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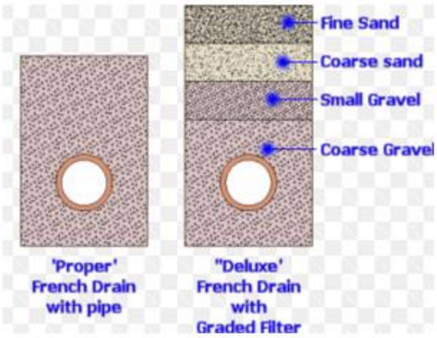
Internal Assessment Test 2 – April 2018

Sub:	Ground improvement Techniques					Sub Code:	15CV654	Branch:	CIVIL
Date:	19/4/2018	Duration:	90 mins	Max Marks:	50	Sem / Sec:	6 A & B		OBE

Answer any FIVE FULL Questions

		MARKS	CO	RBT
1 (a)	What are the requirements of a filter?	[06]	CO1	L1

The space between the soil and the pipe is filled with a coarse grained material known as filter. If the voids of the filter are larger than the finest grains of the adjoining soil there is a possibility for these fines to fill and accumulate and block the flow. If the voids of the filter are smaller than the fines in the soil then the filter itself will get washed into the drain. A material which avoid the above two undesirable conditions is referred to as a filter.



Filters are used in earthdams and sheetpile as a transmission medium to prevent piping.

The gradation of the filter material should satisfy the two requirements:

- The pores in the filter should be small enough such that soil particles doesn't migrate through it.
- Filter should allow rapid drainage of water without developing large seepage forces. If drainage is slow the head causing flow will be high leading to large seepage forces.

These requirements are satisfied by adopting a suitable grain-size distribution for the filter material based on the material to be protected. The following filter criteria should be adopted:

Piping Criteria

$\frac{\mathbf{D15\ (filter)}}{\mathbf{D85\ (Protected\ soil)}} < 4$ to 5 Soil shouldn't go.

The voids of the filter is experimentally = $\frac{1}{5}\ D_{15}$filter

These voids should block a fraction of coarse material of the soil which will block the smaller particles. To do this the voids of the filter should be less than D85 of soil. Then 15% coarser than D85 will be restrained.

$\frac{1}{5}\ D_{15}$filter < D85 soil

Permeability Criteria

$\frac{\mathbf{D15\ (filter)}}{\mathbf{D15\ (Protected\ soil)}} > 4$ to 5   Water should go

For water to go permeability of filter should be 25 times greater than permeability of soil.

kfilter > 25 ksoil

k α D102

D15 filter > 5 D15 soil

In a graded filter there will be multiple layers. Every two adjacent layers have to satisfy the above criteria. The denominator becomes that of the preceding layer.

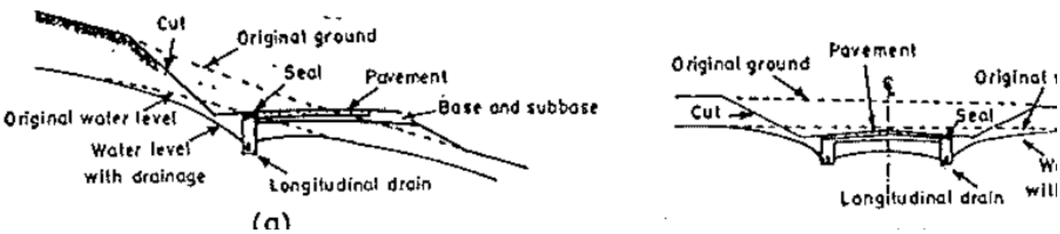
Also, the opening of perforated pipe should be as follows.

Dpipe < 0.5 D85 soil

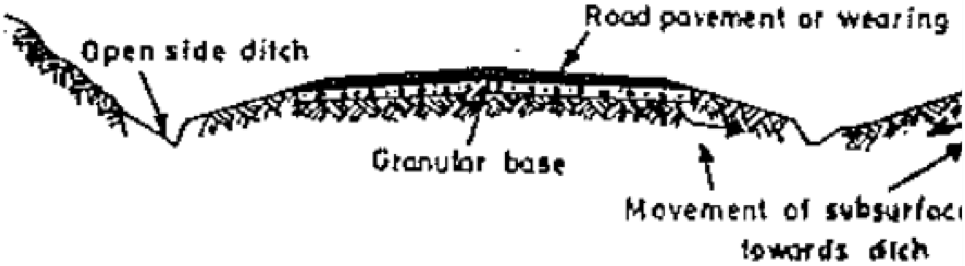
(b) Explain interceptor drains. [04] CO1 L4

In paved highways and runways trench drains are provided parallel to the shoulder. Such drains are provided to lower the groundwater level beneath the pavement and to permit easy lateral drainage for water finding its way into the coarse base material. The purpose of such drainage is to keep the base and subgrade soils dry so as to maintain the adequate strength and stability. It also removes surface water and development of excess pore water pressures.

A filter is essential for continued efficiency of the drain and to prevent seepage erosion of fines and clogging of the pipes.



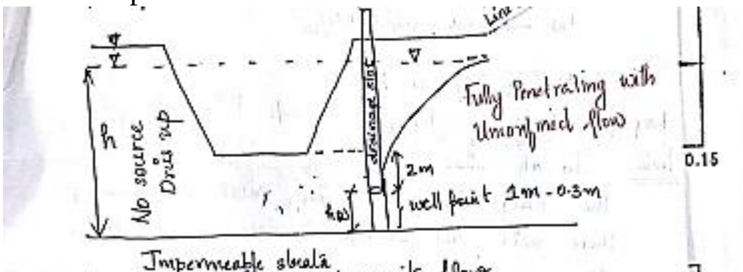
Interceptor drains for a road at hillside and flat terrain respectively



Open ditches on both side of the roads

A filter is essential for continued efficiency of the drain and to prevent seepage erosion of fines and clogging of the pipes.

2 (a)	Write the steps to design a dewatering system for a trench like excavation in a strata which is unconfined with line source only on one side. Depth of excavation is very close to the impermeable strata.	[10]	CO2	L4



* Fully Penetrating slot with gravity flow

$$Q_{tot} = \frac{(h^2 - h_w^2)\,k}{2L} \times Z$$

where Z is the out of plane length of excavation

Let us replace this drainage slot by 'n' number of closely spaced wells each of capacity Q_{max}

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

Q_{max} m^3/s; r, h_0 m; k m/s — empirical

The number of wells, $n = \frac{Q_{tot}}{Q_{max}}$

Spacing of well, $s = Z/n$

Total Depth of well = depth to impermeable strata

Well point is located at a depth = depth of excavation + 2m + 0.2m below h_0 to prevent entry of air.

Pump capacity = $N = \frac{Q \times \text{height of lift} \times \gamma_w}{\eta}$

$Q \rightarrow$ discharge carried m^3/s

$\eta \rightarrow$ efficiency of pump (due to friction the desired amount of water isn't lifted).

height $\rightarrow$ metres

$\gamma_w \rightarrow$ unit weight kN/m^3

$N \rightarrow kJ/s$ or kW

Keeping velocity V_h in collector pipes as 1.5-2m/s $\quad \pi r_h^2 \times V_h = Q_{tot}$ $\quad r_h = \sqrt{Q_{tot}/V_h \times \pi}$

3 (a) How compression is monitored on field during preloading? **OR** Explain the preloading principles and the various methods of preloading. (**ANY ONE**) [10] CO2 L2

The following plots are required prior to preloading:

- Settlement vs time curve
- Settlement time rate vs time rate of increase of height of fill

These two curves help in monitoring whether the field compression is as per designed.

SETTLEMENT VS TIME CURVE

Find the consolidation settlement caused by the actual structure on unconsolidated clay. (Sreq)

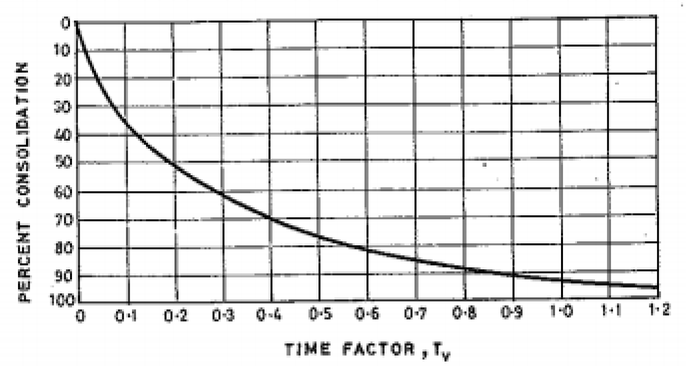
Sreq is the final settlement to be attained after preloading. At any time (t) the settlement achieved is Si.

The degree of consolidation achieved after time (t) is

$$Ui = \frac{S_i}{S_{req}}$$

Obtain Tv from the following curve for degree of consolidation Ui.

$$Tv = \frac{C_v\, t}{d^2}$$



Cv and d can be obtained from laboratory results or from field test. If the soil is heterogeneous laboratory results will be erroneous.

Determining Cv and d from field:

Drainage path (d) is obtained from bore-logs.

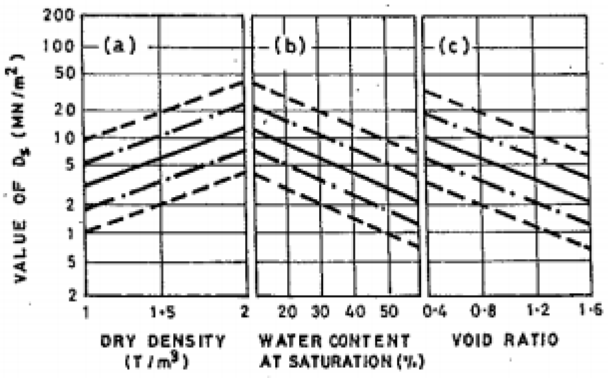
$$Cv = \frac{kD}{\gamma_W}$$

Where,

K is permeability obtained from pumping tests.

D is constrained modulus

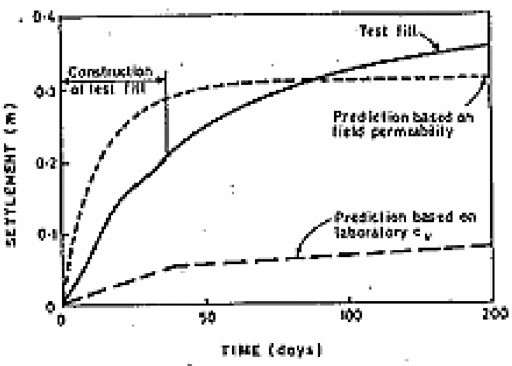
For an average load stress increment of 0.01 MN/m2 the constrained modulus is Ds which is known as the specific constrained modulus. Ds can be used in place of D as error due to variations in load stress increment is less. Ds can be obtained from the following curves:

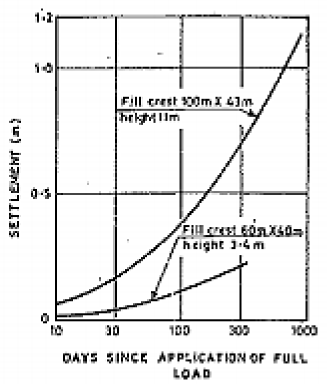


Another way of drawing the settlement time curve is from test fills

The width of the test fill must be wide enough or as wide as the original fill.

If the original fill is not going to experience base failure then the settlements experienced by the test and the original fill will almost be the same if the pressures are same. Otherwise the settlement of soil by the original fill = settlement of soil by test fill × $\frac{load\ stress\ increment\ applied\ for\ test\ fill}{load\ stress\ increment\ for\ original\ fill}$

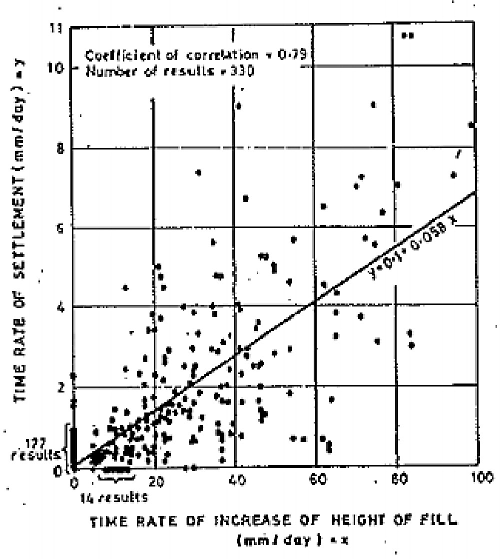




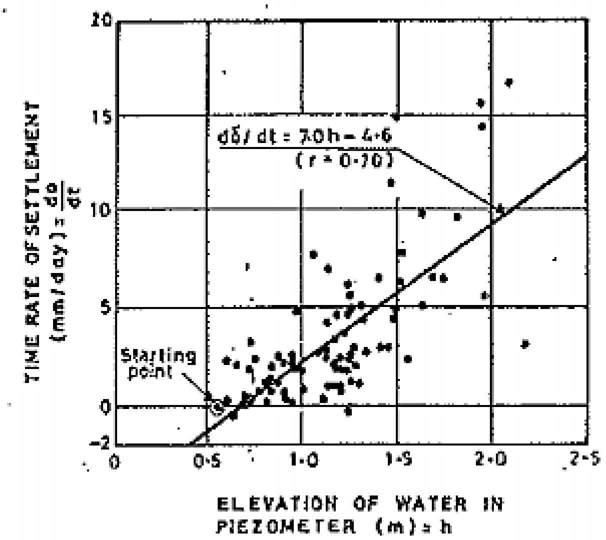
The settlements correspond to the same time.

TIME RATE OF SETTLEMENT VS TIME RATE OF INCREASE OF FILL HEIGHT

This is for monitoring base failure while preloading. This is a plot of average daily rate of settlement with load accumulation. The time rate of settlement is directly proportional to the rate of load application. For soils prone to base failure this curve will be steep. This curve indicates how much amount of preload can be applied without causing shear failure of soil by extrapolating the graph. One such correlation is shown for coastal area soil is as shown:

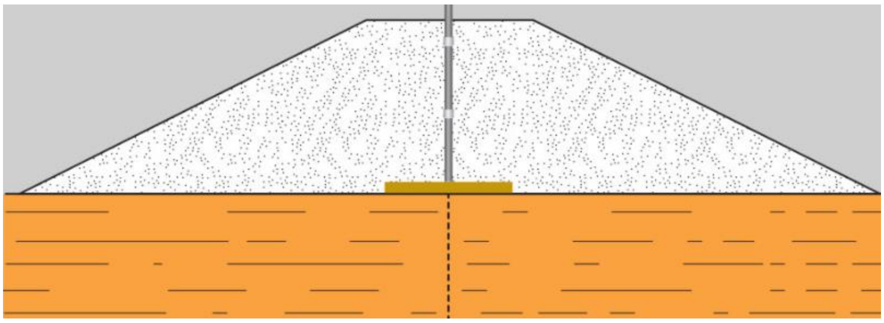


The time rate of settlement can also be related to excess pore water pressure (just after application of load) which is an indication of load applied.



INSTRUMENTATION TO MONITOR CONSOLIDATION ON FIELD

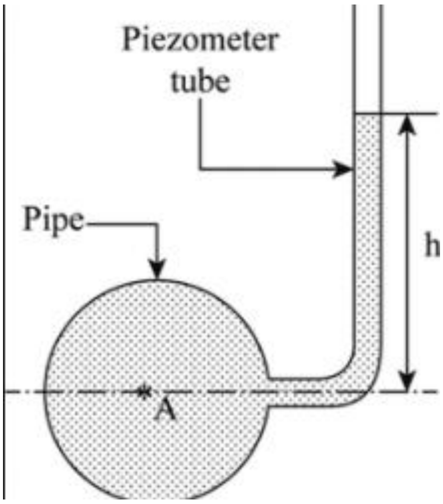
- SETTLEMENT GAUGE



To measure settlement at surface. Settlement plate consist of a steel plate which is first installed at the elevation at which the settlement needs to be measured. At the center of the steel plate one riser pipe or rod is fit. This rod can be extended as fill height increases. The initial elevation of plate and rod is obtained. The elevation of top of rod is noted before extention and after extension. Based on this the time settlement of the plate can be plotted.

- PEIZOMETER

To measure pore water pressure. Piezometers are located at critical points to find out the build-up of excess pore water pressure and the dissipation of pore water pressure. We measure pore water pressure to monitor the progress of consolidation. It helps in the evaluation of shear strength as base failure is a caution in preloading.



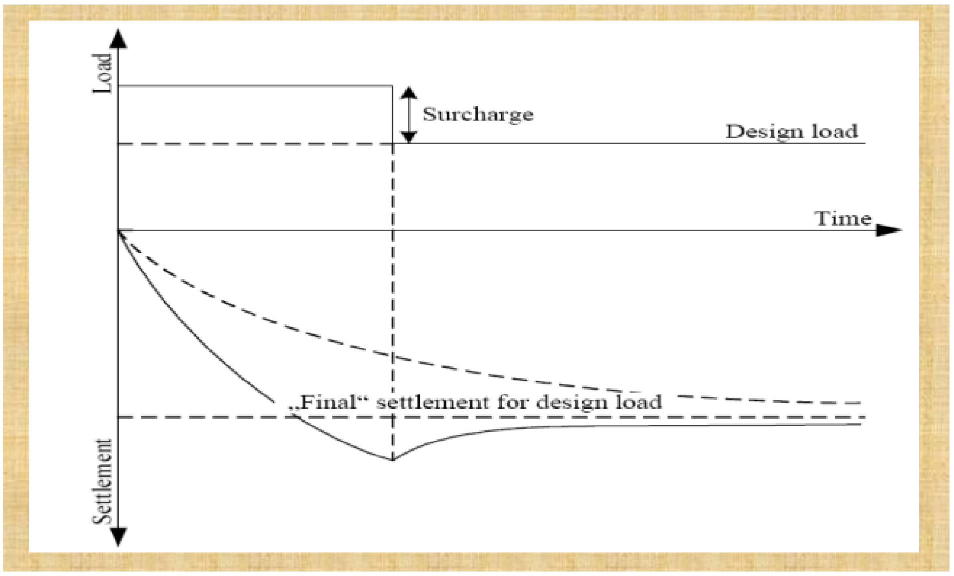
OR

Preloading causes increase in excess pore water pressure initially. The pore water pressure dissipates gradually causing an increase in effective stress which in turn causes settlement. The preloading applied by means of a fill should produce a stress atleast equal to the load of the final structure. The time required for attainment of full consolidation is directly proportional to the square of the thickness of the layer and indirectly proportional to the permeability of the layer.

The ratio of weight of preload to the weight of the final structure is known as coefficient of surcharge (ms). Higher the ms results in:

- lesser the time required for consolidation
- higher the post –preloading factor of safety against base failure.
- More construction time
- More expense
- More attention required for stability

Generally ms varies from 1 to 2.



The design of a preload includes:

- The amount of surcharge.
- Loading period

Surcharge fills causes

- Primary consolidation
- Secondary consolidation → More in peats

The degree of consolidation varies with depth. The surcharge duration should be based on the desired level of consolidation achieved at the points farthest from the drainage boundaries.

The advantages of preloading are as follows:

- Economical
- Fill material used for preloading can be used for site preparation later.
- Only earth moving equipments are required.
- Cost of monitoring preloading is less and the instruments for monitoring can be installed within very less time.
- Effect of preloading can be observed periodically from field-instrumentation

and future prediction can be made of the behavior.

- Provides uniform improved properties of soil.

Preloading should be adopted only in the following conditions:

- There shouldn't be any base failure on placing the preload.
- The duration of preloading should be within the construction schedule.
- There will be no damage to the adjoining structures.
- No undue disturbance to nearby communities.
- Thickness of layer to be consolidated is less.

Note: after the structure is built the settlements should be within the desired range.

PRELOADING METHODS

METHOD 1

Heaping of fill material. The fill can be removed completely or partly and used up for site preparations. The only caution is base failure when the heap of fill is placed. It is less costly. The most frequent method is embankment loading. 3 to 8 months is required for the embankment to produce the required consolidation. The height of the preload fill is minimum 1.5 m and maximum 18 m. The range of settlement is 0.3 m to 1 m and in exceptional cases it might lead to 2 m.

METHOD 2

Using the structure as a means to apply load. It is used in sites having liquid storage tanks. The tank is filled with water incrementally and waited till consolidation is completed. The tank is emptied and the base is levelled by jacking. The time, cost and effort in bringing, filling and removing fill isn't there. Hence it reduces time and cost.

METHOD 3

Another method of preloading is by lowering the water table by dewatering. Lowering of the water table causes increase in effective stress which will cause larger amount of consolidation than before. This method can be combined with heaping with fill (METHOD 1) for better results. It is suitable where water table is high.

A method of dewatering and consolidation is vacuum preconsolidation:

In this 150 mm layer of sand is placed on the surface of a soft clay and the layer is covered with an impervious membrane. The sand layer is subjected to vacuum pressure. The pore water pressure reduces and effective stress increases resulting in consolidation. It is generally combined with vertical drains for better results. This method has got the following advantages:

- No need to worry about embankment stability
- No fill material required
- The installation and removal is quick.

METHOD 4

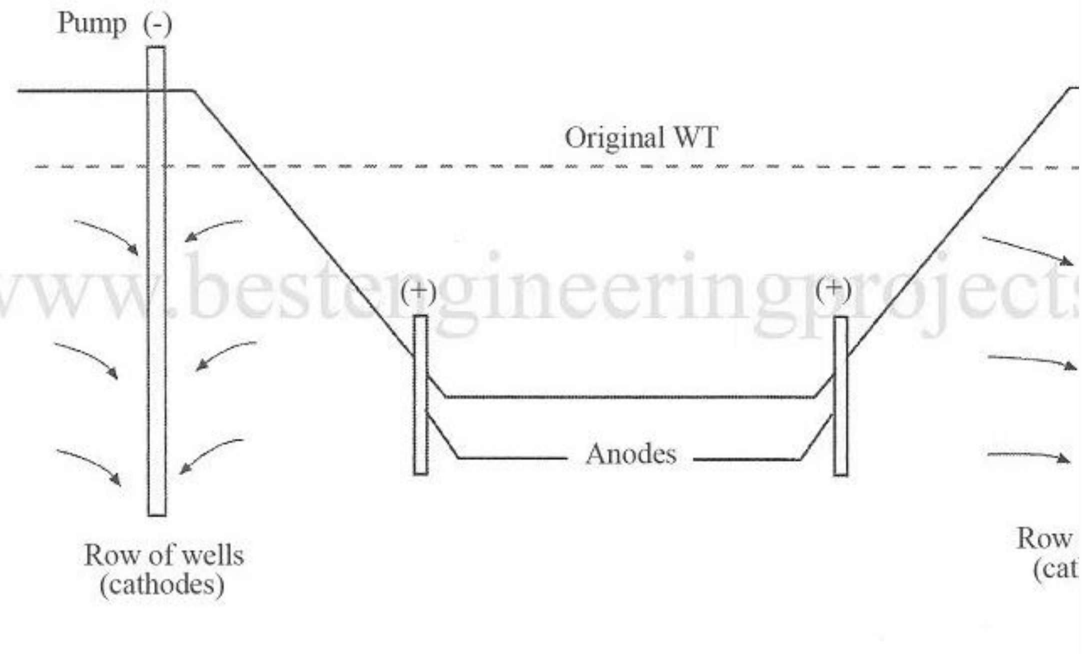
Another approach is by inundating or preponding. When water table is low, load is applied by submerging the land with water. It breaks the bonds between the particles causing more settlement. Generally adopted for fine desert sands.

METHOD 5

Footings are preloaded by jacking.

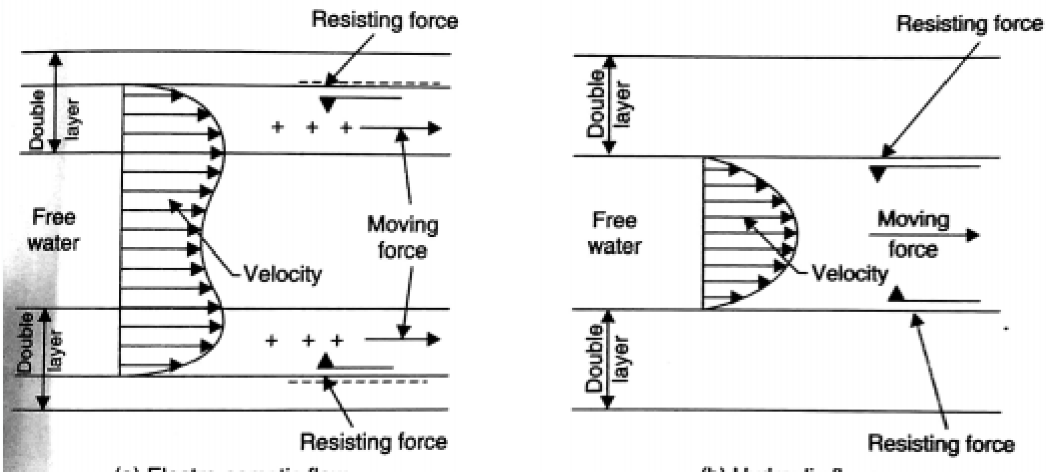
4 (a)	Explain dewatering by electro-osmosis.	[06]	CO2	L4

Electro-osmotic method is used when co-efficient of permeability lies between 10^{-7} cm/see to 10^{-5}cm/sec. In electro-osmotic method, two electrodes are driven into the saturated cohesive soil. The cathode is made out of steel in the form of a well point or a tube. A steel rod or a pipe or a sheet piling is made to serve as anode.



In general the surface of soil is negative charged and is surrounded by polar water and ions of other elements. When a current is passed through the soil, the positively charged ions on the surface are attracted towards cathode. During electro-osmosis process the attracted positively charged ions take the water of the double layer with them. The direction of flow is reversed and water is collected in the well point made of cathode. The collected water is pumped out.

The first layer is adsorbed cations. The second layer is the water molecules around the adsorbed cations. When anode and cathode are installed as shown in figure the electromotive force between the two electrodes in soil, attract the adsorbed cations and the water molecules attached to the cations to the cathode (negatively charged electode). The free water is also carried to the cathode by viscous flow. Thus if cathode is made as a well water gets collected in the well. 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. As these cations move toward the cathode, they bring with them water molecules that clump around the cations as a consequen ce of their dipolar nature. In addition, the frictional drag of these molecules as they move through the clay pores help transport additional water to the cathode. The macroscopic effect is a reduction of water content at the anode and an increase in wate r content of the clay at the cathode.



(a) Electro-osmotic flow (b) Hydraulic flow

Discharge collected in this way?

$Q = k_e i_e A$

How the electrodes are arranged?

The general layout of the electrodes depends on the purpose for which they are intended. Anodes can be old pipes, of 25 mm or 50 mm diameters, which can be easily driven into the soil.

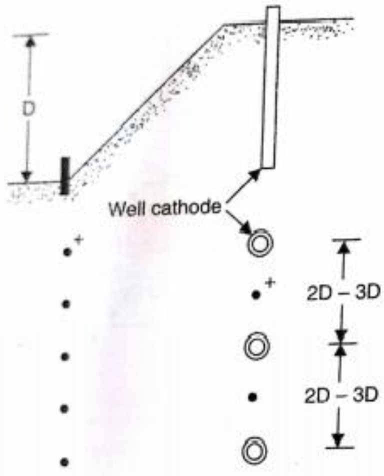


FIGURE 3.16. Electrode Arrangements for Slopes.

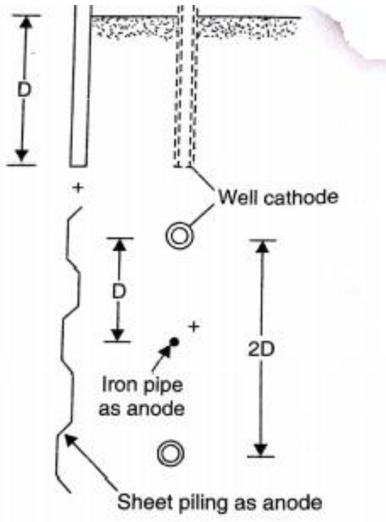


FIGURE 3.17. Electrode Arrangements for Sheated Excavation.

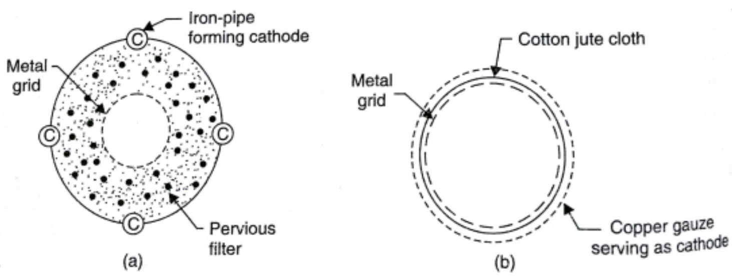


FIGURE 3.18. Combination of Cathode and Well.

The cathode and the well can be arranged in two ways as shown.

- Well is arranged in close proximity to the cathode
- Cathode and the well combined as one body
  The copper gauze acts like cathode.

The cathodes should be of the entire heigth of the excavation. Allowing water to flow into the cathode along the entire heigth. Anode and cathode should reach till equal depths. They both should extent 1.5 m below the slope. IS code suggest cathodes be placed at centre to centre distance of 7.5 m to 10 m, with anodes installed midway between them. The cathode wells should have diameter not less than 100 mm.

(b) What are the factors affecting the efficiency of a prefabricated vertical drain? [04] CO2 L2

For given subsoil conditions, the effect of the vertical drains depends on:

- the drain spacing and the equivalent drain diameter;
- WELL RESISTANCE (i.e., the discharge capacity of the drain):
  The discharge capacity of band drains varies considerably depending on the make of the drain and decreases with increasing lateral pressure. This is caused by either the squeezing in of the filter sleeve into the core channels reducing the cross sectional area of channels. For drains without filter sleeve, the channels themselves are squeezed together.
  Another important factor is the folding of the drain when subjected to large vertical strains. The channels of flow would be reduced and thus reducing the discharge capacity.
  The sedimentation of small particles in the flow channels may also decrease the vertical discharge capacity.
- SMEAR EFFECT: The drain installation results in shear strains and displacement of the soil surrounding the drain.
    - The shearing is accompanied by increases in pore pressure.
    - The disturbance around the drain is mostly dependent on the mandrel size and shape, soil and installation procedure.
    - Minimizing the cross section of mandrel will reduces the smear zone.

5 (a)	Explain soil lime reactions when lime is added to soil. HYDRATION ➢ Quicklime will react with water in the soil. ➢ This drying action is good in moist clays. ➢ If lime is placed as columns this hydration reaction will enhance consolidation as volume increase is there in this reaction. ➢ $CaO + H_2O = Ca(OH)_2$ + HEAT FLOCCULATION ➢ The Ca ion replaces the cation adsorbed on the clay minerals. ➢ This affects the way the structural components of the clay minerals are connected together and hence cause the clay to flocculate. ➢ Clay's plasticity is reduced thus increasing its strength and stiffness.	[6]	CO3	L4

CEMENTATION

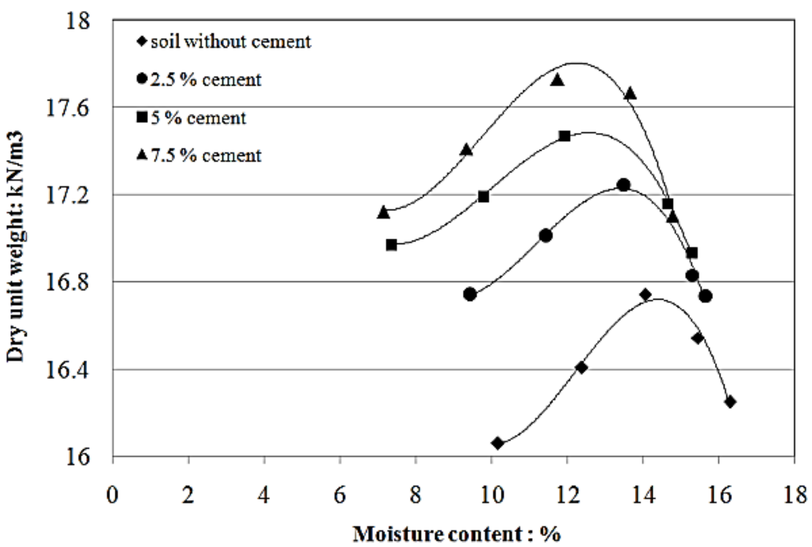
- The second stage of clay-lime reaction removes silics from clay mineral lattice to form products like those of cement hydration.
- Cementation provides the strength.
- The higher the surface area more effective is this process.
- Once the silica is used up there is no improvement in strength. Hence the percentage of lime added should be such that it uses up the available silica.
- Too much of lime will have a negative effect.

CARBONATION

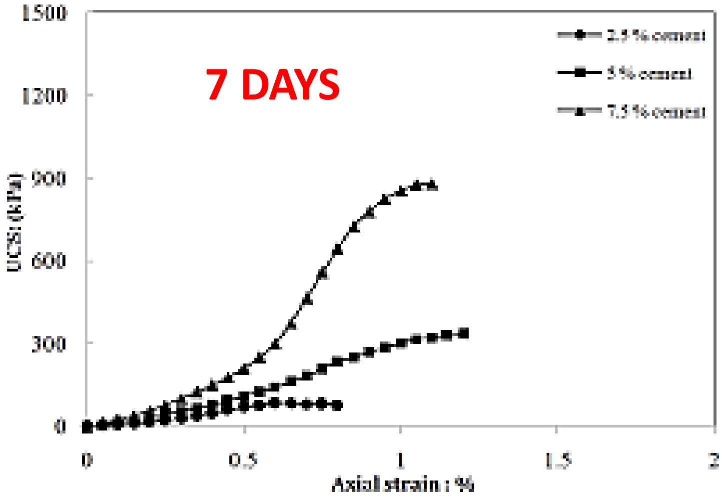
- Lime reacts with carbon dioxide in the voids to form a weak cementing agent CaCO3. The calcium carbonate formed will not react any further.

	(b)	What are the different ways of adding bitumen to soil?	[4]	CO3	L2
6		How engineering properties are altered when cement is added to soil?	[10]	CO3	L2

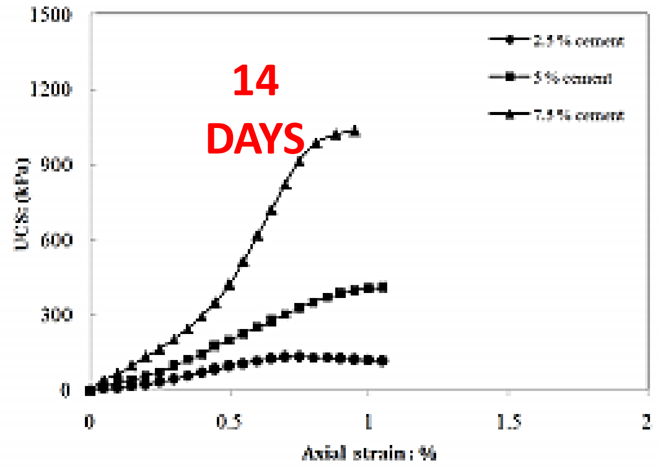
- The optimum moisture content and maximum dry unit weight, decrease and increase, respectively, with increasing amounts of lime portland cement.

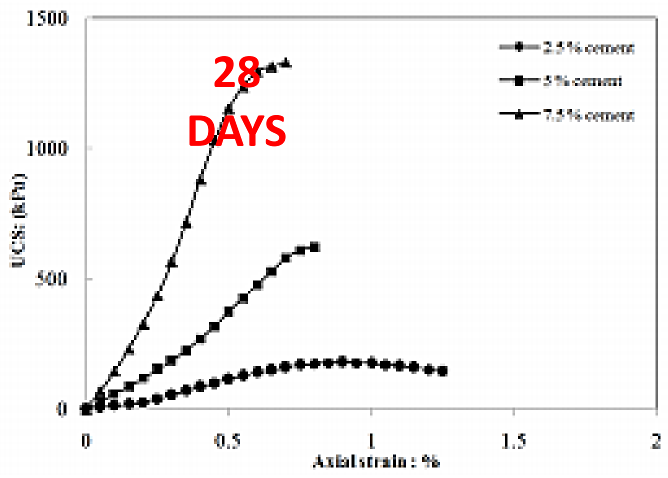


- The addition of lime portland cement even in small amounts can significantly improve the soil strength. The unconfined compression strength increased approximately linearly with an increase in the cement content.
- Increasing the curing time increased the UCS, but the effect of curing time on maximum UCS is more pronounced for higher amounts of cement.



(a)





➢ The unconfined compressive strength varies linearly with % cement. This increase is more pronounced for coarse grained soil than for silts and clay.

➢ According to Mitchell (1976) the following relation was given between qu and curing time:

$$qu(t) = qu(t0) + K \log \frac{t}{t_o}$$

where,

qu(t) = compressive strength at t days, kPa

qu(t0) = compressive strength at t0 days, kPa

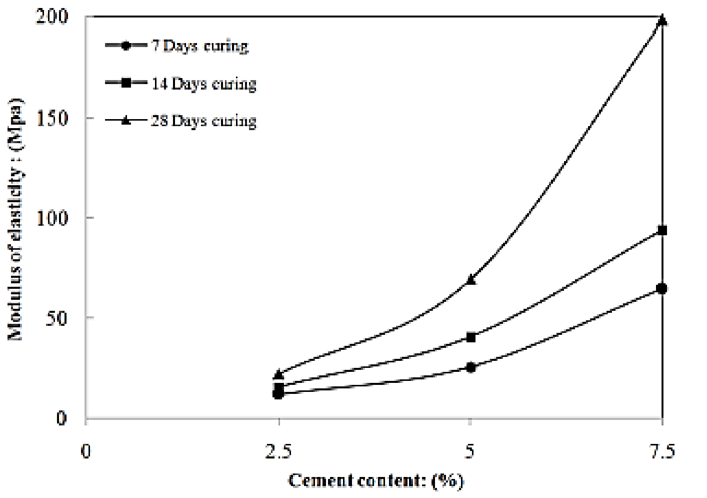
K = a constant

K=480C for granular soils

K=70C for fine grained soils

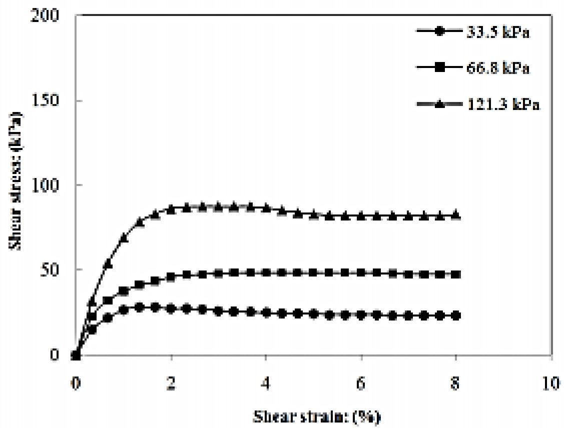
C = cement content (%)

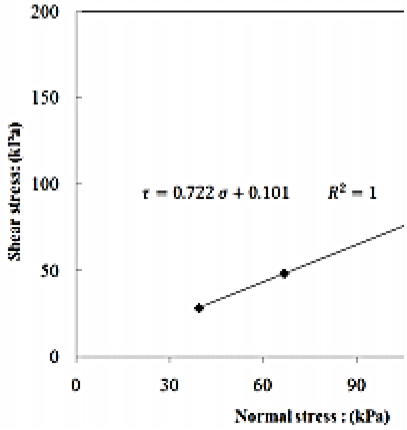
- The stabilized soil exhibits brittle behaviour during UCS test. Significant increases in modulus of elasticity and decreases in the strain at failure occur with the addition of lime portland cement.



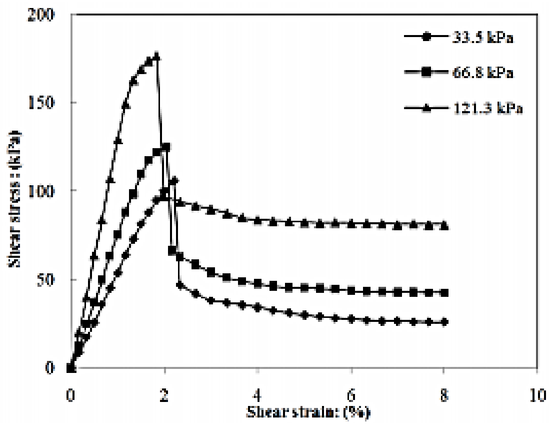
- The shear strength parameters, cohesion and angle of friction increases with cement content. The substantial increase in cohesion is evident than internal friction angle.
- There is a considerable increase in cohesion and internal friction angle in samples containing lime portland cement with increasing curing time, but the effect of curing time is more moderate than cement content.
- After peak shear stress, the maximum shear stress dropped towards approximately the same value found for the direct shear test carried out on the natural soil.

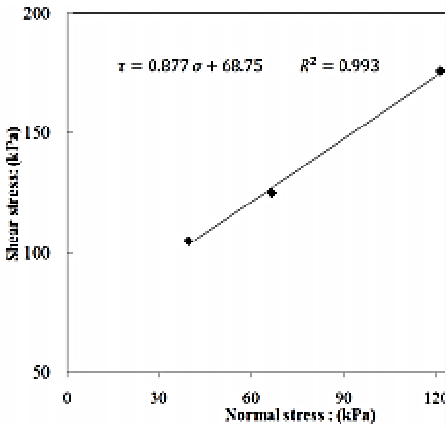
WITHOUT CEMENT





WITH CEMENT





- Cement reduces the plasticity index of clayey soils. It depends on the soil whether it is due to increase of plastic limit or by reduction of liquid limit.
- Even small additions of cement to an expansive subgrade soil significantly reduce shrinkage and swell, generally below 1%. Cement provides stability against freeze thaw cycle and repeated wet and dry cycles.

7 Describe the effect of CaCl2 when added in soil. [10] CO3 L2

- The Ca2+ ion replaces the cations on clay surface.
- This creates more repulsion between clay particles creating the structure more flocculated.
- Reduce the thickness of diffused double layer.
- It reduces the plasticity of soil.

- It increases the strength of soil.
- It changes the characteristics of water present in the pores.
- CaCl2 present in water in the pores lowers the rate of evaporation as CaCl2 has got lower vapour pressure than water.
- CaCl2 is hygroscopic and deliquescent and hence the moisture lost from the pores is less.
- Thus it reduces evaporative losses from soil.
- Hence used for moisture control during construction.
- It helps in control of dust generated from unpaved roads as it reduces visibility as well as the fines which provides cohesion isn't lost (this is the most appreciated use of CaCl2).
- Frost heave is reduced as the salt reduces the freezing point of water.
- All the improvement remain only if the salt remains in the pore water. If it is washed off the benefits due to salt in pore water is lost.
- It damages vegetation and will leach downward.
- In cold regions CaCl2 is used for faster thawing for frozen soils and thus it makes compaction possible.
- The strength reduction after repeated freeze thaw cycles is less for CaCl2.
- It can be a useful additive for cement and lime stabilization. (it supplements with Ca2+ ions).

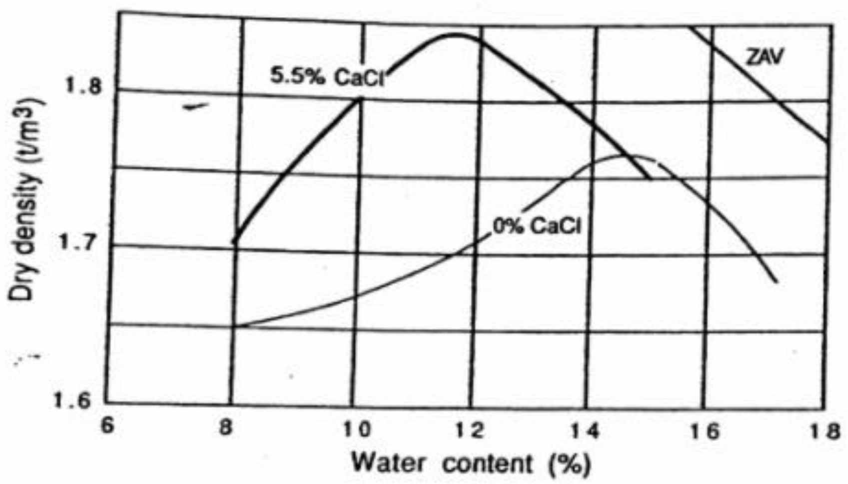


FIGURE 13.8
Compaction curves of a gravelly clay with and without calcium chloride. *(Courtesy Industries Pty. Ltd., 1983.)*

- The maximum dry density increases and OMC decreases in the gravelly clay due to the following factors:
    - CaCl2 increases the surface tension of moisture films aiding compaction.
    - CaCl2 causes flocculation making compaction difficult.
    - Here the collective effect is CaCl2 has aided the compaction but this cannot be generalized as it depends on the soil.

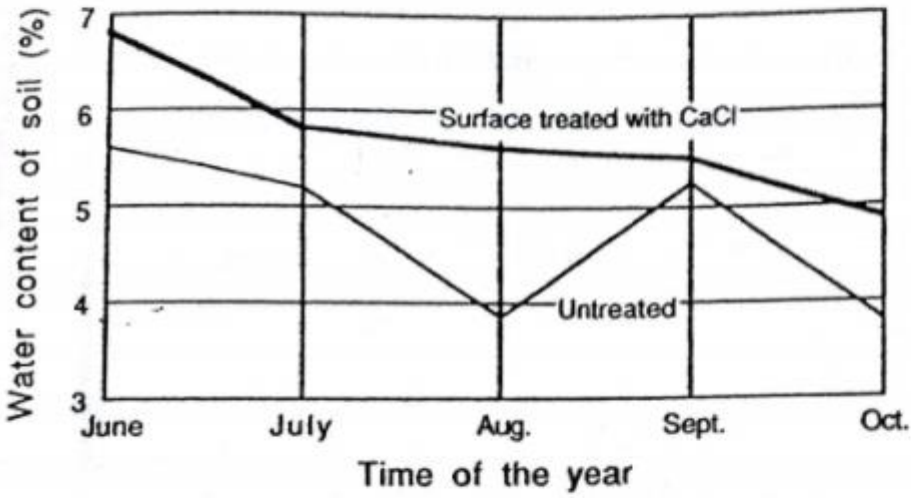


FIGURE 13.9
Moisture loss from a sandy clay. [*Burggraf (1933).*]

- Please note CaCl2 is generally used for moisture control than for strength. IN SOME CASES STRENGTH DECREASES (Brandl).