UNDERGROUND METROS

Industrial Novas

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PROBLEM STATEMENT

Importance of construction methodology in underground metro construction for various soil conditions. How the right design adaption can help in construction

WHY IS METRO IMPORTANT

- Advantages like efficiency, safety, convenience, no traffic jams, punctuality.
- Limited amount of space on land
- Increasing number of commuters puts a strain on public transport system so
- It is important to select the suitable method of construction for each project.

- Problems can occur both during and after construction
- After construction : Due to settlements, seismic activities, collapse etc
- During construction : Due to improper soil profiling

CASE STUDIES

CASE 1 : CHENNAI METRO

- Excavation using Tunnel Boring Machine (TBM)
- While the excavation was underway, water mixed with fine sand and silt started oozing out from joints between different segments of both the diaphragm walls into the box-cut area.
- Prolonged inflow of the slurry into the excavation area resulted in the **development of sinkholes** on the unexcavated side of the diaphragm walls.
- Cracks started appearing in the adjacent buildings and even some tilting was also reported in the nearby taller structures.
- During reinforcement work using grouting with bentonite-cement mix grouting, the grouting materials too outflowed on the floors of some of the nearby buildings, which led to anticipate of the presence of weak zones, cavities, sinkholes and rat-hole type features, acting as conduit for the grouting materials.
- This was a construction-stage problem in a thickly populated urban area. area.

Chennai Metro Distaster

CASE STUDIES

CASE 2 : AHMEDABAD METRO

from Apparel Park to Shahpur
the residents of Gomtipur municipal corporation staff quarters (~150m from Apparel Park) experienced vibrations.
On the night of 17th August 2018, the underground water tank had developed cracks, with a major land subsidence reported on 18th morning.
Around 13 families were evacuated on 18th night and the cave-in was fixed with cement and concrete.

CASE 3 : KOLKATA METRO

On 31 August 2019, one of the tunnel boring machines used for tunnelling in the construction of the Kolkata East-West Metro Line 1 hit an **aquifer**.
This led to flooding of the tunnel and TBM due to severe water leakage and sand, and triggered major subsidence. Forty buildings in the area collapsed or developed notable cracking; hundreds of people had to vacate their homes.

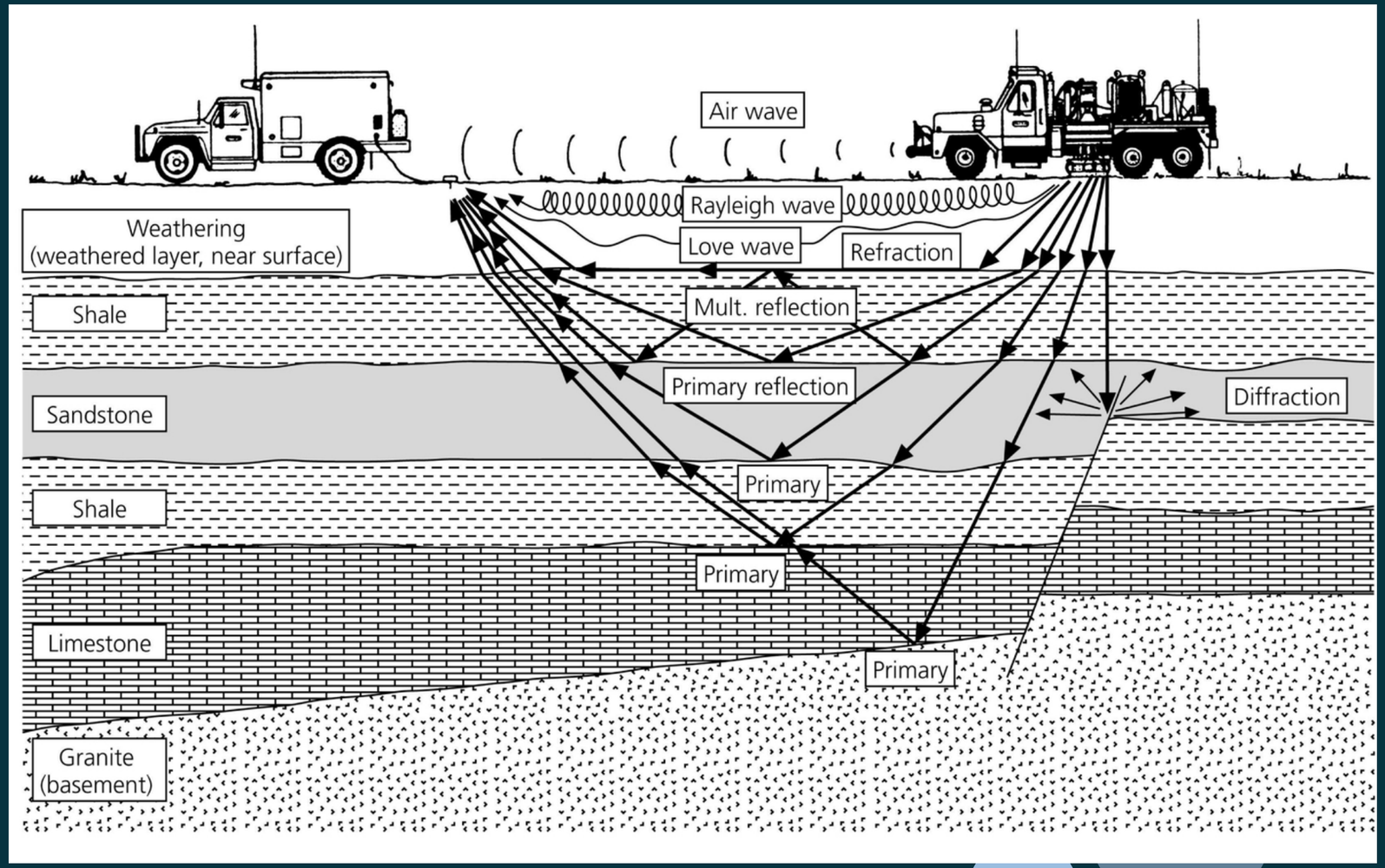
Kolkata Metro Disaster

SOIL PROFILING

GEOPHYSICAL METHODS

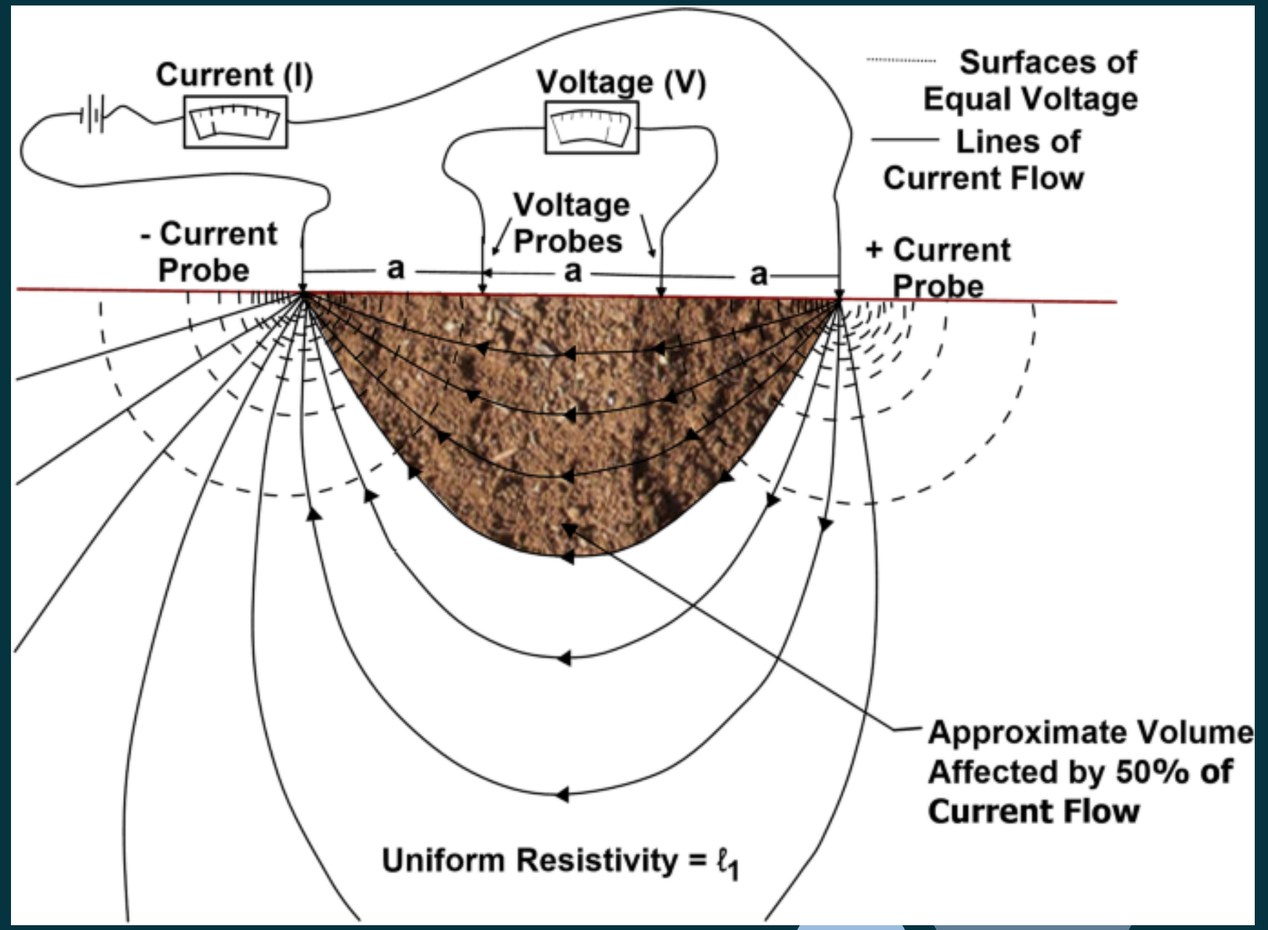
SEISMIC METHOD

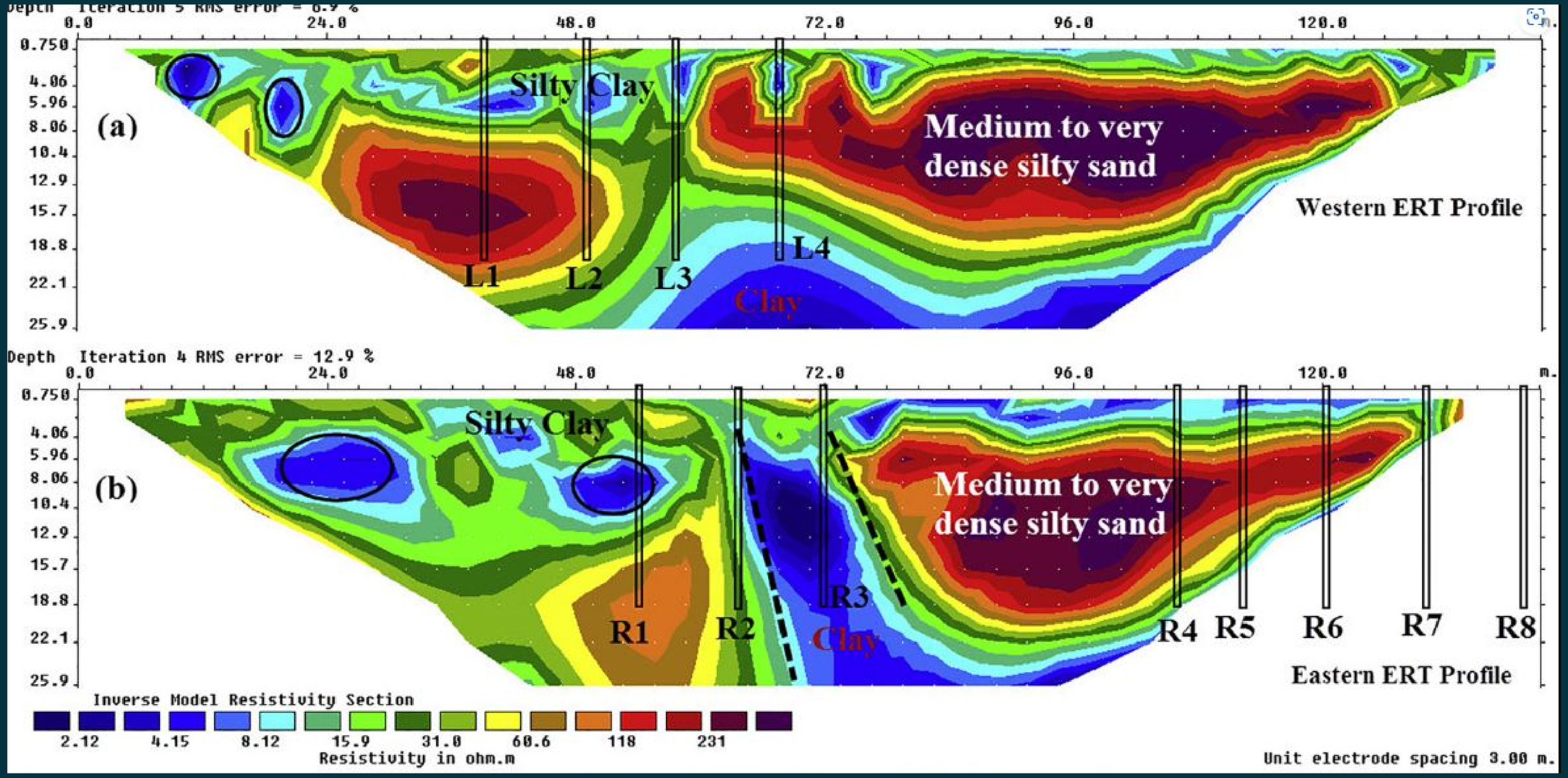
- Sound waves are generated by either explosives or vibrosis truck
- Reflected and refracted waves are picked up by vibration detectors called geophones
- Depth of various strata are determined from the known seismic velocities of different types of soils
- Shear wave velocity (VS) is the fundamental soil property and a key parameter for construction engineering



ELECTRICAL RESISTIVITY METHOD

- Each soil type has different electrical resistivity depending on constituents, water content, compaction
- Electricity is passed between outer electrodes and potential drop between inner electrodes is measured
- Depth of various strata are determined from the known electrical resistivity of different types of soils




Depth Iteration 5 RMS error = 6.9 %
0.0
24.0
48.0
72.0
96.0
120.0
0.750
4.06
5.96
8.06
10.4
12.9
15.7
18.8
22.1
25.9
(a)
Silty Clay
Medium to very dense silty sand
Western ERT Profile
L1
L2
L3
L4
Clay
Depth Iteration 4 RMS error = 12.9 %
(b)
Silty Clay
Medium to very dense silty sand
R1
R2
R3
R4
R5
R6
R7
R8
Clay
Eastern ERT Profile
Inverse Model Resistivity Section
2.12
4.15
8.12
15.9
31.0
60.6
118
231
Resistivity in ohm.m
Unit electrode spacing 3.00 m.

CONSTRUCTION TECHNIQUES

HOW TO PREVENT TUNNEL FROM COLLAPSING

TUNNELING SHIELD

The problem of tunneling under a river had defied the engineering imagination for centuries because of the difficulty of preventing mud and water from seeping in and collapsing the tunnel heading

ORIGIN

In 1818 Marc Isambard Brunel, an French naval officer in England, observed the action of a tiny marine borer, the shipworm, whose shell plates permitted it to bore through timber and push the sawdust out behind it. Brunel built a giant iron casing, or shield, that could be pushed forward through soft ground by means of screw jacks, while miners dug through shutter openings in the face.

FIRST USED AT

Brunel's shield, rectangular in plan, was successfully employed in driving the world's first underwater tunnel, the Thames Tunnel, under the River Thames at London from 1825 to 1842.

TYPE OF SOIL IT IS FOR

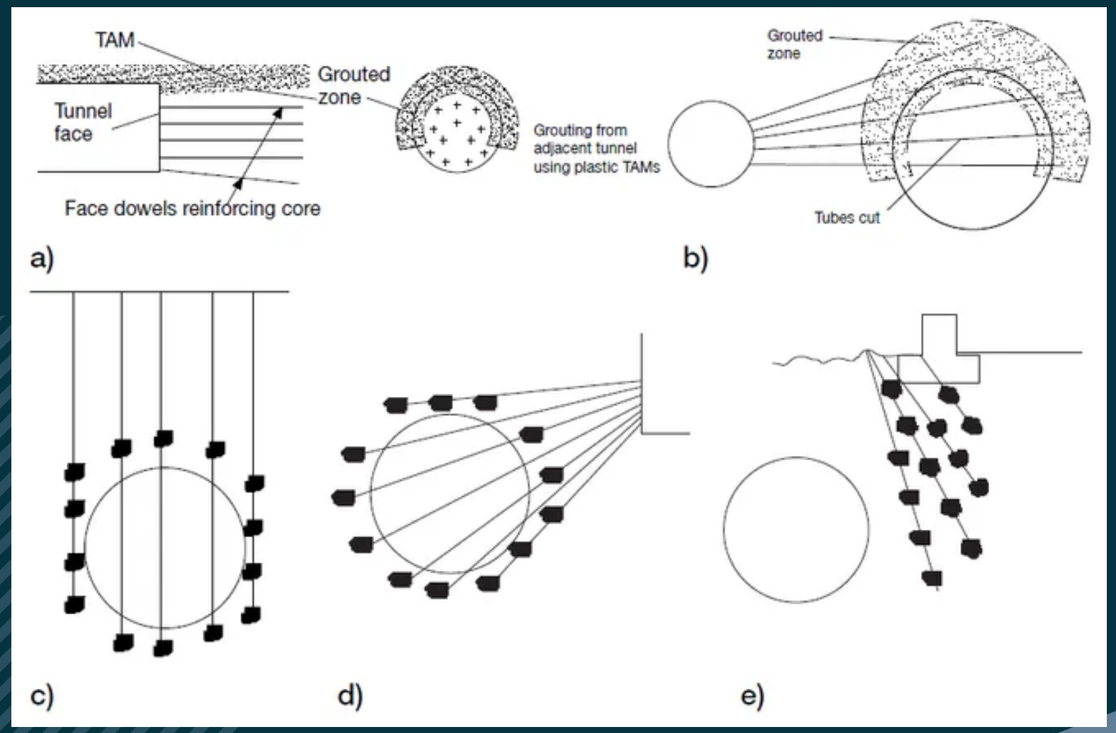
The shield machine mainly tunnels through the 52 medium-density silty sand layer, which has a bearing capacity of 130 kPa.

PRESENT

- Powerful steel cylinders shoved forward by hydraulic jacks.
- A diaphragm, or curtain, in the front has a door that may be opened to permit work in front of the shield, or it may be closed when the shield is shoved through very soft ground. In front of the diaphragm the cylinder is prolonged by a circular cutting edge that projects farther at the top, forming a protective hood for those working in front of the shield.
- Behind the diaphragm an erector arm, an adjunct of the shield, constructs the tunnel lining by successively setting segments of steel rings in place. The steel is later covered over with masonry. Hydraulic jacks to advance the shield are braced against the end of the completed lining.

GROUTING

Grouting refers to the injection of pumpable materials into a soil or rock formation to change its physical characteristics.
done for filling the voids between the rock face and lining in tunnel work



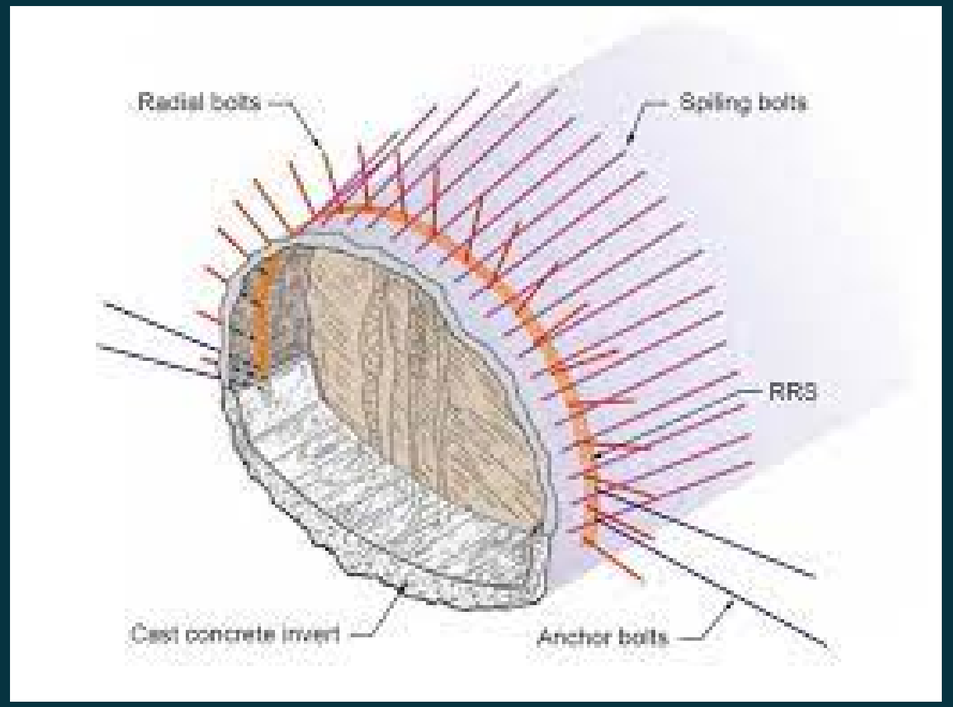
TUNNEL GROUTING

For tunnel grouting. The holes for injecting grouting are drilled at an acute angle to the axis of the tunnel to form overlapping cones of treated ground. Also, it can be drilled from the face of the tunnel. For TBM method the holes can be drilled forward from the rear of the machine to avoid disturbing the cutter wheel.
Also, grouting can be performed toward the face of the tunnel and radially using the shield for shield TBM. Figure 1 shows different forms of ground grouting for tunnels excavation.

Examples of grouting tunnels during construction,
a) from within a tunnel
b) using an adjacent tunnel
c) from the ground surface
d) from an adjacent shaft
e) as protection to adjacent structures

ROCK BOLTING

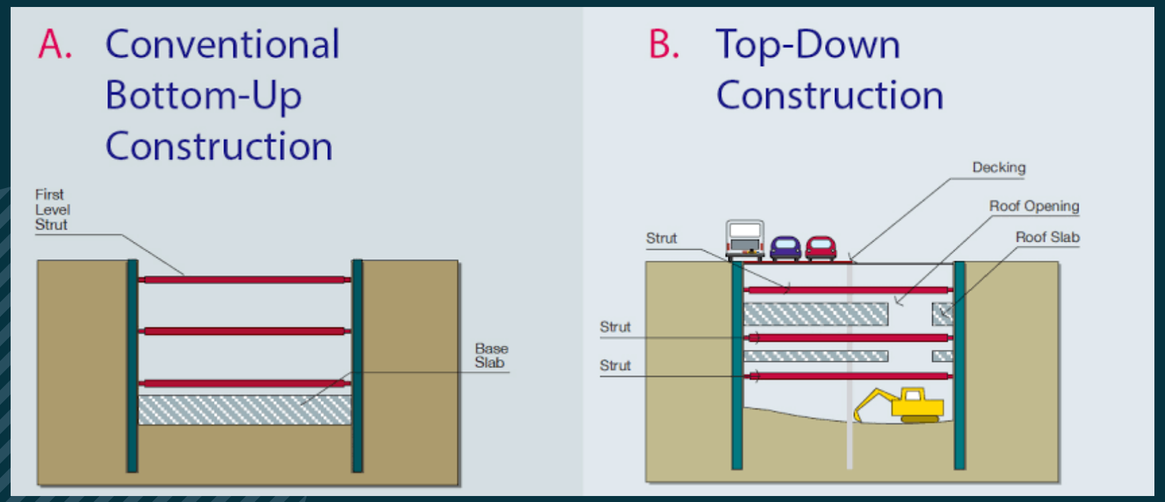
Rock bolt, in tunneling and underground mining, steel rod inserted in a hole drilled into the roof or walls of a rock formation to provide support to the roof or sides of the cavity. Rock bolt reinforcement can be used in any excavation geometry, is simple and quick to apply, and is relatively inexpensive and good for rocky strata at shallow depth



Rock bolts work by 'knitting' the rock mass together sufficiently before it can move enough to loosen and fail by unraveling (piece by piece). As shown in the photo, rock bolts may be used to support wire mesh, but this is usually a small part of their function. Unlike common anchor bolts, rock bolts can become 'seized' throughout their length by small shears in the rock mass, so they are not fully dependent on their pull-out strength.

CUT & COVER

The “cut and cover” method is a traditional form of tunneling that involves opening up the ground surface and excavating to the required depth.
Once the construction is complete, the excavation is backfilled.
The method is used when excavation is possible and economical from the surface, and environmentally acceptable.



ADVANTAGES

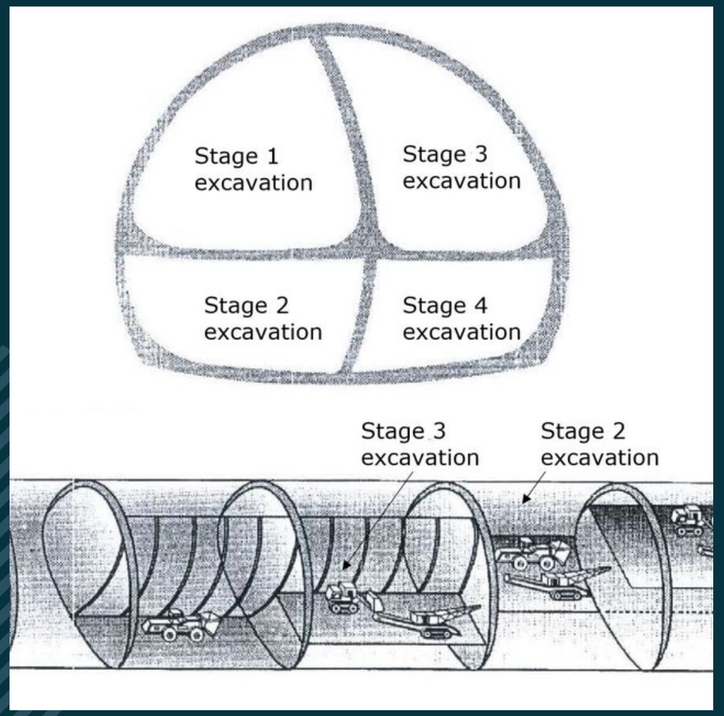
Some of the main advantages of this method involve-
1. Preservation of the environment;
2. Reduced effort in lining construction and
3. Safe geotechnical conditions

DISADVANTAGES

1. Initiation of underground excavation in weak formations with low
overburden might trigger instability above the openings.
2. Structurally controlled wedge sliding or rock falls above the portals are
expected regardless of rock mass quality.
3. Lateral slides due to unfavorable orientation of discontinuities and/or
poor geotechnical conditions are possible.

NEW AUSTRIAN TUNNELING METHOD

The New Austrian Tunneling Method (NATM) is the application of rock mechanics theory and based on maintaining and utilizing the self-bearing capacity of the surrounding rock. The key principle of NATM is using the surrounding rock as a part of the support system [



THE CONSTRUCTION PROCESS

1) Line positioning;
2) drilling, loading and blasting;
3) dust removal by ventilation;
4) anchor and steel arch support and bar-mat reinforcement;
5) shotcreting to form the preliminary bracing;
6) building the concrete as the secondary lining.

Three key points of NATM:

1. application of a thin-sprayed concrete lining;
2. closure of the ring as soon as possible
3. systematic deformation measurement.

NEW AUSTRIAN TUNNELING METHOD

ADVANTAGES

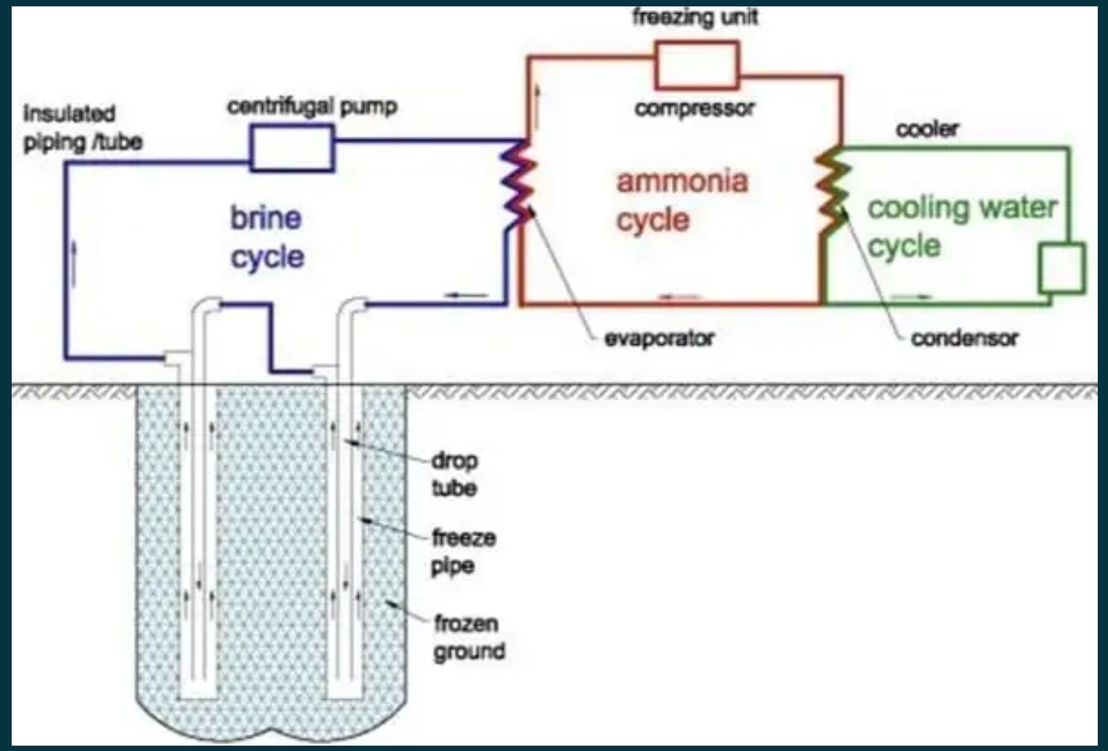
- maintains the strength of the original surrounding rock to the largest extent. The timely support and close contact with the rock surface also helps the integration of the surrounding rock and lining, which omits the supporting component in the traditional construction.
-Besides, the design and construction are much more reasonable with lower cost.
- NATM can show its superiority in weak surrounding rock, poor geology conditions and shallow tunnels.

DISADVANTAGES

- Higher requirement of technology and a number of collapses and failures of NATM tunnels occurred in the history.
-It is mainly applicable to some stable and relatively hard rock masses. In contrast, the applicable of NATM should be assessed carefully for poor geological conditions, such as the existence of water burst and the heaving sand, or when the rock is extremely broken and the excavation surface cannot be completely self-stabilized

GROUND FREEZING

The ground freezing process involves drilling and installing a series of relatively closely spaced pipes and circulating a coolant through these pipes. The refrigerated coolant extracts heat from the ground, converting the soil pore water to ice resulting in an extremely strong, impermeable materia



ADVANTAGES

Cost-effective solution
Can be performed at a significant depth
Can be performed in difficult, disturbed or sensitive ground

HOW THESE TECHNIQUES MADE A DIFFERENCE

Using proper construction techniques will increase the life of the tunnel.
It is a one time investment so, sometimes, investing a little more money in the beginning can reduce long term maintaince costs as well as reparation costs.

Further with the right technique, upto 300% of material and cost can be reduced and can ensure seamless service for years to come.

THANK YOU