GROUTING

Module 2

INTRODUCTION

- Process of ground improvement attained by injecting fluid like material into sub surface soil or rock

- Grouting materials- cement, cement and sand, clay cement, slag cement, gypsum cement, clay asphalt etc.

APPLICATION

- Sealing pockets or voids of permeable or unstable soil
- Fixing ground anchors for sheet pilewalls, concrete pile walls, retaining wall
- Filling the void between the lining and rock face in tunnel work

APPLICATION (Contd..)

- Forming a grout curtains in layers of permeable strata below the dam
- Sealing the base of structures such as cofferdam or caissons.
- Fixing the tendons in prestressed and post tensioned concrete

ASPECTS OF GROUTING

- Principle : Introduce a substance into rock fissures or into soil void by pumping fluid(grout)
- Using small dia pipes to the required location
- It is essential that grout should Penetrate satisfactorily into the voids and seal all void

Varoius functions involved in soil and rock grouting

- **Permeation or penetration**

  grout flows freely with minimum effect into the soil voids or rock seems

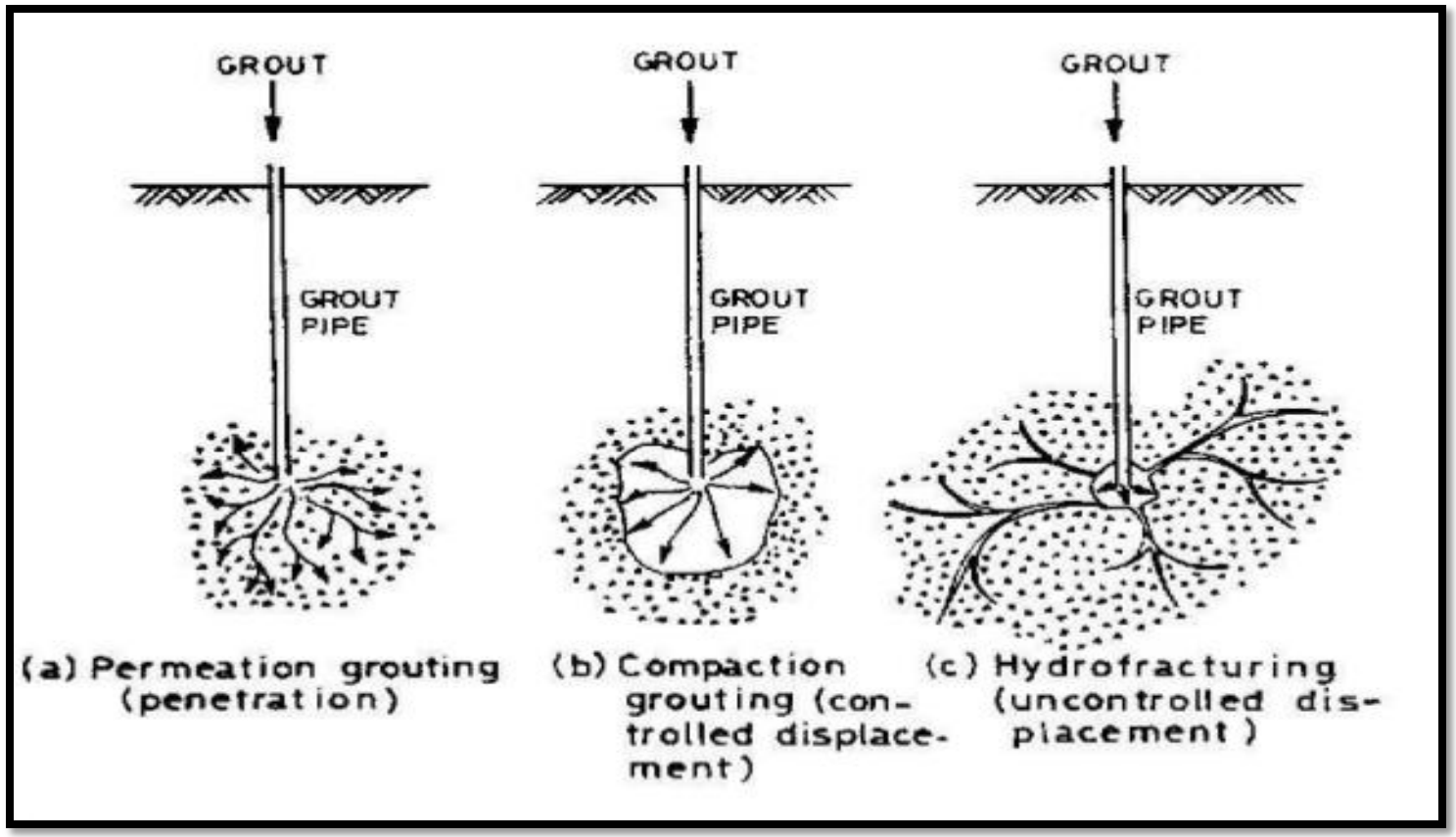
- **Compaction or controlled displacement**

  In this case the grout remains more or less intact as mass and exerts pressure on the soil or rock

- **Hydraulic fracturing or uncontrolled displacement**

  grout rapidly penetrates into a fractured zone which is Created when grouting pressure is higher than tensile strength of rock or soil

Varoius functions involved in soil and rock grouting



GROUTABILITY

Particle size

- By knowing the size of particle, the void space can be obtained. Thus we can decide the size of particle in the suspended grout
- Higher the void size, the size of the particle should be high
- Pumping pressure should not be large enough for particles of soil to be disturbed.
- Grouting pressure is limited to 20 kN/m^2
- Quality of a grout must be sufficiently fluid to enter the soil quickly
- The movement should not be too fast

- Rate of injection of a grout depends on
  - Viscoity of the grout
  - Permeability of soil
  - Shear strength of soil

GROUT MATERIALS

- *Suspensions* – Grout particles in suspension in a liquid medium- Cement+ Water, Clay etc
- *Emulsions* – Minute droplets of liquid in suspension- Asphalt or bitumen with water
- *Solutions* – Liquid homogenous mixture of two or more materials- Chemical Grouts

1. Suspension grouts

- When grouts are injected into the soil formation the relationship between grout particle size and the soil void size should be considered.

Groutability ratio, $GR = \frac{D15\ (formation)}{D85\ (grout)} \geq 20$

- D_{15}= Particle size at which 15% of the soil is finer(of the formation being grouted)
- D_{85}= Particle size at whch 85% is finer (of the grout being injected)

a) SUSPENSION GROUTS-GROUTING WITH SOIL

- GR > 20
- Soil can be used to fill up voids in coarse grained soils
- Soil used as grout- very fine grained
- Clay grouts – to reduce permeability- it behave like a bingham fluid and gels when undisturbed.
- Kaolinite and Illite based clays – low viscosities –filler grouts
- Bentonite clay is commonly used material whose structure is readily acceptable to absorb water. Hence it can control viscosity strength and flowproperties

➢ Mud jacking –

- No flow of soil-grout occurs when the water to soil ratio is kept very low- pressure exerted against the soil mass from grouting pipe.it cause densification and movement of adjacent areas
- Uses:
- to raise pavement slabs and to underpin shallow building foundations
- To strengthen in situ soil by forming compaction piles

b) SUSPENSION GROUTS-GROUTING WITH CEMENT

- Usually cement grouts are formed from OPC and Water
- Water cement ratio – 0.5:1 to 5:1(depending upon the ground condition)
- Rapid hardening cement – preferred to OPC in groundwith flowing water since RHC is finer than OPC and has quick setting time and high early strength
- Super sulphated cement is very finer – used for grouting in fissured rocks-
- Admixtures such as bentonite used to control the final composition of the grout

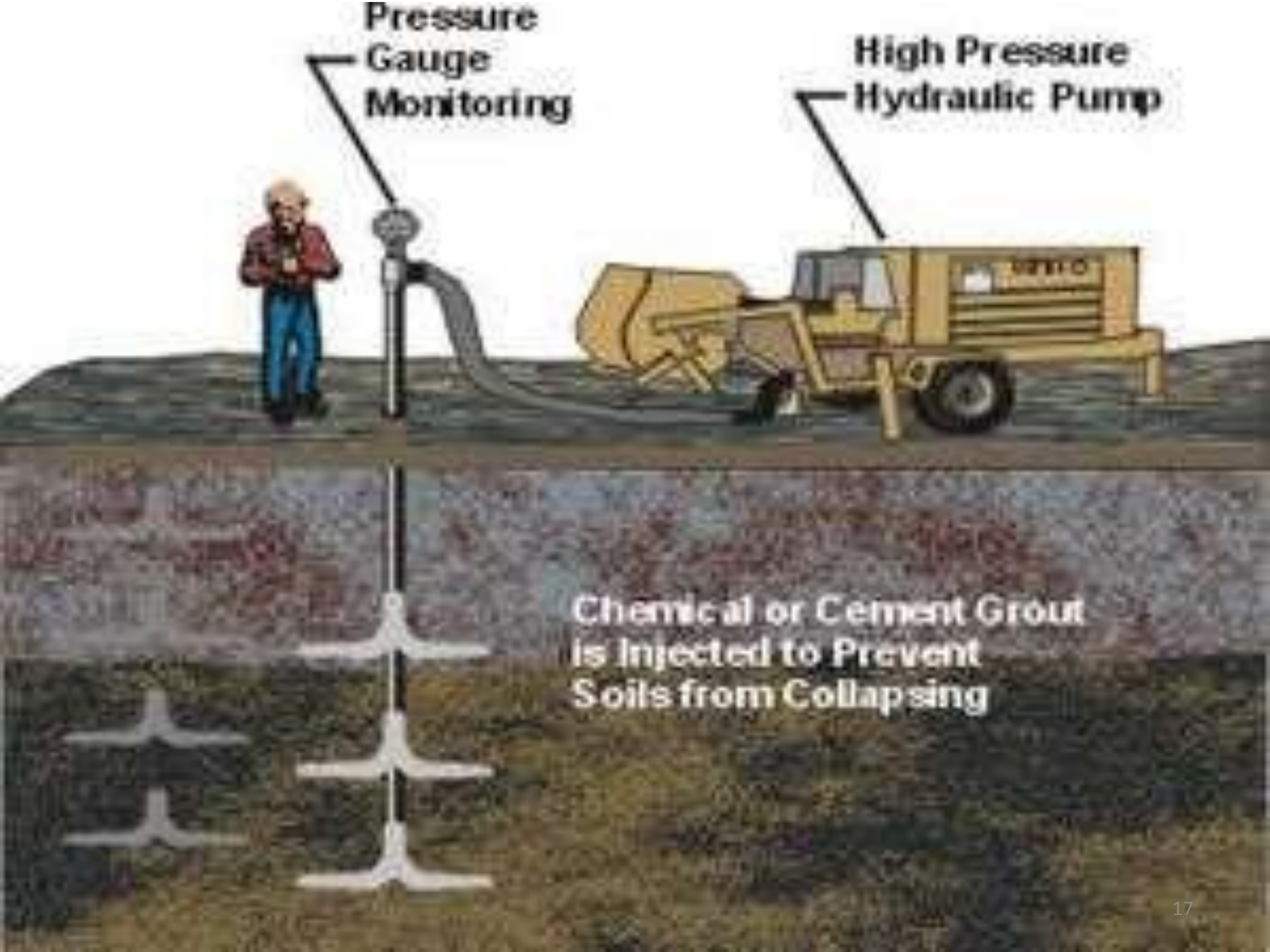
- Selection of cement grout depend on
- Final strength
- Flow rate
- Set time
- Shrinkage
- permeability
- Durability
- cement grouting has been widely used, more often in seepage cut off beneath the dam , but also in ground water control in certain cases

c) EMULSION GROUTS – ASPHALT EMULSION

- Anionic ashpalt globules or cationic asphaltic globules are manufactured by choosing proper emulsifying agent
- The globules (1 to 2 µm dia) along with water used as grout to fill soil voids and rock fissures
- Rock fissues of 10 µm size and medium silts can be grouted
- Slow setting emulsions generally chosen – they can travel longest distnce into the material

2. SOLUTION GROUTS – CHEMICAL GROUTING

- can generally permeate finer soils than can suspension grouts
- termed as chemical grouts
- Done using ONE SHOT and TWO SHOT system
- Commonly used Chemical grouts are silicates, acrylamides, lignosulphate derivatives and acrylic resins
- Solidify by chemical reaction


Pressure
Gauge
Monitoring
High Pressure
Hydraulic Pump
Chemical or Cement Grout
is Injected to Prevent
Soils from Collapsing

ONE SHOT SYSTEM

All chemicals are injected together after premixing

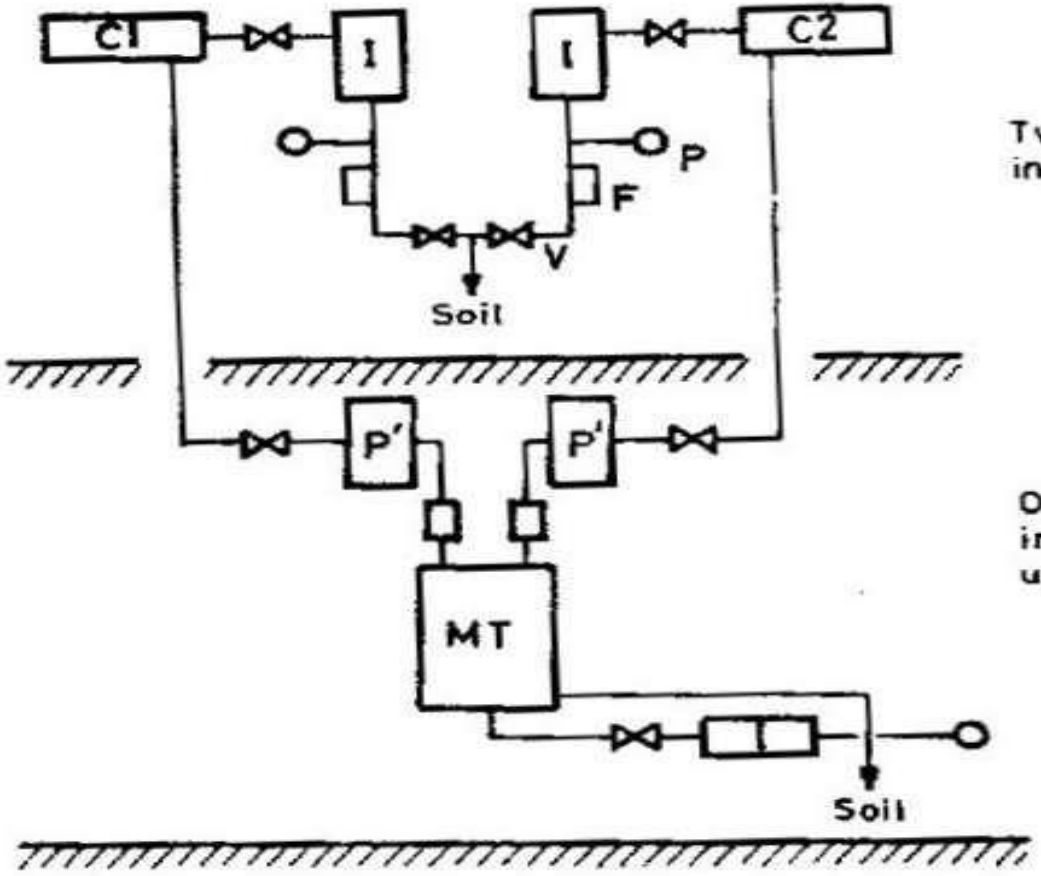
Setting time is controlled by varying the catalyst concentration according to the grout concentration, water composition and temperature

TWO SHOT SYSTEM

One chemical is injected followed by injection of a second chemical which reacts with the first to produce a gel which subsequently hardens

This is slower and require higher injection pressure and more closely spaced grout holes

GROUTING SYSTEMS- ONE SHOT & TWO SHOT



Two-shot chemical injection set-up

One shot chemical injection set up using two chemicals

C1,C2 = Chemical 1 and 2
I = Injection pump
P = Pump
P' = Pressure gauge
F = Flow meter
V = Inlet valve
MT = Mix tank

CLASSIFICATION ON SOLUTION GROUTS

- Aqueus solution- silicate derivatives, other mineral gels, lignosulphate derivatives, aminoplast combination of above
- Colloidal solution- organic solution, mineral solution
- Non aqueous solution- synthetic resins, bitumen and other materials
- Emulsion- Bituminous, others
- Products reacting with ground- reaction with ground or ground water salts, reaction with ground water
- Combined system

COMPACTION GROUTING

- Compaction grouting involves the injection of a very stiff, mortar like, cementatious grout into soil to densify or compact the soil under high pressure.
- When injected, the grout will not permeate the surrounding soils, but instead form "grout bulbs" that laterally displace the soil. By repeating the process in adjacent holes the soil between the holes is densified through the lateral displacement.
- Compaction grouting to depths exceeding 175 feet (53 m)
- Improved soil mass through densification
- Sinkhole remediation

COMPACTION GROUTING (Contd..)

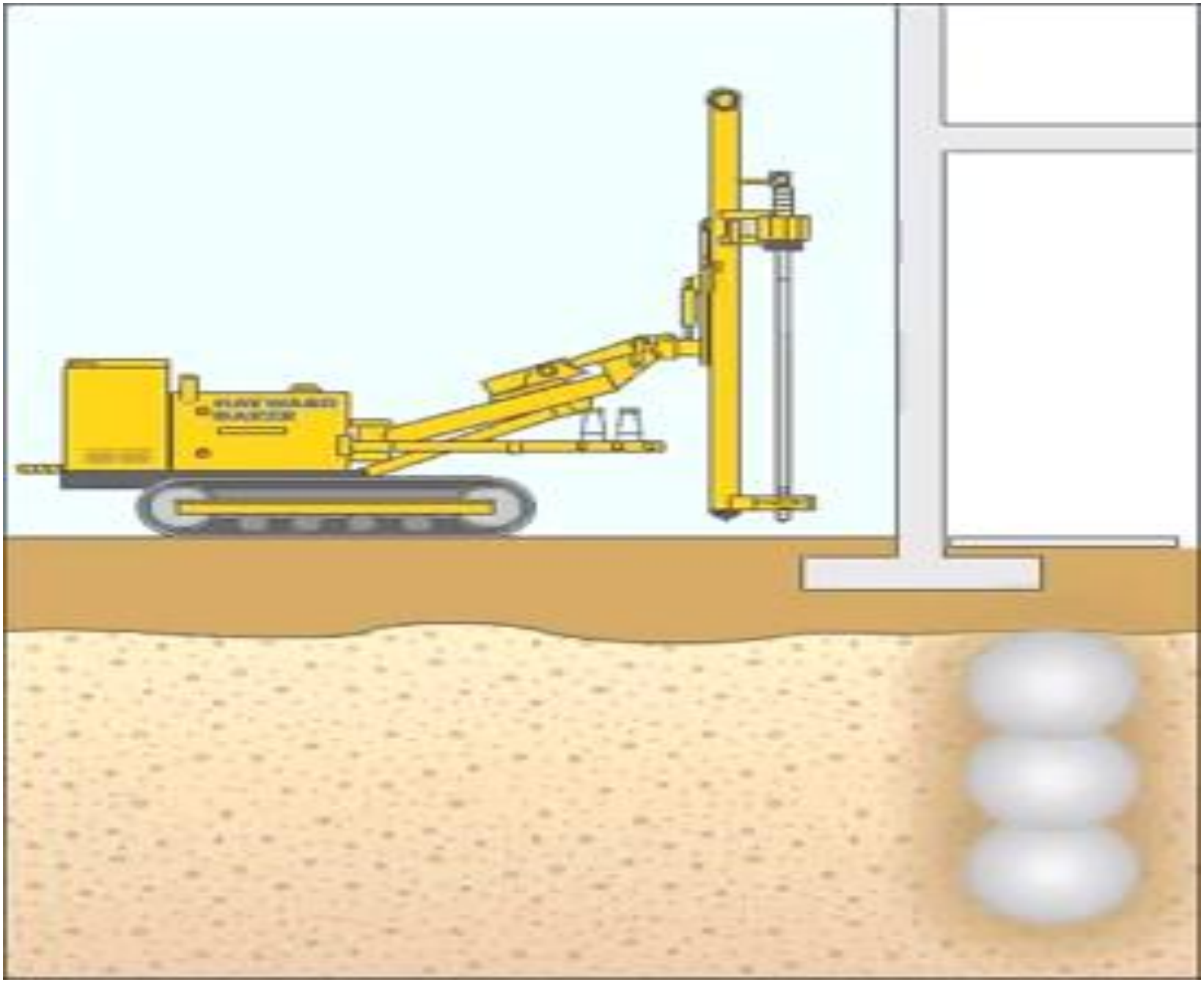
- Applicable to partially saturated cohesive or organic soil masses, silts, sands and soil containg void packets.
- used to stabilise soil under residence and light commercial buildings and sometimes foundations of large structures.

Advantages:

- Minimum distance to the structure and surrounding ground
- Minimum risk during construction
- Greater economy
- Supports all portions of structure
- Reduced need for extensive exploration
- Greater flexibility
- Ground water not affected

Disdvantages:

- Relative ineffectiveness in stabilising near surface soil
- Prohibitive cost for some structures if the soil to be treated as excessively deep
- Grouting adjacent to unsupported slopes may be ineffective
- Difficulty of analysing results
- Not suitable in decomposable materials
- Danger of filling underground pipes with grout



GROUTING PROCEDURE

Depending on the material to be grouted (Rock, natural soil or fill), its quality and the purpose of grouting, a well planned procedure has to be adopted to attain the desired result

i. Pre Grouting Investigation
ii. Grout Holes pattern
iii. Grout characteristics
iv. Grouting Plant and Equipment
v. Grouting sequence
vi. Grouting methods
vii. Grout injection measurements and monitoring

i. Ground Investigation

- It is essential to conduct full site investigation before commencing grouting operation.
- It helps to decide the method and extent grouting in that location
- Include a geological survey, Drilling boreholes, Collection of samples for laboratory tests
  - Geological survey consist of studying the general geology of the area with the help of mapping methods to establish fissures, faults folds etc
  - Final study reveals the extent of soil and rock formations, zones of weakness, the dip and the strike etc of the ground
  - Detailed explorations- drilling method- collecting sample

ii. Grout Holes Pattern

- Based on the nature of work, the number of drill holes, depth and pattern to be decided
- Ideally, Follows a grid pattern such that radius of penetration is sufficient to cause slight overlapping between adjacent holes (fig 6.35)
- a second half size grid is then injected between the adjacent columns.
- sometimes a third and quarter size grid is required
- Grout holes are generally vertical. Sometimes provide inclined hole to meet some requirements

- oblique holes usually providing with 15 degree to the vertical
- As a preliminary guidance the spacing of grout holes may be as given

Coefficient of permeability	Grid spacing(m)	Soil type
>1	6	Fissured rock
1 to $1x10^{-1}$	3	Medium/ coarse sand and gravels
$<10^{-1}$	0.5 to 1	Fine sands

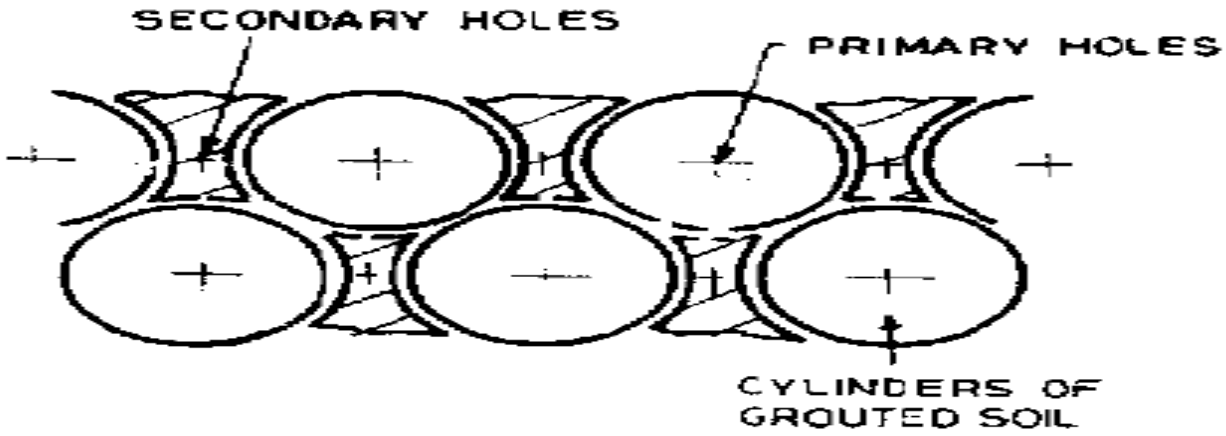


Fig. 6.5. Grouting pattern.

iii. Grout characteristics

- Grout should not set quickly because this may affect the pumping but should set and hardens after the completion of pumping
- Viscosity and hardening controlled by additives

➢ *The principle in choosing the grout are:*

- The grout must be able to penetrate the voids of the mass to be injected
- Grout should resistant to chemical attack in place
- Grout shouldbe able to develop sufficient shear strength against the water pressure

Grout types and applications

Grout type		Applications
suspensions	PFA	Mass filling in very coarse soils and rock fissures
	Cement	Mass filling in very coarse soils and rock fissures plus ground strengthening
	clay	Mass filling in medium coarse soils and impermeability improvement
	Clay/cement	Similar to clay plus added strength
Emulsions		Impermeability improvement
Solutions, One shot		Permeability/ strength improvement in medium coarse soils
Solutions, Two short		As for one short with additional control of gel time. Also suitable in fine soils

iv. Grouting Plant and Equipment

- Measuring Tank – To control the volume of grout injected
- Mixer – To mix grout ingredients
- Agitator – To keep solid particles in suspension until pumped
- Pump – To draw the grout from the agitator to deliver to the pumping line
- Control fittings – To control the injection rate and pressure so that the hole can be regularly blend with water and thin grout
- Piping connected to grout holes

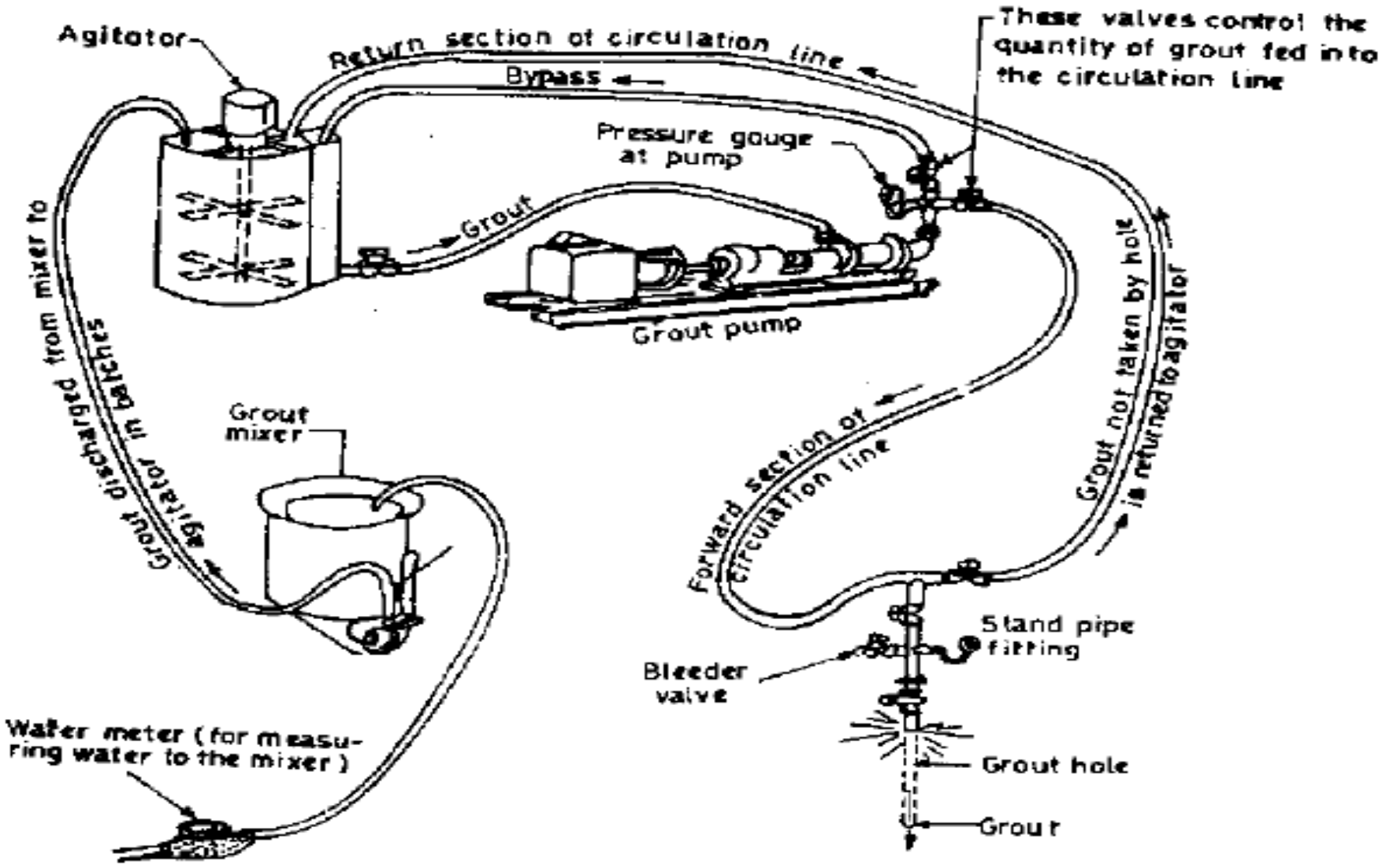


Fig. 6.6. Typical layout of a grouting plant (Adopted from Houlsby, 1983).

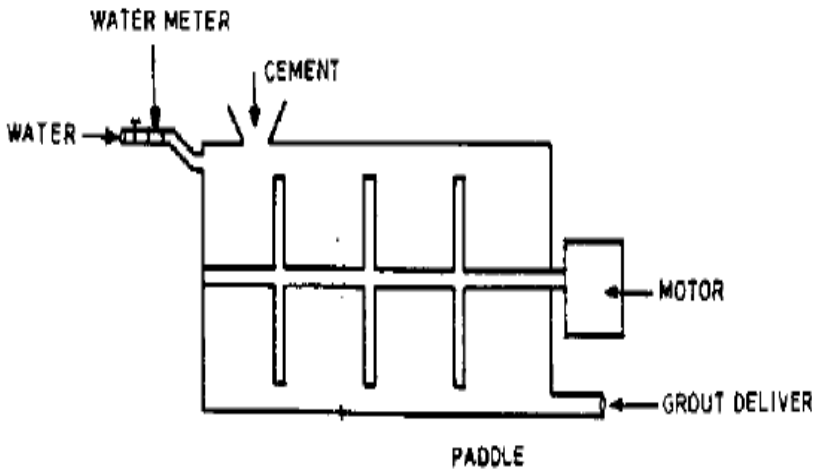
➢ Mixing is done in 3 stages

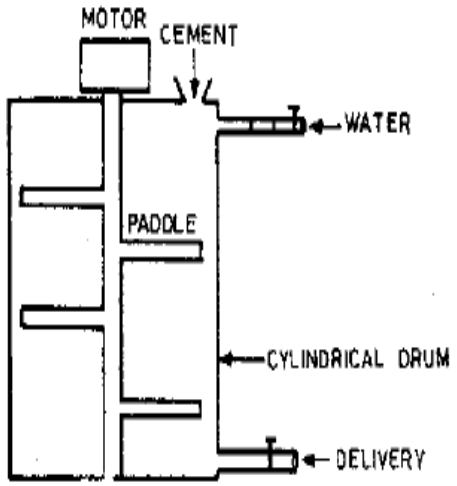
- Formation of a vortex which acts as a centrifugal separator-thicken grouts and unmixed cement are pushed to the periphery of the vortex and passed to a mixing rotor

- Treatment of the above subjected to a violent shearing action in a mixer rotor, which breaks up thicer fraction and lumps of cement and wets and produces a grout resembling colloidal solution

- Circulation of the treated fraction back into the vortex-vortex continuous to spin till all the thicken fraction broken and the entire grout reaches a uniform consistency

Barrel type mixer





7. Vertical and horizontal barrel type mixer (Adopted from Houlsby, 1982).

- barrel type grout mixer consist of a cylindrical drum placed either horizontal or vertical with an axial shaft fitted with paddles or blades
- Cement and water are mixed with the help of paddles
- Vertical type is used to handle small quantity

Grout agitators

- Grout mix should be continuously agitated to prevent setting
- It is achieved by an agitator between the mixer and grout pump
- Agitator sump is a tank which has a agitating mechanism consisting of a vertical shaft to horizontal blades revolved at 30 to 100 rpm
- The grout mix from the mixer is passed through awire screen to remove pieces of sack, strings and other foreign matters
- Another screen is fixed to the agitator near the delivery pipe to prevent the entry of lumps to the pump
- A graduated dipstick is used to measure the qty of grout to the agitator

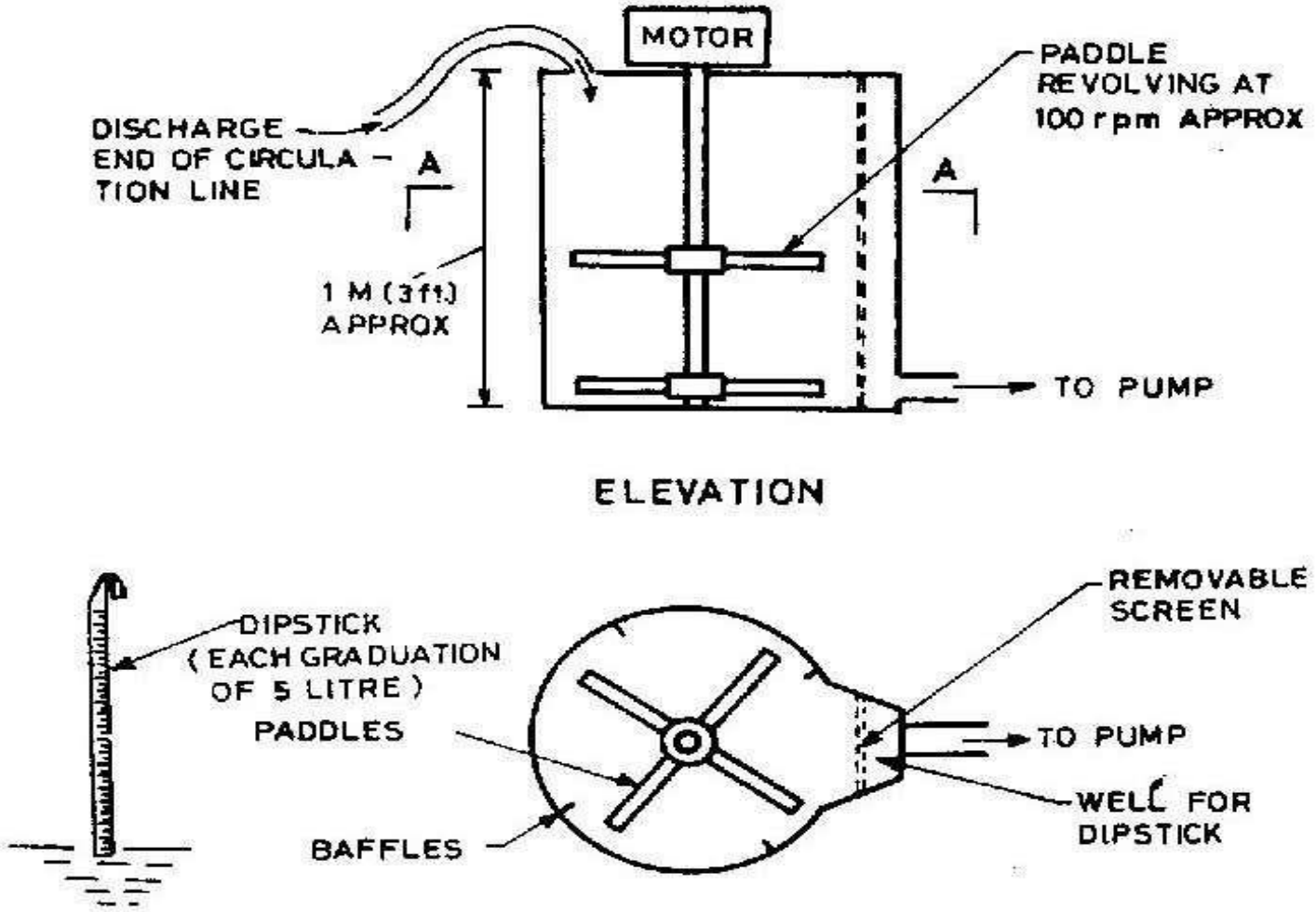


Fig. 6.8. Grout agitators (Adopted from Houlsby, 1982).

Pumps

- Pumps should be able to provide pressures of 2800kN/ m^2 displacement around 0.007 m^3
- Pumps may be piston or diaphragm type
- The following capacities may be preferred depending upon the type of grout

	Pressure(N/ mm^2	Delivery(l/min)
Small sump	0.8	120
	1.5	45
Large sump	3.5	450
	10.0	130

- Othe accessories needed to grouting plant are grout pipe hoses, valves, nipples, pressure gauge, packers , casing tubes, flow meters etc

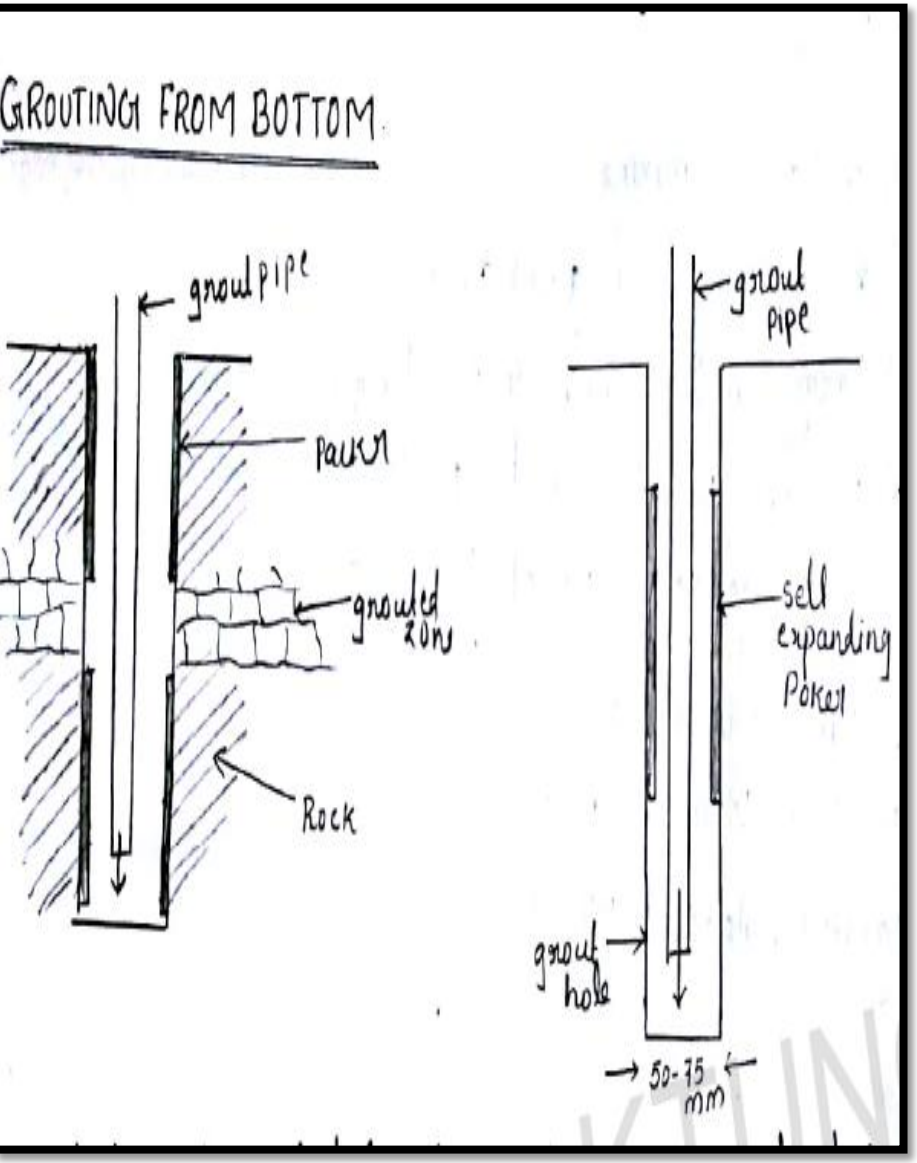
V. GROUTING SEQUENCE

GROUTING FROM BOTTOM

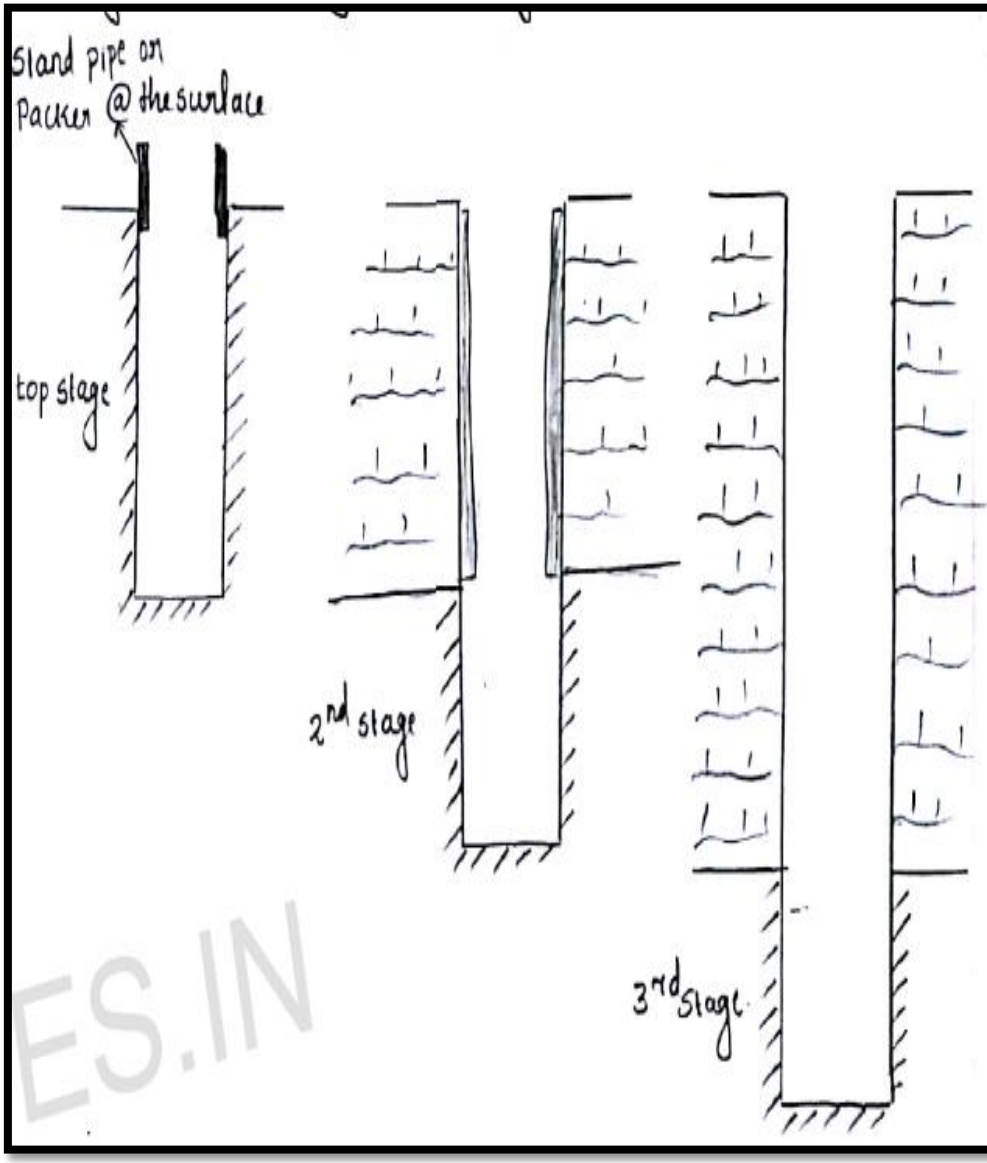
- A grout hole of 50 to 75 mm diameter is drilled to full planned depth.
- In rigid soils or in intact rock strata a self expanding packer is placed directly above the lowest zone and grout is pumped in.
- The procedure is repeated after the packer is raised and fixed to the next zone
- Thus the drill hole is grouted successively upwards

GROUTING FROM TOP

- Holes are drilled down to the seam closest to the surface and grouting is carried out.
- Holes are then cleaned by washing and drilling continued to the next seam.
- Grouting process is then effected.
- Subsequent washing followed further drilling and repeated grouting are done until the entire operation is completed. [Fig. 6.11(a)]
- Grouting is facilitated in a particular zone by fixing packers on the top and bottom. [Fig. 6.11(b)]



GROUTING FROM BOTTOM



GROUTING FROM TOP

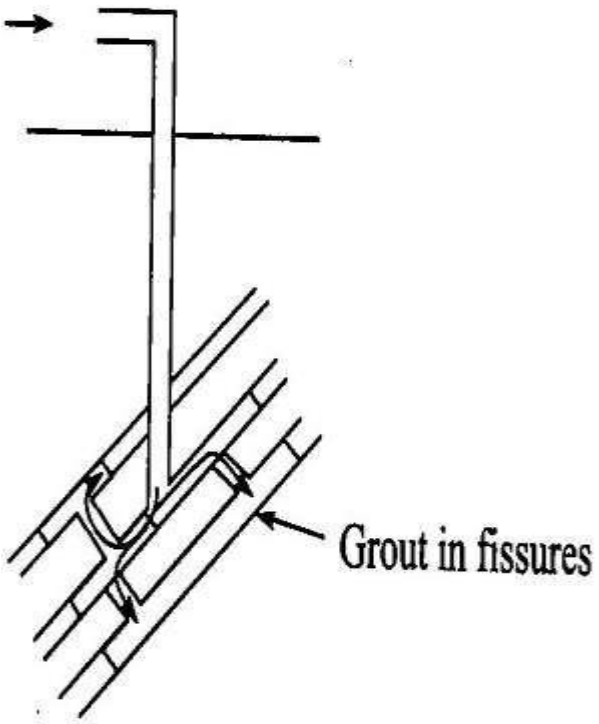
vi. GROUTING METHODS

- Permeation Grouting
- Compaction Grouting
- Circuit Grouting
- Jet Grouting
- Soil Fracture Grouting
- Point Grouting
- Electro kinetic injection

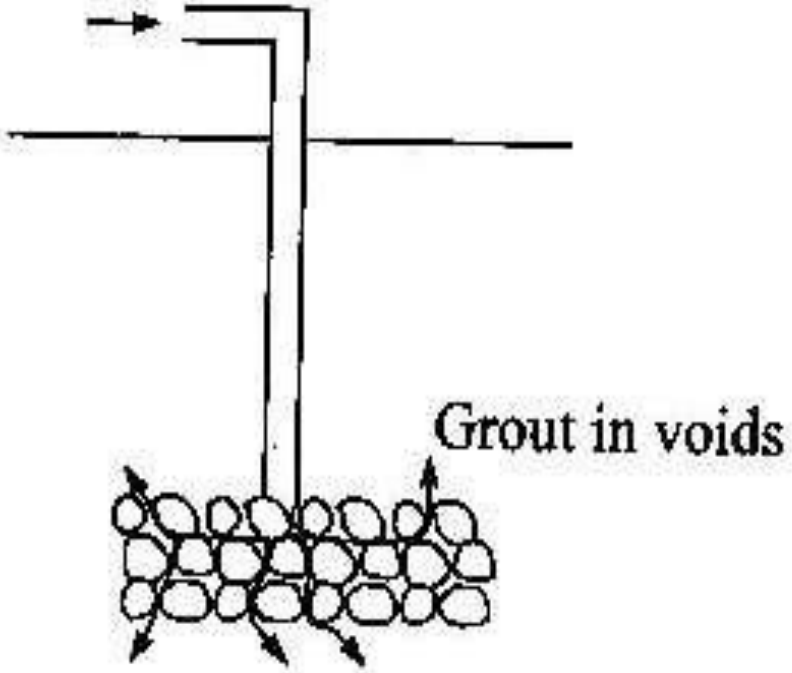
a)Permeation Grouting

- Grout fills the pores without any volume changes. Include Cement grouts, bentonite grouts and chemical grouts.
- Grouting into an open hole in self-supporting ground through pipes at the surface through an injection pipe held in place in the hole
- From a pipe driven into the ground and withdrawn as injection proceeds
- Through a pipe left in place in the ground as with a tube

a) Permeation Grouting



(a) Permeation grouting in rocks



(b) Permeation grouting in soils

Applications of Permeation Grouting

- Seepage Control
  - For making seepage barriers beneath hydraulic structures
  - Stoppage of seepage through joints of underground structures such as tunnel lining/ basement wall, etc.
- Soil Solidification and Stabilization
  - For stabilization of soil around tunnels and shafts

b)Compaction grouting

- A good option if the foundation of an existing building requires improvement, since it is possible to inject the grout from the side or at an inclined angle to reach beneath the building
- A bulb shaped grouted mass is formed.
- Soil-cement grout
- Can be performed as pretreatment before the structure is built

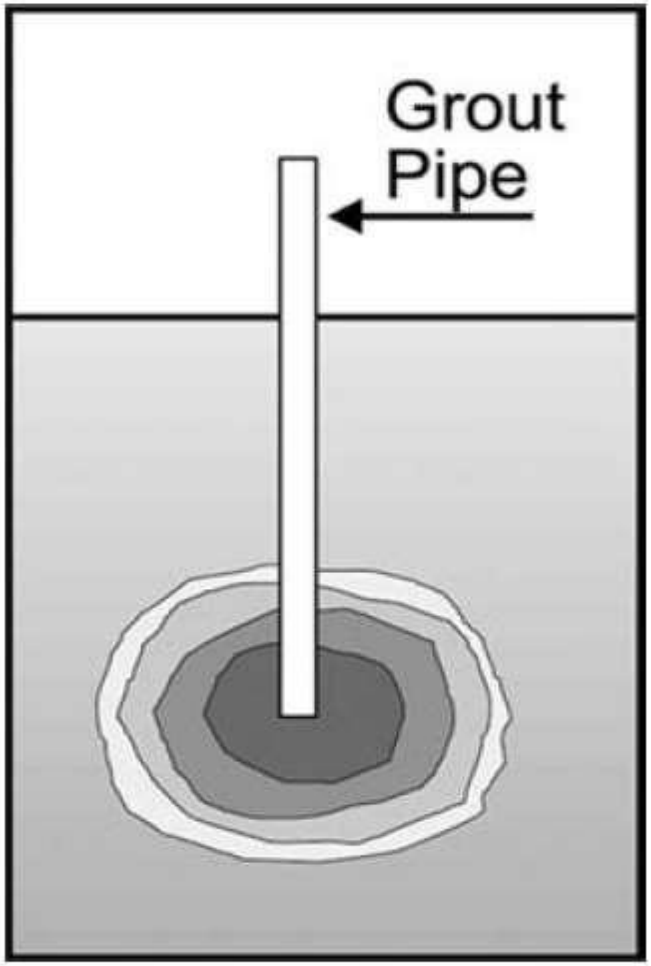


Figure 6.1 Compaction grout bulb

Applications of Compaction Grouting

- Densification of loose stratum
  - i) underlying dense soil
  - ii) beneath foundations or floor slab-slab jacking(mudjacking)
- Filling of large underground cavities
- Densification of collapsible soils
- Densification of soils showing organic degradation

c) Circuit Grouting

- A drill hole is bored to the depth of the bottom zone and grout is pumped down the grout pipe and returned up the drill hole.

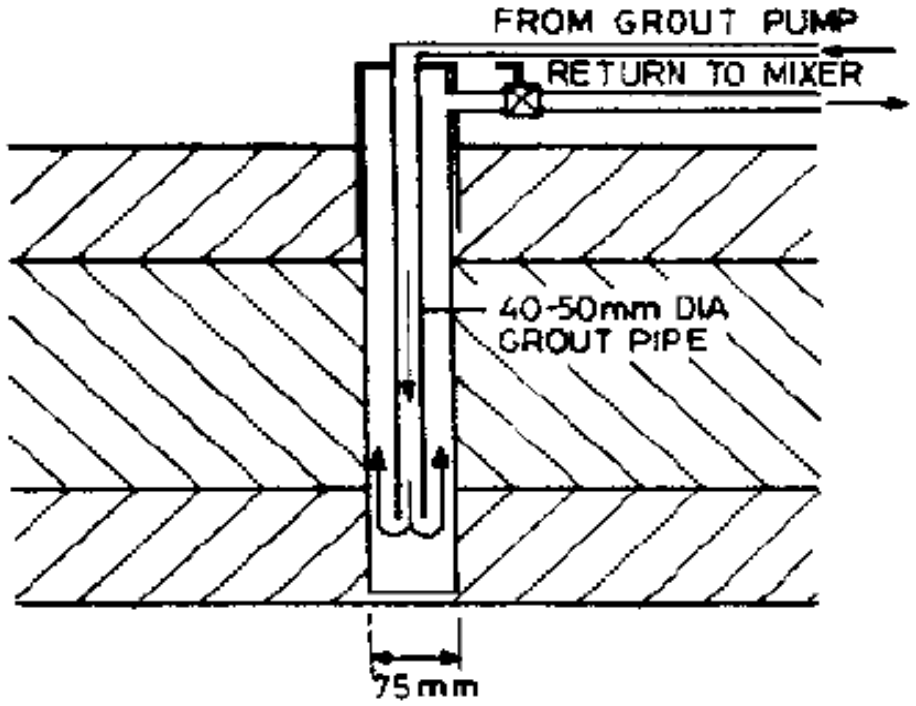


Fig. 6.12. Circulation grouting method.

d) Jet Grouting

- Involves the injection of low viscosity liquid grout into the pore spaces of granular soils. This creates hardened soils to replace loose liquefiable soils
- Jet grouting is used as replacement technique, in which soils ranging from silt to clay and weak rocks can be treated
- This method consists of lowering a drill pipe into a 150 mm dia bore hole
- The drill pipe is specially designed which simultaneously conveys pumped water, compressed air and grout fluid.
- Three systems of jet grouting depending on the nozzle'
  - Single, Double & Triple

Systems of jet grouting

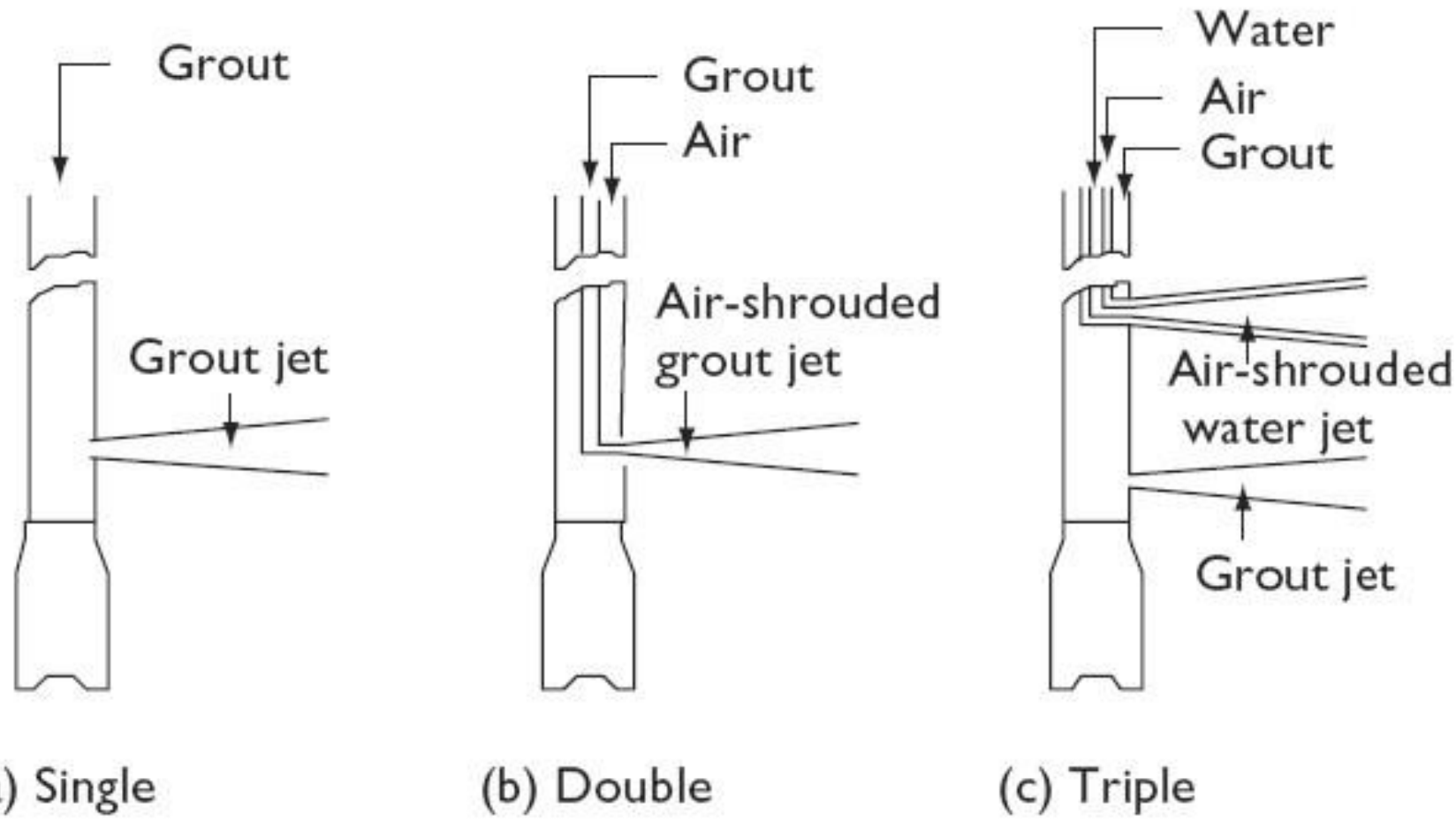


Figure 5.4 Single, double and triple jet grouting.

Sequence in Single Jet Grouting

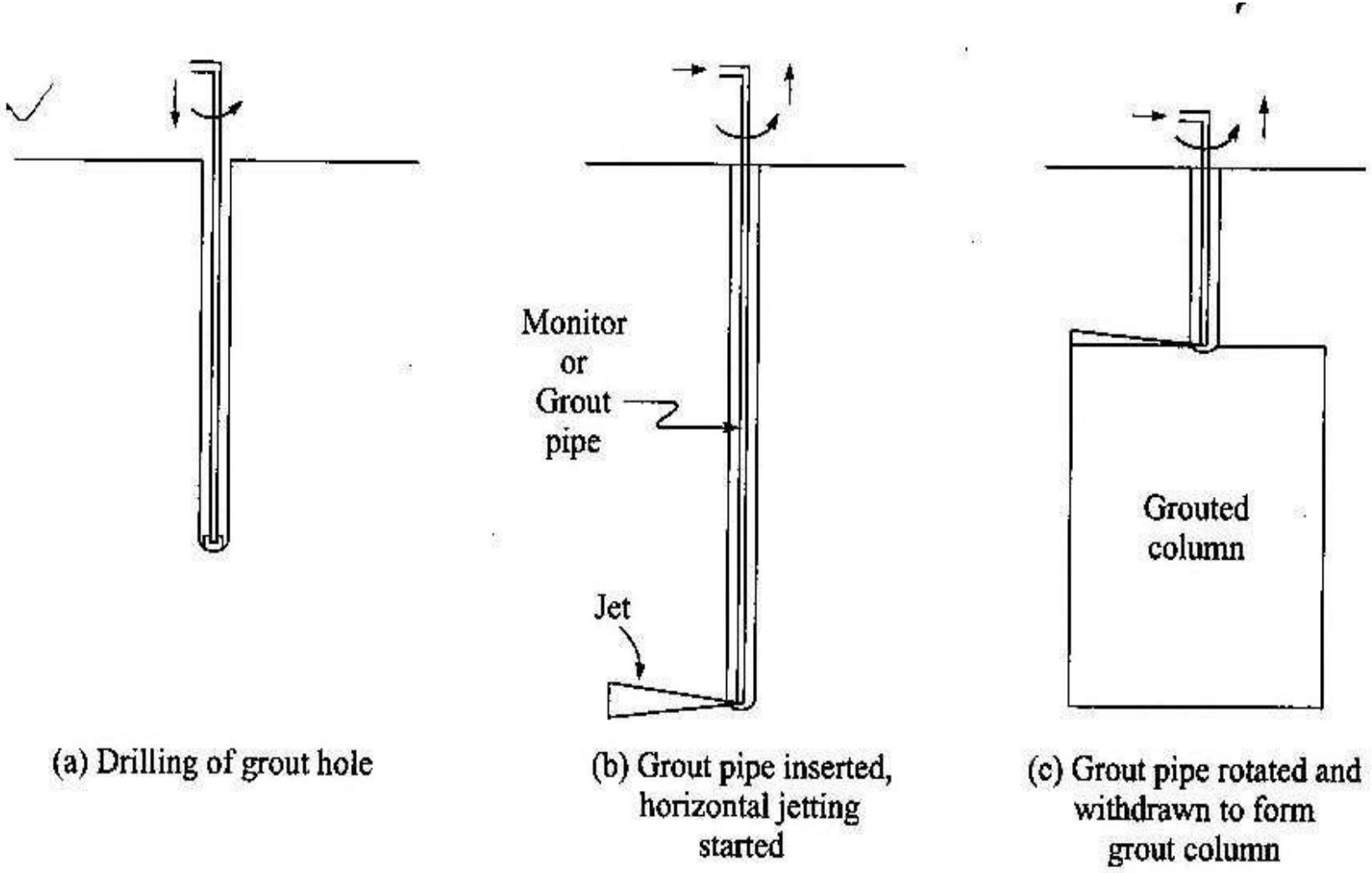
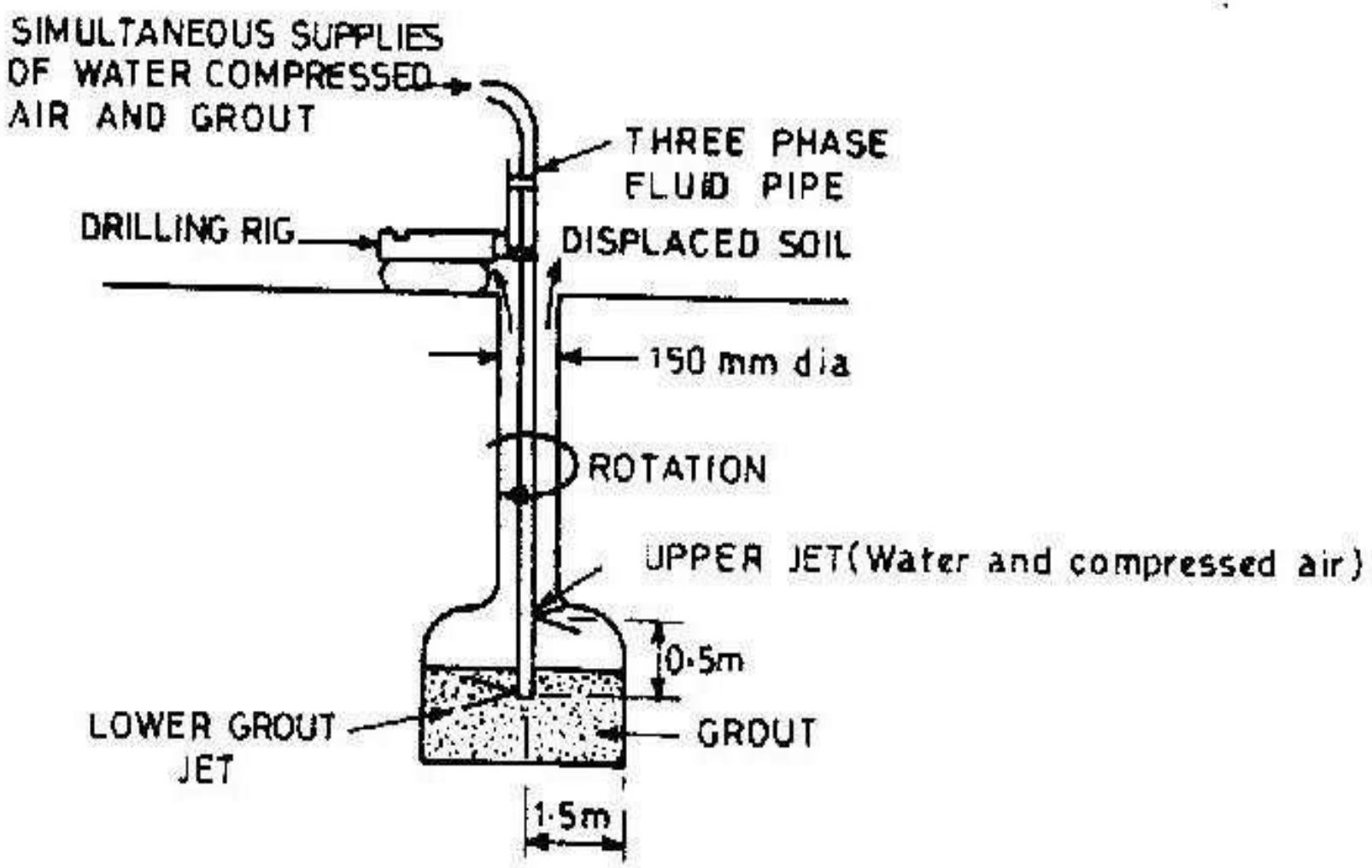


Fig. 31.14 The sequence followed in Jet grouting

Triple Jet Grouting

- At the bottom end of the pipe two nozzles are provided at 500 mm apart.
- The upper nozzle (1.8 mm diameter) delivers water surrounded by a collar of compressed air to produce a cutting jet.
- The grout is delivered through the lower nozzle (7mm dia) at 40 bar
- The excavated material produced from the jetting action is replaced by the grout and forced to the surface.

Triple Jet Grouting Method



e) Electro kinetic Injection

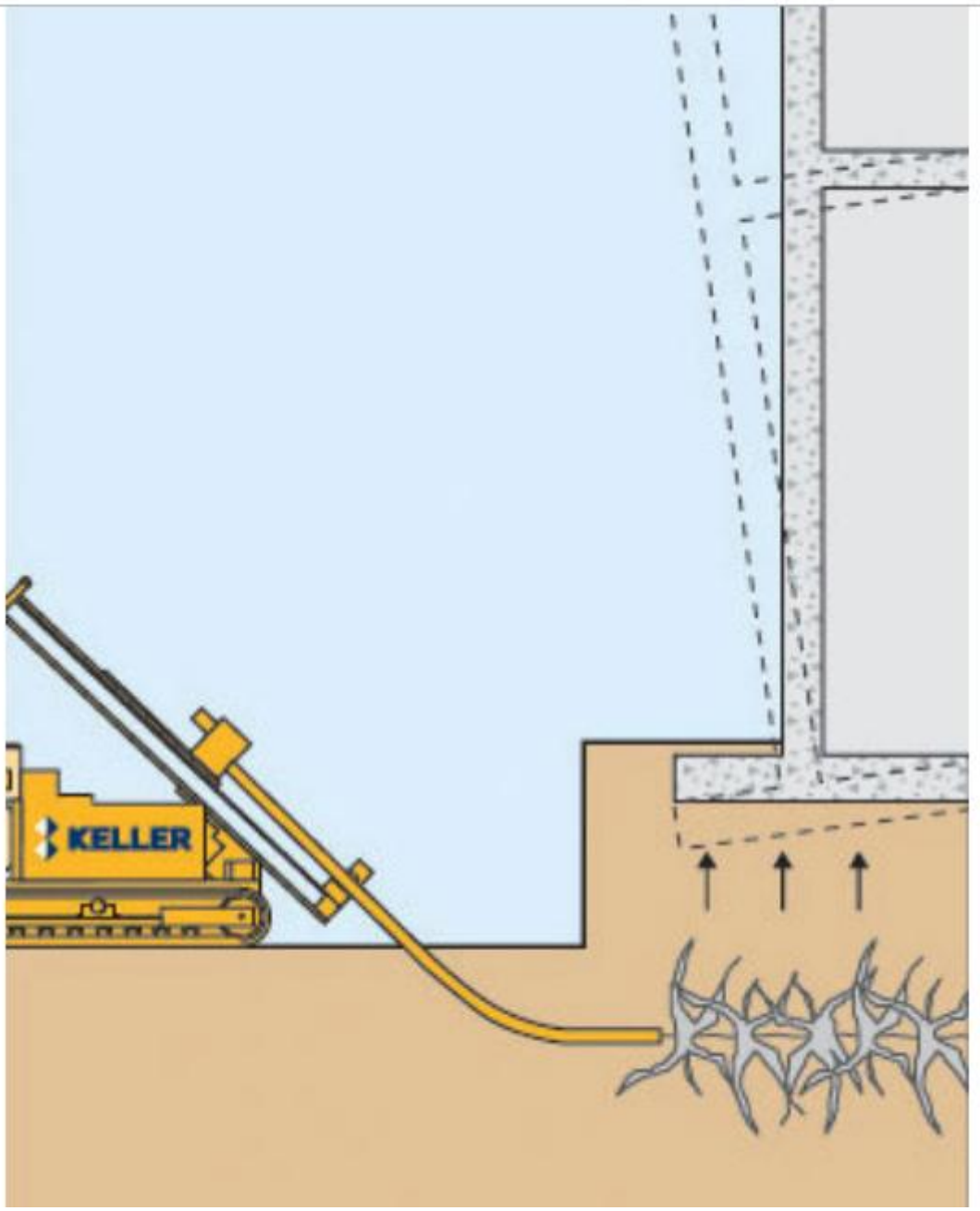
- Stabilization of silty soils may not be possible by chemical or admixture perhaps because of lack of confinement or the necessity to avoid disturbance of the ground.
- Chemical stabilizers are introduced at the anode and carried toward the cathode by electro-osmosis.
- Direct current electrical gradients of the order of 50 to 100 Volts/m are required.

f)Point Grouting

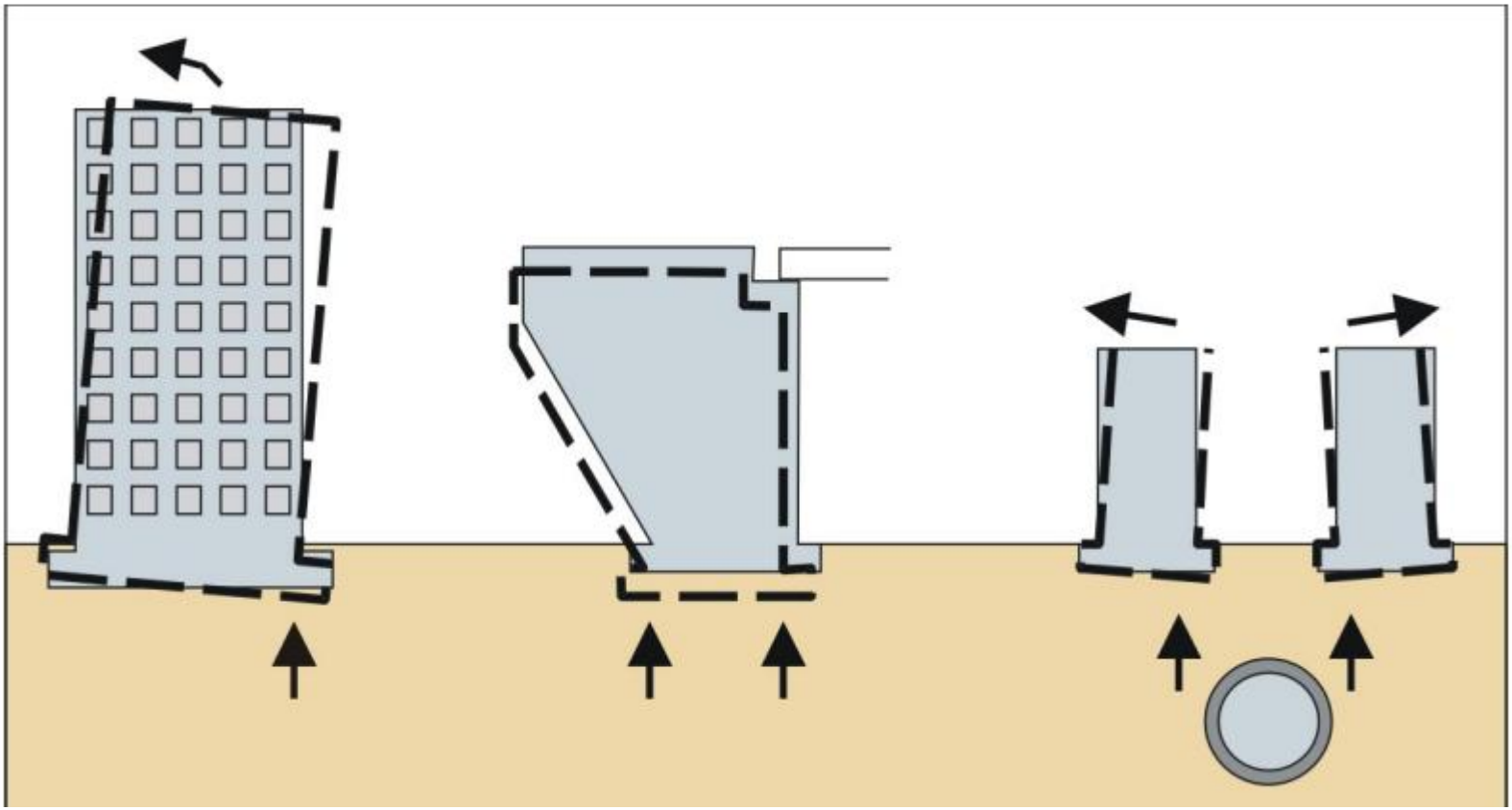
- It is a method of driving injection pipes to the points of failure and injecting the grout
- The applied grout will expand and cures quickly to seal off the leaks and fill voids in soil

f)Soil Fracture Grouting

- Fracture grouting (also referred to as compensation grouting or Soilfracture)
- construction begins beneath a structure by grouting a sleeve port pipe into a pre-drilled hole.
- Then, cement slurry grout is pressurized and injected through the pipe's ports at specific locations.
- The injected grout causes fractures to form in the soil, which are instantly filled and expanded by the flood of grout being pumped in.
- Used for restoration of verticality of a tilted building


KELLER

Uses for Soilfrac® Grouting



PREVIOUS YEAR QUESTIONS

- *Explain any 3 application of groutng(ktu18)*
- *Explain compaction grouting using neat sketch(ktu18)*
- *What are the objectives of grouting?*
- *What is a grout? Explain in detail the applications of grouting.*
- *Describe briefly different grouting techniques.*
- *Explain procedures involved in any types of grouting(ktu18)*

PREVIOUS YEAR QUESTIONS

- *What is the diff between suspension grout and solution grout(ktu18)*
- *What are the aspects of grouting?*
- *What is grouting? Explain the engineering benefits of grouting of soils?*
- *Describe the jet grouting technique of improving the soil with the neat sketches?*
- *What is Hydraulic fracturing? What are its uses and applications?*
- *Explain about stage grouting in detail?*