = 0.5 hours

5th. Activity: Mucking time = $\frac{\text{Mucking quantity}}{\text{productivity of loader}}$

Mucking quantity = C/S area of tunnel × length of drill

= $(\frac{\pi\times d^2}{4})$×drill length = $(\frac{\pi\times 3.1735^2}{4})$ ×3 m = 23.7294 m^3

Mucking quantity = 23.7294 × 1.2 (20 % as over-break quantity)

= 28.4753 m^3 (mucking qty will be more than the excavated quantity because there wil be some voids in the quantity)

Time required for mucking quantity= $\frac{\text{Mucking quantity}}{\text{Productivity of loader}} = \frac{28.4753\ m^3}{65m^3}$ per hour = 0.5 hour

6th. Activity: Scaling time = 0.5 hour

7th.Activity: Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcret machine}}$

Quantityty of shotcrete = Circumference of tunnel × thickness of shotcrete × length per cycle

1. For Good Rock Shotcreting (5 cm) = 2πr×5cm×3m

   = 2π×1.5862×0.05×3

   = 1.4949 m^3× (1.1) (10% as rebound)

   = 1.6444 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{1.6444\ m^3}{6m^3\ per\ hour}$ = 0.5 hours

2. For Fair Rock Shotcreting (10 cm) = 2π×1.5862×0.1×3

= 2.9899 m^3 ×(1.1) (10% as rebound)

= 3.2889 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{3.2889\ m^3}{6m^3 \text{ per hour}}$ = 0.5 hours

3. For Poor Rock Shotcreting (15 cm) = 2π×1.5862×0.15×3

= 4.4848 m^3 ×(1.1) (10% as rebound)

= 4.9333 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{4.9333\ m^3}{6m^3 \text{ per hour}}$ = 1.0 hour

4. For Very Poor Rock Shotcreting (20 cm) = 2π×1.5862×0.2×3

= 5.9798 m^3 ×(1.1) (10% as rebound)

= 6.5778 m^3

Time required for shotcreting = $\frac{\text{Quantity of shotcrete}}{\text{productivity of shotcrete}} = \frac{6.5778\ m^3}{6m^3 \text{ per hour}}$ = 1.0 hours

3.22 Cycle time for benching without rib support of Tailrace tunnel

Table 3.35 Cycle time for benching without rib support of TRT

S.N	Description	Quantity	Units
1	Pull Length	3	m
2	Benching c/s area	23.21	sqm
3	Excavation	69.63	cum
4	Survey	0.5	Hours
5	Drilling	1.5	Hours
6	Charging	0.5	Hours
7	Blasting&defuming	0.5	Hours
8	Mucking	0.5	Hours
9	Scaling	0.5	Hours
10	Shotcreting	**0.5**	Hours
11	Total cycle time for 3m pull length	4.5	Hours

3.22.1 Cycle time for benching with rib support of Tailrace tunnel

Table 3.36 Cycle time for benching with rib support of TRT

S.N	Description	Quantity	Units
1	Pull length	1.5	m
2	Benching c/s area	23.21	sqm
3	Excavation	34.81	cum
4	Survey	0.5	Hours
5	Drilling	1.5	Hours
6	Chrging	0.5	Hours
7	Blasting&defuming	0.5	Hours
8	Mucking	0.5	Hours
9	Scaling	0.5	Hours
10	Shotcreting	1	Hours
12	Rib erection	2	Hours
13	Lagging fixing	**2.5**	Hours
14	Backfill concreting	**2**	Hours
	Total cycle time for 1.5m pull length	11.5	Hours
	Total cycle time for 3m pull length	23	Hours

Time Schedule:

Among the total excavation 90 % is considered as without rib supporting and 10 % as with rib supporting

Weighted average cycle time = (4.5 × 0.9) + (23×0.1) = 6.35 hours per 3m pull length

Progress per month = $\frac{26(\text{working day per month})\times 22(\text{working hours per day})\times 3\text{m}(\text{pull length})}{6.35\ (Hour\ per\ 3m\ \ pull)}$

= 270 m per month

Time required for completion of Benching work = $\frac{\text{Length of Tail Race Tunnel}}{\text{Work progress per month}}$

= $\frac{(502+490+475+46\ \ )\ \text{m}}{(270\ \text{m per month})}$

= 7.13 month = 204 days

3.23 Cycle time in kerb lining of Tailrace tunnel

Kerb lining area = 1.9 m^2

Concrete quantity in 15 m length = 2×1.9 m^2×15m =57 m^3

The rate of concrete for 2 agitator truck with 50 min per hour working : 3.5m^3per hour

Time for placing the concrete = $\frac{concrete\ Quantity}{concrete\ quantity\ in\ one\ truck \times working\ hour} = \frac{57\ m^3}{3.5 \times 22}$ = 1.0 hours

Shutter panel – 1 (15 m length):

Table 3.37 Cycle time in kerb lining for shutter panel – 1 of TRT

S.N	Description	Quantity	Units
1	Kerb shutter	2	Hours
2	Shutter alignment	2	Hours
3	Concreting	1	Hours
4	Concrete setting	20	Hours
5	De- shuttering	1	Hours
6	Miscellaneous	2	Hours
	Total cycle time for 15m panel	28	Hours

Shutter panel – 2 (15 m length):

Table 3.38 Cycle time in kerb lining for shutter panel – 2 of TRT

S.N	Description	Quantity	Units
1	Kerb shutter	2	Hours
2	Shutter alignment	2	Hours
3	Concreting	1	Hours
4	Concrete setting	20	Hours
5	De- shuttering	1	Hours
6	Miscellaneous	2	Hours
	Total cycle time for 15m panel	28	Hours

Time Schedule:

Cycle time for 30m Kerb concreting = 56 Hours

Progress per month =

$$\frac{26(\text{working day per month}) \times 22(\text{working hours per day}) \times 30 \quad (\text{length of lini} \quad \text{in one cycle})}{56(\text{weighted average cycle time in hours})}$$

= 306 m per month

Kerb concreting time = $\frac{\text{Length of the pressure shaft}}{\text{working progress per month}} = \frac{(502+490+475+46\ \ )\ \text{m}}{306\ \text{m per month}}$ = 6.3 month = 190 days

3.24 Cycle time in Invert lining in Tailrace tunnel

Invert lining area = 2.2 m^2

Concrete quantity in 15 m length = 2.2 m^2×15m = 33 m^3

The rate of concrete for 2 agitator truck with 50 min per hour working : 3.5m^3per hour

Time for placing the concrete = $\frac{concrete\ Quantity}{concrete\ quantity\ in\ one\ truck \times working\ hour} = \frac{33\ m^3}{3.5 \times 22} = 0.5$ hours

Shutter panel – 1 (15m length):

Table 3.39 Cycle time in invert lining for Shutter panel – 1 in TRT

S.N	Description	Quantity	Hours
1	Invert template	1.5	Hours
2	Invert template alignment	1	Hours
3	Concreting	0.5	Hours
4	Concrete setting	20	Hours
5	De-shuttering	1	Hours
6	Miscellaneous	2	Hours
	Total cycle time for 15m panel	26	Hours

Shutter panel – 2 (15m length):

Table 3.40 Cycle time in invert lining for Shutter panel – 2 in TRT

S.N	Description	Quantity	Hours
1	Invert template	1.5	Hours
2	Invert template alignment	1	Hours
3	Concreting	0.5	Hours
4	Concrete setting	20	Hours
5	De-shuttering	1	Hours
6	Miscellaneous	2	Hours
	Total cycle time for 15m panel	26	Hours

Time Schedule:

Cycle time for 30m Invert concreting = 52 Hours

Progress per month =

$$\frac{26(\text{working day per month}) \times 22(\text{working hours per day}) \times 30\text{m (length of lining in one cycle)}}{52(\text{weighted average cycle time in hours})}$$

= 330 m per month

Invert concreting time = $\frac{\text{Length of Tailrace Tunnel}}{\text{working progress per month}} = \frac{(502+490+475+\quad)\text{ m}}{330\text{m per month}}$ = 5.8 month = 175 days

3.25 Cycle time in overt lining in Tailrace tunnel:

Overt lining area = 12.22 m^2

Concrete quantity in 15 m length = 12.22 m^2×15m = 183.3 m^3

The rate of concrete for 2 agitator truck with 50 min per hour working : 3.5m^3per hour

Time for placing the concrete = $\frac{concrete\ Quantity}{concrete\ quantity\ in\ one\ truck \times working\ hour} = \frac{183.3\ m^3}{3.5 \times 22}$ = 2.5 hours

Shutter panel – 1 (15m length):

Table 3.41 Cycle time for overt lining for Shutter panel – 1 in TRT

S.N	Description	Quantity	Units
1	Rail fixing	2	Hours
2	Shutter shifting	3	Hours
3	Shutter alignment	3	Hours
4	Bulk had fixing	2	Hours
5	Concreting	2.5	Hours
6	Concrete setting	20	Hours
7	De- shuttering	2	Hours
8	Miscellaneous	3	Hours
	Total cycle time for 15m pannel	**37.5**	Hours

Shutter panel – 2 (15m length):

Table 3.42 Cycle time for overt lining for Shutter panel –2 in TRT

S.N	Description	Quantity	Units
1	Rail fixing	2	Hours
2	Shutter shifting	3	Hours
3	Shutter alignment	3	Hours
4	Bulk had fixing	2	Hours
5	Concreting	2.5	Hours
6	Concrete setting	20	Hours
7	De- shuttering	2	Hours
8	Miscellaneous	3	Hours
	Total cycle time for 15m pannel	**37.5**	Hours

Time Schedule:

Cycle time for 30m Overt concreting = 75 Hours

Progress per month =

$$\frac{26(\text{working day per month}) \times 22(\text{working hours per day}) \times 30\text{m (length of lining in one cycle)}}{75(\text{weighted average cycle time in hours})}$$

= 228 m per month

Overt concreting time = $\frac{\text{Length of Tailrace Tunnel}}{\text{working progress per month}} = \frac{(502+490+475\qquad)\text{ m}}{228\text{m per month}}$ = 8.5 month = 255 days

Table 3.43 Length of different rock conditions in TRT

	Good Rock (10%)	Fair Rock (60%)	Poor Rock (10%)	Very Poor Rock (10%)
Tailrace Tunnel – 1 Length = 502 m	75.3 m	301.2 m	75.3 m	50.2 m
Tailrace Tunnel – 2 Length = 490 m	73.5 m	294 m	73.5 m	49 m
Tailrace Tunnel – 3 Length = 475 m	71.25 m	285 m	71.25 m	47.5 m
Tailrace Tunnel – 4 Length = 460	69 m	276 m	69 m	46 m

m				

Table 3.44 Time duration for different rock conditions in TRT- 1

TRT - 1	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	18	71	18	12	119
Benching	8	32	8	6	54
Kerb	7	27	7	5	46
Overt	7	27	7	5	46
Invert	10	40	10	7	67

Table 3.45 Time duration for different rock conditions in TRT - 2

TRT - 2	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	17	69	17	11	114
Benching	8	33	8	5	54
Kerb	7	27	7	4	45
Overt	7	27	7	4	45
Invert	10	38	10	6	64

Table 3.46 Time duration for different rock conditions in TRT - 3

TRT - 3	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	17	67	17	11	112
Benching	8	32	8	5	53
Kerb	6	26	6	4	42
Overt	6	26	6	4	42
Invert	9	37	9	6	61

Table 3.47 Time duration for different rock conditions in TRT - 4

TRT - 4	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	16	65	16	11	108
Benching	8	31	8	5	52
Kerb	6	25	6	4	41
Overt	6	25	6	4	41

Invert	9	36	9	6	60

Table 3.48 Activities details of TRT for Drill & Blast method

RHP- TRT | Classic WBS Layout | 28-Apr-17 18:50

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
RHP- TRT		252	252	0%	15-May-17	18-Dec-17	0
TRT1		252	252	0%	15-May-17	18-Dec-17	0
A1030	Heading	119	119	0%	15-May-17	24-Aug-17	0
A1040	Benching	54	54	0%	24-Aug-17	10-Oct-17	0
A1060	Kerb	46	46	0%	11-Sep-17	19-Oct-17	0
A1070	Overt	67	67	0%	19-Oct-17	18-Dec-17	0
A1050	Invert	46	46	0%	07-Nov-17	15-Dec-17	1
TRT2		244	244	0%	15-May-17	11-Dec-17	8
A11	Heading	114	114	0%	15-May-17	21-Aug-17	8
A11	Benching	54	54	0%	21-Aug-17	05-Oct-17	8
A12	Kerb	45	45	0%	06-Sep-17	16-Oct-17	8
A12	Overt	64	64	0%	16-Oct-17	08-Dec-17	8
A11	Invert	45	45	0%	01-Nov-17	11-Dec-17	8
TRT3		238	238	0%	15-May-17	05-Dec-17	14
/	Heading	112	112	0%	15-May-17	17-Aug-17	10
/	Benching	53	53	0%	21-Aug-17	04-Oct-17	8
/	kerb	42	42	0%	06-Sep-17	12-Oct-17	14
/	overt	61	61	0%	12-Oct-17	04-Dec-17	14
/	Invert	42	42	0%	30-Oct-17	05-Dec-17	14
TRT4		230	230	0%	15-May-17	28-Nov-17	22
	Heading	108	108	0%	15-May-17	15-Aug-17	22
	Benching	52	52	0%	15-Aug-17	28-Sep-17	22
	kerb	41	41	0%	31-Aug-17	05-Oct-17	22
	overt	60	60	0%	06-Oct-17	27-Nov-17	22
	Invert	41	41	0%	24-Oct-17	28-Nov-17	22

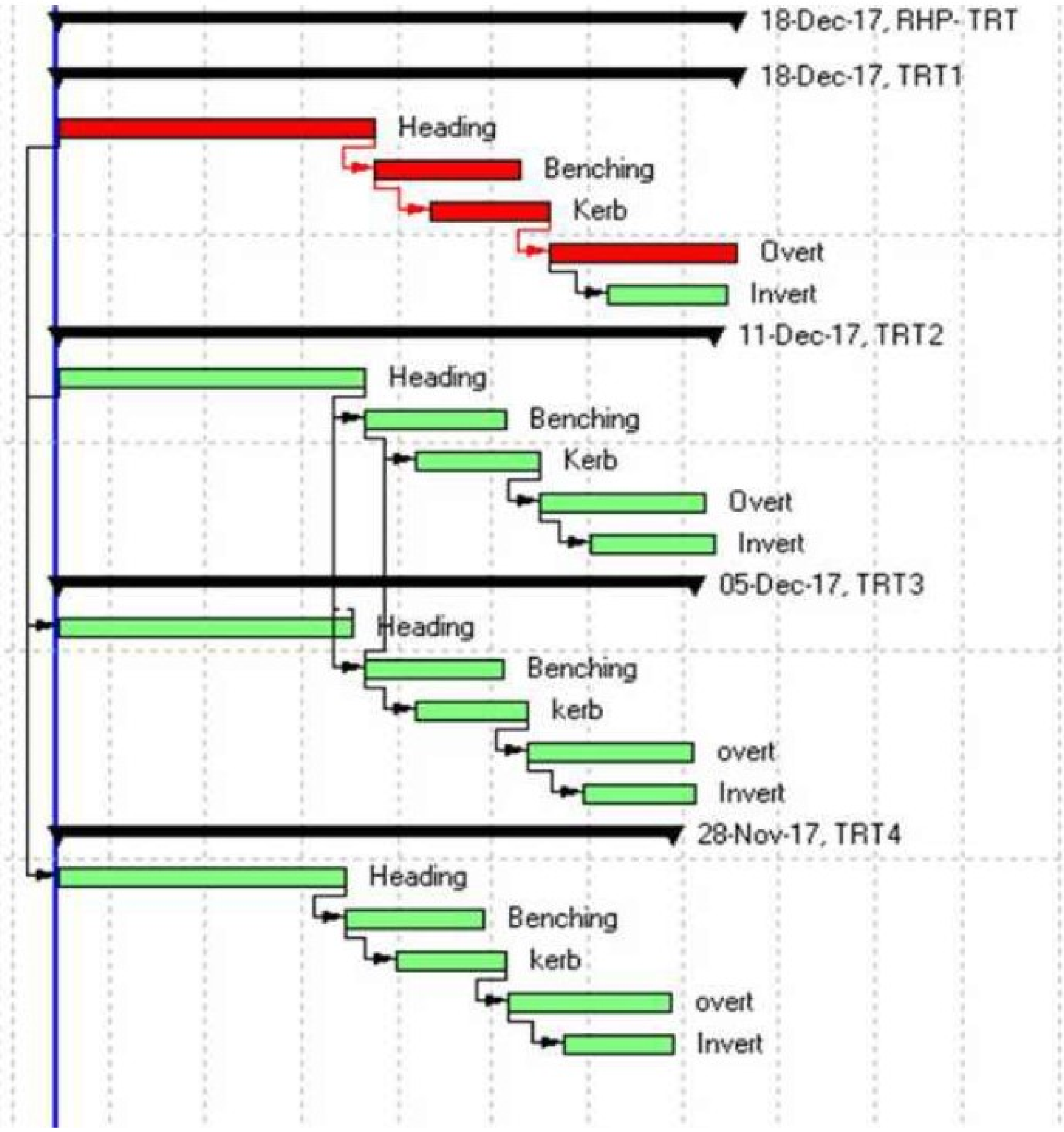


Fig 3.10 Network diagram for Tailrace tunnel in case of Drill & Blast method

3.26 Cost estimation of underground work in Diversion tunnel by Drill & Blast method

ITEM: Excavation for tunnel in the case of Diversion Tunnel by heading and benching.

DATA - Size of tunnel assumed (finished section)	12.345 m dia
Shape of tunnel assumed for excavation	Horse-shoe shaped
Height of tunnel assumed (finished section)	12.345 m dia
Length of DT- 1	472 m

Length of DT- 2	552 m
Thickness of lining	1.0 m
Diameter of tunnel upto pay line for excavation	12.345 m
Distance of dump yard from face	Average 1 km
Haulage of excavated muck	By dumper

Consideration for 3 m pull length:

Checking alignment and marking hole locations:

Use drilling jumbo for 1 hour for marking hole locations.

Drilling holes.

The depth of hole for 3.0 m pull is considered at 2.0 m

Heading portion	
Area of excavation upto payline	82.6734 m^2
Drilling depth	2.0 m
No. of holes considering 2.0 holes per m^2 (82.6734× 2.0)	165 Nos
Drilling depth for 165 holes (165×2.0×1.1)	363.0 m

Benching portion	
Area of excavation upto payline	40.2379 m^2
Drilling depth	2.0 m
No. of holes considering 2.0 holes per m^2 (40.2379×2.0)	81 Nos
Drilling depth for 80 holes (80×2.0×1.1)	176.0 m
Total depth of drilling (363+176)	593.0 m
Average rate of drilling per hour per jack hammer	5 m
Time for 4 jack hammer with pusher leg for drilling	8 hour
Time for 1 air compresser 15 cmm for air supply to 4 jack hammer	8 hour
Time for drilling jumbo for drilling	8 hour

Loading explosive and blasting	
Total area of excavation	123 m^2
Depth of pull per blast for 2.0 m deep holes	3.0 m
Quantity of in-situ excavation per blast (123×3.0)	**369 m^3**
Quantity of explosive small dia per blast @ 0.8 kg per m^3(369×0.8	295.2 kg
Quantity of explosive for secondary blasting @ 10 %	29.52 kg
Quantity of delay detonators per blast (165+81)	246 Nos.
Quantity of electric e detonators for secondary blasting (LS)	10 Nos.
Detonating fuse coil	175 Rm
Time for drilling jumbo for loading explosive. (1.5+0.5)	2.0 hours

Defuming and scaling loose materials:

Ventilation fan required in duct system at 300 m interval and are run for about 1 hour after each blast

Mucking excavated rock	
Quantity of muck per blast considering 20 % bulkage for Heading zone (82.67×1.2)	99.204 m^3
Quantity of muck per blast considering 20 % bulkage for Benching zone (40.23×1.2)	48.276 m^3
Capacity of dumper per load	5 m^3
Quantity of muck per load considered under tunnel working conditions	4.5 m^3

Loading cycle time	
Moving from pocket position and spotting	1 minutes
Loading muck by convey mucker and work force	20 minutes
Time for loading dumper to pass waiting point	1 minutes

Cycle time of loading dumper per load of 4.5 m^3	**22 minutes**
Haulage cycle time	
Running time from loading point to dump yard at average 10 km per hour	6 minutes
Turning and unloading	2 minutes
Retur trip to waiting point @ average 15 km per hour	4 minutes
Waiting time for spotting	9 minutes
Cycle time for haulage per load of 4.5 m^3	**21 minutes**

Round trip cycle time of dumper	**45 minutes**
Quantity of muck disposal per hour per dumper	6 m^3
Time for 2 dumper for conveying muck @ 12 m^3 per hour	6 hours
Time for convey mucker and labour force for loading	7 hours

Overall cycle time	
Survey	0.5 hours
Drilling	5.0 hours
Charging	1.0 hours

Blasting & defuming	0.5 hours
Mucking	3.0 hours
Scaling	1.0 hour
Shotcreting in Good Rock (5cm)	0.5 hour
Shotcreting in Fair Rock (10cm)	1.0 hour
Rockbolt drilling & fixing(Good & Fair Rock)	2.0 hour

Total cycle of excavation & supporting per blast of 3.0 m length : 14.5 hours

Requirement of materials	
Explosive small dia (295.2+29.5)	324.7 kg
Elecic short delay detonators (165+81)	246 Nos
Electric detonators for secondary blasting	10 Nos
Fuse coil	175 Rm

Requirement of machinery	
Deploy drilling jumbo for various opetrations of excavation (marking 1 hr + drilling 5 hr + loading explosive 2 hrs + miscellaneous work 1 hrs)	9 hours
Deploy air compressor 15 cmm for air supply to 4 jack hammers	8 hours
Deploy 10 hp pump for water pusher leg for drilling work	8 hours
Deploy 20 hp ventilation fan for defuming ; 2 hours	
Deploy convey mucker for loading excavated rock	7 hours
Deploy 2 dumper for conveying muck	7 hours

Requirement of workforce (other than machinery crew)	
Surveyer	
For checking alignment and marking hole locations for drilling	1 Nos
Foreman for supervising drilling of holes and other operations	1 Nos
Fitter/Mechanic	
For extending air / water lines	2 Nos
Blaster (Licenced)	2 Nos
Helper Blasting	2 Nos
Hammerman foe scaling	2 Nos
Khalasi	
For pushing muck from header portion	4 Nos
Foe mucking shift	4 Nos
Heavy mazdoor	
For mucking shift	8 Nos
Light mazdoor	
For cleaning & miscellaneous work	4 Nos

Use rate of materials		
Cost of drill rod 2.5 m long @	7175.0 per Nos	7175.0
Life of drill rod with reconditioning		150 m
Use rate of drill rod per Rm drilling	(cost per life)	47.83
Length of air and water hose assumed		25 m each
Cost of 25 mm dia air hose 25 m @	200.0 per Rm	5000.0
Life of air hose		800 .hours
Use rate of air hose per hour	(cost per life)	6.25
Cost of water hose 25 m each @	185.00 per Rm	4625.00
Life of water hose	(cost per life)	800 hours
Use rate of water hose per hour	(cost per life)	5.78

RATE ANALYSIS UNIT : 369 m^3

A. MATERIALS

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Small dia explosive	kg	324.7	60	19482
2	Delay detonators	Nos	246	20	4920
3	Electric detonator	Nos	10	12	120
4	Detonating fuse coil	Rm	175	9	1575
5	Use rate of drill rod 2.0 m long	Rm	539	47.83	25780.37
	Reconditioning charges @ 10%				2578.037
6	Use rate of air hose	Hour	32	6.25	200
7	Use rate of water hose	Hour	32	5.78	184.96
8	Sundries (paint / template etc)	LS	9	44	396
				Total	55236.367

Add for small Tools and Plants	@ 1	552.3636
Add for Contractor's Profit	@ 10%	5523.6367
Add for Contractor's Overheads	@ 5%	2761.8183
Total cost of Material		**64074.1856**

B. MACHINERY:

S.N	Description	Unit	Quantity	Rate in INR	Amount in INR
1	Drilling jumbo	Hour	9	370	3330
	Fuel charges	Hour	9	41	369
2	Air compressor 15 cmm	Hour	8	119	952
	Fuel charges	Hour	8	800	6400
3	Jack hammer (4 x 8 hrs)	Hour	32	16	512
	Fuel charges	Hour	32	8	256
4	Pusher leg	Hour	32	9	288
	Fuel charges	Hour	32	6	192
5	Convey mucker	Hour	7	740	5180
	Fuel charges	Hour	7	223	1561
6	Dumper (2 x 6.5 hrs)	Hour	13	548	7124
	Fuel charges	Hour	13	381	4953
7	Pump 10 hp	Hour	8	5	40
	Fuel charges	Hour	8	64	512
8	Ventilation fans 20 hp (2 x 1 hr x 2)	Hour	4	6	24
	Fuel charges	Hour	4	128	512
9	Sundries (explosive van / magazine)	LS	10	44	440
				Total	32645

Add for small Tools and Plants	@ 1%	326.4
Add for Contractor's Profit	@ 10%	3264.5
Add for Contractor's Overheads	@ 5%	1632.25
Total hire charges of Machinery		**37868.2**

C. LABOUR:

S.N	Description	Unit	Quantity	Rate in INR	Amount in INR
1	Crew for Drilling jumbo	Hour	9	101	909
2	Crew for Air compressor	Hour	8	101	808
3	Crew for Jack hammer	Hour	32	188	6016
4	Crew for Convey mucker	Hour	7	101	707
5	Crew for Dumper	Hour	13	121	1573
6	Crew for Pump	Hour	8	45	360
7	Crew for Ventilation fan	Hour	4	16	64
8	Surveyor	Day	1	284.73	284.73
9	Foreman	Day	1	276.73	276.73
10	Fitter / Mechanic	Day	2	254.73	509.46
11	Blaster (Licensed)	Day	2	243.23	486.46
12	Helper blasting	Day	4	239.73	958.92
13	Hammerman 2 Nos	Day	2	241.73	483.46
14	Maistry 1 in each shift	Day	3	243.23	729.69
15	Khalasi				
	for pushing muck in heading portion	Day	4	241.23	964.92
	for mucking shift 4 Nos	Day	4	241.23	964.92
16	Heavy mazdoor				
	for mucking shift 8 Nos	Day	8	238.73	1909.84
	for other 2 shifts 2 No each shift	Day	4	238.73	954.92
17	Light mazdoor				
	for cleaning & miscellaneous	Day	3	238.23	714.69
				Total	19675.74

Add for small Tools and Plants	@ 1 %	196.7574
Add for Contractor's Profit	@ 10%	1967.574
Add for hidden cost on Labour	@ 15%	2951.331
Add for additional hidden cost on labour	@ 10%	1967.574
Add for Contractor's Overheads	@ 5%	983.787
Total cost of labour		**27742.7634**

3.27 Abstract of cost details for 3 m Pull length in Diversion tunnel by Drill & Blast method

A.Cost of Materials	64074.1856
B.Hire charges of Machinery	37868.2

C.Cost of Labour		27742.7634
TOTAL		**129685.149**
Add for Air and Water line	@ 0.80 %	1037.4811
Add for Ventilation	@ 6.0 %	7781.1089
Add for Lighting	@ 1.80 %	2334.3326
Add for Electrical sub-station / Demand charges	@ 3.80 %	4928.0356
Add for other Enabling works	@ 1.70 %	2204.6475
Total cost for	**369 m^3**	**47970.7547**

Rate per m^3 **401.0047**

For 1 cycle (3 m pull length) rate per m^3 **401.0047**

Total length of DT- 1 **472 m**

Total length of DT- 2 **552 m**

90 % considered without rib support	
Total length in case of without rib support in DT - 1	424.8 m
Total length in case of without rib support in DT - 2	496.8 m

Total cost in DT - 1 **(401.0047×424.8 m×123 m^2)** **20952655.98**

Total cost in DT - 2 **(401.0047×496.8 m×123 m^2)** **24503953.6**

Consideration for 1.5 m pull length:

Checking alignment and marking hole locations:

Use drilling jumbo for 1 hour for marking hole locations.

Drilling holes.

The depth of hole for 1.5 m pull is considered at 1.0 m

Heading portion		
Area of excavation upto payline		82.6734 m^2
Drilling depth		1.0 m
No. of holes considering 2.0 holes per m^2	(82.6734× 2.0)	165 Nos
Drilling depth for 165 holes	**(165×1.0×1.1)**	**181.5 m**

Benching portion		
Area of excavation upto payline		40.2379 m^2
Drilling depth		1.0 m
No. of holes considering 2.0 holes per m^2	(40.2379×2.0)	81 Nos

Drilling depth for 80 holes	**(81×1.0×1.1)**	**89.1 m**
Total depth of drilling	**(181.5+89.1)**	**270.1 m**
Average rate of drilling per hour per jack hammer		5 m
Time for 4 jack hammer with pusher leg for drilling		8 hours
Time for 1 air compresser 15 cmm for air supply to 4 jack hammer		8 hours
Time for drilling jumbo for drilling		8 hours
Time for 10 hp pimp for pumping water to storage tank		8 hours

Loading explosive and blasting		
Total area of excavation		123 m^2
Depth of pull per blast for1.0 m deep holes		1.5 m
Quantity of in-situ excavation per blast	**(123×1.5)**	**184.5 m^3**
Quantity of explosive small dia per blast @ 0.8 kg per m^3	(184.5×0.8)	147.6 kg
Quantity of explosive for secondary blasting @ 10 %		14.76 kg
Quantity of delay detonators per blast	(165+81)	246 Nos.
Quantity of electric electric detonators for secondary blasting (LS)		10 Nos.
Detonating fuse coil		450 Rm
Time for drilling jumbo for loading explosive.	(1.5+0.5)	2.0 hours

Overall cycle time	
Survey	0.5 hours
Drilling	5.0 hours
Charging	1.0 hours
Blasting & defuming	0.5 hours
Mucking	3.0 hours
Scaling	1.0 hours
Shotcreting in Poor Rock (15cm)	2.0 hours
Shotcreting in V.Poor Rock (20cm)	2.5 hour
Rockbolt drilling & fixing in (Poor & V.Poor Rock)	3.0 hour
Rib erection	3.0 hour
Lagging fixing	2.5 hour
Stopper fixing & back fill concrete	4.0 hour
Total cycle of excavation & supporting per blast of 1.5 m length	**28.0 hour**
Total cycle of excavation & supporting per blast of 3.0 m length	**56.0 hours**

Requirement of materials		
Explosive small dia	**(147.6+14.76)**	**162.36 kg**

Elecic short delay detonators	**(165+81)**	**246 Nos**
Electric detonators for secondary blasting		**10 Nos**
Fuse coil		**450 Rm**

RATE ANALYSIS **UNIT** **184.5 m^3**

A. MATERIALS :

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Small dia explosive	kg	162.36	60	9741.6
2	Delay detonators	Nos	246	20	4920
3	Electric detonator	Nos	10	12	120
4	Detonating fuse coil	Rm	450	9	4050
5	Use rate of drill rod 2.0 m long	Rm	270.1	47.83	12918.888
	Reconditioning charges @ 10%				1291.888
6	Use rate of air hose	Hour	32	6.25	200
7	Use rate of water hose	Hour	32	5.78	184.96
8	Sundries (paint / template etc)	LS	9	44	396
				Total	33823.336

3.28 Abstract of cost details for 1.5 m Pull length in Diversion tunnel:

A.Cost of Materials	33823.336
B.Hire charges of Machinery	37868.2
C.Cost of Labour	27742.7634
TOTAL	**99434.2994**

Add for Air and Water line	@ 0.80 %	795.4743
Add for Ventilation	@ 6.0 %	5966.0579
Add for Lighting	@ 1.80 %	1789.8173
Add for Ele sub-station / Demand charges	@ 3.80 %	3778.5033
Add for other Enabling works	@ 1.70 %	1690.3830
Total cost for	**184.5 m^3**	**113454.5352**

Rate per m^3	**614.9297**
For 1 cycle (1.5 m pull length) rate per m^3	**614.9297**
Total length of DT- 1	**472 m**
Total length of DT- 2	**552 m**

10 % considered with rib support		
Total length in case of with rib support in DT - 1		47.2 m
Total length in case of with rib support in DT - 2		55.2 m
Total cost in DT - 1	**(614.9297×47.2 m×123 m^2)**	**570035.866**
Total cost in DT - 2	**(614.9297×55.2 m×123 m^2)**	**175126.691**
Total cost in Excavation for DT- 1	**(20952655.98+3570035.866)**	**4522691.85**
Total cost in Excavation for DT- 2	**(24503953.6+4175126.691)**	**8679080.29**

3.29 Cost calculation in rock bolts support work in Diversion tunnel by Drill & Blast method

ITEM: providing and fixing 25 mm diameter steel rock bolts with the help of resin bond cement capsule Anchorage, and fixing 10 mm thick 180×180 mm size plate washers and nuts.

DATA - Diameter of ribbed steel rock	25 mm
Length of rock bolt including threaded portion	4.15 m
Plate washers 180 x 180 x 10 mm thick	2 Nos.
Resin bond cement grout capsule	1 No.
M S Nuts for bolts	2 Nos.
Diameter of hole for fixing rock bolt	35 mm
Depth of hole for fixing rock bolt	4.0 m

For DT – 1

Rock bolt calculation		
Distance in Good Rock(15%) + Fair Rock(60%) of	472 m	354 m
In 3 m stretch 24 Nos of Rock bolt is required		
So rock bolt only needed in Heading		
So 12 Nos of Rock bolt is required		
Nos of cycle in DT – 1 for rock bolt	(354m/ 3m)	118 Nos
Nos of rock bolt in 354 m	(18×12)	1416 Nos

For Good and Fair Rock	
Length of rock bolt excluding threaded portion for 1416 bolts (1416×4)	5664 m
Quantity of drilling for 1416 bolts	5664 m
Rate of drilling for rock bolts including shifting	4 m / hr
Time for drilling 5664 m with 4 jack hammers (5664 / 4 / 4) say	354 hour

For Poor and V. Poor Rock	
Distance in Poor Rock(15%) + V.Poor Rock(10%) of 472 m	118 m
In 3 m stretch 32 Nos of Rock bolt is required.	
So rock bolt only needed in Heading.	
So 16 Nos of Rock bolt is required	
Nos of cycle in DT – 1 for rock bolt (118m / 3m)	39.33 Nos
Nos of rock bolt in 118 m (39.33×16)	629 Nos
Length of rock bolt excluding threaded portion for 629 bolts (629×4)	2516 m
Quantity of drilling for 629 bolts	2516 m
Rate of drilling for rock bolts including shifting	4 m per hour
Time for drilling 2516 m with 4 jack hammers (2516 / 4 / 4) say	157.25 hour

Requirement of materials (for Good(15%) And Fair Rock (60%))	
Quantity of 25 mm dia bars for (1416) bolts with 2.5 % wastage (1416 x 4.15 x 3.85 x 1.025)	23189.7435 kg
Quantity of washer for 1416 bolts with 2.5 % wastage (1416 x 4 x 0.2 x 0.2 x 78.5 x 1.025)	18229.584 kg
Quantity of nuts for 1416 bolts (1416 x 2 x 0.2)	566.4 kg
Quantity of grout capsule for 1416 bolts (1416 x 1)	1416 Nos

Requirement of materials (for Poor (15%) And V. Poor Rock (10%))	
Quantity of 25 mm dia bars for (629) bolts with 2.5 % wastage (629 x 4.15 x 3.85 x 1.025)	10301.093 kg

Quantity of washer for 629 bolts with 2.5 % wastage (629 x 4 x 0.2 x 0.2 x 78.5 x 1.025)	8097.746 kg
Quantity of nuts for 629 bolts (629x 2 x 0.2)	251.6 kg
Quantity of grout capsule for 629 bolts (629 x 1)	629 Nos

For DT – 2

Rock bolt calculation	
Distance in Good Rock(15%) + Fair Rock(60%) of 552 m	414 m
In 3 m stretch 24 Nos of Rock bolt is required.	
So rock bolt only needed in Heading.	
So 12 Nos of Rock bolt is required	
Nos of cycle in DT – 2 for rock bolt (414m / 3m)	138 Nos
Nos of rock bolt in 414 m (138×12)	1656 Nos
For Good and Fair Rock	
Length of rock bolt excluding threaded portion for 1656 bolts (1656×4)	6624 m
Quantity of drilling for 1656 bolts	6624 m
Rate of drilling for rock bolts including shifting	4 m per hour
Time for drilling 6624 m with 4 jack hammers (6624 / 4 / 4) say	414 hour
For Poor And V. Poor Rock	
Distance in Poor Rock(15%) + V.Poor Rock(10%) of 552 m	138 m
In 3 m stretch 32 Nos of Rock bolt is required.	
So rock bolt only needed in Heading.	
So 16 Nos of Rock bolt is required	
Nos of cycle in DT – 2 for rock bolt (138m / 3m)	46 Nos
Nos of rock bolt in 138 m (46×16)	736 Nos
Length of rock bolt excluding threaded portion for 736 bolts (736×4)	2944 m
Quantity of drilling for 736 bolts	2944 m
Rate of drilling for rock bolts including shifting	4 m per hour

Time for drilling 2944 m with 4 jack hammers (2944 / 4 / 4) say	184 hour

Requirement of materials (for Good(15%) And Fair Rock (60%))	
Quantity of 25 mm dia bars for (1656) bolts with 2.5 % wastage (1656 x 4.15 x 3.85 x 1.025)	27120.2085 kg
Quantity of washer for 1656 bolts with 2.5 % wastage (1656 x 4 x 0.2 x 0.2 x 78.5 x 1.025)	21319.344 kg
Quantity of nuts for 1656 bolts (1656 x 2 x 0.2)	662.4 kg
Quantity of grout capsule for 1656 bolts (1656 x 1)	1656 Nos

Requirement of materials (for Poor (15%) And Very Poor Rock (10%))	
Quantity of 25 mm dia bars for (736) bolts with 2.5 % wastage (736 x 4.15 x 3.85 x 1.025)	12053.426 kg
Quantity of washer for 736 bolts with 2.5 % wastage (736 x 4 x 0.2 x 0.2 x 78.5 x 1.025)	9475.264 kg
Quantity of nuts for 736 bolts (736x 2 x 0.2)	294.4 kg
Quantity of grout capsule for 736 bolts (736 x 1)	736 Nos

Requirement of machinery :

Deploy 1 Air compressor 15 cmm for 1.5 hours with 50 minutes per hour working.

Deploy 4 Jack hammers / Stooper drills for 1.5 hours with 50 minutes per hour working.

Deploy Drilling jumbo for 4 hours including fixing bolts.

Deploy 10 hp pump for 1.5 hour for pumping water to storage tank.

Requirement of workforce (other than machinery crew)	
Gas cutter for preparing washers and wedges	0.5 No.
Turner for threading bolts	1 No.
Hammerman	0.5 No.
Fitter for fixing bolts	0.5 No.

Khalasis 2 Nos for 0.5 day	1 No.
Heavy mazdoor for assisting in cutting / fabrication / fixing	2 Nos.

Re-handling lead for materials:

As rock bolts are stored outside tunnel and are to be conveyed inside tunnel after fabrication at workshop re-handling lead of 1 km is considered.

Use rate of materials		
Cost of drill rod 2.5 m long	@7175.00 / No.	7175.00
Life of drill rod with reconditioning		150 m
Use rate of drill rod per m drilling	(cost / life)	47.83
Cost of air hose 25 m per jack hammer	200.00 / Rm	5000.00
Life of air hose		800 hours
Use rate of air hose per hour	(cost / life)	6.25
Cost of water hose 25m per jack hammer	185.00 / Rm	4625.00
Life of water hose		800 hours
Use rate of water hose per hour (cost / life)	5.78	

RATE ANALYSIS (Good &Fair Rock) in DT - 1 UNIT : 5664.0 Rm

A.MATERIALS:

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Rein.Steel with 2.5 % wastage	kg	23189.7	48.48	1124238.789
2	Steel plate for washers	kg	18229.6	51.14	932260.925
3	Resin bond cement grout capsule	Nos	1416	65	92040
4	M S Nuts for bolts	kg	566.4	90	50976
5	Use rate of drill rod	Rm	5664	47.83	270909.12
	Reconditioning charges @ 10%				
6	Use rate of air hose 4 Nos	Hour	6	6.25	37.5
7	Use rate of water hose 4 Nos	Hour	6	5.78	34.68
8	Sundries(gas for cutting etc)	LS	5	44	220
				Total	2470717.014

Add for small Tools and Plants	@ 1%	24707.1701

Add for Contractor's Profit	@ 10%	247071.701
Add for Contractor's Overheads	@ 5%	123535.8507
Total cost of Materials		**2866031.736**

RATE ANALYSIS (Poor & V. Poor Rock) UNIT : 2516.0 Rm

A.MATERIALS:

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Rein.Steel with 2.5 % wastage	kg	10301.09	48.48	499396.988
2	Steel plate for washers	kg	8097.746	51.14	414118.73
3	Resin bond cement grout capsule	Nos	629	65	40885
4	M S Nuts for bolts	kg	251.6	90	22644
5	Use rate of drill rod	Rm	2516	47.83	120340.28
	Reconditioning charges @ 10%				
6	Use rate of air hose 4 Nos	Hour	6	6.25	37.5
7	Use rate of water hose 4 Nos	Hour	6	5.78	34.68
8	Sundries(gas for cutting etc)	LS	5	44	220
				Total	1097677.178

Add for small Tools and Plants	@ 1%	10976.771
Add for Contractor's Profit	@ 10%	109767.717
Add for Contractor's Overheads	@ 5%	54883.8589
Total cost of Materials		**1273305.525**

Rate analysis (Good & Fair Rock) in DT – 2 UNIT : 6624 Rm

A.MATERIALS:

S.N	Particulars	Unit	Quantity	Rate in INR	Amount in INR
1	Rein. Steel with 2.5% wastage	kg	27120.209	48.48	1314787.708
2	Steel plate for washers	kg	21319.344	51.14	1090271.252
3	Resin bond cement grout capsule	Nos	1656	65	107640
4	M S Nuts for bolts	kg	662.4	90	59616
5	Use rate of drill rod	Rm	6624	47.83	316825.92
	Reconditioning charges @ 10%				31682.592
6	Use rate of air hose 4 Nos	Hour	6	6.25	37.5
7	Use rate of water hose 4 Nos	Hour	6	5.78	34.68
8	Sundries(gas for cutting)	LS	5	44	220
				Total	2921115.652

Add for small Tools and Plants	@ 1%	29211.156

Add for Contractor's Profit on Energy	@ 10%	292111.5652
Add for Contractor's Overheads	@ 5%	146055.782
Total cost of Materials		**3388494.155**

RATE ANALYSIS (Poor & Very Poor Rock) UNIT : 2944 Rm

A.MATERIALS:

S.N	Particulars	Unit	Quantity	Rate in INR	Amount in INR
1	Rein. Steel with 2.5% wastage	kg	12053	48.48	584335.5485
2	Steel plate for washers	kg	9475.3	51.14	484565.001
3	Resin bond cement grout capsule	Nos	736	65	47840
4	M S Nuts for bolts	kg	294.4	90	26496
5	Use rate of drill rod	Rm	2944	47.83	140811.52
	Reconditioning charges @ 10%				
6	Use rate of air hose 4 Nos	Hour	6	6.25	37.5
7	Use rate of water hose 4 Nos	Hour	6	5.78	34.69
8	Sundries(gas for cutting)	LS	5	44	220
				Total	1284340.26

Add for small Tools and Plants	@ 1%	12843.4026
Add for Contractor's Profit on Energy	@ 10%	128434.026
Add for Contractor's Overheads	@ 5%	64217.013
Total cost of Materials		**1489834.702**

B. MACHINERY:

S.N	Description	Unit	Quantity	Rate in INR	Amount in INR
1	Air compressor 15 cmm	Hour	1.5	119	178.5
	Fuel charges	Hour	1.5	800	1200
2	Pump 10 hp	Hour	1.5	5	7.5
	Fuel charge	Hour	1.5	64	96
3	Jack hammer	Hour	6	16	96
	Fuel charges	Hour	6	8	48
4	Pusher leg	Hour	6	9	54
	Fuel charges	Hour	6	6	36
5	Drilling jumbo	Hour	4	370	1480
	Fuel charges	Hour	4	41	164
6	Sundries (lathe, etc)	LS	7	44	308
				Total	3668

Add for small Tools and Plants	@ 1%	36.68
Add for Contractor's Profit on Energy	@ 10%	185.20

Add for Contractor's Overheads	@ 5%	183.40
Total hire charges on machinery		**4073.28**

C.LABOUR

S.N	Description	Unit	Quantity	Rate in INR	Amount in INR
1	Crew for Air compressor	Hour	1.5	101	151.5
2	Crew for pump	Hour	1.5	45	67.5
3	Crew for Jack hammer	Hour	6	188	1128
4	Crew for Drilling jumbo	Hour	4	101	404
5	Fitte	Day	0.5	254.73	127.37
6	Gas cutter	Day	0.5	254.73	127.37
7	Turner	Day	1	253.73	254.73
8	Khalasi (2 x 0.5)	Day	1	241.23	241.23
9	Hammerman	Day	0.5	241.73	120.87
10	Heavy mazdoor	Day	2	238.73	477.46
				Total	3100.02

Add for small Tools and Plants	@ 1%	31.00
Add for Contractor's Profit	@ 10%	310.00
Add for hidden cost on Labour	@ 15%	465.00
Add for additional hidden cost on labour	@ 10%	310.00
Add for Contractor's Overheads	@ 5%	155.00
Total cost of labour		**4371.02**

3.30 Abstract of cost details of Rock bolt support in DT – 1 by Drill & Blast method

For DT – 1

For Good and fair Rock	
A. Cost of Materials	2866031.736
B. Hire charges of Machinery	4073.28
C. Cost of Labour	4371.02
TOTAL	**2874476.036**

Add for Air and Water line	@ 0.80%	22995.808
Add for Lighting	@ 1.80%	51740.568
Add for Ele sub-station / Demand charges	@ 3.80%	10923.0894
Add for other enabling works	@ 1.70%	48866.092
TOTAL		**009001.593**
Add for 1 km rehandling lead charges		
For steel 150 kg	@ 218.40 per tonne (0.15×218.40)	32.76
Total cost for	**5664 Rm**	**009034.353**

For Poor and V. Poor Rock	
A. Cost of Materials	1097677.178
B. Hire charges of Machinery	4073.28
C. Cost of Labour	4371.02
TOTAL	**1106121.478**

Add for Air and Water line	@ 0.80%	8848.9718
Add for Lighting	@ 1.80%	19910.1866
Add for Eletrical sub-station / Demand charges	@ 3.80%	42032.616
Add for other enabling works	@ 1.70%	18804.0651
TOTAL		1195717.318
Add for 1 km rehandling lead charges		
For steel 150 kg	@218.40 per tonne (0.15×218.40)	32.76
Total cost for	**2516 Rm**	**1195750.078**

Total cost for Rock bolt support work in (Good & Fair Rock + Poor & Very Poor Rock):

Total cost for Rock bolt support work (3009034.353+1195750.078) : 4204784.431

3.31 Abstract of cost details of Rock bolt support in DT- 2 by Drill & Blast method

For DT- 2

For Good and fair Rock	
A. Cost of Materials	3388494.155
B. Hire charges of Machinery	4073.28
C. Cost of Labour	4371.02
TOTAL	**3396938.455**

Add for Air and Water line	@ 0.80%	27175.507
Add for Lighting	@ 1.80%	61144.892
Add for Ele sub-station / Demand charges	@ 3.80%	129083.661
Add for other enabling works	@ 1.70%	57747.953
TOTAL		**3672090.501**
Add for 1 km rehandling lead charges		
For steel 150 kg	@218.40 per tonne(0.15×218.40)	32.76
Total cost for	**6624 Rm**	**3672123.261**

For Poor and V. Poor Rock	
A. Cost of Materials	1489834.702
B. Hire charges of Machinery	4073.28
C. Cost of Labour	4371.02
TOTAL	**1498279.002**

Add for Air and Water line	@ 0.80%	11986.232
Add for Lighting	@ 1.80%	26969.022
Add for Eletrical sub-station / Demand charges	@ 3.80%	56934.602

Add for other enabling works	@ 1.70%	25470.743
TOTAL		1619639.601
Add for 1 km rehandling lead charges		
For steel 150 kg	@218.40 per tonne (0.15×218.40)	32.76
Total cost for	**2944 Rm**	**1619672.361**

Total cost for Rock bolt support work in (Good & Fair Rock + Poor & V. Poor Rock):

Total cost for Rock bolt support work (3672123.261+1619672.361): **5291795.622**

3.32 Cost estimation in kerb and invert lining for Diversion tunnel by Drill & Blast method

ITEM: Providing and laying insitu vibrated **M-20 grade cement concrete** using **40 mm** clean, hard, graded **aggregates** crushed from tunnel excavated rock **for kerb and Invert lining.** Cement content 270 kg per m^3

Cost of shuttering:

Consider 1 shutter and 1 soldier set:

Shutter size: 800 mm x 1200 mm, Soldier length: 2.3 m, Shutter area : 1.20 m^2

4 mm thick plate 1.5 m^2	@ 31.5 kg per m^2 (1.5×31.5)	47.25 kg
50x50x6 mm angle 6.5 m length	@ 3.5 kg per m (6.5×3.5)	22.75 kg
50x6 mm flat 2.0 m length	@ 2.5 kg per m (2×2.5)	5.0 kg
ISLC 200 2.5 m length	@ 8.0 kg per m (2.5×8)	20.0 kg
6 mm plate 0.05 m^2	@ 47.5 kg per m^2 (0.05×47.5)	2.375 kg
Cost of 4 mm plate 47.25 kg	@ 51.14 per kg (47.25×51.14)	2416.365
Cost of 6.5 m angle 22.75 kg	@ 49.14 per kg (22.75×49.14)	1117.935
Cost of 2 m flat 5 kg	@ 51.14 per kg (5×51.14)	255.7
Cost of 2.5 m soldier 20 kg	@ 49.14 per kg (20×49.14)	982.8
Cost of 6mm plate 2.375 kg	@ 51.14 per kg (2.375×51.14)	121.457

TOTAL		**4894.257**

Add wastage	@ 2.5 %	122.356
Add for bolts & nuts	@ 0.5 kg per m^2 ; 90.00 / kg (0.5×90)	45.00
Add for fabrication of shutter	@16.00 per kg (47.25+22.75+5+20+2.375)×16	1558
TOTAL		**6619.613**
Less salvage value	@ 10%	- 661.9613
TOTAL		**5957.651**

Use rate of shutters		
Use rate of shutters considering average 40 uses		126.47
Add for repairs/ replacements etc	@ 15%	18.97
Add for binding wire/ temperary supports etc	@ 5%	6.32
Add for shutter oil at 0.2 litre per m^2	@35.00 per litre (0.2×35)	7.00
TOTAL		**158.77**

Effective area of shutter & soldier with 10 cm margin at top and bottom	: 1.00 m^2
Cost of shuttering for concrete per m^2	: **158.77**
Erection & dismantling shuttering :	
Fitters 1 Carpentor and 5 mazdoors erect 50 m^2 shuttering / day.	
Cost of dismantling assumed at 50 % of erection charges.	
Area of shuttering with supports considered.	: 100 m^2

Cleaning, conveying, erecting and oiling		
Fitter shuttering 4 Nos	@ 244.23 per day (4×244.23)	976.92
Carpentor 2 Nos	@ 244.23 per day (2×244.23)	488.46
Heavy mazdoor 10 Nos	@ 238.73 per day (10×238.73)	2387.30
Dismantling and stacking		

Fitter shuttering 2 Nos	@ 244.23 per day (2×244.23)	488.46
Carpentor 1 Nos	@ 244.23 per day (1×244.23)	244.23
Heavy mazdoor 5 Nos	@ 238.73 per day (5×238.73)	1193.65
TOTAL		**5779.02**

Labour charges for erecting and dismantling shuttering per m^2 : **57.79**

DATA: **Concrete mix details for 50-70 mm slump:**

For 1m^3cement concrete :-Coarse aggregates:0.85m^3(1350 kg) Blending ratio : 50:30:20

Fine aggregate : 0.41m^3(665 kg) Cement : 270 kg Super plasticizer : 0.81 litre

Wastage : 1 % for cement and 2 % for coarse & fine aggregates.

Consider 2 m^3 capacity agitator car for conveying concrete.

Cycle time for one round trip:

Turning and spotting	2 minutes
Loading 4 mixes of 0.5 m^3 @ 5 min per mix	20 minutes
Running time from batching plant to placing point average 1 km	10 minutes
Unloading concrete	**15** minutes
Return trip to batching Plant	**10 minutes**
Total cycle time for round	57 minutes

Deploy 2 Agitator cars for conveying concrete.

The rate of concreting for 2 agitator cars with 50 min/hr working: 3.50 m^3per hour

Progress per shift of 8 hours	**(8 x 3.50)**	**28 m^3**
Requirement of materials		
Cement for mixture with 1 % wastage	(28 x 270 x 1.01)	7636 kg
Cement for incidentals @ 1 kg / m^3	(28 x 1)	28 kg
Coarse aggregate 40-20 mm size range	(28 x 0.85 x 0.5 x 1.02)	12.15 m^3
Coarse aggregate 20-10 mm size range	(28 x 0.85 x 0.3 x 1.02)	7.30 m^3
Coarse aggregate 10-4.75 mm size	(28 x 0.85 x 0.2 x 1.02)	4.85 m^3
Fine aggregate	(28 x 0.41 x 1.02)	11.70 m^3
Super plasticiser	(28 x 0.81 x 1.02)	23.00 litres

2. Requirement of machinery :

Deploy 6 m^3per hour rated capacity batching plant for 8 hours production of concrete.

Deploy 2 Nos 2 m^3 capacity agitator cars for 8 hours conveying concrete.

Deploy 1 Needle vibrater 40 mm dia for 8 hours vibrating concrete.

Deploy 1 Pump 10 hp for 4.00 hour for water required for concrete mixing / curing / cleaning

3. Formwork & scaffolding:

For kerb / bed concreting average 1 shuttering is required per cum of concrete.

Requirement of shuttering for 28 m^3 concrete : 28 m^2

4. Requirement of workforce (other than machinery crew) :

Consider batching of materials and conveyance & laying of concrete by manual labour.

Maistry (1 @ batching plant and 1 @ placing point)	2 Nos.
Mason Class - I	1 No.
Mason Class - II	1 No.

Cement handling mazdoor	
for loading cement to Batching Plant bin	2 Nos **Heavy mazdoor**
for remixing & filling mortar pans	2 Nos
for loading mortar pan	2 Nos
for laying concrete	2 Nos
for cleaning bed and assisting Mason	1 Nos
for miscellaneous works at Batching Plant	1 Nos
Light mazdoor	
for conveying concrete @ 2 m^3 per day	14 Nos
for cleaning, curing & miscellaneous	1 Nos

5. Re-handling lead for materials:

As cement store can be located close to Batching Plant.

Consider 2 cement handling mazdoors for loading cement to Batching Plant bin.

As coarse and fine aggregates can be stocked near the Batching Plant

Consider 4 heavy and 4 light mazdoors for loading Coarse Aggregate to Batching Plant bins @ 6 m^3 per day

Consider 2 heavy and 2 light mazdoors for loading Fine Aggregate to BP bins @ 6m^3 per day

RATE ANALYSIS **UNIT** **: 28.00 m^3**

A.MATERIALS:

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Cement 43 Gr	kg	7636	7.5	57270
	Cement for incidentals @ 1 kg / cum	kg	28	7.5	210
2	Fine aggregate (screened)	cum	11.7	730	8541
3	Coarse aggregate 40-20 mm	cum	12.15	740	8991
	Coarse aggregate 20-10 mm	cum	7.3	950	6935
	Coarse aggregate 10-4.75 mm	cum	4.85	1160	5626
4	Super plasticiser	ltr	23	105	2415
5	Use rate of shuttering for kerb / bed	sqm	28	158.77	4445.45
	Supports for shuttering @ 5 %				222.27
6	Sundries	LS	2	44	88
				Total	94743.72

Add for small Tools and Plants	@ 1%	947.744
Add for Contractor's Profit	@ 10%	9474.37
Add for Contractor's Overheads	@ 5%	4737.19
Total cost of materials		**109902.72**

B.Machinery

S.N	Description	Unit	Quantity	Rate inINR	Amount in INR
1	Batching plant 6 cum / hr rated capacity	Hour	8	144	1152
	Fuel charges	Hour	8	160	1280
2	Agitator car 2 cum (2 Nos)	Hour	16	708	11328
	Fuel charges	Hour	16	832	13312
3	Needle Vibrator	Hour	8	8	64
	Fuel charges	Hour	8	6	48
4	Pump 10 hp	Hour	4	5	20
	Fuel charges	Hour	4	64	256
5	Sundries	LS	2	44	88
				Total	27548

Add for small Tools and Plants	@ 1%	275.48
Add for Contractor's Profit on Energy	@ 10%	1498.40
Add for Contractor's Overheads	@ 5%	1377.40
Total hire charges of Machinery		**30699.28**

C.LABOUR

S.N	Description	Unit	Quantity	Rate inINR	Quantity in INR
1	Crew for Batching plant	Hour	8	181	1448
2	Crew for Agitator car	Hour	16	151	2416
3	Crew for vibrator	Hour	8	90	720
4	Crew for pump	Hour	4	45	180
5	Masom Class - 1	Day	1	256.73	256.73
6	Masom Class - 2	Day	1	244.23	244.23
7	Hammerman for scaling bed	Day	1	241.73	241.73
8	Maistry	Day	2	241.23	482.46
9	Cement handling mazdoor				
	for loading cement to BP bin	Day	2	239.73	479.46
10	Heavy mazdoor				
	for miscellaneous work at BP	Day	1	238.73	238.73
	for scaling & cleaning bed	Day	1	238.73	237.73
	for loading CA to BP bins	Day	4	238.73	954.92
	for loading FA to BP bin	Day	2	238.73	477.46
	for laying concrete	Day	6	238.73	1432.38
11	Light mazdoor				
	for loading CA to BP bins	Day	4	237.23	948.92
	for loading FA to BP bin	Day	2	237.23	474.46
	for conveying concrete	Day	14	237.23	3321.22
	for curing / miscellaneous	Day	1	237.23	237.23
12	Labour charges for shuttering	sqm	28	57.79	1618.13
	Labour charges for supports @ 5 %				80.91
				Total	16491.69

Add for small Tools and Plants	@ 1%	164.92
Add for Contractor's Profit	@ 10%	1649.17
Add for hidden cost on Labour	@ 15%	2473.75
Add for additional hidden cost on labour	@ 10%	1649.17
Add for Contractor's Overheads	@ 5%	824.58
Total cost of Labour		**23253.29**

3.33 Abstract of cost details of Kerb & Invert lining for Diversion tunnel by Drill & Blast method

A. Cost of Materials	109902.72
B. Hire charges of Machinery	30699.28
C. Cost of Labour	23253.29
TOTAL	**163855.28**
Add for Air and Water line @ 0.80%	1310.84
Add for Lighting @ 1.80%	2924.40
Add for Electrical sub-station / Demand charges @ 3.80%	6226.50
Add for other enabling works @ 1.70%	2785.54
Total cost for 28.00 m^3	**177127.56**
Rate per m^3	**6326.00**

Total cost for Kerb and Invert Lining in DT – 1 (4+4+3.1) = 11.1 m^2 × 472 m ×6326 =**33143179.2**

Total cost for Kerb and Invert Lining in DT – 2 (4+4+3.1) = 11.1 m^2 × 552 m ×6326 =**38760667.2**

3.34 Cost estimation for Overt lining in Diversion tunnel by Drill & Blast method

ITEM. Providing and laying insitu vibrated **M-20 grade cement concrete** using **40 mm** clean, hard, graded **aggregates** crushed from tunnel excavated rock **for Overt lining.**

DATA. Concrete mix details per m^3 for 80-100 mm slump:

Cement 43 Grade		300 kg
Fine aggregate	680 kg per m^3	0.425 m^3
Coarse aggregate	1265 kg per m^3	0.79 m^3
Blending ratio		50 : 30 : 20

Concrete admixture (Super plasticiser)	0.90 litre
Diameter of tunnel (finished) considered	12.345 m
Hight of tunnel (finished) considered	12.345 m

Track mounted collapsible gantry considered for supporting sides and arch concrete.

Assume 15 m long collapsible type steel gantry:

Quantity of concrete per gantry considering 1.0m thick lining (16.54$\boldsymbol{m^3}$×15m)	248.1 $\boldsymbol{m^3}$
Concrete for filling support reaches @ 45 %	14.75 $\boldsymbol{m^3}$
Average quantity of concrete per gantry length of lining say	**248.1** $\boldsymbol{m^3}$
Placing concrete for sides and arch	Placer pump
Cycle time for one round trip	
Turning and spotting	2 minute
Loading 4 mixes of 0.5 $\boldsymbol{m^3}$ @ 5 minute per mix	20 minute
Running time from Batching Plant to placing point average 1 km	10 minute
Unloading concrete to placer drum	24 minute
Return trip to BP	10 minute
Total cycle time for round trip	66 minute
Consider $2m^3$ capacity agitator cars for conveying concrete.	
Rate of concreting for 2 agitator cars with 50 min / hr working (2 x 2 x 60 x 50 / 60 / 66)	3.0 m^3/ hr
Progress per shift of 8 working hours (8 x 3.00)	24 $\boldsymbol{m^3}$
Time required for concreting one gantry length (48 / 3)	16 hours
Cycle time of various operations for concreting	
Cleaning bed for laying track line	2.0 hour
Dismantling & extending track line	4.0 hour
Releasing / moving / aligning gantry	4.0 hour
Cleaning & Oiling gantry / Bulk head fixing	4.0 hour
Placer pipe assembling for different positions	6.0 hour
Concreting 48 m^3 @ 3.00 m^3 per hour	16.0 hour
Miscellaneous / Break downs / pipe clogging etc	4.0 hour

Setting time before release of gantry	12.0 hour

Considering cleaning / scaling bed / track dismsntling and erection are carried out as parallel activities during setting time of concrete, the total cycle time for one gantry length concreting will be about 48 hours.

Out of 6 shifts (48 hours) 3 shifts are considered as concreting shifts and 3 shifts are considered as preparatory shifts.

Requirement of materials		
Cement for mix with 1 % wastage	(248.1 x 300 x 1.01)	75174.3 kg
Cement for incidentals @ 1 kg / m^3	(248.1 x 1)	248.1 kg
Coarse aggregate 40-20 mm size range	(248.1 x 0.79 x 0.5 x 1.02)	99.9594 $\boldsymbol{m^3}$
Coarse aggregate 20-10 mm size range	(248.1 x 0.79 x 0.3 x 1.02)	59.9756 $\boldsymbol{m^3}$
Coarse aggregate 10-4.75 mm size	(248.1 x 0.79 x 0.2 x 1.02)	39.9837 $\boldsymbol{m^3}$
Fine aggregate	(248.1 x 0.425 x 1.02)	107.5513 $\boldsymbol{m^3}$
Super plasticiser	(248 x 0.90 x 1.02)	227.7558 liters

2. Requirement of machinery:

Deploy 6 m^3 per hour rated capacity batching plant for 16 hours for production of concrete.

Deploy 2 Nos 2 m^3 capacity agitator cars for 16 hours for conveying concrete.

Deploy 8.5 cmm air compressor for 16 hours for supplying air to placer pump.

Deploy pneumatically operated placer pump for 16 hours for pumping concrete.

Deploy 1 Needle vibrater 40 mm dia for 16 hours for vibrating concrete.

Deploy 1 Pump 10 hp for 8 hours for water required for concrete mixing / curing / cleaning

3. Formwork & scaffolding :

Track mounted collapsible gantry for supporting sides concrete	100 m^2
End shuttering (front face)	6 m^2

4. Requirement of workforce (other than machinery crew) :

Consider batching of materials and conveyance & laying of concrete by manual labour.

Maistry (1 @ batching plant and 1 @ placing point for 2 shifts)	4 Nos.

Mason Class – 1 (1 in each shift for 2 shifts)	2 Nos.
Foreman	1 Nos.
Surveyor	1 Nos.
Stone chiseller Class - 2	0.5 Nos.
Fitter shuttering	1 Nos.
Helper shuttering	1 Nos.
Khalasi (4 for 0.5 day)	2 Nos
Heavy mazdoor	
for miscellaneous works at BP (1 in each shift for 2 shifts)	2 Nos.
for miscellaneous works at placer point (1 in each shift for 2 shifts)	2 Nos.
Light mazdoor	
for cleaning, curing & miscellaneous (1 in each shift for 2 shifts)	2 Nos.

5. Re-handling lead for materials:

Consider 4 cement handling mazdoor (2 in each shift) for loading cement to BP bin.

Consider 6 heavy and 6 light mazdoor (3 each in each shift) for loading CA to BP bins.

Consider 4 heavy and 4 light mazdoor (2 each in each shift) for loading FA to BP bins.

RATE ANALYSIS UNIT : 248.1 m^3

A.MATERIALS:

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Cement 43 Gr	kg	75174.3	7.5	563807.25
	Cement for incidentals @ 1 kg / cum	kg	248.1	7.5	1860.75
2	Fine aggregate (screened)	cum	107.531	730	78512.449
3	Coarse aggregate 40-20 mm	cum	99.9594	740	73969.956
	Coarse aggregate 20-10 mm	cum	59.9756	950	56976.82
	Coarse aggregate 10-4.75 mm	cum	39.9837	1160	46381.092
4	Super plasticiser	ltr	227.756	105	23914.359
5	Use rate of end shuttering	sqm	6	158.77	952.6
6	Use rate of steel gantry	sqm	100	176.95	17695.03
7	Sundries (placer pipe etc)	LS	5	44	220
				Total	864290.306

Add for small Tools and Plants	@ 1%	8642.9030

Add for Contractor's Profit on Energy	@ 10%	86492.0306
Add for Contractor's Overheads	@ 5%	43214.5153
Total cost of Materials		**1002576.745**

B.MACHINERY:

S.N	Description	Unit	Quantity	Rate in INR	Amount in INR
1	Air compressor 8.5 cmm	Hour	16	119	1904
	Fuel charges @ 75 % load	Hour	12	360	4320
2	Batching plant 6 cum / hr rated capacity	Hour	16	144	2304
	Fuel charges	Hour	16	160	2560
3	Agitator car 2 cum (2 Nos)	Hour	32	708	22656
	Fuel charges	Hour	32	832	26624
4	Concrete placer pump	Hour	16	147	2352
	Fuel charges	Hour	16	6	96
5	Needle Vibrator / Shutter vibrator	Hour	16	8	128
	Fuel charges	Hour	16	6	96
6	Pump 10 hp	Hour	8	5	40
	Fuel charges	Hour	8	64	512
7	Sundries	LS	2	44	88
				Total	63680

Add for small Tools and Plants	@ 1%	636.80
Add for Contractor's Profit on Energy	@ 10%	3429.60
Add for Contractor's Overheads	@ 5%	3184
Total hire charges of Machinery		**70930.40**

C.LABOUR

S.N	Description	Unit	Quantity	Rate in INR	Amount in INR
1	Crew charges for Air compressor	Hour	16	94	1504
2	Crew charges for Batching plant	Hour	16	181	2896
3	Crew charges for Agitator car	Hour	32	151	4832
4	Crew charges for placer pump	Hour	16	48	768
5	Crew charges for vibrato	Hour	16	90	1440
6	Crew charges for Pump	Hour	8	45	360
7	Stone chiseller Class - 1				
	for scaling & cleaning	Day	0.5	241.73	120.87
8	Surveyer				
	for laying / aligning track	Day	0.5	284.73	142.37
	for moving / positioning gantry	Day	0.5	284.73	142.37
9	Foreman				
	for laying / aligning track	Day	0.5	276.73	138.37
	for releasing / moving gantry	Day	0.5	276.23	138.37
10	Khalasi				
	for releasing / moving gantry (4 x 0.5)	Day	2	241.23	482.46
11	Fitter shuttering				
	for bulk head / placer pipe fixing (0.5 x 2	Day	1	244.23	244.23
12	Helper shuttering				
	for bulk head / placer pipe fixing (0.5 x 2	Day	1	239.73	239.73
13	Cement handling mazdoor				
	for loading cement to BP bin (2 x 2)	Day	4	239.73	958.92
14	Heavy mazdoor				
	for loading CA to BP bins	Day	6	238.73	1432.38
	for loading FA to BP bin	Day	4	238.73	954.92
	for miscellaneous works of BP (1 x 2)	Day	2	238.73	477.46
	for misc works @ placer point (1 x 2)	Day	2	238.73	477.46
15	Mason Class - 1				
	for Laying concrete by placer (1 x 2)	Day	2	256.73	513.46
16	Light mazdoor				
	for loading CA to BP bins	Day	6	237.23	1423.38
	for loading FA to BP bin	Day	4	237.23	948.92
	for curing / miscellaneous	Day	2	237.23	474.46
17	Maistry (2 x 2)	Day	4	241.23	964.92
				Total	22075.05

Add for small Tools and Plants	@ 1%	220.75
Add for Contractor's Profit	@ 10%	2207.5

Add for hidden cost on Labour	@ 15%	3311.25
Add for additional hidden cost on labour	@ 10%	2207.5
Add for Contractor's Overheads	@ 5%	1103.75
Total cost of Labor		**31125.79**

3.35 Abstract of cost details for Overt lining in Diversion tunnel by Drill & Blast method

A. Cost of Materials	1002576.745
B. Hire charges of Machinery	70930.40
C. Cost of Labour	31125.79
TOTAL	**1104632.935**
Add for Air and Water line @ 0.80%	8837.0635
Add for Lighting @ 1.80	19883.3928
Add for Electrical sub-station charges @ 3.80%	41976.0516
Add for other enabling works @ 1.70%	18778.7599
Total cost for 248.1 m^3	1194108.202
Cost for per m^3	**4813.0117**

Total cost for Overt Lining (16.54 m^2)×(472 m)×(4813.0117) : 37574604.78

Total cost in DT- 1 (Excavation + Rock bolt support + Kerb & Invert Lining + Overt Lining):

(90% without rib support +10% with rib support + Good & Fair rock + Poor & Very Poor rock + Kerb & Invert lining + Overt lining):

(20952655.98 + 3570035.866 + 3009034.353 + 1195750.078 + 33143179.2 + 37574604.78) = **99445260.26**

Total cost in DT – 1 : 99445260.26

Total cost in DT- 2 (Excavation + Rock bolt support + Kerb & Invert Lining + Overt Lining):

Length of DT – 2 **: 552 m**

90% consideration without rib support:

Cost: (401.0047×496.8 m×123 m^2) = 24503953.6

10% consideration with rib support:

Cost: (614.9297×55.2 m×123 m^2) = 4175126.691

Kerb and Invert Lining:

Cost: (4+4+3.1)×(552m)×(6326) = 38760667.2

Overt Lining:

Cost: (16.54 m^2)×552m×4813.0117 = 43943181.86

(90% without rib support +10% with rib support + Good & Fair rock + Poor & Very Poor rock + Kerb & Invert lining + Overt lining) :

(24503953.6+4175126.691+3672123.261+1619672.361+38760667.2+43943181.86) =**116674725**

Total cost in DT- 2 **: 116674725**

Total cost of Diversion Tunnel (99445260+116674725) **: 216119985**

3.36 Cost estimation in Pressure shaft by Drill & Blast method

ITEM: Excavation for tunnel in the case of Diversion Tunnel by heading and benching.

DATA Size of tunnel assumed (finished section)	7.645 m dia
Shape of tunnel assumed for excavation	Horse-shoe shaped
Height of tunnel assumed (finished section)	7.645 m dia

Length of Pressure Shaft (211 + 197 + 184 + 172) m	764 m
Thickness of lining	0.70 m
Diameter of tunnel upto pay line for excavation	7.645 m

Consideration for 3 m pull length:

Checking alignment and marking hole locations:

Use drilling jumbo for 1 hour for marking hole locations.

Drilling holes.

The depth of hole for 3.0 m pull is considered at 2.0 m

Heading portion	
Area of excavation upto payline	34.0369 m^2
Drilling depth	2.0 m
No. of holes considering 2.0 holes per m^2 (34.0369× 2.0)	69 Nos
Drilling depth for 69 holes (69×2.0×1.1)	151.8 m
Benching portion	
Area of excavation upto payline	13.8665 m^2
Drilling depth	2.0 m
No. of holes considering 2.0 holes per m^2 (13.8665×2.0)	28 Nos
Drilling depth for 80 holes (28×2.0×1.1)	61.6 m
Total depth of drilling (151.8+61.6)	213.4 m
Loading explosive and blasting	
Total area of excavation (34.0369+13.8665)	47.9034 m^2
Depth of pull per blast for 2.0 m deep holes	3.0 m
Quantity of in-situ excavation per blast (47.9034×3.0)	**143.7102 m^3**
Quantity of explosive small dia per blast @ 0.8 kg per m^3(143.7102×0.8)	114.96 kg
Quantity of explosive for secondary blasting @ 10 %	11.49 kg
Quantity of delay detonators per blast (69+28)	97 Nos.
Quantity of electric detonators for secondary blasting (LS)	10 Nos.
Detonating fuse coil	213.4 Rm

Requirement of materials

Explosive small dia (114.96+11.49)	126.45 kg
Elecic short delay detonators (69+28)	97 Nos
Electric detonators for secondary blasting	10 Nos

Fuse coil	213.4 Rm

RATE ANALYSIS **UNIT** **: 143.7102 m^3**

A.MATERIALS

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Small dia explosive	kg	126.45	60	7587
2	Delay detonators	Nos	97	20	1940
3	Electric detonator	Nos	10	12	120
4	Detonating fuse coil	Rm	213.4	9	1920.6
5	Use rate of drill rod 2.0 m long	Rm	214	47.83	10235.62
	Reconditioning charges @ 10%				1023.562
6	Use rate of air hose	Hour	32	6.25	200
7	Use rate of water hose	Hour	32	5.78	185
8	Sundries (paint / template etc)	LS	9	44	396
				Total	23607.782

Add for small Tools and Plants	@ 1	236.077
Add for Contractor's Profit	@ 10%	2360.778
Add for Contractor's Overheads	@ 5%	1180.389
Total cost of Material		**27385.026**
Add for Air and Water line	@ 0.80 %	743.967
Add for Ventilation	@ 6.0 %	5579.759

3.37 Abstract of cost details of 3m Pull length in Pressure shaft by Drill & Blast method

A.Cost of Materials	27385.026
B.Hire charges of Machinery	37868.2
C.Cost of Labour	27742.7634
TOTAL	**92995.9894**
Add for Lighting @ 1.80 %	1673.927
Add for Electrical sub-station / Demand charges @ 3.80 %	3533.847
Add for other Enabling works @ 1.70 %	1580.931

Total cost for 143.7102 m^3	**106108.4204**

Rate per m^3	**738.349**
For 1 cycle (3 m pull length) rate per m^3	**738.349**
Total length of Pressure Shaft (211 + 197 + 184 + 172)	**764 m**
90 % considered without rib support	
Total length in case of without rib support	687.6 m
Total cost (738.349 × 687.6 m × 47.9034 m^2)	**24320018.34**

Consideration for 1.5 m pull length:

Heading portion	
Area of excavation upto payline	34.0369 m^2
Drilling depth	1.0 m
No. of holes considering 2.0 holes per m^2 (34.0369× 2.0)	69 Nos
Drilling depth for 165 holes **(69×1.0×1.1)**	**75.9 m**
Benching portion	
Area of excavation upto payline	13.8665 m^2
Drilling depth	1.0 m
No. of holes considering 2.0 holes per m^2 (13.8665×2.0)	28 Nos
Drilling depth for 80 holes **(28×1.0×1.1)**	**30.8 m**
Total depth of drilling **(75.9 + 30.8) m**	**106.7 m**
Loading explosive and blasting	
Total area of excavation	47.9034 m^2
Depth of pull per blast for1.0 m deep holes	1.5 m
Quantity of in-situ excavation per blast (47.9034×1.5)	**71.8551 m^3**
Quantity of explosive small dia per blast @ 0.8 kg per m^3(71.8551×0.8)	57.4840 kg
Quantity of explosive for secondary blasting @ 10 %	5.7484 kg
Quantity of delay detonators per blast (69+28)	97 Nos.

Quantity of electric electric detonators for secondary blasting (LS)	10 Nos.
Detonating fuse coil	213.4 Rm
Requirement of materials	
Explosive small dia **(57.4840 + 5.7484)**	**63.2324 kg**
Elecic short delay detonators **(69 + 28)**	**97 Nos**
Electric detonators for secondary blasting	**10 Nos**
Fuse coil	**213.4 Rm**

RATE ANALYSIS UNIT : 71.8551 m^3

A.MATERIALS

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Small dia explosive	kg	63.232	60	3793.944
2	Delay detonators	Nos	97	20	1940
3	Electric detonator	Nos	10	12	120
4	Detonating fuse coil	Rm	213.4	9	1920.6
5	Use rate of drill rod 2.0 m long	Rm	200	47.83	9566
	Reconditioning charges @ 10%				956.6
6	Use rate of air hose	Hour	32	6.25	200
7	Use rate of water hose	Hour	32	5.78	185
8	Sundries (paint / template etc)	LS	9	44	396
				Total	19078.144

Add for small Tools and Plants	@ 1	190.781
Add for Contractor's Profit	@ 10%	1907.814
Add for Contractor's Overheads	@ 5%	953.907
Total cost of Material		**22130.646**

3.38 Abstract of cost details for 1.5m pull length in Pressure shaft by Drill & Blast method

A.Cost of Materials	22130.646
B.Hire charges of Machinery	37868.2
C.Cost of Labour	27742.7634

TOTAL	**87741.6094**
Add for Air and Water line @ 0.80 %	701.932
Add for Ventilation @ 6.0 %	5264.496
Add for Lighting @ 1.80 %	1579.348
Add for Ele sub-station / Demand charges @ 3.80 %	3334.181
Add for other Enabling works @ 1.70 %	1491.607
Total cost for 71.8551 m^3	**100113.173**
Rate per m^3	**1393.264**

For 1 cycle (1.5 m pull length) rate per m^3	**1393.264**
Total length of Pressure Shaft (211 + 197 + 184 + 172) m	**764 m**
10 % considered with rib support	
Total length in case of without rib support	76.4 m
Total cost (1393.264×76.4 m×47.9034 m^2)	**5099095.118**
Total cost in Excavation for Pressure Shaft (24320018.34+5099095.118)	**29419113.46**

3.39 Cost estimation for rock bolts support work in Pressure shaft by Drill & Blast method

Rock bolt calculation:

Distance in Good Rock(15%) + Fair Rock(60%) of (211 + 197 + 184 + 172 = 764 m) : 573 m

In 3 m stretch 17 Nos of Rock bolt is required.

So rock bolt only needed in Heading.

So 9 Nos of Rock bolt is required

Nos of cycle in Pressure Shaft for rock bolt (573m / 3m) : 191 Nos

Nos of rock bolt in 573 m (191×9) : 1719 Nos

For Good and Fair Rock	
Length of rock bolt excluding threaded portion for 1719 bolts (1719×4)	6876 m

Quantity of drilling for 1416 bolts	764 m
Rate of drilling for rock bolts including shifting	4 m / hr
Time for drilling 6876 m with 4 jack hammers (6876 / 4 / 4) say	429.75 hour
For Poor and V. Poor Rock	
Distance in Poor Rock(15%) + V.Poor Rock(10%) of m	191 m
In 3 m stretch 22 Nos of Rock bolt is required.	
So rock bolt only needed in Heading.	
So 11 Nos of Rock bolt is required	
Nos of cycle in Pressure Shaft for rock bolt (191m / 3m)	63.66 Nos
Nos of rock bolt in 191 m (63.66×11)	700 Nos
Length of rock bolt excluding threaded portion for 700 bolts (700×4)	2800 m
Quantity of drilling for 700 bolts	764 m
Rate of drilling for rock bolts including shifting	4 m per hour
Time for drilling 2516 m with 4 jack hammers (2800 / 4 / 4) say	175 hour

Requirement of materials (for Good(15%) And Fair Rock (60%))	
Quantity of 25 mm dia bars for (1719) bolts with 2.5 % wastage (1719 x 4.15 x 3.85 x 1.025)	28151.955 kg
Quantity of washer for 1719 bolts with 2.5 % wastage (1719 x 4 x 0.2 x 0.2 x 78.5 x 1.025)	22130.406 kg
Quantity of nuts for 1719 bolts (1719 x 2 x 0.2)	687.6 kg
Quantity of grout capsule for 1719 bolts (1719 x 1)	1719 Nos
Requirement of materials (for Poor (15%) And V. Poor Rock (10%))	
Quantity of 25 mm dia bars for (700) bolts with 2.5 % wastage (700 x 4.15 x 3.85 x 1.025)	11463.856 kg
Quantity of washer for 700 bolts with 2.5 % wastage (700 x 4 x 0.2 x 0.2 x 78.5 x 1.025)	9011.8 kg
Quantity of nuts for 700 bolts (700x 2 x 0.2)	280 kg

Quantity of grout capsule for 700 bolts (700 x 1)	700 Nos

RATE ANALYSIS (Good &Fair Rock) UNIT : 6876.0 Rm

A.MATERIALS

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Rein.Steel with 2.5 % wastage	kg	28151.96	48.48	1364806.778
2	Steel plate for washers	kg	22130.41	51.14	1131748.963
3	Resin bond cement grout capsule	Nos	1719	65	111735
4	M S Nuts for bolts	kg	687.6	90	61884
5	Use rate of drill rod	Rm	6876	47.83	328879.08
	Reconditioning charges @ 10%				32887.908
6	Use rate of air hose 4 Nos	Hour	6	6.25	37.5
7	Use rate of water hose 4 Nos	Hour	6	5.78	34.69
8	Sundries(gas for cutting etc)	LS	5	44	220
				Total	3032233.919

Add for small Tools and Plants	@ 1%	30322.339
Add for Contractor's Profit	@ 10%	303223.391
Add for Contractor's Overheads	@ 5%	151611.696
Total cost of Materials		**3517391.345**

RATE ANALYSIS (Poor & V. Poor Rock) UNIT : 2800.0 Rm

A.MATERIALS:

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Rein.Steel with 2.5 % wastage	kg	11463.9	48.48	555767.738
2	Steel plate for washers	kg	9011.8	51.14	460863.452
3	Resin bond cement grout capsule	Nos	700	65	45500
4	M S Nuts for bolts	kg	280	90	25200
5	Use rate of drill rod	Rm	2800	47.83	133924
	Reconditioning charges @ 10%				13392.4
6	Use rate of air hose 4 Nos	Hour	6	6.25	37.5
7	Use rate of water hose 4 Nos	Hour	6	5.78	34.69
8	Sundries(gas for cutting etc)	LS	5	44	220
				Total	1234939.78

Add for small Tools and Plants	@ 1%	12349.397
Add for Contractor's Profit	@ 10%	123439.978
Add for Contractor's Overheads	@ 5%	61746.989

Total cost of Materials		**1432476.144**

3.40 Abstract of cost details for Rock bolt support in Pressure shaft by Drill & Blast method

For Good and fair Rock	
A. Cost of Materials	3517391.345
B. Hire charges of Machinery	4073.28
C. Cost of Labour	4371.02
TOTAL	**3525835.645**
Add for Air and Water line @ 0.80%	28206.685
Add for Lighting @ 1.80%	63465.041
Add for Ele sub-station / Demand charges @ 3.80%	133981.754
Add for other enabling works @ 1.70%	59939.205
TOTAL	**3811428.33**
Add for 1 km rehandling lead charges	
For steel 150 kg @ 218.40 per tonne (0.15×218.40)	32.76
Total cost for 6876 Rm	**3811461.09**

For Poor and V. Poor Rock	
A. Cost of Materials	1432476.144
B. Hire charges of Machinery	4073.28
C. Cost of Labour	4371.02
TOTAL	**1440920.444**
Add for Air and Water line @ 0.80%	11527.363
Add for Lighting @ 1.80%	25936.567
Add for Eletrical sub-station / Demand charges @ 3.80%	54754.976
Add for other enabling works @ 1.70%	24495.647
TOTAL	1557634.997
Add for 1 km rehandling lead charges	
For steel 150 kg @ 218.40 per tonne (0.15×218.40)	32.76

Total cost for 2800 Rm : 1557667.757

Total cost for Rock bolt support work in (Good & Fair Rock + Poor & Very Poor Rock):

Total cost for Rock bolt support work (3811461.09+1557667.757): **5369128.847**

3.41 Cost estimation for kerb & invert lining in Pressure shaft by Drill & Blast method

Rate per m^3 : 6326.00

Total cost for Kerb and Invert Lining (1.3+1.3+1.3) = 3.9 m^2 × 764 m ×6326 = **18848949.6**

3.42 Cost estimation for overt lining in Pressure shaft by Drill & Blast method

Assume 15 m long collapsible type steel gantry	
Quantity of concrete per gantry considering 0.7m thick lining (9.79m^2×15m)	146.85 m^3
Concrete for filling support reaches @ 45 %	66.082 m^3
Average quantity of concrete per gantry length of lining say	**146.85 m^3**
Requirement of materials	
Cement for mix with 1 % wastage (146.85 x 300 x 1.01)	4495.55 kg
Cement for incidentals @ 1 kg per m^3 (146.85 x 1)	146.85 kg
Coarse aggregate 40-20 mm size range (146.85 x 0.79 x 0.5 x 1.02)	59.165 m^3
Coarse aggregate 20-10 mm size range (146.85 x 0.79 x 0.3 x 1.02)	35.499 m^3
Coarse aggregate 10-4.75 mm size (146.85 x 0.79 x 0.2 x 1.02)	23.666 m^3
Fine aggregate (146.85 x 0.425 x 1.02)	63.659 m^3
Super plasticiser (146.85 x 0.90 x 1.02)	143.808 litres

RATE ANALYSIS UNIT : 146.85 m^3

A.MATERIALS:

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Cement 43 Gr	kg	4495.6	7.5	33716.625
	Cement for incidentals @ 1 kg per cum	kg	146.85	7.5	1101.375
2	Fine aggregate (screened)	cum	63.659	730	46471.07
3	Coarse aggregate 40-20 mm	cum	59.165	740	43782.1
	Coarse aggregate 20-10 mm	cum	35.499	950	33724.05
	Coarse aggregate 10-4.75 mm	cum	23.666	1160	27452.56
4	Super plasticiser	litre	143.81	105	15099.84
5	Use rate of end shuttering	sqm	6	158.77	952.6
6	Use rate of steel gantry	sqm	100	176.95	17695.03
7	Sundries (placer pipe etc)	LS	5	44	220
				Total	220215.25

Add for small Tools and Plants	@ 1%	2202.152
Add for Contractor's Profit on Energy	@ 10%	22021.525
Add for Contractor's Overheads	@ 5%	11010.762
Total cost of Materials		**55449.689**

3.43 Abstract of cost details for Overt lining in Pressure shaft by Drill & Blast method

A. Cost of Materials	255449.689
B. Hire charges of Machinery	70930.40
C. Cost of Labour	31125.79
TOTAL	**357505.879**
Add for Air and Water line @ 0.80%	2860.047
Add for Lighting @ 1.80	643510.582
Add for Electrical sub-station charges @ 3.80%	13585.223
Add for other enabling works @ 1.70%	607759.994
Total cost for 146.85 m^3	**1625221.671**

Cost for per m^3	11067.22

Total cost for Overt Lining (9.79 m^2)×(764 m)×(11067.22) : **82777936.02**

Total cost in Pressure Shaft (Excavation + Rock bolt support + Kerb & Invert Lining + Overt Lining):

(90% without rib support +10% with rib support + Good & Fair rock + Poor & Very Poor rock + Kerb & Invert lining + Overt lining):

(24320018.34+5099095.118 + 3811461.09 + 1557667.757 + 18848949.6 + 82777936.02)
= 136415128

3.44 Cost estimation in Tailrace tunnel by Drill & Blast method

ITEM: Excavation for tunnel in the case of Diversion Tunnel by heading and benching.

DATA Size of tunnel assumed (finished section)	9.645 m dia
Shape of tunnel assumed for excavation	Horse-shoe shaped
Height of tunnel assumed (finished section)	9.645 m dia
Length of Pressure Shaft (502 + 490 + 475 + 460) m	1927 m
Thickness of lining	0.70 m
Diameter of tunnel upto pay line for excavation	9.645 m

Consideration for 3 m pull length:

Checking alignment and marking hole locations:

Use drilling jumbo for 1 hour for marking hole locations.

Drilling holes.

The depth of hole for 3.0 m pull is considered at 2.0 m

Heading portion	
Area of excavation upto payline	52.44 m^2
Drilling depth	2.0 m
No. of holes considering 2.0 holes per m^2 (52.44× 2.0)	105 Nos
Drilling depth for 105 holes (105×2.0×1.1)	231 m
Benching portion	
Area of excavation upto payline	23.21 m^2
Drilling depth	2.0 m

No. of holes considering 2.0 holes per m^2 (23.21×2.0)	47 Nos
Drilling depth for 47 holes (47×2.0×1.1)	103.4 m
Total depth of drilling (231+103.4) m	334.4 m
Loading explosive and blasting	
Total area of excavation	75.65 m^2
Depth of pull per blast for 2.0 m deep holes	3.0 m
Quantity of in-situ excavation per blast (75.65×3.0)	**226.95 m^3**
Quantity of explosive small dia per blast @ 0.8 kg per m^3(226.95×0.8)	181.56 kg
Quantity of explosive for secondary blasting @ 10 %	18.156 kg
Quantity of delay detonators per blast (105+47)	152 Nos
Quantity of electric detonators for secondary blasting (LS)	10 Nos
Detonating fuse coil	305 Rm

Requirement of materials	
Explosive small dia (181.56+18.156)	199.716 kg
Elecic short delay detonators (105+47)	152 Nos
Electric detonators for secondary blasting	10 Nos
Fuse coil	305 Rm

RATE ANALYSIS UNIT : 226.95 m^3

A.MATERIALS

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Small dia explosive	kg	199.72	60	11983.2
2	Delay detonators	Nos	152	21	3192
3	Electric detonator	Nos	10	12	120
4	Detonating fuse coil	Rm	305	9	2745
5	Use rate of drill rod 2.0 m long	Rm	334.4	47.83	15994.352
	Reconditioning charges @ 10%				1599.435
6	Use rate of air hose	Hour	32	6.25	200
7	Use rate of water hose	Hour	32	5.78	185
8	Sundries (paint / template etc)	LS	9	44	396
				Total	36414.987

Add for small Tools and Plants	@ 1	364.149
Add for Contractor's Profit	@ 10%	3641.498
Add for Contractor's Overheads	@ 5%	1820.749
Total cost of Material		**42241.383**

3.45 Abstract of cost details for 3m Pull length in Tailrace tunnel by Drill & Blast method

A.Cost of Materials	42241.383
B.Hire charges of Machinery	37868.2
C.Cost of Labour	27742.7634
TOTAL	**107852.346**
Add for Air and Water line @ 0.80 %	862.818
Add for Ventilation @ 6.0 %	6471.140
Add for Lighting @ 1.80 %	1941.342
Add for Electrical sub-station / Demand charges @ 3.80 %	4098.389
Add for other Enabling works @ 1.70 %	183348.988
Total cost for 226.95 m^3	**304575.015**
Rate per m^3	**1342.035**

For 1 cycle (3 m pull length) rate per m^3	**1342.035**
Total length of Tailrace Tunnel (502 + 490 + 475 + 460)	**1927 m**
90 % considered without rib support	
Total length in case of without rib support	1734.3 m
Total cost (1734.3 m × 75.65 m^2 × 1342.035)	**176074716.9**

Consideration for 1.5 m pull length:

Heading portion	
Area of excavation upto payline	52.44 m^2
Drilling depth	1.0 m
No. of holes considering 2.0 holes per m^2 (52.44× 2.0)	105 Nos
Drilling depth for 105 holes **(105×1.0×1.1)**	**115.5 m**
Benching portion	
Area of excavation upto payline	23.21 m^2
Drilling depth	1.0 m
No. of holes considering 2.0 holes per m^2 (23.21×2.0)	47 Nos
Drilling depth for 47 holes **(47×1.0×1.1)**	**51.7 m**
Total depth of drilling **(115.5 + 51.7) m**	**106.7 m**
Loading explosive and blasting	
Total area of excavation	75.65 m^2
Depth of pull per blast for1.0 m deep holes	1.5 m
Quantity of in-situ excavation per blast (75.65×1.5)	**113.475 m^3**

Quantity of explosive small dia per blast @ 0.8 kg per m^3(113.475×0.8)	90.78 kg
Quantity of explosive for secondary blasting @ 10 %	9.078 kg
Quantity of delay detonators per blast (105+47)	152 Nos.
Quantity of electric electric detonators for secondary blasting (LS)	10 Nos.
Detonating fuse coil	305 Rm

Requirement of materials	
Explosive small dia **(98.78 + 9.078)**	**107.858 kg**
Elecic short delay detonators **(105 + 47)**	**152 Nos**
Electric detonators for secondary blasting	**10 Nos**
Fuse coil	**305 Rm**

RATE ANALYSIS UNIT : 113.475 m^3

A.MATERIALS

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Small dia explosive	kg	107.86	60	6471.48
2	Delay detonators	Nos	152	20	3040
3	Electric detonator	Nos	10	12	120
4	Detonating fuse coil	Rm	305	9	2745
5	Use rate of drill rod 2.0 m long	Rm	106.7	47.83	5103.461
	Reconditioning charges @ 10%				510.346
6	Use rate of air hose	Hour	32	6.25	200
7	Use rate of water hose	Hour	32	5.78	185
8	Sundries (paint / template etc)	LS	9	44	396
				Total	18771.287

Add for small Tools and Plants	@ 1	187.712
Add for Contractor's Profit	@ 10%	1877.128
Add for Contractor's Overheads	@ 5%	938.564
Total cost of Material		**21774.691**

3.46 Abstract of cost details for 1.5m Pull length in Tailrace tunnel by Drill & Blast method

A.Cost of Materials	21774.691
B.Hire charges of Machinery	37868.2

C.Cost of Labour	27742.7634
TOTAL	**87385.654**
Add for Air and Water line @ 0.80 %	699.085
Add for Ventilation @ 6.0 %	5243.139
Add for Lighting @ 1.80 %	1572.941
Add for Ele sub-station / Demand charges @ 3.80 %	3320.654
Add for other Enabling works @ 1.70 %	1485.556
Total cost for 113.475 m^3	99707.029
Rate per m^3	**878.669**
For 1 cycle (1.5 m pull length) rate per m^3	878.669
Total length of Tailrace Tunnel (502 + 490 + 475 + 460) m	**1927 m**
10 % considered with rib support	
Total length in case of without rib support	**192.7 m**
Total cost (192.7 m×75.65 m^2×878.669)	12809021.41
Total cost in Excavation for Tailrace Tunnel (176074716.9+12809021.41) = **188883738.3**	

3.47 Cost estimation for rock bolts support work in Tailrace tunnel by Drill & Blast method

Rock bolt calculation:

Distance in Good Rock(15%) + Fair Rock(60%) of (502 + 490 + 475 + 460 = 1927 m) : 1445.25 m

In 3 m stretch 20 Nos of Rock bolt is required.

So rock bolt only needed in Heading.

So 10 Nos of Rock bolt is required

Nos of cycle in Pressure Shaft for rock bolt (1445.25m / 3m) : 482 Nos

Nos of rock bolt in 1445.25 m (482×10) : 4820 Nos

For Good and Fair Rock	
Length of rock bolt excluding threaded portion for 4820 bolts (4820×4)	19280 m

Quantity of drilling for 4820 bolts	19280 m
Rate of drilling for rock bolts including shifting	4 m / hr
Time for drilling 19280 m with 4 jack hammers (6876 / 4 / 4) say	1205 hour
For Poor and V. Poor Rock	
Distance in Poor Rock(15%) + V.Poor Rock(10%) of m	481.75 m
In 3 m stretch 26 Nos of Rock bolt is required.	
So rock bolt only needed in Heading.	
So 13 Nos of Rock bolt is required	
Nos of cycle in Pressure Shaft for rock bolt (481.75m / 3m)	161 Nos
Nos of rock bolt in 481.75 m (161×13)	2093 Nos
Length of rock bolt excluding threaded portion for 2093 bolts (2093×4)	8372 m
Quantity of drilling for 2093 bolts	8372 m
Rate of drilling for rock bolts including shifting	4 m per hour
Time for drilling 8372 m with 4 jack hammers (2800 / 4 / 4) say	524 hour

Requirement of materials (for Good(15%) And Fair Rock (60%))	
Quantity of 25 mm dia bars for (4820) bolts with 2.5 % wastage (4820 x 4.15 x 3.85 x 1.025)	78936.838 kg
Quantity of washer for 4820 bolts with 2.5 % wastage (4820 x 4 x 0.2 x 0.2 x 78.5 x 1.025)	62052.68 kg
Quantity of nuts for 4820 bolts (4820 x 2 x 0.2)	1928 kg
Quantity of grout capsule for 4820 bolts (4820 x 1)	4820 Nos
Requirement of materials (for Poor (15%) And V. Poor Rock (10%))	
Quantity of 25 mm dia bars for (2093) bolts with 2.5 % wastage (2093 x 4.15 x 3.85 x 1.025)	34276.930 kg
Quantity of washer for 2093 bolts with 2.5 % wastage (2093 x 4 x 0.2 x 0.2 x 78.5 x 1.025)	26945.282 kg
Quantity of nuts for 2093 bolts (2093x 2 x 0.2)	837.2 kg

Quantity of grout capsule for 2093 bolts	(2093 x 1)	2093 Nos

RATE ANALYSIS (Good &Fair Rock) UNIT : 19280 Rm

A.MATERIALS

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Rein.Steel with 2.5 % wastage	kg	34277	48.48	1661745.566
2	Steel plate for washers	kg	26945	51.14	1377981.721
3	Resin bond cement grout capsule	Nos	2093	65	136045
4	M S Nuts for bolts	kg	837.2	90	75348
5	Use rate of drill rod	Rm	19280	47.83	922162.4
	Reconditioning charges @ 10%				92216.24
6	Use rate of air hose 4 Nos	Hour	6	6.25	37.5
7	Use rate of water hose 4 Nos	Hour	6	5.78	34.69
8	Sundries(gas for cutting etc)	LS	5	44	220
				Total	4265791.117

Add for small Tools and Plants	@ 1%	42657.911
Add for Contractor's Profit	@ 10%	426579.111
Add for Contractor's Overheads	@ 5%	213289.555
Total cost of Materials		**4948317.694**

RATE ANALYSIS (Poor & V. Poor Rock) UNIT : 8372 Rm

B.MATERIALS:

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Rein.Steel with 2.5 % wastage	kg	34277	48.48	1661745.566
2	Steel plate for washers	kg	26945	51.14	1377981.721
3	Resin bond cement grout capsule	Nos	2093	65	136045
4	M S Nuts for bolts	kg	837.2	90	75348
5	Use rate of drill rod	Rm	8372	47.83	400432.76
	Reconditioning charges @ 10%				40043.276
6	Use rate of air hose 4 Nos	Hour	6	6.25	37.5
7	Use rate of water hose 4 Nos	Hour	6	5.78	34.69
8	Sundries(gas for cutting etc)	LS	5	44	220
				Total	3691888.513

Add for small Tools and Plants	@ 1%	36918.885
Add for Contractor's Profit	@ 10%	369188.851
Add for Contractor's Overheads	@ 5%	184594.425
Total cost of Materials		**4282590.675**

3.48 Abstract of cost details for Rock bolt support in Tailrace tunnel by Drill & Blast method

For Good and fair Rock	
A. Cost of Materials	4948317.694
B. Hire charges of Machinery	4073.28
C. Cost of Labour	4371.02
TOTAL	**4956761.994**
Add for Air and Water line @ 0.80%	39654.095
Add for Lighting @ 1.80%	89221.715
Add for Ele sub-station / Demand charges @ 3.80%	188356.955
Add for other enabling works @ 1.70%	84264.953
TOTAL	**5358259.712**
Add for 1 km rehandling lead charges	
For steel 150 kg @218.40 per tonne (0.15×218.40)	32.76
Total cost for 19280 Rm	**5358292.472**

For Poor and V. Poor Rock	
A. Cost of Materials	4282590.675
B. Hire charges of Machinery	4073.28
C. Cost of Labour	4371.02
TOTAL	**4291034.975**
Add for Air and Water line @ 0.80%	34328.279
Add for Lighting @ 1.80%	77238.629
Add for Eletrical sub-station / Demand charges @ 3.80%	163059.329
Add for other enabling works @ 1.70%	72947.594
TOTAL	4638608.806
Add for 1 km rehandling lead charges	
For steel 150 kg @218.40 per tonne (0.15×218.40)	32.76
Total cost for 8370 Rm	**4638641.566**

Total cost for Rock bolt support work in (Good & Fair Rock + Poor & Very Poor Rock):

Total cost for Rock bolt support work (5358292.472+4638641.566) **: 9996934.038**

3.49 Cost calculation for kerb & invert lining in Tailrace tunnel by Drill & Blast method

Rate per m^3 : 6326.00

Total cost for Kerb and Invert Lining (1.9+1.9+2.2) = 6.0 m^2 × 1927 m × 6326 = **73141212.0**

3.50 Cost estimation for Overt lining in Tailrace tunnel by Drill & Blast method

Assume 15 m long collapsible type steel gantry	
Quantity of concrete per gantry considering 1.0m thick lining(12.22m^2×15m)	183.3 m^3
Concrete for filling support reaches @ 45 %	82.485 m^3
Average quantity of concrete per gantry length of lining say	**183.3 m^3**

Requirement of materials		
Cement for mix with 1 % wastage	(183.3 x 300 x 1.01)	55539.9 kg
Cement for incidentals @ 1 kg per m^3	(183.3 x 1)	183.3 kg
Coarse aggregate 40-20 mm size range	(183.3 x 0.79 x 0.5 x 1.02)	73.851 m^3
Coarse aggregate 20-10 mm size range	(183.3 x 0.79 x 0.3 x 1.02)	44.310 m^3
Coarse aggregate 10-4.75 mm size	(183.3 x 0.79 x 0.2 x 1.02)	29.540 m^3
Fine aggregate	(183.3 x 0.425 x 1.02)	79.460 m^3
Super plasticiser	(183.3 x 0.90 x 1.02)	168.269 litres

RATE ANALYSIS UNIT : 183.3 m^3

A.MATERIALS

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Cement 43 Grade	kg	55540	7.5	416549.25
	Cement for incidentals @ 1 kg per cum	kg	183.3	7.5	1374.75
2	Fine aggregate (screened)	cum	79.46	730	58005.8
3	Coarse aggregate 40-20 mm	cum	73.851	740	54649.74
	Coarse aggregate 20-10 mm	cum	44.31	950	42094.5
	Coarse aggregate 10-4.75 mm	cum	29.54	1160	34266.4
4	Super plasticiser	litre	168.27	105	17668.245
5	Use rate of end shuttering	sqm	6	158.77	952.6
6	Use rate of steel gantry	sqm	100	176.95	17695.03
7	Sundries (placer pipe etc)	LS	5	44	220
				Total	643476.315

Add for small Tools and Plants	@ 1%	6434.763
Add for Contractor's Profit on Energy	@ 10%	64347.631
Add for Contractor's Overheads	@ 5%	32173.838
Total cost of Materials		**746432.547**

3.51 Abstract of cost details for Overt lining in Tailrace tunnel by Drill & Blast method

A. Cost of Materials	746432.547

B. Hire charges of Machinery	70930.40
C. Cost of Labour	31125.79
TOTAL	**848488.737**
Add for Air and Water line @ 0.80%	6787.909
Add for Lighting @ 1.80	15272.797
Add for Electrical sub-station charges @ 3.80%	32242.572
Add for other enabling works @ 1.70%	14424.308
Total cost for 183.3 m^3	**917216.323**
Cost for per m^3	**5003.907**

Total cost for Overt Lining (12.22 m^2)×(1927 m)×(5003.907) : 117831701.8

Total cost in Tailrace Tunnel (Excavation + Rock bolt support + Kerb & Invert Lining + Overt Lining):

(90% without rib support +10% with rib support + Good & Fair rock + Poor & Very Poor rock + Kerb & Invert lining + Overt lining) :

(176074716.9+12809021.41+5358292.472+4638641.566+73141212+117831701.8) = **389853586.1**

EXCAVATION BY MECHANICAL METHOD

3.52 **Cycle Time calculation for different activities for heading work in Diversion tunnel by Mechanical method**

1st.Activity: Survey - 0.5 hours

2nd.Activity: Time required for Excavation work = $\frac{\text{Excavated Quantity}}{\text{productivity of Roadheader}}$

Excavated quantity = c/s area of tunnel × length of drill = $(\frac{\pi \times d^2}{4})$×length of drill

$= \frac{\pi \times 8.0225^2}{4} \times 3 = 151.6458\ \boldsymbol{m^3}$

= Excavated quantity = 151.6458 × 1.2 (20 % as over-break quantity)

= 182.0m^3 (Excavated quantity will be more because there wil be some voids in the quantity)

Time required for Excavated quantity = $\frac{\text{Excavated quantity}}{\text{Productivity of Roadheader}} = \frac{182\ m^3}{15 m^3 per\ hour}$ = 12.0 Hour

3rd Activity: Mucking time = $\frac{\text{Mucking quantity}}{\text{Productivity of Loader}} = \frac{182\ m^3}{65 m^3 per\ hou}$ = 3.0 hour

4th Activity: Scaling time – 1.0 hours

4th.Activity: Time required for shotcreting =

1.For Good Rock Shotcreting (5 cm) = 0.5 hour

2.For Fair Rock Shotcreting (10 cm) = 1.0 hour

3.For Poor Rock Shotcreting (15 cm) = 2.0 hour

4.For Very Poor Rock Shotcreting (20 cm) = 2.5 hour

5th. Activity: Rock bolt drilling & fixing:

For Good & Fair Rock: Total rock bolt drilling fixing time = (1+1) hour = 2.0 hour

For Poor & Very Poor Rock: Total rock bolt drilling fixing time = (1.5+1.5) hour = 3.0 hour

3.53 Cycle time for Heading in Diversion Tunnel

3m pull length per cycle to be considered for heading without rib and 1.5 m pull length to be considered for heading with rib.

3.53.1. Cycle time for heading without rib support in Diversion tunnel

Table 3.49 Cycle time for heading without rib support in DT

S.N	Description	Quantity	Units
1	Pull length	3	m
2	Heading c/s area	82.67	sum
3	Excavation quantity	248.01	cum
4	Survey	0.5	Hour
5	Excavation time	12	Hour
6	Mucking	3	Hour
7	Scaling	1	Hour
8	shotcreting	1	Hour
9	Rockbolt drilling & fixing	2	Hour
	Total cycle time for 3m pull length	19.5	**Hour**

3.53.2 Cycle time for heading with rib support in Diversion tunnel

Excavation with rib supporting is considered as 10 % of total excavation in Diversion tunnel

Table 3.50 Cycle time for heading with rib support in DT

S.N	Description	Quantity	Units
1	Pull Length	1.5	m
2	Heading c/s area	82.67	sqm
3	Excavation quantity	124.005	cum
4	Survey	0.5	Hour
5	Excavation time	12	Hour
6	Mucking	3	Hour
7	Scaling	1	Hour
8	Shotcreting	2.5	Hour
9	Rockbolt drilling & fixing	3	Hour
10	Rib erection	3	Hour
11	Lagging fixing	2.5	Hour
12	Stopper fixing&Back fill concrete	4	Hour
	Total cycle time per 1.5m pull length	31.5	Hour
	Total cycle time per 3m pull length	63	**Hour**

Time Schedule:

Among the total excavation 90 % is considered as without rib supporting and 10 % as with rib supporting.

Weighted average cycle time = $(19.5 \times 0.9) + (63 \times 0.1) = 24$ hours per 3m pull length

Progress per month = $\frac{26(\text{working day per month})\times 22(\text{working hours per day})\times 3\text{m}(\text{pull length})}{24\ (\text{weighted cycle time in hours})}$

= 71.5 m per month

Time required for completion of heading work = $\frac{\text{Length of Diversion tunnel}-1}{\text{Work progress per month}}$

= $\frac{472}{71.5\ \text{m per month}}$ = 6.60 month = 198 days

Time required for completion of heading work = $\frac{\text{Length of Diversion tunnel}-2}{\text{Work progress per month}}$

= $\frac{552}{71.5\ \text{m per month}}$ = 7.72 month = 231 days

3.54 Cycle time calculation for Benching in Diversion tunnel by Mechanical method

1st. Activity: Surveying time – 0.5 hours

2nd. Activity: Excavation time = $\frac{\text{Excavation quantity}}{\text{productivity of Roadheader}}$

Excavated quantity = C/S area of tunnel × length of drill

= $(\frac{\pi\times d^2}{4})$×drill length = $(\frac{\pi\times 4.3225^2}{4})$ ×3m = 41.4690 m^3

Excavated quantity = 41.4690 × 1.2 (20 % as over-break quantity)

= 52.8277m^3 (Excavated quantity will be more because there will be some voids in the quantity)

Time required for Excavation quantity= $\frac{\text{Excavation quantity}}{\text{Productivity of Roadheader}} = \frac{52.8277\ m^3}{15m^3/hour}$ = 3.5 hour

3rd. Activity Time required for Mucking quantity= $\frac{\text{Mucking quantity}}{\text{Productivity of Loader}} = \frac{52.8277\ m^3}{65\ \ ^3/hour}$ = 1.0 hour

4th. Activity: Scaling time = 0.5 hour

5th.Activity: Time required for shotcreting =

1.For Good Rock Shotcreting (5 cm) = 0.5 hour

2.For Fair Rock Shotcreting (10 cm) = 0.5 hour

3.For Poor Rock Shotcreting (15 cm) = 1.0 hour

4.For Very Poor Rock Shotcreting (20 cm) = 1.5 hour

3.54.1 Cycle time for benching without rib support in Diversion tunnel

Table 3.51 Cycle time for benching without rib in DT

S.N	Description	Quantity	Units
1	Pull length	3	m
2	Benching c/s area	40.23	sqm
3	Excavation quantity	120.69	cum
4	Survey	0.5	Hour
5	Excavation time	3.5	Hour
6	Mucking	1	Hour
7	Scaling	0.5	Hour
8	shotcreting	0.5	Hour
	Total cycle time for 3m pull length	6	**Hour**

3.54.2 Cycle time for benching with rib support in Diversion tunnel

Table 3.52 Cycle time for benching with rib in DT

S.N	Description	Quantity	Units
1	Pull length	1.5	m
2	Benching c/s area	40.23	sqm
3	Excavation quantity	60.345	cum
4	Survey	0.5	Hour
5	Excavation time	3.5	Hour
6	Mucking	1	Hour
7	Scaling	0.5	Hour
8	Shotcreting	1.5	Hour
9	Rib erection	2	Hour
10	Lagging fixing	1	Hour
11	Backfill concreting	1	Hour
	Total cycle time for 1.5m pull length	11	Hour
	Total cycle time for 3m pull length	22	**Hour**

Time Schedule:

Weighted average cycle time = (6×0.9) + (22×0.1) = 7.6 hours per 3m pull

Progress per month = $\frac{(26(\text{working day per month}) \times 22(\text{working hours per day}) \times 3\text{m pull length})}{7.6\ (\text{weighted average cycle time in hours})}$

= 226 m per month

Time required for Completion of benching work = $\frac{\text{Tunnel length} - 1}{\text{progress per month}}$

= $\frac{472}{226}$ = 2.0 month= 60 days

Time required for Completion of benching work = $\frac{\text{Tunnel length} - 2}{\text{progress per month}}$

= $\frac{552}{226}$ = 2.44 month= 72 days

Table 3.53 Time duration for different rock conditions in Diversion tunnel- 1

DT - 1	Source	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	Inlet	15	59	15	10	99
Heading	Outlet	15	59	15	10	99
Benching	Inlet	4	19	4	4	31

Benching	Outlet	4	19	4	4	31
Kerb	Inlet	3	13	3	2	21
Kerb	Outlet	3	13	3	2	21
Overt	Inlet	3	13	3	3	22
Overt	Outlet	3	13	3	3	22
Invert	Inlet	15	19	15	3	52
Invert	Outlet	15	19	15	3	52

Table 3.54 Time duration for different rock conditions in Diversion tunnel- 2

DT - 2	Source	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	Inlet	17	69	17	11	114
Heading	Outlet	17	69	17	11	114
Benching	Inlet	5	22	5	3	35
Benching	Outlet	5	22	5	3	35
Kerb	Inlet	4	15	4	2	25
Kerb	Outlet	4	15	4	2	25
Overt	Inlet	4	15	4	2	25
Overt	Outlet	4	15	4	2	25
Invert	Inlet	5	23	5	4	37
Invert	Outlet	5	23	5	4	37

Table 3.55 Activities details of DT in case of Roadheader

RHP - ROAD HEADER(50-50)		Classic WBS Layout					28-Apr-17 18:48
Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
RHP - ROAD HEADER(5(		249	249	0%	15-May-17	14-Dec-17	0
mobilisation		30	30	0%	15-May-17	08-Jun-17	0
A1290	mobilisation	30	30	0%	15-May-17	08-Jun-17	0
DT portal		55	55	0%	08-Jun-17	26-Jul-17	0
A1270	dt portal inlet	55	55	0%	08-Jun-17	26-Jul-17	0
A1280	dt portal outlet	28	28	0%	08-Jun-17	03-Jul-17	0
DIVERSION TUNNEL 1		193	193	0%	21-Jun-17	05-Dec-17	11
A1030	Heading Inlet	99	99	0%	21-Jun-17	14-Sep-17	11
A1080	Heading outlet	99	99	0%	21-Jun-17	14-Sep-17	11
A1040	Benching Inlet	31	31	0%	14-Sep-17	11-Oct-17	11
A1090	Benching outlet	31	31	0%	14-Sep-17	11-Oct-17	11
A1060	Kerb inlet	22	22	0%	02-Oct-17	20-Oct-17	11
A1110	kerb outlet	22	22	0%	02-Oct-17	20-Oct-17	11
A1070	Overt inlet	52	52	0%	20-Oct-17	05-Dec-17	11
A1120	overt outlet	52	52	0%	20-Oct-17	05-Dec-17	11
A1050	Invert Inlet	21	21	0%	07-Nov-17	24-Nov-17	22
A1100	Invert Outlet	21	21	0%	07-Nov-17	24-Nov-17	22
DIVERSION TUNNEL 2		204	204	0%	21-Jun-17	14-Dec-17	0
A1170	Heading Inlet	114	114	0%	21-Jun-17	27-Sep-17	0
A1220	Heading outlet	114	114	0%	21-Jun-17	27-Sep-17	0
A1180	Benching Inlet	35	35	0%	27-Sep-17	27-Oct-17	0
A1230	Benching outlet	35	35	0%	27-Sep-17	27-Oct-17	0
A1200	Kerb inlet	25	25	0%	16-Oct-17	06-Nov-17	0
A1250	kerb outlet	25	25	0%	16-Oct-17	06-Nov-17	0
A1210	Overt inlet	37	37	0%	06-Nov-17	07-Dec-17	0
A1260	overt outlet	37	37	0%	06-Nov-17	07-Dec-17	0
A1190	Invert Inlet	25	25	0%	22-Nov-17	14-Dec-17	0
A1240	Invert Outlet	25	25	0%	22-Nov-17	14-Dec-17	0

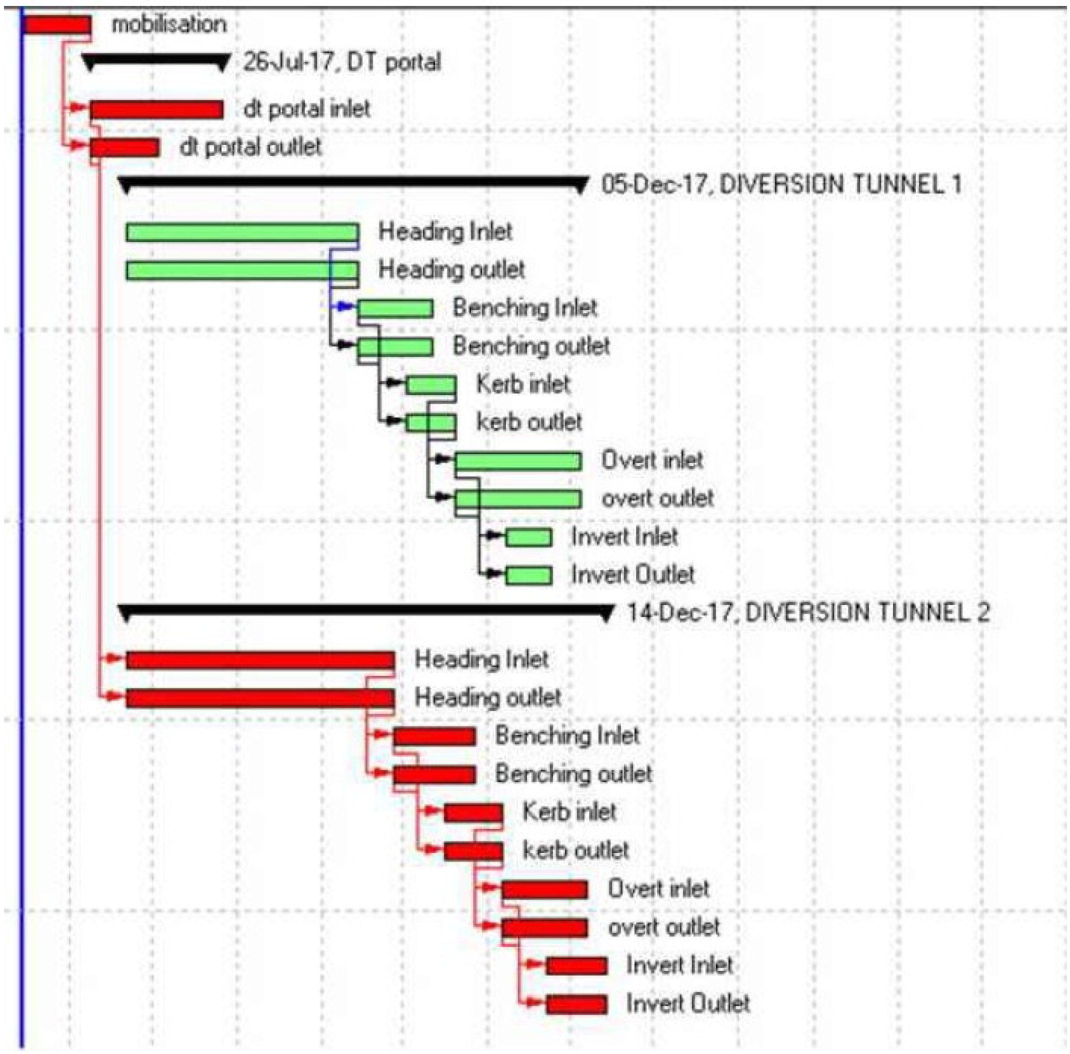


Fig 3.11 Network diagram of Diversion tunnel in case of Roadheader

3.55 Cycle time calculation for different activities for heading work in Pressure shaft by Mechanical method

1st Activity: Survey - 0.5 hours

2nd. Activity: Time required for Excavation work = $\frac{\text{Excavation Quantity}}{\text{productivity of Roadheader}}$

Excavated quantity = $\frac{\text{C/S area of tunnel}}{\text{length of drill}} = (\frac{\pi \times d^2}{4}) \times \text{length of drill}$

$= \frac{\pi \times 5.2725^2}{4} \times 3 = 65.5004\ \boldsymbol{m^3}$

= Excavated quantity = 65.5004 × 1.2 (20 % as over-break quantity)

= $78.6005m^3$ (Excavated quantity will be more because there wil be some voids in the quantity)

Time required for Excavated quantity = $\frac{\text{Excavated quantity}}{\text{Productivity of Roadheader}} = \frac{78.6005\ m^3}{15\ \ ^3}$ per hour = 5.0 hour

3rd. Activity Time required for Mucking quantity = $\frac{\text{Mucking quantity}}{\text{Productivity of Loader}} = \frac{78.6005\ m^3}{65m^3}$ per hour = 1.5hour

4th. Activity: Scaling time – 0.5 hours

5th. Activity: Time required for shotcreting =

1. For Good Rock Shotcreting (5 cm) = 0.5 hour

2. For Fair Rock Shotcreting (10 cm) = 1.0 hour

3. For Poor Rock Shotcreting (15 cm) = 1.5 hour

4. For Very Poor Rock Shotcreting (20 cm) = 2.0 hour

5th. Activity: **Rock bolt drilling & fixing:**

For Good & Fair Rock = 1.5 hour

For Poor & V. Poor Rock = 1.5 hour

3.56 **Cycle time for Heading**

3m pull length per cycle to be considered for heading without rib and 1.5 m pull length to be considered for heading with rib

3.56.1 Cycle time for heading without rib support in Pressure shaft

Table 3.56 Cycle time for heading without rib in PS

S.N	Description	Quantity	Units
1	Pull length	3	m
2	Heading c/s area	34.0369	sqm
3	Excavation quantity	102.11	cum
4	Survey	0.5	Hour
5	Excavation time	5	Hour
6	Mucking	1.5	Hour
7	Scaling	0.5	Hour
8	shotcreting	1	Hour
9	Rockbolt drilling & fixing	1.5	Hour
	Total cycle time for 3m pull length	10	**Hour**

3.56.2 Cycle time for heading with rib support in Pressure shaft

Table 3.57 Cycle time for heading with rib in PS

S.N	Description	Quantity	Units
1	Pull Length	1.5	m
2	Heading c/s area	34.0369	sqm
3	Excavation quantity	51.055	cum
4	Survey	0.5	Hour
5	Excavation time	5	Hour
6	Mucking	1.5	Hour
7	Scaling	0.5	Hour
8	Shotcreting	2	Hour
9	Rockbolt drilling & fixing	1.5	Hour
10	Rib erection	2	Hour
11	Lagging fixing	2.5	Hour
12	Stopper fixing&Back fill concrete	2.5	Hour
	Total cycle time per 1.5m pull length	18	Hour
	Total cycle time per 3m pull length	36	**Hour**

Time Schedule:

Among the total excavation 90 % is considered as without rib supporting and 10 % as with rib supporting.

Weighted average cycle time = (10 × 0.9) + (36×0.1) = 12.6 hours per 3m pull length

$$\text{Progress per month} = \frac{26(\text{working day per month}) \times 22(\text{working hours per day}) \times 3\text{m}(\text{pull length})}{12.6\ (\text{weighted cycle time in hours})}$$

= 136 m per month

Time required for completion of heading work = $\frac{\text{Length of Pressure Shaft}}{\text{Work progress per month}}$

= $\frac{211+197+184+172=764\ m}{136\ \text{m per month}}$ = 5.61 month = 168 days

3.57 Cycle time calculation for Benching in Pressure shaft

1st. Activity: Surveying time – 0.5 hours

2nd. Activity: Excavation time = $\frac{\text{Excavated quantity}}{\text{productivity of Roadheader}}$

Excavated quantity = Cross-sectional area of tunnel × length of drill

= $(\frac{\pi \times d^2}{4})$×drill length = $(\frac{\pi \times 2.3725^2}{4})$ ×3 m = 13.2624 m^3

Excavated quantity = 13.2624 × 1.2 (20 % as over-break quantity)

= 15.9149 m^3 (Excavated quantity will be more than because there will be some voids in the quantity)

Time required for Excavated quantity= $\frac{\text{Excavated quantity}}{\text{Productivity of Roadheader}} = \frac{15.9149\ m^3}{15 m^3}$ per hour = 1.0 hour

Time required for Mucking quantity= $\frac{\text{Mucking quantity}}{\text{Productivity of Loader}} = \frac{15.9149\ m^3}{65 m^3}$ per hour = 0.5 hour

3rd. Activity: Scaling time = 0.5 hour

4th.Activity: Time required for shotcreting =

1.For Good Rock Shotcreting (5 cm) = 0.5 hours

2.For Fair Rock Shotcreting (10 cm) = 0.5 hours

3.For Poor Rock Shotcreting (15 cm) = 0.5 hour

4.For Very Poor Rock Shotcreting (20 cm) = 1.0 hours

3.57.1 Cycle time for benching without rib support in Pressure shaft

Table 3.58 Cycle time for benching without rib in PS

S.N	Description	Quantity	Units
1	Pull length	3	m
2	Benching c/s area	13.8665	sqm
3	Excavation quantity	41.599	cum
4	Survey	0.5	Hour
5	Excavation time	1	Hour
	Mucking	0.5	Hour
6	Scaling	0.5	Hour
7	shotcreting	0.5	Hour
	Total cycle time for 3m pull length	3	**Hour**

3.57.2 Cycle time for benching with rib support in Pressure shaft

Table 3.59 Cycle time for benching with rib in PS

S.N	Description	Quantity	Units
1	Pull length	1.5	m
2	Benching c/s area	13.8665	sqm
3	Excavation quantity	20.799	cum
4	Survey	0.5	Hour
5	Excavation time	1	Hour
6	Mucking	0.5	Hour
7	Scaling	0.5	Hour
8	Shotcreting in	1	Hour
9	Rib erection	2	Hour
10	Lagging fixing	2.5	Hour
11	Backfill concreting	2	Hour
	Total cycle time for 1.5m pull length	10	Hour
	Total cycle time for 3m pull length	20	**Hour**

Time Schedule:

Weighted average cycle time = (3×0.9) + (20×0.1) = 4.7 hours per 3m pull

Progress per month = $\frac{(26(\text{working day per month}) \times 22(\text{working hours per day}) \times 3\text{m pull length})}{4.7\ (\text{weighted average cycle time in hours})}$

= 365 m per month

Time required for Completion of benching work = $\frac{\text{length of Pressure Shaft}}{\text{progress per month}}$

$= \frac{211+197+184+172=764\ m}{365}$ = 2.0 month= 60 days

Table 3.60 Activities duration for different rock conditions in PS – 1

Pressure Shaft – 1	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	7	28	7	4	46
Benching	2	10	2	2	16
Kerb	8	11	8	2	29
Overt	8	11	8	2	29
Invert	8	16	8	3	35

Table 3.61 Activities duration for different rock conditions in PS – 2

Pressure Shaft – 2	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	6	26	6	4	42
Benching	2	10	2	2	16
Kerb	2	11	2	1	16
Overt	2	11	2	1	16
Invert	4	15	4	2	25

Table 3.62 Activities duration for different rock conditions in PS – 3

Pressure Shaft – 3	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	6	24	6	4	40
Benching	2	9	2	2	15
Kerb	2	10	2	1	15
Overt	2	10	2	1	15
Invert	4	14	4	2	24

Table 3.63 Activities duration for different rock conditions in PS – 4

Pressure Shaft – 4	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	5	23	5	3	36
Benching	2	8	2	1	13
Kerb	2	9	2	1	14
Overt	2	9	2	1	14
Invert	3	13	3	2	21

Table 3.64 Activities duration of PS in case of Roadheader

RHP- PS ROAD HEADER		Classic WBS Layout					28-Apr-17 18:49
Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
RHP- PS ROAD HEADER		144	144	0%	15-May-17	14-Sep-17	0
ps1		144	144	0%	15-May-17	14-Sep-17	0
A1030	Heading	46	46	0%	15-May-17	22-Jun-17	0
A1040	Benching	16	16	0%	22-Jun-17	06-Jul-17	0
A1060	Kerb	29	29	0%	10-Jul-17	03-Aug-17	0
A1070	Overt	35	35	0%	03-Aug-17	01-Sep-17	0
A1050	Invert	29	29	0%	21-Aug-17	14-Sep-17	0
ps2		131	131	0%	15-May-17	04-Sep-17	13
A11	Heading	42	42	0%	15-May-17	19-Jun-17	17
A11	Benching	16	16	0%	19-Jun-17	03-Jul-17	17
A12	Kerb	16	16	0%	06-Jul-17	19-Jul-17	17
A12	Overt	25	25	0%	20-Jul-17	10-Aug-17	17
A11	Invert	16	16	0%	21-Aug-17	04-Sep-17	13
ps-3		104	104	0%	15-May-17	10-Aug-17	40
A	Heading	40	40	0%	15-May-17	16-Jun-17	19
A	kerb	15	15	0%	15-May-17	26-May-17	80
A	overt	24	24	0%	15-May-17	02-Jun-17	109
A	Invert	15	15	0%	31-May-17	13-Jun-17	109
A	Benching	15	15	0%	19-Jun-17	03-Jul-17	17
ps4		104	104	0%	15-May-17	10-Aug-17	40
	Heading	36	36	0%	15-May-17	14-Jun-17	40
	Benching	13	13	0%	14-Jun-17	26-Jun-17	40
	kerb	14	14	0%	30-Jun-17	13-Jul-17	40
	overt	21	21	0%	13-Jul-17	31-Jul-17	40
	Invert	14	14	0%	31-Jul-17	10-Aug-17	40

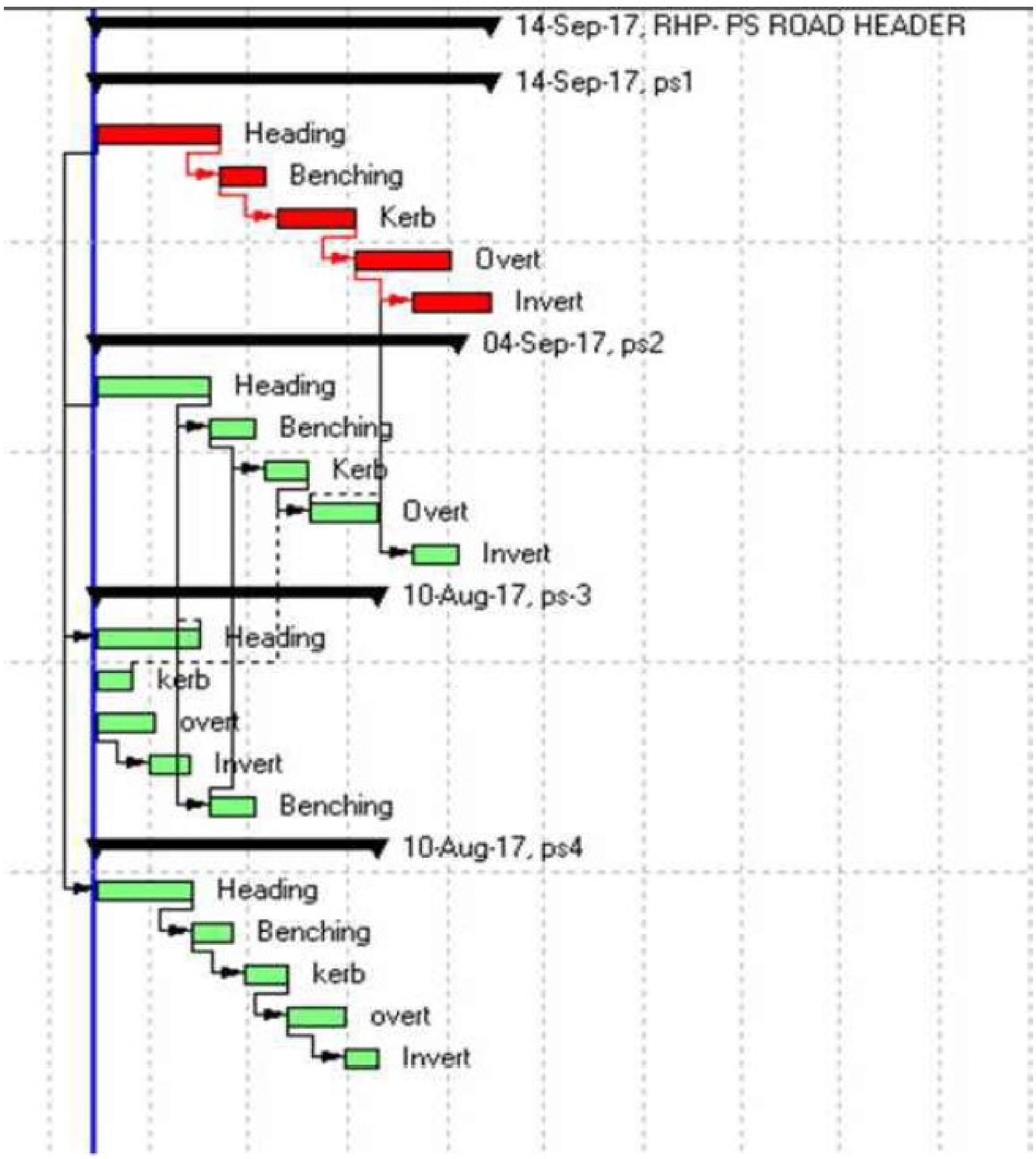


Fig 3.12 Network diagram of Pressure shaft in case of Roadheader

3.58 Cycle time calculation for different activities for heading work in Tailrace tunnel by Mechanical method

1st Activity: Survey - 0.5 hours

2nd. Activity: Time required for Excavation work = $\frac{\text{Excavated Quantity}}{\text{productivity of Roadheader}}$

Excavated quantity = $\frac{\text{C/S area of tunnel}}{\text{length of drill}}$ = ($\frac{\pi\times d^2}{4}$)×length of drill

= $\frac{\pi\times 6.4725^2}{4}$ × 3 = 98.7086 $\boldsymbol{m^3}$

= Excavated quantity = 98.7086 × 1.2 (20 % as over-break quantity)

= 118.4503 m^3 (Excavated quantity will be more than because there will be some voids in the quantity)

Time required for Excavated quantity = $\frac{\text{Excavated quantity}}{\text{Productivity of roadheader}}$ = $\frac{118.4503\ m^3}{15\quad ^3}$ per hour = 8.0 hour

3rd. Activity Time required for Mucking quantity = $\frac{\text{Mucking quantity}}{\text{Productivity of Loader}}$ = $\frac{118.4503\ m^3}{65\quad ^3}$ per hour = 2.0 hour

4th. Activity: Scaling time – 0.5 hours

5th. Activity: Time required for shotcreting =

1.For Good Rock Shotcreting (5 cm) = 0.5 hour

2.For Fair Rock Shotcreting (10 cm) = 1.0 hour

3.For Poor Rock Shotcreting (15 cm) = 1.5 hour

4.For V. Poor Rock Shotcreting (20 cm) = 2.0 hour

5th. Activity: **Rock bolt drilling & fixing:**

For Good & Fair Rock = 1.5 hour

For Poor & V.Poor Rock = 2.0 hour

3.59 **Cycle time for Heading in Tailrace tunnel**

3m pull length per cycle to be considered for heading without rib and 1.5 m pull length to be considered for heading with rib

3.59.1 Cycle time for heading without rib support in Tailrace tunnel

Table 3.65 Cycle time for heading without rib in TRT

S.N	Description	Quantity	Units
1	Pull length	3	m
2	Heading c/s area	52.44	sqm
3	Excavation quantity	157.32	cum
4	Survey	0.5	Hour
5	Excavation time	8	Hour
	Mucking	2	Hour
6	Scaling	0.5	Hour
8	shotcreting	1	Hour
9	Rockbolt drilling & fixing	1.5	Hour
	Total cycle time for 3m pull length	13.5	**Hour**

3.59.2 Cycle time for heading with rib support in Tailrace tunnel

Table 3.66 Cycle time for heading with rib in TRT

S.N	Description	Quantity	Units
1	Pull Length	1.5	m
2	Heading c/s area	52.44	sqm
3	Excavation quantity	78.66	cum
4	Survey	0.5	Hour
5	Excavation time	8	Hour
6	Mucking	2	Hour
7	Scaling	0.5	Hour
8	Shotcreting	2	Hour
9	Rockbolt drilling & fixing	2	Hour
10	Rib erection	2.5	Hour
11	Lagging fixing	2	Hour
12	Stopper fixing&Back fill concrete	3	Hour
	Total cycle time per 1.5m pull length	22.5	Hour
	Total cycle time per 3m pull length	45	**Hour**

Time Schedule:

Among the total excavation 90 % is considered as without rib supporting and 10 % as with rib supporting

Weighted average cycle time = (13.5 × 0.9) + (45×0.1) = 16.65 hours per 3m pull length

$$\text{Progress per month} = \frac{(26(\text{working day per month}) \times 22(\text{working hours per day}) \times 3\text{m pull length})}{16.65\ (\text{weighted cycle time in hours})}$$

= 103 m per month

Time required for completion of Heading work = $\frac{\text{Lengt of Tail Race Tunnel}}{\text{Work progress per month}}$

= $\frac{(502+490+475+460=1927)\text{ m}}{(103\text{ m per month})}$ = 18.70 month = 561 days

3.60 Cycle time calculation for Benching in Tailrace tunnel by Mechanical method

1st. Activity: Surveying time – 0.5 hours

2nd. Activity: Excavation time = $\frac{\text{Excavated quantity}}{\text{productivity of Roadheader}}$

Excavated quantity = C/S area of tunnel × length of drill

= $(\frac{\pi\times d^2}{4})$×drill length = $(\frac{\pi\times 3.1735^2}{4})$ ×3 m = 23.7294 m^3

Excavated quantity = 23.7294 × 1.2 (20 % as over-break quantity)

= 28.4753 m^3 (Excavated quantity will be more because there will be some voids in the quantity)

Time required for Excavated quantity= $\frac{\text{Excavated quantity}}{\text{Productivity of Roadheader}} = \frac{28.4753\ m^3}{15m^3}$ per hour = 2.0 hour

3rd. Activity Time required for Mucking quantity= $\frac{\text{Mucking quantity}}{\text{Productivity of Loader}} = \frac{28.4753\ m^3}{65\quad ^3}$ per hour = 0.5 hour

4th. Activity: Scaling time = 0.5 hour

4th.Activity: Time required for shotcreting =

1.For Good Rock Shotcreting (5 cm) = 0.5 hours

2.For Fair Rock Shotcreting (10 cm) = 0.5 hours

3.For Poor Rock Shotcreting (15 cm) = 1.0 hour

4.For V. Poor Rock Shotcreting (20 cm) = 1.0 hours

3.60.1 Cycle time for benching without rib support in Tailrace tunnel

Table 3.67 Cycle time for benching without rib in TRT

S.N	Description	Quantity	Units
1	Pull length	3	m
2	Benching c/s area	23.21	sqm
3	Excavation quantity	69.63	cum
4	Survey	0.5	Hour
5	Excavation time	2	Hour
	Mucking	0.5	Hour
6	Scaling	0.5	Hour
8	shotcreting	0.5	Hour
	Total cycle time for 3m pull length	4	**Hour**

3.60.2 Cycle time for benching with rib support in Tailrace tunnel

Table 3.68 Cycle time for benching with rib in TRT

S.N	Description	Quantity	Units
1	Pull length	1.5	m
2	Benching c/s area	23.21	sqm
3	Excavation quantity	34.815	cum
4	Survey	0.5	Hour
5	Excavation time	2	Hour
	Mucking	0.5	Hour
6	Scaling	0.5	Hour
7	Shotcreting	1	Hour
9	Rib erection	2	Hour
10	Lagging fixing	1	Hour
11	Backfill concreting	1	Hour
	Total cycle time for 1.5m pull length	8.5	Hour
	Total cycle time for 3m pull length	17	**Hour**

Time Schedule:

Among the total excavation 90 % is considered as without rib supporting and 10 % as with rib supporting

Weighted average cycle time = (4.0 × 0.9) + (17×0.1) = 5.3 hours per 3m pull length

Progress per month = $\frac{26(\text{working day per month})\times 22(\text{working hours per day})\times 3\text{m(pull length)}}{5.3\ (Hour\ per\ 3m\ \ pull)}$

= 324 m per month

Time required for completion of Benching work = $\frac{\text{Length of Tail Race Tunnel}}{\text{Work progress per month}}$

= $\frac{(502+490+475+460=1927)\text{ m}}{(324\text{ m per month})}$

= 6.0 month = 180 days

Table 3.69 Activities duration for different rock conditions in TRT – 1

TRT - 1	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	22	87	22	14	145
Benching	7	28	7	7	49
Kerb	7	27	7	5	46
Overt	7	27	7	5	46
Invert	10	40	10	7	67

Table 3.70 Activities duration for different rock conditions in TRT – 2

TRT – 2	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	21	85	21	14	141
Benching	7	27	7	4	45
Kerb	7	27	7	4	45
Overt	7	27	7	4	45
Invert	10	38	10	6	64

Table 3.71 Activities duration for different rock conditions in TRT – 3

TRT – 3	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	21	83	21	14	139
Benching	6	26	6	4	42
Kerb	6	26	6	4	42
Overt	6	26	6	4	42
Invert	9	37	9	6	61

Table 3.72 Activities duration for different rock conditions in TRT – 4

TRT – 4	Good Rock	Fair Rock	Poor Rock	Very Poor Rock	Total Days
Heading	21	80	21	13	133
Benching	6	25	6	4	41
Kerb	6	25	6	4	41
Overt	6	25	6	4	41
Invert	9	36	9	6	60

Table 3.73 Activities duration of TRT in case of Roadheader

RHP- TRT ROAD HEADER | Classic WBS Layout | 28-Apr-17 19:02

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
RHP- TRT ROAD HEADER		295	295	0%	15-May-17	23-Jan-18	0
TRT1		295	295	0%	15-May-17	23-Jan-18	0
A1030	Heading	145	145	0%	15-May-17	15-Sep-17	17
A1040	Benching	49	49	0%	15-Sep-17	27-Oct-17	17
A1060	Kerb	46	46	0%	03-Oct-17	10-Nov-17	17
A1070	Overt	67	67	0%	10-Nov-17	09-Jan-18	17
A1050	Invert	46	46	0%	29-Nov-17	08-Jan-18	18
TRT2		295	295	0%	15-May-17	23-Jan-18	0
A11	Heading	141	141	0%	15-May-17	12-Sep-17	0
A11	Benching	45	45	0%	12-Sep-17	20-Oct-17	24
A12	Kerb	45	45	0%	29-Sep-17	07-Nov-17	24
A12	Overt	64	64	0%	07-Nov-17	02-Jan-18	24
A11	Invert	45	45	0%	24-Nov-17	02-Jan-18	24
TRT3		295	295	0%	15-May-17	23-Jan-18	0
/	Heading	139	139	0%	15-May-17	11-Sep-17	26
/	overt	61	61	0%	15-May-17	05-Jul-17	233
/	Invert	42	42	0%	31-May-17	06-Jul-17	233
/	Benching	42	42	0%	12-Sep-17	18-Oct-17	27
/	kerb	42	42	0%	29-Sep-17	03-Nov-17	27
TRT4		295	295	0%	15-May-17	23-Jan-18	0
	Heading	133	133	0%	15-May-17	05-Sep-17	0
	Benching	41	41	0%	05-Sep-17	11-Oct-17	0
	kerb	41	41	0%	22-Sep-17	27-Oct-17	0
	overt	60	60	0%	27-Oct-17	19-Dec-17	0
	Invert	41	41	0%	19-Dec-17	23-Jan-18	0

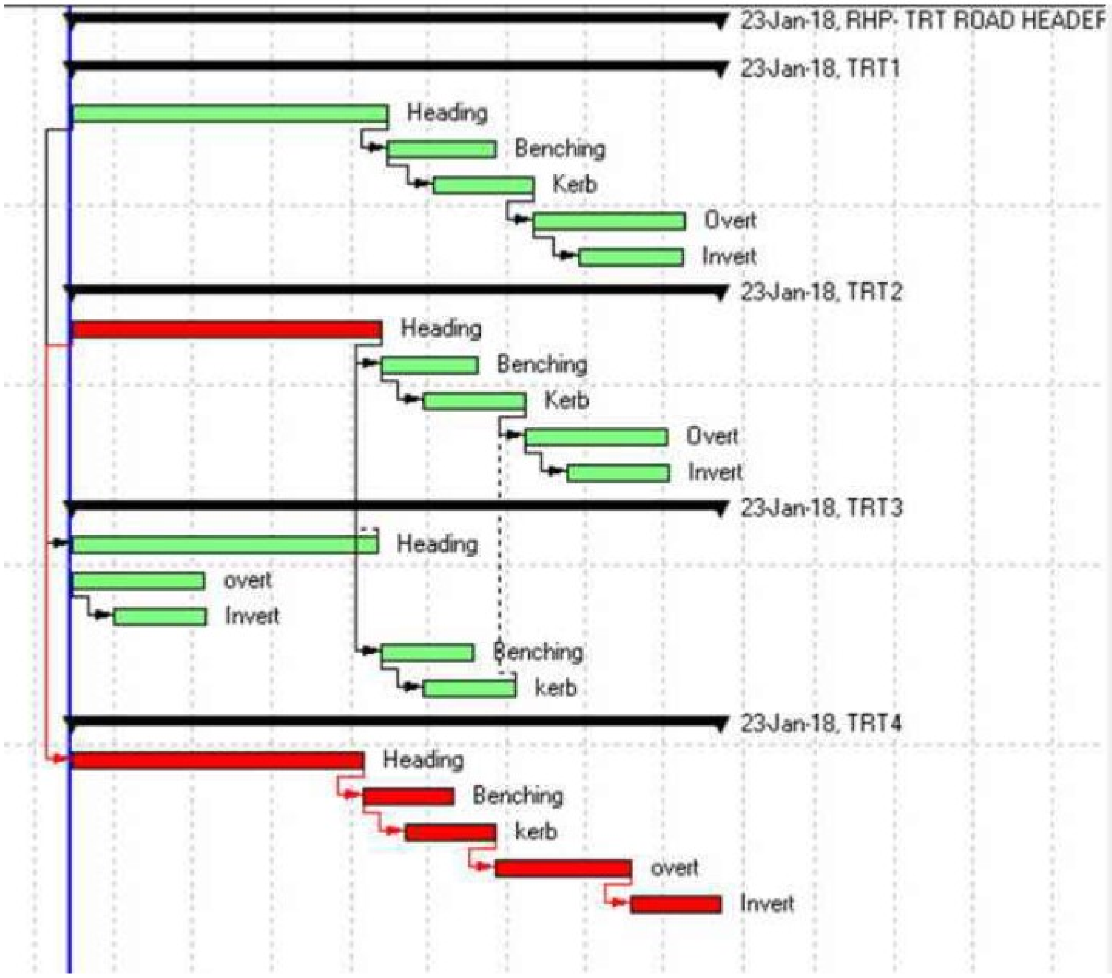


Fig 3.13 Network diagram of Tailrace tunnel in case of Roadheader

3.61 **Cost estimation of diversion tunnel for Mechanical method**

ITEM: Excavation for tunnel in the case of Diversion Tunnel by heading and benching.

DATA Size of tunnel (finished section)	12.345 m dia
Length of DT- 1	472 m
Length of DT- 2	552 m
Thickness of lining	1.0 m
Diameter of tunnel upto pay line for excavation	12.345 m
Consideration for 3 m pull length	
Heading portion	
Area of excavation upto payline	82.6734 m^2

Benching portion	
Area of excavation upto payline	40.2379 m^2
Total depth of drilling (24×4+32×5=256 m)	256.0 m
Quantity of in-situ excavation per cycle (82.67+40.23) x 3.0 =(123×3.0)	**369 m^3**

RATE ANALYSIS

A.MATERIALS

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Use rate of drill rod 2.0 m long	Rm	256	47.83	12244.48
	Reconditioning charges @ 10%				1224.448
2	Use rate of air hose	Hour	32	6.25	200
3	Use rate of water hose	Hour	32	5.78	184.96
4	Sundries (paint / template etc)	LS	9	44	396
				Total	14249.888

Add for small Tools and Plants	@ 1	142.498
Add for Contractor's Profit	@ 10%	1424.988
Add for Contractor's Overheads	@ 5%	712.494
Total cost of Material		**16387.37**

B.MACHINERY

S.N	Description	Unit	Quantity	Rate in INR	Amount in INR
1	Roadheader machine	Per day	4	31333.333	125333.332
	Fuel charges	Hour	8	41	328
2	Drilling jumbo	Hour	9	370	3330
	Fuel charges	Hour	9	41	369
3	Convey mucker	Hour	7	740	5180
	Fuel charges	Hour	7	223	1561
4	Dumper (2 x 6.5 hrs)	Hour	13	548	7124
	Fuel charges	Hour	13	381	4953
5	Pump 10 hp	Hour	8	5	40
	Fuel charges		8	64	512
				Total	148730.332

Add for small Tools and Plants	@ 1%	1487.303

Add for Contractor's Profit	@ 10%	14873.033
Add for Contractor's Overheads	@ 5%	7436.516
Total hire charges of Machinery		**172527.184**

C.LABOUR

S.N	Description	Unit	Quantity	Rate in INR	Amount in INR
1	Crew for Roadheader	Hour	9	1200	10800
2	Crew for Drilling jumbo	Hour	8	101	808
3	Crew for Convey mucker	Hour	7	101	707
4	Crew for Dumper	Hour	13	121	1573
5	Crew for Pump	Hour	8	45	360
6	Foreman	Day	1	276.73	276.73
7	Maistry 1 in each shift	Day	3	243.23	729.69
8	for pushing muck in heading portion	Day	4	241.23	964.92
9	for mucking shift 4 Nos	Day	4	241.23	964.92
10	Heavy mazdoor				
	for mucking shift 8 Nos	Day	8	238.73	1909.84
11	for other 2 shifts 2 No each shift	Day	4	238.73	954.92
12	Light mazdoor				
	for cleaning & miscellaneous	Day	3	238.23	714.69
				Total	20763.71

Add for small Tools and Plants	@ 1 %	207.637
Add for Contractor's Profit	@ 10%	2076.371
Add for hidden cost on Labour	@ 15%	3114.556
Add for additional hidden cost on labour	@ 10%	2076.371
Add for Contractor's Overheads	@ 5%	1038.185
Total cost of labour		**29276.83**

3.62 Abstract of cost details for 3m Pull length in Diversion tunnel for Mechanical method

A.Cost of Materials	16387.37
B.Hire charges of Machinery	172527.184
C.Cost of Labour	29276.83
TOTAL	**218191.384**
Add for Air and Water line @ 0.80 %	1745.531
Add for Ventilation @ 6.0 %	13091.483
Add for Lighting @ 1.80 %	3927.444
Add for Electrical sub-station / Demand charges @ 3.80 %	8291.272
Add for other Enabling works @ 1.70 %	3709.253

Total cost for 369 m^3	248956.367
Rate per m^3	**674.678**

For 1 cycle (3 m pull length) rate per m^3	**674.678**
Total length of DT- 1	472 m
Total length of DT- 2	552 m
90 % considered without rib support	
Total length in case of without rib support in DT - 1	424.8 m
Total length in case of without rib support in DT - 2	496.8 m
Total cost in DT - 1 (674.678×424.8 m×123 m^2)	**35252195.37**
Total cost in DT - 2 (674.678×496.8 m×123 m^2)	**41227143.74**

Consideration for 1.5 m pull length:

Heading portion	
Area of excavation upto payline	82.6734 m^2
Benching portion	
Area of excavation upto payline	40.2379 m^2
Total depth of drilling **(24×4+32×5=256)**	**270.1 m**
Total area of excavation (82.67+40.23=123)	123 m^2
Depth of pull per blast for1.0 m deep holes	1.5 m
Quantity of in-situ excavation per cycle (123×1.5)	**184.5 m^3**

RATE ANALYSIS: UNIT : 184.5 m^3

3.63 Abstract of cost details for 1.5m Pull length in Diversion tunnel for Mechanical method

A.Cost of Materials	16387.37
B.Hire charges of Machinery	172527.184
C.Cost of Labour	29276.83
TOTAL	**218191.384**
Add for Air and Water line @ 0.80 %	1745.531
Add for Ventilation @ 6.0 %	13091.483
Add for Lighting @ 1.80 %	3927.444
Add for Electrical sub-station / Demand charges @ 3.80 %	8291.272
Add for other Enabling works @ 1.70 %	3709.253
Total cost for 184.5 m^3	**248956.367**
Rate per m^3	**1349.357**

For 1 cycle (1.5 m pull length) rate per m^3	**1349.357**

Total length of DT- 1	472 m
Total length of DT- 2	552 m
10 % considered with rib support	
Total length in case of with rib support	47.2 m
Total length in case of with rib support	55.2 m
Total cost in DT - 1 (1349.357×47.2 m×123 m^2)	**7833826.999**
Total cost in DT - 2 (1349.357×55.2 m×123 m^2)	**9161594.28**
Total cost in Excavation for DT- 1 (35252195.37+7833826.999)	**43086022.37**
Total cost in Excavation for DT- 2 (41227143.74+9161594.28)	**50388738.02**

Total cost for Rock bolt support work in DT - 1 (Good & Fair Rock + Poor & Very Poor Rock):

Total cost for Rock bolt support work in DT- 1 (3009034.353+1195750.078): **4204784.431**

Total cost for Rock bolt support work in DT – 2 (Good & Fair Rock + Poor & V. Poor Rock):

Total cost for Rock bolt support work in DT - 2 (3672123.261+1619672.361): **5291795.622**

Total cost for Kerb and Invert Lining in DT – 1 (4+4+3.1) = 11.1 m^2 × 472 m ×6326 =**33143179.2**

Total cost for Kerb and Invert Lining in DT – 2 (4+4+3.1) = 11.1 m^2 × 552 m ×6326 =**38760667.2**

Total cost for Overt Lining in DT - 1 (16.54 m^2)×(472 m)×(4813.0117) : **37574604.78**

Total cost for Overt Lining in DT - 2 (16.54 m^2)×(552 m)×(4813.0117) : **43943181.86**

Total cost in DT- 1 (Excavation + Rock bolt support + Kerb & Invert Lining + Overt Lining):

(90% without rib support +10% with rib support + Good & Fair rock + Poor & Very Poor rock + Kerb & Invert lining + Overt lining):

(35252195.37+7833826.99+3009034.353+1195750.078+33143179.2+37574604.78) = **118008590.8**

Total cost in DT – 1 **: 118008590.8**

Total cost in DT- 2 (Excavation + Rock bolt support + Kerb & Invert Lining + Overt Lining):

(90% without rib support +10% with rib support + Good & Fair rock + Poor & Very Poor rock + Kerb & Invert lining + Overt lining):

(41227143.74+9161594.28+3672123.261+1619672.361+38760667.2+43943181.86) **=138384382.7**

Total cost in DT- 2 **: 138384382.7**

Total cost in Diversion Tunnel (118008590+138384382) **: 256392974**

3.64 Cost estimation of Pressure shaft for Mechanical method

ITEM: Excavation for tunnel in the case of Pressure Shaft Tunnel by heading and benching.

DATA Size of tunnel assumed (finished section)	7.645 m dia
Length of Pressure Shaft (211 + 197 + 184 + 172) m	764 m
Thickness of lining	0.70 m
Diameter of tunnel upto pay line for excavation	7.645 m
Consideration for 3 m pull length	
Heading portion	
Area of excavation upto payline	34.0369 m^2
Benching portion	
Area of excavation upto payline	13.8665 m^2
Total depth of drilling for Rock bolt (17×4+22×5=178 m)	178 m
Quantity of in-situ excavation per cycle (34.0369+13.8665=47.9034×3.0)	**143.7102 m^3**

RATE ANALYSIS **UNIT** **: 143.7102 m^3**

A.MATERIALS:

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Use rate of drill rod 2.0 m long	Rm	178	47.83	8513.74
	Reconditioning charges @ 10%				851.374
2	Use rate of air hose	Hour	32	6.25	200
3	Use rate of water hose	Hour	32	5.78	184.96
4	Sundries (paint / template etc)	LS	9	44	396
				Total	10146.074

Add for small Tools and Plants	@ 1	101.460
Add for Contractor's Profit	@ 10%	1014.607
Add for Contractor's Overheads	@ 5%	507.303
Total cost of Material		**11667.984**

3.64.1 Abstract of cost details for 3m Pull length of Pressure shaft for Mechanical method

A.Cost of Materials	11667.984
B.Hire charges of Machinery	172527.184
C.Cost of Labour	29276.83
TOTAL	**213471.998**
Add for Air and Water line @ 0.80 %	1707.775
Add for Ventilation @ 6.0 %	12808.319
Add for Lighting @ 1.80 %	3842.495
Add for Electrical sub-station / Demand charges @ 3.80 %	8111.935
Add for other Enabling works @ 1.70 %	3629.0239
Total cost for 143.7102 m^3	**243571.545**
Rate per m^3	**1694.880**

For 1 cycle (3 m pull length) rate per m^3	**1694.880**
Total length of DT of Pressure Shaft (211+197+184+172=764 m)	764 m
90 % considered without rib support	
Total length in case of without rib support in Pressure Shaft	687.6 m
Total cost in Pressure Shaft (1694.880×687.6 m×47.9034 m^2)	**55826597.83**

Consideration for 1.5 m pull length:

Heading portion	
Area of excavation upto payline	34.0369 m^2

Benching portion	
Area of excavation upto payline	13.8665 m^2
Total depth of drilling **(17×4+22×5=178)**	**178.0 m**
Total area of excavation (34.0369+13.8665=47.9043)	47.9043 m^2
Depth of pull per blast for1.0 m deep holes	1.5 m
Quantity of in-situ excavation per cycle (47.9043×1.5)	**71.856 m^3**

RATE ANALYSIS: UNIT : 71.856 m^3

3.64.2 Abstract of cost details for 1.5m Pull length of Pressure shaft for Mechanical method

A.Cost of Materials	11667.984
B.Hire charges of Machinery	172527.184
C.Cost of Labour	29276.83
TOTAL	**213471.998**
Add for Air and Water line @ 0.80 %	1745.531
Add for Ventilation @ 6.0 %	13091.483
Add for Lighting @ 1.80 %	3927.444
Add for Electrical sub-station / Demand charges @ 3.80 %	8291.272
Add for other Enabling works @ 1.70 %	3709.253
Total cost for 71.856 m^3	**243571.545**
Rate per m^3	**3389.717**

For 1 cycle (1.5 m pull length) rate per m^3	**3389.717**
Total length of Pressure Shaft	**764 m**
10 % considered with rib support	
Total length in case of with rib support	76.4 m
Total cost in Pressure Shaft (3389.717×76.4 m×47.9043 m^2)	**12405986.33**
Total cost in Excavation for Pressure Shaft (55826597.83+12405986.33)	**68232584.16**

Total cost for Rock bolt support work in Pressure Shafts (Good & Fair Rock + Poor & Very Poor Rock):

Total cost for Rock bolt support work in Pressure Shafts (3811461.09+1557667.757) **=5369128.847**

Total cost for Kerb and Invert Lining in Pressure Shaft = **18848949.6**

Total cost for Overt Lining in Pressure Shaft **= 82777936.02**

Total cost in Pressure Shaft (Excavation + Rock bolt support + Kerb & Invert Lining + Overt Lining):

(90% without rib support +10% with rib support + Good & Fair rock + Poor & Very Poor rock + Kerb & Invert lining + Overt lining):

(55826597.83+12405986.33+3811461.09+1557667.757+18848949.6+82777936.02) =**175228599**

Total cost in Pressure Shaft = 175228599

3.65 Cost estimation of Tailrace tunnel for Mechanical method

ITEM: Excavation for tunnel in the case of Diversion Tunnel by heading and benching.

DATASize of tunnel assumed (finished section)	9.645 m dia
Length of Tailrace Tunnel (502 + 490 + 475 + 460) m	1927 m
Thickness of lining	0.70 m
Diameter of tunnel upto pay line for excavation	9.645 m

Consideration for 3 m pull length:

Heading portion	
Area of excavation upto payline	52.44 m^2
Benching portion	
Area of excavation upto payline	23.21 m^2
Total depth of drilling for Rock bolt work (20×4+26×5=210) m	210 m
Total area of excavation (52.44+23.21=75.65)	75.65 m^2
Depth of pull per cycle for 2.0 m deep holes	3.0 m
Quantity of in-situ excavation per cycle (75.65×3.0)	**226.95 m^3**

RATE ANALYSIS UNIT : 226.95 m^3

A.MATERIALS

S.N	Perticulars	Unit	Quantity	Rate in INR	Amount in INR
1	Use rate of drill rod 2.0 m long	Rm	210	47.83	10044.3
	Reconditioning charges @ 10%				1004.43
2	Use rate of air hose	Hour	32	6.25	200
3	Use rate of water hose	Hour	2	5.78	11.56
4	Sundries (paint / template etc)	LS	9	44	396
				Total	11656.29

Add for small Tools and Plants	@ 1	116.562
Add for Contractor's Profit	@ 10%	1165.629
Add for Contractor's Overheads	@ 5%	582.814
Total cost of Material		**13521.295**

3.65.1 Abstract of cost details for 3m Pull length of Tailrace tunnel for Mechanical method

A.Cost of Materials	13521.295
B.Hire charges of Machinery	172527.184
C.Cost of Labour	29276.83
TOTAL	**215325.309**
Add for Air and Water line @ 0.80 %	1722.602
Add for Ventilation @ 6.0 %	12919.518
Add for Lighting @ 1.80 %	3875.855
Add for Electrical sub-station / Demand charges @ 3.80 %	8182.361
Add for other Enabling works @ 1.70 %	3660.530
Total cost for 226.95 m^3	**245686.175**
Rate per m^3	**1082.556**

For 1 cycle (3 m pull length) rate per m^3	**1082.556**
Total length of Tailrace Tunnel (502+490+475+460=1927 m)	**1927 m**
90 % considered without rib support	
Total length in case of without rib support in Pressure Shaft	1734.3 m
Total cost in Tailrace Tunnel (1082.556×1734.3 m×75.65 m^2)	**142031125.3**

Consideration for 1.5 m pull length:

Heading portion	
Area of excavation upto payline	52.44 m^2
Benching portion	
Area of excavation upto payline	23.21 m^2
Total depth of drilling for Rock bolt work **(20×4+26×5=210 m)**	**210 m**
Total area of excavation (52.44+23.21=75.65)	75.65 m^2
Depth of pull per blast for1.0 m deep holes	1.5 m
Quantity of in-situ excavation per cycle (75.65×1.5)	**113.475 m^3**

RATE ANALYSIS: UNIT : 113.475 m^3

Total cost for 113.475 m^3	**245686.175**
Rate per m^3	**2165.112**

For 1 cycle (1.5 m pull length) rate per m^3	**2165.112**
Total length of Tailrace Tunnel	**1927 m**
10 % considered with rib support	
Total length in case of with rib support	192.7 m
Total cost in Tailrace Tunnel (2165.112×192.7 m×75.65 m^2)	**31562472.28**

Total cost in Excavation for Tailrace Tunnel (142031125.3+31562472.28) =**173593597.6**

Total cost for Rock bolt support work in Tailrace Tunnel (Good & Fair Rock + Poor & Very Poor Rock):

Total cost for Rock bolt support work in Tailrace Tunnel (5358292.472+4638641.566) **=9996934.038**

Total cost for Kerb and Invert Lining in Tailrace Tunnel **= 73141212**

Total cost for Overt Lining in Pressure Shaft **= 117831701.8**

Total cost in Tailrace Tunnel (Excavation + Rock bolt support + Kerb & Invert Lining + Overt Lining):

(90% without rib support +10% with rib support + Good & Fair rock + Poor & Very Poor rock + Kerb & Invert lining + Overt lining):

(142031125.3+31562472.28+5358292.472+4638641.566+73141212+117831701.8) = **418754362.3**

Total cost in Tailrace Tunnel : 418754362

3.66 Safety

1. Every Personnel working inside the tunnel shall wear personal protective equipment such as helmets, shoes, gloves and reflective bands etc.
2. In the location of drilling where personnel are employed to higher noise level, noise protection shall be provided.
3. Employees, working in places having an inherent danger of eye or face injury, shall be provided with protection glass, goggles or masks.

4. Stretchers, appliances for artificial breathing, oxygen flask, gas masks etc. shall be available in the front.
5. Fire extinguishers shall be provided at suitable locations in the tunnels where construction activity is carried out.
6. The electrical cables used shall be of waterproof and earthed.
7. Suitable communication system working in underground areas shall be provided for better communication during works.
8. An effective safety program should follow as
9. Planning to avoid hazards.
10. Detection of potential hazards.
11. Timely correction of hazards.
12. Dedication to the protection of the public and the worker.
13. Dedicated safety staff.

CHAPTER 4

CONCLUSION AND FUTURE SCOPE

4.1 Conclusion

4.1.1 Conclusion in Schedule

By Drill and Blast method

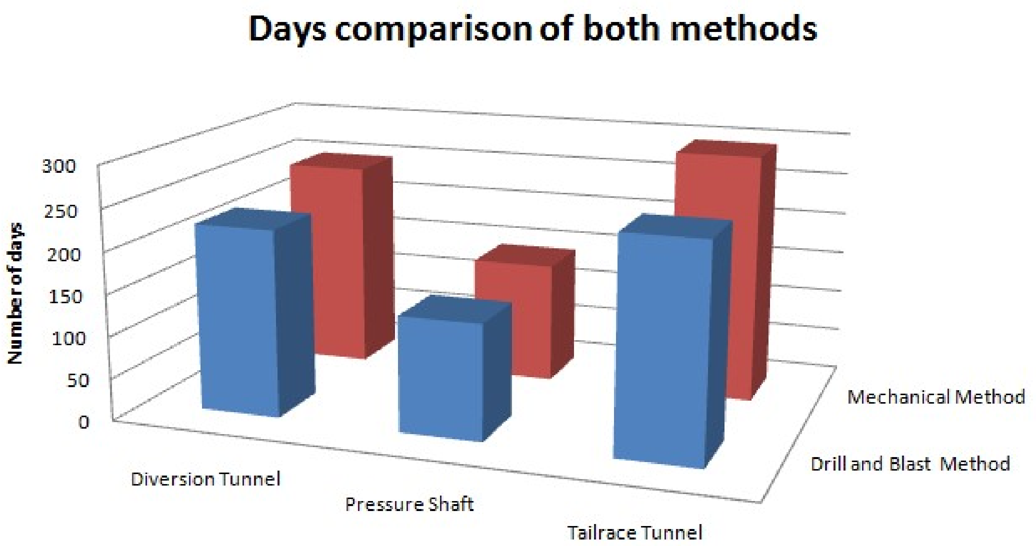
1. Diversion Tunnel requires 223 days to complete the excavation and lining work
2. Pressure Shaft requires 137 days to complete the excavation and lining work
3. Tailrace Tunnel requires 252 days to complete the excavation and lining work

By Mechanical method

1. Diversion Tunnel requires 249 days to complete the excavation and lining work
2. Pressure Shaft requires 144 days to complete the excavation and lining work
3. Tailrace Tunnel requires 295 days to complete the excavation and lining work

Differences in Days in Tunnels

1. Difference in Diversion Tunnel = 23 days
2. Difference in Pressure Shaft = 7 days
3. Difference in Diversion Tunnel = 43 days



	Diversion Tunnel	Pressure Shaft	Tailrace Tunnel
Drill and Blast Method	223	137	252
Mechanical Method	249	144	295

Fig 4.1 Days comparison of both method adopted

Hence we can clearly say that in Mechanical method more number of days is required with respect to Drill and Blast method.

4.1.2 Conclusion in Cost

By Drill and Blast method

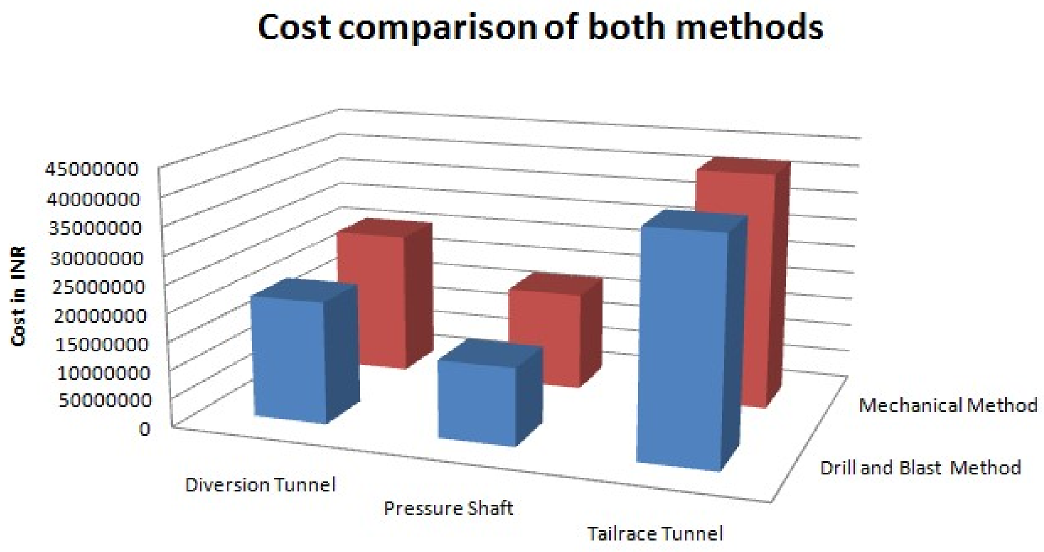
1. Cost in Diversion Tunnel = 216119985
2. Cost in Pressure Shaft = 136415128
3. Cost in Tailrace Tunnel = 389853586

By Mechanical method

1. Cost in Diversion Tunnel = 256392974
2. Cost in Pressure Shaft = 175228599
3. Cost in Tailrace Tunnel = 418754362

Differences in cost in Tunnels

1. Cost difference in Diversion tunnels = 40272989
2. Cost difference in Pressure shaft = 38813471
3. Cost difference in Tailrace tunnels = 28900776



	Diversion Tunnel	Pressure Shaft	Tailrace Tunnel
Drill and Blast Method	216119985	136415128	389853586
Mechanical Method	256392974	175228599	418754362

Fig 4.2 Cost comparison of both method adopted

Hence we can clearly say that in Mechanical method more number of costs is required with respect to Drill and Blast method.

4.2 Scope for future work

1. We can perform excavation work in hard strata by other method also like Cut and cover method, TBM method. But there are some restrictions in these methods.
2. Comparisons in the cost can be done in the case of other method adopted. So we can find which method is best suitable and economical.

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