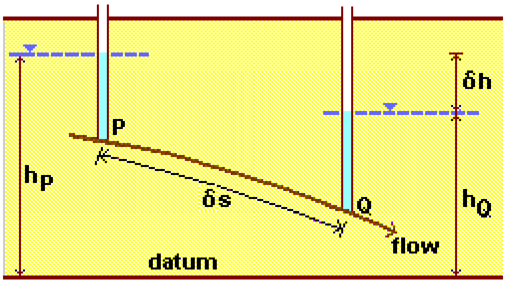
LECTURE 9

Effective stress under Hydrodynamic Conditions:

There is a change in pore water pressure in conditions of **seepage flow** within the ground. Consider seepage occurring between two points **P** and **Q**. The potential driving the water flow is the hydraulic gradient between the two points, which is equal to the head drop per unit length. In steady state seepage, the gradient remains constant.

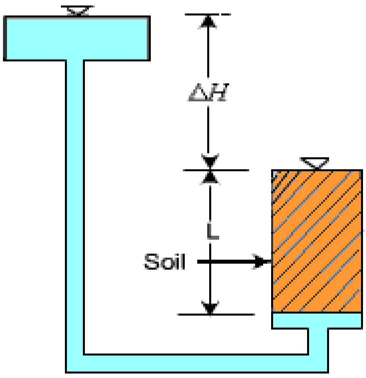


Hydraulic gradient from P to Q, **i = Δh/Δs**

As water percolates through soil, it exerts a drag on soil particles it comes in contact with. Depending on the flow direction, either downward of upward, the drag either increases or decreases inter-particle contact forces.

A downward flow increases effective stress.

In contrast, an upward flow opposes the force of gravity and can even cause to counteract completely the contact forces. In such a situation, effective stress is reduced to zero and the soil behaves like a very viscous liquid. Such a state is known as **quick sand condition.** In nature, this condition is usually observed in coarse silt or fine sand subject to artesian conditions.



At the bottom of the soil column,

$$\sigma = \gamma . L$$
$$u = \gamma_w (L + \Delta H)$$

During quick sand condition, the effective stress is reduced to zero.

$$\gamma . L = \gamma_w (L + \Delta H)$$
$$L(\gamma - \gamma_w) = \gamma_w . \Delta H$$
$$L . \gamma_b = \gamma_w . \Delta H$$
$$\frac{\Delta H}{L} = \frac{\gamma_b}{\gamma_w} = i_{cr} \approx 1$$

where i_{cr} = **critical hydraulic gradient**

This shows that when water flows upward under a hydraulic gradient of about 1, it completely neutralizes the force on account of the weight of particles, and thus leaves the particles suspended in water.

Importance of Effective stress:

At any point within the soil mass, the magitudes of both total stress and pore water pressure are dependent on the ground water position. With a shift in the water table due to seasonal fluctuations, there is a resulting change in the distribution in pore water pressure with depth.

Changes in water level ***below ground*** result in changes in effective stresses below the water table. A rise increases the pore water pressure at all elevations thus causing a decrease in effective stress. In contrast, a fall in the water table produces an increase in the effective stress.

Changes in water level ***above ground*** do not cause changes in effective stresses in the ground below. A rise above ground surface increases both the total stress and the pore water pressure by the same amount, and consequently effective stress is not altered.

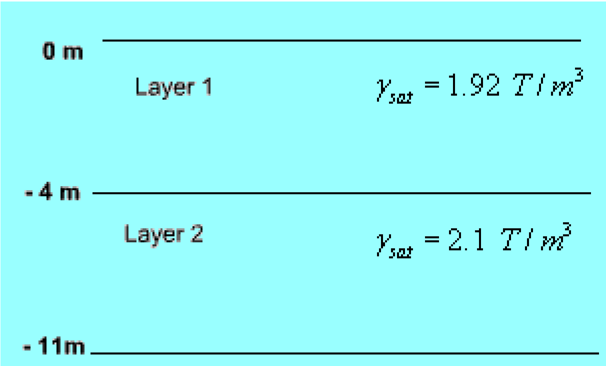
In some analyses it is better to work with the *changes* of quantity, rather than in absolute quantities. The effective stress expression then becomes:

$\sigma' = \boldsymbol{\sigma} - \mathbf{u}$

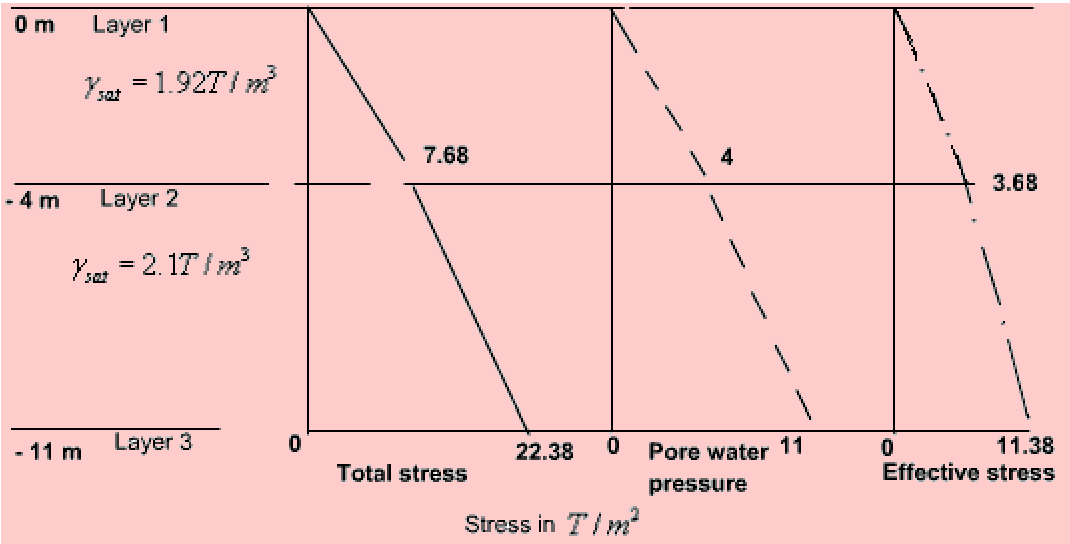
If both total stress and pore water pressure change by the same amount, the effective stress remains constant.

Total and effective stresses must be distinguishable in all calculations. Ground movements and instabilities can be caused by changes in total stress, such as caused by loading by foundations and unloading due to excavations. They can also be caused by changes in pore water pressures, such as failure of slopes after rainfall.

Example 1: For the soil deposit shown below, draw the total stress, pore water pressure and effective stress diagrams.The water table is at ground level.



Solution:



Total stress

At - 4m, σ = 1.92 x 4 = 7.68 T/m^2

At -11m, σ = 7.68 + 2.1 x 7 = 22.38 T/m^2

Pore water pressure

At - 4 m, u = 1 x 4 = 4 T/m^2

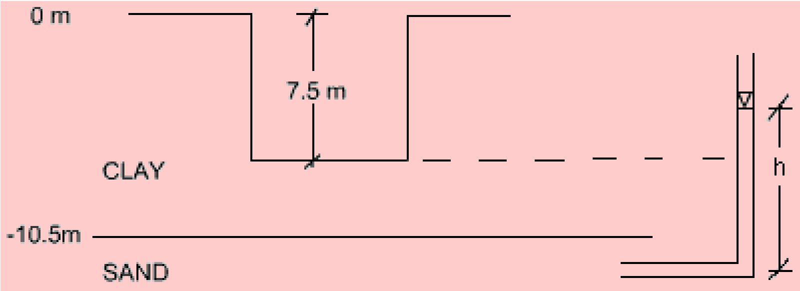
At -11 m, u = 1 x 11 = 11 T/m^2

Effective stress

At - 4 m , $\bar{\sigma}$ = 7.68 - 4 = 3.68 T/m^2

At -11m , $\bar{\sigma}$ = 22.38 - 11 = 11.38 T/m^2

Example 2: An excavation was made in a clay stratum having γ_t = 2 T/m^3. When the depth was 7.5 m, the bottom of the excavation cracked and the pit was filled by a mixture of sand and water. The thickness of the clay layer was 10.5 m, and below it was a layer of pervious water-bearing sand. How much was the artesian pressure in the sand layer?



Solution:

When the depth of excavation was 7.5 m, at the interface of the CLAY and SAND layers, the effective stress was equal to zero.

Downward pressure due to weight of clay = Upward pressure due to artesian pressure

(10.5 - 7.5) γ_t = $\gamma_w . h$, where h = artesian pressure head

3 x 2 = 1 x h

$\therefore$ h = 6 m = 0.6 kg/cm^2 or 6 T/m^2 artesian pressure