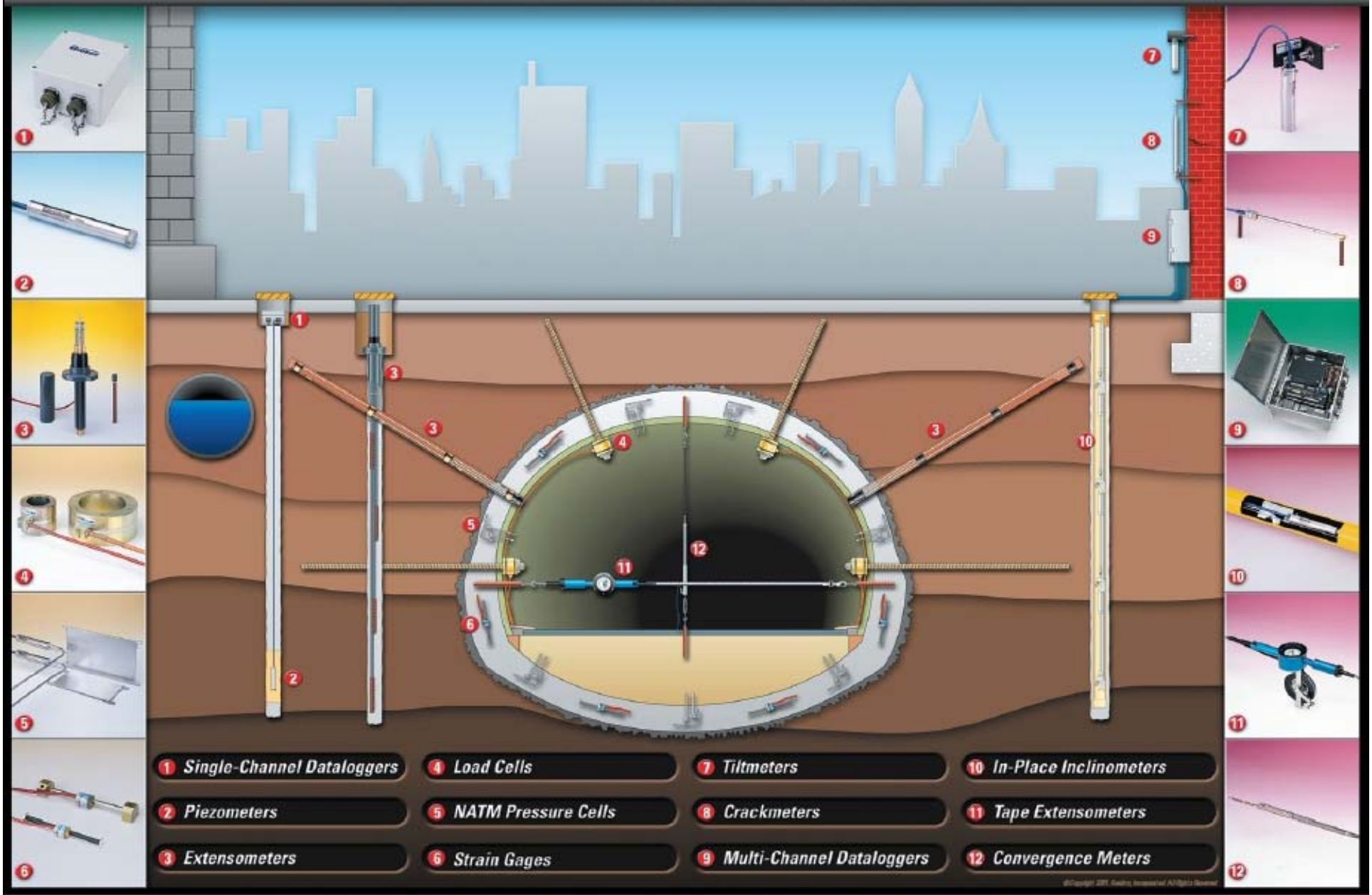
Tunnelling Instrumentation

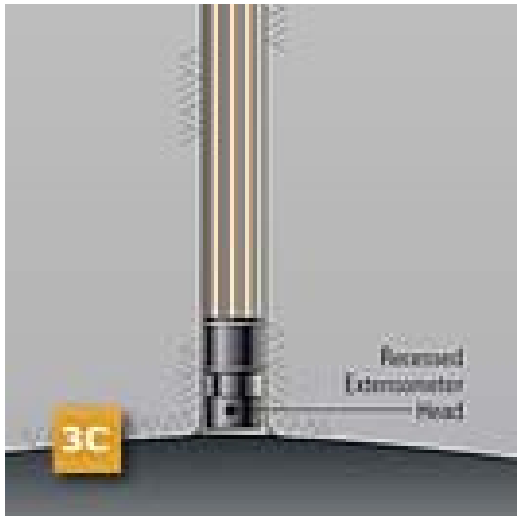



1


2


Protective Cap
Flanges
Stand Pipe
3A


3B


Recessed Extensometer Head
3C


4


5


6


7


8


9


10

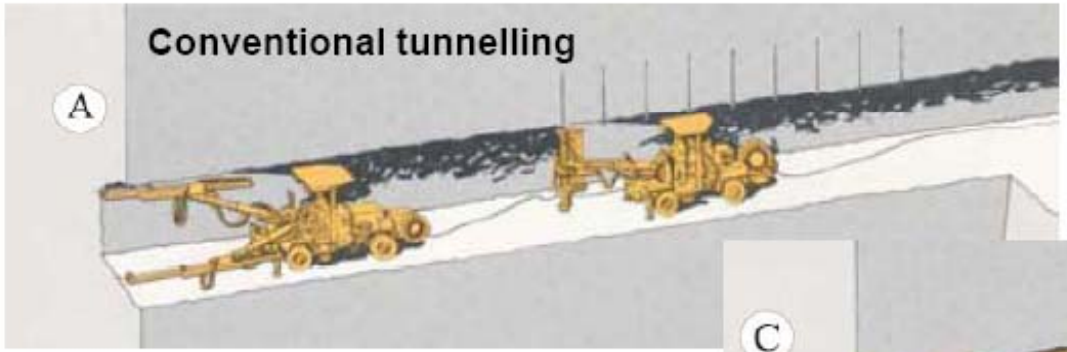

11

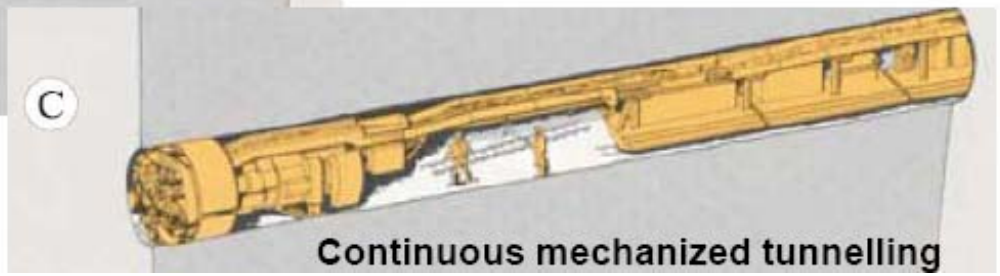

12


13

Conventional underground tunnelling

- Conventional tunnelling, often called incremental or cyclic tunnelling, is the alternative to continuous tunnelling
- Conventional tunnelling is done in small advance steps (longitudinally and transversally)
- The step length and the surface of excavation face are important design parameters: the freshly excavated space has to remain stable until the support has been installed
- Conventional tunnelling can be executed in full face or partial face





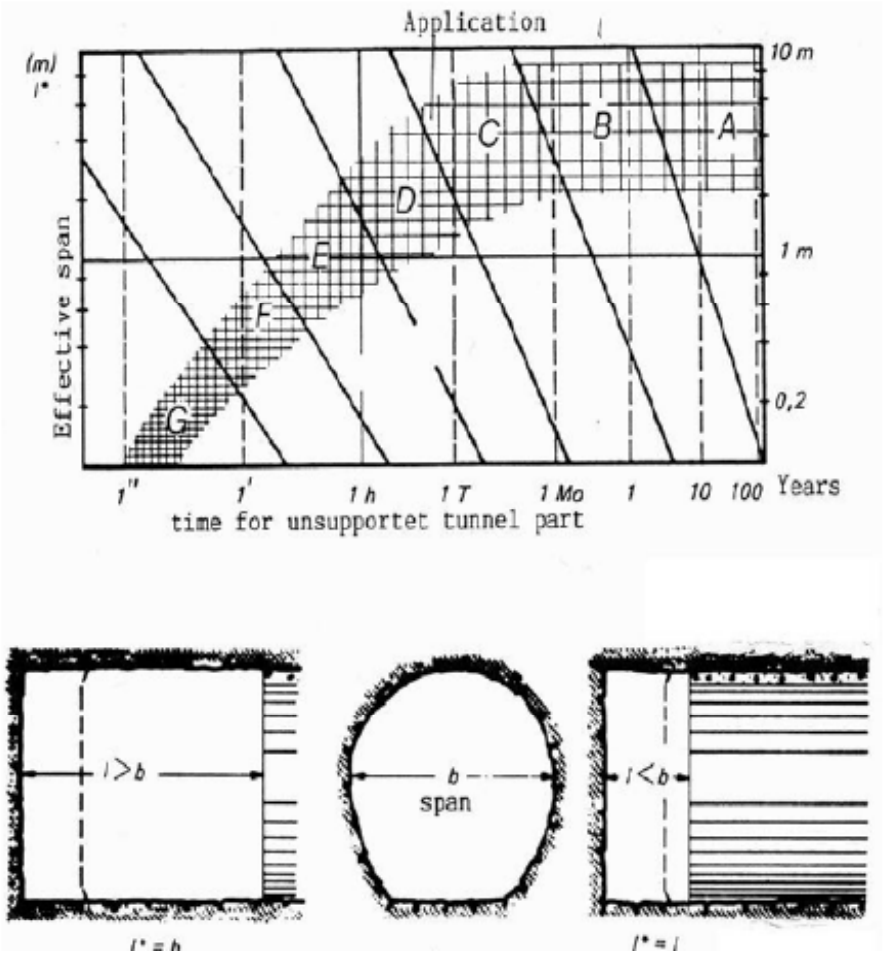
Conventional underground tunnelling

Full face or partial face excavation?

1. Stability issues

-The stand-up time depends on the span of the tunnel and the geomechanical characteristics of the rock mass

-Partial face excavation might be used as piloting to gather information on geology and reduce incertainty



Conventional underground tunnelling

Full face or partial face excavation?

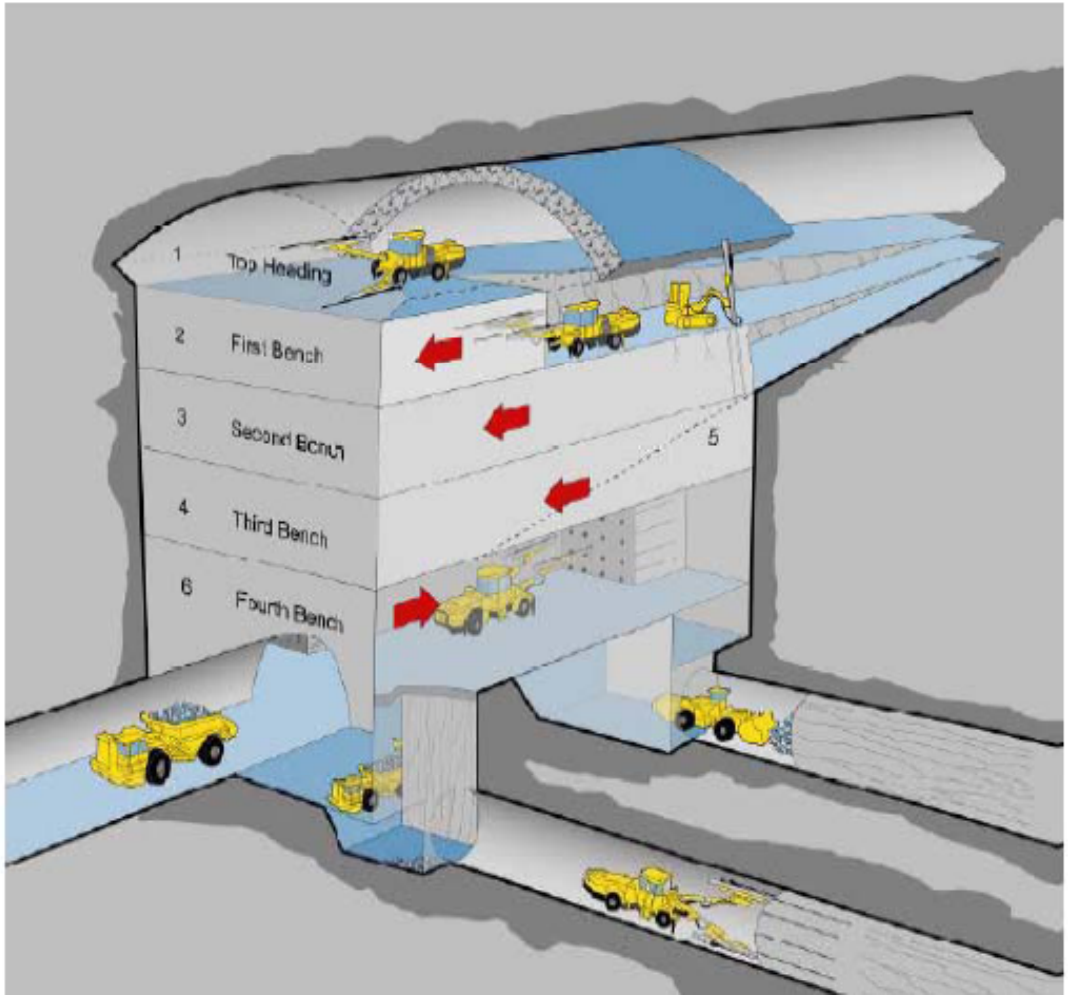
2. Production issues

-The face is too large to be covered by regular tunnelling equipment

-Opportunity to create another face

-Optimization of the advance rate

-The support measures can be installed in due time



Conventional underground tunnelling

Full face excavation

-The whole section of the tunnel is excavated at once

-It might need stabilisation of the face (i.e. fibre glass bolts)

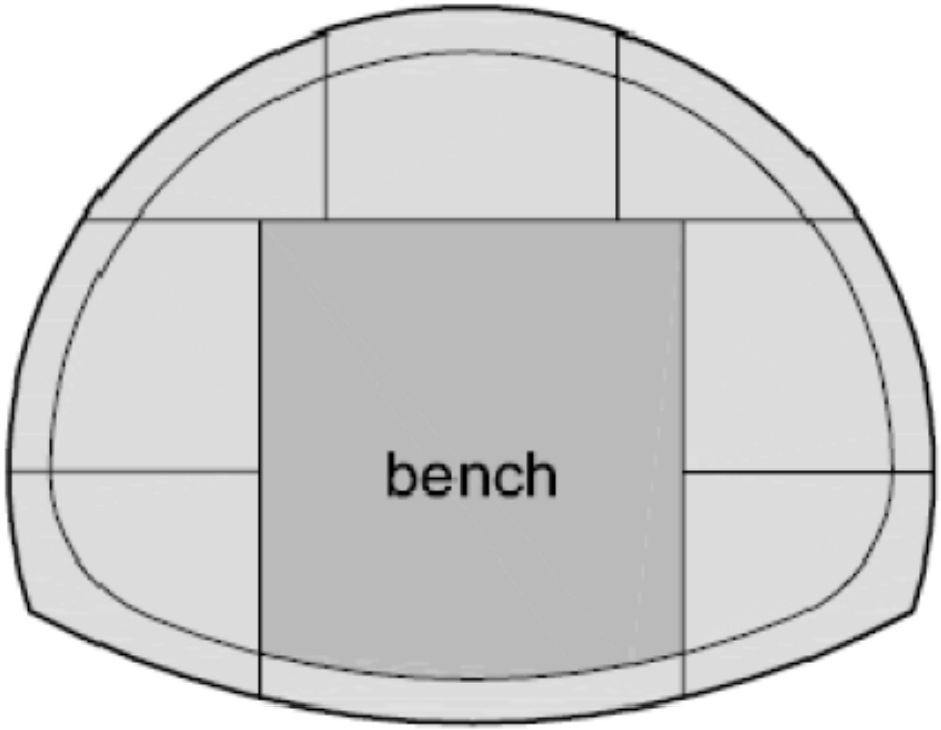
-Very popular in Italy

Conventional underground tunnelling

Partial face excavation

-Core Heading (or German method)

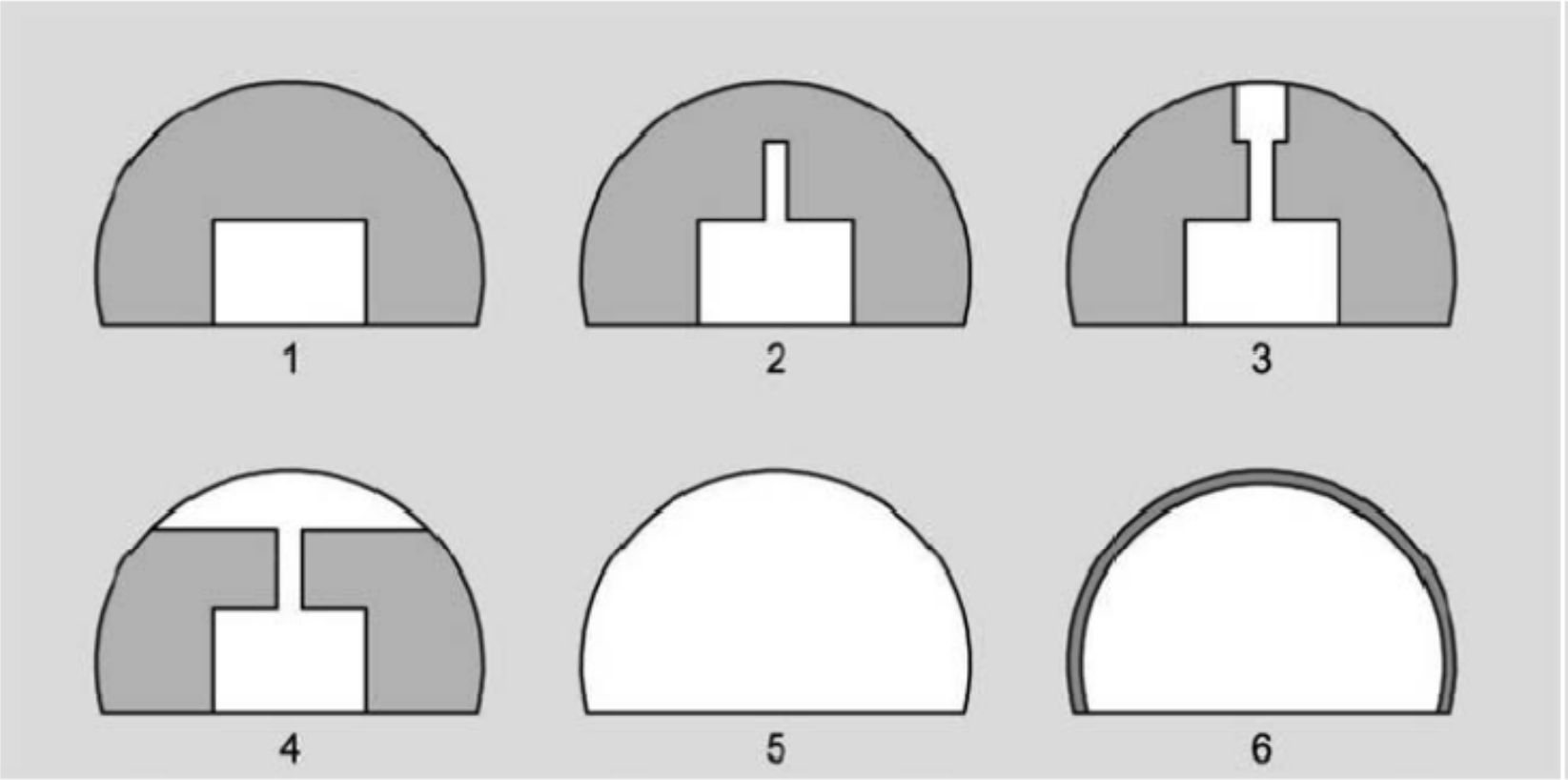
1) Side and top parts of the section
2) Core
3) Invert



Conventional underground tunnelling

Partial face excavation

- Old Austrian Tunnelling Method:



Conventional underground tunnelling

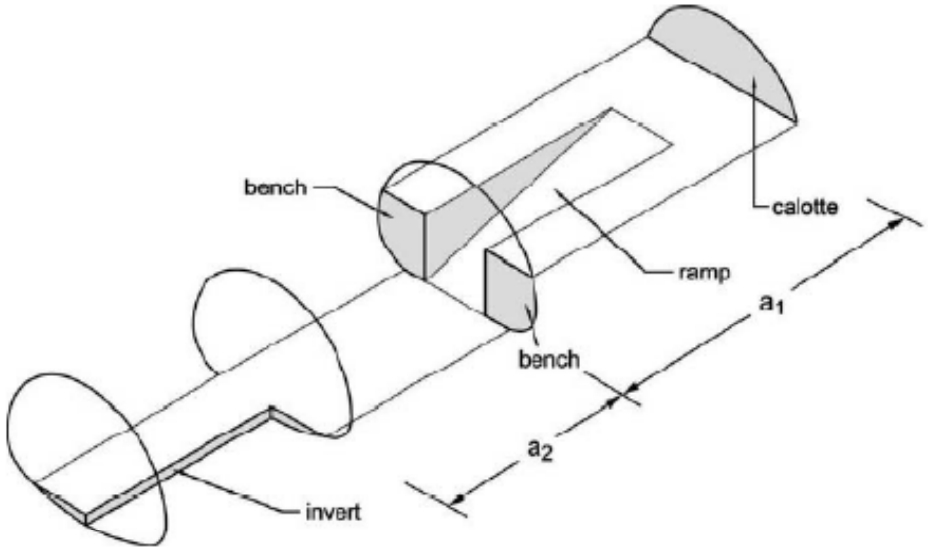
Partial face excavation

-Top heading and bench

-The crown is excavated before the bench

-The temporary support of the crown can be conceived as a sort of arch bridge

-Special measures might need to be taken to prevent the abutments to fail: micropiles strenghtening, « elephant feet » or temporary invert



Conventional underground tunnelling

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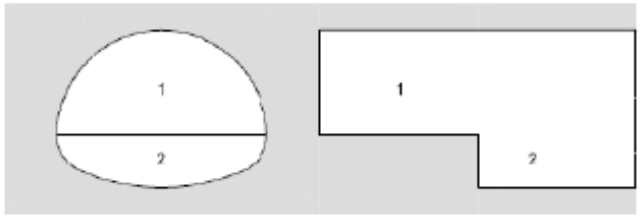
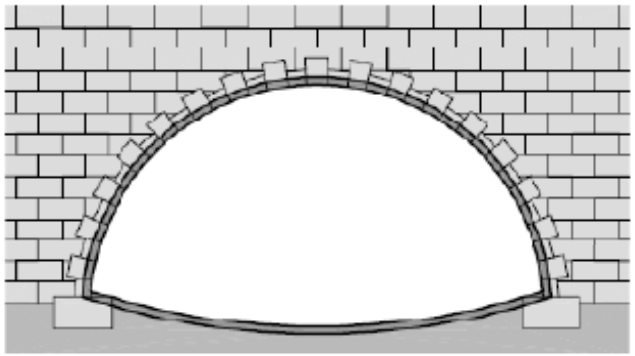
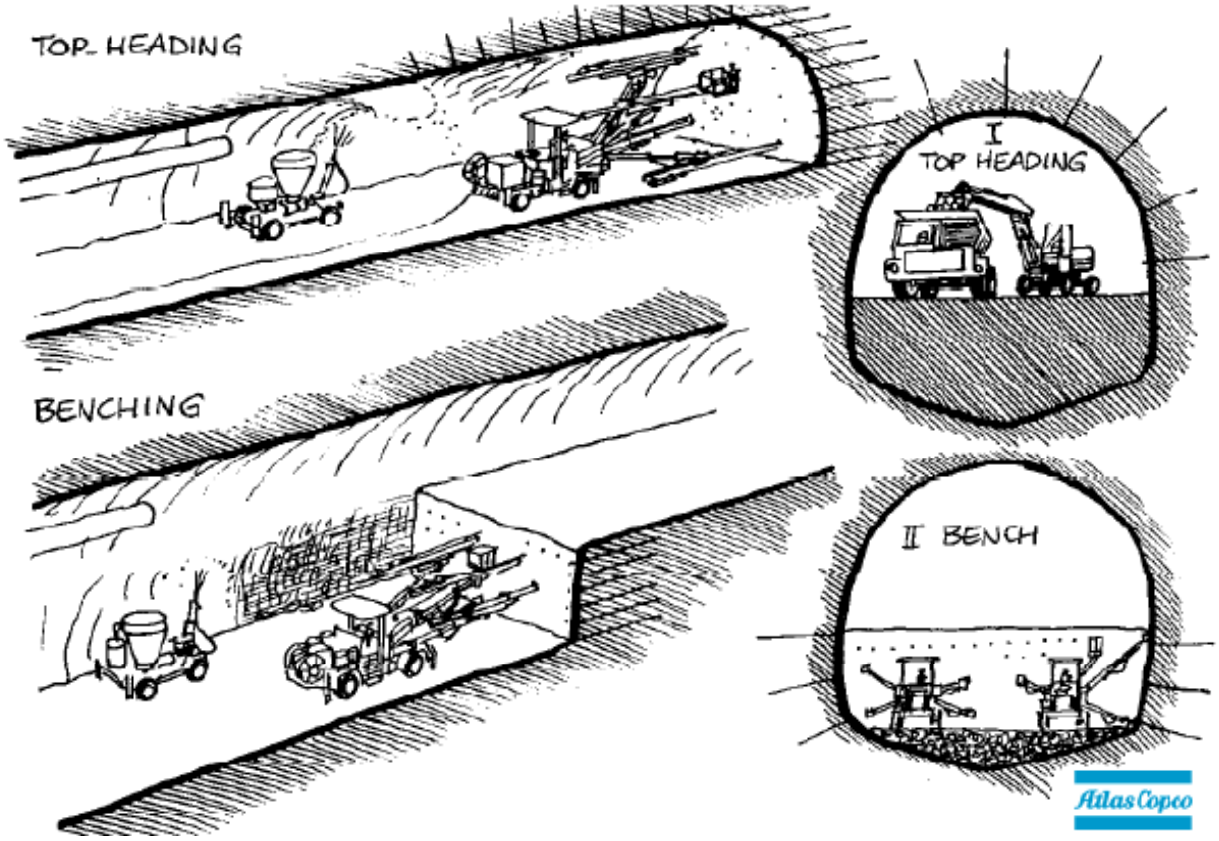


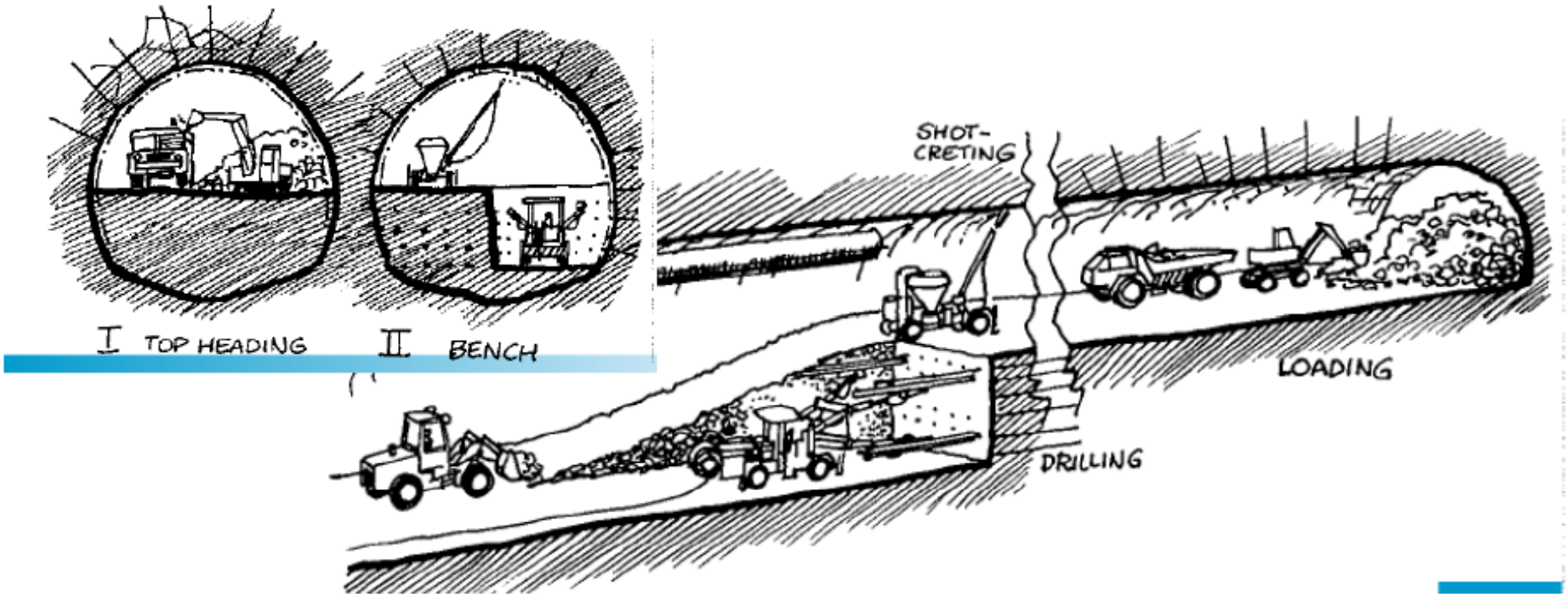




Conventional underground tunnelling

Partial face excavation

-Top heading and bench



Conventional underground tunnelling

Partial face excavation

-Sidewall drift

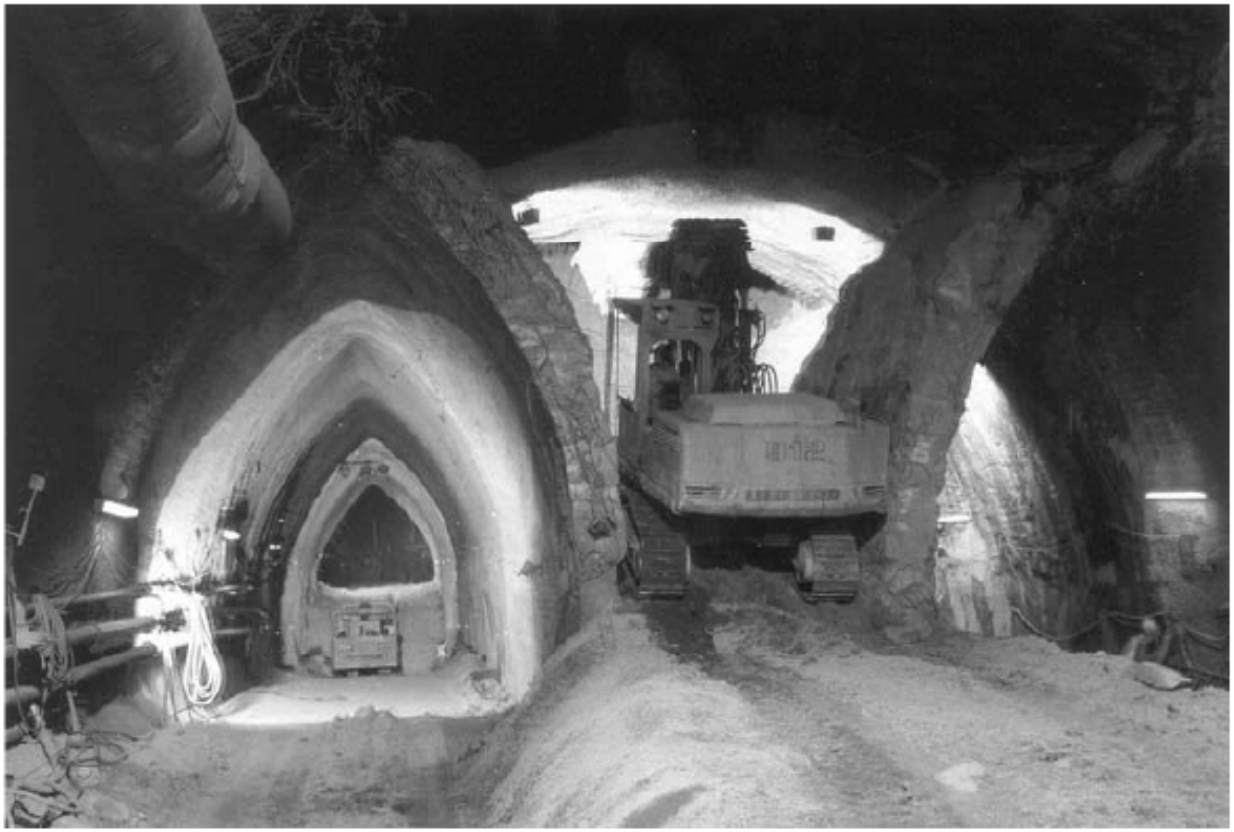
-The side galleries are excavated and supported first.

-The latter serve as abutments for the support of the crown

-Then, the crown is excavated

-50% more expensive and slower than top heading

-Suitable for very bad ground



Conventional underground tunnelling

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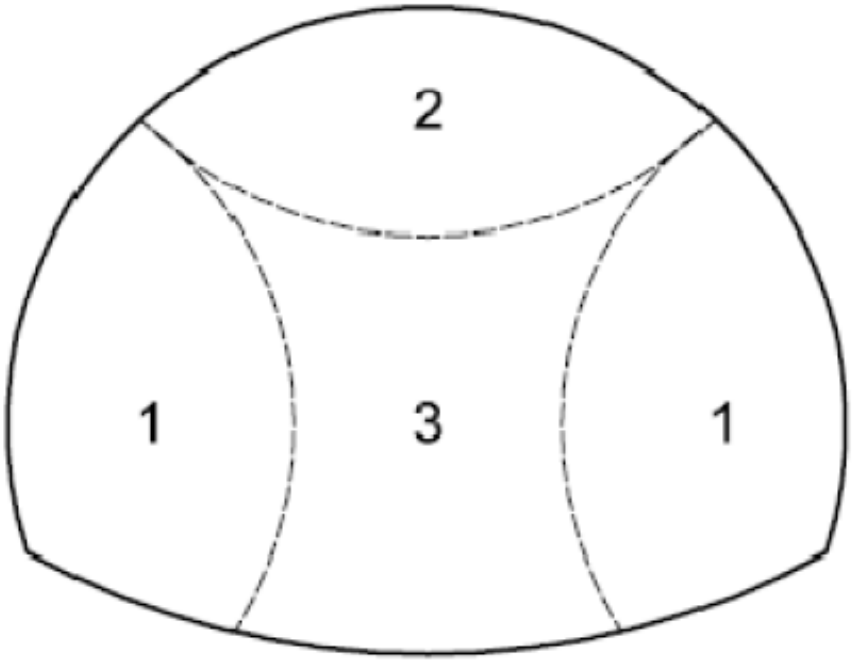

Excavation Methods: Drill and Blast

- Advantageous for:
  - Very hard rock
  - Rocks with varying properties (high flexibility)
  - Short tunnels where TBM does not pay
  - Non-circular cross sections
  - Tunnels with different cross sections
  - Big underground spaces: Caverns, stations, etc

Factors Unique to Tunnelling

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- Uncertainty in the nature and variability of ground conditions (rock quality, ground water, gas, etc) - *need for adequate site investigations prior to and vigilance during tunnelling*
- Confined space of tunnel environment (limited access, escape, air quality control)
- Difficulty in communications (sound and signal barriers)
- Work in compressed air (soft ground)

Types of Emergency

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- Ground collapse (need we say more?)
- Support failure
- Flooding
- Gas explosion
- Oxygen deficiency
- Fire (encountering inflammable gas)
- Accidents : moving plants
- Plant and power failure
- Stoppages

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Principal Causes of Accidents

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- Falling from heights or falling on level (tripping/slipping)
- Materials falling from height or from stacks or vehicles
- Burial by fall of material (rock collapse or stacking collapse)
- Flooding or inrush of water
- Machinery related (cranes, excavators, etc)
- Vehicles (excavators, dump trucks)
- Electrical installations
- Fire and explosions (gas and explosives)
- Air pollution (oxygen deficiency, toxic fumes & radon gas)

Hazards Related to Blasting

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- Blasting a “way of life” in hard rock tunnelling
- Fly rock
- Airblast and ground shock
- Toxic fumes
- Accidental explosions

Drilling of Charge Holes

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Hazards

- Being knocked over/crushed
- rock fall
- dust and noise

Protection

- Keep away from danger area
- wet drilling
- hearing protection

Warning sign to cordon off people from drilling face

Charging Explosives

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Hazards

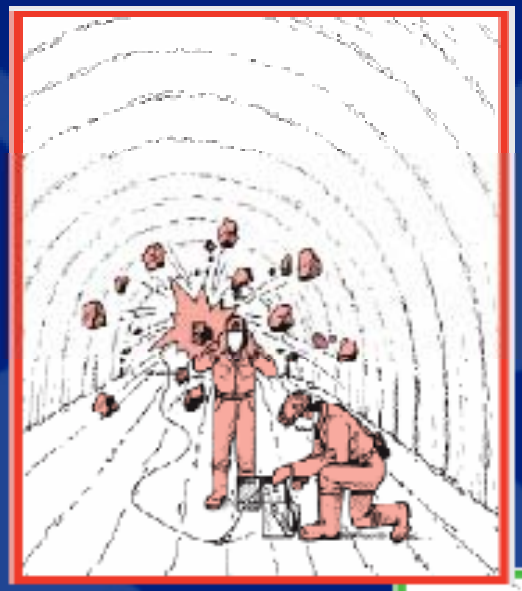
- accidental detonation by drilling into explosives
- being knocked over or crushed by drilling boom
- falling

Protection

- Only charge after the whole face has been drilled
- work can only be carried out under supervision of authorised blasting specialist
- use working platforms
- Bulk emulsion

Mobile Charging Unit

Blasting



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Hazards

- Fly rock and airblast
- toxic fumes

Protection

- keep away from area
- switch off ventilation completely before firing
- switch on ventilation at full capacity after blasting
- evacuate team or provide shelter(containers or niches)

Use of rubber-tyre mats and concrete blocks to minimise rock throw during blasting open areas

Air Quality Underground

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- Oxygen deficiency
- Dust
- Toxic gas (CO, CO2, NO)
- Heat and fire

Measurement Limits for Air

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- Parameters for Air Monitoring
  - Oxygen – 19.5 to 23%
  - Nitrogen Dioxide – Less than 5ppm
  - Lower Explosive Limit – Less than 10%
  - Carbon Monoxide – Less than 25ppm
  - Dust – Less than 10mg/m3 (Long term)

Typical Results in Tunnels **(Average readings after blasting)**

Time of the day	O2 (%)	NO2 (PPM)	LEL (%)	CO (PPM)	Remarks
Daily	20.3 – 20.9	0-2 2-5*	1-5	2-5 5-21*	*During mucking-out operation, the levels of NO_2 and CO tends to be higher

Radon Gas Underground

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- Naturally occurring in rock and soil
- Radon and radon daughters are radioactive and can cause adverse health effects (lung cancer)
- Is released by exposed surface, blasted rock, groundwater, from outside air
- Conditions improve with proper ventilation

Shotcreting

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Hazards

- Falling from heights
- Rebound & dust
- Chemical additives

Protection

- Use working baskets
- Use protective clothing
- Use shotcrete robot where possible
- Wear protective hardhat for shortcreting
- Wear respiratory protection

Mucking Out

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Hazards

- Being struck or crushed
- Falling Material
- Dust and Noise
- Tripping and falling

Protection

- Do not enter into loading area
- Keep running surface in good condition
- Do not overload dumper
- Good lighting to work area

Scaling

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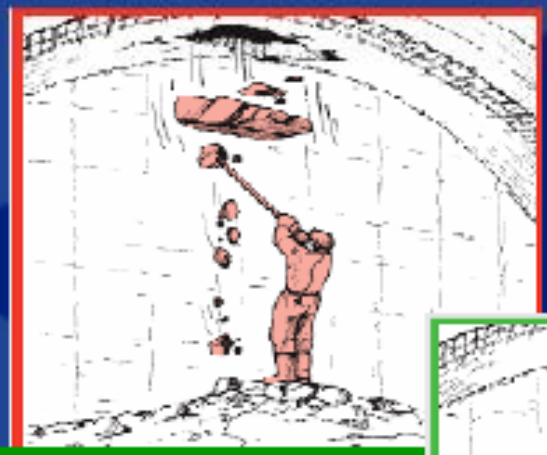
Hazards

- Rock fall
- Collapse as result from instability of exposed rock surface

Protection

- Use machine for rock scaling
- Do not enter danger zone before scaling is completed
- Lighting adequately



Manual Scaling

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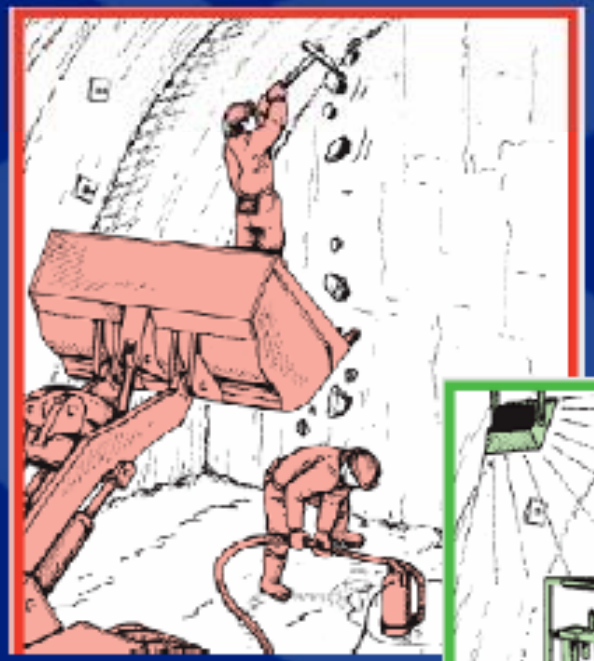
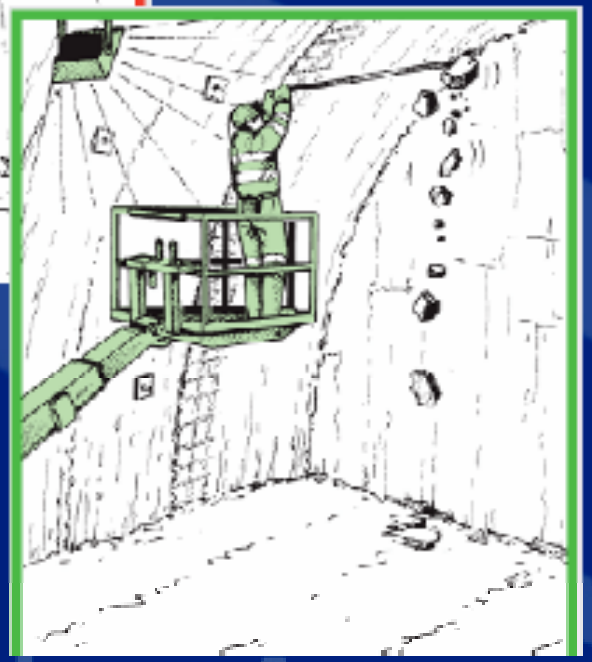
Hazards

- Rock fall
- Falling from heights
- Being crushed

Protection

- Only work from a safe area
- Use working platforms
- Light the area adequately





Installing Rock Bolts

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Hazards

- Falling from heights
- Noise

Protection

- Use working platforms
- Use eye and hearing protection

Shotcreting Robots

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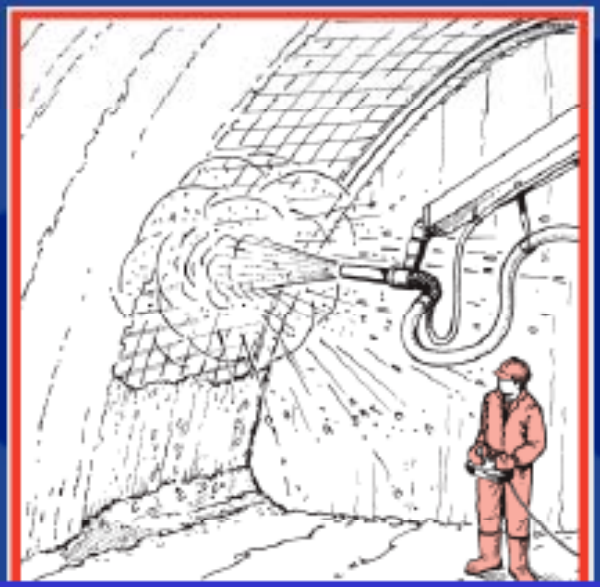
Hazards

- Being crushed
- Rebound & dust
- Burst of concrete hose

Protection

- Do not enter danger zone
- Distance between nozzle & wall <1.5
- Wear shotcrete protective helmet
- Wear respiratory protection
- Wet mix with alkali free additive to reduce dust & air pollution



Rock Support as Safety Measures for Construction

- Use of CT-Bolts
  - Easier to install than normal rebar bolts
  - Faster installation hence cost efficient
- Adoption of Rock Support System
  - Permanent rock bolts design adopted during construction phase
  - All tunnel crown sprayed with shotcrete to reduce hazards of spalling rocks
  - Shotcrete used as temporary support for safety