Construction of Tunnel by Conventional Method in Bhutan

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Topic

- History
- Introduction
- Method of excavation
- Differences in methodology
- Why Conventional Method of Tunneling (CMT) in Bhutan
- Resources Planning
- The activities of CMT

History

- Prehistoric people dug “long” caves for inhabitation
- First recorded tunnel constructed in ancient Babylon 2100 BC under river Euphrates to connect Royal Palace and Temple of Jove. The tunnel measured 0.9km long, 3,6m (W) x 4.5m (H)

Latest

- Gotthard Base Tunnel in Switzerland is the longest and deepest railway tunnel through Alps completed in June 2016. Measures 57km.

Introduction

- It is an underground or underwater passageway dug through surrounding rock mass
- A tunnel is used for purposes of:
  - Traffic (subways, underpass, metros, tube)
  - Utility (water supply, irrigation, sewer, pipeline)
  - Military (secret passage)
  - Special tunnels for wildlife crossings
  - *Hydroelectric projects (Adits, Diversion Tunnel, De-silting Chambers, Flushing out tunnels, Head Race Tunnels, Penstock, Tail Race Tunnels)*

Total tunnel length in Bhutan: 151.6km

Method of Excavation

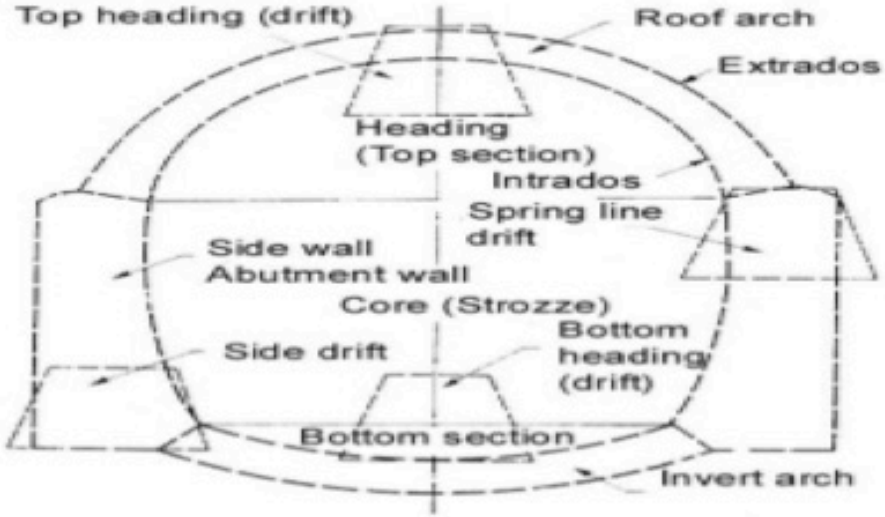
- Dictated by:
- Geological and hydrological conditions
- Dimensions and length of tunnel
- Shape of tunnel
- Cost and time of project

Contd…Method of Excavation

- Classical
- Cut and cover
- Tunnel Boring Machine
- Drill and blast (Conventional Method)

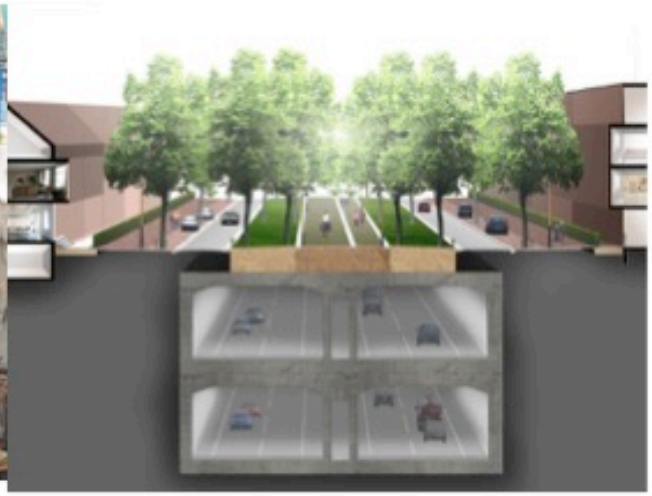
Contd…Classical Method

- Used in Mining in early 19th Century: American, Austrian, Belgian, English, Italian and German systems



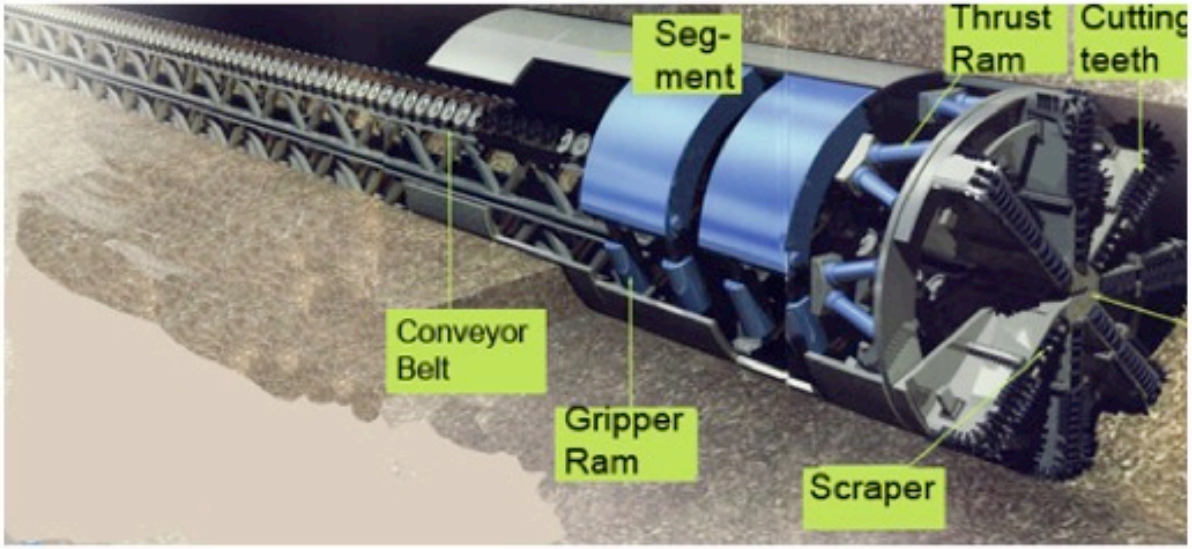
Contd…Cut & Cover Method

- Constructed in shallow depths where the excavated trench is covered from the top



Contd…Tunnel Boring Machine (TBM)

- Machine with a rotating wheel (cutter head) which works on the principle of percussion drill head.



Why Conventional Tunneling Method in Bhutan

- Due to the geological conditions
- Local experience
- Project cost

Resources Planning

1. Machinery

Drill Jumbo
Shotcrete Machine
Wheel loader
Excavator/pay loader
Cranes/scissors platform

2. Tools &Plants

Concrete Batching Plant
Aggregate Processing Plant
Survey & Geology Equipment

3. Pumps

Grout pumps
Dewatering
Concrete

4. Workshop (Auto & Electrical)

Rebar Threading Machine
Steel Bending Machine
Welding & Cutting sets
Automobile and electrical

5. QC & QA Establishment (instrumentation)

6. Materials

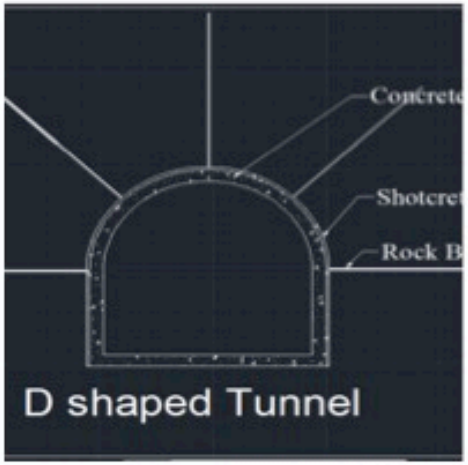
Explosives
Cement, sand and aggregate
Reinforcement and anchor bars
Steel plates, channels (ISMB, ISMC, ISHB)
Steel fiber, wire mesh Trailers
Chemicals (admixtures and superplasticers)
HSD/POL

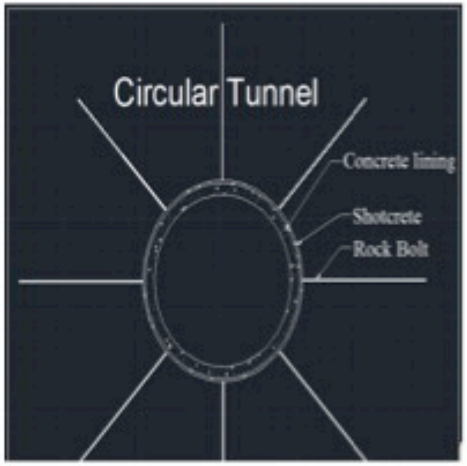
7. Others

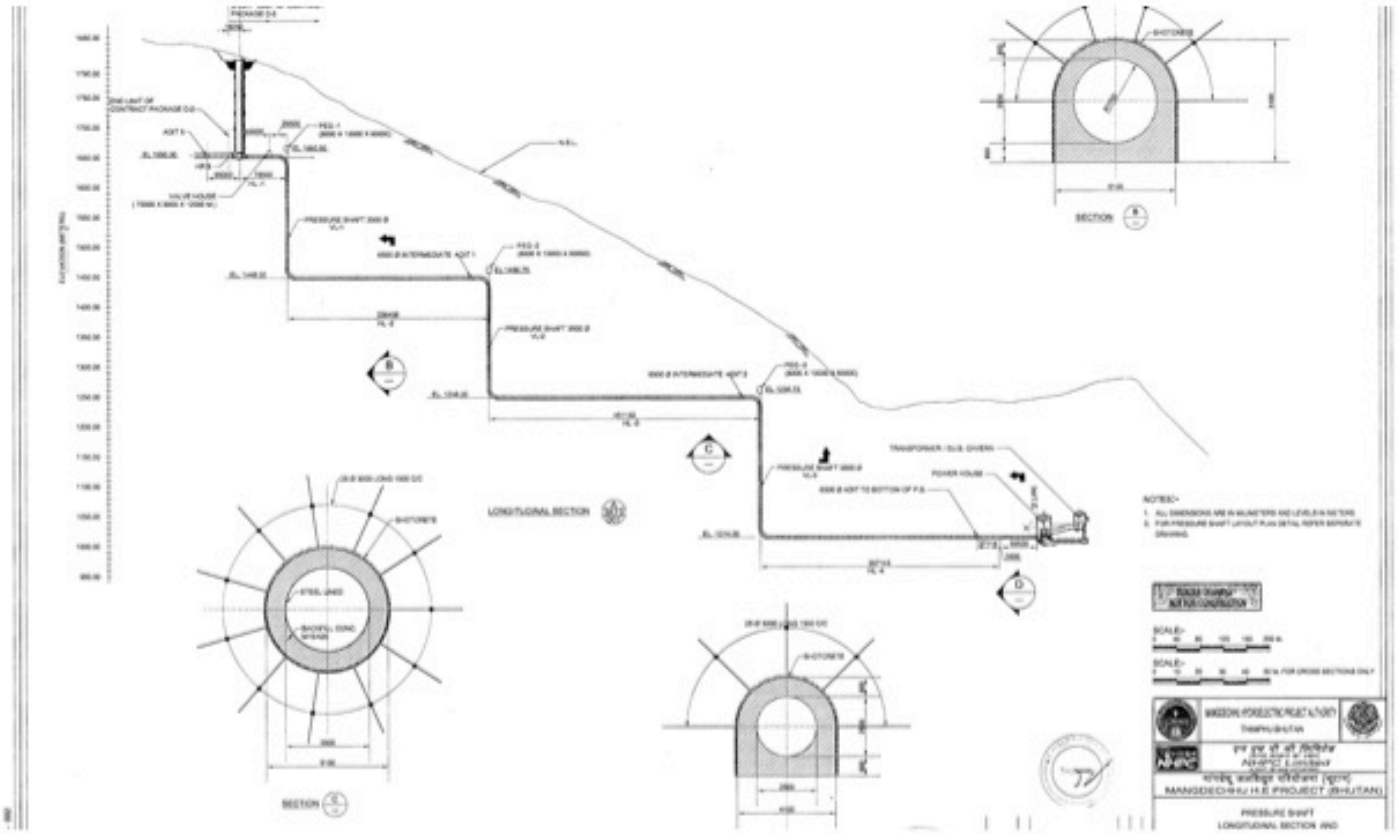
Transit Mixers
Dumpers
Inspection vehicle
Bus/ambulance
Fuel Tanker/sprinkler
DG Set
Ventilation Motors & Ducts

8. Spare parts

Shapes of Tunnel






LONGITUDINAL SECTION
SECTION
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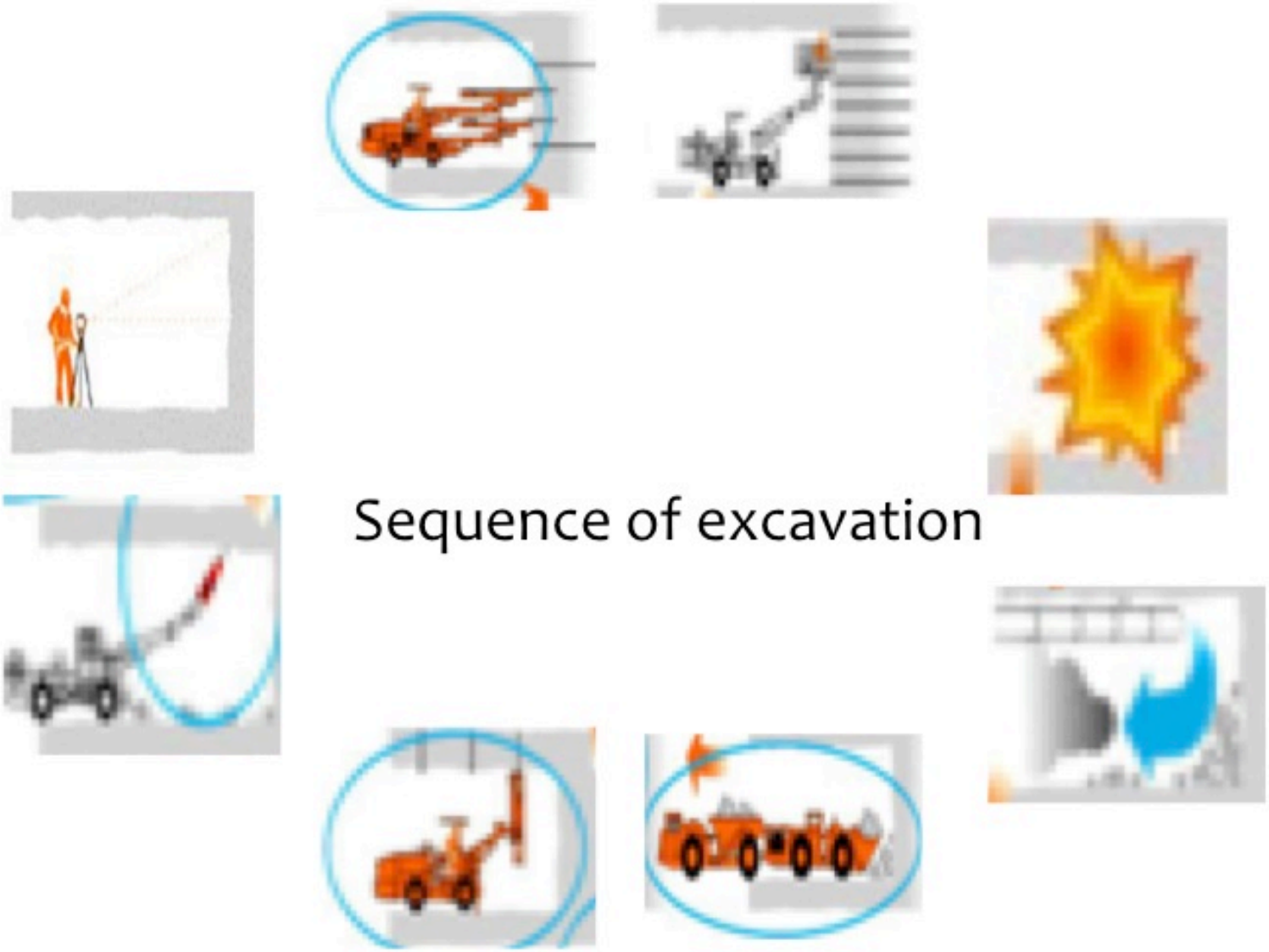
NOTES:-
MANGDECHHU H.E PROJECT (BHUTAN)
PRESSURE SHAFT
LONGITUDINAL SECTION AND

The excavation sequence in CTM

- Profile marking
- Drill
- Load and blast
- Ventilate
- Mucking
- Rock supports
- Scaling

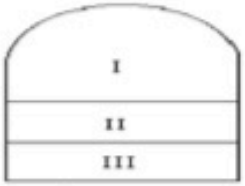


Sequence of excavation

Types of Excavation

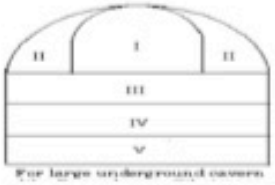
- Full face

- Heading Benching



- Multi-drifting

- Pilot



Blasting

Contd…Blasting

- Efficient blast saves time and money due to:

➢ Less over break and under break

➢ Smooth walls

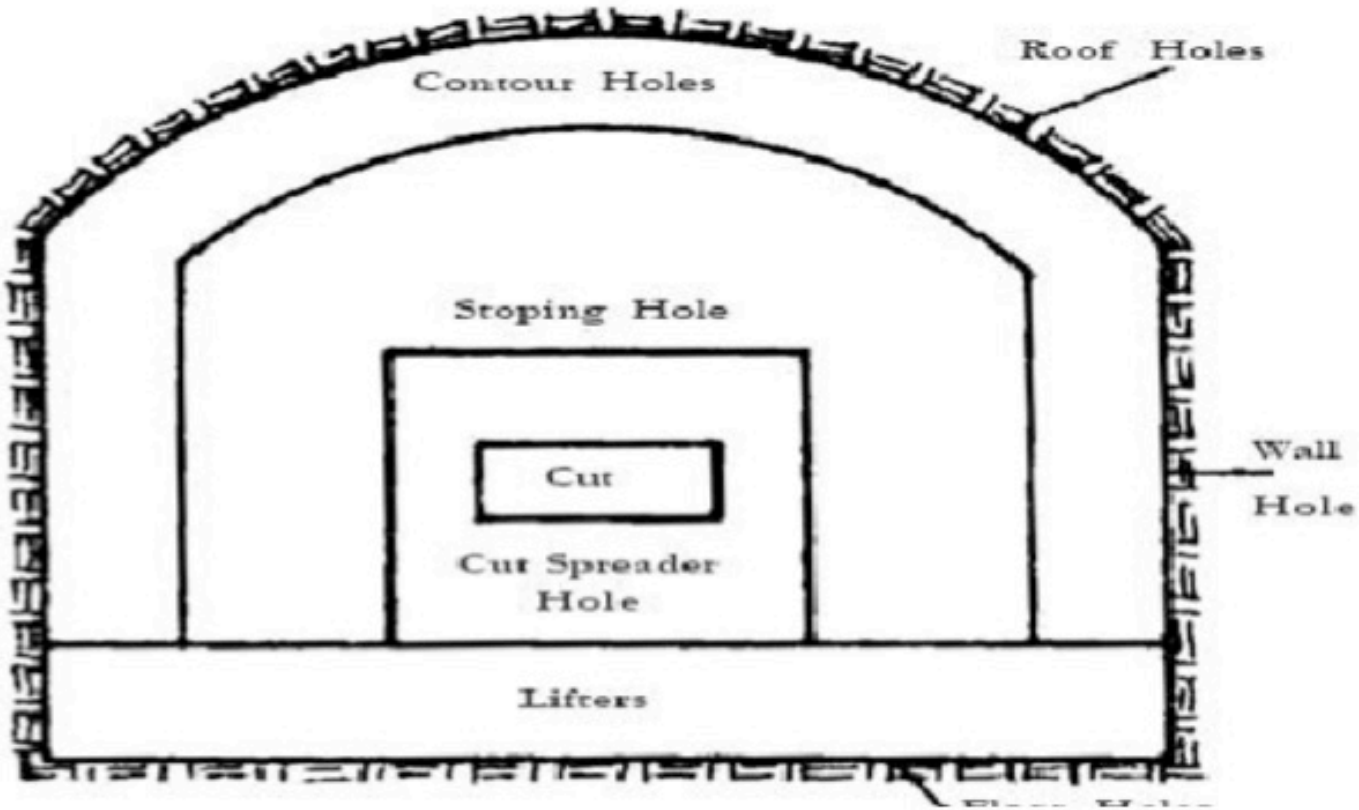
➢ More advance of tunnel per round

➢ Safety to men, machine and equipment

Contd…the difference

- Blast in the tunnel varies from open blast.
- Tunnel blast has only free surface when open blast is done in more than two free surfaces which restricts volume of rock to be blasted at single time.
- For efficient blast, second face has to be created (drilling pattern comes into picture)

Profiling the zones



Drilling Pattern

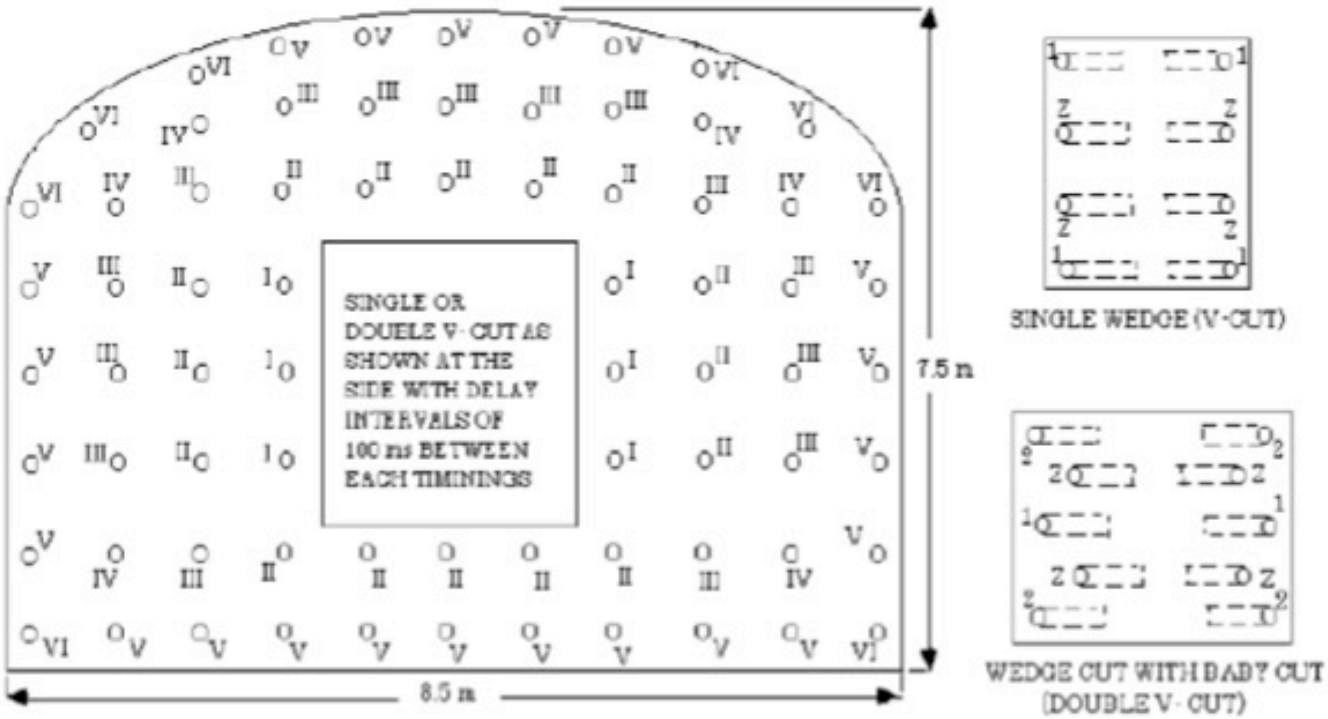
- The selection of drilling pattern depends pn:
- Tunnel size
- Tunnel shape
- Size of drill hole
- Conditions of rock
- Presence of water

- The most commonly used patterns are

1. Wedge cut
2. Burn cut

The right selection of pattern and accurate transfer on the face while drilling gives more advance/pull

Drilling Pattern



DRILL ROUND USING SINGLE OR DOUBLE WEDGE (V-CUT) WITH DELAY SEQUENCE (FOR CUT HOLES 100MS DELAYS & 500MS DELAYS FOR EASER & TRIMMER)

Blast Design

- Blast design is derived from drilling pattern to achieve two parameters which indicate the economy and efficiency of blast:
- Powder factor (kilograms of explosives per cubic meter of blasted rock).
- Drill factor (total length of drill holes per cubic meter of blasted rock (meter/cubic meter))

(For most typical tunnel blasting, powder factor varies from 0.6 – 5kg/m^3 and drill factor from 0.8-6m/m^3)

Firing Sequence

- Start from the central cut holes and progress outward the tunnel contour
- The minimal time interval of two adjacent holes must be less 25ms

Muck after blast

Ventilation

- Blast produces huge quantities of obnoxious fumes, dusts and gases which affect the health of workers.
- Each worker to work safely in the tunnel, about 300-500 cft per worker of air has to be continuously supplied.
- Quantity of fumes produced depend on the size and length of tunnel, powder factor, humidity and temperature, gases produced from the ground, types & number of diesel operated machines.

Density of Dust Emitted

Tunneling Works	The Density of Dust Formed in mg/m^3
Excavation	10 -1000
Loading of materials that are excavated	10 – 1000
Mucking	10 – 100
Drilling	1--50

Allowable density of poisonous gases

Gas	Allowable density (ppm)
CO	100
NO	25

Two types of ventilating tunnel using electric motor fans and duct:

1. Exhaust principle
2. Blowing in

Taking out muck

Mucking arrangement is done depending on the size of tunnel and available equipment

- Load and haul (common)

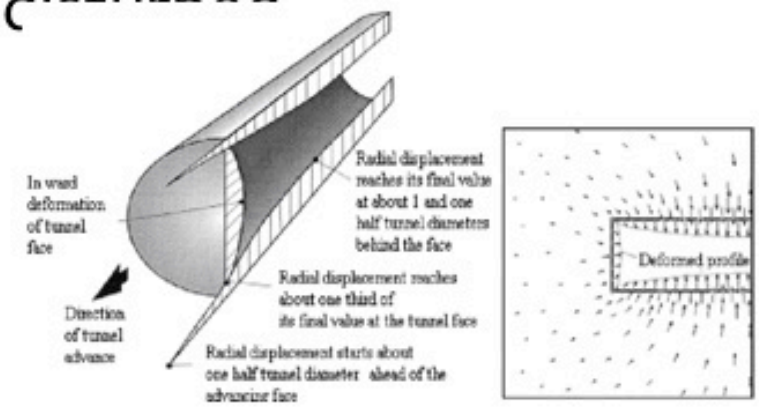
- Auto-loading machine is gaining popularity

Mucking other arrangement

- Track system

Rock support

- In each blast, the tunnel undergoes deformation when the stresses in equilibrium state are disturbed



- Appropriate rock supports have to be installed to prevent failure of tunnel

Type of rock supports

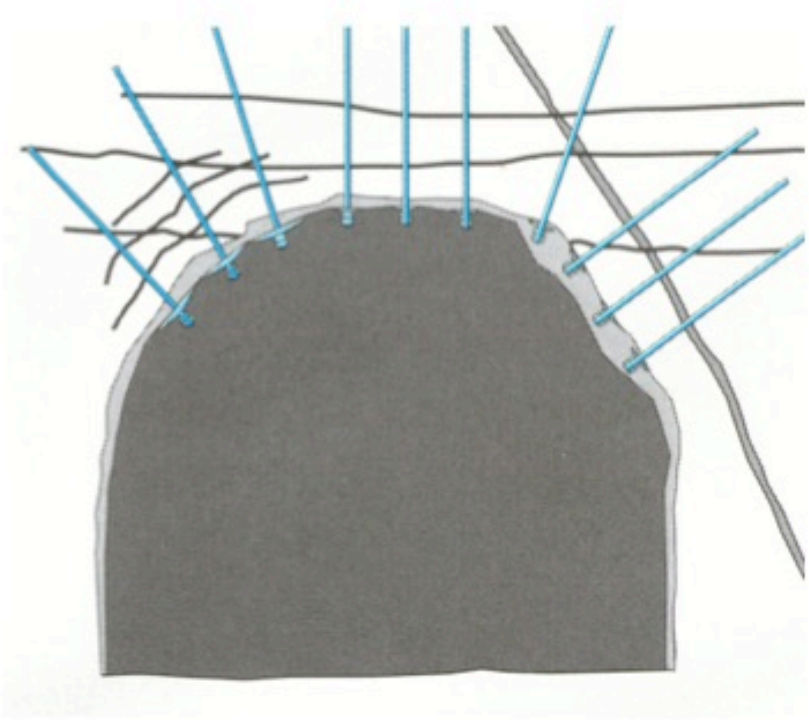
- Rock bolt
- Shotcrete (SFRS/PFRS)
- Fore poling
- Pipe roofing/Grouting
- Lattice girder
- Steel support and concrete lagging

Important: Too less of support will be fatal. Too much will be costly.

Rock bolt / anchors

Reinforces the rock (stitching principle)

- Resin/cement grouted
- Water expandable friction anchor
- Self drilling hollow core anchor

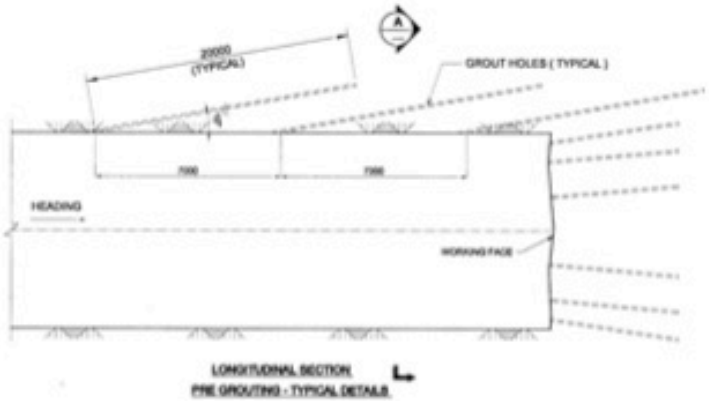


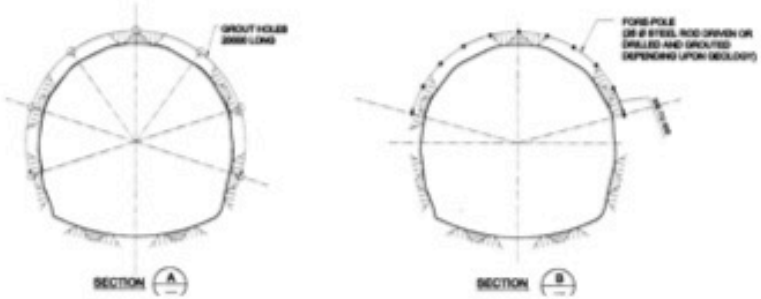
Shotcrete

- Applied by pressure to blasted surface. Arrests stress in surrounding mass
- Prevents loose fall

Fore poling

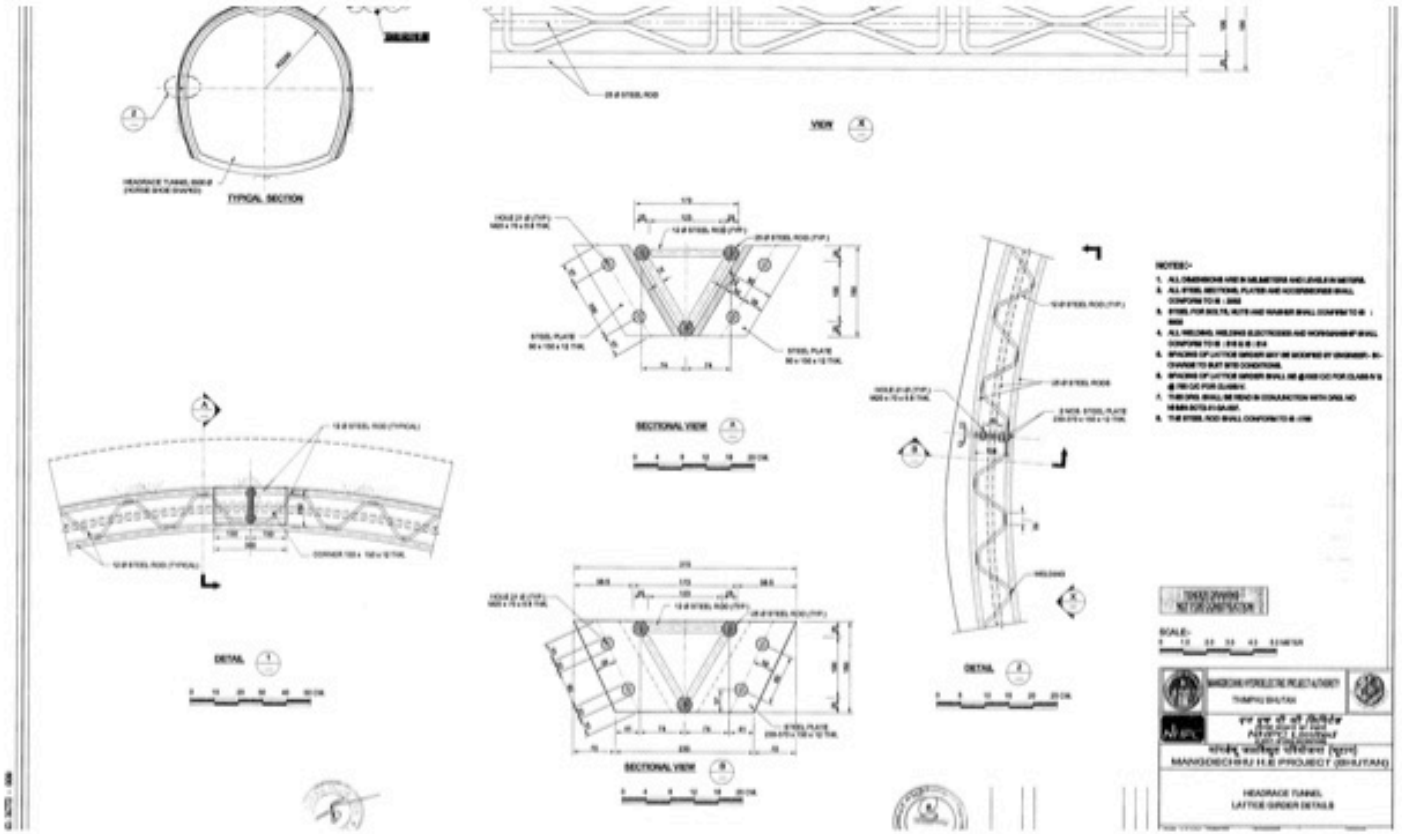
- Supports the crow
- Applies in poor roc



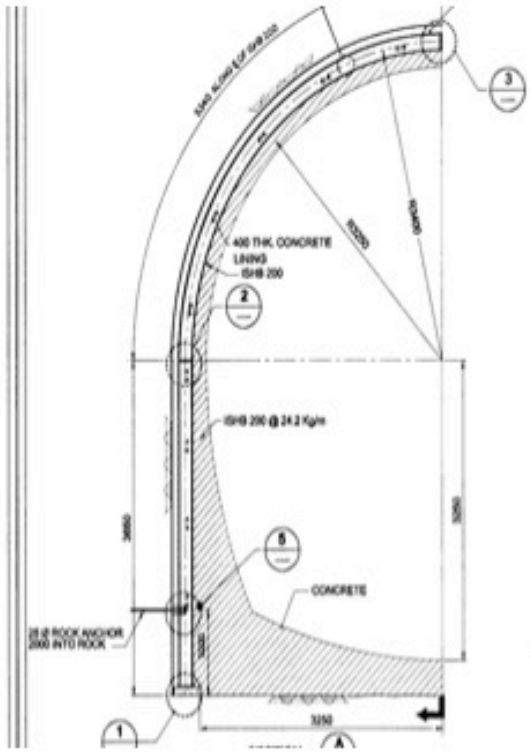


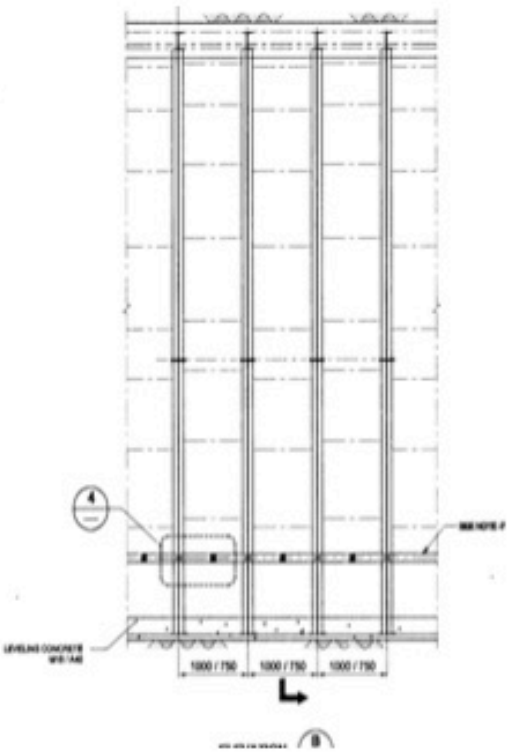
Pipe roofing

Lattice girder



Steel Rins & Backfilling

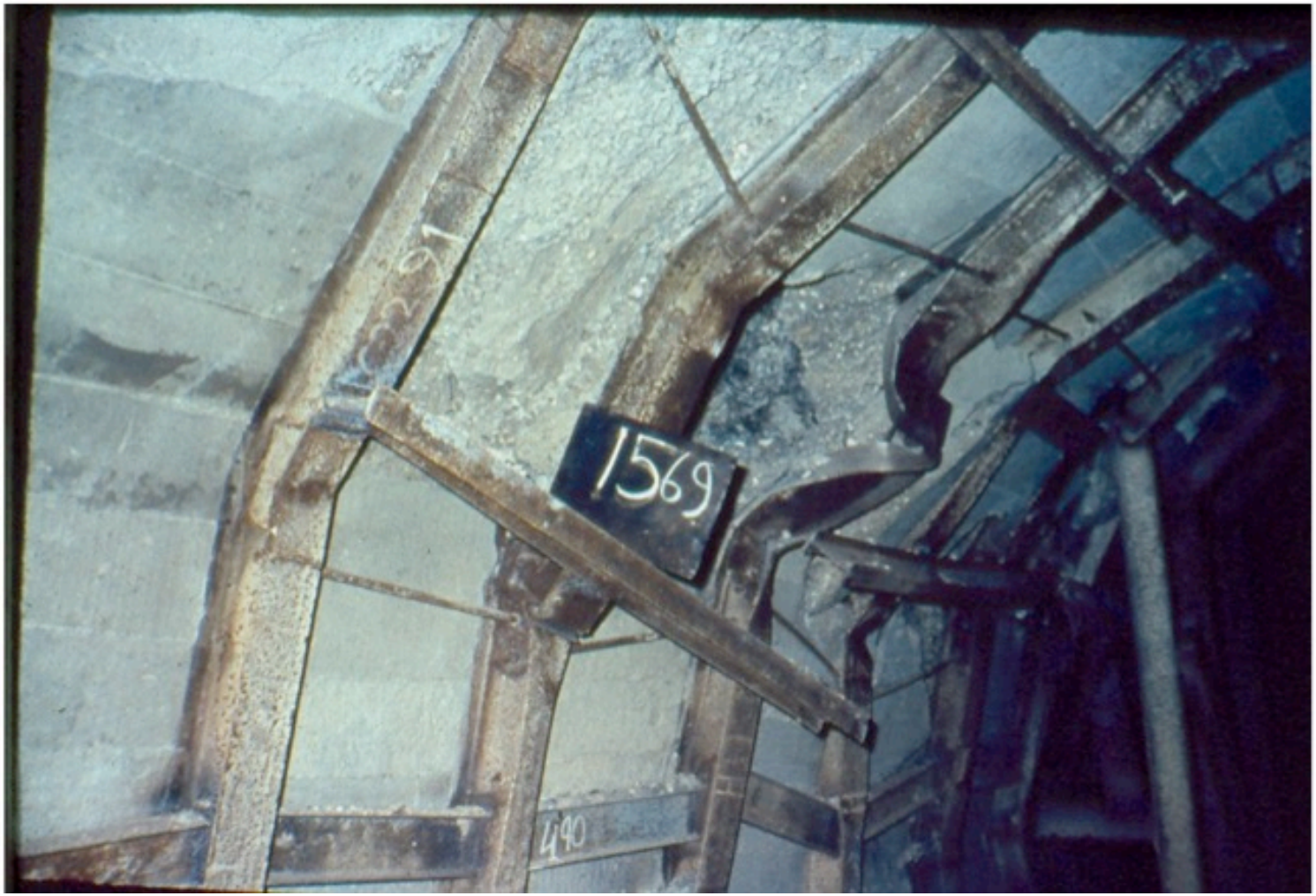




Challenges

- Swelling
- Squeezing
- Shear zone
- Wedge failure
- Ingression of water

Squeezing



Water ingression

Wedge failure

Cavity formation

Conclusion

- Proper planning
- Adequate investigations
- Put right equipment
- Field experienced workers
- Due diligence

Finally

A light at the end of tunnel?
It just means
you are just
watching
at the bunch
of engineers
working with
the torches on.

THANK YOU