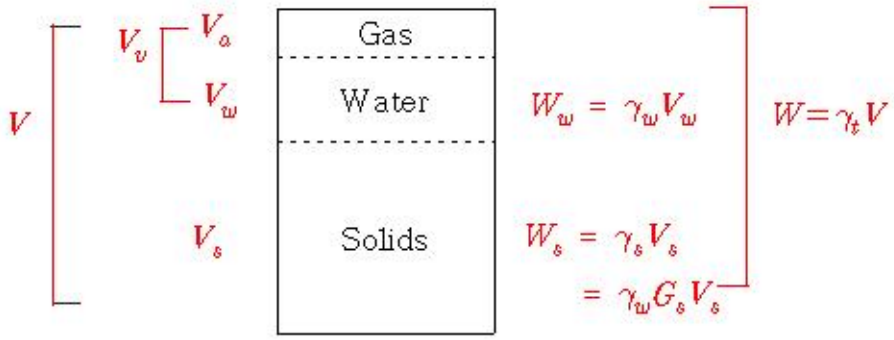
Phase* Relationships

1. Void ratio, Porosity, Degree of Saturation, Air Content

- Three separate phases of a soil element



- void ratio

$$e = \frac{V_v}{V_s}$$

- porosity

$$n = \frac{V_v}{V}(\%)$$

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

- degree of saturation

$$S = \frac{V_w}{V_v}(\%)$$

- air content

$$A = \frac{V_a}{V}$$

- water content, $w = \frac{W_w}{W_s}$

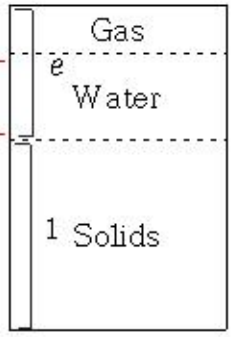
Phase* : A distinct period or stage in a process of change or forming part of something's development.

2. Unit Weights [G_s, γ_w, S, e, w]

- A soil element with volume of soil solids equal to one

$V_v = \frac{e}{1+e} V$ $\quad V_w = \frac{S \cdot e}{1+e} V$ $\quad W_w = \frac{S \cdot e}{1+e} \gamma_w V$

$V_s = \frac{1}{1+e} V$ $\quad W_s = \frac{1}{1+e} \gamma_w V \cdot G_s$ $\quad W = \frac{G_s + S \cdot e}{1+e} \gamma_w V$



- total unit weight :

$$\gamma_t = \frac{W}{V} = \frac{G + S \cdot e}{1+e} \gamma_w = \frac{1+w}{1+e} G \cdot \gamma_w$$

[∵ S·e = G·w, Eq. 1-17]

- dry unit weight :

$$\gamma_d = \frac{G}{1+e} \gamma_w \qquad [\because S = w = 0]$$

- submerged unit weight :

$$\gamma_{sub} = \underbrace{\frac{G + S \cdot e}{1+e} \gamma_w}_{= \gamma_t} - \gamma_w = \frac{G-1}{1+e} \gamma_w \qquad [\because S = 1]$$

3. Relative density (D_R, %)

- $D_R = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100$
- D_R vs ϕ, N (보충자료 1)

Soil Compaction

1. Definition : The process of increasing the density of a soil by packing the particles closer together with a reduction in the volume of air. The volume of water remains unchanged.

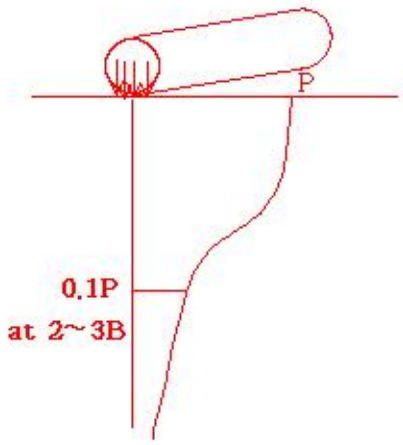
2. Equipments : rollers, vibrators, rammers (보충자료 2)

- Rollers : Smooth-wheeled / Pneumatic-typed / Sheeps foot

- Vibrators : Vibrating roller / Plates

- Rammers : Compaction of small area (tampers)

3. Degree of compaction



- measured in terms of dry density

$$\gamma_d = \frac{\gamma_t}{1+w}$$

- depends on i) types of soils
  ii) water content of soils
  iii) efforts (energy applied)

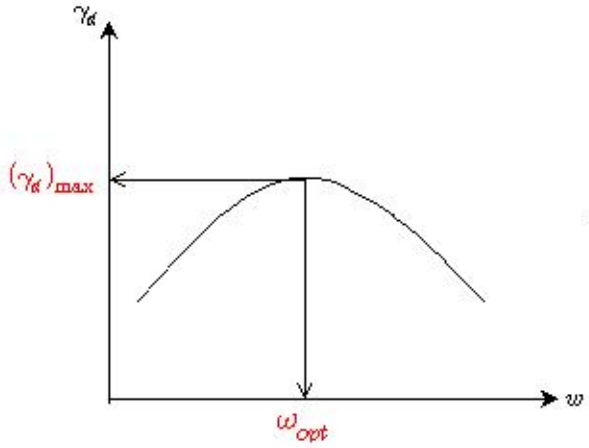
4. Laboratory tests for compaction characteristics of soils

* except for clean sands or gravels

- Compaction test (보충자료3)

	Standard effort			Modified effort		
Method	A	B	C	A	B	C
Mould diameter (mm)	101.6	101.6	152.4	101.6	101.6	152.4
Soil fraction passing sieve (mm)	4.75	9.5	19	4.75	9.5	19
Rammer (N)	24.4			44.5		
Drop height (mm)	305			457		
No. of layers	3			5		
No. of blows	25	25	56	25	25	56
E ($kN-m/m^3$)	600			2700		

- Test results



* Repeat at least 5 times
(for each water content)

- The maximum possible value of γ_d for a given water content

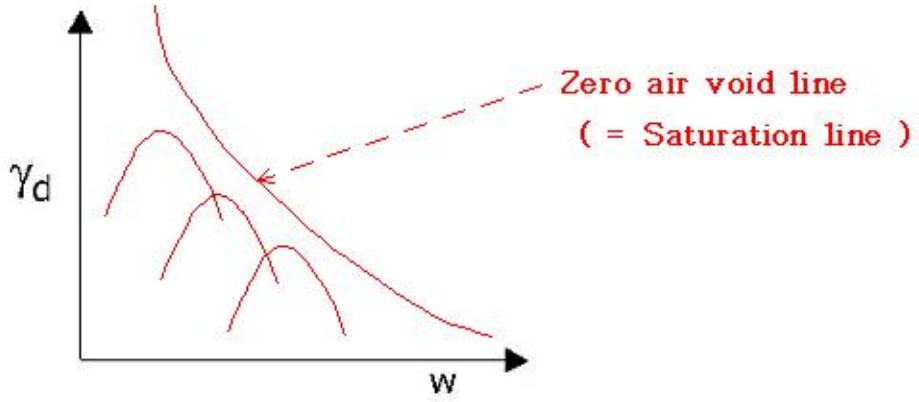
$$(\gamma_d)_{max} = \frac{G_s}{1+\omega G_s}\gamma_w$$

- γ_d with an air content, A

$$\gamma_d = \frac{G_s(1-A)}{1+\omega G_s}\gamma_w$$

5. Remarks

- zero air void line



c[1] : Higher the compactive effort, higher $(\gamma_d)_{max}$ & lower w_{opt}

c[2] : Lab. compaction test is only a rough guide.
Used for classification & selection of soils

- Relative compaction, R(%)

$$R = \frac{(\gamma_d)_{field}}{(\gamma_d)_{max-lab}} \times 100$$

*Field measurement (보충자료4)
-core cutter method
-sand replacement method
-nuclear method

- Specifications for field compaction

Ex. $R \geq 95\%, \quad \omega = \omega_{opt} \pm 2\%$

- compactibility, F (보충자료 5, Table 7.3)

$$F = \frac{e_{max} - e_{min}}{e_{min}}$$

Well-graded soils → high compatibility