23CE707: GROUND IMPROVEMENT TECHNIQUES

Topic: Hydraulic Modifications

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Hydraulic modifications

- pore water is forced out of the soil via (by means of) drains.
- - In coarse grained soils , This is achieved by lowering the ground water level through pumping from boreholes or trenches.
- - In fine-grained soils, The long term application of external loads (preloading) or electrical forces (electro kinetic stabilization) is required.
- Hydraulic Modification can be termed as dewatering. Dewatering means modifying ground by lowering the water table, redirecting seepage or simply reducing its water content.

PURPOSES FOR DEWATERING

- To provide suitable working surface of the bottom of the excavation.
- Lowering the water table can also be utilized to increase the effective weight of the soil and consolidate the soil layers.

Vertical drains can be classified in to two types

- 1)sand drains
- 2)prefabricated sand drains(wick drains)

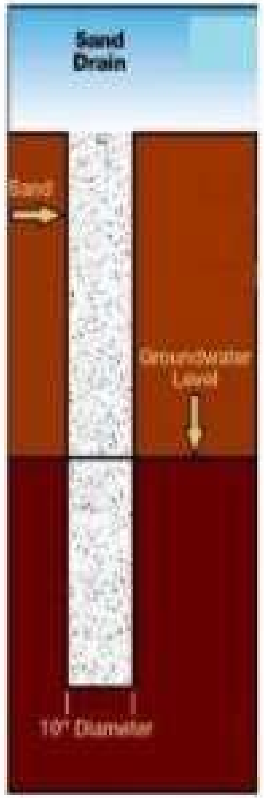
SAND DRAINS

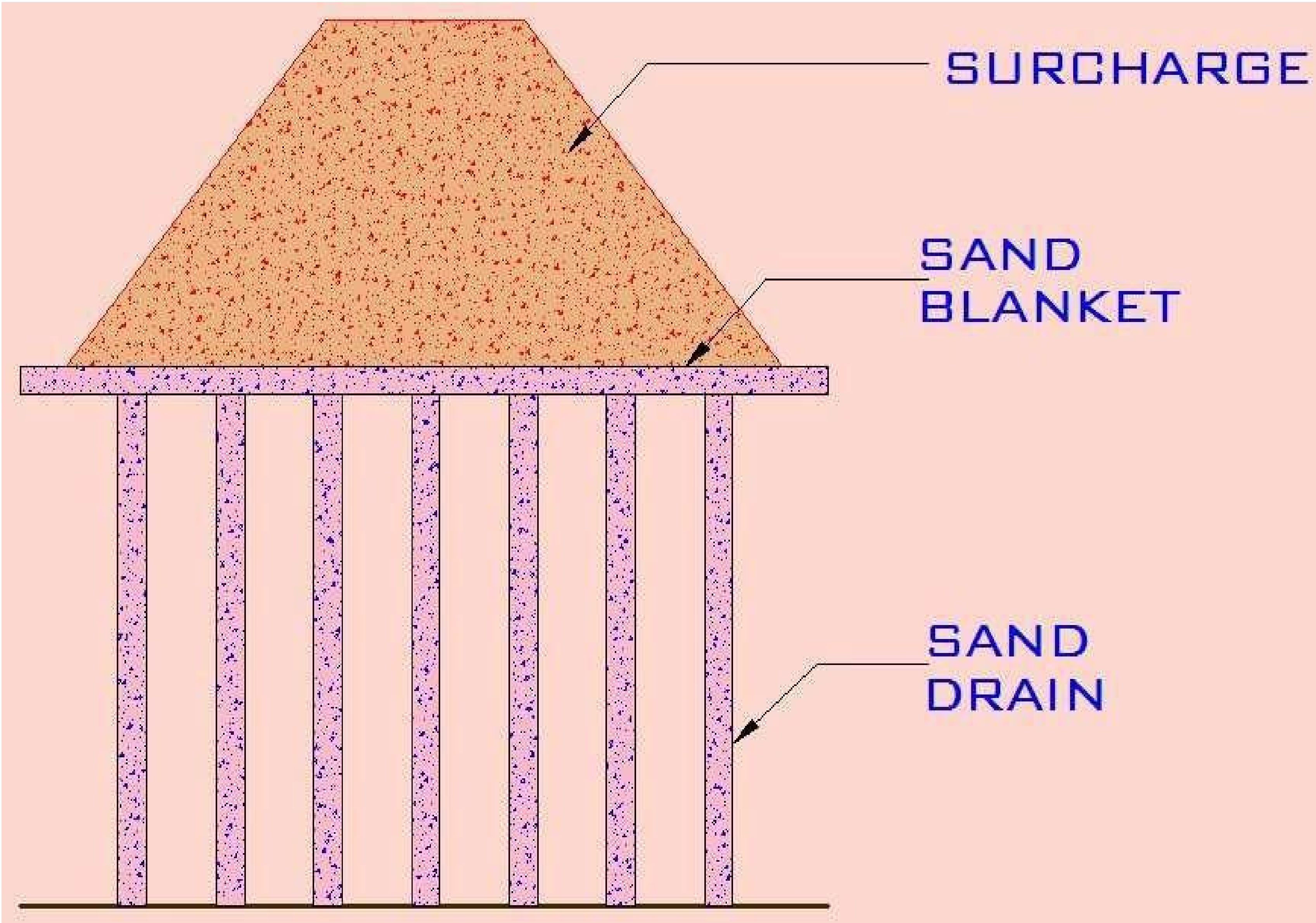
- The sand drain system uses to reinforce good to poor soils, including soft to stiff clay and silt, loose to dense sand, organic silt and peat.
- Sand drains are used to reinforce and stiffen compressible foundation soils and increase the time-rate of settlement by expulsion of pore water pressure.
- A circular casing or hollow steel mandrel, of about 25-cm internal diameter and 6-m height, is driven vertically into the soft soil up to the required depth

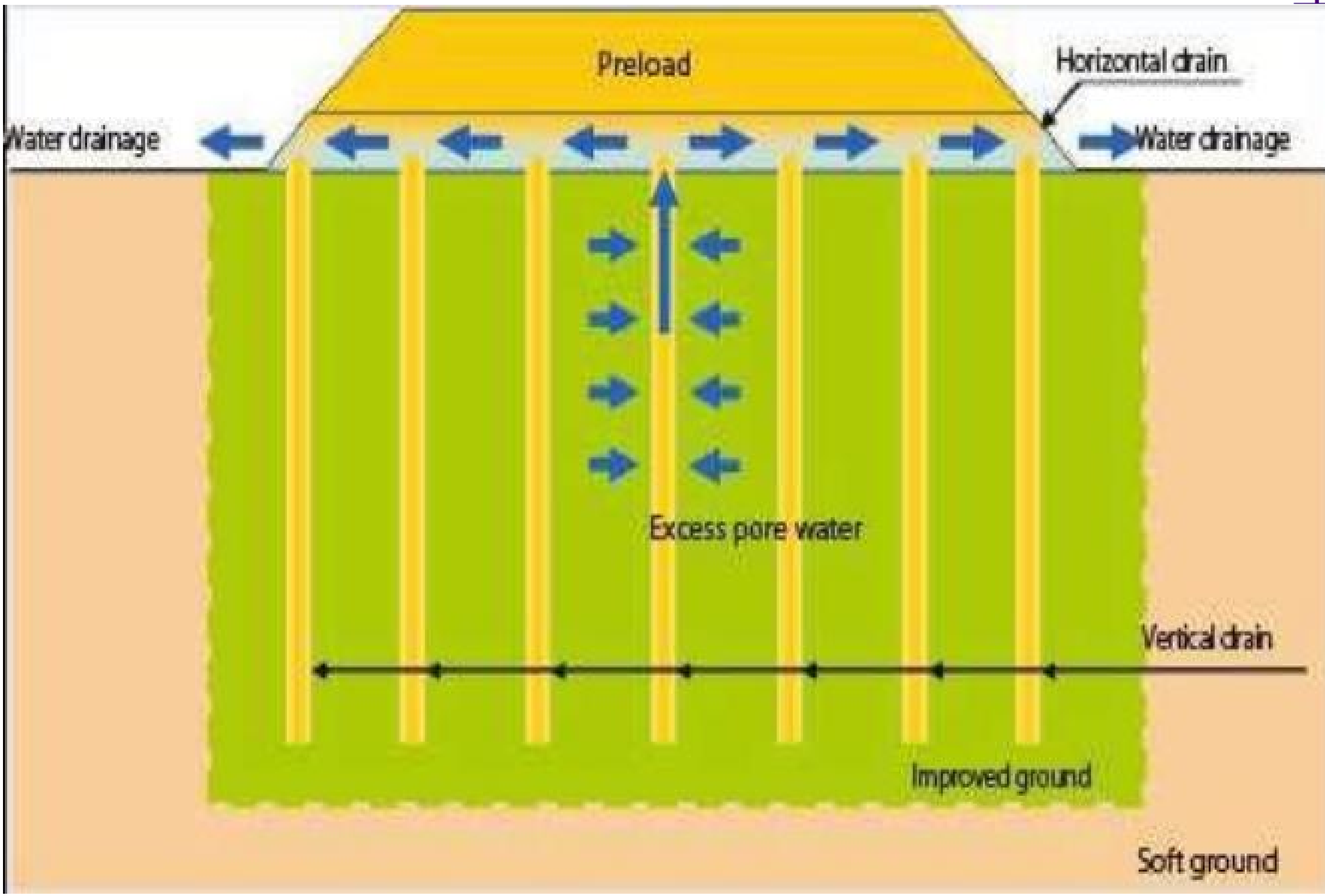
SAND DRAINS

A sand drain is a simple process, employing a column of at least 10 inches in width augered into ground to be surcharged & consolidated.

The column is then filled with sand and connected to a free-draining blanket of granular soil.




SURCHARGE
SAND
BLANKET
SAND
DRAIN



Preload
Horizontal drain
Water drainage
Water drainage
Excess pore water
Vertical drain
Improved ground
Soft ground

Three different techniques for installation of sand drains

- Mandrel drive
- Hollow stem continuous flight auger
- Jetted hollow or closed end pipe

Mandrel drive

- In this method a closed end pipe (mandrel) is driven to the bottom of the soil to be consolidated, it is filled with sand which is placed under approximately 100 Ib/in2 of air pressure and then it is gradually lifted out of ground. The closed end, being a hinged valve, opens and the sand under pressure rushes out.
- The pipe continues to be lifted until it reaches the ground surface.
- The entire process is then repeated for next sand drain.
- The cycle takes 2 to 10 minute, depending upon local conditions.

Hollow stem continuous flight auger

- Here a continuous flight auger of the diameter as the intended sand drains is rotated into the soil to the specified depth. Since the auger is formed around a hollow pipe, sand under pressure can be introduced into it.
- Auger is back rotated out of the hole; the sand drain is left behind and forms the sand drain.
- Cycle time for this installation method is 5 to 20 minutes.

Jetted hollow or closed end pipe

- The driving in to the soil of either hollow or either closed end hinged pipes via water jetting is also used for sand drain installation.
- After pipe placement, the sand is introduced under pressure as the pipe withdrawn.
- Cycle time is 5 to 20 minutes.

Process of construction of sand drains:

- The driven casing is withdrawn after the sand has been filled. A sand blanket is placed over the top of the sand drains to connect all the sand drains.
- To accelerate the drainage, a surcharge load is placed on the sand blanket. The surcharge is usually in the form of dumped soil.

Mechanism of consolidation:

- The pore water pressure is increased by the applied surcharge load in the embankment.
- The drainage occur in the vertical and horizontal directions. The horizontal drainage occur because of sand drains.
- The sand drains accelerate the process of dissipation of excess pore water created by the surcharge.

Spacing of Sand drains :

- The drains are generally laid either in a square pattern or a triangular pattern.
- The typical design parameter for sand drain may vary as below :

a) Spacing of sand drains, S = (2 ~ 5) m

b) Depth of sand drains = (3 ~ 35) m

c) Radius of sand drains well = (0.2 ~ 0.3) m

d) Thickness of sand blanket = (0.6 ~ 1) m

Application Of Sand Drains:

- Airport Runways
- Golf Courses
- Mine Tailings Consolidation
- Tailing Ponds
- Swampland/Wetland Development
- Building Foundations
- Retaining Walls
- Parking Lots
- Landfills

ADVANTAGES

- Provision of sand drains allows drainage of pore water in radial direction in addition to the drainage in vertical direction.
- With faster consolidation
- The long-term stability of the structure is also increased

- DISADVANTAGES

- Requires frequent maintenance.
- Time taking process about an years based on soil type.
- sand drains may have discontinuities if the mandril is withdrawn too fast

Wick drains

- sand drains people were using in the olden days. Now we are using pre-fabricated vertical drains.
- It is composed of a polypropylene strip with drainage channels wrapped in a geotextile filter fabric
- In this drain, you have a drain inside, which has drainage channels; so, the moment you apply the load, water comes here, and then goes to the drainage channels.

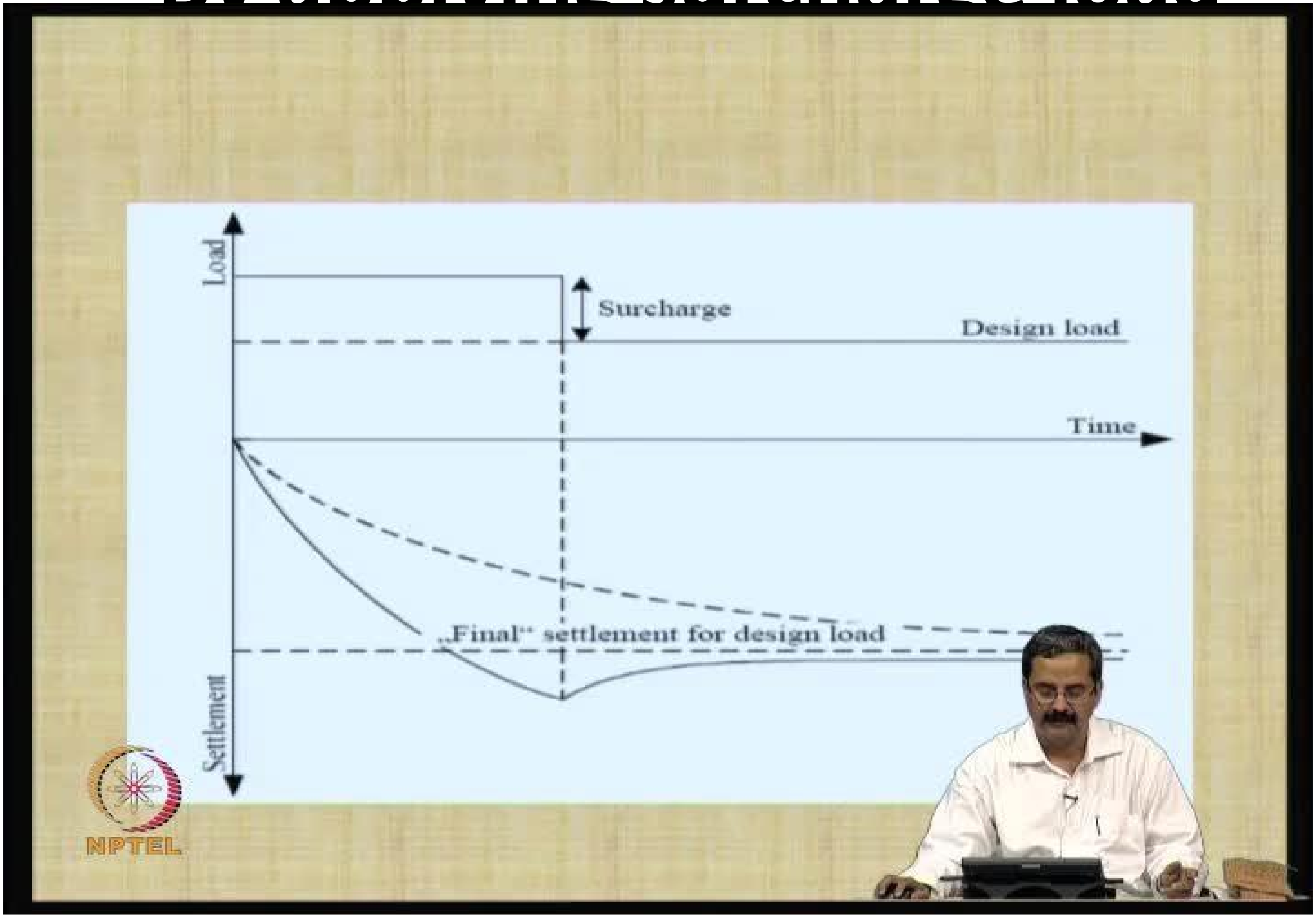
- wick drains are prefabricated vertical drains installed to accelerate the consolidation of compressible soils.
- The drain consists of a geotextile filter-wrapped plastic strip with extruded channels that allow water to drain from soft soil as it consolidates under an applied surcharge load.
- The geotextile filter prevents soil particles from entering the channels and clogging the drain.
- The time required for the consolidation to occur depends on the permeability of the soft strata, the existence of sand layers in the strata, the weight of the surcharge, and the spacing of the wicks.


VOLVO


Applications

- Wick drains can be applied to any site that requires consolidation, including sites for:
- Roadway embankments
- Bridge approaches and overpasses
- Storage tanks
- Dams
- residential buildings
- Railway embankments
- Mining wastes and tailings

By applying surcharge load



Installation procedure of wick drains

- Before installation can begin, the working surface must be prepared to ensure a stable working platform.
- Since wick drain sites are typically soft, a sand or gravel blanket may be needed to provide support for the equipment.
- The sand and gravel will also act as a drainage blanket to direct water away from the treatment area.
- Drains can be installed up to 140 feet deep from a track-mounted excavator

- The installation force is typically provided by vibratory hammers, static force methods, or a combination of these methods depending on the soil conditions.
- Generally PVD is installed by using a MANDREL mounted on a installation machine.
- MANDREL is a metallic hollow tube either rectangular or cylindrical contains the PVD.
- A disposable metallic shoe is connected at the end of the mandrel so that PVD can be easily inserted within the soil.
- After inserting the PVD the mandrel is extracted while the PVD remains at its position within the ground.

Wick drain material

- The wick drain material is a 4-in. wide x 0.25-in. (100 mm x 0.64 mm) thick plastic band shaped conduit.
- It is composed of a polypropylene strip with drainage channels wrapped in a geotextile filter fabric.

Figure 5. Example of wick drain material rolls.

Spacing

- Layout usually consists of triangular or square grid patterns.
- Typical spacing ranges from 2.5 to 8 feet on center.

PVD Installation Sequence

- Position Rig at Drain Location
- Place Anchor on Drain End
- Penetrate Mandrel to Desired Depth
- Withdraw Mandrel
- Cut Drain Material Above Drainage Blanket

INSTALLATION METHODS OF VERTICAL DRAINS

GROUP DESCRIPTION	PARTICULAR METHODS	REMARKS
DISPLACEMNT METHODS	Driving Vibration Pull Down(static Force) Washing Combinations Of Above	A mandrel with or without a disposal shoe is used in each case

Continued…

GROUP DESCRIPTION	PARTICULAR METHODS	REMARKS
DRILLING METHODS	Rotary drill, with or without a casing Rotary anger, including continuous standard and hollow fight augers Percussive(shell and auger) methods, with or without casing Hand auger	A mandrel with or without a disposal shoe is used in each case.

Continued…

GROUP DESCRIPTION	PARTICULAR METHODS	REMARKS
WASHING METHODS	Rotary wash jet Washed open ended case Weighted wash jet head on flexible hose	Methods in which sand is washed in via the jet pipe are not suitable for prefabricated drains

Ground Improve

Depth of PVD	10.00 m to 18.00 m below OGL
Spacing of PVD (Triangular)	1.00 m c/c below stacker reclaimers 1.50 m c/c in other area
Consolidation Period	For 1.00 m spacing: 65 days For 1.50 m spacing:
Thickness of Sand Mat	300 mm
Horizontal Drainage System	Geotextile pipes filled by boulders / gravels; PVD laid horizontally
Machinery Used	Hydraulic Stitchers

Advantages

- There is no risk of PVDs breaking installation, while sand drains may have discontinuities if the mandril is withdrawn too fast.
- There is no risk of shear failure of PVDs during settlement, while sand drains are vulnerable to shear failure during settlement.
- PVDs have discharge capacities, typically 30 X 10-6 to 90 X 10-6 m3/s, while a 0.35 m diameter sand drain has a discharge capacity of 20 X 10-6 m3/s

- When installed with a properly designed mandril, smear effects are much less for PVDs than for large diameter sand drains. The zone of smear is directly proportional to the diameter of mandril used for installation.
- PVDs are factory produced materials and are quality controlled, whereas sand drains are subject to the quality variance of naturally occuring sands.

Disadvantages

- If the compression layer is overlain by dense fills or sands, very stiff clay or other obstructions, drain installation could require predrilling, jetting, and/or use of a vibratory hammer, or may not even be feasible under such conditions, general pre-excavation can be performed if appropriate.
- Cost is more.

Example:

During construction of a highway bridge, the average permanent load on the clay layer is expected to increase by about 115 kN/m^3. The average effective overburden pressure at the middle of the clay layer is 210 kN/m^3. Here, $H_c = 10m$, $C_c = 0.81$, $e_o = 2.7$ and $C_v = 1.08 m^2/month$. The clay is normally consolidated. Determine

a. The total primary consolidation settlement of the bridge without precompression.

b. The surcharge, $\Delta\sigma'_{(f)}$, needed to eliminate the entire primary consolidation settlement in nine months by precompression.

Solution

Part a
The total primary consolidation settlement may be calculated from Eq(1):

$$S_{c(p)} = \frac{C_c H_c}{1 + e_o} \log \frac{\sigma'_o + \Delta\sigma'_{(p)}}{\sigma'_o}$$

$$= \frac{(0.81)(10)}{1 + 2.7} \log \left[\frac{210 + 115}{115}\right]$$

= 0.4152m = 415.2mm

Part b We have,

$$T_v = \frac{C_v t_2}{H^2}$$

$C_v = 1.08\ m^2/\text{month}$.

$H = 6m$ (two way drainage)

$t_2 = 9$ months.

Hence,

$$T_v = \frac{(1.08)(9)}{6^2} = 0.27$$

According to Figure 3, for $T_v = 0.27$, the value of U is 40%.

we have,

$\Delta\sigma'_{(p)} = 115\ kN/m^2$

and $\Delta\sigma'_o = 210 kN/m^2$

so

$$\frac{\Delta\sigma'_{(P)}}{\sigma'_o} = \frac{115}{210} = 0.548$$

According to Figure 2, for U=40% and $\Delta\sigma'_{(p)}/\sigma'_o = 0.548$,
$\Delta\sigma_{(f)}/\sigma'_{(p)} = 2.5$; $\Delta\sigma'_{(f)} = (2.5)(115) = 287.5 kN/m^2$

Assuming a bulk density of 20 kN/m^3 for fill material and a height of 5m gives a pre-load of 100 kN/m^2. The required surcharge is higher than pre-load and hence consolidation by sand drains/PVDs is required.

Vaccum consolidation

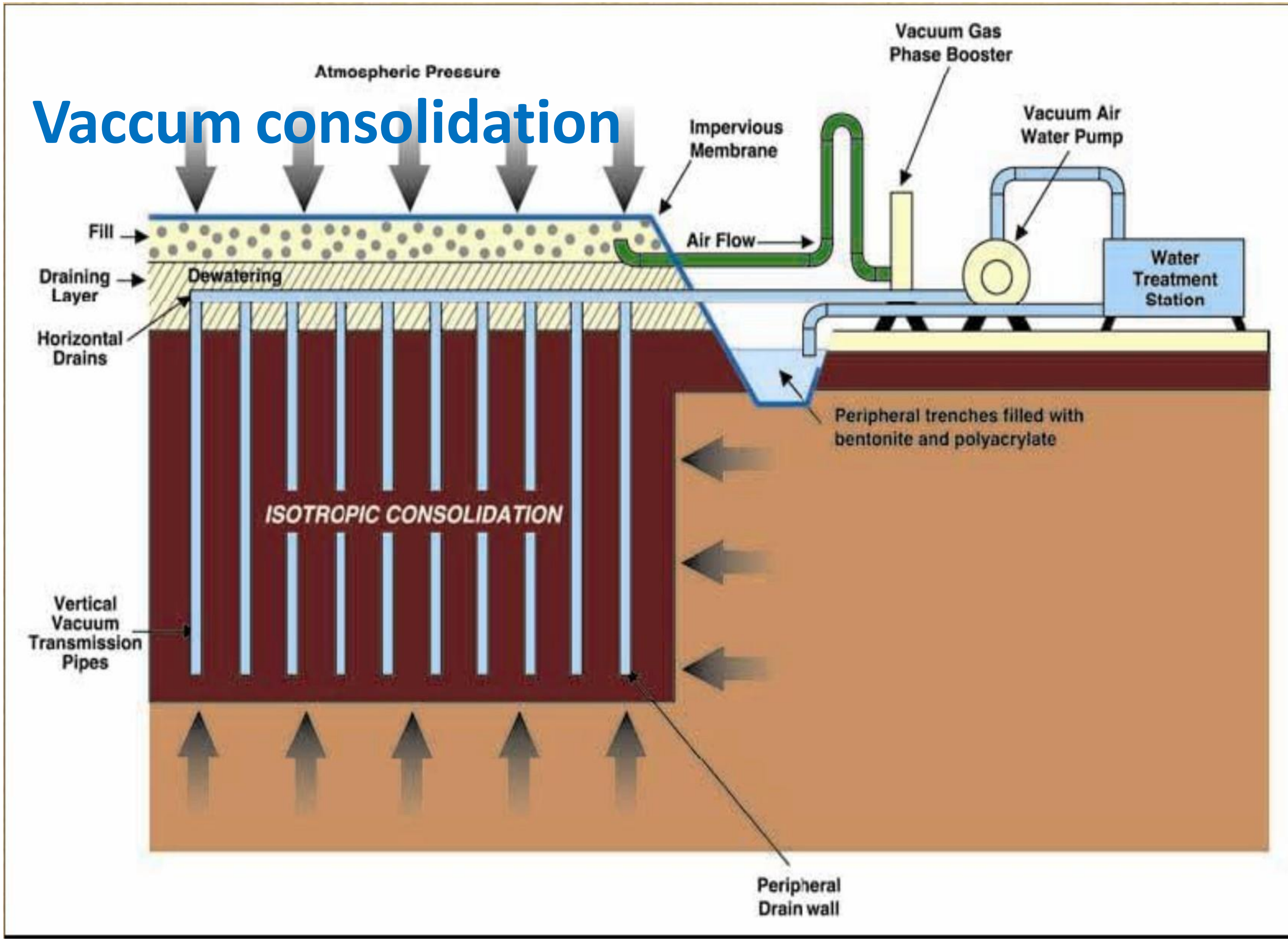
- Vacuum consolidation was first proposed in the early 1950s by Kjellman (1952), the developer of the prefabricated vertical "wick" drain. In the 1960s, isolated studies of vacuum induced or assisted consolidation continued for the next two decades (Holtz 1975). However, vacuum consolidation was not seriously investigated as an alternative to conventional surcharging until recently due to the low cost of placing and removing surcharge fills and the difficulties involved in applying and maintaining the vacuum.

- The steadily increasing direct and indirect costs of placing and removing surcharge fill the vacuum- consolidation an economically viable method as a replacement for or supplement to surcharge fill.
- Vacuum Consolidation is an effective means for accelerating the improvement of saturated soft soils.
- The soil site is covered with an airtight membrane and a vacuum is created underneath it by using a dual Venturi and vacuum pump.
- The technology can provide an equivalent pre-loading of about 4.5 m high as compared with a conventional surcharging fill.

- Instead of increasing the effective stress in the soil mass by increasing the total stress as in conventional mechanical surcharging, vacuum-assisted consolidation preloads the soil by reducing the pore pressure while maintaining a constant total stress.

- The effectiveness can be increased when applied with combination of a surcharge fill. Field experience indicates a substantial cost and time savings by this technology compared to conventional surcharging.

Vaccum consolidation



The current main application of vacuum assisted consolidation include:

- Replacement of standard pre-loading techniques, eliminating the risk of pre-loading induced foundation failures.
- Combining VCP with water pre-loading in scare fill areas. The method has been used to build large development projects on thick compressible soil.
- Combining VCP with surcharge pre-loading to increase foundation stability and thereby optimize pre-loading stage sequence and reduce project time.

DEWATERING

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

Purpose of Dewatering

- dry excavation
- work efficiently
- To decrease seepage and pore water pressure
- Improve characteristics of foundation materials
- Increase stability of slopes
- Prevent frost heaving in pavements

Factors Controlling Selection

- Nature and Permeability of Ground
- Geological conditions of soil
- Extent of area to be Dewatered
- Depth of Water table below ground level
- Amount by which it has to be lowered
- Proposed methods of excavation and ground support
- Proximity of existing structure

HOW IT IS DONE?

Collection of water → Pumping → Filtering and removing silt and impurities → Discharge at proper location

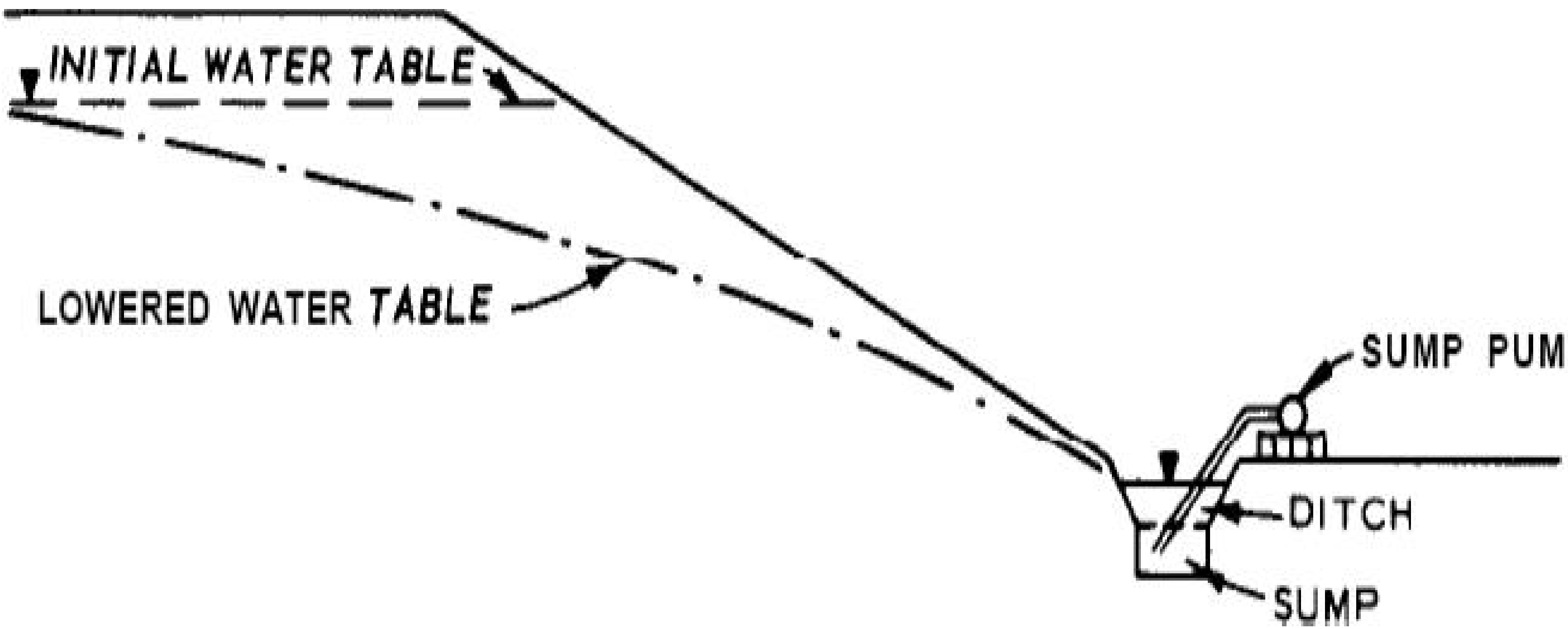
Methods of Dewatering

- Open sumps and ditches
- Well point systems
- Deep well drainage
- Vacuum Dewatering Systems
- Electro Osmosis

Open sumps and ditches

- The essential feature of this method is a sump below the ground level of the excavation at one or more Corners or sides..
- A small ditch is cut around the bottom of the excavation , falling towards the sump.
- It is the most widely used and economical of all methods of ground water lowering. Sumps provide localized, very shallow dewatering (less than 3 feet) and consist of pumping from perforated drums or casings in a gravel-filled backhoe pit. Sumps work best in fine grained soils, or very coarse, boulder deposits.
- There is also a disadvantage that the groundwater flows towards the excavation with a high head or a steep slope and hence there is a risk of collapse of the sides.

Open sumps and ditches



Open sumps and ditches

Advantages	Disadvantages
1. Widely used method. 2. Most economical method for installation and maintenance. 3. Can be applied for most soil and rock conditions. 4. Most appropriate method in situation where boulders or massive obstructions are met within the ground. Greatest depth to which the water table can be lowered by this method is about 8 m below the pump.	1. Ground water flows towards the excavation with high head or a steep slope and hence there is a risk of collapse of sides. 2. In open or timbered excavations there is risk of instability of the base due to upward.

Well point systems

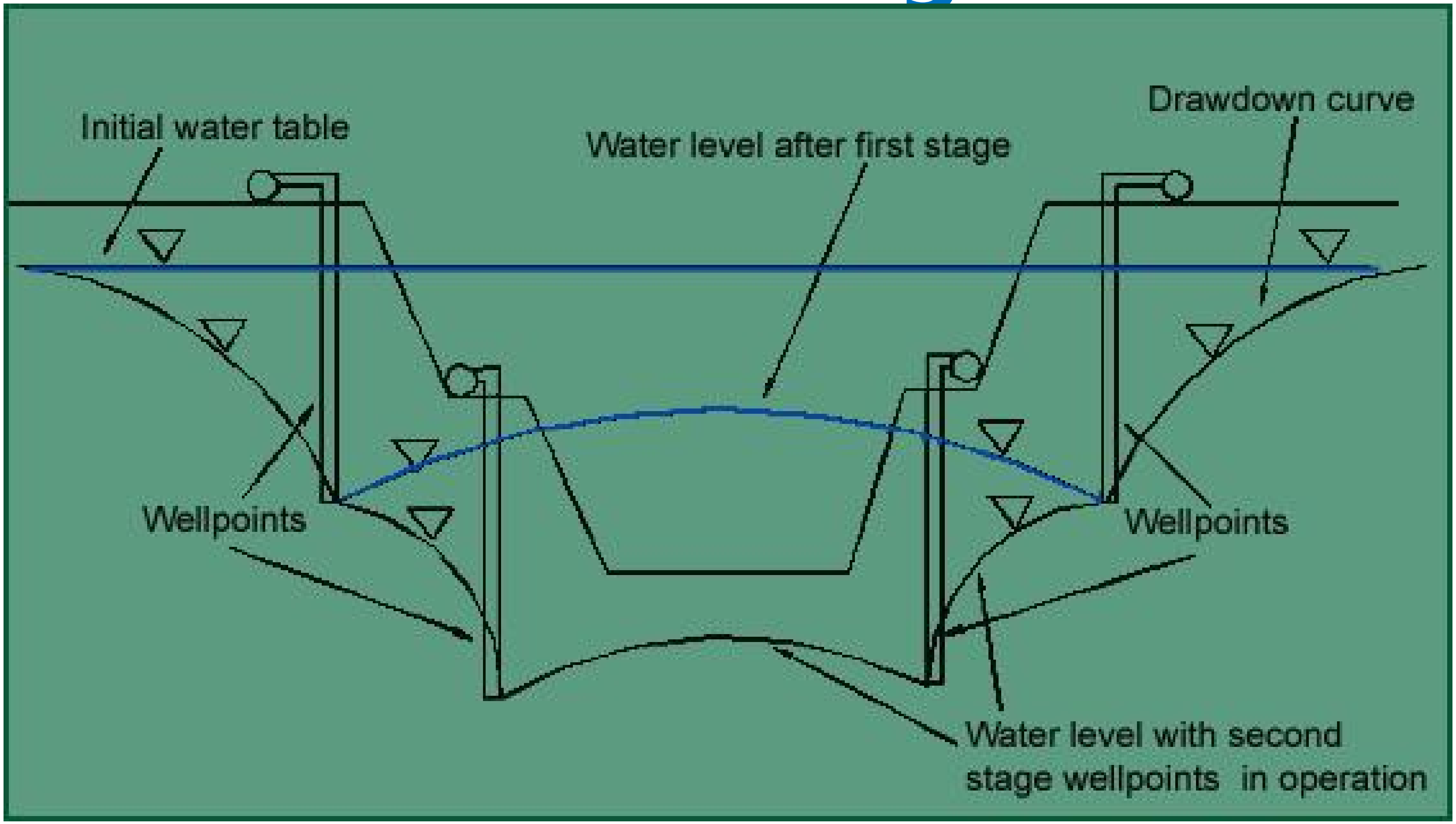
- Wells are systematically drilled around the construction area and submersible pumps placed into these wells.
- Wells are large-diameter (greater than 6 inches) holes, drilled relatively deep (greater than10 feet), and contain slotted casings and down hole pumps
- This practice appears to work effectively for many projects, especially those building projects that require excavations for deep basements.
- For dewatering deeper excavations, the well points must be installed in two or more stages

1. Single stage unit
2. Double stage unit

Setup and Procedure of working:

- A well-point is 5.0-7.5 cm diameter metal or plastic pipe 60 cm – 120 cm long which is perforated and covered with a screen.
- The lower end of the pipe has a driving head with water holes for jetting as shown in fig. Well-points are connected to 5.0-7.5 cm diameter pipes known as riser pipes and are inserted into the ground by driving or jetting.
- The upper ends of the riser pipes lead to a header pipe which, in turn, connected to a pump. The ground water is drawn by the pump into the wellpoints through the header pipe and discharged as shown in fig.
- The well-points are usually installed with 0.75m – 3m spacing

Double stage unit



Well point systems

Well point systems

Advantages	disadvantages
1. Effective in sandy soils 2. Provide drawdown up to 5-6 meters in sand and 4 meters in silty soil. 1. Relatively cheap and flexible 2. Installation is very rapid. 3. Water is filtered and carries little or no soil particles. 4. There is less danger of subsidence of the surrounding ground than with open-sump pumping	1. Not effective beyond 4-6 meters of drawdown 2. Might require stages of well installation.

DEEP WELL

- Deep well drainage system consists of deep wells and submersible or turbine pumps which can be installed outside the zone of construction operations and the water table lowered to the desire level.
- Deep wells are usually spaced from 8-80 meters depending upon the level to which water table must be lowered, permeability of the sand stratum, source of seepage and amount of submergence available.
- Deep wells may be combined with the well point system on certain field conditions for lowering the ground water tables

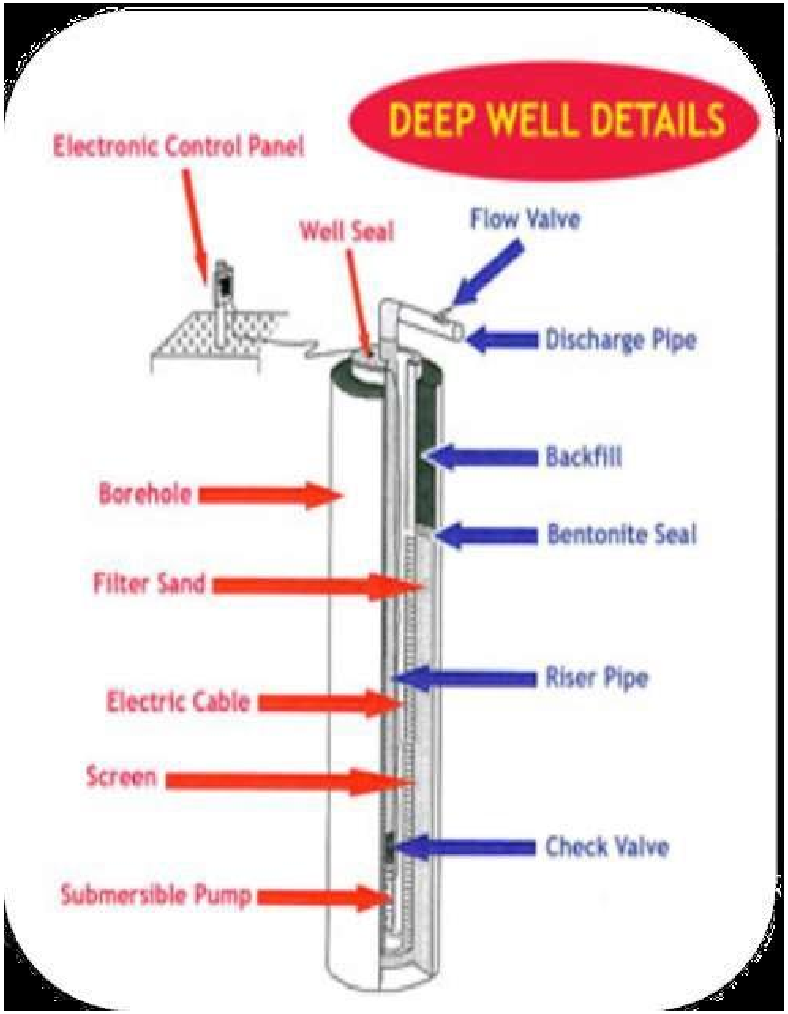
SPACING OF DEEP WELL POINT SYSTEM

- Normally, individual wells are spaced at an approximate distance of 15 m (50 feet) apart.
- However, depending upon soil conditions and the dewatering plan the spacing may need to be just a few meters apart.

DEWATERING CAPACITY OF DEEP WELL POINT SYSTEM

- Individual well capacities are from 2100 to 3000 gallons per minute and with total systems the capacities can be as high as 60,000 gallons per minute.
- Deep well pumps can lift water 30 m (100 feet) or more in a single stage and the variation of the typical deep well system is a pressure within an aquifer.
- Deep well points require no pump as the water is forced to the surface by its own pressure. To boost the water flow a vacuum pump is frequently used.

Deep well point system



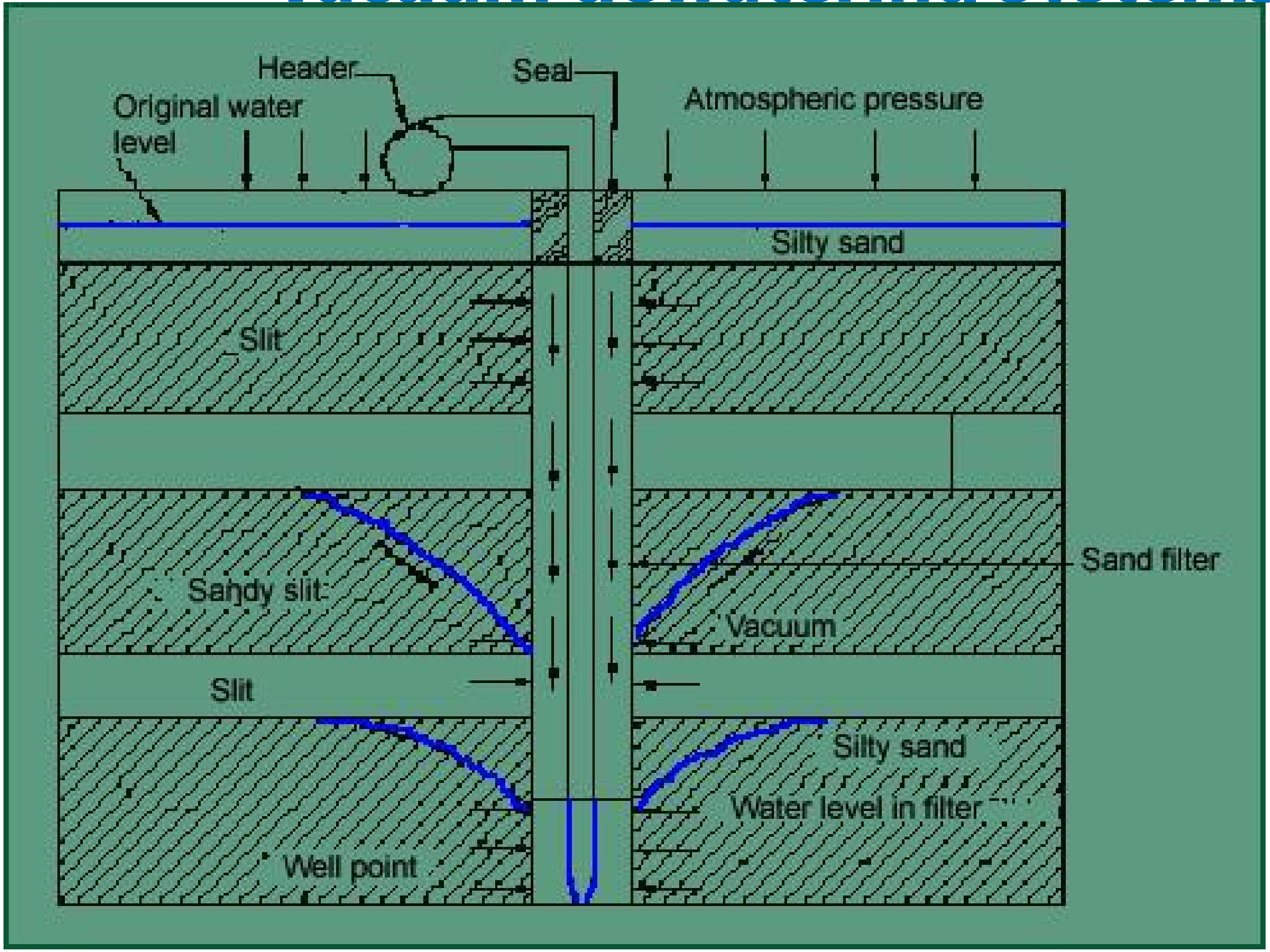
Deep well point system

advantages	Disadvantages
1. No limits on drawdown 2. Fewer wells required than well system	1. Expensive to install

Vacuum dewatering systems

- Gravity methods, such as well points and deep wells are not much effective in the fine-grained soils. Such soils can be dewatered satisfactorily by applying a vacuum to the piping system.
- A vacuum dewatering system requires that the well-point screens, and rise a pipe be surrounded with filter sand extending to within a few metres of the ground surface.
- This method is most suitable in layered or stratified soils.

Vacuum dewatering systems



Design steps for dewatering systems

- Design of a dewatering system requires the determination of the number, size, spacing, and penetration of wells or well points and the rate at which water must be removed from the pervious strata to achieve the required groundwater lowering or pressure relief. The size and capacity of pumps and collectors also depend on the required discharge and drawdown.
- The essential steps involved in the designing of the dewatering system are given below:

1. **Subsoil investigation**
2. **Source And Water Table Details**
3. **Distance of well points**

4.Effective Wall Radius

- The effective wall radius is decided based on the installation of the wells with or without filter. If a well is installed without gravel or a sand filter the effective radius can be taken as one half the outer diameter of the well screen. If a filter is used, the well radius is taken as one half the outside diameter of the filter

5.Discharge computations

The discharge Q of the well is then calculated using the formula given below:

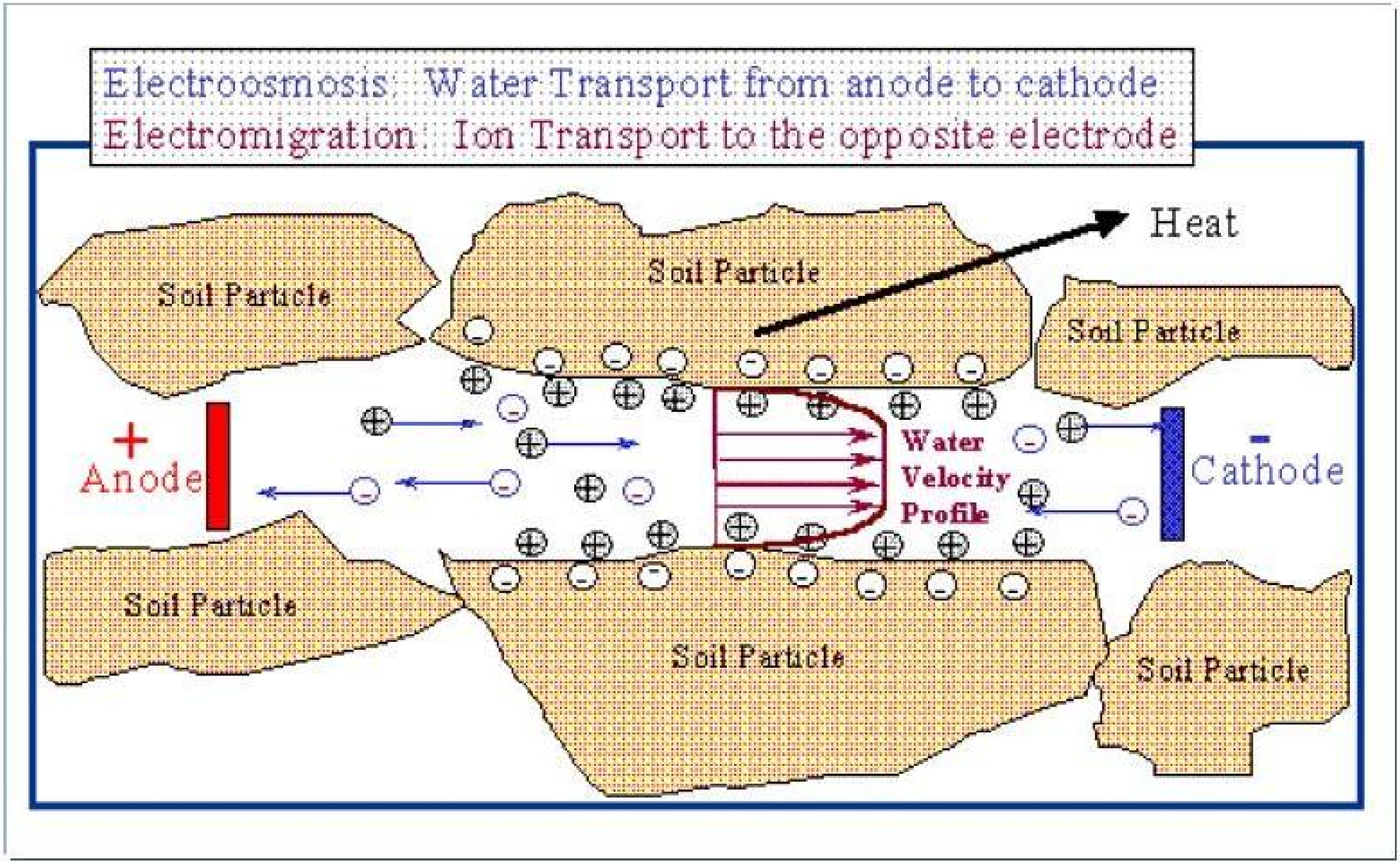
$$Q = \pi k \frac{H^2 - h^2}{2.3 \log_{10}\left(\frac{R}{r}\right)}$$

where Q is the discharge, k is the permeability, H is the depth of strata, h is the height of water in the well, r is the radius of well, R is the radius of influence.

Electro osmosis

- Dewatering Technique is done through the use of cathodes and anodes with passage of Electrical current.
- Electro-osmosis is defined as “the movement of water through a porous media by applying a direct current (DC) field”.
- It is the only effective method of dewatering in deep clay soils, silty clays, silts and some peats.

Electro osmosis



Mechanism of Electro-osmosis

- When electrodes are placed across a clay mass and a direct current is applied, water in the clay pore space is transported to the cathodically charged electrode by electro-osmosis.
- Electro-osmotic transport of water through a clay is a result of diffuse double layer cations in the clay pores being attracted to a negatively charged electrode or cathode.
- The macroscopic effect is a reduction of water content at the anode and an increase in water content of the clay at the cathode.

Effectiveness of Electro-osmosis

- First, electro-osmosis provides uniform pore water movement in most types of soil.
- The entire soil mass between the electrodes is basically treated equally

Disadvantages

- Installation and running costs are usually high.