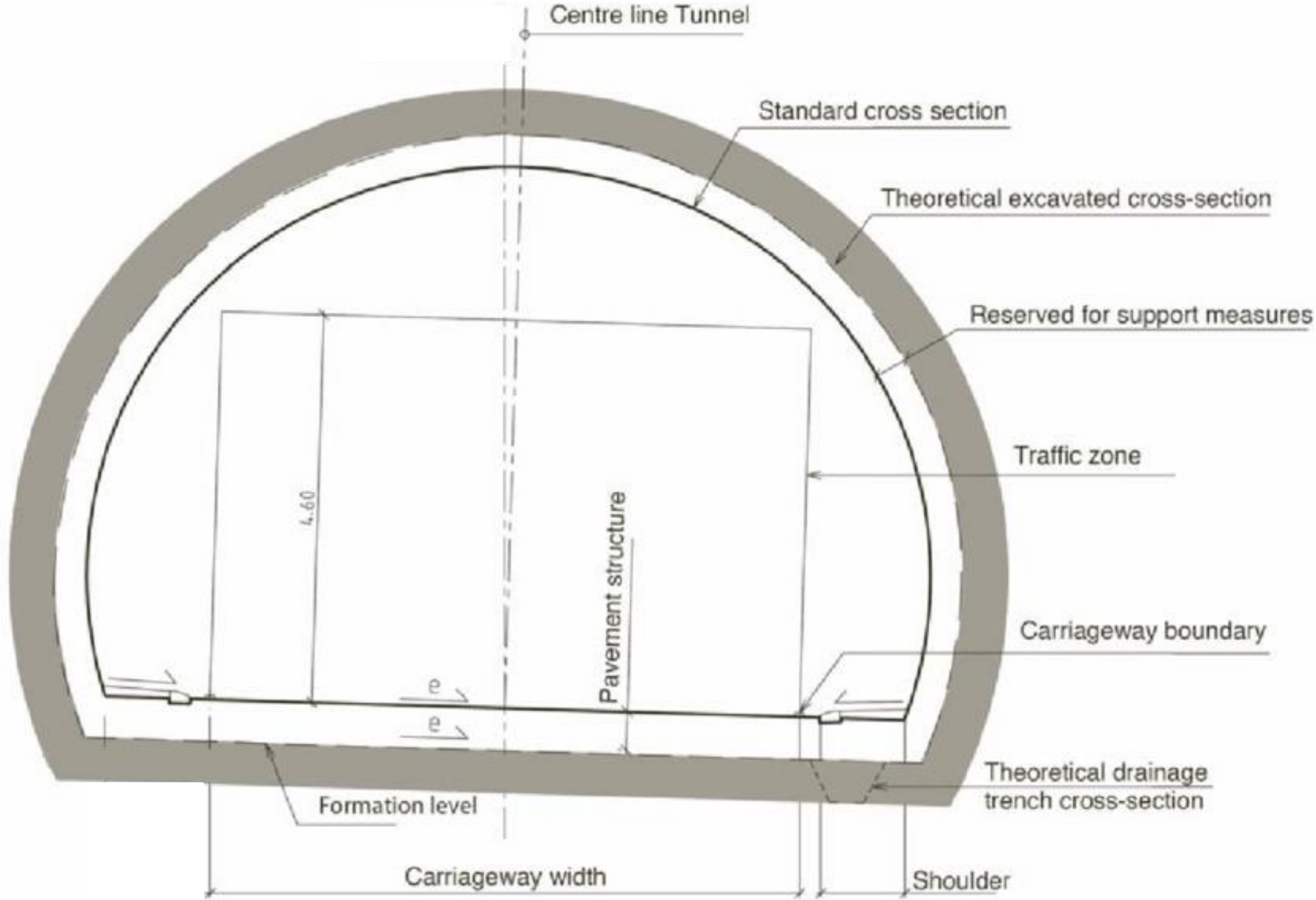
Lecture-15

Tunnels

Tunnels

- Tunnels are horizontal underground passageway produced by excavation or occasionally by nature’s action in dissolving a soluble rock, such as limestone.
- Tunnels have many uses: for mining ores, for transportation—including road vehicles, trains, subways, and canals—and for conducting water and sewage. Underground chambers, often associated with a complex of connecting tunnels and shafts, increasingly are being used for such things as underground hydroelectric-power plants, ore-processing plants, pumping stations, vehicle parking, storage of oil and water, water-treatment plants, warehouses, and light manufacturing; also command centres and other special military needs.
- True tunnels are excavated from the inside—with the overlying material left in place—and then lined as necessary to support the adjacent ground. Cut-and-cover tunnels are built by excavating from the surface, constructing the structure, and then covering with backfill



Centre line Tunnel
Standard cross section
Theoretical excavated cross-section
Reserved for support measures
Traffic zone
4.60
Pavement structure
e
e
Carriageway boundary
Theoretical drainage trench cross-section
Formation level
Carriageway width
Shoulder

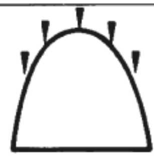
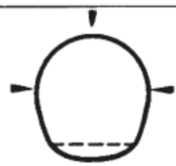
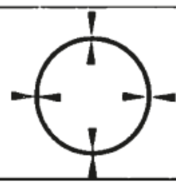
	Rectangular Used when the external forces do not lead to any damaging movement of the rock mass into the tunnel.
	Semi-elliptical, parabolic or semi-circular Used when vertical forces act.
	Horseshoe, vaulted Used when horizontal and vertical forces act.
	Circular Used when forces act from all sides and particularly with internal water pressure.

Figure 1-14 Basic cross-section shapes [135].

Geological Survey and Site Selection of Tunnel

In a tunnel route study, the following issues should be considered:

- Subsurface, geological, and geo-hydraulic conditions
- Constructability.
- Long-term environmental impact
- Seismicity.
- Land use restrictions
- Potential air right developments
- Life expectancy.
- Economical benefits and life cycle cost
- Operation and maintenance
- Security.
- Sustainability

Geological Survey and Site Selection of Tunnel

- Geotechnical investigations are critical for proper planning of a tunnel. Good knowledge of the expected geological conditions is essential.
- Planning and design of road tunnel alignments must consider the geological, geotechnical and groundwater conditions at the site.
- The type of the ground encountered along the alignment would affect the selection of the tunnel type and its method of construction.
- Study of the impact of geological features on the tunnel alignment in the presence of active or inactive faults. During the planning phase, avoid crossing a fault zone. If it is un avoidable then proper measures for crossing it should be implemented.
- Presence of faults or potentially liquefiable materials would be of concern during the planning process.
- Geotechnical issues such as the soil or rock properties, the ground water regime, the ground cover over the tunnel should be analysed. The investigation should address not just the soil and rock properties, but also their anticipated behaviors during excavation.

Geological Survey and Site Selection of Tunnel

- The investigation should also address groundwater. For example, in soft ground Sequential Excavation Method (SEM) tunneling, the stability of the excavated face is greatly dependent on control of the groundwater. Dewatering, pre-draining, grouting, or freezing are often used to stabilize the excavation.
- Analyzing the ground behavior during tunneling will affect potential settlements on the surface. Measures to minimize settlements by using suitable tunneling methods or by preconditioning the ground to improve its characteristics would be required.
- Risk assessment is an important factor in selecting a tunnel alignment. Construction risks. Sensitive existing structures. Very Hard spots (rock, for example) beneath parts of a tunnel.

Geological Survey and Site Selection of Tunnel

- The first phase of an investigation program for a tunnel project starts with collection and review of available information to develop an overall understanding of the site conditions and constraints at little cost.
- Existing data can help identify existing conditions and features that may impact the design and construction of the proposed tunnel, and can guide in planning the scope and details of the subsurface investigation program to address these issues.
- Published topographical, hydrological, geological, geotechnical, environmental, zoning, and other information should be collected, organized and evaluated.

Geological Survey and Site Selection of Tunnel

- Aerial Photographs identifies manmade structures, provides geologic and hydrological information which can be used as a basis for site reconnaissance and track site changes over time.
- Topographic maps and aerial photographs are useful in showing terrain and geologic features (i.e., faults, drainage channels, sinkholes, etc.). When overlapped with published geological maps they can often, by interpretation, show geologic structures.
- Aerial photographs taken on different dates may reveal the site history in terms of earthwork, erosion and scouring, past construction, etc.
- Geologic Maps and Reports, Prior Subsurface Investigation Reports , Prior Underground and Foundation details, Construction Records are helpful data.
- Provides information on local soil/rock type; strength parameters; hydrogeological issues; environmental concerns; tunnel construction methods and problems

Geological Survey and Site Selection of Tunnel

- Water Well Logs provide stratigraphy of the site and/or regional areas. Yield rate and permeability, Groundwater levels.
- Initial on-site studies should start with a careful reconnaissance over the tunnel alignment with a particular interest in locations of portal and shaft.
- Features identified on maps and aerial photos should be verified. Rock outcrops, often exposed in highway and railroad cuts, provide a source for information about rock mass fracturing and bedding and the location of rock type boundaries, faults, dikes, and other geologic features.
- For tunnel projects, detailed topographic maps, plans and profiles must be developed to establish primary control for final design and construction based on a high order horizontal and vertical control field survey.
- Accurate topographic mapping is required to support surface geology mapping and the layout of exploratory borings. The principal survey techniques include: Conventional Survey, Global Positioning System (GPS), Electronic Distance Measuring (EDM) with Total Stations, Remote Sensing, and Laser Scanning

Geological Survey and Site Selection of Tunnel

- Detailed geologic mapping collects local, detailed geologic data systematically. The following surface features should also be observed and documented during the geologic mapping program:
  - slides (new or old)
  - Faults
  - Rock weathering
  - Karstic terrain.
  - Groundwater springs
  - Volcanic activity.
  - Gypsum, pyrite, or swelling shales.
  - Stress relief cracks.

Geological Survey and Site Selection of Tunnel

- Ground conditions including geological, geotechnical, and hydrological conditions, have a major impact on the planning, design, construction and cost of a road tunnel, and often determine its feasibility and final route. Detailed subsurface investigations are done to determine these details.
- Subsurface investigation include
  - Defining the subsurface profile (i.e. stratigraphy, structure, and principal soil and rock types),
  - Determining soil and rock material properties and mass characteristics
  - Identify geological anomalies, fault zones and other hazards (squeezing soils, methane gas, etc.), Adverse Geological Features. Known or suspected active faults
  - Defining hydrogeological conditions (groundwater levels, aquifers, hydrostatic pressures, etc.);
  - Site characterization should investigate for signs of and nature of: - Groundwater pressure, - Groundwater flow, - Artesian pressure, Multiple aquifers, - Higher pressure in deeper aquifer
  - Identifying potential construction risks (boulders, etc.).
  - Classification and geological as well as engineering properties of soil and rock
  - Identify presence of lenses and layers of higher permeability soils and potential for nested boulders.
- Subsurface investigation is carried out using geophysical explorations, open pits, boreholes, rock coring, in-situ testing, laboratory testing etc.

Introduction to Blasting

- Tunneling through solid rock may be performed either with a tunneling machine or by use of conventional drilling and blasting. Machine tunneling is comparatively new, having come into general use since the 1950s; but the drilling and blasting method has been practiced for several centuries.
- Rock that is too hard to cut economically with a machine must be excavated in the conventional manner: using drills and explosives. Tunneling machines are expensive both to purchase and to install; consequently, they are frequently uneconomical in shorter tunnels. Improvements into drilling and blasting methods are continuously being made as a result of research.

Introduction to blasting

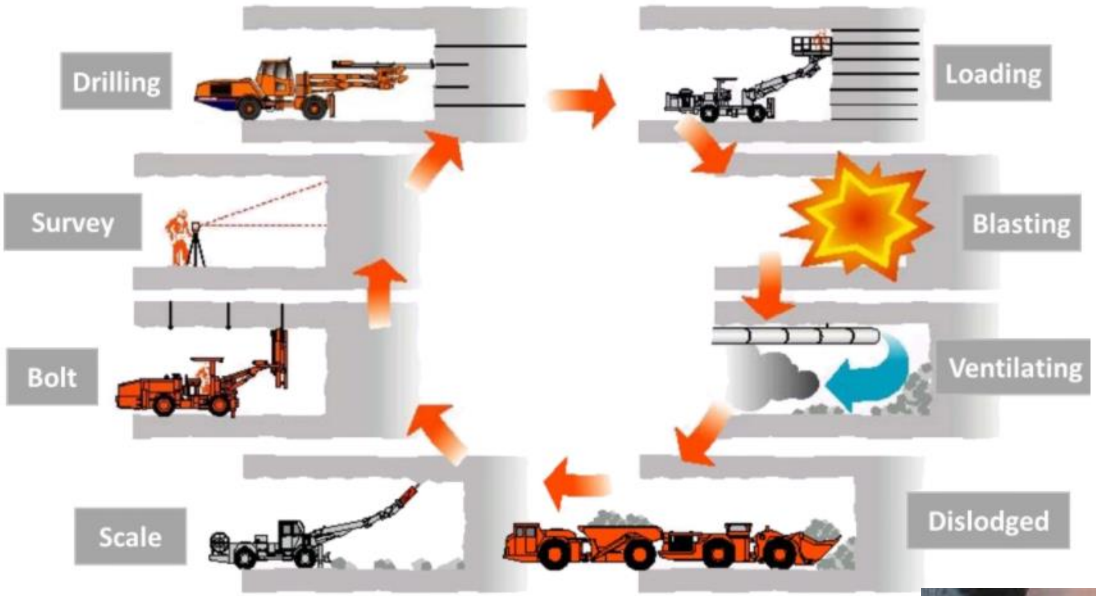
- The technique of rock breakage using explosives involves drilliing blast-holes by percussion or rotary-percussive means, loading the blast-holes with explosives and then detonating the explosive in each hole in sequence according to the blast design.
- When the drilling and blasting method is used, the ground is shattered by the detonation of explosives within holes drilled into the solid rock. These holes are usually 25.4 to 50.8 mm (1 to 2 in) in diameter, spaced several centimeters to a meter apart in a preplanned pattern, and drilled to a depth that is dependent on the length of round to be pulled.
- Pneumatic percussion drills are customarily used. Small drills can be hand held, but larger and more powerful drills, which are now commonly used, must be mounted on positioning devices to obtain maximum drilling speed with a minimum of labor.

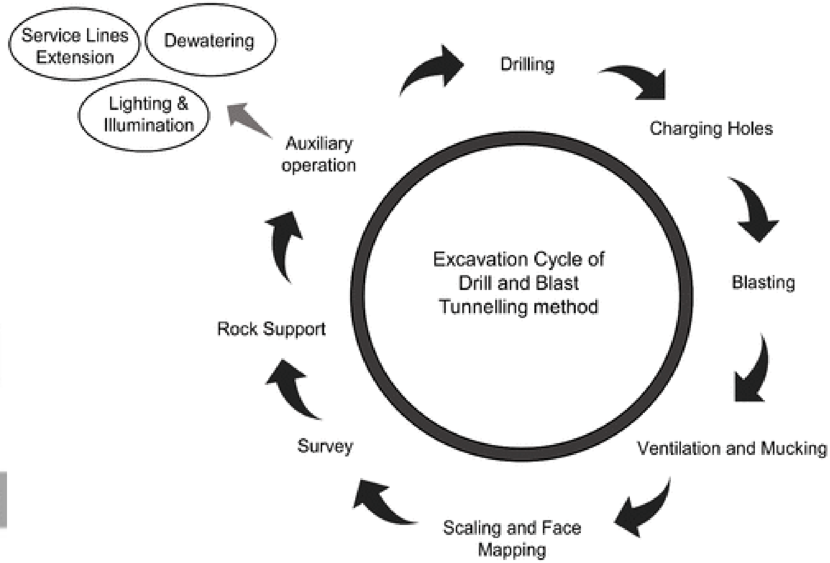
Introduction to Blasting

- Explosives for tunnel blasting can be either gelatine dynamite or ammonium nitrate. Detonation is accomplished by use of electric blasting caps.
- Drilling and blasting is cyclical. To excavate a round requires the sequential operations of drilling the holes, loading the explosive, detonating the blast, and finally removing and disposing of the broken rock, installing supports (when needed), and extending utilities.
- The aim of the tunnel engineer is to reduce the cycle time to a minimum, thereby permitting a maximum number of rounds to be "pulled“ in a 24-h day and keeping the cost of tunneling as low as possible.

The typical cycle of excavation by blasting is performed in the following steps:

a. Drilling blast holes and loading them with explosives.
b. Detonating the blast, followed by ventilation to remove blast fumes.
c. Removal of the blasted rock (mucking).
d. Scaling crown and walls to remove loosened pieces of rock.
e. Installing initial ground support.
f. Advancing rail, ventilation, and utilities.





Drilling Machine
https://hips.hearstapps.com/pop.h-cdn.co/assets/16/01/1452241927-giphy-3.gif

Lining of Tunnels

If the tunnel is passing through hard stratum, it may be left unlined. However, the tunnels in loose rock and soft soils are liable to disintegrate and, therefore, a lining is provided to strengthen their sides and roofs so as to prevent them from collapsing. The objectives of a lining are as follows.

(a) Strengthening the sides and roofs to withstand pressure and prevent the tunnel from collapsing.

(b) Providing the correct shape and cross section to the tunnel.

(c) Checking the leakage of water from the sides and the top.

(d) Binding loose rock and providing stability to the tunnel.

(e) Reducing the maintenance cost of the tunnel.

Types and Thickness of Lining

- Lining may be of two types:
  - **Temporary lining:** It is provided for supporting the roof and the walls of tunnel during construction.
  - **Permanent lining: I**t is provided in soft soil which is always liable to disintegrate. The ideal lining should be easy to maintain, economical, durable, simple to construct and stable.
- The basic materials for tunnel lining construction are cast-in-place concrete, cast-in-place and prefabricated reinforced concrete, cast iron and steel. These materials are chosen according to conditions of construction area and tunneling methods.
- The shape and size of lining are defined by size, depth and function of the tunnel and sort of take up load (rock pressure, hydrostatical pressure, traffic load, etc). Cast-in-place lining is mainly used for construction of tunnels with most complex structure and big cross-section.

Types and Thickness of Lining

- Theoretically, the lining provided inside tunnels may be of timber, iron, steel, brick, or any other construction material but in practical terms the lining provided most commonly is that of reinforced concrete or concrete surface.
- Concrete lining is provided in tunnels because of (a) its superiority in structural strength, (b) ease of placement, (c) its durability, and (d) lower maintenance cost.
- The thickness of concrete lining depends upon various factors such as conditions of the ground, size and shape of the tunnel, soil pressure, and the method of concreting. The thickness of concrete is calculated by the following empirical formula:

$$T = 0.083D \quad (30.1)$$

- where T is the thickness of the lining in centimeters and D is the diameter of the tunnel in metres.
- On the basis of field experience, railway engineers have devised a thumb rule of providing 2.5 cm of lining for every 30 cm of the diameter in the rail tunnel. As per this thumb rule, the thickness of the lining of a tunnel with a 1 m diameter would be (100/30) x 2.5 cm = 8.3 cm.

Sequence of Lining

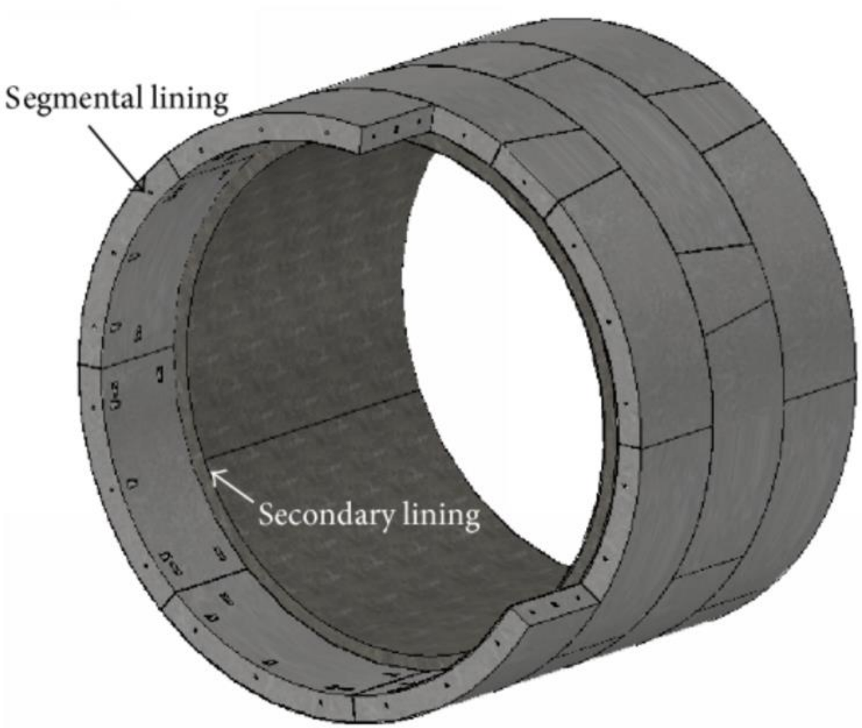
- The lining of a tunnel is done in the following steps.

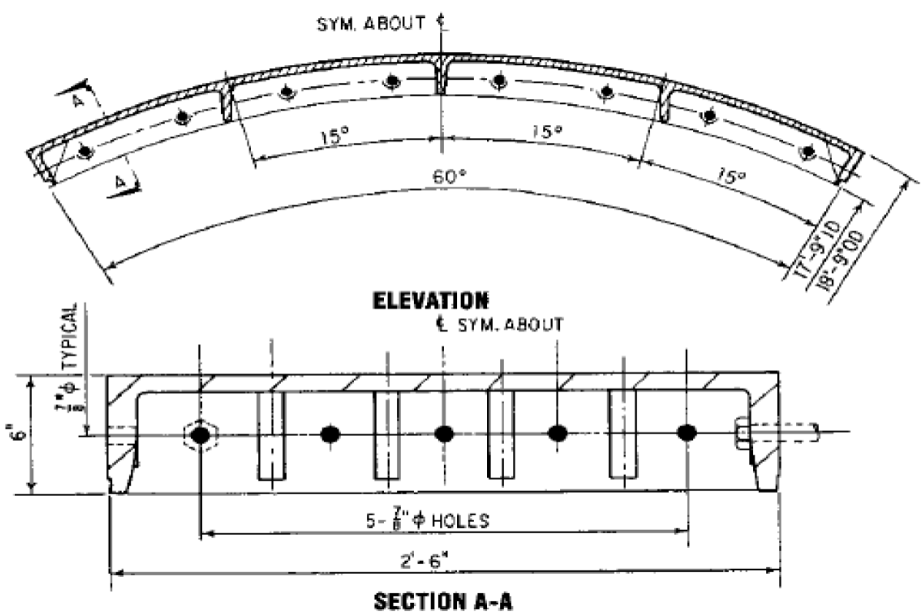
1. In the first stage guniting is done to seal the water in rock tunnels.

2. Concrete lining is done either in one attempt as in the case of circular tunnels or by separately tackling the the sidewall, and the arch. For small tunnels that measure 1.2 to 3.0 m in diameter, the concrete lining can be provided by the hand placing method. In the case of bigger tunnels, concrete pumps or pneumatic placers are used for placing the concrete.

3. The concrete is cured to its maximum strength. If the humidity inside the tunnel is not sufficient, curing can be done by spraying water through perforated pipes.

Section of Lining





(a) CAST-IRON LINER SEGMENT

Case Studies

- https://www.researchgate.net/publication/319454588_Case_Studies_of_Tunnel_Instability_and_Interaction_with_the_Ground_Surface_and_Manmade_Structures