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, Desilting 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

- D shaped Tunnel
- Horse Shoe shaped Tunnel
- Circular Tunnel
- Desilting Chamber
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 on:
  - 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 easier & trimmer)

SINGLE OR DOUBLE V-CUT AS SHOWN AT THE SIDE WITH DELAY INTERVALS OF 100 MS BETWEEN EACH TIMING.

SINGLE WEDGE (V-CUT)

WEDGE CUT WITH BABY CUT (DOUBLE V-CUT)
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/m³ and drill factor from 0.8-6m/m³)
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

<table>
<thead>
<tr>
<th>Tunneling Works</th>
<th>The Density of Dust Formed in mg/m³</th>
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</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>10 - 1000</td>
</tr>
<tr>
<td>Loading of materials that are excavated</td>
<td>10 – 1000</td>
</tr>
<tr>
<td>Mucking</td>
<td>10 – 100</td>
</tr>
<tr>
<td>Drilling</td>
<td>1–50</td>
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</table>
Allowable density of poisonous gases

<table>
<thead>
<tr>
<th>Gas</th>
<th>Allowable density (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>100</td>
</tr>
<tr>
<td>NO</td>
<td>25</td>
</tr>
</tbody>
</table>

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 crown
- Applies in poor roc
Pipe roofing
Lattice girder
Steel Rins & Backfilling
Challenges

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