GROUND IMPROVEMENT TECHNIQUES

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UNIT-4

CHEMICAL AND PHYSICAL MODIFICATION

Grouting

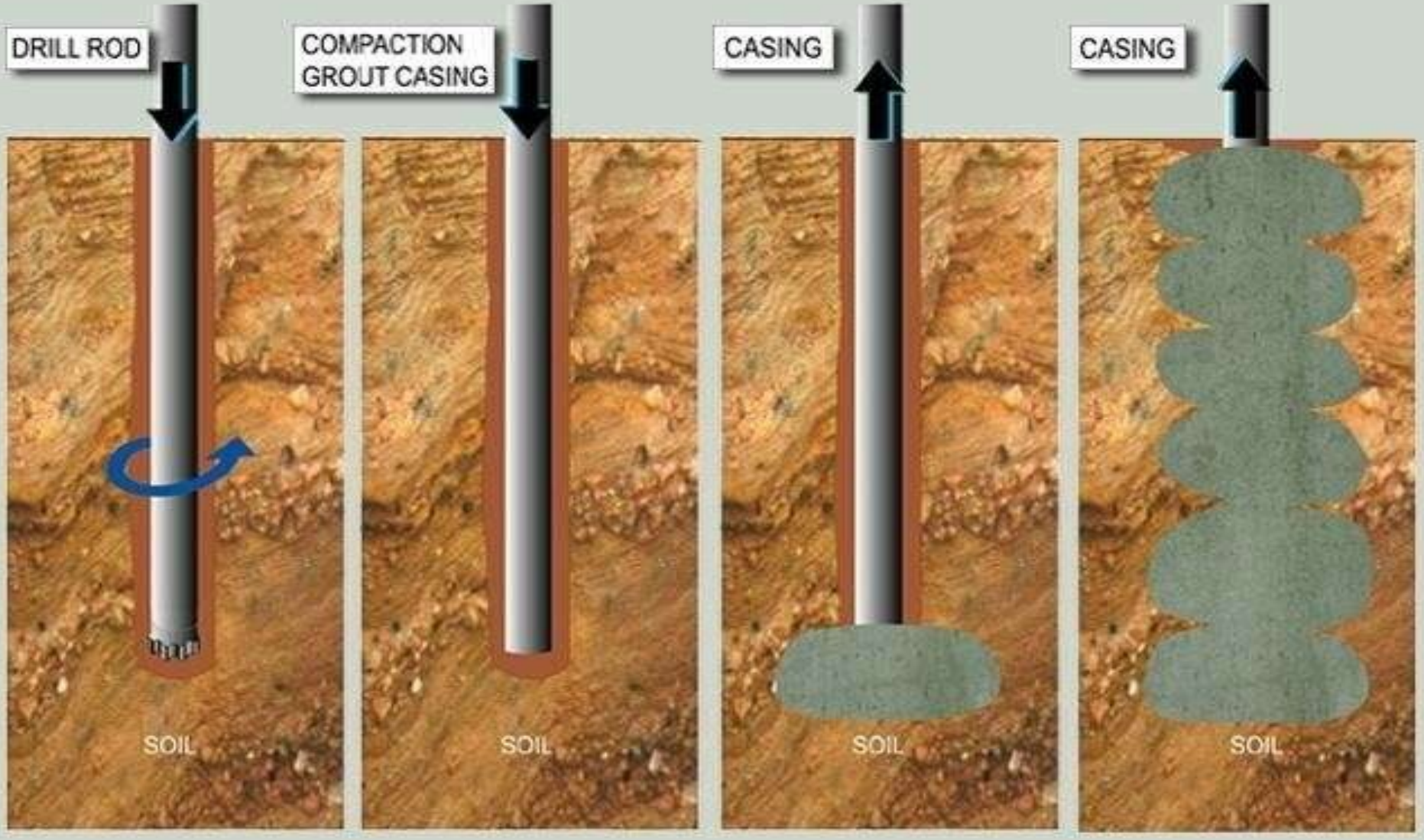
- **Grout** is a construction material used to embed rebars in masonry walls, connect sections of pre-cast concrete, fill voids, and seal joints (like those between tiles).
- Grout is generally composed of a mixture of water, cement, sand, often color tint, and sometimes fine gravel (if it is being used to fill the cores of cement blocks). It is applied as a thick liquid and hardens over time, much like mortar.
- Initially, its application confines mainly in void filling, water stopping and consolidation. Nowadays, it extends to alleviate settlement of ground caused by basement and tunnel excavation works, to strengthen ground so that it can be used as a structural member or retaining structure in solving geotechnical problems.

Grouting

- Grouting is the process to inject grout into the ground. Hence, the volume of the ground ready to accept grout is the primary consideration before any other considerations.
- GROUT can be defined as a solution, an emulsion or suspension in water, which will harden after a certain time interval. It can be divided into two main groups:
- a. Suspension Grout
- b. Liquid Grout or Solution Grout.
- **Suspension grout** is a mixture of one or several inert materials like cement, clays etc. suspended in a fluid -- water. According to its dry matter content it is either of the stable or unstable type. suspension grout is a mixture of pure cement with water.
- **Liquid grout or solution grout** consists of chemical products in a solution or an emulsion form and their reagents. The most frequently used products are sodium silicate and certain resins.

Use of Grouting in Civil Engineering

- Its traceable record can be as early as in the beginning of 1800s.
- In 1802, the idea of improving the bearing capacity under a sluice by the injection of self-hardening cementitious slurry was first introduced
- In 1864, Peter Barlow patented a cylindrical one-piece tunnel shield which could fill the annular void left by the tail of the shield with grout. It is the first recorded use cementitious grout in underground construction.
- In 1893, the first systematic grouting of rock in the USA as performed at the New Croton Dam, in New York.
- In 1960s, jet grouting technique was developed.
- In 1977, first application of compaction grouting for controlling ground movement during construction of the Bolton Hill Tunnel.
- In 1995, the first industrial application of the compensation grouting concept was conducted at the construction site of the Jubilee Line Extension Project in London.



STEP ONE:
PREDRILLED COMPACTION GROUTING HOLE TO DESIRED DEPTH.

STEP TWO:
INSERT COMPACTION GROUT CASIING IN PREDRILLED HOLE.

STEP THREE:
BEGIN PUMPING LOW SLUMP COMPACTION GROUT MIX IN STAGES AND WITHDRAW AT CONTROLLED RATE.

STEP FOUR:
WITHDRAW CASING AS STAGES ARE COMPLETE UNTIL THE HOLE IS COMPLETE

Types of Grouts

- **Cement-based Grouts:**
  - Cement-based grouts are the most frequently used in both water stopping and strengthening treatment. They are characterized by their water cement ratio and their Total Dry Matter / Water weight ratio. The properties and characteristics of these grouts vary according to the mix proportions used.
    However, they have the following properties and characteristics in common.
    - Stability and fluidity according to the dosage of the various components and their quality
    - Unconfined compressive strength linked to water cement ratio
    - Durability depending on the quantity and quality of the components
    - Easy preparation and availability
    - Ease of use
    - Relatively low cost mixes

- **Pure cement grout**
- It is an unstable grout. However, bleeding can be avoided with water cement ratio less than 0.67.
- Usual mix proportions are from water cement ratio 0.4 to 1 for grouting. Very high mechanical strength can be attained with this type of grout.
- During grouting, cement grains deposit in inter-granular voids or fissures is analogous to a kind of hydraulic filling.
- The grout usually undergoes a significant filtration effect. The grain fineness is an important factor for fine fissures.

Bentonite cement grout

It is a stable grout. When bentonite is added to a cement suspension, the effects are: -

- Obtain a homogeneous colloidal mix with a wide range of viscosity.
- Avoid cement sedimentation during grouting.
- Decrease the setting time index and separation filtering processes.
- Increase the cement binding time.
- Improve the penetration in compact type soils
- Obtain a wide range of mechanical strength values.
- In water stopping, grout will include a lot of bentonite and little cement. In consolidation works, grout will contain a lot of cement and little bentonite. Ideal mixes should be both stable and easy to pump.

Grouts with fillers

- Fillers are added in order to modify the viscosity of a given grout so as to obtain a low cost product to substitute the cement. The most commonly used fillers are the natural sands and fly ash from thermal power stations.
- The term “mortar” is commonly used to specify grouts with fillers that have a high sand content. Adding fillers reduces the grout penetrability, as the fillers are of larger grain sizes.
- Grouts with fillers are used when water absorption and/or the size of voids are such that filling becomes essential and when the leaking of grout into adjoining areas should be limited.
- In addition, fillers in grout will produce low slump grout with high viscosity for certain grouting purposes.

Silicate based grouts

- Slicates based grouts are sodium silicate in liquid form diluted and containing a reagent.
- Their viscosity changes with time to reach a solid state that is called the “gel”.
- They are used in soils with low permeability values such that all suspension grouts cannot penetrate. According to the type of grout used, the gel obtained will be water-
- Tightness and/or with strength that are temporary or permanent.
- When the temperature of a silicate decreases, its viscosity increases very rapidly. This temperature should not fall below 0 degree C in order to eliminate any risks of modification of its properties.

Soft gels

- It is mainly for water stopping purpose. They are gels with a very low dosage in silicate in which the gelling process is most generally obtained by adding a mineral reagent
- Their very low degree of viscosity (close to water) ensures the injection of very fine sand to achieve the water stopping purpose.
- Reduction in permeability can be up to 1 x 10-6 m/s and, in some case even up to 1 x 10-7 m/s when more lines of grout holes are added. There is also a slight improvement in strength, about 0.2 MPa.

Grout Injection Methods

- Different grout injection methods have been developed for different grouting techniques. There are four main injection methods to inject grout into the ground.
- Drill Hole Method
  - A hole is drilled through the pores/voids of the ground. Then grout is pumped via the grouting line into the surrounding ground of a section with the use of single or double packers.
- Drill Tool Method
  - It is a one-stage grouting method by means of the drill casings or rods. There are two injection methods.
  - A very permeable soil maybe injected during rotary drilling. During the drilling of the grout hole, each time a re-determined distance has been reached the drill rod is withdrawn a certain length and the grout is injected through the drill rod into the section of soil drilled. During each injection the top of the grout hole, a collar is used to seal the gap between the hole and the drill rod.

Grout Pipe Method

Grout pipes are installed in drilled hole for later on gout injection operation. The gaps between the grout pipe and the drilled hole are normally sealed. When compared with above Drill Tool Method, it is more flexible as the drilling plant is not engaged in the grouting operation.

- For multiple-stage grouting, the sealed-in sleeve pipe injection method (the tube-à-manchettes method) is used. It allows several successive injections in the same zone.
- The method is to place a grout pipe with rubber sleeves into a grout hole, which is kept open by casing or by mud. This pipe is then permanently sealed in with a sleeve grout composed of a bentonite-cement grout.

Jetting Method

- Finally, a different type of injection method, the jet grouting method, is introduced in the 60s, which has a revolutionary change to the grouting concept so far.
- The grout, with the aid of high pressure cutting jets of water or cement grout having a nozzle exit velocity >= 100m /sec and with air-shrouded cut the soil around the predrilled hole.
- The cut soil is rearranged and mixed with the cement grout.

The soil cement mix is partly flushed out to the top of the predrilled hole through the annular space between the jet grouting rods and the hole wall. Different shape of such soil cement mix can be produced to suit the geotechnical solution. The cutting distance of the jet varies according to the soil type to be treated, the configuration of the nozzle system, the combination of water, cement and shrouded-air, and can reach as far as 2.5m.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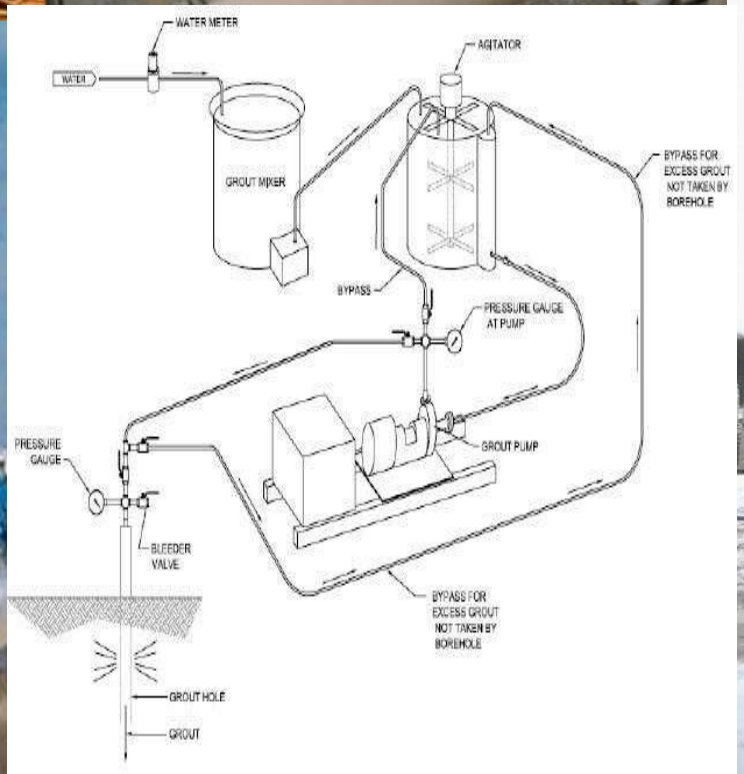

WATER METER
WATER
AGITATOR
GROUT MIXER
BYPASS FOR EXCESS GROUT NOT TAKEN BY BOREHOLE
BYPASS
PRESSURE GAUGE AT PUMP
GROUT PUMP
PRESSURE GAUGE
BLEEDER VALVE
BYPASS FOR EXCESS GROUT NOT TAKEN BY BOREHOLE
GROUT HOLE
GROUT

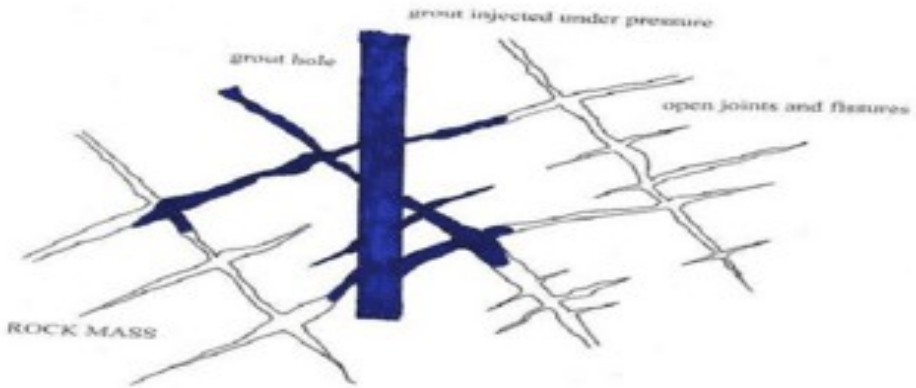
Different Types of Grouting Mechanisms

- There are lots of names as far as grouting techniques are concerned. They can be categorized according to their functions, their grout materials used etc. Five major techniques are:
- the Rock Fissure Grouting,
- TAM Grouting,
- Compaction Grouting,
- Compensation Grouting and
- Jet Grouting.

The five selected grouting techniques should have covered the basic mechanisms of all existing grouting techniques.

Rock Fissure Grouting

- Rock fissure grouting is the use of a hole drilled through the fissures and joints of a rock mass to allow grout to be injected at close centers vertically and re-injecting, if necessary.
- Grouting Mechanism
  - There is only one grouting mechanism for rock grouting. The following schematic diagrams show how is the mechanism for grouting in rock. The grout is injected under pressure through the grout hole drilled into the rock mass to be treated.
- Rock fissure grouting technique has a long history of application in civil engineering.
- Its main applications are:
- Sealing rock mass underneath and at ends of dams to prevent seepage or
- leaking of the reservoirs.

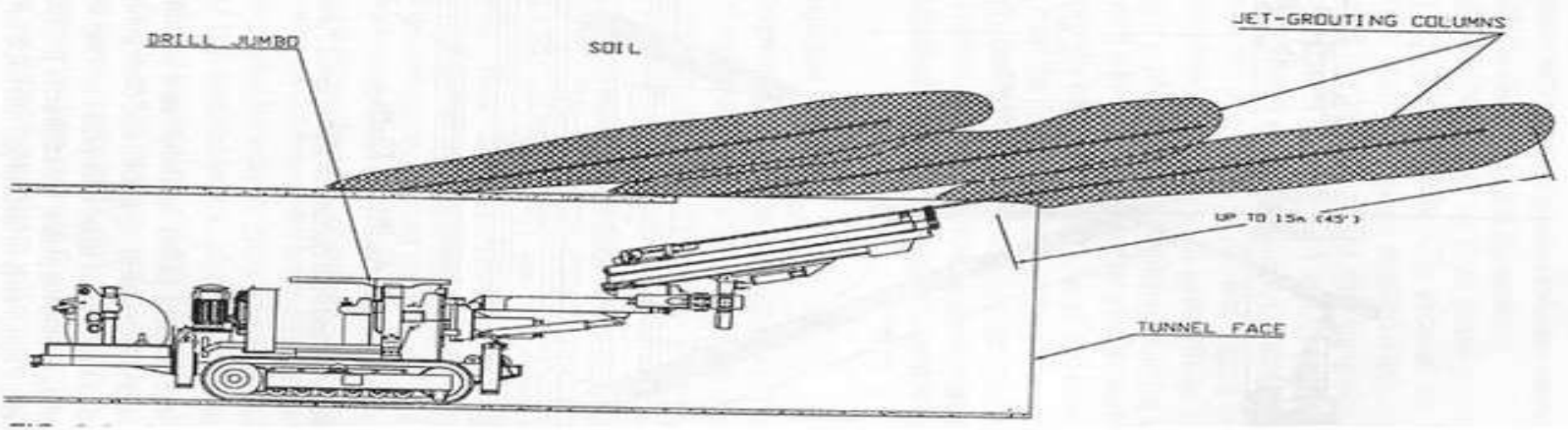


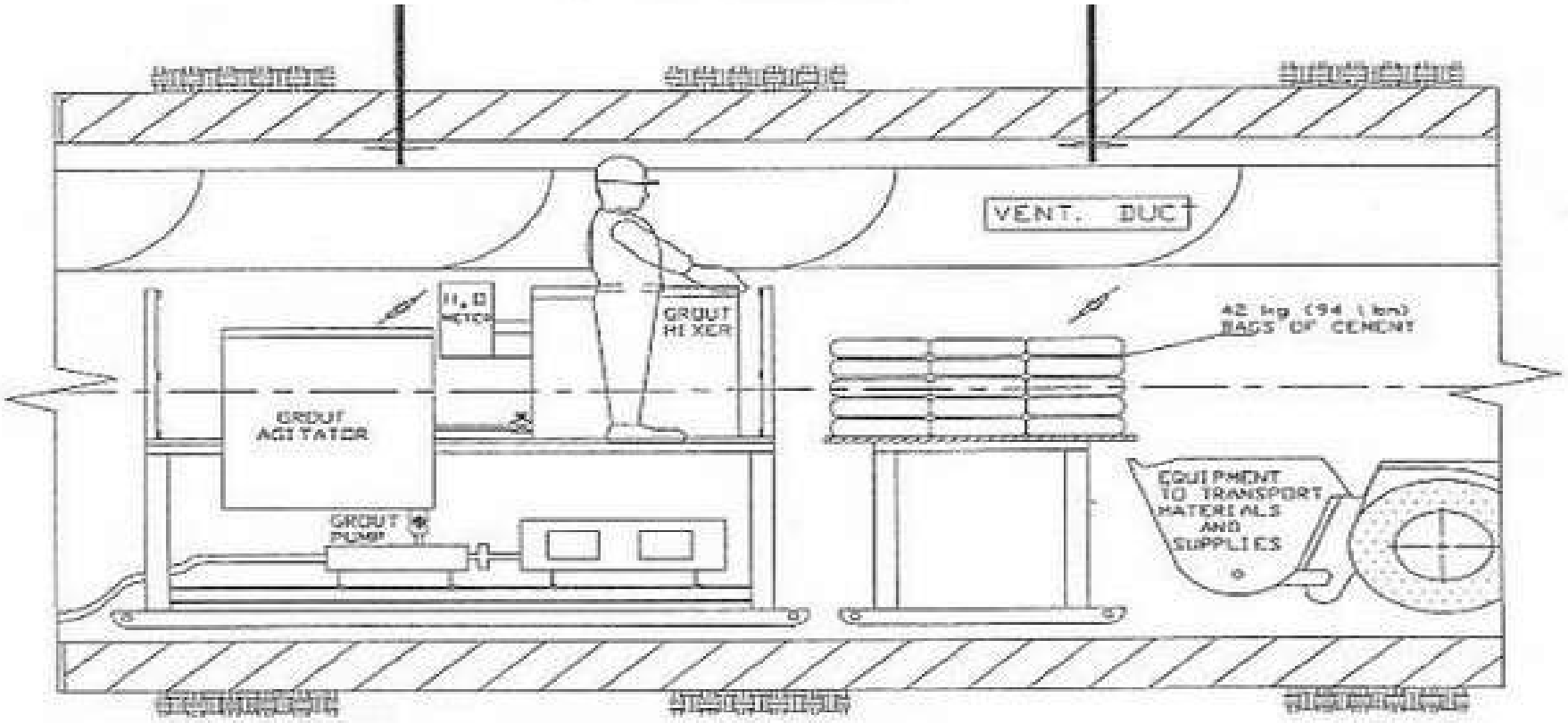
Grouting in Progress

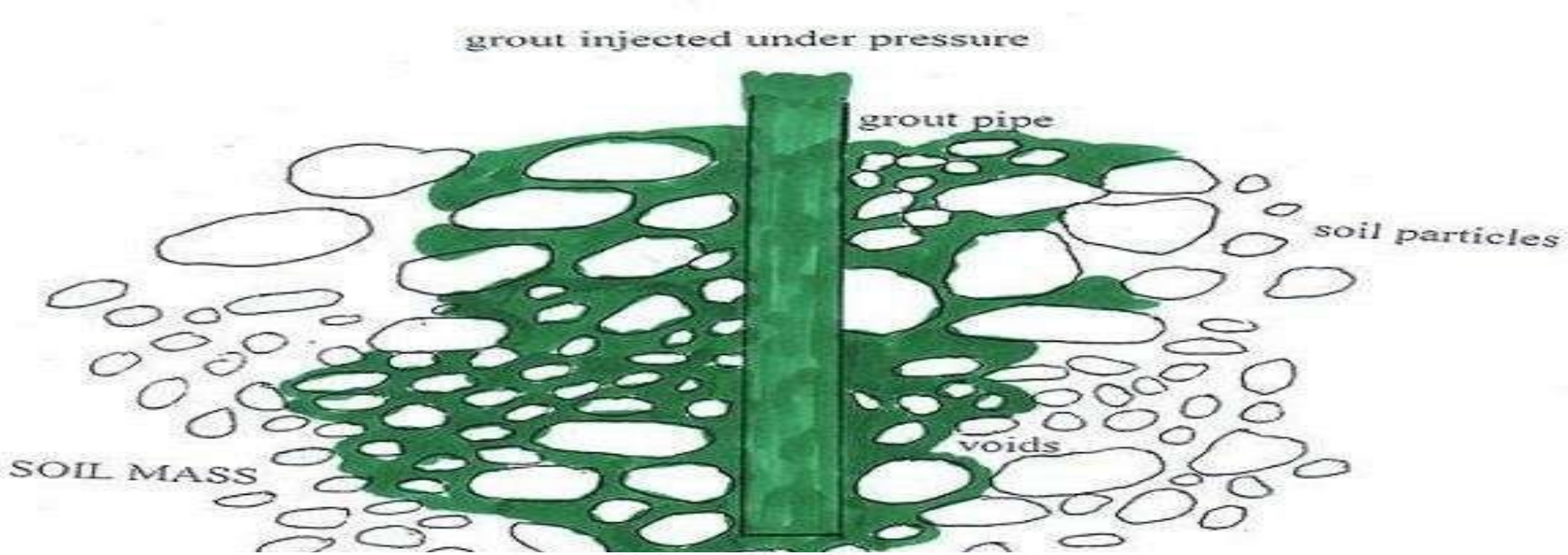
Grouting Completed

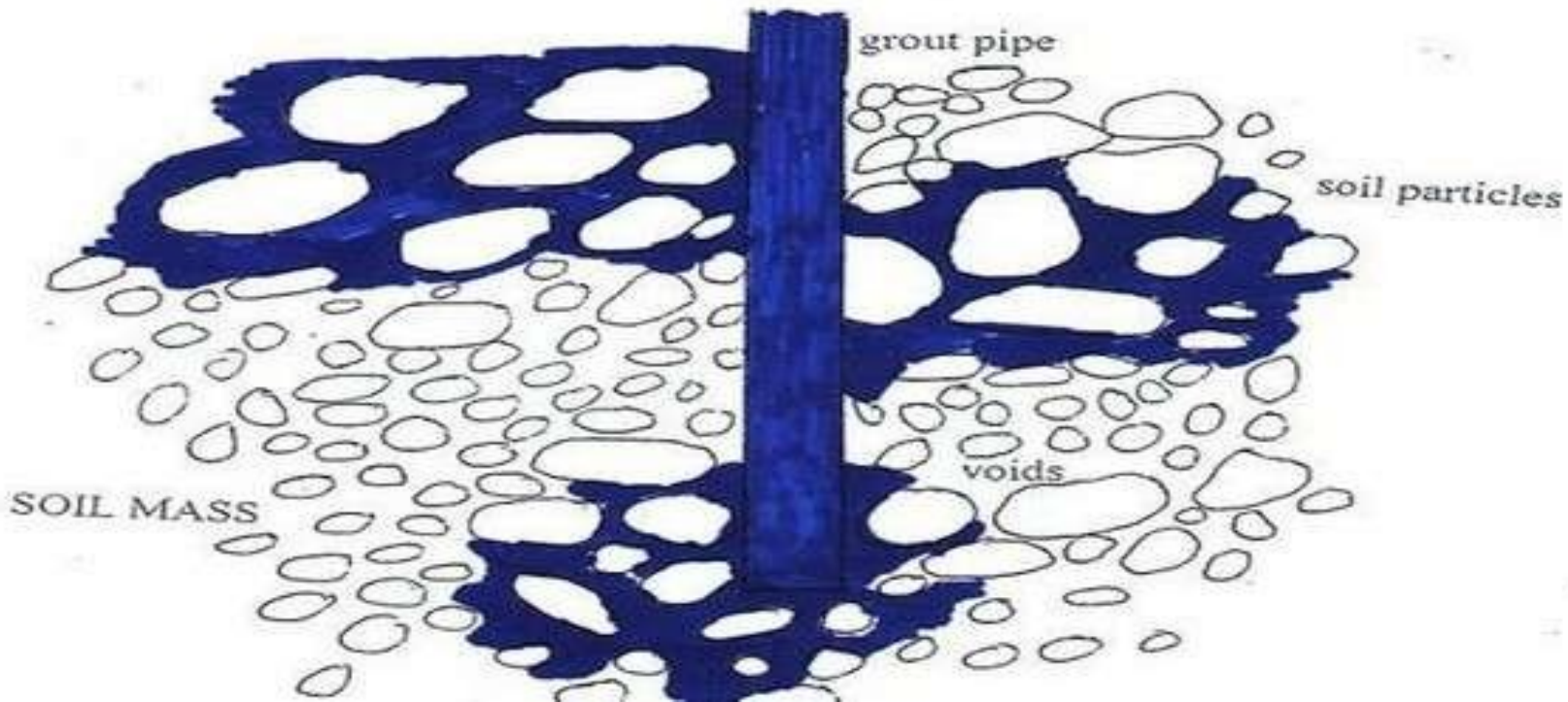
Application

- Rock fissure grouting technique has a long history of application in civil engineering. Its main applications are:
- Sealing rock mass underneath and at ends of dams to prevent seepage or leaking of the reservoirs.
- Sealing rock mass above and underneath a rock tunnel to prevent water seepage into the excavated tunnel.
- Cementing fractured rock mass. Although Rock Fissure Grouting technique can be used to cemented sugar clubs rock formation, like in slope stability projects, its main application is in the field of water stopping, especially in tunnel excavation project.


DRILL JUMBO
SOIL
JET-GROUTING COLUMNS
UP TO 15m (45')
TUNNEL FACE


VENT. DUCT
GROUT MIXER
GROUT AGITATOR
GROUT PUMP
42 kg (94 lbs) BAGS OF CEMENT
EQUIPMENT TO TRANSPORT MATERIALS AND SUPPLIES


grout injected under pressure
grout pipe
soil particles
voids
SOIL MASS


grout injected under pressure
grout pipe
soil particles
voids
SOIL MASS

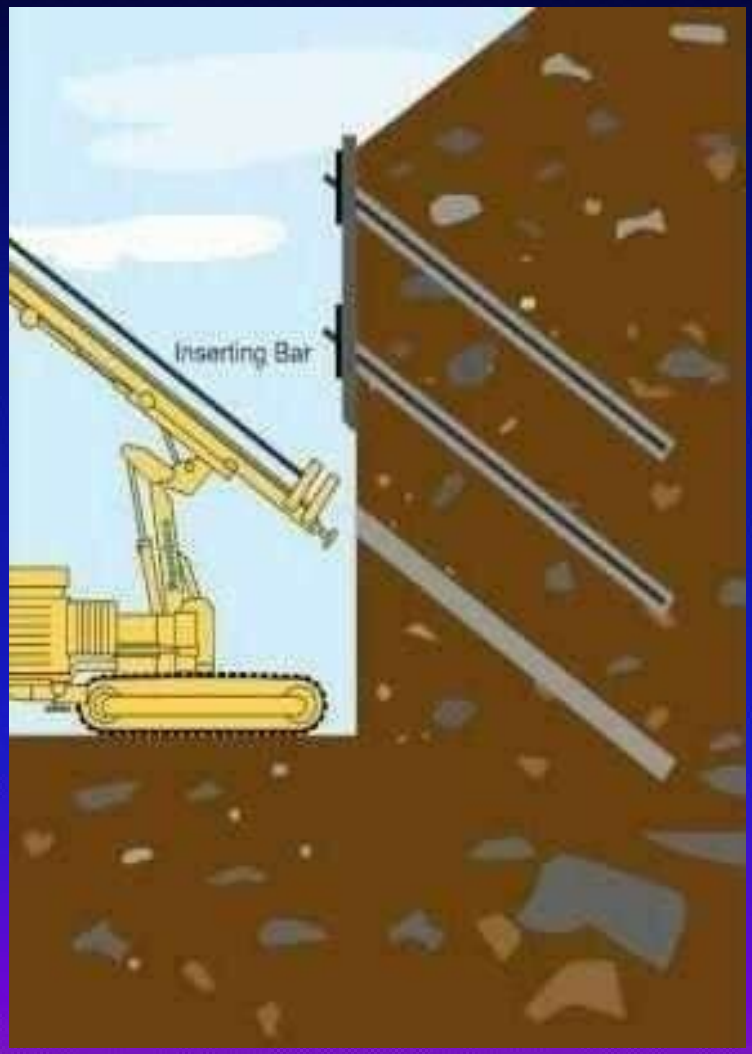
UNIT-5
MODIFICATION BY INCLUSIONS AND CONFINEMENT

INTRODUCTION

- Soil Nailing is a technique to reinforce and strengthen ground adjacent to an excavation by installing closely spaced steel bars called “nails” ,as construction proceeds from top down.

It is an effective and economical method of constructing retaining wall for excavation support, support of hill cuts, bridge abutments and high ways.

- The nails are subjected to tension compression, shear and bending moments



HISTORY OF SOIL NAILING

- Technique came from New Austrian Tunneling Method in 1960.
- Stabilization works in underground tunnel in Europe in 1970.
- The first recorded use of soil nailing in its modern form was in France in 1972.
- The United States first used soil nailing in 1976 for the support of a 13.7 m deep foundation excavation in dense silty sands.

FAVOURABLE GROUND CONDITIONS

- Critical excavation depth of soil is about 1-2 m high vertical or nearly vertical cut.
- All soil nails within a cross section are located above groundwater table .
- FAVOURABLE SOILS

  Stiff to hard fine grained soils, dense to very dense granular soils with some apparent cohesion, weathered rock with no weakness planes and glacial soils etc.

- UNFAVOURABLE SOILS

  Dry, poorly graded cohesion less soils, soils with cobbles and boulders , soft to very soft fine grained soils ,organic soils.

APPLICATIONS

- Stabilization of railroad and highway cut slo

- Excavation retaining structures in urban areas for
  - high-rise building and
  - underground facilities.

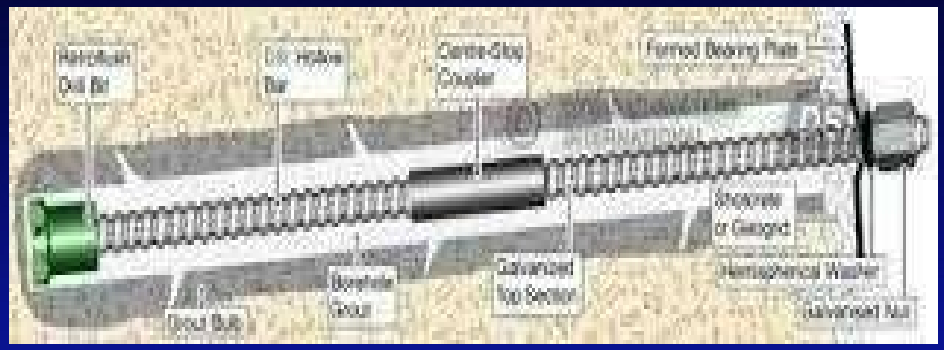
APPLICATIONS (CONT…..)

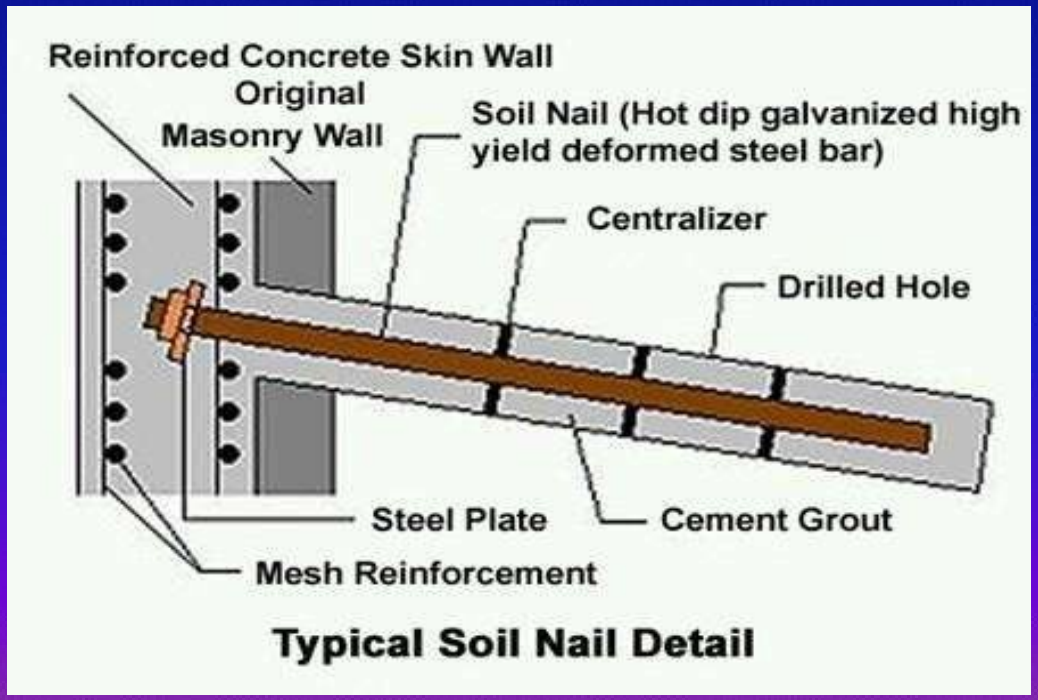
- Existing concrete or masonry structures such as failing retaining walls and bridge abutments.
- Tunnel portals in steep and unstable stratified slop

- construction and retrofitting of bridge abutments.
- Stabilizing steep cuttings to maximize development space.

NAILS

- Driven Nails
- Grouted Nails
- Corrosion Protected nails
- Jet grouted Nails
- Launched Nails





Typical Soil Nail Detail

MACHINERIES AND MATERIALS

DRILLING EQUIPMENT

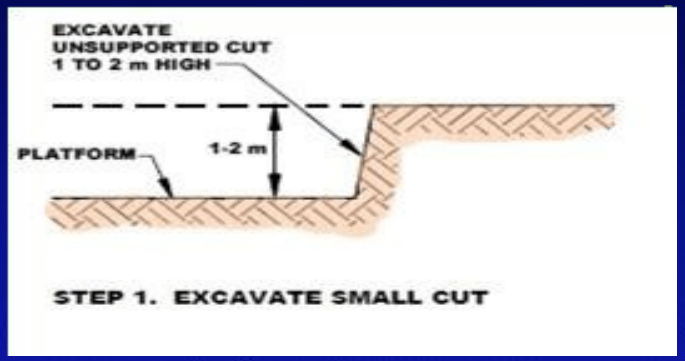
GROUT MIXER

COMPRESSOR

- STEEL REINFORCEMENTS
- GROUT MIX
- SHOTCRETE / GUNITE

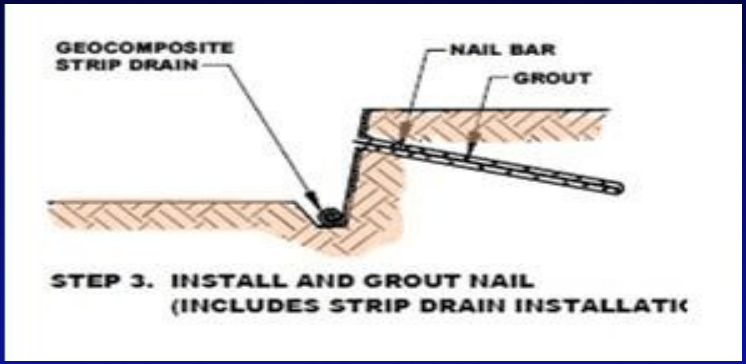
CONSTRUCTION SEQUENCES

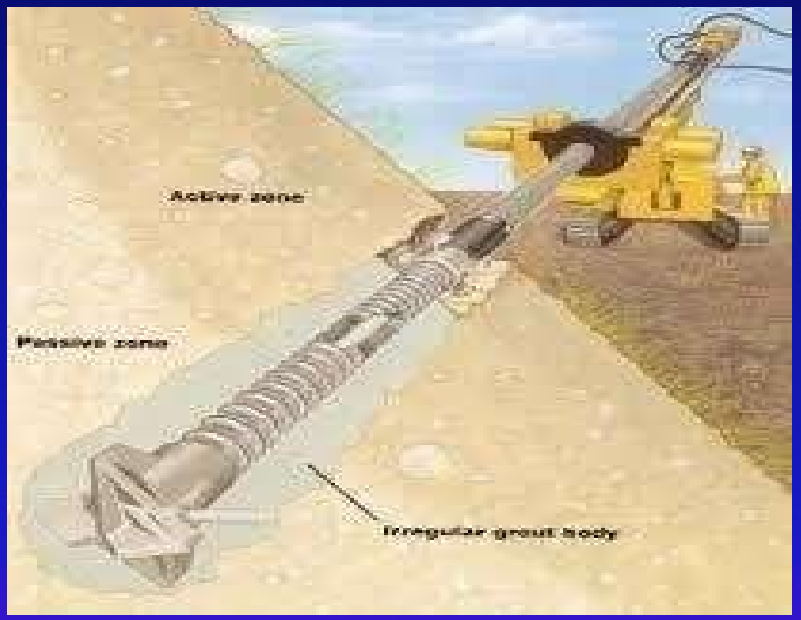
- INITIAL EXCAVATION



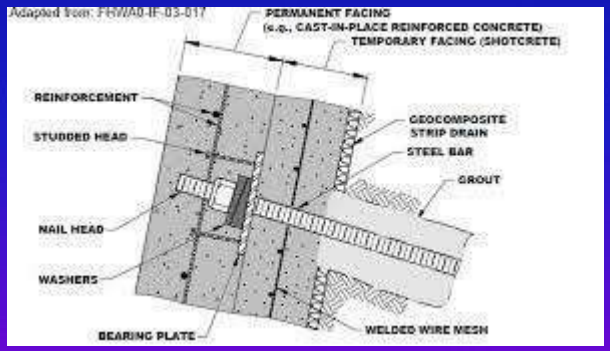
- DRILLING OF HOLES

- NAIL INSTALLATION





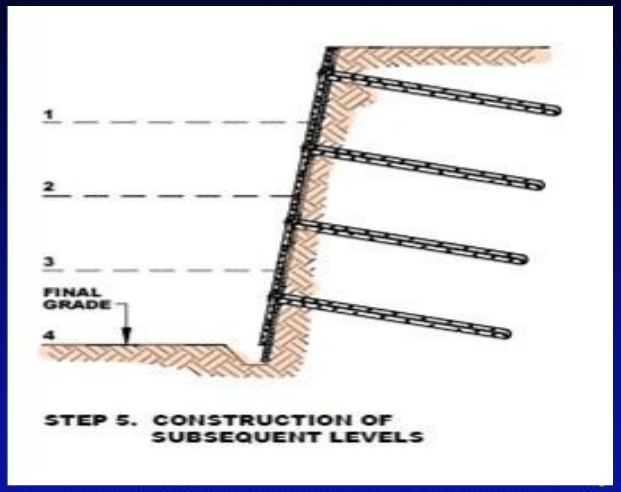
- GROUTING



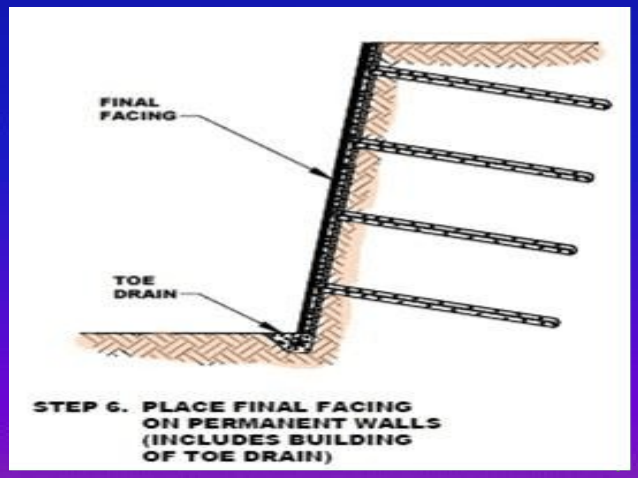
- PLACE REINFORCEMENT AND DRAINAGE

- SHOTCRETING AND INSTALLING BEARING PLATES

- REPEAT STEPS TO FINAL SUBGRADE



- PERMANENT FACING



ADVANTAGES

- With the right soil and site conditions, a rapid and economical means of constructing earth retention support systems and retaining walls.
- Shorter drill holes.
- Smaller diameter bars at shorter lengths.
- Retaining walls are secured laterally into the soil, eliminating piles and foundation footers.

ADVANTAGES (CONT…..)

- Creates less noise and traffic obstructions.
- Less impact on nearby properties
- Allow in-situ strengthening on existing slope surface with minimum excavation and backfilling, particularly very suitable for uphill widening, thus environmental friendly,
- Allow excellent working space in front of the excavation face,

DISADVANTAGES

- Nail encroachment to retained ground rendering unusable underground space,
- Generally larger lateral soil strain during removal of lateral support and ground surface cracking may appear,
- Tendency of high ground loss due to drilling technique, particularly at course grained soil,
- Less suitable for course grained soil and soft clayey soil, which have short self support time, and soils prone to creeping
- Suitable only for excavation above

CONCLUSION

- Since this process is effective in cohesive soil, broken rock, shale, or mixed face conditions it permits flexibility to conform to a variety of geometric shapes to meet specific site needs.

- Due to its rather straightforward construction method and is relatively maintenance free, the method has gained popularity in India for highway and also hillside development projects. Soil nailing is an economical means of creating shoring systems and retaining walls.