

---

# INTRODUCTION TO BRIDGE AND TUNNEL ENGINEERING

ABHASH ACHARYA

M.SC. IN TRANSPORTATION ENGINEERING



ABHASH ACHARYA

1

1

---

## CONTENTS

- Choice of Location of Bridge Site
- Classification of Bridges and Component Parts of a Bridge
- Introduction to River Bank and Protection Structure
- Components Parts of Tunnel and Tunnel Cross-section
- Types of Road and Railway Tunnels
- Survey of Tunnel Alignment



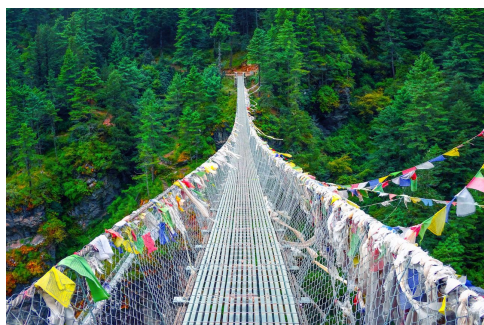
ABHASH ACHARYA

2

2

## BRIDGE

- Structure providing passage over an obstacle without closing the way beneath.
- As per NRS 2070, bridge is such a cross drainage structure whose span length is more than 6m, otherwise as the span length is less than 6m is termed as culvert.



ABHASH ACHARYA

3

3

## IDEAL BRIDGE

- Bridge axis should be perpendicular to river flow
- Line of bridge should not be deviated from line of approach roads
- Bridge should be absolutely in level
- Width should be adequate to cater future traffic
- Should be able to carry standard loading with FOS
- Should not produce undue obstruction to waterway
- Hard and solid foundation, preferable rock
- Headroom should be a little above HFL in case of Unnavigable channel while for navigable channel, headroom should be fixed based on height of vessels
- Should fit surrounding landscape
- Should provide services for sewerage, water, telephone
- Road surface over bridge should be similar to that in approaching sections
- Adequate provision for drainage of road section
- Should be economical in capital and maintenance cost



ABHASH ACHARYA

4

4

## IDEAL LOCATION OF BRIDGE SITE

- Straight reach of River
- Steady regime of river
- Narrow and well-defined channel
- Rocky or non erodible foundation
- Secure and economical approaches
- Reasonable proximity to direct alignment of road
- Absence of sharp curves in approaches
- Absence of excessive under water construction work
- Absence of costly drainage works, river training works
- Availability of construction materials



ABHASH ACHARYA

5

5

## CHOICE OF BRIDGE TYPE

- Most suitable to carry the desired traffic
- Adequately strong to support the design loads
- Aesthetically pleasing
- Economy in overall construction cost
- Large navigational clearances may dictate use of particular type of bridge
- To reduce number of piers, cantilever or cable stayed bridges may be preferred
- Climatic and environmental conditions
- Topographical and soil conditions (Rocky banks is ideal for an arch bridge)
- Availability of funds
- Type of traffic
- Personal preferences of designer



ABHASH ACHARYA

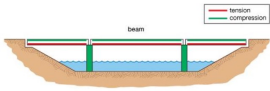
6

6

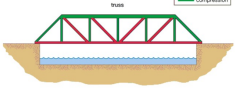
## CLASSIFICATION OF BRIDGE

- Based on Loading characteristics
  - Beam or slab bridge
  - Truss bridge
  - Arch bridge
  - Suspension bridge
  - Cantilever bridge
  - Cable stayed bridge

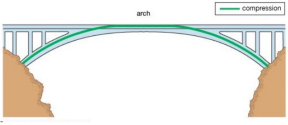
### 01. BEAM BRIDGE




### 02. TRUSS BRIDGE



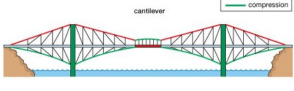
### 03. ARCH BRIDGE



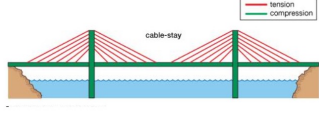
### 04. SUSPENSION BRIDGE




### 05. CANTILEVER BRIDGE



### 06. CABLE-STAYED BRIDGE





Source: [7 Jenis Jembatan yang dibangun di Dunia - affinf \(wordpress.com\)](https://www.affinf.com/7-jenis-jembatan-yang-dibangun-di-dunia/)


ABHASH ACHARYA
7

## CLASSIFICATION OF BRIDGE

- Based on Utility
  - Highway Bridge
  - Railway bridge
  - Compound bridge (dual purpose)
  - Pedestrian bridge




ABHASH ACHARYA
8

## CLASSIFICATION OF BRIDGE

- Classification based on span
  - Minor bridge: 6 m span length and up to 20 m total length
  - Medium Bridge : span length < 20 m and total length > 20 m
  - Major Bridge: Span greater than 20 m



ABHASH ACHARYA

9

9

## CLASSIFICATION OF BRIDGE

- Classification based on construction material
  - Masonry Bridge
  - RCC bridge
  - PCC bridge
  - Steel Bridge
  - Timber bridge
  - Floating bridge



ABHASH ACHARYA

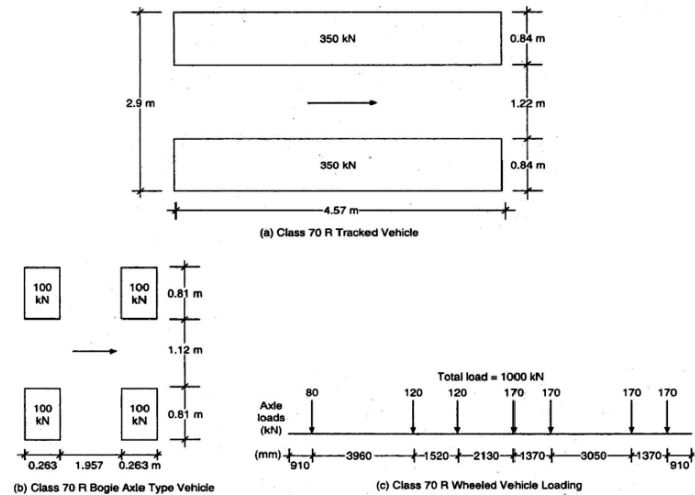
10

10

## CLASSIFICATION OF BRIDGE

- Based on Loading
  - Major Bridge: IRC class AA or Class 70 R
    - In this category, two types of vehicles are specified and they are grouped as **tracked vehicle and wheeled vehicles.**

The tracked vehicle simulating an **army tank of 700 KN** and **wheeled vehicle of 400 KN (a heavy army truck)** are standardized for the designing of all the bridges located on National Highways and State Highways.



I.R.C. Class 70 R Tracked and Wheeled Vehicles.



ABHASH ACHARYA

11

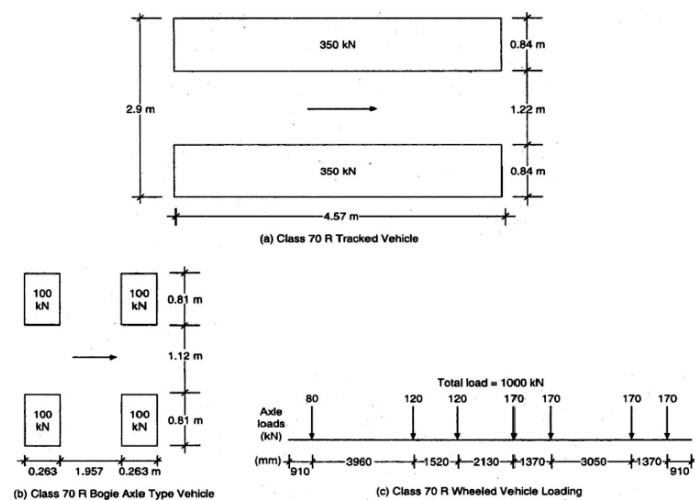
11

## CLASSIFICATION OF BRIDGE

- Based on Loading
  - Major Bridge: IRC class AA or Class 70 R

The following vehicles are considered for the design under this category:

- The tracked vehicle of the total load of 700 KN with tracks each weighing 350 KN each
- Wheeled vehicle of the total load of 400 KN with each wheels weighing 100 KN each
- Wheeled vehicle with a **train of vehicles on seven axles with a total weight of 1000 KN**



I.R.C. Class 70 R Tracked and Wheeled Vehicles.



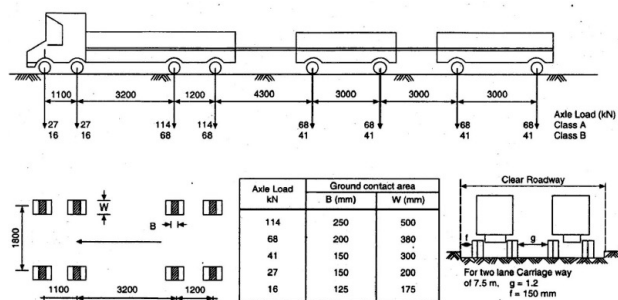
ABHASH ACHARYA

12

12

## CLASSIFICATION OF BRIDGE

- Based on Loading
  - Medium Bridge or minor bridge: IRC Class A
    - The IRC Class A loading is consists of a wheel load train of a total load of **554 KN**. It comprises a heavy-duty truck with two trailers that transmit loads from **8 axles** varying from a minimum of **27 KN** to a maximum of **114 KN**
    - This type of loading is recommended for all roads on which permanent bridges and culverts are constructed.
  - Temporary bridges: IRC Class B
    - The loading of this class is similar to the Class A loading except that the axle loads are of lesser magnitude. The total axle loads of this Class are **332 KN** with a train of wheeled vehicles on **eight axles**



ABHASH ACHARYA

13

13

## CLASSIFICATION OF BRIDGE

- Classification based Obstacle to be crossed
  - River bridge
  - Fly over



ABHASH ACHARYA

14

14

## CLASSIFICATION OF BRIDGE

- Classification based on position of pavement on the carriageway
  - Carriageway at bottom (through)
  - Carriageway at top (Deck)
  - Carriageway at middle (semi through)



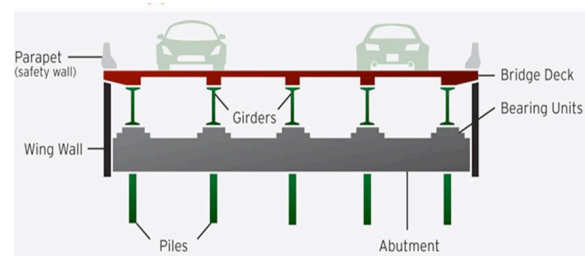
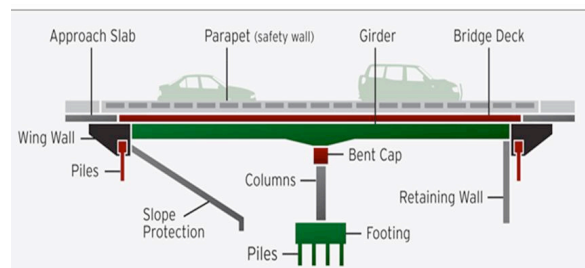
ABHASH ACHARYA

15

15

## COMPONENTS OF BRIDGE

- Superstructure
  - Structure of a bridge above the bearing.
  - Structure above which traffic moves safely.
  - Main girders, cross girders, deck slab, parapet, roadway, footpath, kerb stones, etc.
- Substructure
  - Supports the super structure and distributes the loads to the soil below through foundation.
  - Abutment and its cap, pier and its cap, foundations for abutments and piers, etc.
  - Foundation may be pile or well foundation.



ABHASH ACHARYA

16

16

## COMPONENTS OF BRIDGE

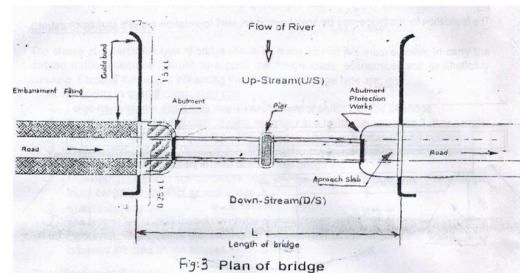
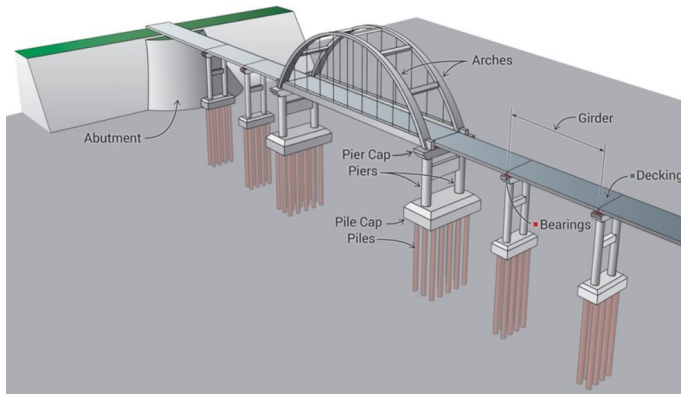


Fig-3 Plan of bridge



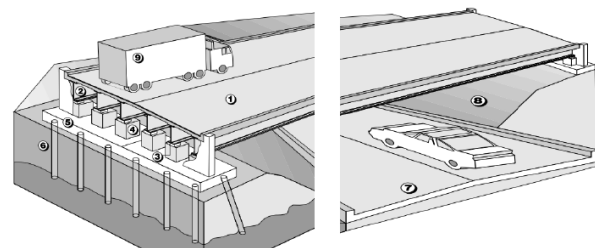
ABHASH ACHARYA

17

17

## COMPONENTS OF BRIDGE

- Deck – Physical extension of the roadway across the obstruction to be bridged.
- Pedestals – Short column on an abutment or pier under a bearing which directly supports a superstructure primary member.
- Abutments – Earth retaining structures which support the superstructure and overpass roadway at the beginning and end of a bridge.
- Piers – Structures which support the superstructure in intermediate points between the end supports (abutments).
- Bearings – Mechanical systems which transmit the vertical and horizontal loads of the superstructure to substructure and adjust movements between them.



- |              |             |                 |
|--------------|-------------|-----------------|
| 1-Deck and   | 2-Stringer  | 3-Bearing       |
| 4- Pedestal  | 5-Footing   | 6-Piles         |
| 7- Underpass | 8-Embakment | 9- Live Loading |

- Footing – As bearings transfer the superstructure loads to the substructure, so in turn do the abutment and pier footings transfer loads from the substructure to the subsoil or piles.
- Piles – When the soil under a footing cannot provide adequate support for the substructure, support is obtained through the use of piles.



ABHASH ACHARYA

18

18

## HYDRAULIC ANALYSIS OF BRIDGE

- Data to be collected:
  - Size, shape and surface characteristics of catchments
  - Storage in catchment
  - Longitudinal and cross slope of catchment area
  - The intensity and frequency of rainfall
  - HFL and year of occurrence
  - Low water level
  - Observed maximum depth of scour



ABHASH ACHARYA

19

19

## HYDRAULIC ANALYSIS OF BRIDGE

- Length and Number of Span:
  - Cost of super structure = cost of sub structure
  - **For masonry arch bridges:**  $S = 2H$ , S is clear span and H is total height of pier including foundation
  - For RCC slab bridges:  $S = 1.5 H$ 
    - Efforts should be made to provide as minimum number of spans as possible as greater the number of spans, greater the number of piers and hence more the obstruction to the flow under the structure.
    - Large span reduces the number of piers but RCC slab thickness or size of plate girder increases.
    - Piers should be located in such a way that the required linear waterway is obtained with minimum obstruction and required clearance is obtained if needed for navigational purposes.
    - If linear waterway, L is less than economical span S, provide single span
    - If  $L > S$ , number of span is found from  $L=NS$ , where N is the number of spans (whole number)



ABHASH ACHARYA

20

20

## HYDRAULIC ANALYSIS OF BRIDGE

- Linear Waterway
  - Well defined if banks are rigid
  - For large alluvial stream, banks are undefined, required linear waterway is defined using Lacy's formula:  $W = C * Q^{0.50}$

Where, W = Linear waterway

Q = Design maximum discharge

C = constant usually taken as 4.75 for regime channel

- Not desirable to reduce the linear waterway below that for regime condition.
- If a reduction is unavoidable due attention should be given to afflux and velocity under the structure.
- With reduced waterway, velocity increases and greater scour depth would be involved, requiring deeper foundations leading to extra expenses on deeper foundation and protective works.

$$B = \sum l + 2\sum t$$

where,  $\sum l$  = effective linear waterway required,  $\sum t$  = sum of all pier thickness, B = length of the bridge from face to face of abutments.



ABHASH ACHARYA

21

21

## HYDRAULIC ANALYSIS OF BRIDGE

- Design Discharge
  - From Unit Hydrograph
    - Hydrograph is graphical representation of Discharge Vs. Time
    - Unit hydrograph is hydrograph representing runoff from uniform unit rainfall for given duration
    - Rainfall excess is determined and the ordinates of unit hydrograph multiplied with this value to determine value of discharge



ABHASH ACHARYA

22

22

## HYDRAULIC ANALYSIS OF BRIDGE

- Design Discharge
- Using utility curve
  - Graph plotted discharge as ordinate and percent occurrence as abscissa on logarithmic scale
  - Knowing frequency of occurrence, discharge can be read
  - Highest discharge can be used as design discharge if it does not exceed next highest discharge by more than 50%. If it exceeds this limit, it should be restricted to 1.5 times the lower estimate.
  - The structure should be capable of passing a flood of a specified frequency which is usually 20 years for culverts and small bridges and 100 years for big bridges.
  - In case of unusual flood, excessive damage should not be caused to the structure or to the bed.



ABHASH ACHARYA

23

23

## HYDRAULIC ANALYSIS OF BRIDGE

- Design Discharge
  - Afflux: Heading up of water over the flood level caused by constriction of waterway at bridge site.

$$X = \frac{V^2}{2g} \left( \frac{L^2}{C^2 W^2} - 1 \right)$$

where, X is afflux in m

V is velocity of normal flow in the river in m/secs

L = width of stream at HFL

C = coefficient of discharge through the structure

- The afflux should be kept minimum and limited to 30 cm.
- Afflux causes increase in velocity on the downstream side, leading to greater scour and requiring deeper foundations.
- The road formation level and the top level of bridge bunds are dependent on the maximum water level on the upstream side including afflux.



ABHASH ACHARYA

24

24

## RIVER BANK PROTECTION STRUCTURES

- River Bank may fail due to:
  - Erosion of soil by river currents
  - Excessive hydrostatic pressure in materials
  - Rotational failure
  - Liquefaction and subsequent movement of soil mass
  
- Objectives of river training works:
  - To provide safe and expeditious passage to flood flow without overflowing of banks
  - To prevent outflanking of hydraulic structures as bridges, weirs or barrages, etc.
  - To ensure minimum depth of flow for navigational purposes
  - To deflect flow of river from the bank which is damaged by the river by constructing spurs
  - To fix the direction of flow through certain alignment



ABHASH ACHARYA

25

25

## RIVER BANK PROTECTION STRUCTURES

- River training works
  - Stone pitching with adequate apron
  - Lining with cement concrete blocks
  - Construction of spurs, guide bunds
  
- Guide bunds
  - To guide and confine the flow of large meandering rivers when the flow has to be contracted through the opening in the bridges.
  
- Spurs
  - Constructed to deflect the current away from the bank.
  - To protect the river bank by deflecting, repelling or attracting the flow of river.
  - To contract the wide shallow river channel to improve navigation.
  - To train the river to flow along a specified course.



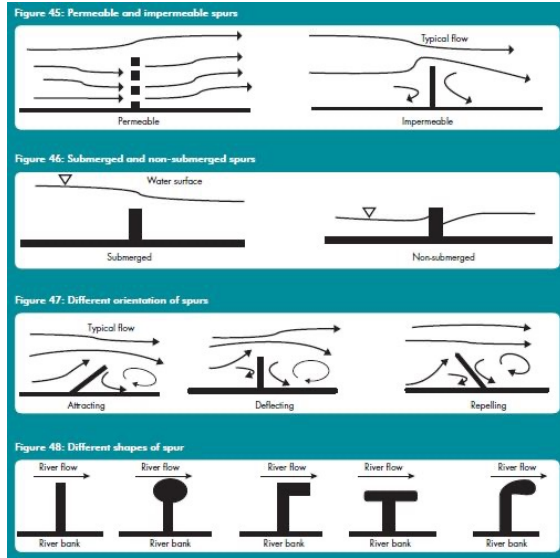
ABHASH ACHARYA

26

26

## RIVER BANK PROTECTION STRUCTURES

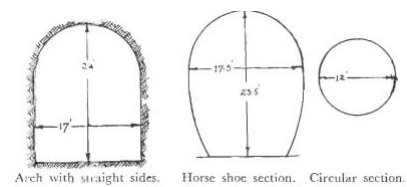
- Spurs
  - Repelling spurs (deflecting spurs) incline upstream at an angle of 60 degrees to 70 degrees to the river course and deflect the current towards the opposite bank.
  - Attracting spurs incline downstream and make the deep channel flow continuously along their noses. The river flow is attracted towards the spur.
  - Normal spurs (holding or sedimenting spurs) are built at right angles to the bank to keep the stream in a particular position. They have practically no effect on the diversion of the current and are mostly used for training of rivers for navigational purposes.



ABHASH ACHARYA

## ROAD AND RAILWAY TUNNEL

- Tunnels are artificial underground passages constructed for transportation purposes and may be required for highways, railways, sewerage, water supply, public utility and canals.
- Required when other methods of construction are unavailable and when tunneling is an essential element of the project.



ABHASH ACHARYA

## ROAD AND RAILWAY TUNNEL

- Design of tunnel is governed by
  - Purpose of tunnel
  - Wider channel
  - Clearance prescribed
  - Method of tunneling
  - Soil characteristics
  - Methods of lighting and ventilation
- Types
  - Rail road tunnel
  - Highway tunnel
  - Rapid transit tunnel or subways



ABHASH ACHARYA

29

29

## ROAD AND RAILWAY TUNNEL

- For highway tunnels, a pair of tunnels is considered more economic and safer than a single tunnel or larger cross-section
  - Economy in cost of construction
  - Improves safety and avoid head-on collision
  - Facilitates ventilations
  - Exit and entrance can be separated
  - Easy repair and maintenance



ABHASH ACHARYA

30

30

## SURVEY OF TUNNEL ALIGNMENT

- After reconnaissance of the area, two or three alignments are selected and the final alignment is selected out considering feasibility and economy.
- Both the ends of tunnel are fixed accurately on the hill and then the center line of the tunnel is located on the ground and then the correct length of the tunnel is determined for the final alignment.
- IS 5858
  - Part I Precision survey and setting out
  - Part II Underground excavation in rocks
  - Part III Underground excavation in soft strata
  - Part IV Tunnel support
  - Part V Concrete Lining
  - Part VI Steel lining



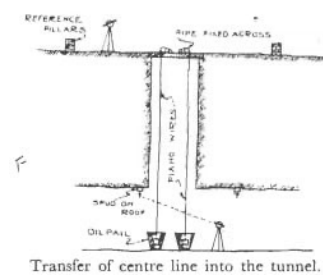
ABHASH ACHARYA

31

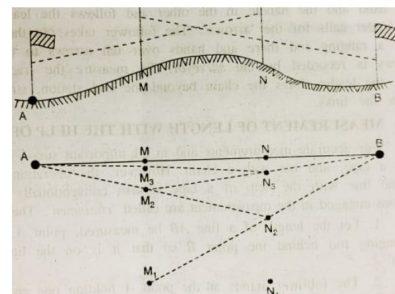
31

## SURVEY OF TUNNEL ALIGNMENT

- Initial Survey
  - Prepare detail topographic map for preliminary setting out of tunnel
  - Tachometric reconnaissance survey giving horizontal and vertical control
  - Fixing portal points on the topographical maps
- Setting out of tunnel centerline on surface
  - Surface control points are not mutually visible; summit point is established and a straight line joining two points and summit point is set on the ground
- Triangulation
  - It is not possible to align tunnel ends by direct ranging of reciprocal ranging hence precise triangulation is required
- Setting out inside tunnels
  - Reference points are constructed every 300m in roof of tunnels
  - Transfer of tunnel center line on ground through staff



Transfer of centre line into the tunnel.



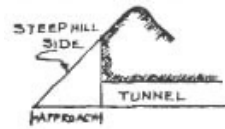
ABHASH ACHARYA

32

32

## SURVEY OF TUNNEL ALIGNMENT

- Approximate location of tunnel is dictated by the purpose it has to serve
- Final location is based on the results of surface and sub surface explorations
- Tunnel approaches are open cuts on both sides of the tunnel. In steep hill slopes, these are very short while for flat sloped hills, these are longer.
- The transfer of tunnel center line on the ground is very important operation as the alignment entirely depends upon this operation. This operation needs utmost care and accuracy in operation, otherwise center line worked from opposite faces will not meet.



ABHASH ACHARYA

33

33

## DRAINAGE

- Pre-drainage
  - Before starting of construction work
  - Divert surface drainage
  - Provision of counterweight against hydrostatic pressure
- Dewatering
  - During process of tunnel construction
  - Remove by gravity flow or by pumping
  - If tunnel is driven upgrade, water may be removed normally through drains
  - If tunnel is driven downgrade or in flat land, water must be pumped
- Permanent drainage (Depends on nature of tunnel, type of soil, quality of water in drainage and type of lining used)
  - Provision of longitudinal drains
  - Continuous open gutter
  - Concrete lining
  - Grouting with cement or chemicals



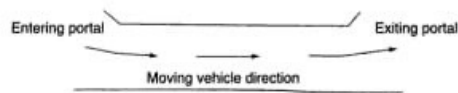
ABHASH ACHARYA

34

34

## TUNNEL VENTILATION

- To make working space safe by providing fresh air and bringing down the tunnel temperature
- Natural ventilation
  - Possible if the tunnel is a short one with large diameter
  - Effective when the orientation of the tunnel is in the direction of the wind
  - In straight reach, uniform grades up to 100m tunnel length would not need any mechanical ventilation



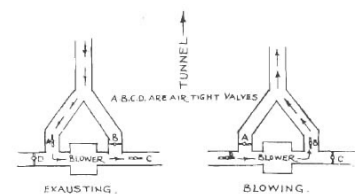
ABHASH ACHARYA

35

35

## TUNNEL VENTILATION

- Mechanical ventilation
  - Blowing of fresh air
    - Supplying of fresh air by ducts to the working face
    - The foul air while being expelled through the tunnel, itself make the approach unhealthy
  - Exhausting foul air by ducts
    - Foul air and dust are drawn into an exhausting duct near the working faces, creating a flow of fresh air into the tunnel from the entrance.
    - Useful after blasting when it is desirable to remove blast fumes
    - Fresh air may absorb moisture, foul gases, heat, etc.
  - Combination of blowing in and exhaust system
    - Blowing system have a small diameter duct sufficient for providing enough fresh air
    - Immediately after the blasting operation, the exhausting system is operated for 15-30 minutes to remove the objectionable air, after which the blowing system operates for the rest of the working period to supply fresh air



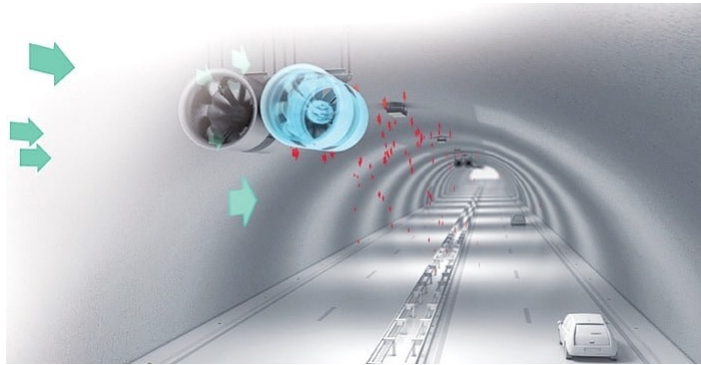
ABHASH ACHARYA

36

36

## TUNNEL VENTILATION

- Requirements of good ventilation system
  - Smoke and fumes should be removed as soon as possible
  - Amount of dust produced should be brought within permissible limits
  - Should provide atmosphere at the face
  - Accumulation of dangerous fumes must be avoided



ABHASH ACHARYA

37

37

## LIGHTING REQUIREMENTS

- Minimum 100 lux for tunnel and shaft heading, drilling, mucking. Minimum 50 lux for efficient and safe working.
- Any obstruction should be well lighted to avoid accidents while hauling units are moving.
- No single light should be so powerful to cause temporary blinding.
- Voltage can be reduced from 230V to 110V. Water proof cable should be laid.
- Lamps should be fixed in center of roof.
- Electric circuit should be divided into a number of independent circuits.
- In addition to fixed lighting, hauling equipment should have their own light.



ABHASH ACHARYA

38

38

## DUST CONTROL

- Presence of dust may cause serious health hazards to the workers in the tunnel.
- Steps to limit dust are:
  - Wet drilling instead of dry drilling
  - Muck piles should be sprinkled with water to keep down the dust
  - Adequate and efficient ventilation
  - Use of vacuum hood



ABHASH ACHARYA

39

39

## TUNNEL LINING

- Objectives
  - To provide **desired shape and cross section**
  - Withstand **soil pressure** and prevent tunnel from collapsing
  - To keep tunnel free from **water leakage**
  - **Bind loose rock** and provide stability
  - Reduce maintenance cost
  - In sewer or water supply tunnels, lining is used **to reduce coefficient of rugosity** and prevent seepage and contamination
  - For better appearance



ABHASH ACHARYA

40

40

## TUNNEL LINING

- Loads Supported by Tunnel Lining
  - Weight of lining, internal structure if any
  - Weight of surrounding ground and superimposed loads
  - Weight and impact of traffic
  - Loads due to temporary construction like compressed air pressure and reaction of shield jacks



ABHASH ACHARYA

41

41

## TUNNEL LINING

- Materials for Tunnel Lining
  - Brick Lining
    - In old tunnel when concrete technology had not been evolved. Not popular these days because
      - It requires heavy and large centering
      - Unsuitable to be used in shield
  - Stone Masonry Lining
    - Used when the bricks had not been introduced
    - Limitations same as brick lining
  - Timber Lining
    - Often used in the earlier stages of tunneling as temporary lining or support in other types of lining
    - Uses as **semi permanent lining** replaced by concrete lining
    - Cheap and readily available however not suitable when water-proof lining is required



ABHASH ACHARYA

42

42

## TUNNEL LINING

- Materials for Tunnel Lining
  - Concrete Lining
    - Thin Lining
    - Cast insitu RCC lining is extensively used particularly in tunnels for water supply, sewerage, rail road, etc.
  - Cast Iron Tunnel Lining
    - Useful for the lining of shield driven tunnels particularly in sub aqueous regions
  - Structural Steel
    - Used in lining in the form of steel ribs and liner plates
    - For the same strength, it is lighter than cast iron lining



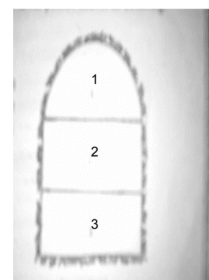
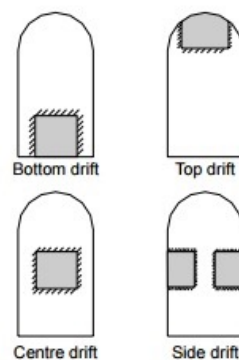
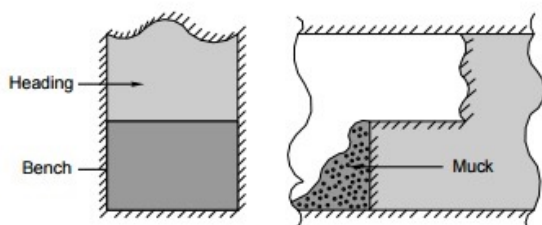
ABHASH ACHARYA

43

43

## METHODS OF TUNNELING

- Firm Ground
  - Full face method
  - Top heading and benching
  - Drift method



ABHASH ACHARYA

44

44

## METHODS OF TUNNELING

- Firm Ground
  - Full face method
    - Suitable for comparatively firm soils where the excavated portion can hold itself for sufficient time to permit mucking and supporting operations to be completed.
    - Excavation to be done is divided into 3 sections and is started from top to bottom I-II-III.
    - This is the recommended method for tunnels of smaller size (usually whose dimension do not exceed 3m).
    - Vertical columns are erected at the face of the tunnel and a large number of drills mounted or fixed on these columns at a suitable height.
    - A series of holes measuring 10 mm to 40 mm diameter with about 1200 mm centre to centre spacing are then drilled into the rock.
    - The holes are charged with explosives and ignited. Muck is removed before repeating the process of drilling holes.



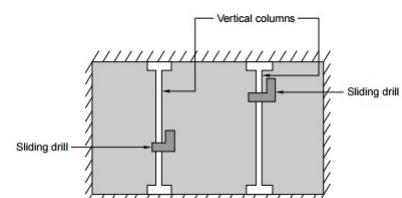
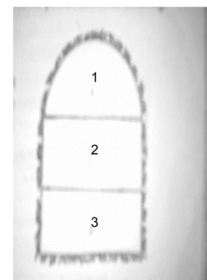
ABHASH ACHARYA

45

45

## METHODS OF TUNNELING

- Firm Ground
  - Full face method
    - Advantages
      - Since an entire section of the tunnel is tackled at one time, the method is completed expeditiously.
      - Can be used for large tunnels with the development of drill carriage.
    - Disadvantages
      - Requires heavy mechanical equipment.
      - Not very suitable for unstable rocks.
      - Can normally be adopted for small tunnels only.



ABHASH ACHARYA

46

46

## METHODS OF TUNNELING

- Firm Ground
  - Top heading and benching
    - Where the excavated portion cannot hold itself by the time mucking and supporting operations are carried out, the heading is excavated and supported to the full length or part of the tunnel before benching is started.
    - The heading is always ahead of the benching by a convenient length and may be formed by excavating full width of the tunnel above the springing line.
    - In hard rock, the drill holes for the bench are driven at the same time as the removal of the muck.
  - Advantages
    - The work of drilling of holes for the explosives and the removal of muck can progress simultaneously.
    - Method requires the use of low quantities of gunpowder than the full-face method.

The point where the curved portion of a tunnel roof meets the top of the wall.  
In a circular tunnel the springlines are at the opposite ends of the horizontal centerline.



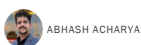
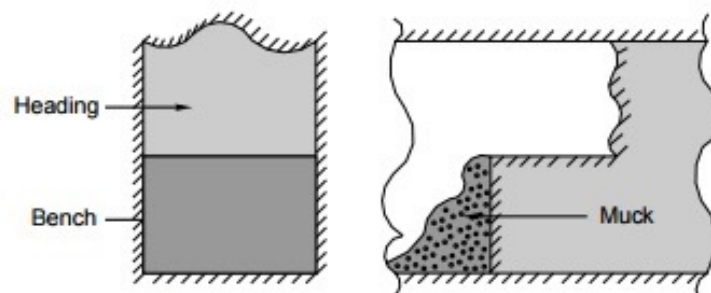
ABHASH ACHARYA

47

47

## METHODS OF TUNNELING

- Firm Ground
  - Top heading and benching



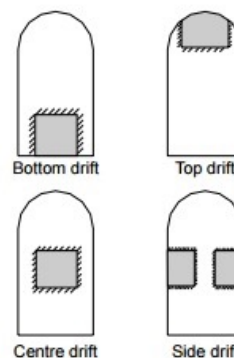
ABHASH ACHARYA

48

48

## METHODS OF TUNNELING

- Firm Ground
  - Drift Method
    - In the case of **large size tunnels, a pilot tunnel or drift is made** in the side or at the center of the tunnel by drilling and blasting is not done.
    - The drift is widened by drilling holes on its faces.
    - **Drill holes are filled up with explosives and ignited** so that the size of the drift expands to become equal to the required cross section of the tunnel.
    - Depending upon the position of drift, the method of tunneling is further classified as side drift, central drift, top drift, bottom drift.
    - **Central drift is the best choice as per field experience as it requires lower quantities of explosives.**



ABHASH ACHARYA

49

49

## METHODS OF TUNNELING

- Firm Ground
  - Drift Method
    - Advantages
      - Drift assists in the ventilation of tunnels
      - Quantity of explosives required is less
      - Side drift allows the use of timber to support the roof
      - **If the quality of the rock is bad or if it contains excessive water, this is detected in advance and corrective measures can be taken in time.**
    - Disadvantages
      - Time consuming process, as the excavation of the main tunnel gets delayed till the drift is completed.
      - The cost of drilling and removing the muck from the drift is high, as the work has to be done using manually operated power-driven equipment.



ABHASH ACHARYA

50

50

## METHODS OF TUNNELING

- Firm Ground
  - Pilot Tunnel Method
    - Involves the **digging of two tunnels**, namely a pilot tunnel and a main tunnel.
    - Pilot tunnel is driven parallel to the main tunnel and connected to the main tunnel and connected to the centre line of the main tunnel with cross cuts at many points.
    - The main tunnel is then excavated from a number of points.
    - The pilot tunnel offers the following advantages
      - **Helps in removing the muck from the main tunnel quickly**
      - **Helps in proper ventilation and lighting in the main tunnel**
    - However, requires the construction of an additional tunnel and therefore the time and cost of construction are higher as compared to other methods.



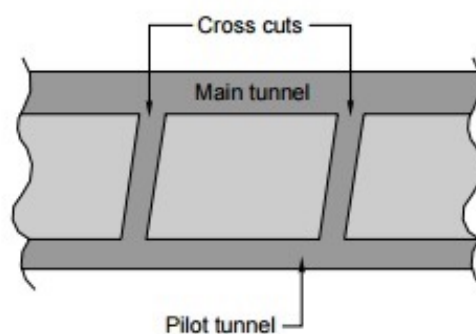
ABHASH ACHARYA

51

51

## METHODS OF TUNNELING

- Firm Ground
  - Pilot Tunnel Method



ABHASH ACHARYA

52

52

## METHODS OF TUNNELING

- Tunneling in Rock
  - Full face method: For good rock
  - Top heading and benching: When tunneling section is very large and rock is not structurally sound
  - Bottom heading and stopping: When section is large and rock is consistent and sound
  - Drift method



ABHASH ACHARYA

53

53

## METHODS OF TUNNELING

- Soft Ground
  - Tunneling in soft strata **requires temporary support immediately after the construction.**
  - The different ways to provide temporary support may be:
    - Suitably spaced bents of woods
    - Suitably spaced bents of steel with lagging
    - Liner plates
    - Fore poling placed to retain the material between adjacent bents



ABHASH ACHARYA

54

54

## METHODS OF TUNNELING

- Soft Ground
  - Method of tunneling depends upon
    - Nature of ground
    - Size of tunnel
    - Equipment available
    - Sequence of operations



ABHASH ACHARYA

55

55

## METHODS OF TUNNELING

- Soft Ground: Fore-poling Method
  - "A" frame is prepared and placed near facing of tunnel
  - Poles are then inserted at top of the frame up to a viable depth
  - Excavation is carried out below these poles, which are supported by vertical posts
  - The excavation is carried out on the sides and the excavated portion is suitably supported by timber.
  - Fore poles consist of plank with wedge ends and are inserted at a time
  - Driven through half length at 15cm/m inclination
  - Forepoling is a slow and tedious process and requires skilled manpower and strict supervision.



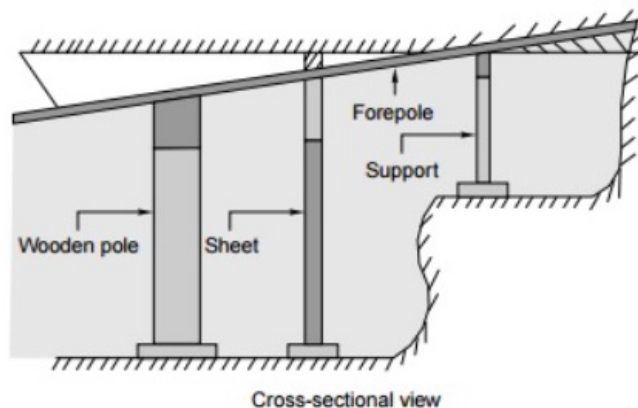
ABHASH ACHARYA

56

56

## METHODS OF TUNNELING

- Soft Ground: Fore-piling Method



ABHASH ACHARYA

57

57

## METHODS OF TUNNELING

- Soft Ground: Needle Beam Method
  - Adopted in terrains where the soil permits the roof of the tunnel section to stand without support for few minutes.
  - Requires temporary support immediately after construction
  - First of all a small drift of size of about 1\*1 m is prepared on the working face of the tunnel
  - The needle beam consisting of two I girders, bolted together with a wooden block at the center is inserted in the drift and its roof is supported on lagging carried on the wooden segment as shown in the figure.
  - The needle beam is placed horizontally with its front end supported on the drift and the rear end supported on a vertical post resting on the lining of the tunnel.
  - The jack is placed on the top of the beam to support the roof with lagging and then drift is widened side ways and the whole section is excavated. After excavating, lining may be provided.



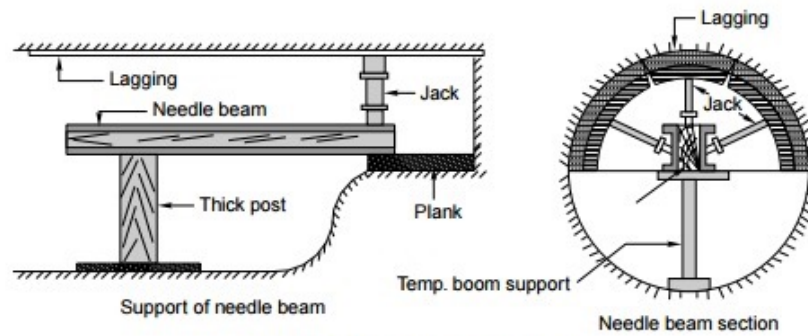
ABHASH ACHARYA

58

58

## METHODS OF TUNNELING

- Soft Ground: Needle Beam Method



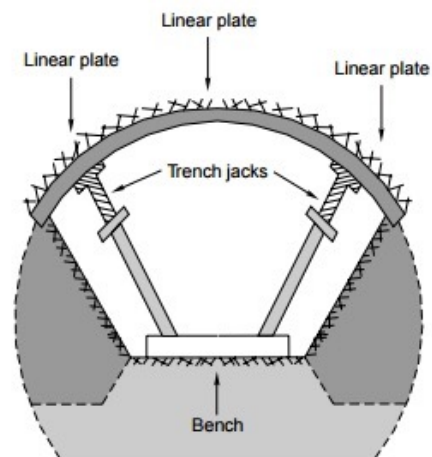
ABHASH ACHARYA

59

59

## METHODS OF TUNNELING

- Soft Ground: Liner Plate Method
  - Timber is replaced by standard size pressed steel plates.
  - Use of pressed steel plates is a recent development.
  - Advantages
    - Liner plates are light and can be handled easily
    - Number of joints is less
    - Low maintenance cost
    - Steel plates are fireproof and can be safely used while working in compressed air condition
    - Work can be carried out by semi-skilled staff



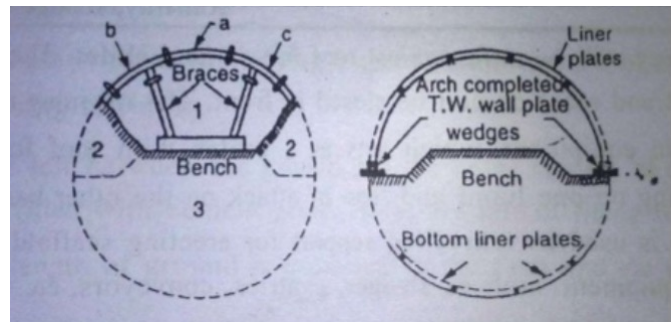
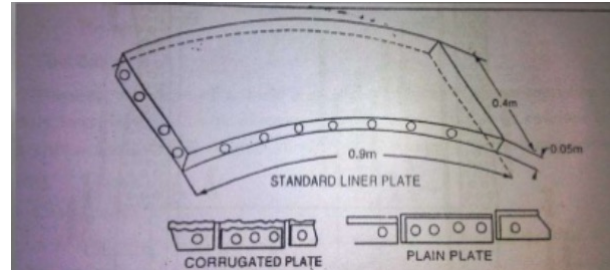
ABHASH ACHARYA

60

60

## METHODS OF TUNNELING

- Soft Ground: Liner Plate Method
  - Employed for driving steel lined small section drifts or heading on medium soft ground
  - The size of plates are 0.91\*0.41 m with flange of 0.05 m
  - Plates are bolted to each other through holes in the flange
  - A hole of 0.4m depth is cut at crown and liner plate "a" is inserted
  - Excavate sides and place "b" and "c" plates
  - Wooden wall plates of 20cm \* 5cm are placed on each side of bench
  - Bench is cleared and wall plates are underpinned at bottom



 ABHASH ACHARYA

61

61

## METHODS OF TUNNELING

- Soft Ground: Shield Method
  - Suitable for clayey soil
  - **Used for driving tunnel through water bearing strata**
  - Works as bridge with roof for workers
  - Shield is movable frame and is used to support the face of tunnel
  - Machine consists of a cutting edge, plate in the form of shell structure and a hood of jacks, ring girders, stiffening steel plates
  - Excavation is carried out by hand or pneumatically operated clay spades
  - The shield is pushed forward into excavation by hydraulic jacks pressing against previously erected lining

 ABHASH ACHARYA

62

62

## METHODS OF TUNNELING

- Soft Ground: Shield Method
  - Methods of shield tunneling in different soils

<i>Type of soil</i>	<i>Method of tunneling</i>
Silt	One or two port doors are opened. The material is excavated and deposited at the bottom of the tunnel.
Clay	One or two ports are opened and the material flows continuously into the tunnel. Excavation is carried out and the soil is removed immediately after the excavation.
Sand	In this case, tunnelling is of the open type. The sand settles on the floor of the shield and it should be continuously removed. Proper care should be taken to ensure that the material does not block the propelling jacks and other equipment.
Running sand	The bulk head shield is used in this case. Other details regarding tunnelling in such a soil are the same as for sand.



ABHASH ACHARYA

63

63

## METHODS OF TUNNELING

- Soft Ground: Shield Method
  - Usually have a circular section because of the following considerations
    - Rotation of the shield is easy in circular section
    - Grants protection to the primary lining
    - Circular section provides the maximum cross-sectional area with the smallest perimeters
    - Ideally suited to resist the semi-fluid pressure exerted by the soft ground



ABHASH ACHARYA

64

64

## METHODS OF TUNNELING

- Soft Ground
  - English Method
  - Austrian Method
  - Belgian Method



ABHASH ACHARYA

65

65

## METHODS OF TUNNELING

- TBM
  - Tunnel Boring Machine(TBM) also known as a “mole”, as the name suggests is simply a machine assembled using sophisticated types of equipment for excavating tunnels with the help of a variety of soil and rock strata.
  - On average, a **TBM excavates around 50-60 feet per day which is 20 hours of excavation approximately.**
  - In order to understand how a Tunnel Boring Machine works, we will divide its components into three parts:
    1. Cutting Head (front)
    2. Tunnel Field (middle)
    3. Trailing Gear (rear)

Source: [All About Tunnel Boring Machine – Components, Types & Advantages \(encardio.com\)](https://encardio.com/all-about-tunnel-boring-machine-components-types-advantages/)



ABHASH ACHARYA

66

66

## METHODS OF TUNNELING

- TBM
  - The type of machine to be used will always depend on the geology of the project.
    - Hard Rock TBM
    - Soft Ground TBM
      - Slurry Shield TBM
      - Earth Pressure Balance TBM
      - Open Face Type TBM

Source: [All About Tunnel Boring Machine – Components, Types & Advantages \(encardio.com\)](http://AllAboutTunnelBoringMachine-Components.Types&Advantages(encardio.com))

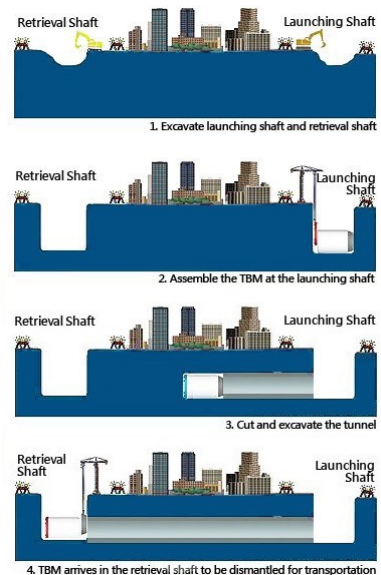
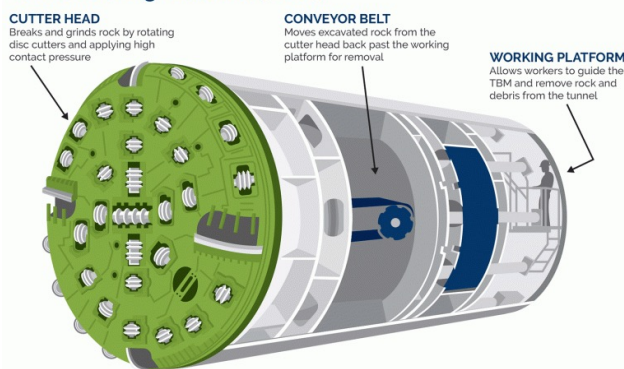


ABHASH ACHARYA

## METHODS OF TUNNELING

- TBM

### Tunnel Boring Machine (TBM)



ABHASH ACHARYA

Source: [All About Tunnel Boring Machine – Components, Types & Advantages \(encardio.com\)](http://AllAboutTunnelBoringMachine-Components.Types&Advantages(encardio.com))

## METHODS OF TUNNELING

- TBM
  - Advantages
    - Higher advance rates
    - Continuous operations
    - Less rock damage
    - Fewer support requirements
    - Uniform muck characteristics
    - Greater worker safety
    - Potential for remote, automated operation

Source: [All About Tunnel Boring Machine – Components, Types & Advantages \(encardio.com\)](#)



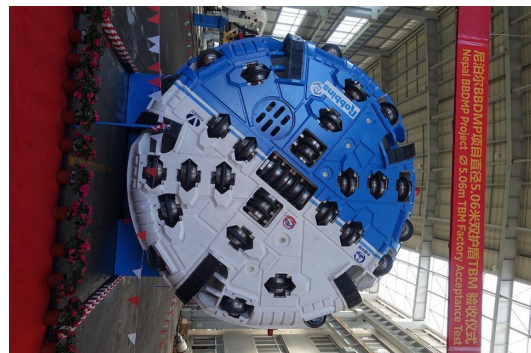
ABHASH ACHARYA

69

69

## METHODS OF TUNNELING

- TBM



Source: [Gallery :: Bheri Babai Diversion Multipurpose Project \(BBDMP\)](#)



ABHASH ACHARYA

70

70

## TYPICAL CROSS SECTION



Source: NGS Webinar series on: Nagdhunga Tunnel: First Roadway Tunnel in Nepal



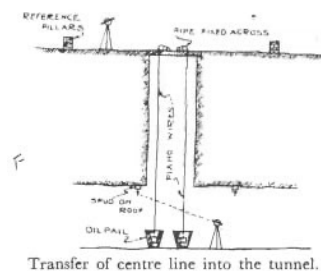
ABHASH ACHARYA

71

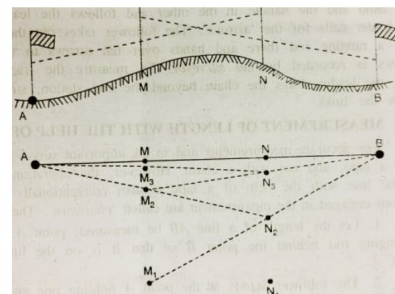
71

## SURVEY OF TUNNEL ALIGNMENT

- Initial Survey
  - Prepare detail topographic map for preliminary setting out of tunnel
  - Tachometric reconnaissance survey giving horizontal and vertical control
  - Fixing portal points on the topographical maps
- Setting out of tunnel centerline on surface
  - Surface control points are not mutually visible; summit point is established and a straight line joining two points and summit point is set on the ground
- Triangulation
  - It is not possible to align tunnel ends by direct ranging of reciprocal ranging hence precise triangulation is required
- Setting out inside tunnels
  - Reference points are constructed every 300m in roof of tunnels
  - Transfer of tunnel center line on ground through staff



Transfer of centre line into the tunnel.



ABHASH ACHARYA

72

72

---

**THANK YOU!**



Abhash Acharya

M.Sc. In Transportation Engineering

[acharyaabhash@gmail.com](mailto:acharyaabhash@gmail.com)

[abhashacharya.com.np](http://abhashacharya.com.np)

