Lecture 2 Notes – Phase Relationships

B. Weight-Volume Relationships (Phase Relations)

Soil is inherently "multiphase". It contains three distinct phases: Solid (mineral particles), gas (air), and liquid (usually water). It is very important that students of soil mechanics become familiar with these relationships and can fluently utilize them.

Development of Phase Relations:

Definitions of Symbols: \( V, V_v, V_d, V_w, V_s, & W_w, W_s, W \)

(1) Define three volumetric relationships between phases:

- Porosity \( n = V_v/V = V_v/(V_v+V_s) = e/(1+e) \)
- Void Ratio \( e = V_v/V_s = V_v/(V-V_v) = n/(1-n) \)
- Degree of Saturation \( S = V_w/V_v \)

(2) Define Weight relationships between phases

Moisture content \( w = W_w/W_s \)

Define weight – volume relationships:

- Total Unit Wt. \( \gamma = W/V \)
- Solid Unit Wt. \( \gamma_s = W_s/V_s \)
- Water Unit Wt. \( \gamma_w = W_w/V_w \)
- Dry Unit Wt. \( \gamma_d = W_v/V \)
- Submerged Unit Wt. \( \gamma_b = \gamma - \gamma_w \) (or known as buoyancy unit weight)
- Saturated Unit Weight. \( \gamma_{sat} = (\gamma_w V_v + W_s)/V \)
- Specific Gravity of Solid. \( G_s = \gamma_s/\gamma_w \)
- Specific Gravity of Mass. \( G_m = \gamma / \gamma_w \)

It is easier for measuring the weight of soil than measuring its volume.
Some other inter-relation can be further developed by mathematically inter-changing the terms.

The way to compute the phase relations is:

1. Draw the phase diagram
2. List the known quantities
3. Compute the unknown quantities and fill out the phase diagram
4. Compute the required quantities

Examples:

Find an equation to express w in terms of G, γ_w, γ_sat

2) Known quantities: G, w, γ_w, γ_sat (implies S = 100%, V_w = V_v, V_a = 0)

3) Fill in all blanks
   a) Assume V = 1 then V_v + V_s = 1;
   b) W = γ_sat (1);
   c) W_w = w W_s;
      W_w + W_s = γ_sat; w W_s + W_s = γ_sat;
      (1+w)W_s = γ_sat; W_s = γ_sat/(1+w);
   d) W_w = w W_s = w γ_sat / (1+w)
   e) V_s = W_s / (G γ_w) = γ_sat / [G γ_w (1+w)]
   f) V_w = W_w/ = w γ_sat / [γ_w (1+w)]

4) Find the relationship

   w γ_sat / [γ_w (1+w)] + γ_sat /[G γ_w (1+w)] = 1 = total vol.
   w G γ_sat + γ_sat = G γ_w (1+w)
\[ w \, G \, \gamma_{\text{sat}} - w \, G \, \gamma_w = G \, \gamma_w - \gamma_{\text{sat}} \]

\[ w = (G \, \gamma_w - \gamma_{\text{sat}}) / [G \, (\gamma_{\text{sat}} - \gamma_w)] \]