Lecture 2

PHYSICAL AND INDEX PROPERTIES

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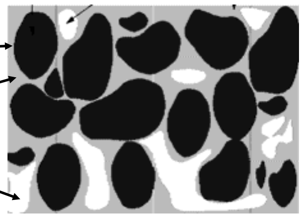
Soil Composition

- Solids
- Water
- Air



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Analytical Representation of Soil

- For the purpose of defining the physical and index properties of soil it is more convenient to represent the soil skeleton by a block diagram or phase diagram.

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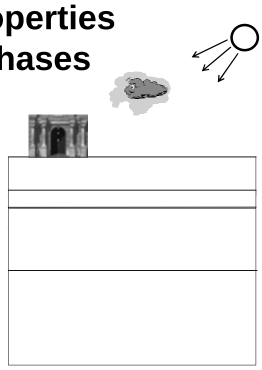
Soil Properties
Soil Phases

- Dry
- Partially Saturated
- Fully Saturated
- Submerged



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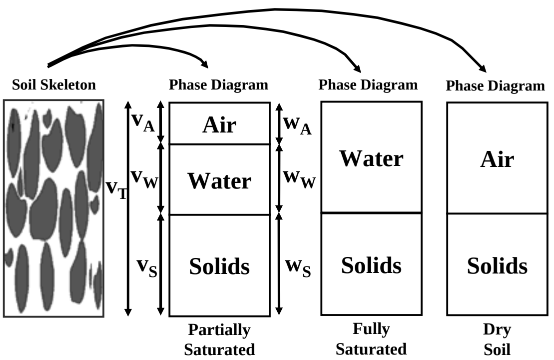
Phase Diagram



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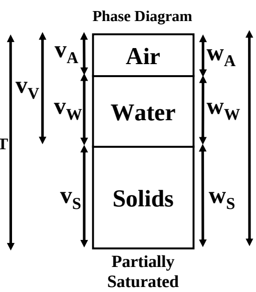
Volume - Weight

Relationships

Volume

$V_T = V_A + V_w + V_s$

$V_T = V_v + V_s$



Weight

$W_T = W_w + W_s$

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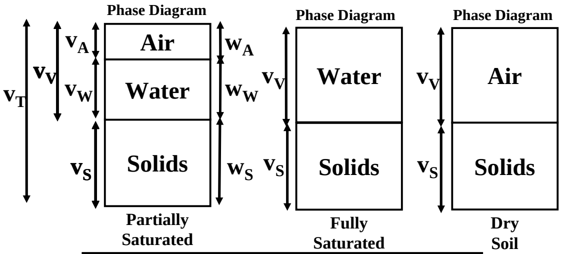
Void Ratio



$$e = \frac{\text{Volume of Voids}}{\text{Volume of Solids}} = \frac{Vv}{Vs}$$

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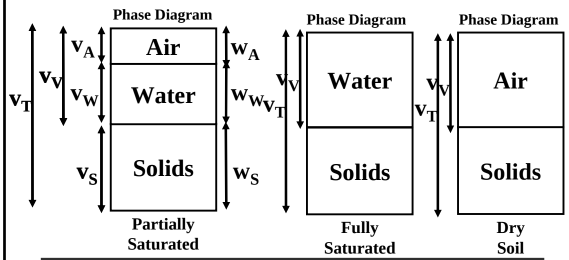
Porosity



$$n = \frac{\text{Volume of Voids}}{\text{Total Volume}} = \frac{V_V}{V_t} x100\%$$

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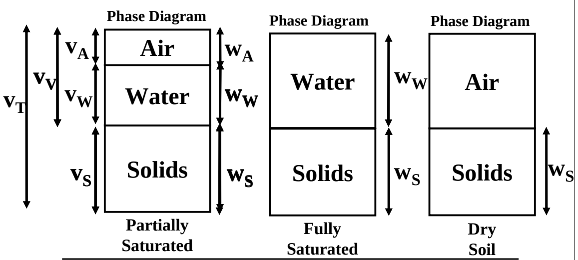
Water Content



$$w = \frac{\text{Weight of water}}{\text{Weight of Solids}} = \frac{W_W}{W_S} x100$$

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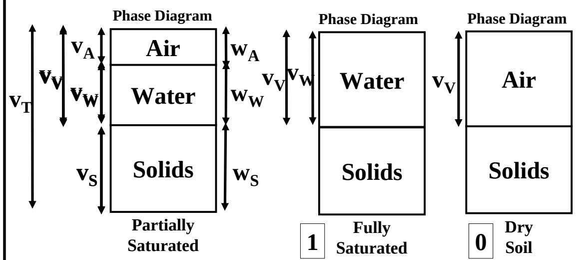
Degree of Saturation



$$S_r = \frac{\text{Volume of Water}}{\text{Volume of voids}} = \frac{V_w}{V_V}$$

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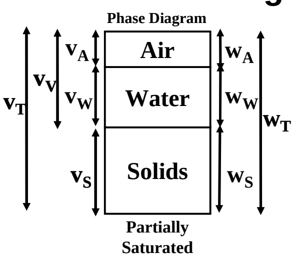
Unit Weight - Density



- Also known as
  - ✓Bulk Density
  - ✓Soil Density
  - ✓Wet Density

$$\gamma_{Soil} = \frac{\text{Total Weight}}{\text{Total Volume}} = \frac{Wt}{Vt}$$

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Specific Gravity

$$G = \frac{\text{Unit Weight in Air of a Material}}{\text{Unit Weight in Air of Referance Material}} = \frac{\gamma s}{\gamma w}$$

Remember That **Unit Weight = The Weight / Unit Volume**

- Usually the reference material is Water
- At 4° C the unit weight of water
  - ✓γ_w = 62.4 lb/ft^3
  - ✓γ_w = 1 gram/cm^3
- G = ranges Between 2.65 – 2.8 (Sand – Clay)

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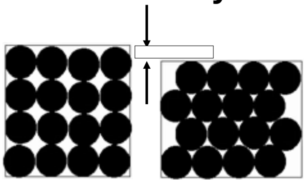
Relative Density

How can we get the maximum and minimum densities?



e_{max} e_{min}

$$Dr = \frac{e_{max} - e_{field}}{e_{max} - e_{min}}$$

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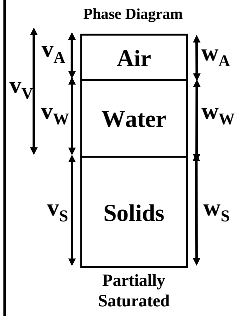
Summary Phase Diagram



- $e = \frac{V_V}{V_S}$ Void Ratio
- $n = \frac{V_V}{V_t}$ Porosity
- $w = \frac{W_W}{W_S}$ Water content

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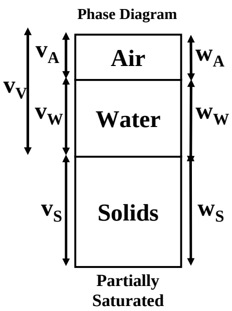
Summary Phase Diagram



- $S = \frac{V_w}{V_V}$ Degree of Saturation
- $\gamma = \frac{W_t}{V_t}$ Unit weight
- $G = \frac{\gamma_S}{\gamma_w}$ Specific Gravity

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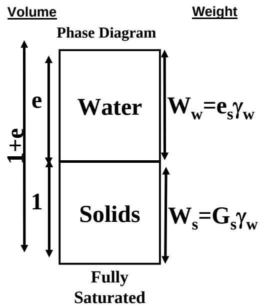
Saturated Conditions



- $e = V_v / V_s$ *(Assume that $V_s = 1$)*

$\therefore e = V_v$

- Now $\gamma_w = Ww/V_w$ or $\gamma_w = W_w/e$

$\therefore W_w = e\,\gamma_w$

- $\gamma_s = W_s/V_s$ (But $V_s = 1$)
- $\therefore \gamma_s = W_s$
- Remember $G_s = \gamma_s/\gamma_w$

$\therefore \gamma_s = Gs\,\gamma_w$

$\therefore G_w\gamma_w = e\,W_s$

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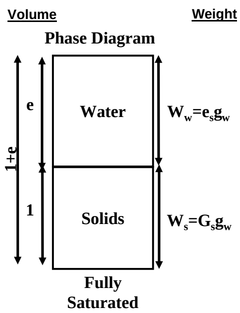
Saturated Conditions



- From the Phase diagram
- Water content $w = W_w / W_s$
- $w = W_w / W_s = e\gamma_w / \gamma_s\gamma_w = e/G_s$

$\therefore e = w\,G_s$

$\gamma_{Saturated} = W_t/V_t = e\gamma_w + G_s\,\gamma_w/1+e$

$\gamma_{Saturated} = \gamma_w(e+G_s)/1+e$

$\gamma_{Submerged} = \gamma_{Saturated} - \gamma_w$

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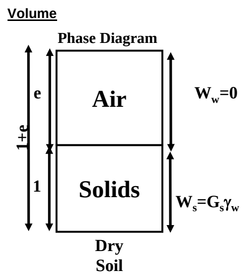
Dry Unit Weight



Weight

$\gamma_{dry} = W_T/V_T = G_s\,\gamma_w/1+e$

$\gamma_d = G_s\,\gamma_w/1+e$

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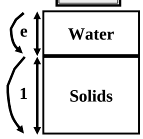
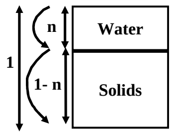
Relation Between e &n Fully Saturated

$e = \frac{V_V}{V_S}$ $\quad$ $n = \frac{V_V}{V_T}$



From Similarity

$\frac{e}{n} = \frac{1}{1-n}$



- X multiplication

- $n = e(1 - n)$

$\therefore e = \frac{n}{1-n}$

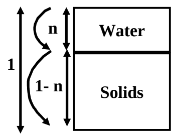
- $n = e - e\,n$
- $n = e(1 - n)$
- $n + en = e$
- $n(1 + e) = e$

$\therefore n = \frac{e}{1+e}$

Relations in Fully Saturated

$n = \frac{V_V}{V_T}$

From last Slide



$\therefore w_w = \gamma_w\, n$

How can we Find the weight relation?

$\therefore w_s = \gamma_s\, (1\text{-}n)$

- $\gamma_w = w_w/v_w$ $\quad$ $\therefore \gamma_w = w_w/\,n$ $\quad$ $\therefore w_w = \gamma_w\, n$
- $\gamma_s = w_s/v_s$ $\quad$ $\therefore \gamma_s = w_s/\,(1 - n)$ $\quad$ $\therefore w_s = \gamma_s\, (1\text{-}n)$

Remember $G_s = \gamma_s/\gamma_w$ $\quad$ $\therefore \gamma_s = G_s\, \gamma_w$

$\therefore W_s = G_s\, \gamma_w\, (1 - n)$

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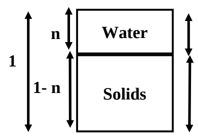
Relations in Fully Saturated



$w_w = \gamma_w\, n$

$w_s = G_s\, \gamma_w\, (1\text{-}n)$

- $\gamma_w = w_w/v_w$ $\quad$ $\therefore \gamma_w = w_w/\,n$ $\quad$ $\therefore w_w = \gamma_w\, n$
- $\gamma_s = w_s/v_s$ $\quad$ $\therefore \gamma_s = w_s/\,(1 - n)$ $\quad$ $\therefore w_s = \gamma_s\, (1\text{-}n)$
- Remember $G_s = \gamma_s/\gamma_w$ $\quad$ $\therefore \gamma_s = G_s\, \gamma_w$

$\therefore W_s = G_s\, \gamma_w\, (1 - n)$

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Three Types of Problems

- Type I
  - Only masses and/or volumes are known
- Type II
  - Only defined ratios are known
- Type III
  - Both defined ratios and masses/volumes known

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