Karl Terzaghi was born in Vienna and subsequently became a professor of soil mechanics in the USA. He was the first person to propose the relationship for effective stress (in 1936):

\[
\text{effective stress} = \text{total stress} - \text{pore pressure}
\]

Effective stress, \( \sigma' \): stress carried by the solid particles.
Pore water pressure, \( u \): stress carried by pore water.
It is the combined effect of total stress and pore pressure that controls soil behaviour such as
- shear strength,
- compression and
- distortion.

The difference between the total stress and the pore pressure is called the effective stress:

\[ \text{effective stress} = \text{total stress} - \text{pore pressure} \]
\[ \sigma' = \sigma - u \]

Note that the prime (dash mark \( \prime \)) indicates effective stress.

The total vertical stress acting at a point below the ground surface is due to the weight of everything lying above:

soil, water, and surface loading.

Total stresses are calculated from the unit weight of the soil. Unit weight ranges are:

- dry soil, \( \gamma_d \): 14 - 20 kN/m\(^3\) (average 17kN/m\(^3\))
- saturated soil, \( \gamma_{sat} \): 18 - 23 kN/m\(^3\) (average 20kN/m\(^3\))
- Water, \( \gamma_w \): 9.81 kN/m\(^3\) (\( \approx \) 10 kN/m\(^3\))
Total stress in homogeneous soil

Total stress increases with depth and with unit weight:

Vertical total stress at depth \( z \),

\[ \sigma_v = \gamma z \]

The unit weight, \( \gamma \), will vary with the water content of the soil.

\( \gamma_d, \gamma_b \) and \( \gamma_{sat} \)
Groundwater and hydrostatic pressure

**Pore water pressure** Under hydrostatic conditions (no water flow) the pore pressure at a given point is given by the **hydrostatic pressure**:

\[ u = \gamma_w \cdot h_w \]

where

\[ h_w = \text{depth below water table or overlying water surface} \]
Water table, phreatic surface

- **Pore pressure** The natural static level of water in the ground is called the **water table** or the **phreatic surface** (or sometimes the **groundwater level**).

- Under conditions of no seepage flow, the water table will be horizontal, as in the surface of a lake.

- The magnitude of the pore pressure at the water table is zero.

- Below the water table, pore pressures are positive.
  \[ u = \gamma_w \cdot h_w \]

- In conditions of steady-state or variable seepage flow, the calculation of pore pressures becomes more complex.

For fully saturated soils

**effective stress = total stress - pore pressure**

\[ \sigma'_A = \sigma_A - u_A \]

\[ \sigma'_A = \gamma_{sat} \cdot Z - \gamma_w \cdot Z \]

\[ Z(\gamma_{sat} - \gamma_w) \]

\[ Z(\gamma') \]

\[ \gamma' = \text{Effective unit weight} \]

\[ \text{Bouyant unit weight} \]

\[ \text{Submerged unit weight} \]
Negative pore pressure (suction)

- **Pore pressure** Below the water table, pore pressures are **positive**.

- In dry soil, the pore pressure is **zero**.

- Above the water table, when the soil is saturated, pore pressure will be **negative**.
  \[ u = -\gamma_w \cdot hw \]

Negative pore pressure (suction)

The height above the water table to which the soil is saturated is called the **capillary rise**, and this depends on the grain size and type (and thus the size of pores):

- in coarse soils capillary rise is very small
- in silts it may be up to 2m
- in clays it can be over 20m