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## Important Relationship

$$\begin{aligned}
 Y_{bulk} &= \frac{W}{V} = \frac{W_S + W_w}{V_S + V_V} \\
 &= \frac{W_S \left(1 + \frac{W_w}{W_S}\right)}{V_S \left(1 + \frac{V_V}{V_S}\right)} \\
 &= \frac{W_S}{V_S} \frac{(1+w)}{(1+e)} \\
 &= Y_S \frac{(1+w)}{(1+e)}
 \end{aligned}$$

$$\frac{W_w}{W_S} = w$$

$$\frac{V_V}{V_S} = e$$

$$Y_t = Y_s \frac{(1+\omega)}{(1+e)}$$

$$= \frac{Q_s Y_\omega (1+\omega)}{(1+e)}$$

$$= \frac{(Q_s + Q_s \omega) Y_\omega}{(1+e)}$$

$$Y_t = \frac{(Q_s + se) Y_\omega}{(1+e)}$$

imp

$$Q_s = \frac{Y_s}{Y_\omega}$$

$$Y_s = Q_s Y_\omega$$

$$se = \omega Q_s$$

Dry soil

$$\gamma_{\text{dry}} = \frac{G_s \gamma_w}{(1+e)} \quad \checkmark$$

$$S=0$$

Saturated soil

$$\gamma_{\text{sat}} = \frac{(G_s + e) \gamma_w}{(1+e)} \quad \checkmark$$

$$S=1$$

$$\begin{aligned}Y_{\text{sub}} &= Y_{\text{sat}} - Y_{\omega} \\&= \frac{(q+e)Y_{\omega}}{1+e} - Y_{\omega} \\&= \frac{(q+e - 1 - e)Y_{\omega}}{1+e}\end{aligned}$$

$$Y_{\text{sub}} = \frac{(q-1)Y_{\omega}}{(1+e)}$$

$$\checkmark \eta = \frac{e}{1+e}$$

$$\checkmark e = \frac{\eta}{1-\eta}$$

$$\frac{1}{1+e} = (1-\eta)$$

## Important Terms

Relative Density / Density IndexDegree of Densness

↳ Cohesionless soil

$$I_D \% = \left[ \frac{e_{\max} - e}{e_{\max} - e_{\min}} \right] \times 100$$

$$\gamma_d = \frac{G \gamma_w}{1+e}$$

$$\gamma_d \propto \frac{1}{e}$$

 $I_D \%$  $e_{\max} \rightarrow$  loose $e_{\min} \rightarrow$  Densest.

$$0 \leq I_D \% \leq 100\%$$

$$Y_{d \max} \propto \frac{1}{e_{\min}}$$

$$Y_{d \min} \propto \frac{1}{e_{\max}}$$

$$\checkmark \checkmark I_D \% = \left[ \frac{\frac{1}{Y_{d \min}} - \frac{1}{Y_d}}{\frac{1}{Y_{d \min}} - \frac{1}{Y_{d \max}}} \right] \times 100$$



Relative Compaction  $\rightarrow R_c$

Cohesive & cohesionless

$$\Rightarrow R_c = \frac{\gamma_{dry}}{\gamma_{d\max}} = \frac{\frac{\cancel{G} \gamma_w}{1+e}}{\frac{\cancel{G} \gamma_w}{1+e_{min}}}$$

$$\Rightarrow R_c = \left[ \frac{1+e_{min}}{1+e} \right]$$

## Relationship between Relative Density & Relative Compaction

$$R_c \% = 80 + 0.2 I_D \%$$

valid for  
cohesionless  
soil.

✓  
✓  
R.G (80% - 100%)

[0 - 100%]

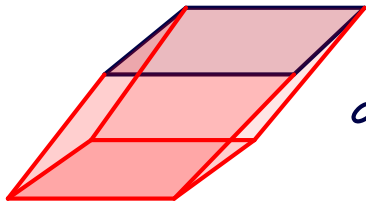
## Maximum & Minimum Theoretical Void Ratio

$e_{max} = 0.91 \rightarrow$  loosest state  $\rightarrow$  Rectangular  
or Cubical.

$n_{max} = 47\%$

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$e_{min} = 0.35 \rightarrow$  Densest state  $\rightarrow$  prismsidal  
or  
Rhombohedral



$$\alpha = 60^\circ$$

$$n_{min} = 26\%$$