UNIT-3

Hydraulic Modifications

Dewatering or construction dewatering are terms used to describe the action of removing groundwater or surface water from a construction site. Normally dewatering process is done by pumping or evaporation and is usually done before excavation for footings or to lower water table that might be causing problems during excavations. Dewatering can also be known as the process of removing water from soil by wet classification.

PURPOSES FOR DEWATERING

- For construction excavations or permanent structures that are below the water table and are not waterproof or are waterproof but are not designed to resist the hydrostatic pressure
- Permanent dewatering systems are far less commonly used than temporary or construction dewatering systems
- To provide suitable working surface of the bottom of the excavation.
- To stabilize the banks of the excavation thus avoiding the hazards of slides and sloughing.
- To prevent disturbance of the soil at the bottom of excavation caused by boils or piping. Such disturbances may reduce the bearing power of the soil.
- Lowering the water table can also be utilized to increase the effective weight of the soil and consolidate the soil layers. Reducing lateral loads on sheeting and bracing is another way of use.

VARIOUS METHODS OF DEWATERING

- ➢ Surface water control like ditches, training walls, embankments. Simple methods of diverting surface water, open excavations.
- ➢ Simple pumping equipment. Gravity drainage. Relatively impermeable soils. Open excavations especially on sloping sites. Simple pumping equipment.
- ➢ Sump pumping
- ➢ WellPoint systems with suction pumps.
- ➢ Shallow (bored) wells with pumps.
- ➢ Deep (bored) wells with pumps.

- Educator system
- Drainage galleries. Removal of large quantities of water for dam abutments, cut-offs, landslides etc. Large quantities of water can be drained into gallery (small diameter tunnel) and disposed of by conventional large – scale pumps.
- Electro-osmosis. Used in low permeability soils (silts, silty clays, some peats) when no other method is suitable. Direct current electricity is applied from anodes (steel rods) to cathodes (well-points, i.e. small diameter filter wells)

ADVANTAGES AND DISADVANTAGES

ADVANTAGES

- Reduces the amount of sediment leaving the site
- Allows for a more in-depth site assessment – additional necessary erosion control measures may be identified

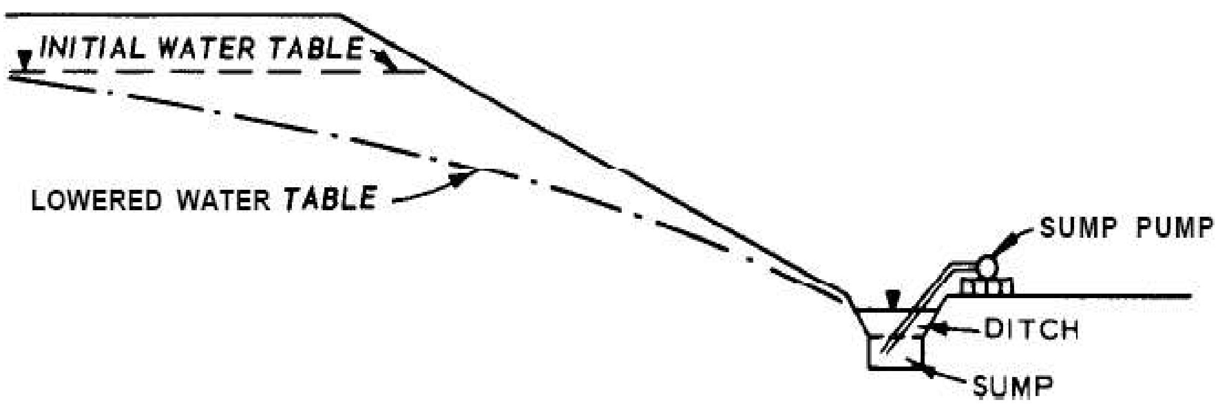
DISADVANTAGES

- Must abide by multiple government laws and standards and obtain appropriate permits
- Requires frequent maintenance
- May be costly

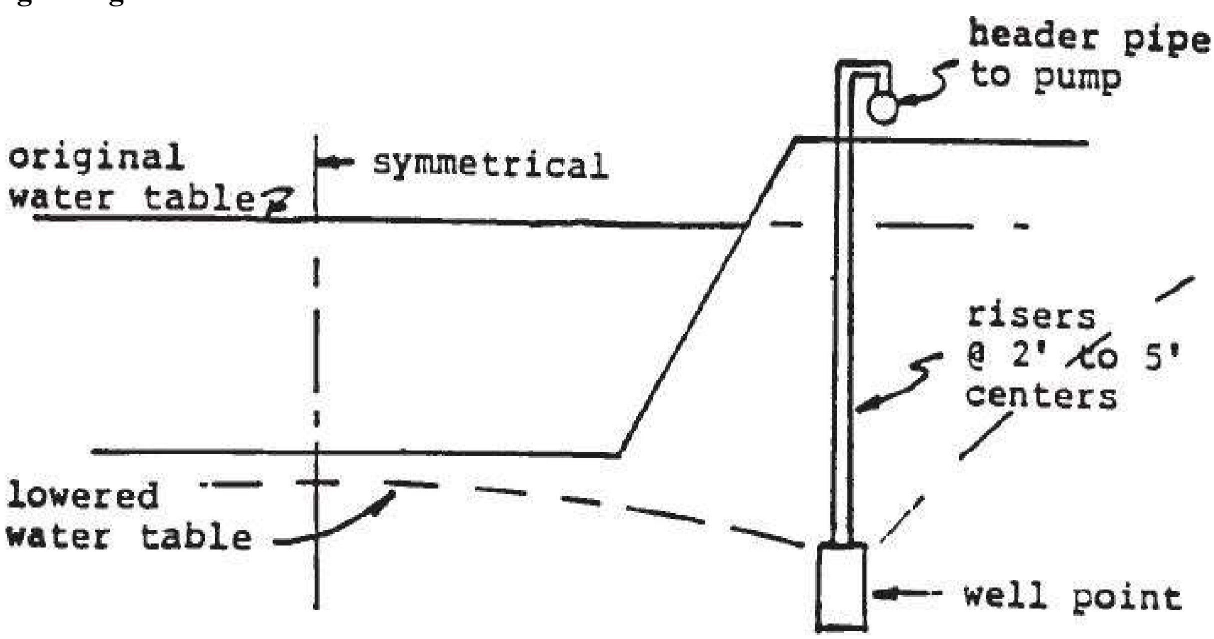
Sumps and sump pumping:

A sump is merely a hole in the ground from which water is being pumped for the purpose of removing water from the adjoining area (Fig 9.1). They are used with ditches leading to them in large excavations. Up to maximum of 8m below pump installation level; for greater depths a submersible pump is required. Shallow slopes may be required for unsupported excavations in silts and fine sands. Gravels and coarse sands are more suitable. Fines may be easily removed from ground and soils containing large percent of fines are not suitable. If there are existing foundations in the vicinity pumping may cause settlement of these foundations. Subsidence of adjacent ground and sloughing of the lower part of a slope (sloped pits) may occur. The sump should be preferably lined with a filter material which has grain size gradations in compatible with the filter rules. For prolonged pumping the sump should be prepared by first driving sheeting around the sump area for the full depth of the sump and installing a cage inside the sump made of wire mesh with internal strutting or a perforating pipe filling the filter material in the space outside the cage and at the bottom of the cage and withdrawing the sheeting. Two simple

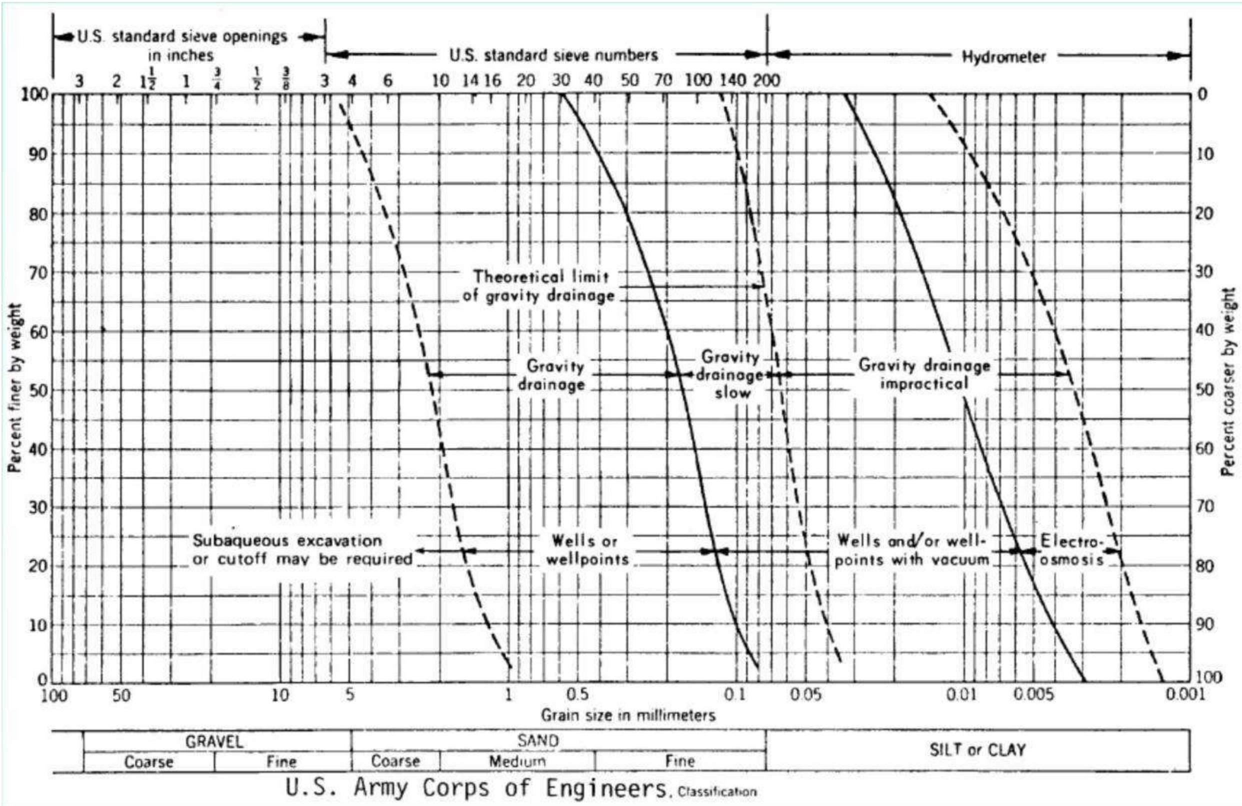
The essential feature of this method is a sump below the ground level of the excavation at one or more corners or sides.. a small ditch is cut around the bottom of the excavation , falling towards the sump. It is the most widely used and economical of all methods of ground water lowering. This method is also more appropriate in situations where boulders or other massive obstructions are met with the ground. 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.



Single Stage Well Point



Applicability of Dewatering Systems



Settlement of Adjacent Structures

$$\delta = \frac{H}{1+e_0} C_c \log \frac{\sigma'_{vo} + \Delta\sigma}{\sigma'_{vo}}$$

$$\Delta\sigma = \Delta h \gamma_w$$

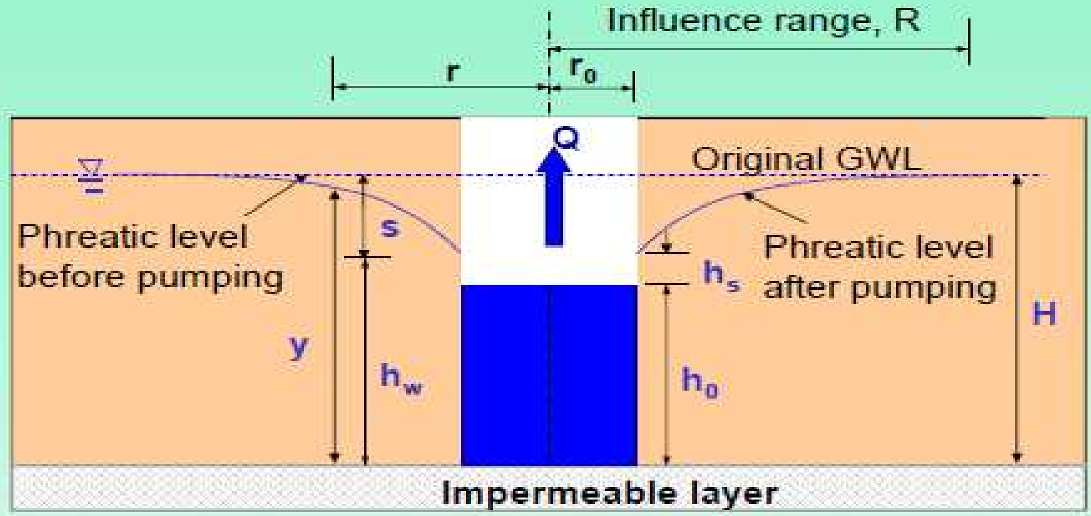
Δh = reduction of groundwater level
Cut off walls/trenches are used to prevent the damage.

Design Input Parameters

Most important input parameters for selecting and designing a dewatering system:

- The height of the groundwater above the base of the excavation
- The permeability of the ground surrounding the excavation

Dupuit-Thiem Approximation for Single Well



$$Q = \frac{\pi k\left(H^2 - h_w^2\right)}{\ln(R/r_0)} = 1.366k\frac{\left(H^2 - h_w^2\right)}{\log(R/r_0)} \qquad y^2 - h_w^2 = \frac{Q\ln(r/r_0)}{\pi k}$$

Height of Free Discharge Surface

$$h_s = \frac{C\left(H - h_0\right)}{H}$$

Ollos proposed a value of C = 0.5

Influence Range

$$L = C'\left(H - h_w\right)\sqrt{k}$$

Sichardt (1928) C = 3000 for wells or 1500 to 2000 for single line well points
H, hw in meters and k in m/s

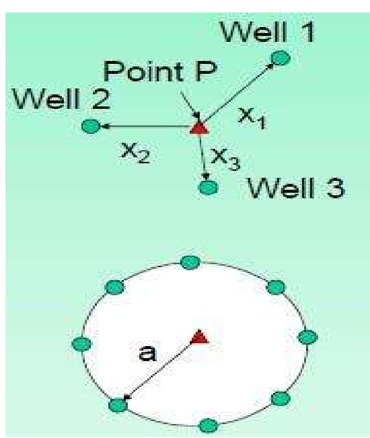
Forchheimer Equation for Multiwells

Forchheimer (1930)

$$Q = \frac{\pi k\left(H^2 - y^2\right)}{\ln L - (1/n)\ln x_1 x_2 \ldots x_n}$$

Circular arrangement of wells

$$Q = \frac{\pi k\left(H^2 - y^2\right)}{\ln L - \ln a}$$



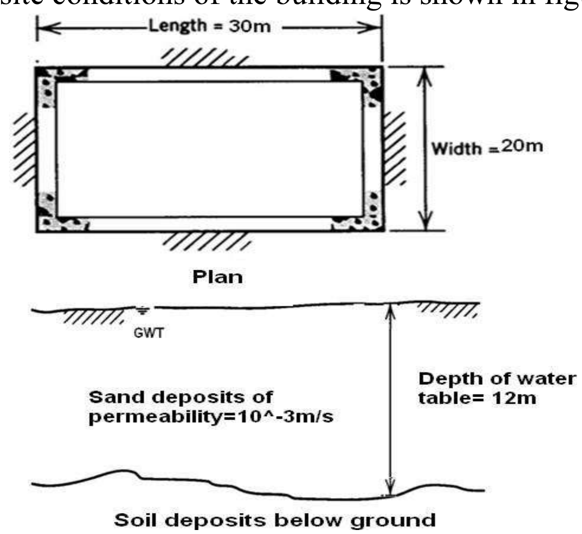
Spacing of Deep Wells

- Obtain an estimate of the total quantity of water to be pumped from Eq.1. The values of H, y and R are determined by the type of aquifer, the required draw down and soil type. If a is the radius of the equivalent circular area and X and Y are the dimensions of the excavation,

$$a = \frac{Sq(XY)}{3.14}$$

- The number of wells is obtained by dividing the total yield with that of yield of a single well.

Example: 1 A building has to be constructed on ground which has the following ground conditions: Dimensions of the building=30mx20m and the depth of excavation is 10m (water table is at ground level) Permeability of sand deposits below ground level = 10-3 m/s.
The depth of water level has to be decreased by 2m below excavation level. In order to construct the building, dewatering has to be done by laying pumps at various junctions. Calculate the rate of flow of water when one pump is laid and compare it with the discharge when the number of pumps is increased. The site conditions of the building is shown in figure (1).



Solution:

From the given data we know:
Permeability of the sand, k= 10^{-3} m/s
Depth of water level, h= 12m
Depth of drawdown= 2m

In most of the cases, there is an empirical relationship to obtain an approximate value for the line of influence, L(=R) and this is given by Sichardt:

The value of constant C in meters when k is in meters /second are:

C= 3000 for wells

=1500 to 2000 for single line wells (Mansur and Kaufmann)

Consider C=3000

Hence, L= 3000*2*(10^{-3})0.5 = 189.73m

The formula for discharge is given by Forchheimer is:

$$Q = \frac{\pi k\left(H^2 - y^2\right)}{\ln L - \ln a}$$

Here H= 12m, y=10m, L =189.73 and a= 7.8m

$$Q = \frac{\pi k\left(12^2 - 10^2\right)}{\ln 189.73 - \ln 7.8}$$

= 0.0433 m3/s

Expression for yield from a single well is given by

$$Q_{max} = 2\pi r h_0 \frac{\sqrt{k}}{15}$$

Substituting r = 0.1m, ho = 2m and k = 10-3 m/s, the yield for a single well is obtained as 0.01 m3/s. Hence, the number of wells can be taken as 5 to cater to the discharge of = 0.0433 m3/s.

If the number of pumps are increased to more than one, the formula given by Forchheimer is:

$$Q = \frac{\pi k\left(h^2 - y^2\right)}{lnL - \frac{1}{n} lnx_1x_2x_3\ldots\ldots x_n}$$

Consider five pumps at different locations in and around the building at 10m respectively in different directions. Now n=5, x_1=10m, x_2=10m, x_3=10m, x_4=10m and x_5 =10m

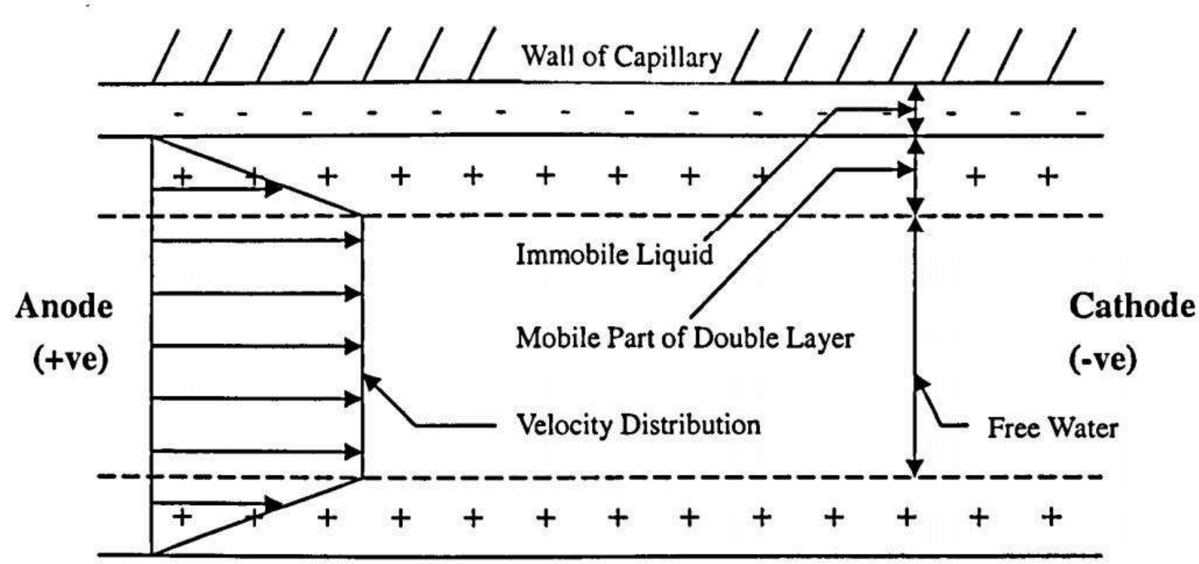
$$Q = \frac{\pi * 10^{-3} * (12^2 - 10^2)}{\ln 189.73 - \frac{1}{4}\ln(10^5)} = 0.058 m^3/s$$

Hence five number of pumps will be able to cater to the discharge with adequate margin of safety.

Dewatering techniques need considerable practical experience and many of the terms and parameters in the formula have uncertainties and variability. Hence trials are useful to confirm if the design is going to work in a satisfactory manner.

Dewatering by electro – osmosis

When an external electro motive force is applied across a soild liquid interface the movable diffuse double layer is displaced tangentially with respect to the fixed layer . this is electro osmosis. As the surface of fine grained soil particles causes negative charge, the positive ions in solution are attracted towards the soil particles and concentrate near the surfaces. Upon application of the electro motive force between two electrodes in a soil medium the positive ions adjacent to the soil particles and the water molecules attached to the ions are attracted to the cathode and are repelled by the anode. The free water in the interior of the void spaces is carried along to the cathode by viscous flow. By making the cathode a well, water can be collected in the well and then pumped out.



INTRODUCTION

Electro osmotic consolidation means the consolidation of soft clays by the application of electric current. It was studied and applied for the first time by Casagrande. It is inherent that fine grained clay particles with large interfacial surface will consolidate and generate significant settlement when loaded. The settlement creates problem in the foundation engineering. Electro osmosis was originally developed as a means of dewatering fine grained soils for the consolidation and strengthening of soft saturated clayey soils. Electro osmotic dewatering essentially involves applying a small electric potential across the sediment layer. It is the process where in positively charged ions move from anode to cathode. ie. Water moves from anode to cathode where it can be collected and pumped out of soil Electro osmotic flow depends on soil nature, water content, pH and on ionic type concentration in the pore water.

ELECTRO OSMOTIC CONSOLIDATION Due to the applied electric potential the electrolysis of water occurs at the electrodes 2H2O -> O2 (g) + 4H+ +4e- oxidation (anode) 4H2O + 4e- -> 2H2 (g) + 4OH- reduction (cathode) The clay particles have a â€oeve charge. These above charge produce an electro static surface property known as the double layer which creates a net abundance of captions

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in pore space. Electro osmotic transfer of water through clay is a result of diffuse double layer captions in the clay pores being attracted to a negatively charged electrode or cathode. When electrodes are placed across saturated clay mass and direct current is applied, water in the clay pore space is transported towards cathode by electro osmosis. In addition frictional drag is created by the motion of ions as they move through the clay pores helping to transport additional water. The flow generated by the electric gradient is called electro osmotic flow.

EVALUATION OF ELECTRO OSMOTIC CONSOLIDATION Determination of parameters Electrical operation systems for field application Materials Spacing between electrodes Cost of electrodes and installation cost.

DESIGN OF SUB-SURFACE DRAINAGE SYSTEMS

Sub-surface drainage is the removal of excess groundwater below the soil surface. It aims at increasing the rate at which water will drain from the soil, and so lowering the water table, thus increasing the depth of drier soil above the water table. Sub-surface drainage can be done by open ditches or buried drains.

Sub-Surface Drainage Using Ditches

Ditches have lower initial cost than buried drains; there is ease of inspection and ditches are applicable in some organic soils where drains are unsuitable. Ditches, however, reduce the land available for cropping and require more maintenance that drains due to weed growth and erosion.

Sub-Surface Drains Using Buried

DrainsSub-Surface Drainage Using Buried DrainsBuried drains refer to any type of buried conduits having open joints or perforations, which collect and convey drainage water.

They can be fabricated from clay, concrete, corrugated plastic tubes or any other suitable material. The drains can be arranged in a parallel, herringbone, double main or random fashion. Sub-Surface Drainage Designs The Major Considerations in Sub-surface Drainage Design Include: Drainage Coefficient; Drain Depth and Spacing; Drain Diameters and Gradient;

Drainage Filters. Drainage Coefficient This is the rate of water removal used in drainage design to obtain the desired protection of crops from excess surface or sub-surface water and can be expressed in mm/day , m/day etc.

Drainage is different in Rain-Fed Areas and Irrigated Areas

Electrokinetic Stabilisation – Chief Mechanism

1. From studies of clay mineralogy it is known that clays are made up of small particles (<0.002 mm) with a very large surface area in comparison to their mass.
2. The properties of a clay are therefore greatly influenced by the surface forces. These surfaces are negatively charged, primarily as a result of the isomorphism substitution of aluminium or silicon atoms by lower valency atoms.

3. This negative charge attracts (dipolar) water molecules, resulting in the clay particles being surrounded by layers of water, known as diffuse water layers (or diffuse double layers). The concentration of cations available in the pore water and the surface charge of the clay particle together control the thickness of this layer.
4. In addition, the pH of the system can influence the negative charge of the clay particles, in some cases (e.g. kaolinite) significantly, and therefore directly influence the thickness of the diffuse water layer.
5. The cations commonly found in the diffuse water layer and the pore water are variously sodium, potassium, calcium, magnesium and lithium, and in some cases higher order ions are also present (Little, 1987).
6. When cations of a higher valency and/or a larger ionic radius, such as calcium, silicon or aluminum, are introduced in significant concentrations, they saturate the solution and become adsorbed at the clay surface in preference to those ions originally present.
7. The result of this cation exchange, due for example to the classic case of lime (and hence calcium ion) addition, is a considerable reduction in the thickness of the diffused water layer, as illustrated in Fig. 3.
8. This allows closer contact between the clay platelets, which promotes edge-to-face attraction, or flocculation, and results in changes in the soil"s workability, permeability, plasticity and swell properties.
9. Alteration of the soil pH results in changes in the solubility of the clay minerals present.
10. The reaction products such as amorphous calcium aluminates hydrate and calcium silicate hydrate gels, crystallizes with time to form a strong, brittle solid. This process is termed stabilization.

Preloading and Vertical Drains

When highly compressible, normally consolidated clayey soil layers lie at limited/large depths, large consolidation settlements are expected as the result of the loads from large buildings, highway embankments, or earth dams etc. Pre-compression and provision of vertical drains in soft soil may be used to minimize post construction settlement.

This approach has resulted in a number of techniques involving

- ☐ Pre-compression or Pre-loading
- ☐ Sand drains

- Pre-fabricated Vertical Drains
- Vacuum consolidation
- High Vacuum Densification Method (HVDM)

Preloading

- Increases the bearing capacity
- Reduces the compressibility of weak ground

Achieved by placing temporary surcharge on the ground. Surcharge generally more than the expected bearing capacity.

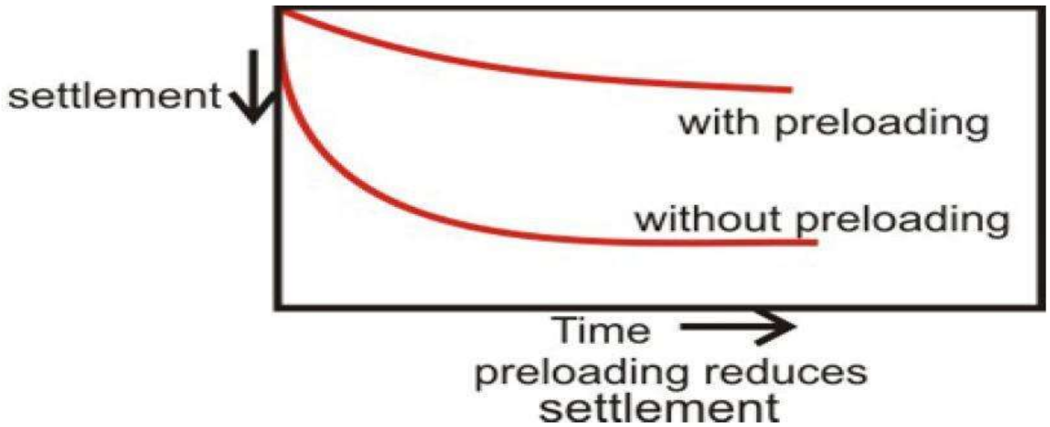
In cohesion less soil and gravel -→ lowering water table

Most effective -→ soft cohesive ground.

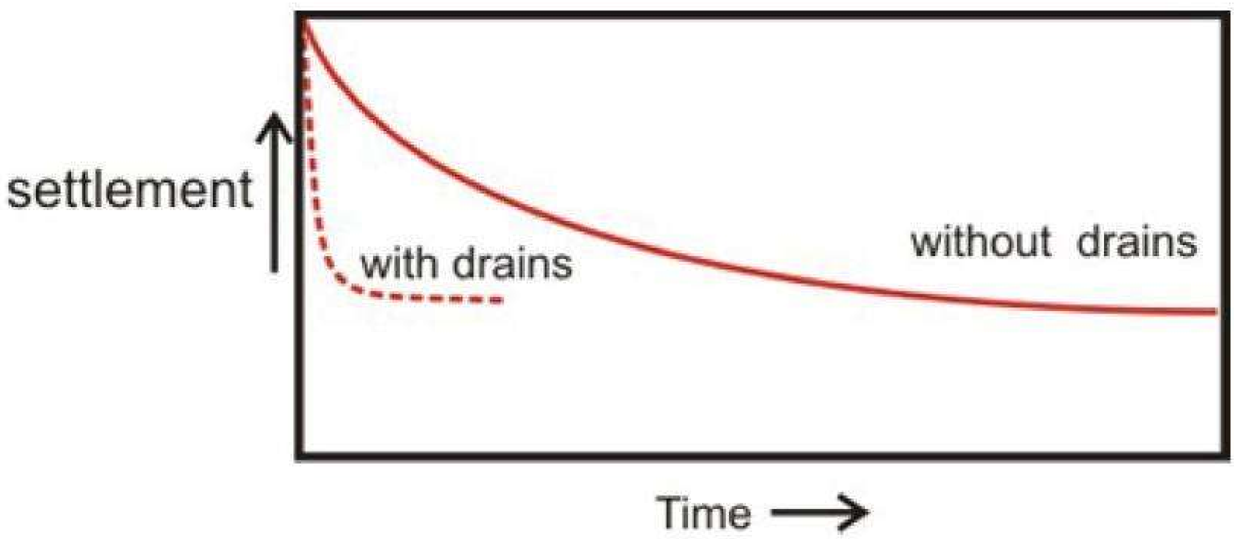
PRELOADING AND VERTICAL DRAINS

- The process may be speed up by vertical sand drains.
- Vertical drains are installed in order to accelerate settlement and gain in strength of soft cohesive soil.
- Vertical drains accelerate primary consolidation only.
- As significant water movement is associated with it. Secondary consolidation causes only very small amount of water to drain from soil;
- Secondary settlement is not speeded up by vertical drains.
- Only relatively impermeable soil with benefit from vertical drains.
- Soils which are more permeable will consolidate under surcharge.
- Vertical drains are effective where a clay deposit contain many horizontal sand or silt lenses.

Preloading	Vertical
Reduce total and differential settlement	Speed up to settlement process
Economy in foundation system	Do not reduce the amount of deformation under a given load



- Pre loading allows cheaper spread footings.
- Pre loading allows savings on foundation costs.



- Vertical drains accelerate settlements and do not reduce final movements

GEOSYNTHESIS

Geosynthetics are artificial fibres used in conjunction with soil or rock as an integral part of a man made project

They are mainly grouped into two categories

a. Geotextiles – permeable

b. Geomembrane – impermeable

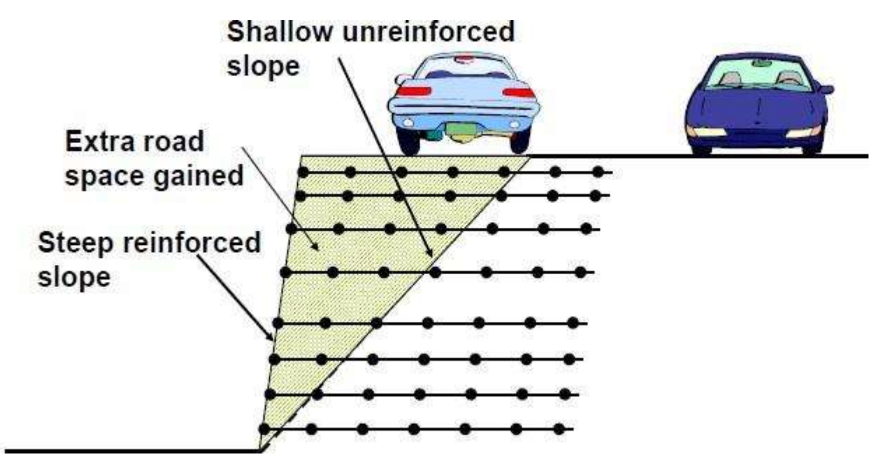
VARIOUS TYPES OF GEOSYNTHESIS

- Geonets
- Geomats
- Geosynthetic clay liners
- Geofoam
- Geocells
- Geocomposites
- Geotextiles
- Geogrids
- Geomembranes

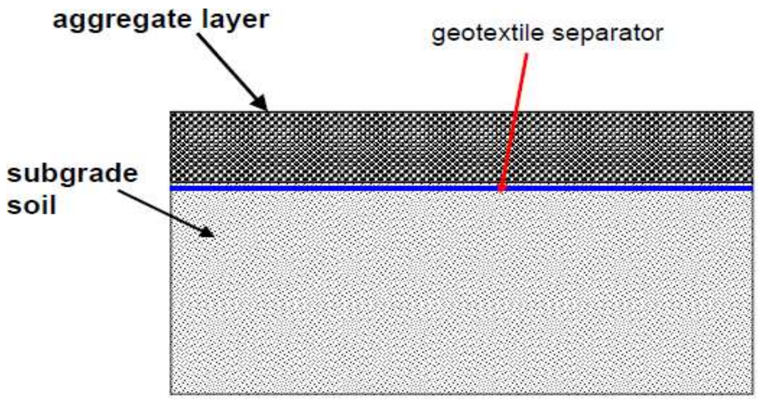
Letter Symbols for

Different Functions of Geosynthetics

B **Barrier (fluid)**
D **Drainage**
E **Surficial Erosion Control**
F **Filtration**
P **Protection (of geomembranes)**
R **Reinforcement**
S **Separation**



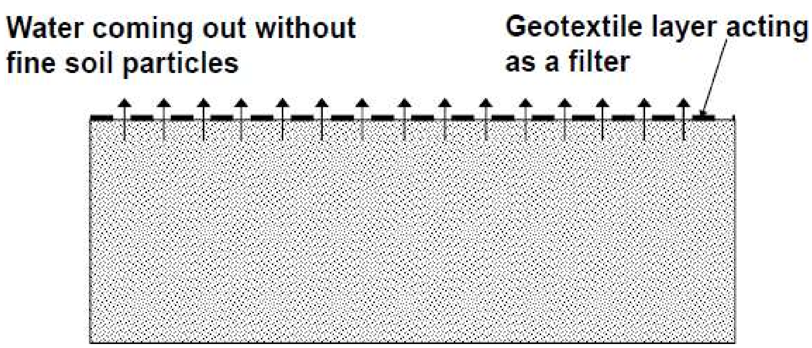
Geosynthetic reinforcement layers



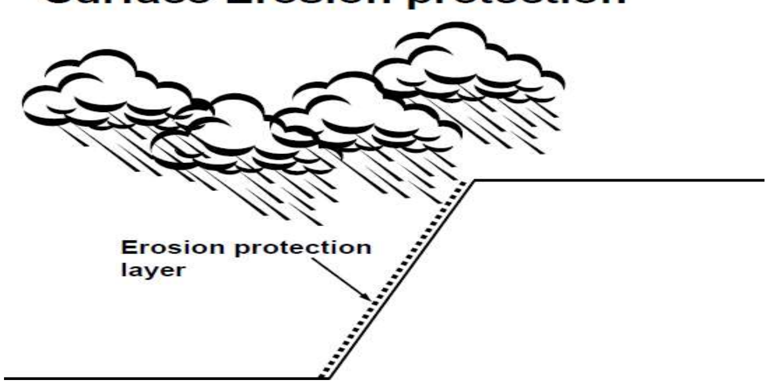
Prevents the intermixing, prevents piping, strength of aggregate is preserved

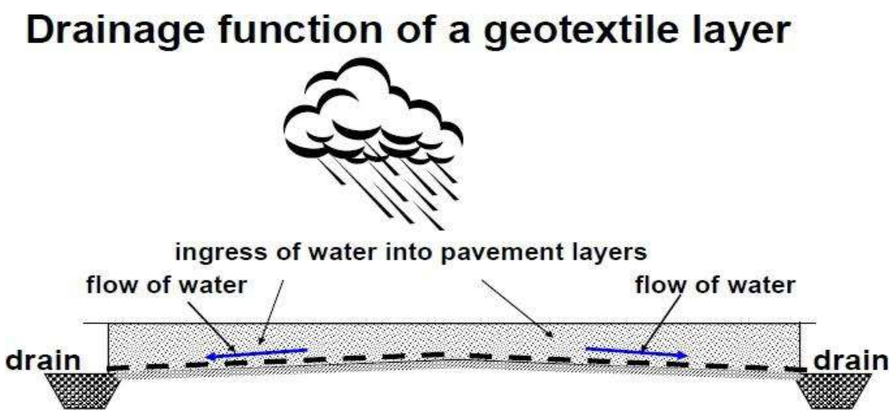
Separation Function in a pavement layer

Filtration Function



Surface Erosion protection





How does the use of a geosynthetic as a filter differ from that of Drainage

Filtration applications are highway under drain systems, retaining wall drainage, landfill leachate collection systems, as silt fences and curtains, and as flexible forms for bags, tubes and container . Drainage applications for these different geosynthetics are retaining walls, sport fields, dams, canals, reservoirs, and capillary breaks.

Preloading and vertical drains

In times of urbanization, growth of population and associated developments, construction activities are more and more focused on soils which were considered unsuitable in the past decades. These soft soil deposits have a low bearing capacity and exhibit large settlements when subjected to loading. It is therefore inevitable to treat soft soil deposits prior to construction activities in order to prevent differential settlements and subsequently potential damages to structures. Different ground improvement techniques are available today. Every technique should lead to an increase of soil shear strength, a reduction of soil compressibility and a reduction of soil permeability. The choice of ground improvement technique depends on geological formation of the soil, soil characteristics, cost, availability of backfill material and experience in the past. According to Bergado et al. (1996) they can be divided broadly into two categories. The first category includes techniques which require foreign materials and utilisation of reinforcements. They are based on stiffening columns either by the use of a granular fill (stone columns), by piling elements which are not reaching a still soil stratum (creep piles) or by in situ mixing of the soil with chemical agents (deep stabilisation). The second category includes methods which are strengthening the soil by dewatering, i.e. preloading techniques often combined with vertical drains. This report will focus on preloading techniques and utilisation of vertical drains. Preloading is the application of surcharge load on the site prior to construction of the permanent structure, until most of the primary settlement has occurred. Since compressible soils are usually characterized by very low permeability, the time needed for the desired consolidation can be very long, even with very high surcharge load. Therefore, the application of preloading alone may not be feasible with tight construction schedules and hence, a system of vertical drains is often introduced to achieve accelerated radial drainage and consolidation by reducing the length of the drainage paths.

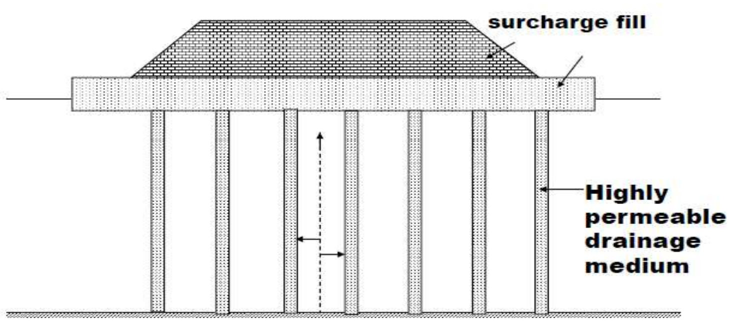
Pre-fabricated vertical drains to accelerate the pre-consolidation of soft clay soils

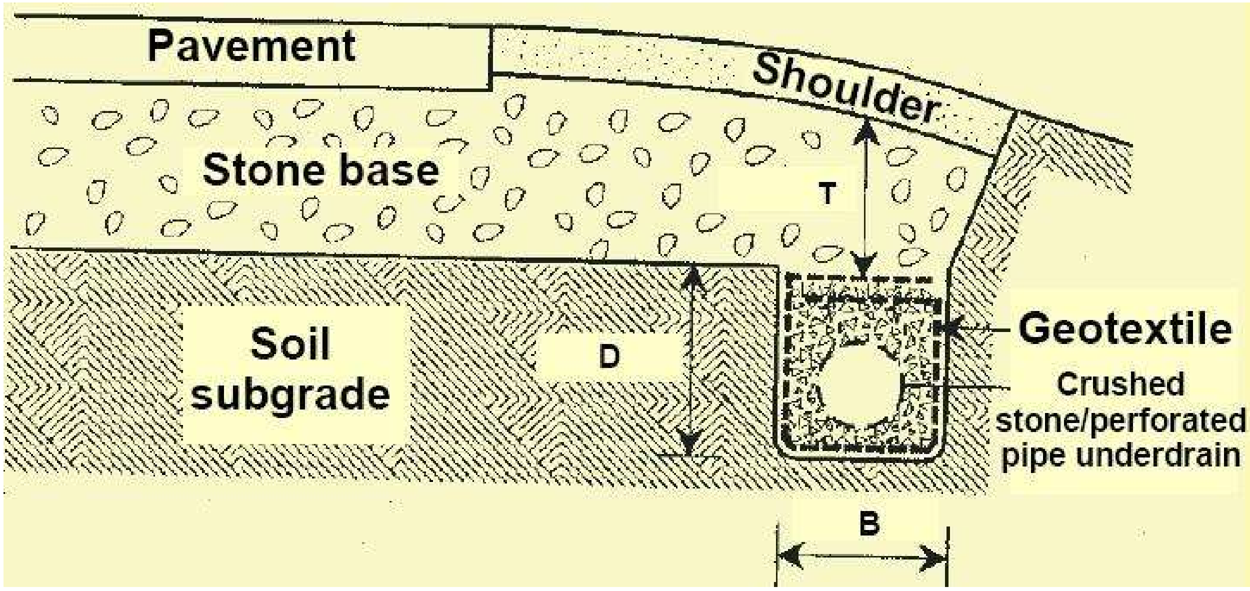
$$T_v = \frac{c_v t}{d^2} \qquad T_v \Rightarrow f(U\%)$$

$$t = \frac{T_v d^2}{c_v}$$

T_v = time factor
t = time
c_v = coefficient of consolidation
d = drainage path length
U% = degree of consolidation

Reducing the flow path length to accelerate rate of consolidation





Typical Applications of geosynthetics as drainage material

- Pavement edge drains
- Interceptor trenches on slopes
- Drainage behind abutments and retaining structures
- Relief of water pressure on buried structures
- Substitute for conventional drains
- Leachate collection and gas venting
- Drainage mats in horizontal applications e.g. roofing
- PVDs for accelerated consolidation of clay soils