GROUND IMPROVEMENT TECHNIQUES
(COURSE CODE : ACE509)
REGULATION : IARE-R16
B.TECH VII SEM

Prepared by:
S. SIVA RAMA KRISHNA ASST.PROF
CH. BALA KRISHNA ASST.PROF

Syllabus

- UNIT-1-Introduction to ground Modification: Need and objectives, Identification of soil types, In Situ and laboratory tests to characterize problematic soils; mechanical , hydraulic, physico-chemical, Electrical, Thermal methods, and their applications.
- UNIT-2-Mechanical Modification – Deep Compaction Techniques-Blasting vibrocompaction, Dynamic Tamping and Compaction piles.
- UNIT-3-Hydraulic Modification- Objective and techniques, traditional dewatering methods and their choice, Design of dewatering system, electro-osmosis, electro kinetic dewatering. Filtration, Drainage and seepage control with geosynthetics, preloading the vertical drains.

- UNIT-4-Physical and Chemical Modification- Modification by admixtures, shotcreting and guniting Technology, Modification at depth by grouting, crack grounting and compaction grouting. Jet grouting , Thermal modification, Ground freezing.

- UNIT-5-Modification by inclusions and confinement- Soil reinforcement, reinforcement with strip, and grid reinforced soil. In-situ ground reinforcement, and ground anchors, rock bolting and soil nailing.

UNIT-I
INTRODUCTION TO GROUND MODIFICATION

Why ground improvement required.....??

Introduction:

Large Civil Engineering Projects are being executed in all over the country in order to enhance the infrastructure of the country. Thus it is increasingly important for the engineer to know the degree to which soil properties may be improved or other alternations that can be thought of for construction of an intended structure at stipulated site.



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Need for engineered ground improvement Concerns

- Mechanical properties are not adequate
- Swelling and shrinkage
- Collapsible soils
- Soft soils
- Organic soils and peaty soils
- Sands and gravelly deposits.
- Foundations on dumps and sanitary landfills
- Handling dredged materials
- Handling hazardous materials in contact with soils
- Use of old mine pits

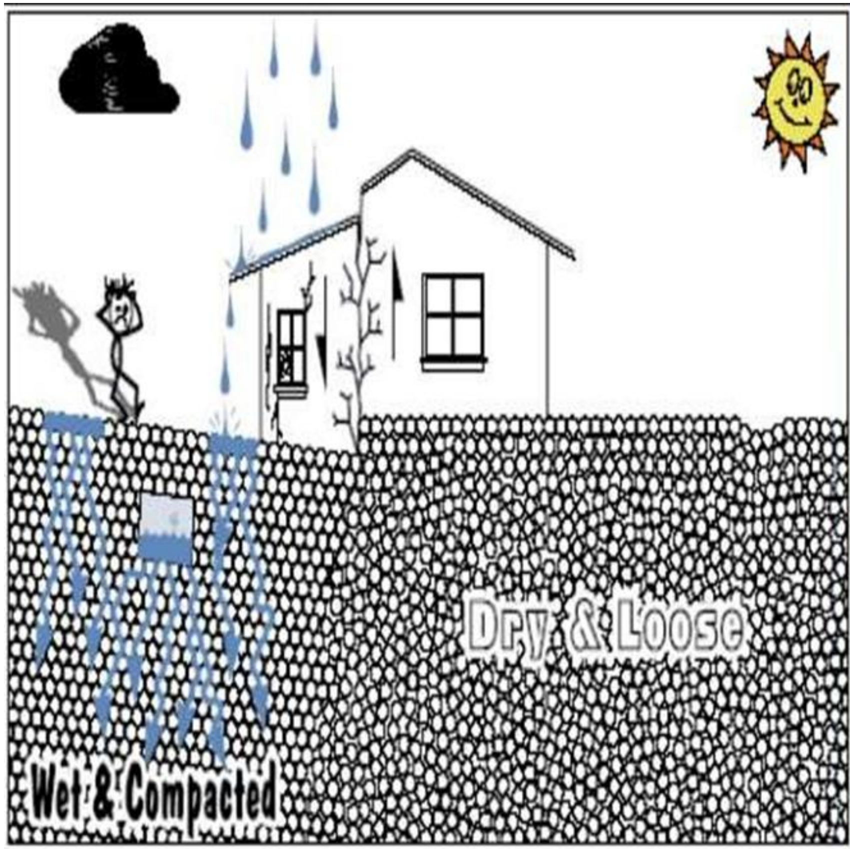
Leaning tower of Pisa

Effect of Swelling

Effect of shrinkage

- Swelling and shrinking soils exist in many areas in India, Large tracts of Maharashtra, Andhra, Deccan plateau, Chennai

Collapsible soils



- Collapse occurs due to saturation, loss of cementation bonds, specific clay structure and areas in some areas in Rajasthan and in some counties abroad this is prevalent.

Effects of liquefaction

Failure of slope

Definition……

- Ground Improvement refers to a technique that improves the engineering properties of the soil mass treated.
- Usually, the properties that are modified are shear strength, stiffness and permeability.
- Ground improvement has developed into a sophisticated tool to support foundations for a wide variety of structures.

Need for engineered ground improvement Strategies

- **When a project encounters difficult foundation conditions, possible alternative solutions are**
- Avoid the particular site
- Design the planned structure (flexible/rigid) accordingly
- Remove and replace unsuitable soils
- Attempt to modify existing ground
- Enable cost effective foundation design
- Reduce the effects of contaminated soils
- Ensure sustainability in construction projects using ground improvement techniques

Ground Improvement Techniques for different soil types

Ground improvement can be done through various mechanisms

- Compaction
- Dewatering
- Reinforcement
- Admixtures or grouting

Classification of ground modification techniques

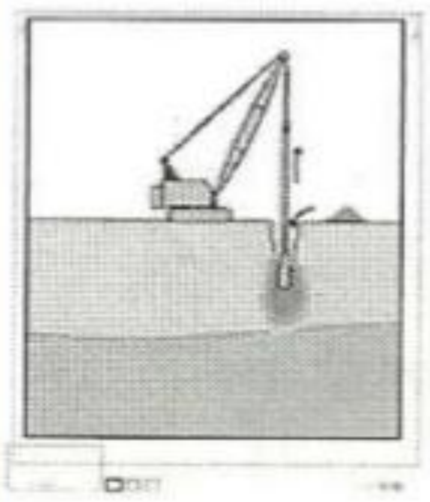
- Mechanical modification
- Hydraulic modification
- Physical and chemical modification
- Modification by inclusion and confinement
- Combination of the above

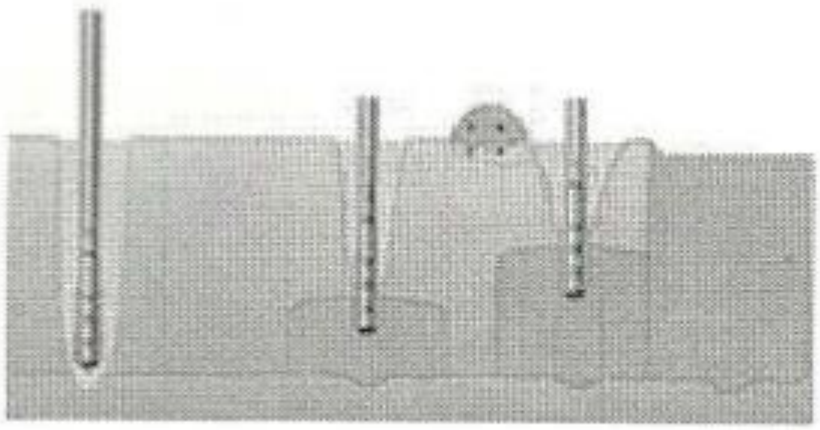
1Vibro Compaction:

Vibro Compaction is a method for compacting deep granular soils by repeatedly inserting a vibratory probe. It is also known as VIBRO DENSIFICATION.

By inserting depth vibrations, the vibrations are produced by rotating a heavy eccentric weight with the help of an electrical motor with in the vibrator. The vibratory energy is used to rearrange the granular particles in a denser state. Penetration of the vibro is typically aided by water jetting at the tip of the probe.

The Vibro-Compaction Process





Some of advantages and disadvantages of this method are given below.

- It is often an economical alternative to deep foundations, especially when considering the added liquefaction protection in seismic ares.
- It is most effective in granular soils
- It cannot be sued in cohesive soils.

Dynamic Compaction:

Dynamic Compaction is normally used under the following circumstances:

- To increase in-situ density and this way improve the bearing capacity and consolidation characteristics of soils (or waste materials) to allow conventional foundation and surface bed construction to be carried out. The technique typically improves the in-situ soils such that allowable bearing pressures of up to 250 kpa can be used with foundation settlements of the order of 10 to 20 mm.
- To increase in-situ density and in this way improve in-situ permeability and/or reduce liquefaction potential.

Blasting:

- Blasting is most effective in loose sands that contain less than 20% silt and less than 5% clay.
- Although blasting is quite economical, it is limited by several considerations, as it produces strong vibrations that may damage near by structures or produce significant ground movements.

Reinforcement Techniques:

In some cases it is possible to improve the strength and stiffness of a existing soils deposit by installing discrete inclusions that reinforce the soil. These inclusions may consist of structural materials, such as steel, concrete or timber and geomaterials such as densified gravel.

If unsuitable soil conditions are encountered at the site of a proposed structure, one of the following four procedures may be adopted to insure satisfactory performance of the structure.

- By pass the unsuitable soil by means of deep foundations extending to a suitable bearing material.
- Redesign the structure and it's foundation for support by the poor soil. This procedure may not be feasible or economical.
- Remove the poor material and either treat it to improve and replace it (or) substitute for it with a suitable material.
- Treat the soil in place to improve its properties.

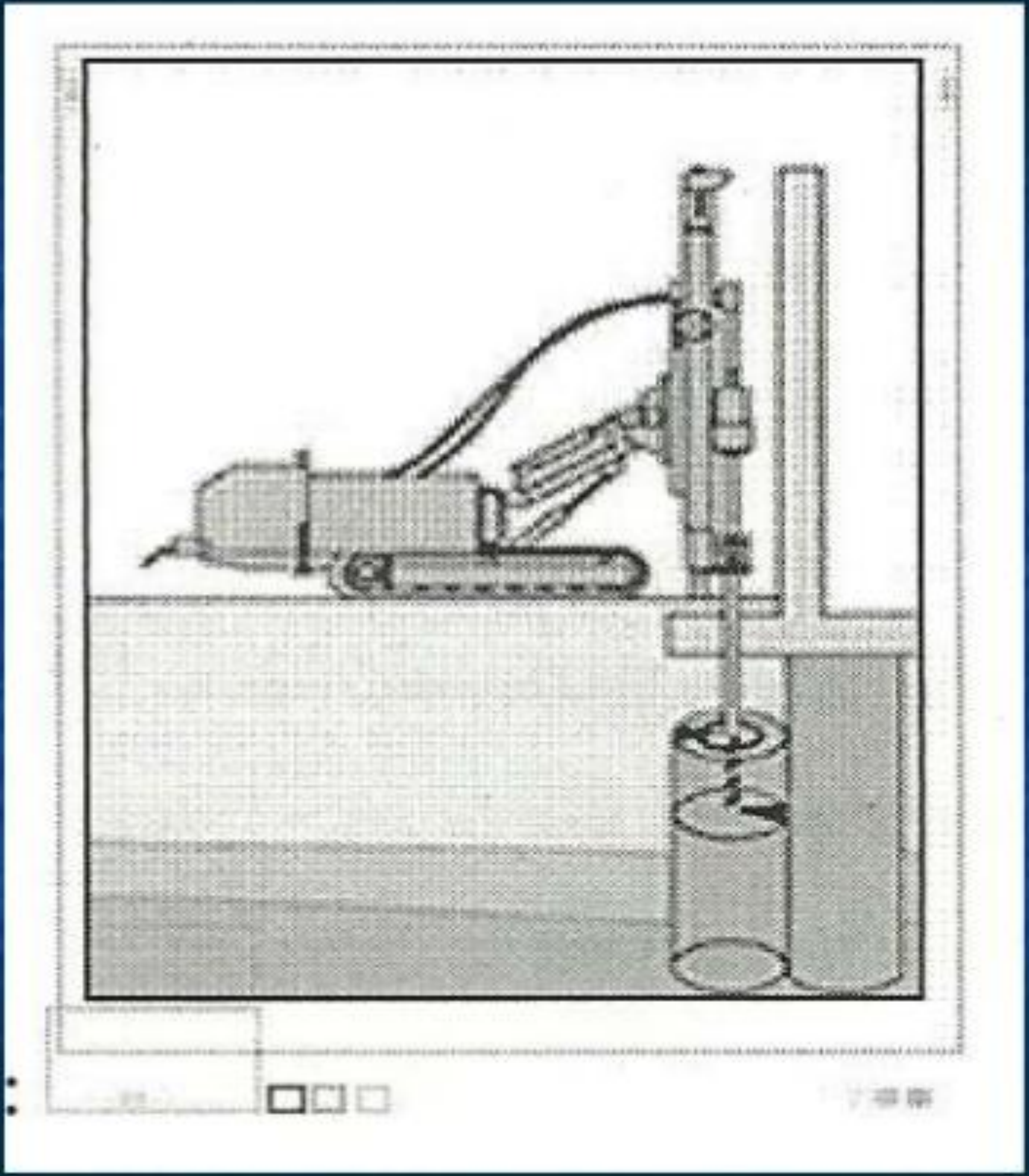
- Densification is probably the most commonly used soil improvement technique. Most densification techniques relay on tendency of granular soils to densify when subjected to vibrations. However there is a possibility of damaging adjacent structures and pipelines due to application of this technique.
- Reinforcement techniques introduce discrete inclusions that stiffen and strengthen a soil deposit. The high stiffness and strength of the inclusions also tend to reduce the stresses imposed on the weaker materials between the inclusion.

Compaction Piles:

Compaction piles improve the seismic performance of a soil by three different mechanisms. First the flexural strength of piles themselves provides resistance to soil movement (reinforcement). Second, the vibrations and displacements produced by their installation cause densification. Finally, the installation process increses the lateral stress in the soil surrounding the piles.

Compaction piles generally densify the soil with in a distance of 7 to 12 pile diameters and consequently installed in a grid pattern. Between compaction piles a relative density of up to 75% to 80% are usually achieved. Improvement can be obtained with

JET GROUTING



Electro Osmasis and Electro Chemical Hardening Method:

The electroosmasis process can be used to increase the shear strength and reduce the compressibility of soft clayey and silty soils beneath foundation. By introducing an electrolyte such as calcium chloride at the anode, the base exchange reaction between the iron anode and surrounding soil is increased, resulting in the formation of ferric hydroxides which bind the soil particles together. However because cost of electric power and wastage of electrodes, electroosmasis with or without electrochemical hardening can be considered only for special situations where the alternative of piling cannot be adopted.

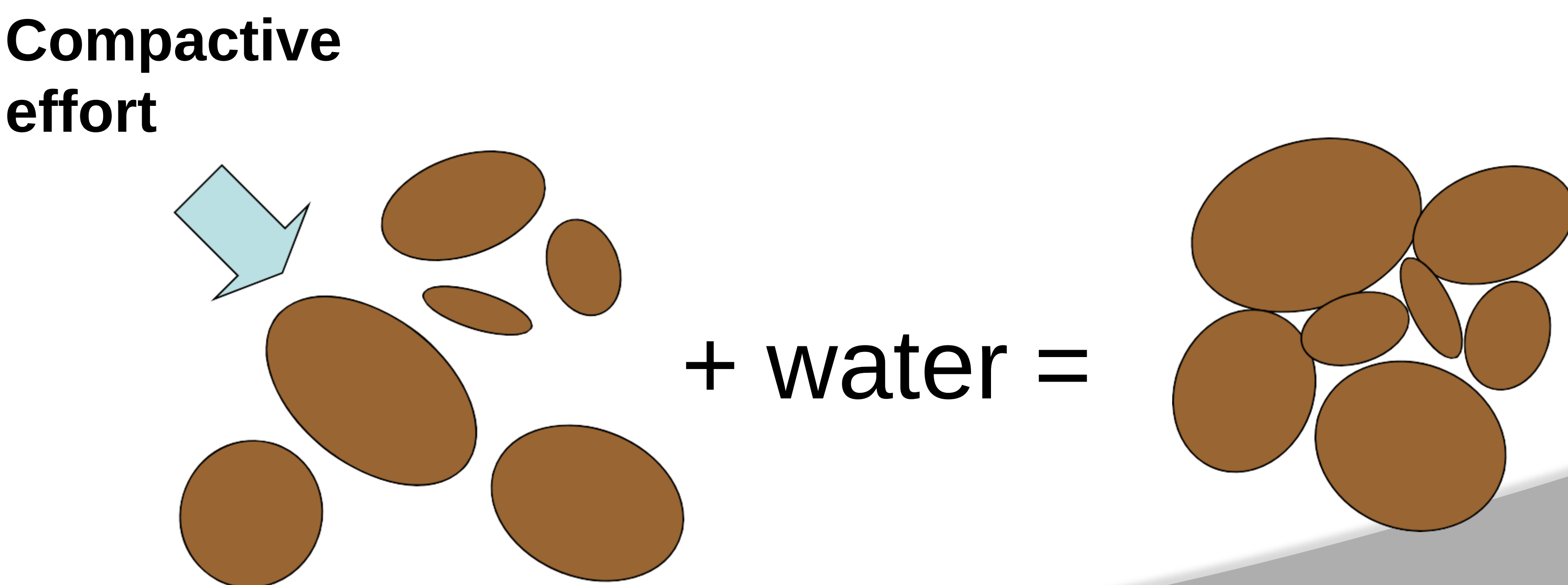
Conclusion:

- Unfavorable soil conditions can frequently be improved using soil improvement techniques. A variety of soil improvement techniques have been developed. However a suitable technique has to be adopt according to necessity of the structure and economy.
- Mainly soil improvement techniques can be divided in to four broad categories; Densification technique, Reinforcement technique, grouting or mixing technique and stabilization technique.

UNIT-II
MECHANICAL MODIFICATION

What is compaction?

- A simple ground improvement technique, where the soil is densified through external compactive effort.



Compaction of soil

- Advantages of Compaction

  1.Increases shear strength

  2.Reduces compressibility

  3.Reduces permeability

  4.Reduces liquefaction potential

  5.Controls swelling and shrinking

  6.Prolongs durability

- Strategies for compaction process are

1. In the case of constructed fills, specify placement conditions (water content, density,depth of layers, etc.)
2. Select appropriate equipment (roller compactor, tamping) and method of operation (number of passes, patterns of tamping,etc.).
3. Set up adequate control procedures (type and number of tests, statistical evaluation,etc.).

Laboratory Compaction Test

To obtain the compaction curve and define the optimum water content and maximum dry density for a specific compactive effort.

Standard Proctor:

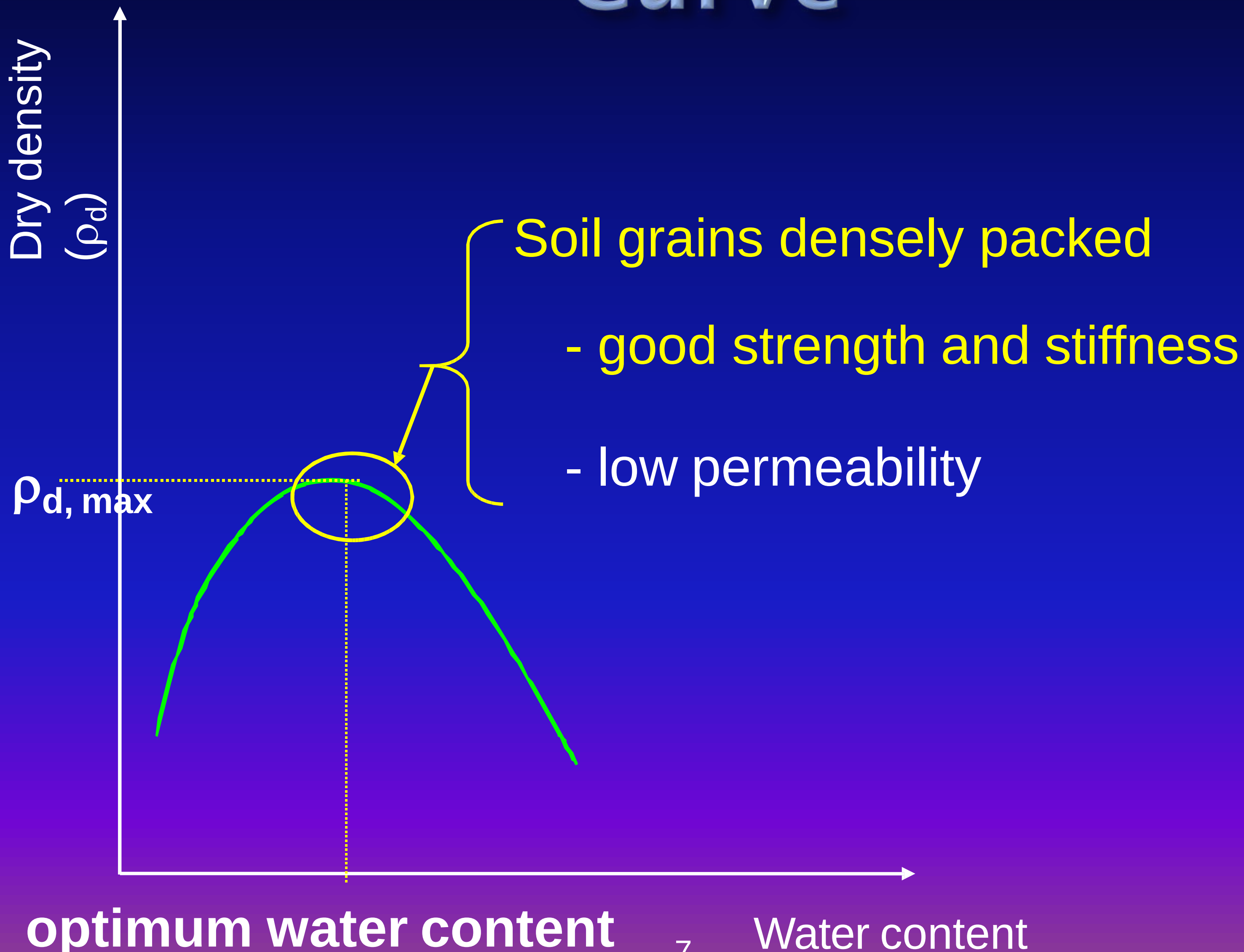
- 3 layers
- 25 blows per layer
- 2.7 kg hammer
- 300 mm drop

Modified Proctor:

- 5 layers
- 25 blows per layer
- 4.9 kg hammer
- 450 mm drop

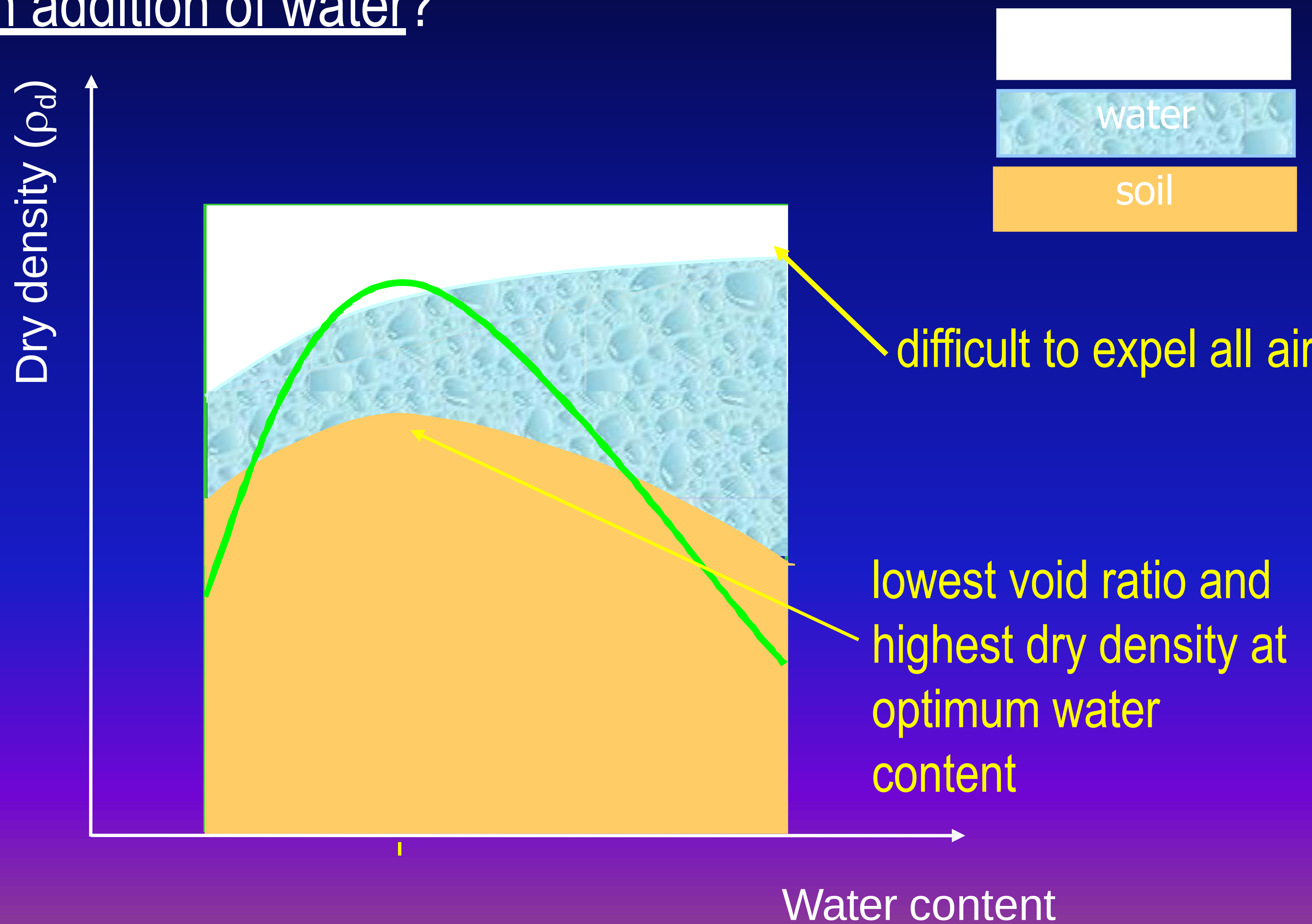
1000 ml compaction mould

Compaction Curve

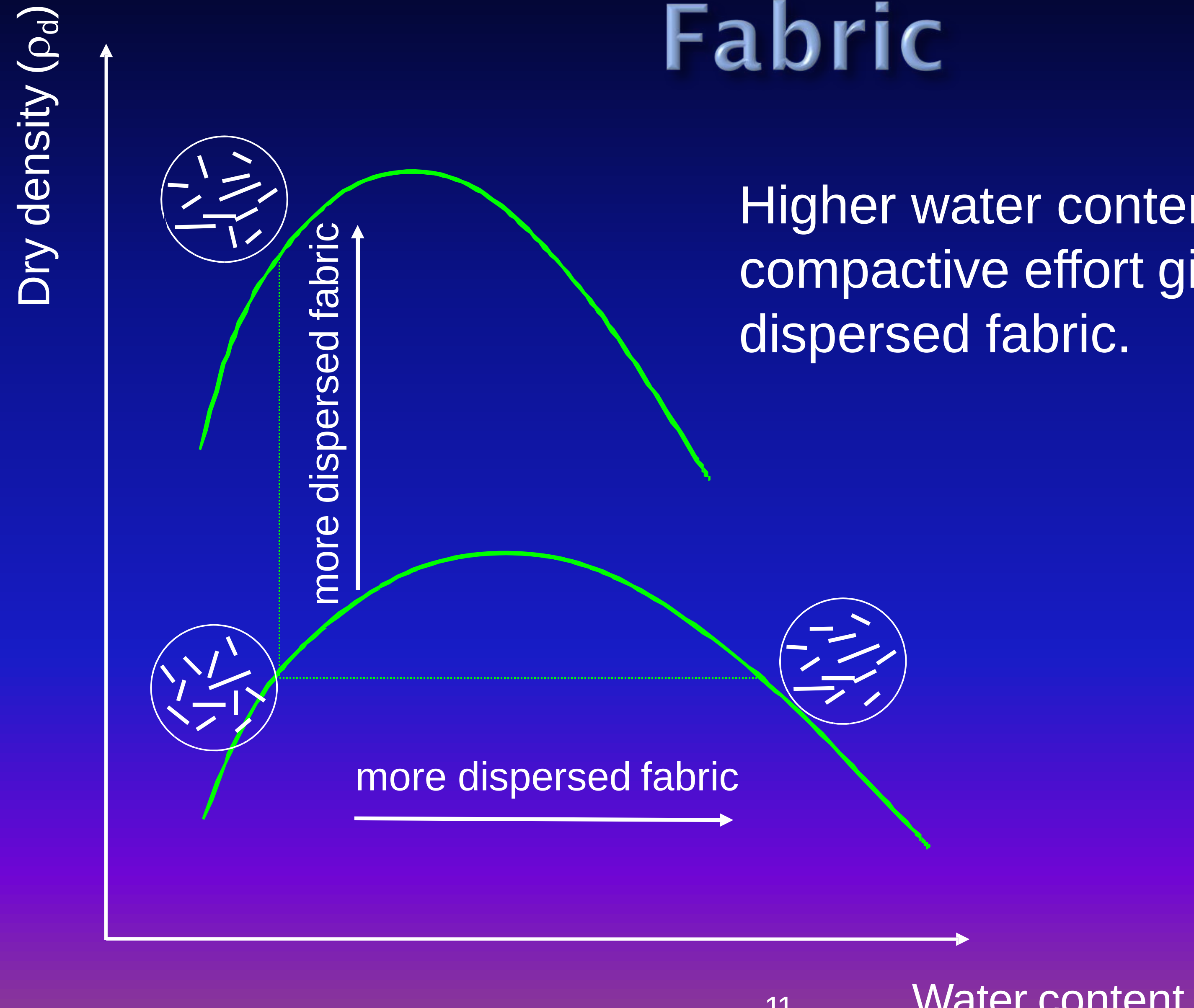


Compaction Curve

What happens to the relative quantities of the three phases with addition of water?



Compaction and Clay Fabric



Higher water content or higher compactive effort gives more dispersed fabric.

❑ Shallow Surface Compaction:

- Static rollers:
- Smooth steel rollers and pneumatic rollers.
- Sheepsfoot rollers.
- Grid rollers.

❑ Impact and vibratory equipment:

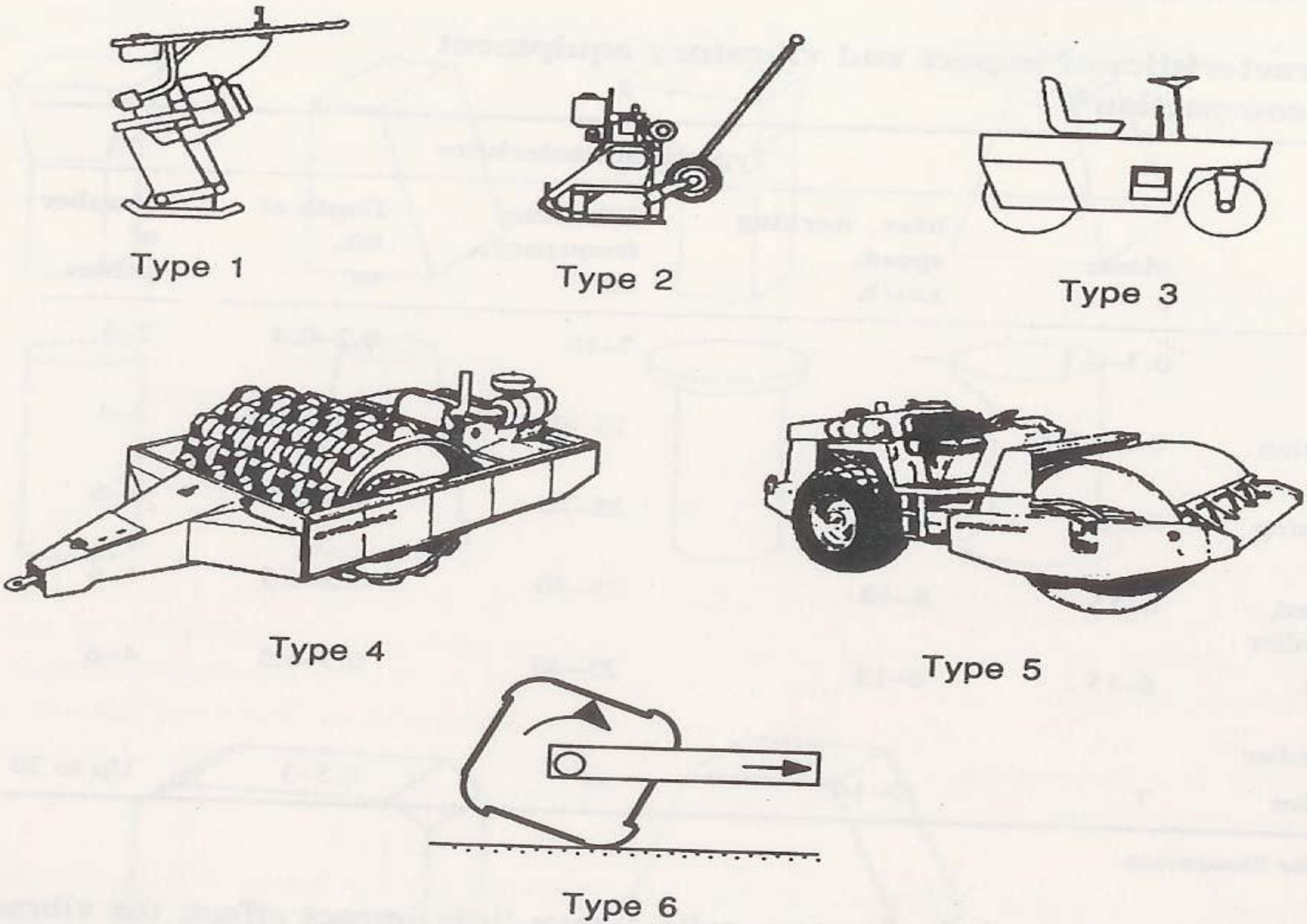
- Tampers,rammers and plate compactors
- Vibrating rollers.
- Impact rollers.

Field Compaction

Different types of rollers (clockwise from right):

- Smooth-wheel roller
- Vibratory roller
- Pneumatic rubber tired roller
- Sheeps foot roller

Vibratory And Impact Compactors For Shallow Compaction



Definition……

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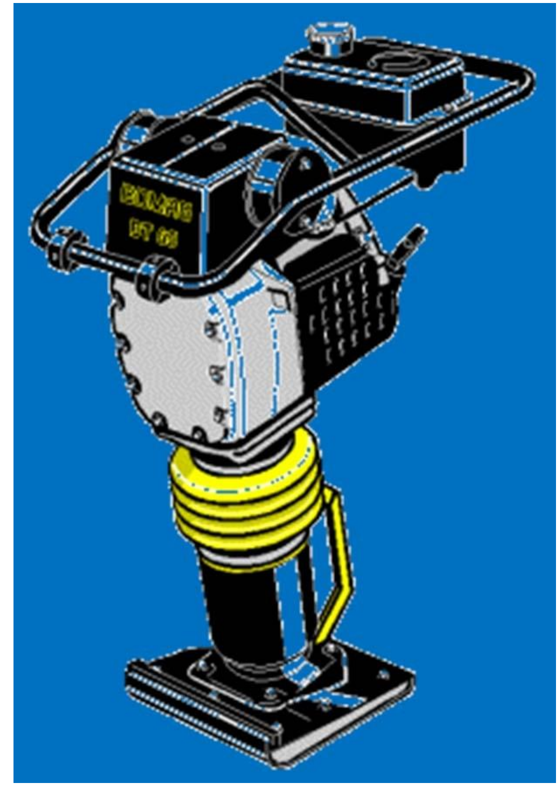
Field Compaction

- **Smooth Wheeled Roller**

Compacts effectively only to 200-300 mm; therefore, place the soil in shallow layers (lifts)

Field Compaction

Vibrating Plates



- for compacting very small areas
- effective for granular soils

Field Compaction

Sheeps foot Roller

- Provides kneading action; “walks out” after compaction
- Very effective on clays

Field Compaction

Impact Roller

- Provides deeper (2-3m) compaction. e.g., air field

Properties of Compacted Cohesive and Cohesion less Soils

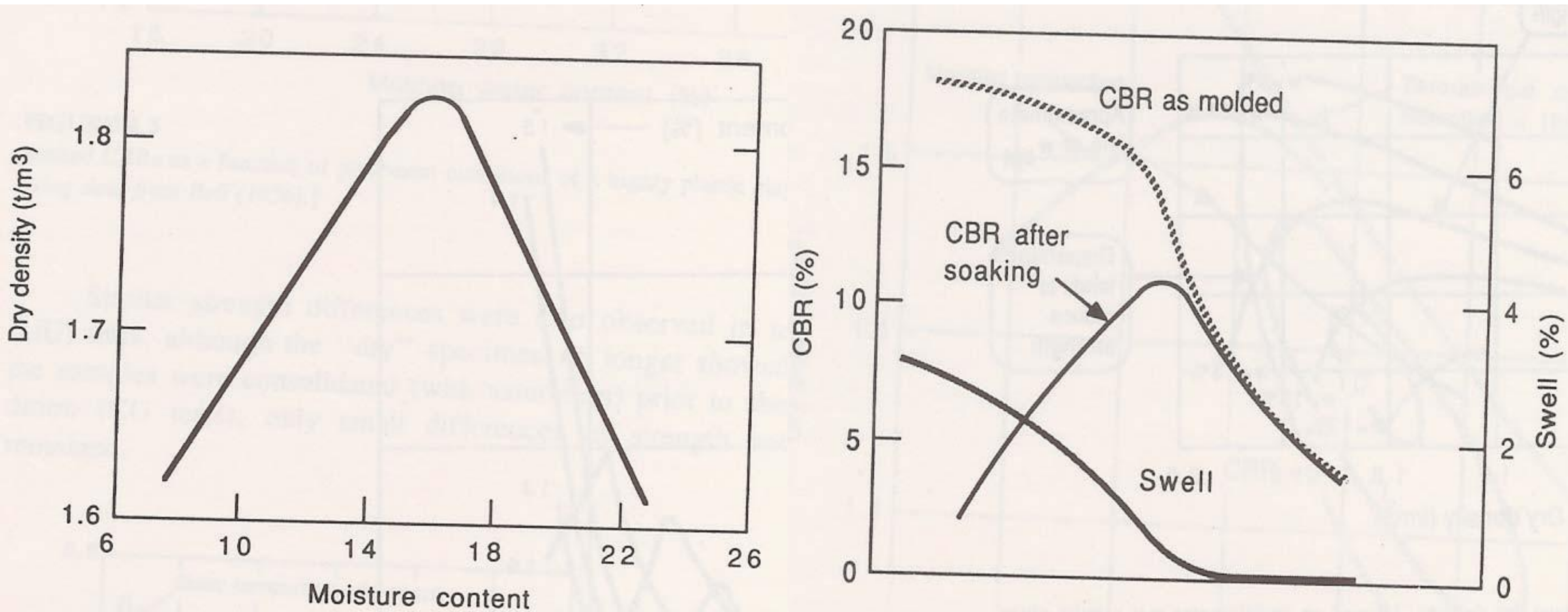
- **Cohesive Soil**
- OMC increases and MDD decreases with increase in plasticity of soil
- Empirical relationships connecting the above to liquid limit, plastic limit are available in literature

Cohesion less Soil

- MDD is connected to the grain size distribution parameters

Properties of compacted cohesive soil

⊙ Strength of Cohesive Soil



- CBR as a function of initial water content for a typical silty clay

Summary

- Methods of Shallow compaction, properties of compacted soils and its implications in engineering response are discussed.

UNIT-III
HYDRAULIC MODIFICATION

Dewatering

- Dewatering is a process in which groundwater contained within the site's soil is extracted , ensuring a stable foundation

Water is discharged Through

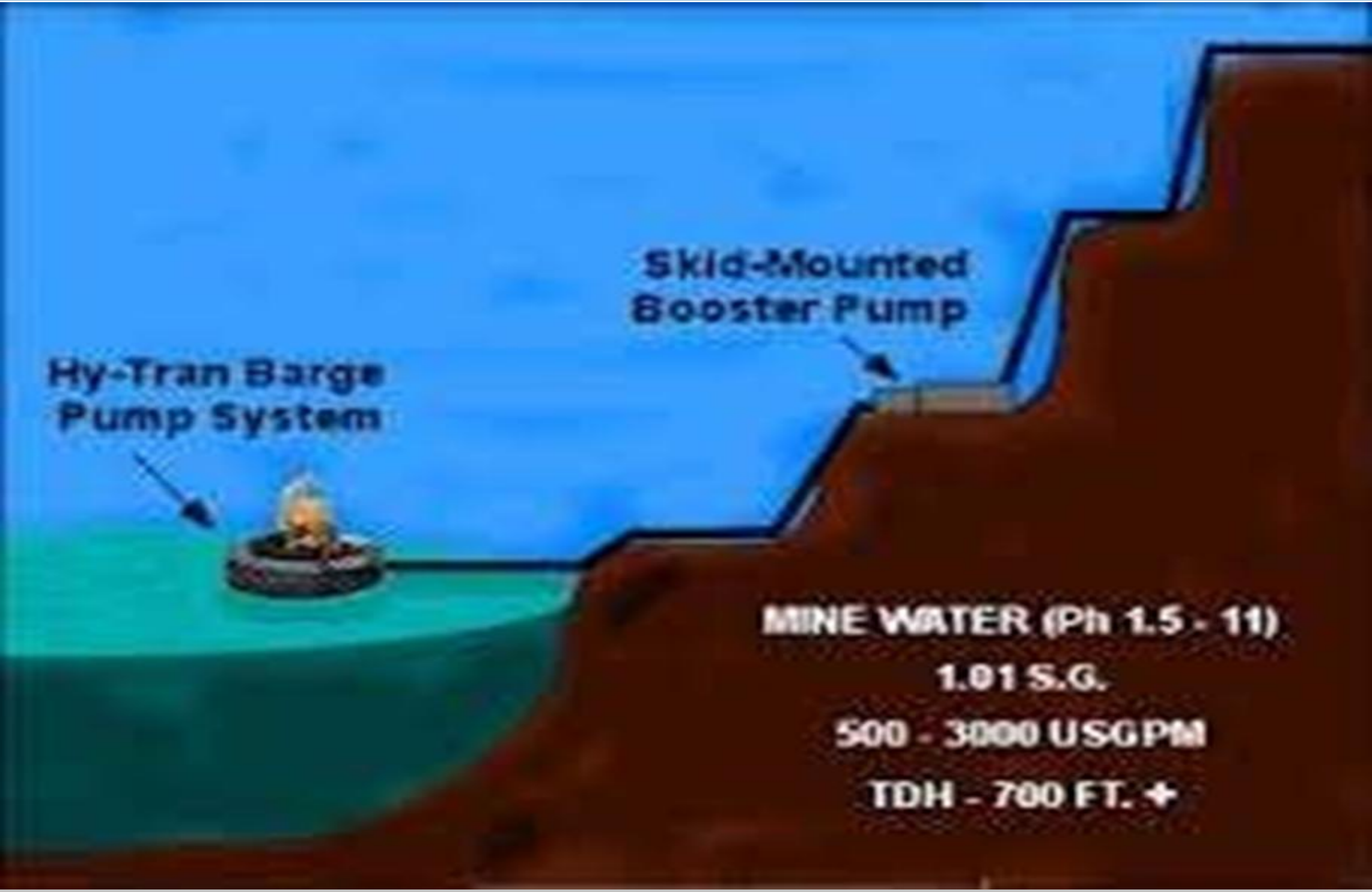
1. Storm drains
2. Municipal sewer System
3. Irrigation Purposes

Different methods of Dewatering

1. Open dewatering
2. Well point dewatering
3. Deep well dewatering
4. General Sump pumping

Open dewatering

- It enable one to lower the groundwater table adequately in cohesive and low permeable soils.
- Water is pumped off directly from sumps (ditches) along the toes of the slopes of the excavation works.



Skid-Mounted
Booster Pump
Hy-Tran Barge
Pump System
MINE WATER (Ph 1.5 - 11)
1.01 S.G.
500 - 3000 USGPM
TDH - 700 FT. +

The suction hose with strainer is merely placed in the sump and the collected water is primed and discharged. This makes the open dewatering system easy to install and simple to operate.

The open dewatering system utilizes

1. self priming
2. vacuum assisted centrifugal pumps

Well point dewatering

1. Well point dewatering systems enable one to lower the groundwater table adequately for deep and large construction sites.

2. It has proven to be a very flexible system. The water from high permeable soils is pumped from well points, installed along the trench of the site.

3. The well points are jetted and spaced to obtain an efficient drawdown against lowest capacity.

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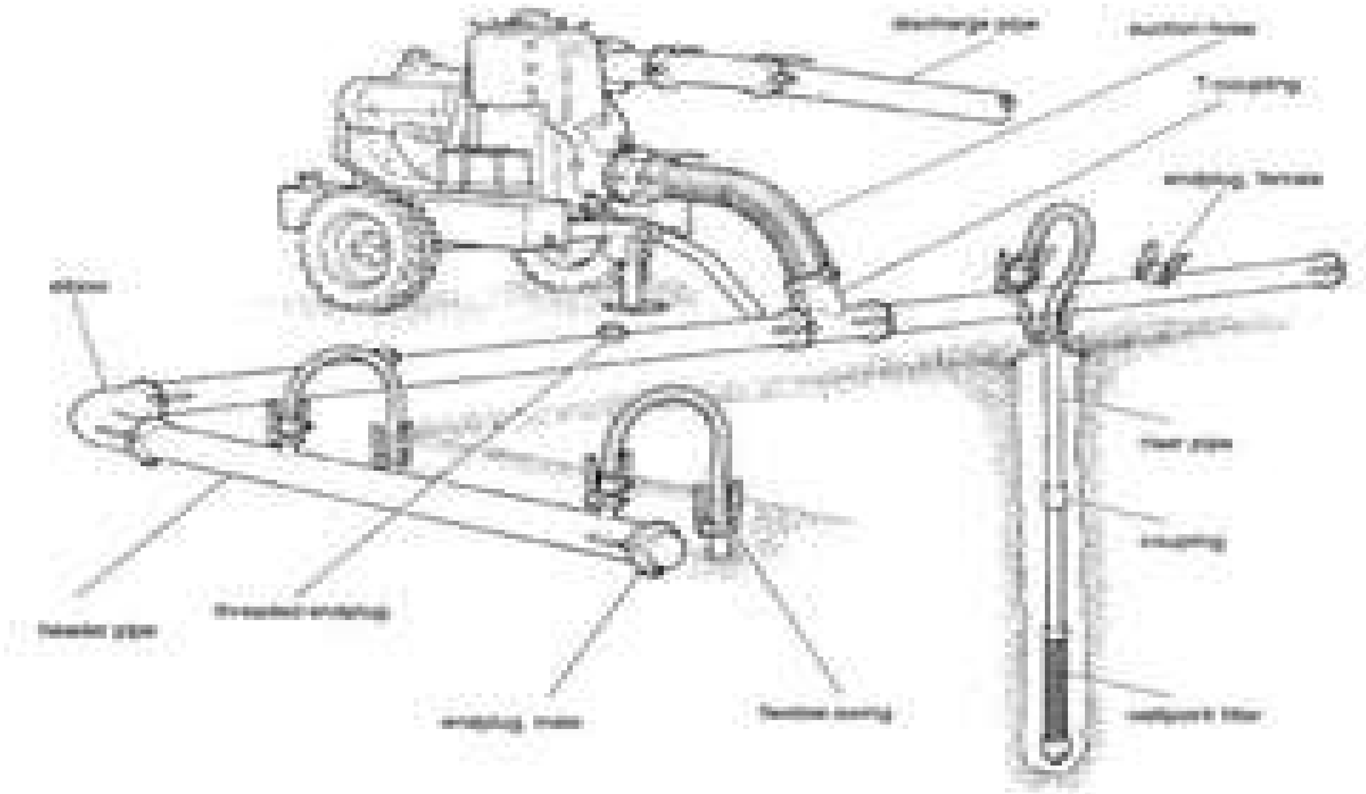
4.The well points with integral strainers are joined to transparent flexible hoses, which are connected by quick release couplers to the ring main header pipeline.

5. Wellpoint dewatering is done either by gravity



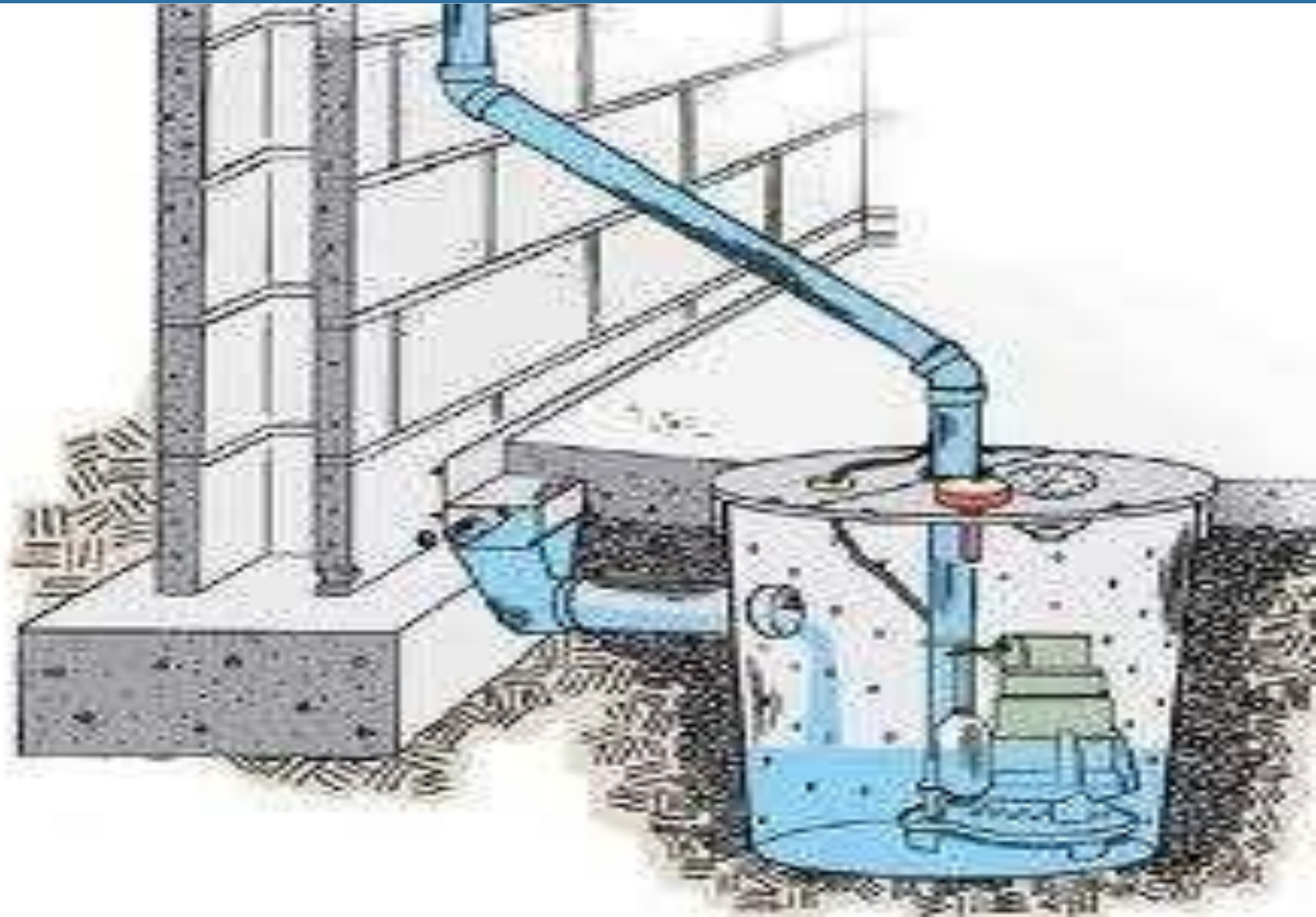
Deep well dewatering

- Deep well dewatering systems enable one to lower the groundwater table to a considerable depth.
- A submersible pump is installed at the bottom of the well, of which the casing generally has a minimum diameter of 150 mm.
- The discharge pipes from the submersible pumps of a number of adjacent wells are connected to a common delivery main.
- The water is raised from the well by a multi-staged pump

Deep well dewatering

General Sump pumping

- Sump Pumps are used in applications where excess water must be pumped away from a particular area.
- They generally sit in a basin or sump that collects this excess water
- This classification includes bilge and ballast pumps, centrifugal pumps, cantilever pumps, sewage pump pumps, submersible sump pumps and utility pumps, among others



Dewatering

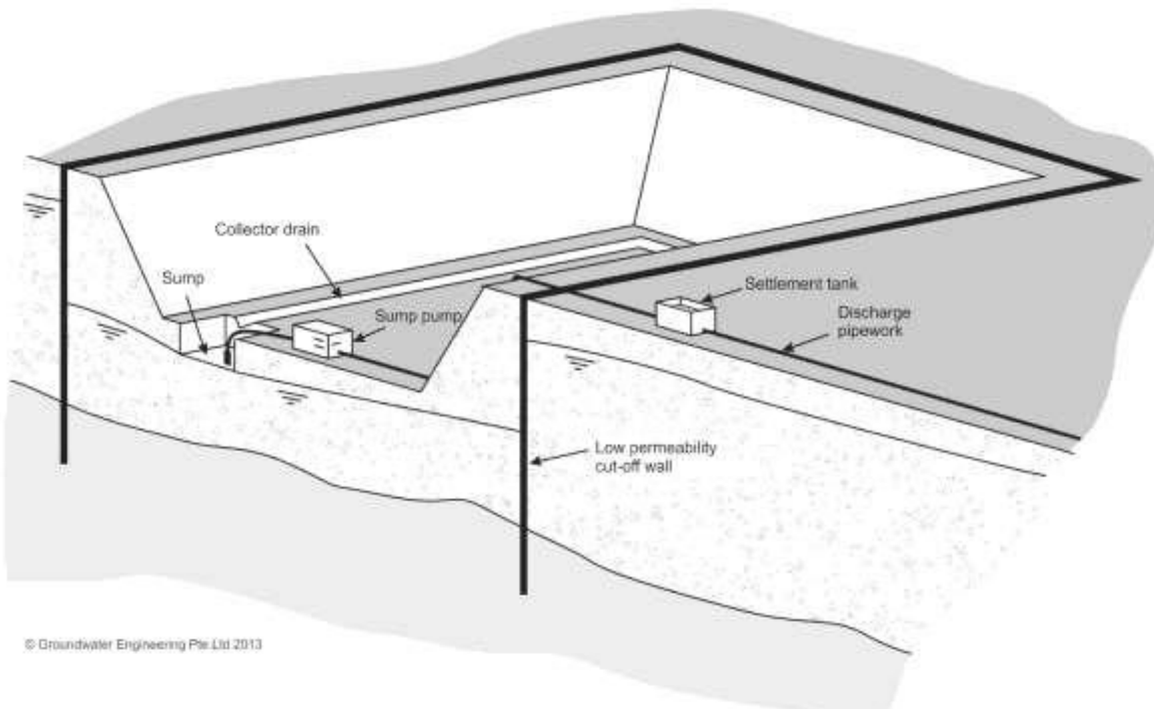
- Dewatering is the term for the control of groundwater by pumping. On construction sites it may be known as '**construction dewatering**'.

- The method is also used on mine sites – '**mine dewatering**'

- The process of dewatering can be defined as – pumping from wells or sumps to temporarily lower groundwater levels, to allow excavations to be made in dry and stable conditions below natural groundwater level

Dewatering

- As an alternative to groundwater control by pumping, physical cut-off walls can be installed around a site to exclude groundwater from the site



Surface Water Control

Surface water must also be controlled:

Sources of surface water
- Rainfall
- Construction operations (e.g. concreting, washing of plant)
- Seepage through cut-off walls

Detrimental effects of poorly-managed surface water
- Risk of localised flooding
- Softening of soil exposed in excavation

Methods of Surface Water Control

Source control

- intercept run-off before it reaches the excavation
- prevent unnecessary generation of water in the excavation
- collect water as soon as it reaches the work area (or before!)

Water collection

- French drains to intercept run off
- collector drains and sumps
- pumping systems (keep it simple!)

Water treatment

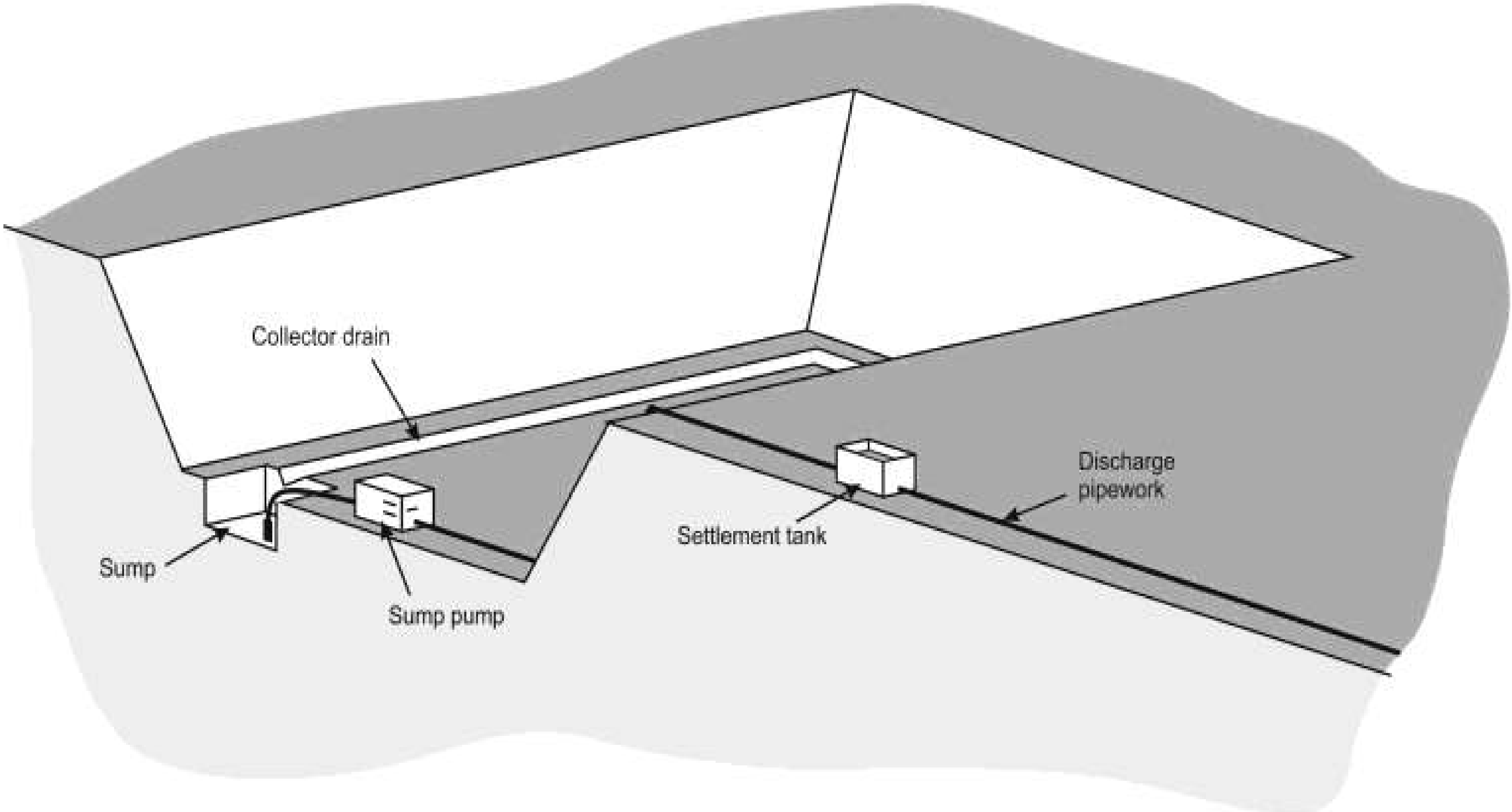
- solids removal (settlement tanks, Siltbusters)

Dewatering Techniques

❑ **Widely used dewatering techniques**

- Sump Pumping
- WellPoint
- Deep wells
- Ejector wells

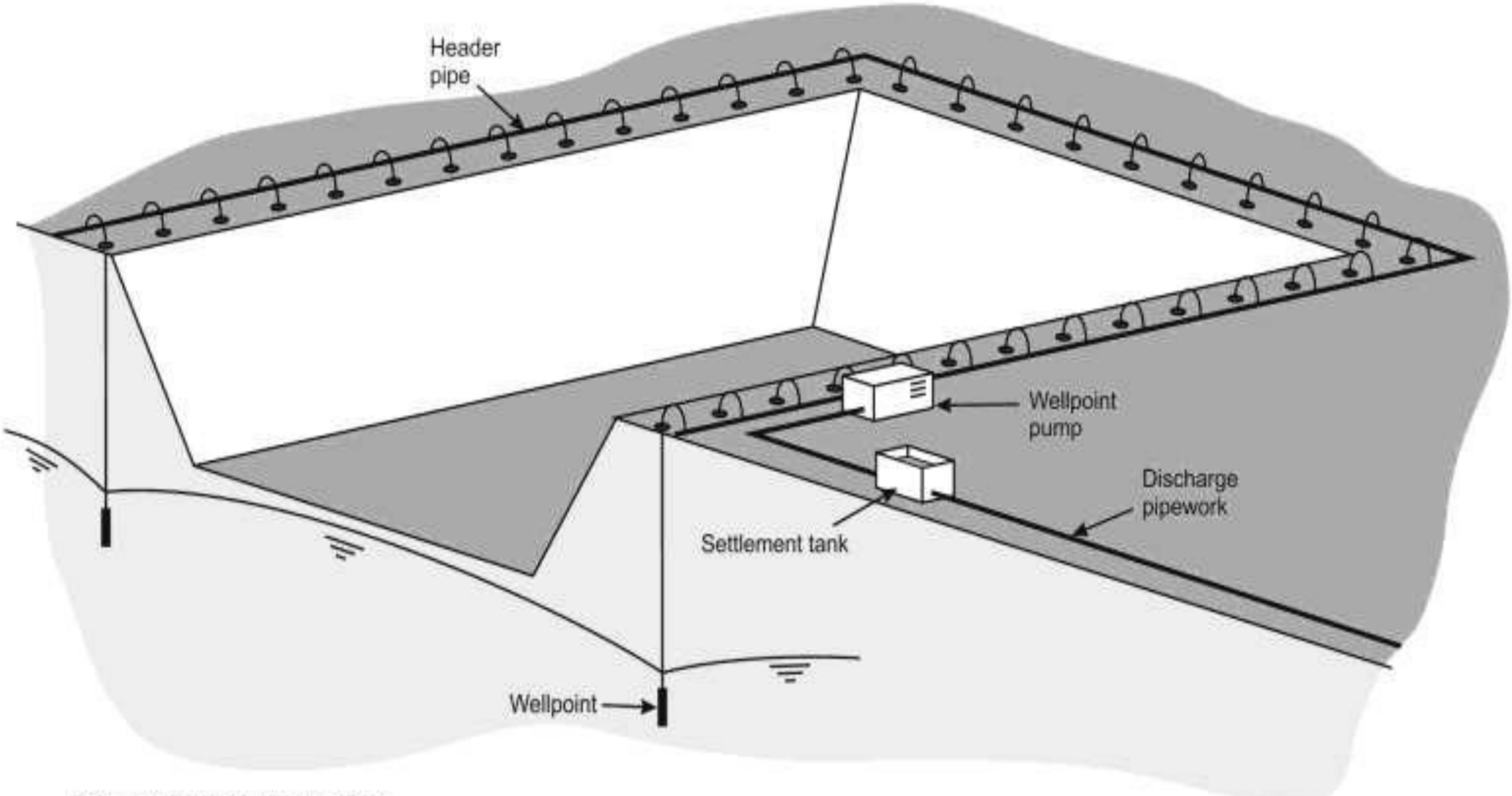
Sump Pumping



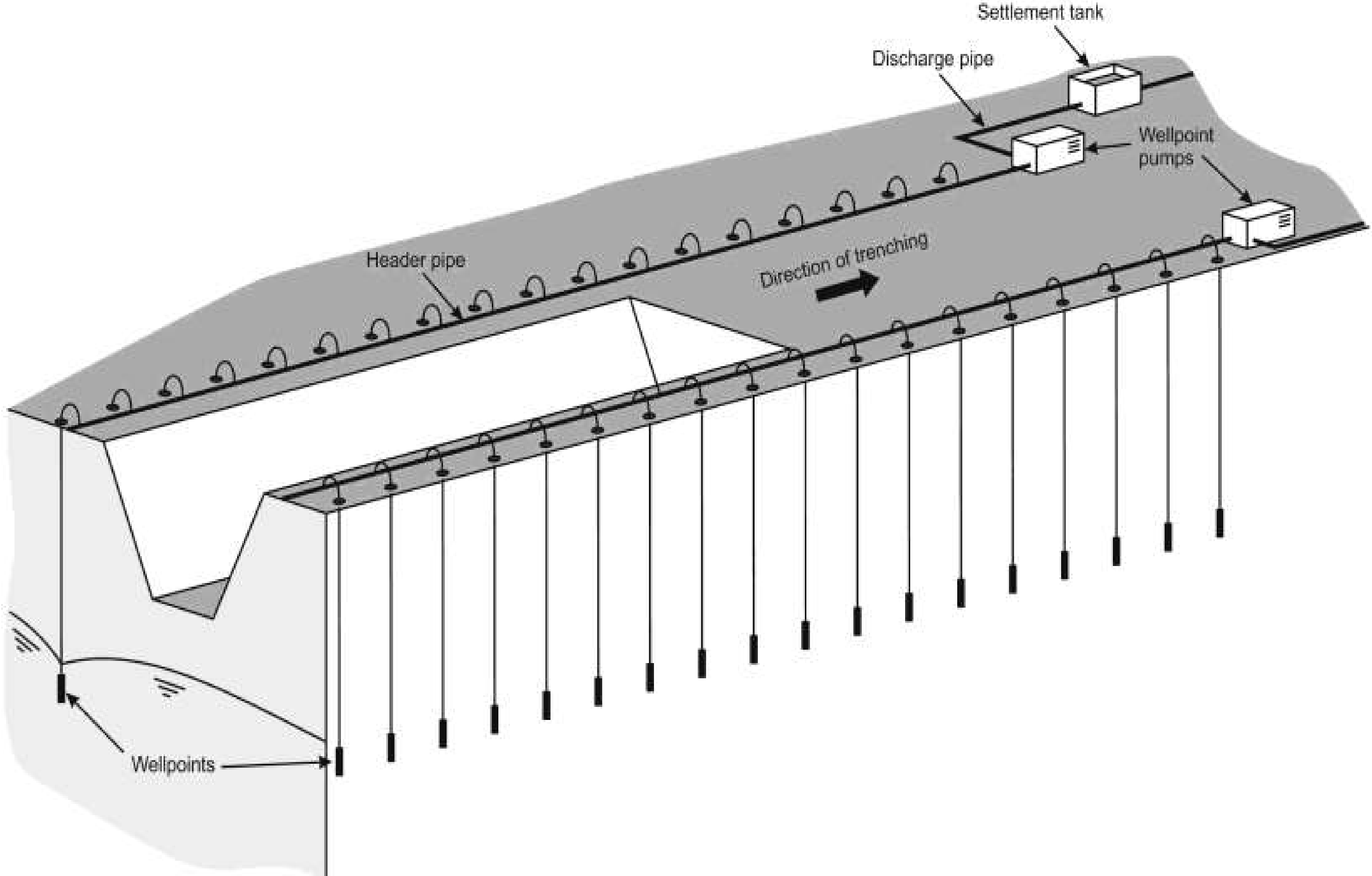
Sump Pumping

- Water is collected in deeper parts of the excavation (called sumps) and pumped away
- Simple and cheap method of dewatering in favourable ground conditions
- Limited to use in relatively coarse soils or fissured rock – if used in fine grained soils can lead to erosion and loss of fines with the risk of resulting instability
- The sump takes up space within an excavation
- Can lead to water pollution problems due to silt-laden water

Well points


Header
pipe
Wellpoint
pump
Discharge
pipework
Settlement tank
Wellpoint

Well points

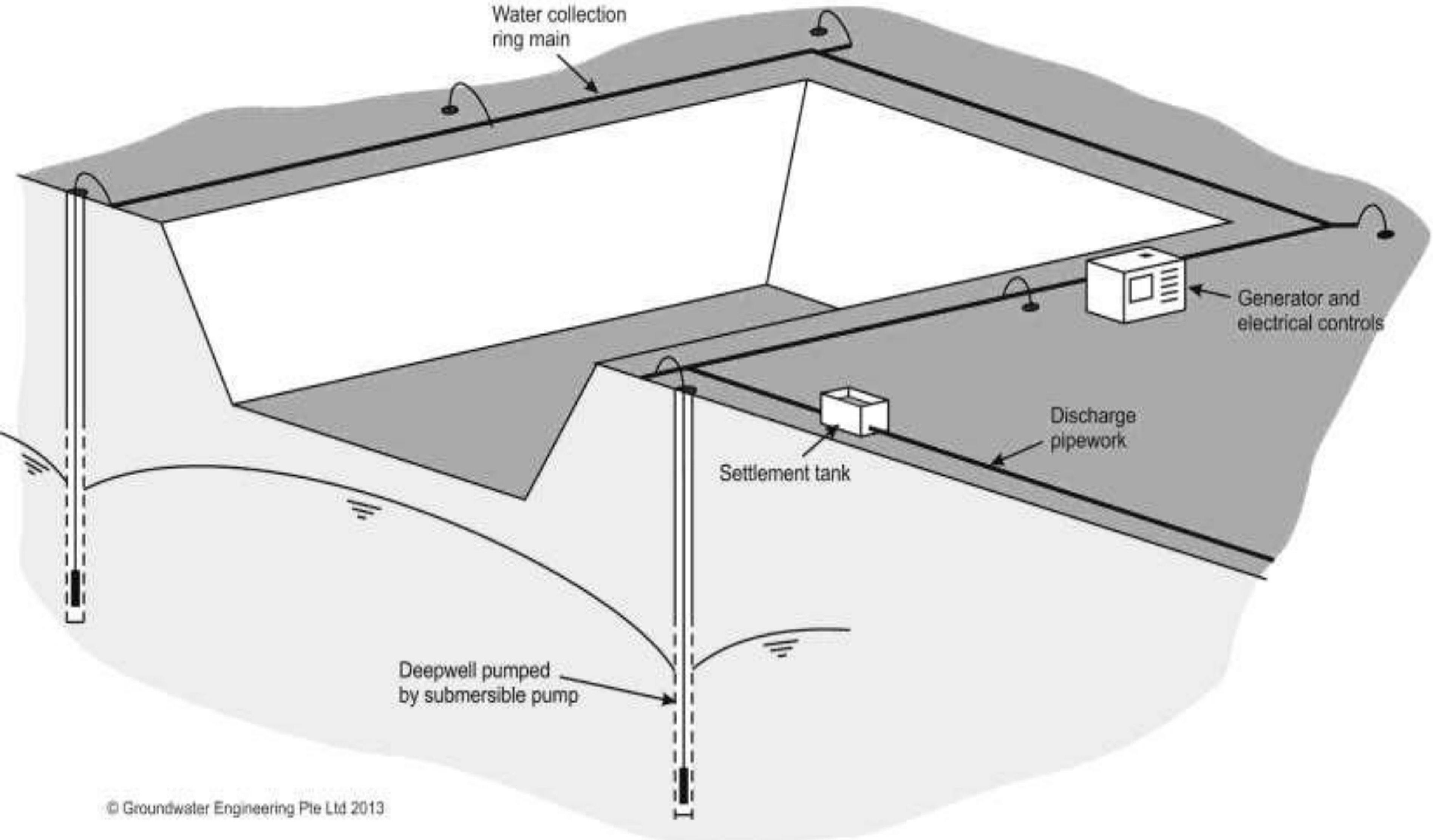


Settlement tank
Discharge pipe
Wellpoint pumps
Header pipe
Direction of trenching
Wellpoints

Well points

- A line or ring of small diameter shallow wells (called wellpoints) installed at close spacing (1 to 3 m centres) around the excavation.
- Commonly used for dewatering of pipeline trenches
- Can be a very flexible and effective method of dewatering in sands or sands and gravels
- Drawdown limited to 5 or 6 m below level of pump due to suction
  lift limits
- Individual wellpoints may need to be carefully adjusted ("trimming")

Deep wells

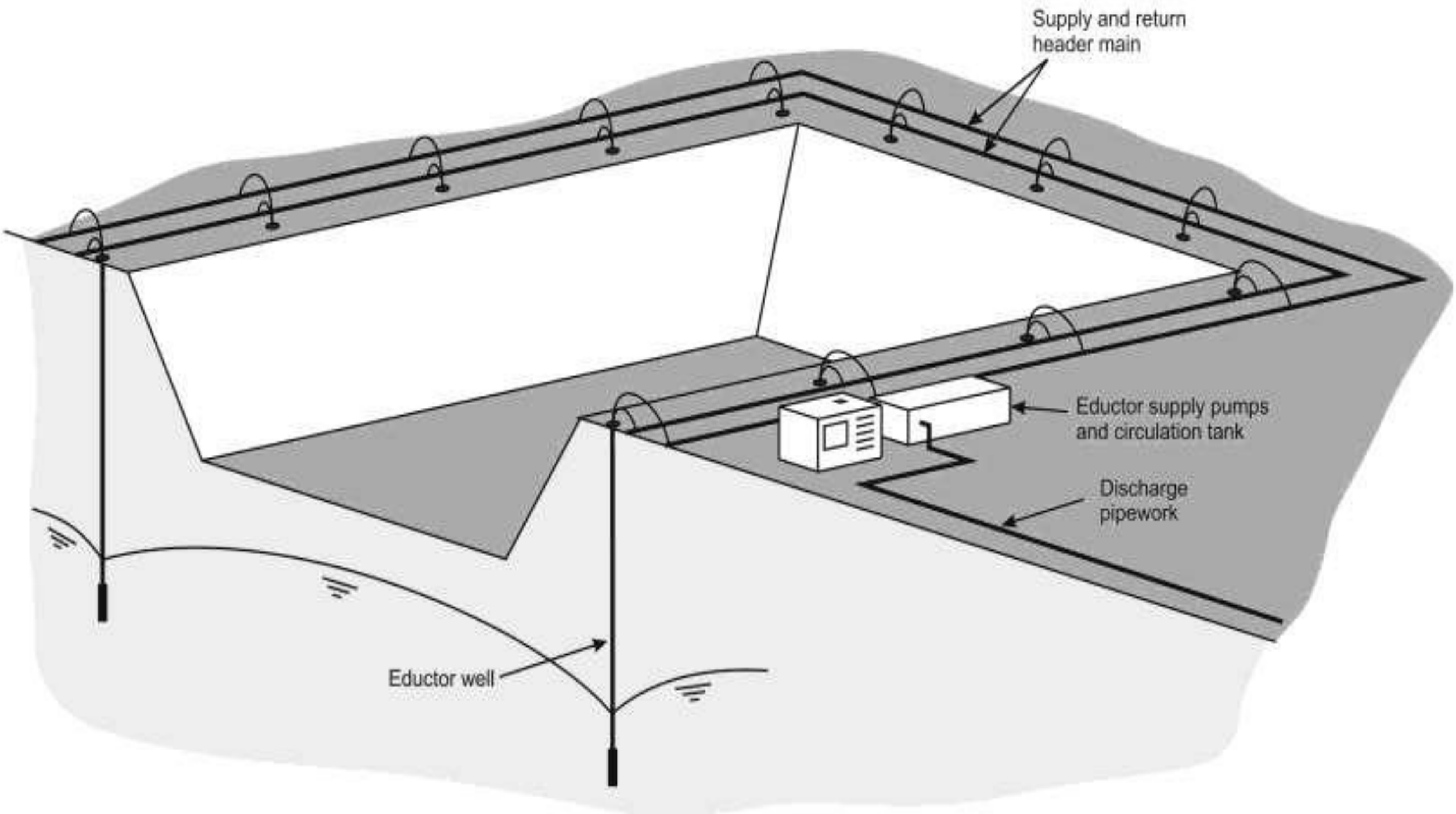


Water collection ring main
Generator and electrical controls
Discharge pipework
Settlement tank
Deepwell pumped by submersible pump
© Groundwater Engineering Pte Ltd 2013

Deep wells

- Wells are drilled at wide spacing (10 to 60 m between wells) to form a ring around the outside of the excavation
- An electric submersible pump is installed in each well. Drawdown limited only by well depth and soil stratification
- Effective in a wide range of ground conditions, sands, gravels, fissured rocks

Eductor wells



Eductor wells

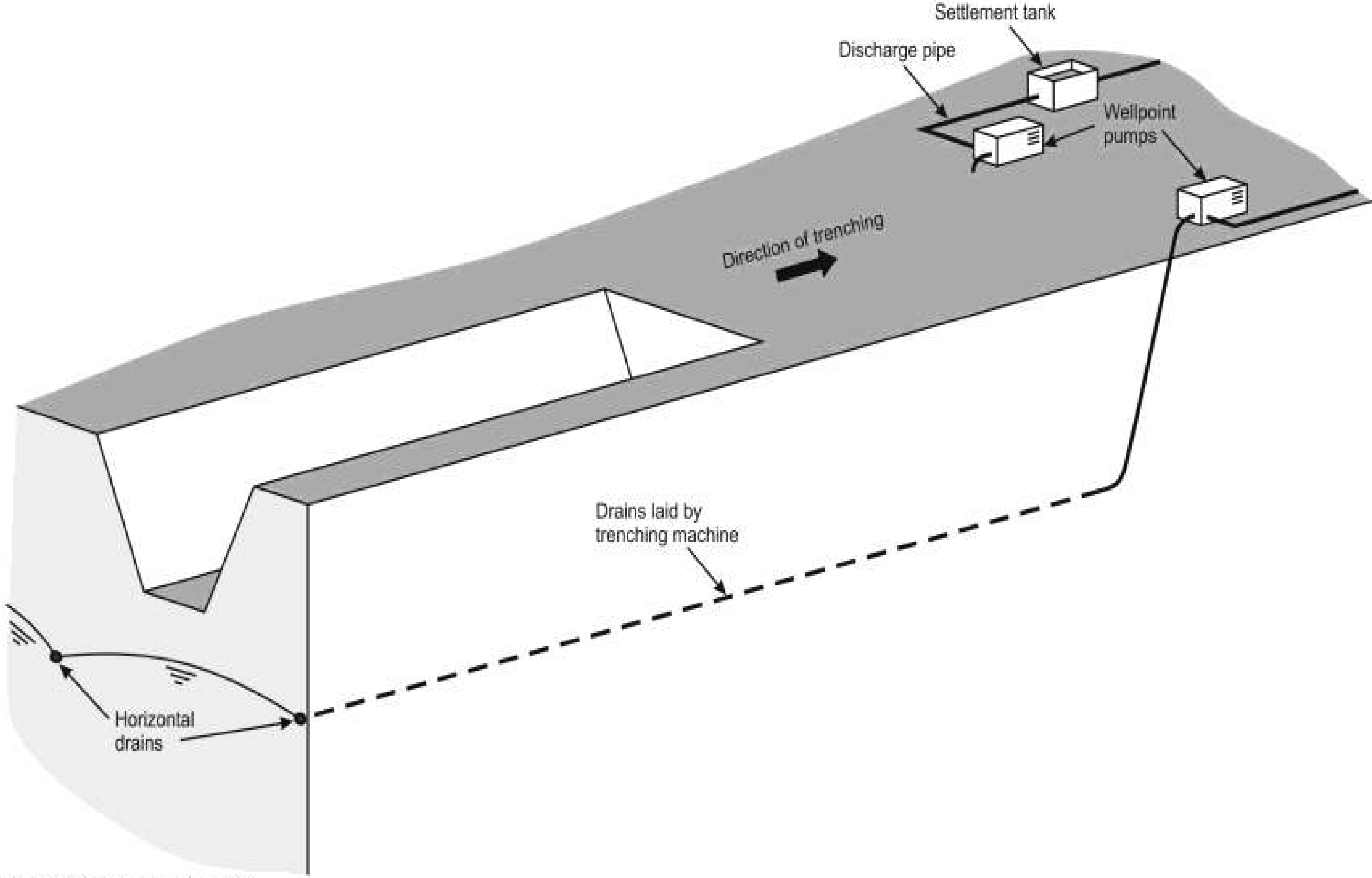
- Effective in stabilising fine soils (silts, silty sands) by reducing pore water pressures
- Wells are drilled around or alongside the excavation
- Suitable when well yields are low. Flow capacity 30 to 50 litres/min per well
- Drawdown generally limited to 25 to 30 m below pump level
- Vacuum of 0.95 Bar can be generated in the well, making this very effective in low permeability soils

Dewatering Techniques

Less commonly used dewatering techniques

- Horizontal wellpoints
- Relief wells
- Artificial recharge
- Groundwater remediation

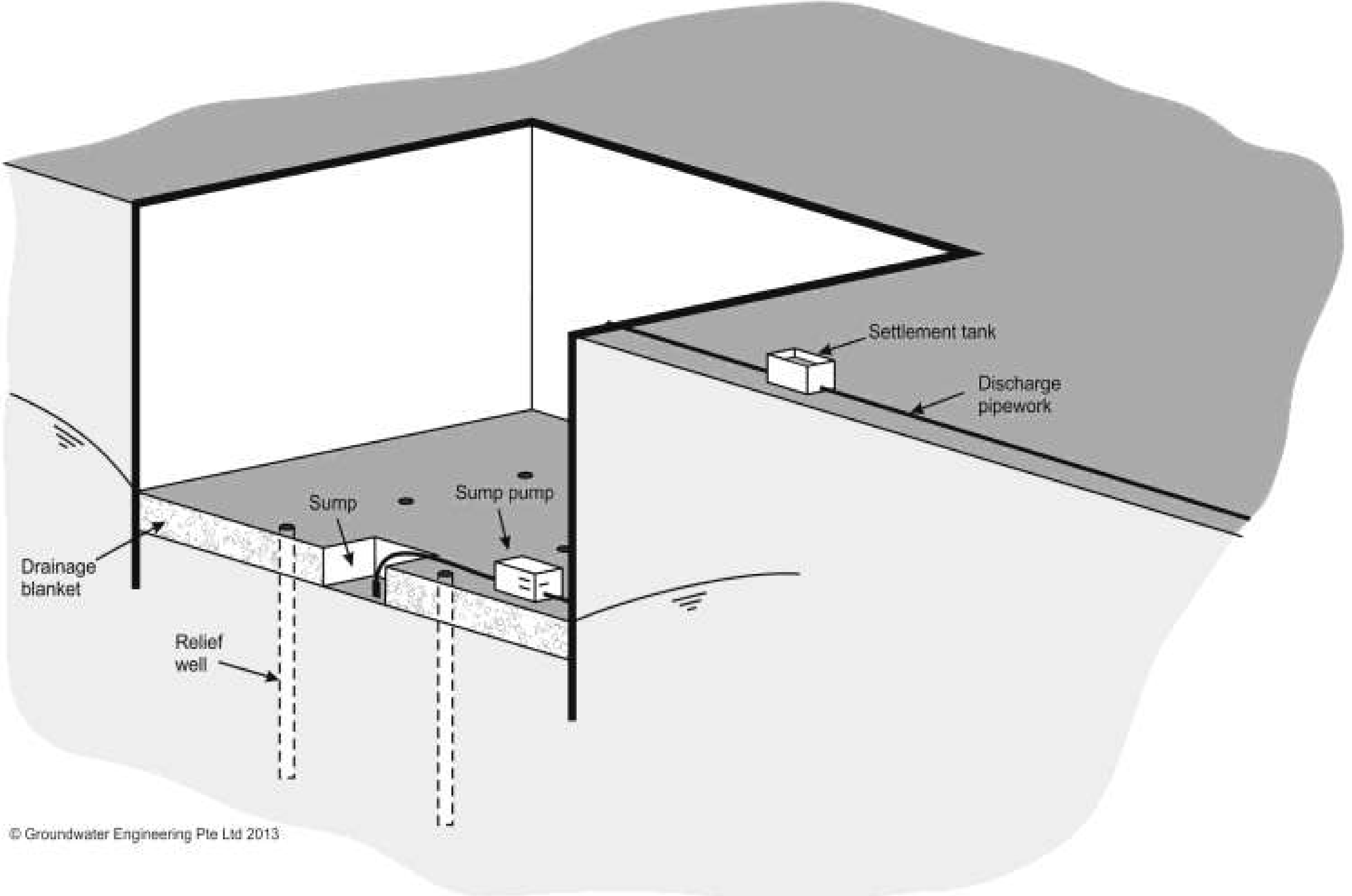
Horizontal wellpoints



Horizontal wellpoints

- Perforated drainage pipe, typically laid sub- horizontally by specialist trenching machine and surrounded by gravel filter media
- Used to dewater for pipeline trenches or to drain large shallow excavations
- Pumped by wellpointing pumps. Drawdown limited to 5 or 6 m below level of pump due to suction lift limits

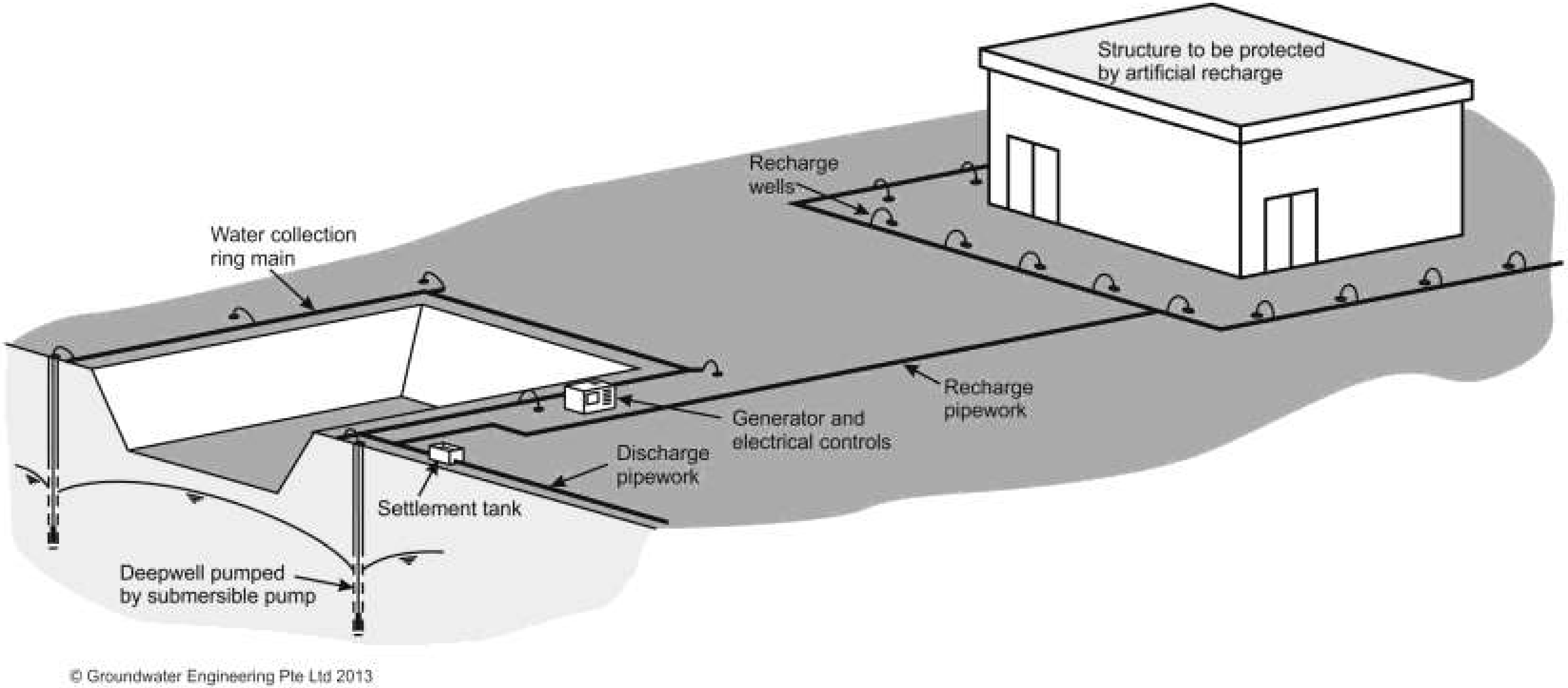
Relief wells



Relief wells

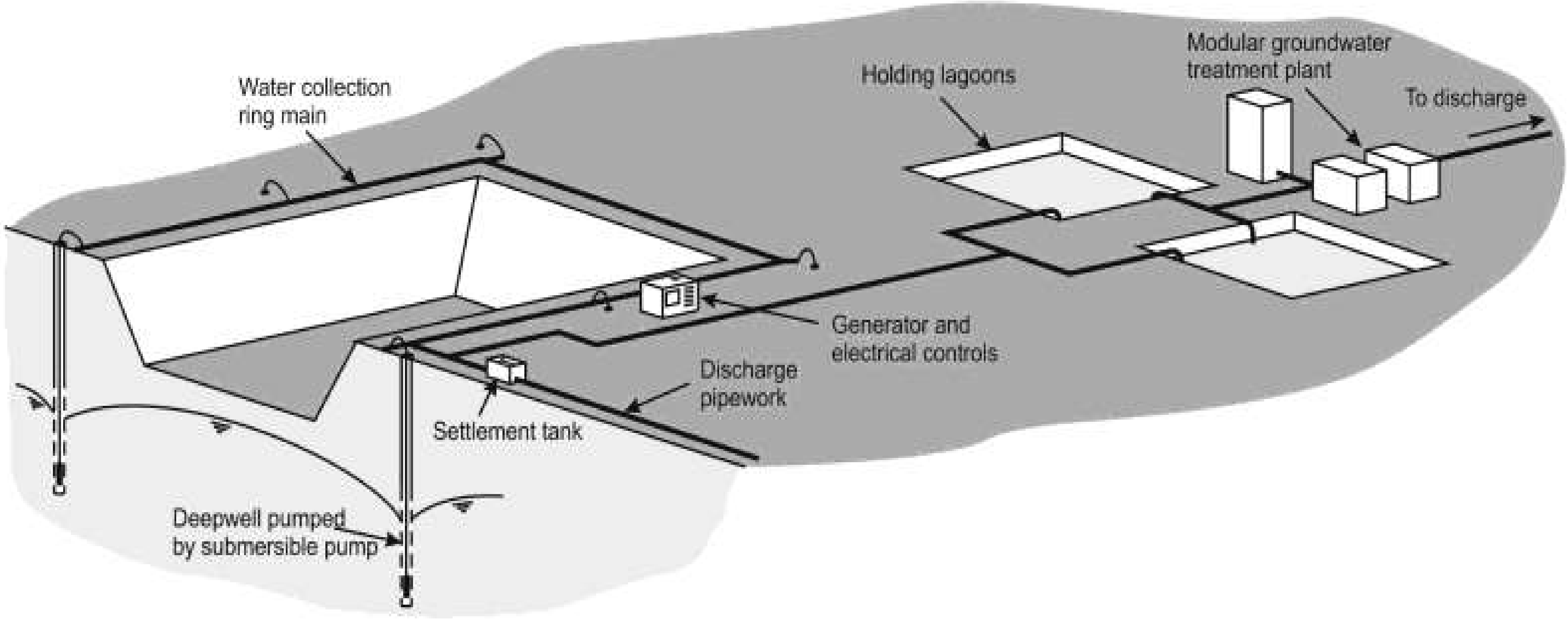
- Relief wells are used to form preferential vertical flow paths to relieve water pressures in confined aquifers beneath an excavation
- Water flows upward into the excavation and is collected in a drainage blanket and sumps and pumped away
- Commonly used to prevent heave or uplift of the base of excavations

Artificial Recharge



Artificial Recharge

- Artificial recharge involves re-injecting or re-infiltrating the discharge water into the ground
- Can be used to reduce external drawdowns around a dewatering system.
- This is sometimes necessary to reduce ground settlements in compressible caused by effective stress increases
- Also sometimes used to help protect groundwater resources by reducing net abstraction from the aquifer – used in aquifers which are important sources of public or private water supply


Water collection
ring main
Holding lagoons
Modular groundwater
treatment plant
To discharge
Generator and
electrical controls
Discharge
pipework
Settlement tank
Deepwell pumped
by submersible pump

Groundwater Remediation

- Dewatering technologies may used as part of the remediation strategy on contaminated sites
- Pumping from wells may be used to manipulate hydraulic gradients to control the migration of contaminated groundwater
- The pumped groundwater will require treatment to remove contamination prior to discharge

UNIT-IV
CHEMICAL AND PHYSICAL MODIFICATION

Grouting

- Grout is a construction material used to embed rebar's 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

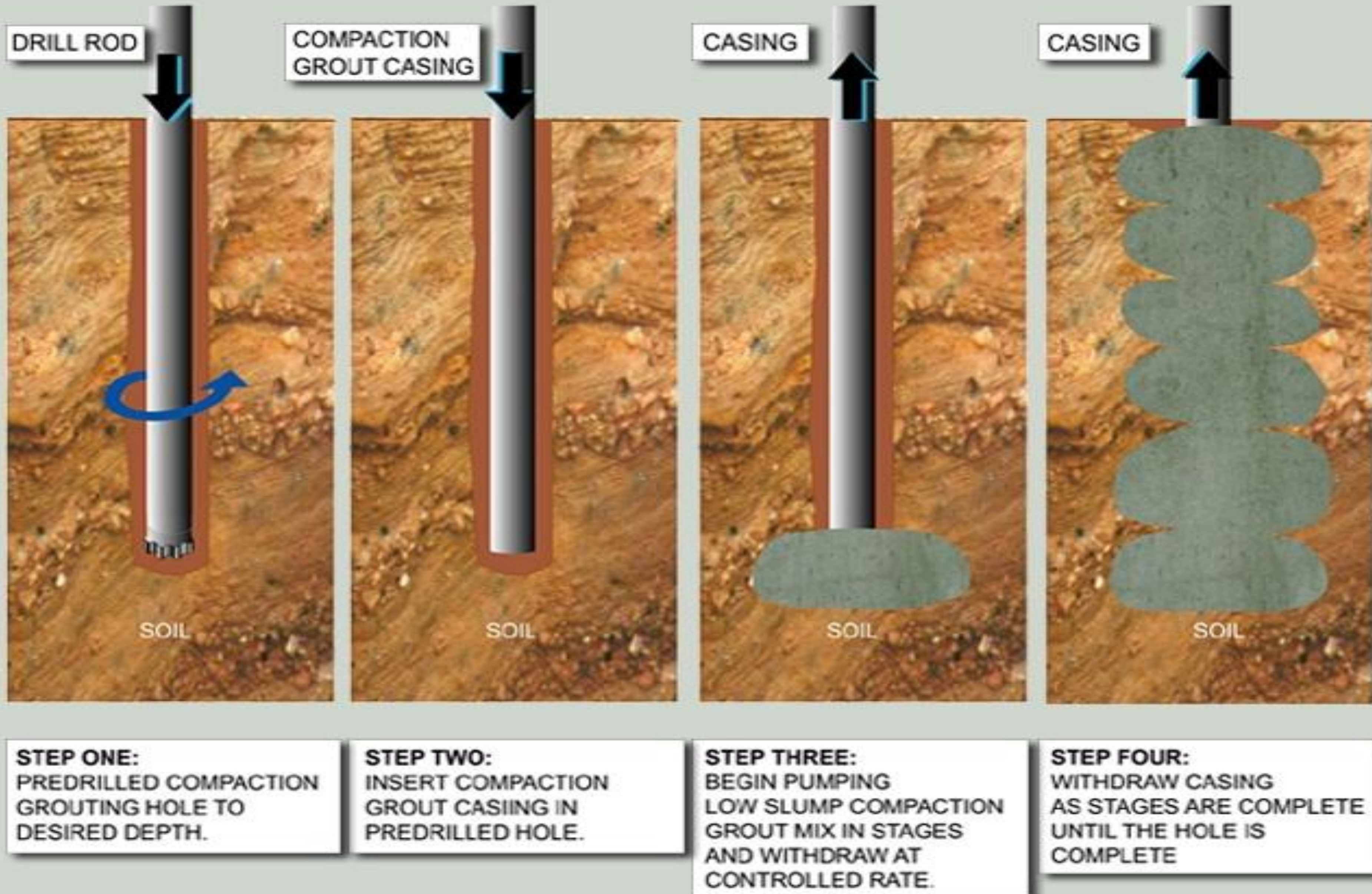
- In 1864, Peter Barlow patented a cylindrical one-piece tunnel shield which could fill the annular void left by the tail of the shield with grout. It is the first recorded use cementitious grout in underground construction.

- In 1893, the first systematic grouting of rock in the USA as performed at the New Croton Dam, in New York.

Use of Grouting in Civil Engineering….

- 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.

Grouting


DRILL ROD
COMPACTION GROUT CASING
CASING
CASING
SOIL
SOIL
SOIL
SOIL
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.

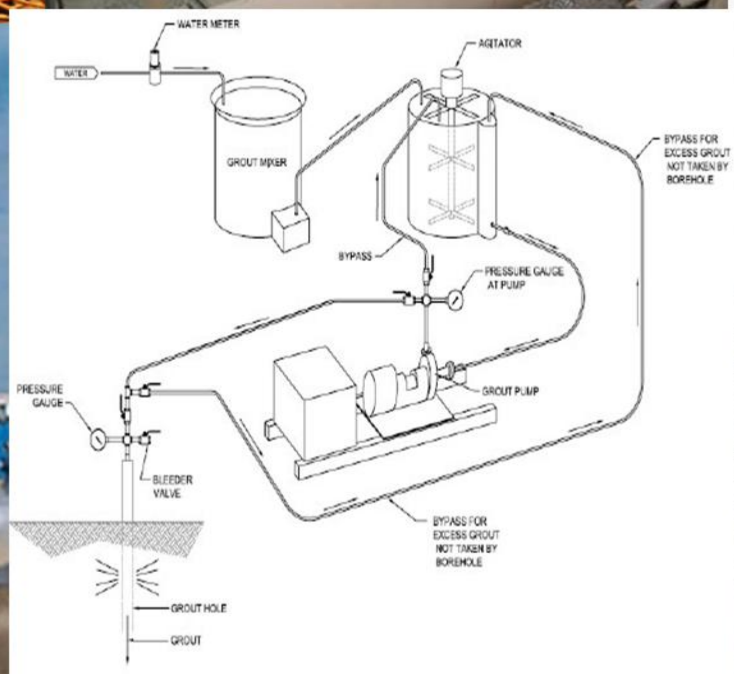
Grout Pipe Method

- 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 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.


B20


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.

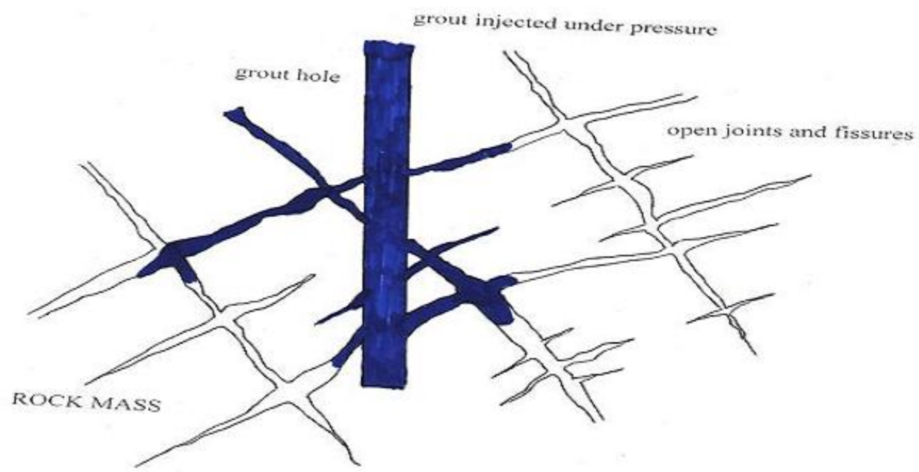
The five selected grouting techniques should have covered the basic mechanisms of all existing grouting techniques.

Rock Fissure Grouting

- Rock Fissure Grouting
- 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.

Rock Fissure Grouting

- 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.

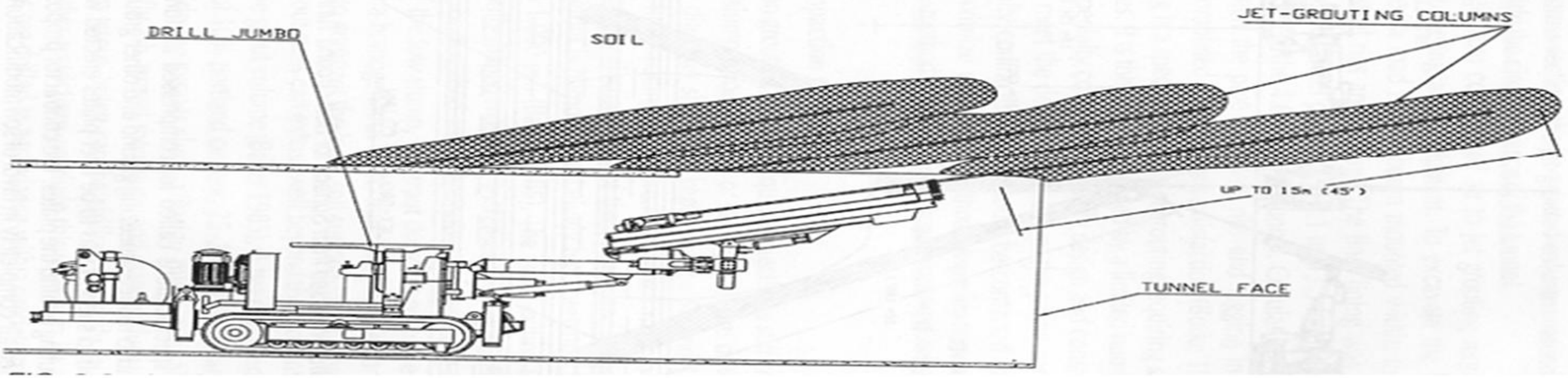


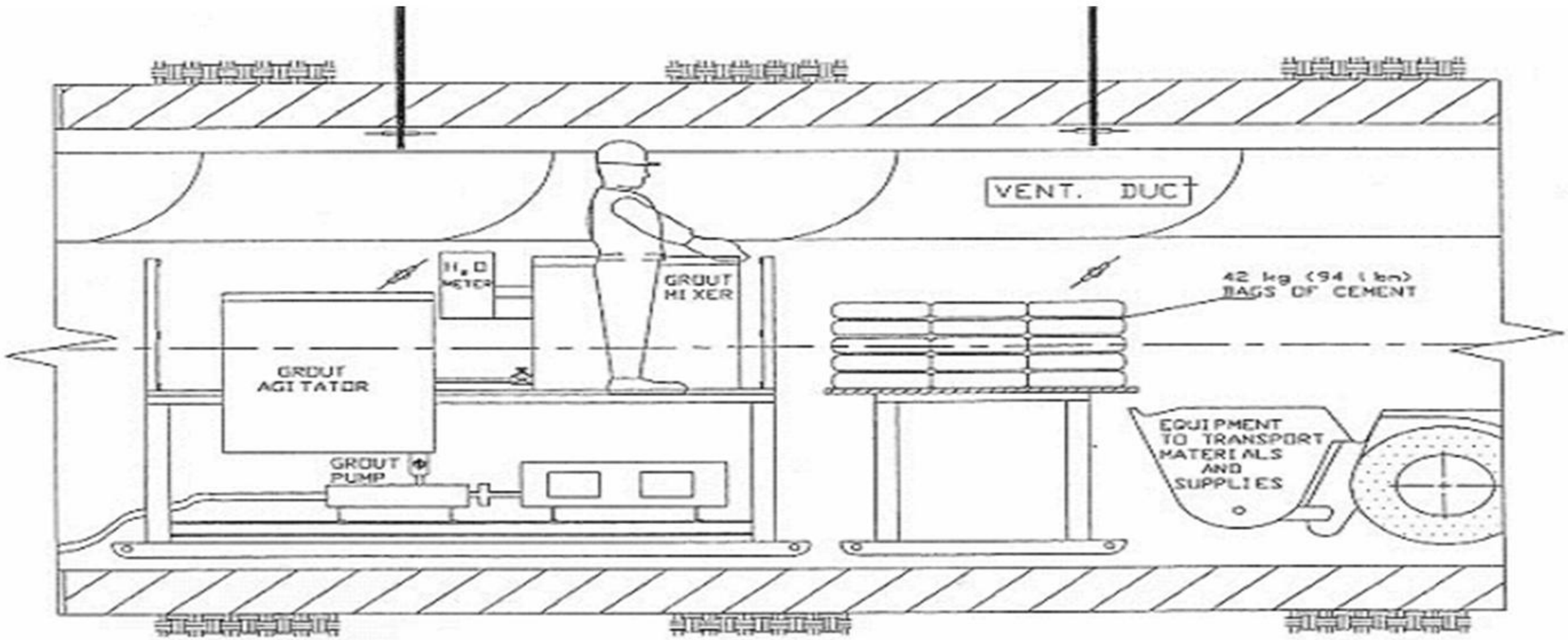
Grouting in Progress

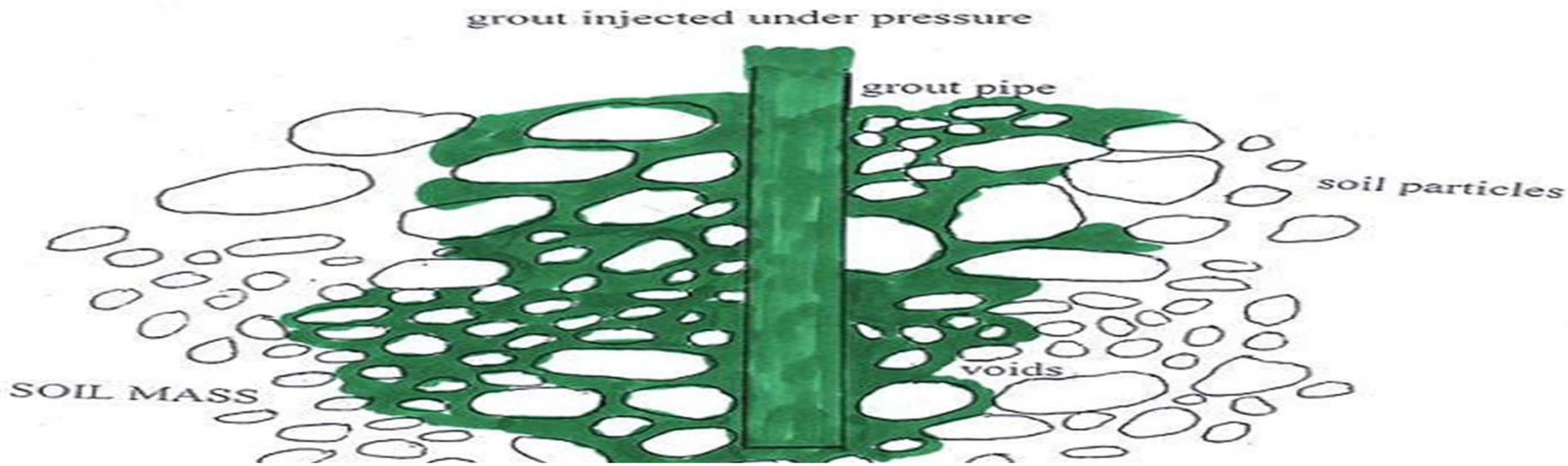
Grouting Completed

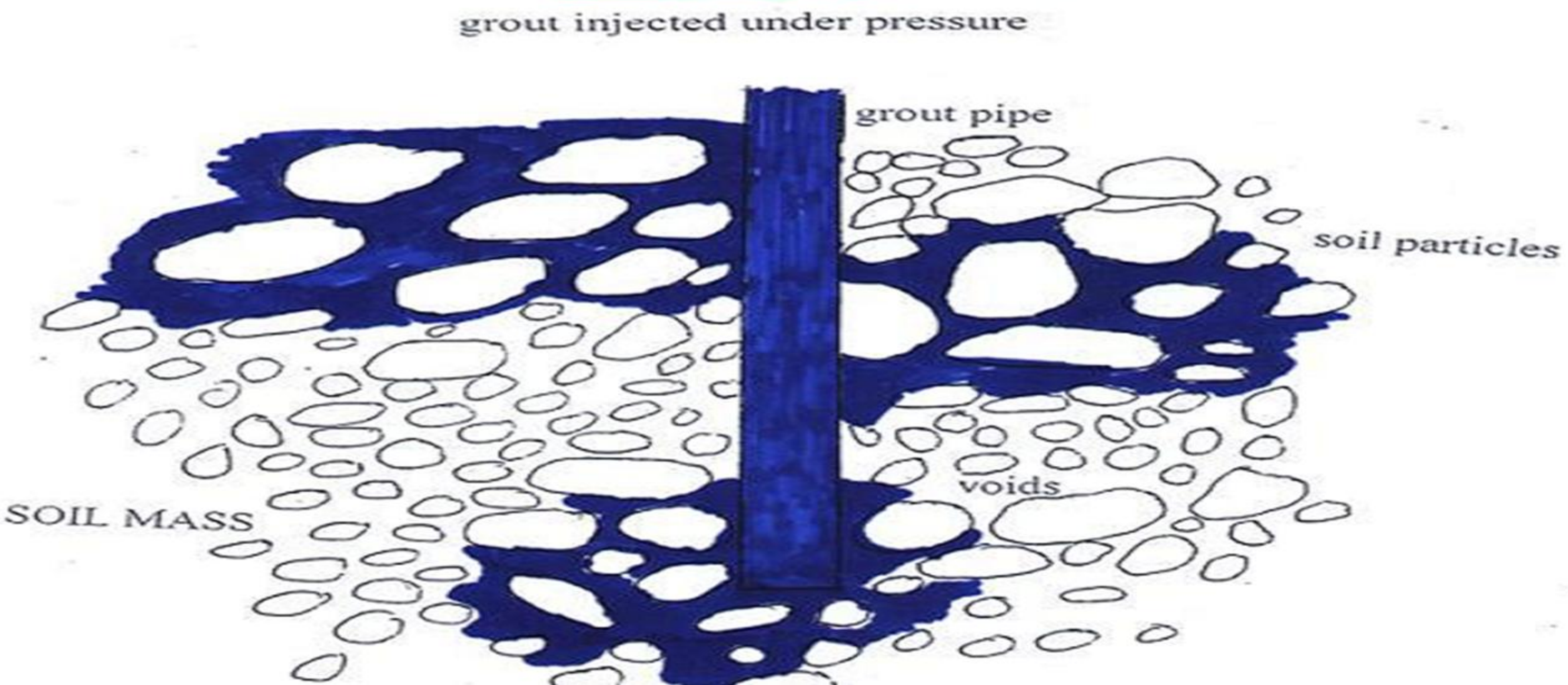
Rock Fissure Grouting Application

- 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.


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


VENT. DUCT
H_2O METER
GROUT MIXER
42 kg (94 lbs) BAGS OF CEMENT
GROUT AGITATOR
GROUT PUMP
EQUIPMENT TO TRANSPORT MATERIALS AND SUPPLIES

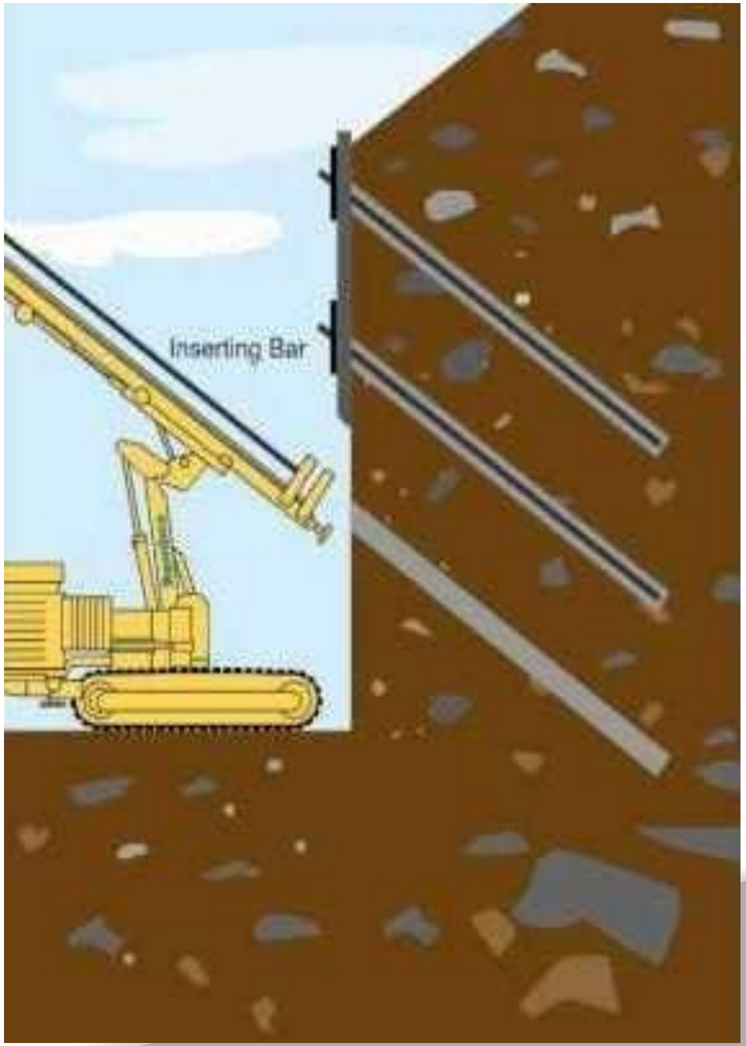

grout injected under pressure
grout pipe
soil particles
voids
SOIL MASS


grout injected under pressure
grout pipe
soil particles
voids
SOIL MASS

UNIT-V
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 slopes.

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

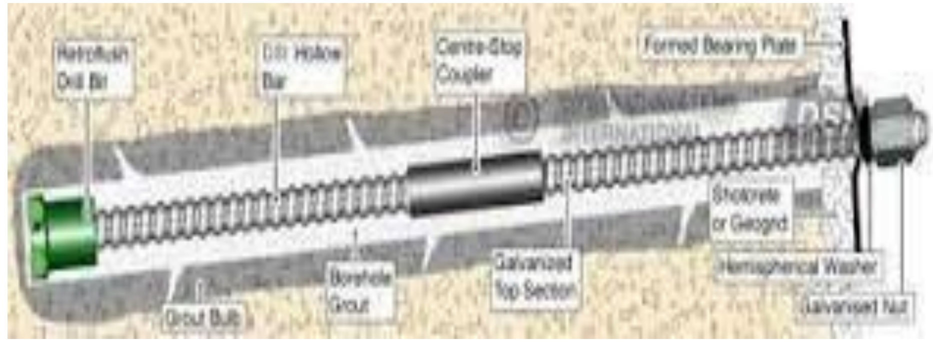
Applications (Cont.....)

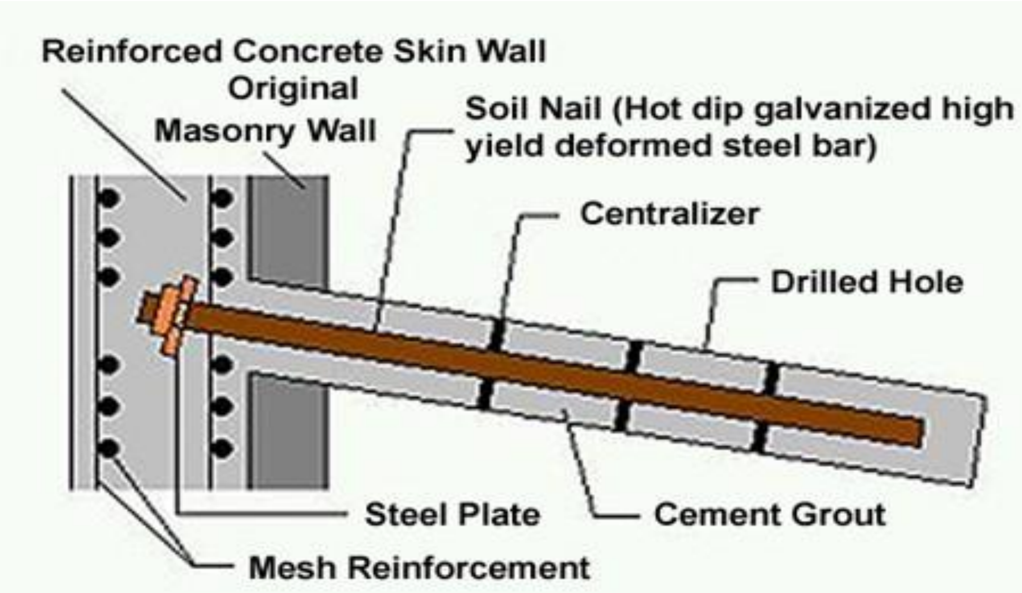
- Existing concrete or masonry structures such as failing retaining walls and bridge abutments.
- Tunnel portals in steep and unstable stratified slopes.

- 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

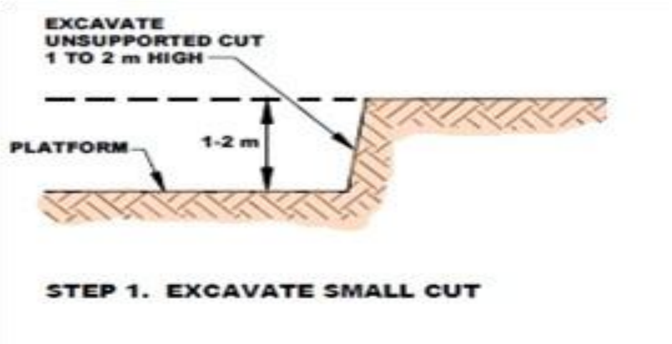
GROUT MIXER

COMPRESSOR

- STEEL REINFORCEMENTS
- GROUT MIX
- SHOTCRETE / GUNITE

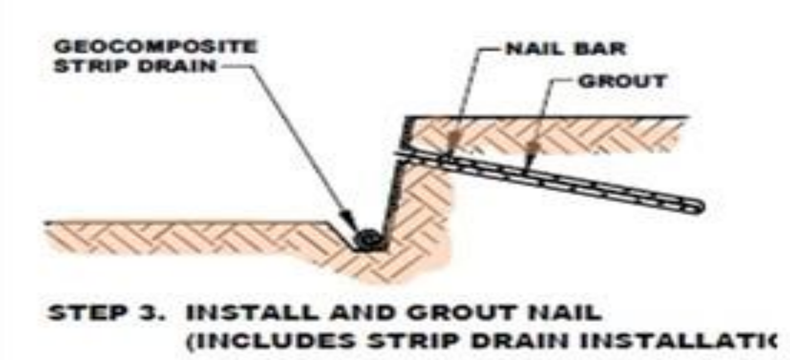
Construction Sequences

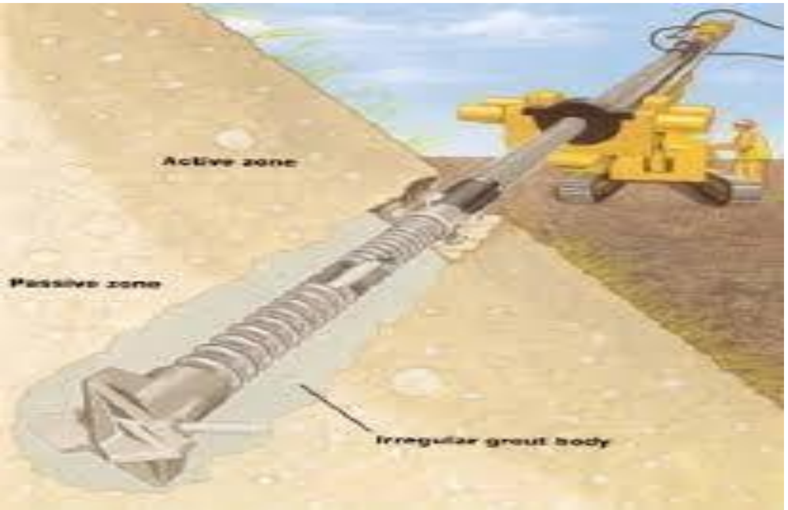
❑ INITIAL EXCAVATION



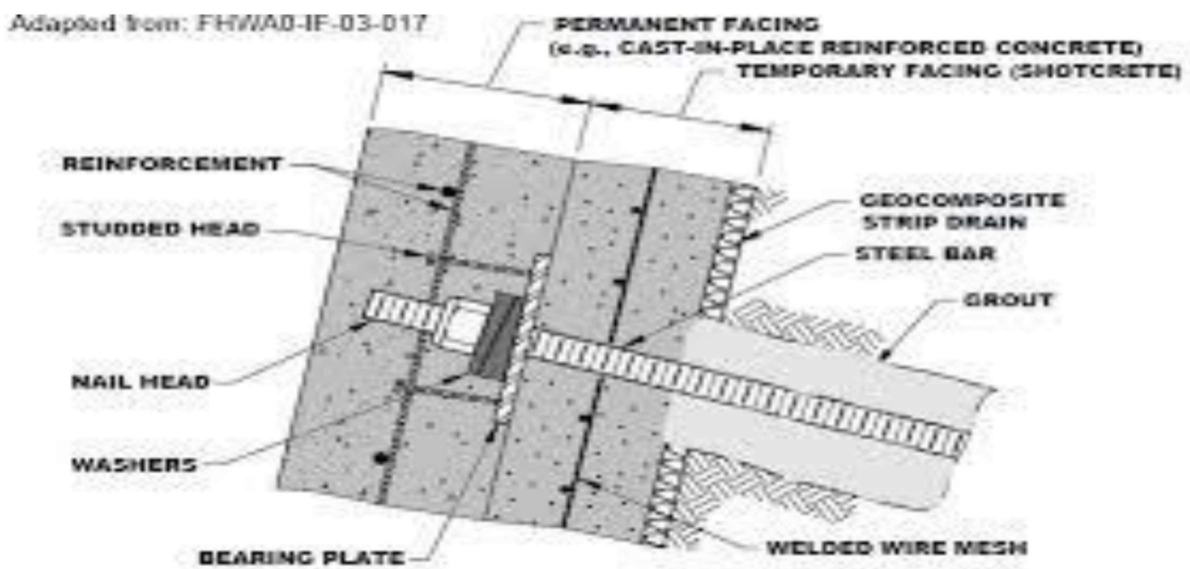
❑ DRILLING OF HOLES

❑ NAIL INSTALLATION





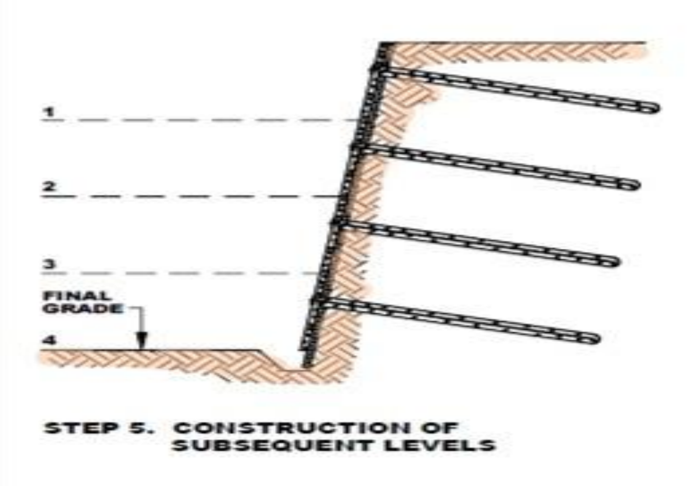
❑ GROUTING



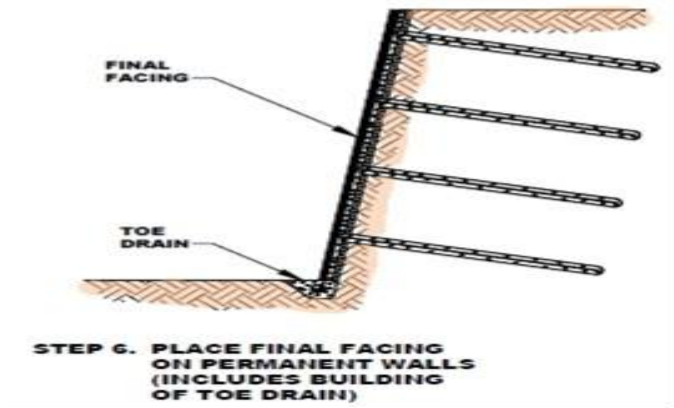
- PLACE REINFORCEMENT AND DRAINAGE

- 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.
- Grouting only once is required, saving time and labor.
- The technique is flexible, easily modified.

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,
- Can be used for strengthening of either natural slope, natural or man- made cut slopes,

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 groundwater

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.