Total and differential settlement

Settlement deals with the sinking of structure due to compression of soil.

As per IS code, the following types of settlements are reported:

1. Total settlement:- it is combination of initial and consolidation settlement

Elastic settlement/ initial settlement:- initial/elastic settlement is the settlement caused due to elastic

properties of the soil due to applied load.

Consolidation settlement -

Primary consolidation: - is the consolidation occurs due to the expulsion of air from the voids.

Secondary/creep:- is the consolidation due to expulsion of water from the voids.

2**. Differential settlement/ angular distortion**:- it is the difference in settlement between two points below the

footing.

soil improvement through installation of drains and preloading.

Introduction

- 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.

Introduction cont.

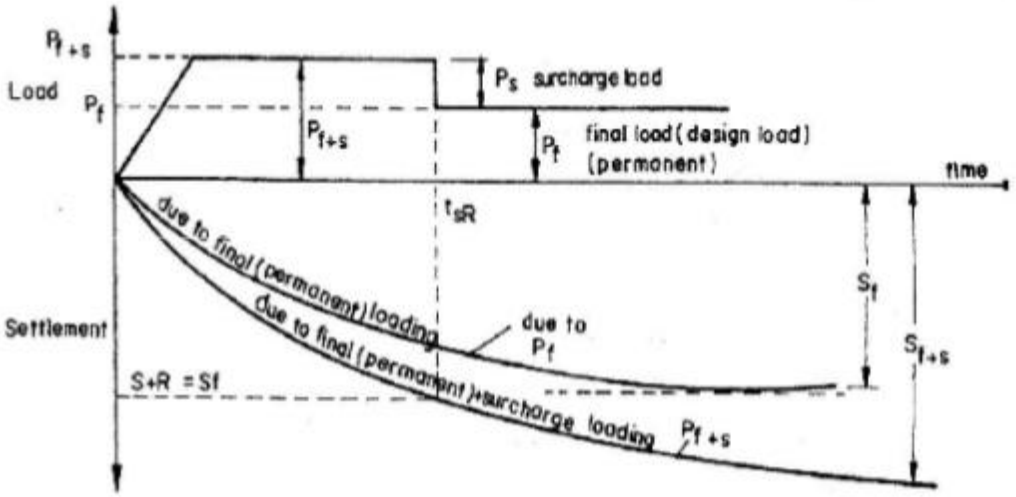
- According to Bergado et al. (1996) ground improvement techniques can be divided broadly into two categories.

1. Technique 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).
2. Technique which includes strengthening of the soil by dewatering, i.e. preloading techniques often combined with vertical drains.

Preloading OR Precompression

- Preloading is surcharging the ground with a uniformly distributed surface load prior to the construction of the structure such as Buildings, Embankments, Motorways, and Runways Tanks etc.)
- The purpose is to take up the settlements under the Civil Engineering structures before they are built.
- Soils suitable for preloading: Compressible soft to medium soft saturated clays and silts, organic clays, peats.

Preloading cont.



Primary consolidation by using surcharge loading

Preloading cont.

- Types of preloads:

  Earth fills (Most common), Water in tanks or ponds, vaccum application under a membrane, special anchor and jack systems, groundwater lowering, electro osmosis.

- The surcharge results in;

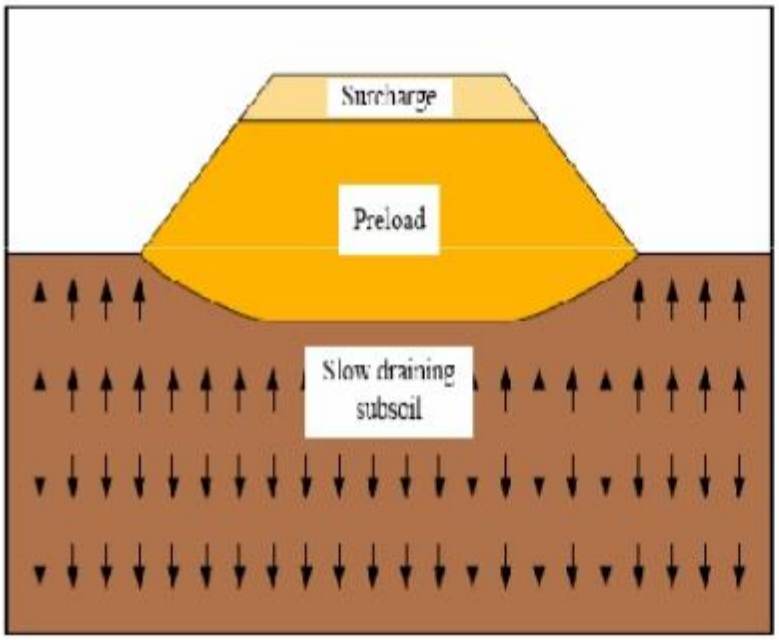
1. Primary Consolidation Settlement
2. Secondary Consolidation Settlement
3. Increase in the undrained shear strength of the soil.

Preloading Techniques

A. Conventional Preloading

- The simplest solution of preloading is a preload, e. g. by means of an embankment.
- When the load is placed on the soft soil, it is initially carried by the pore water. When the soil is not very permeable, which is normally the case; the water pressure will decrease gradually because the pore water is only able to flow away very slowly in vertical direction.
- In order not to create any stability problems, the load must mostly be placed in two or more stages.

Conventional Preloading cont.



The principle of Conventional Preloading

If the temporary load exceeds the final construction load, the excess refers to as surcharge load.

Conventional Preloading cont.

- The temporary surcharge can be removed when the settlements exceeds the predicted final settlement.
- This should preferably not happen before the remaining excess pore pressure is below the stress increase caused by the temporary surcharge.
- By increasing the time of temporary overloading, or the size of the overload, secondary settlement can be reduced or even eliminated.
- This is because by using a surcharge higher than the work load, the soil will always be in an over consolidated state and the secondary compression for over consolidated soil are much smaller than that of normally consolidated soil. This will benefit greatly the subsequent geotechnical design.

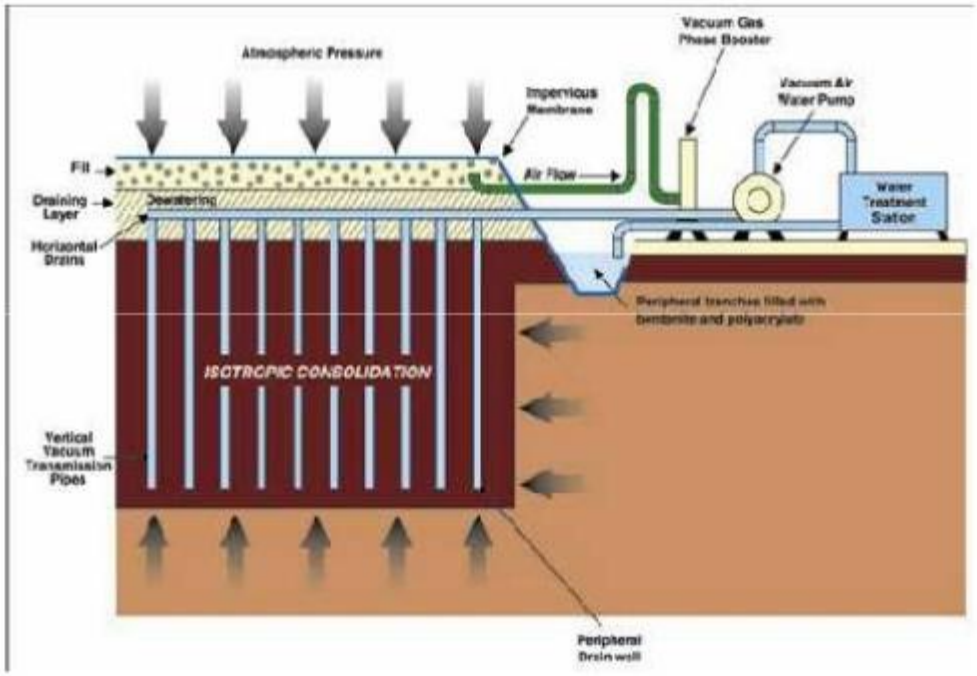
B. Vacuum Preloading

- Sometimes soft soil may be so weak that even a common 1.5 m embankment might cause stability problems. Then it can be suitable to use the method of vacuum preloading.
- In 1952 Kjellman was the first who introduced vacuum preloading to accelerate consolidation. In vacuum consolidation the surcharge load is replace by atmospheric pressure.
- In its simplest form the method of vacuum consolidation consists of a system of vertical drains and a drainage layer (sand) on top.

Vacuum Preloading Conti….

- The common advantages of vacuum preloading are that there is no extra fill material needed, the construction times are generally shorter and it requires no heavy machinery. Moreover, no chemical admixtures will penetrate into the ground and thus it is an environmental friendly ground improvement method.

Vacuum Preloading cont.



Vacuum Preloading cont.

Possible problems associated with vacuum preloading are:

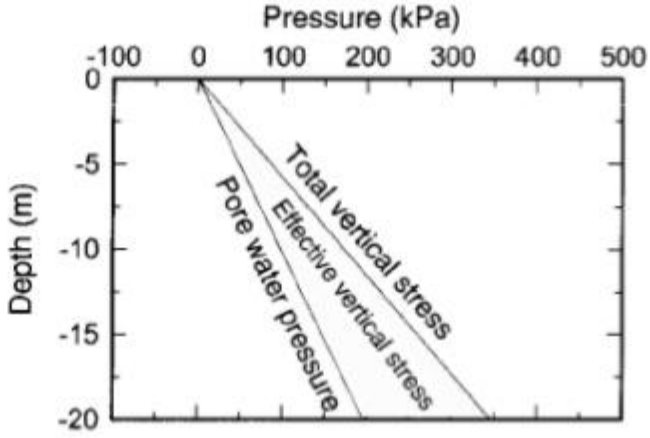
- To maintain an effective drainage system under the membrane that expels water and air throughout the whole pumping duration.
- Keeping non-water saturated medium below the membrane.
- To maintain an effective level of vacuum.
- To maintain a leak proof system in particular at the pumps / membrane connections and over the entire membrane area.

Vacuum Preloading cont.

- Anchoring and sealing of the system at the periphery.
- Reducing lateral seepage towards the vacuum area.

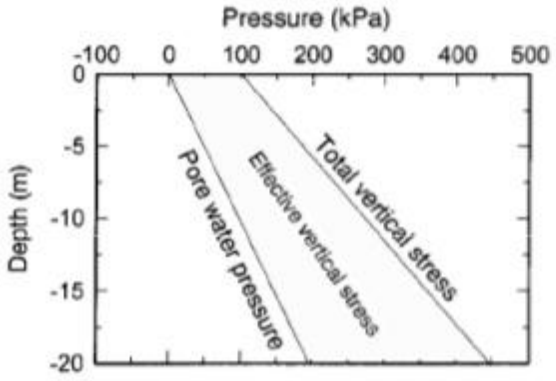
Principles of Preloading

Figure illustrates schematically a vertical stress profile when a vacuum load (assuming 100 % efficiency) is applied to the ground surface in comparison with initial conditions and conventional surcharge.

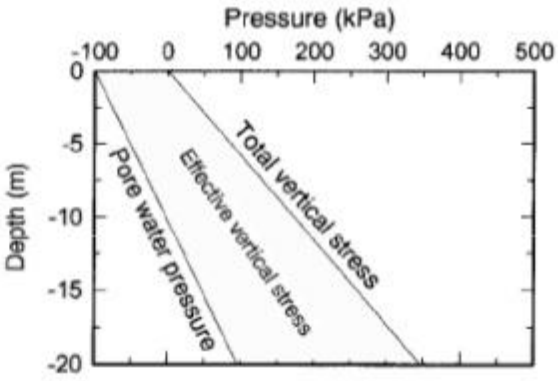


a) initial in situ conditions

Principles of Preloading cont.



b) conventional surcharge



c) vacuum induced surcharge

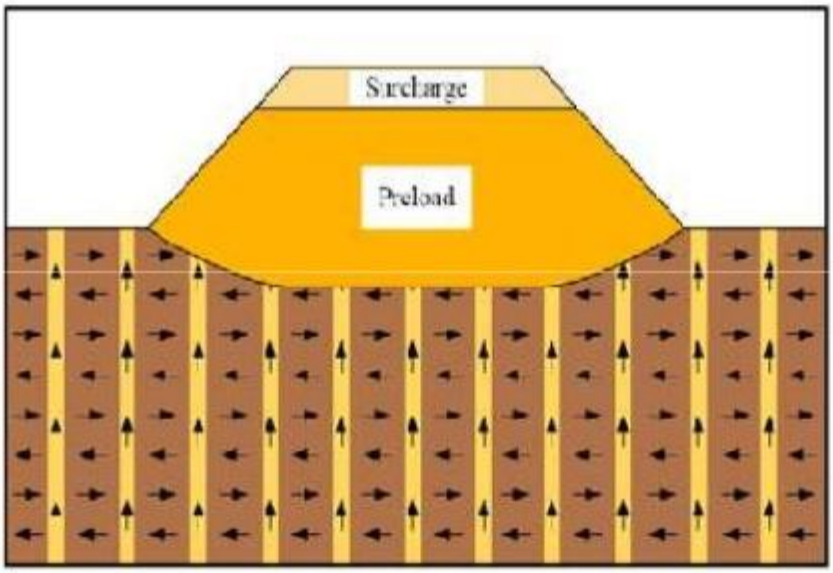
Vertical Drains

- Preloading technique may not work sometimes alone due to a thick uniform soft clay layer or permeability of the clay is very low.
- so time for precompression is very long and not practical or surcharge will be very high for reasonable waiting periods.
- Because of its low permeability, the consolidation settlement of soft clays takes a long time to complete. To shorten the consolidation time, vertical drains are installed together with preloading either by an embankment or by means of vacuum pressure.

Vertical Drains cont.

- Therefore, the vertical drain installation reduces the length of the drainage path and, consequently, accelerates the consolidation process and allows the clay to gain rapid strength increase to carry the new load by its own.

Vertical Drains cont.



Preloading with vertical drains

Drain Type	Installation Method	Drain Diameter [m]	Typical Spacing [m]	Maximum Length [m]
Sand Drain	Driven or vibratory closed-end mandrel (displacement type)	0.15-0.6	1-5	<=30
Sand Drain	Hollow stem continuous flight auger (low displacement)	0.3-0.5	2-5	<=35
Sand Drain	Jetted (non-displacement)	0.2-0.3	2-5	<=30
Prefabricated Sand Drains ("sand wicks")	Driven or vibratory closed-end mandrel; flight auger; rotary wash boring (displacement or non-displacement)	0.06-0.15	1.2-4	<=30
Prefabricated band-shaped drains	Driven or vibratory closed-end mandrel (displacement or low displacement)	0.05-0.1 (equivalent diameter)	1.2-3.5	<=60

Types of Vertical Drains

- Sand drains are basically boreholes filled with sand. As for the displacement type of sand drains, a closed mandrel is driven or pushed into the ground with resulting displacement in both vertical and horizontal directions.
- The installation causes therefore disturbances, especially in soft and sensitive clays, which reduces the shear strength and horizontal permeability.
- The low- or non-displacement installations are considered to have less disturbing effects on the soil. Drilling of the hole is done by means of an auger or water jets. In terms of jetting, however, installation is very complex.

Types of Vertical Drains conti.

- The installation of prefabricated vertical drains is also done by a mandrel and it is a displacement installation. The dimensions of the prefabricated drains are much smaller compared to sand drains and subsequently are the dimensions of the mandrel. Thus, the degree of soil disturbance caused by the size of the mandrel during installations is lower.
- At the tip of the mandrel is detachable shoe or anchor made of a small piece of metal (given in following figure). Sometimes it might also be a piece of drain itself. The purpose of the anchor is to prevent soil from entering the mandrel and plugging it during penetration. It also keeps the drain at the desired depth as the mandrel is withdrawn.

Some disadvantages of sand drains

- To receive adequate drainage properties, sand has to be carefully chosen which might seldom be found close to the construction site.
- Drains might become discontinuous because of careless installation or horizontal soil displacement during the consolidation process.
- During filling bulking of the sand might appear which could lead to cavities and subsequently to collapse due to flooding.
- Construction problems and/or budgetary burdens might arise due to the large diameter of sand drains.
- The disturbance of the soil surrounding each drain caused by installation may reduce the permeability, the flow of water of water to the drain and thus the efficiency of the system.
- The reinforcing effect of sand drains may reduce the effectiveness of preloading the subsoil.