Soil Mechanics and Foundation Engineering (council)

2. Soil Mechanics and Foundation Engineering **(ACiE02)**

2.1 Soil properties and laboratory tests: tests for strength, permeability, compressibility, phase relationships; determination of index and engineering properties of soils; soil classification (descriptive, textural, ISI, MIT, USCS); boring log interpretation; sieve analysis and interpretation of results; determination of Atterberg limits of soils. (ACiE0201)

2.2 Stresses on soil and seepage: effective stress (factors affecting effective stress, capillary rise, and quick sand conditions); seepage analysis [Seepage pressure, flow nets and their applications]; soil compressibility (including various indices) and compaction (definition, affecting factors). (ACiE0202)

2.3 Shear strength of soil and stability of slopes: Concept of shear strength, principal planes and principal stresses; Mohr-Coulomb theory of shear strength; calculation of normal and shear stresses at different planes; relation of principle stress at failure condition; types of shear tests; stability of slopes. (ACiE0203)

2.4 Soil exploration, earth pressure and retaining structures: soil exploration (methods, planning, soil sampling and samplers, field tests, site investigation reports); earth pressure theories; stability analysis of retaining walls; techniques to increase stability of retaining walls. (ACiE0204)

2.5 Fundamentals of foundation: Definition, Types (Shallow and Deep), functions, factor affecting, site investigation of foundation, concept of spread and mat foundation. (ACiE0205)

2.6 Bearing capacity and foundation settlements: bearing capacity (types, effects of various factors); modes of foundation failure; Terzaghi's general bearing capacity theory; ultimate bearing capacity of cohesion-less and cohesive soils; consolidation (concept, types and tests); settlement (types, nature, effects and calculations) (ACiE0206)

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Soil Types and Classification

- Soil is defined as an assemblage of discrete solid particles of organic or inorganic composition.
- Soil are formed by weathering of rocks (mechanical disintegration or Chemical decomposition).
- Soils resulting from disintegration of rock may stay at the place of their formation, known as **residual soil or sedentary soil**.
- If the soil are carried away by forces of gravity, water, wind and ice and deposited at another location, they are known as **transported soil**.

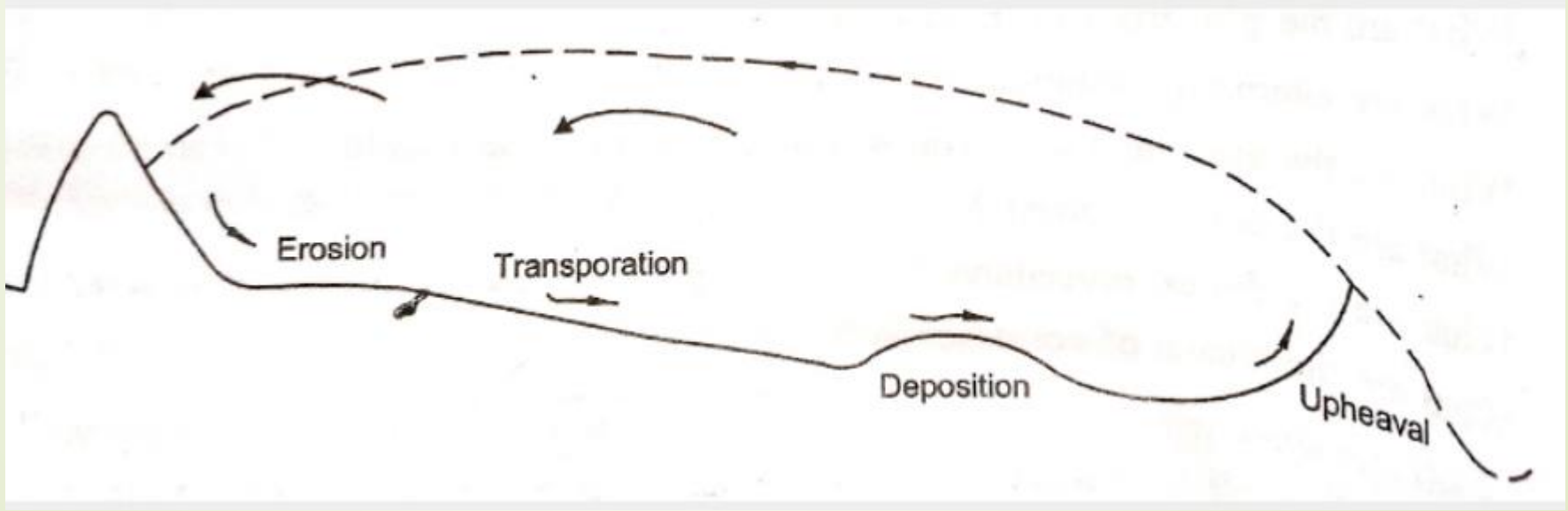


Fig: Geological Cycle (K. R. Arora, "Soil Mechanics and Foundation Engineering," Standard Publishers Distributors, Delhi, 2008)

Transported soil are further classified based on mode of transportation and place of deposition:

- **Glacial Soil or (Till) or (Drift):** Soils that are transported by **glaciers**.
- **Aeoline deposit or Loess:** Soil deposited formed by **wind**.
- **Alluvial deposit:** Soil deposits formed by **rivers and streams.**
- **Marine Deposit:** Soil deposit formed by **sea water**.
- **Lacustrine deposit:** Soil deposit in **lake beds.**
- **Colluvial (Talus):** Soil that are transported by **gravity.**

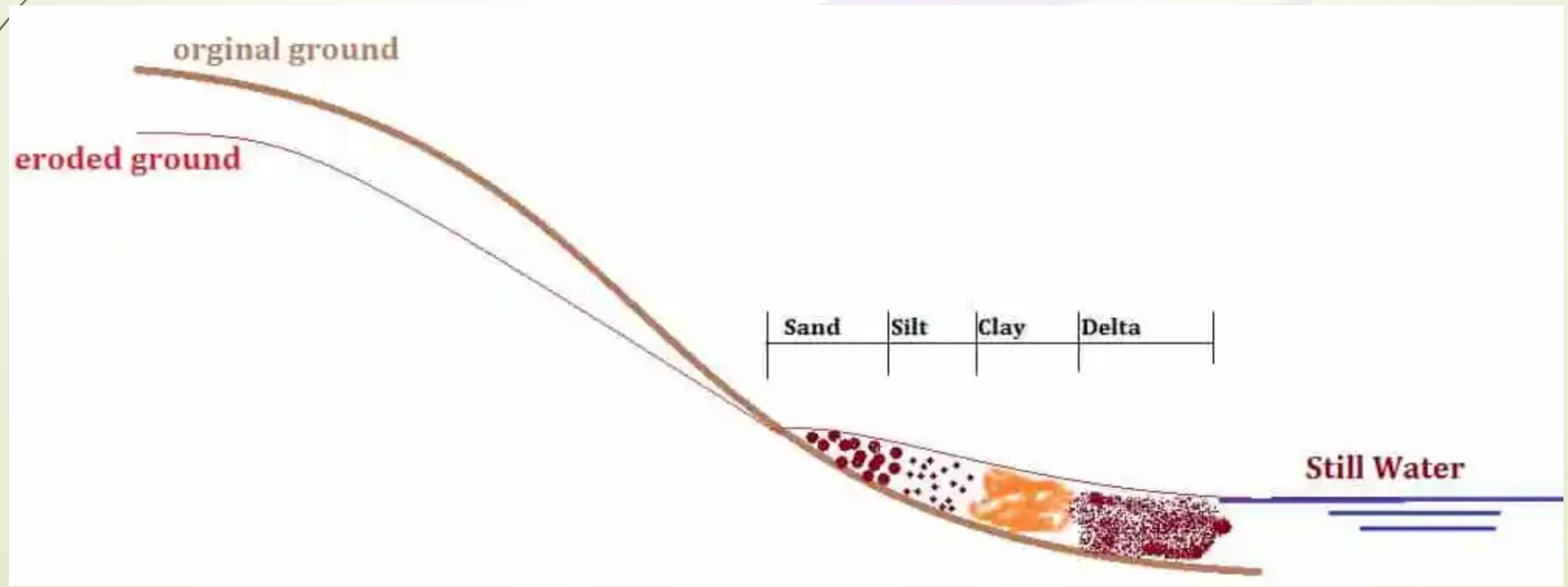


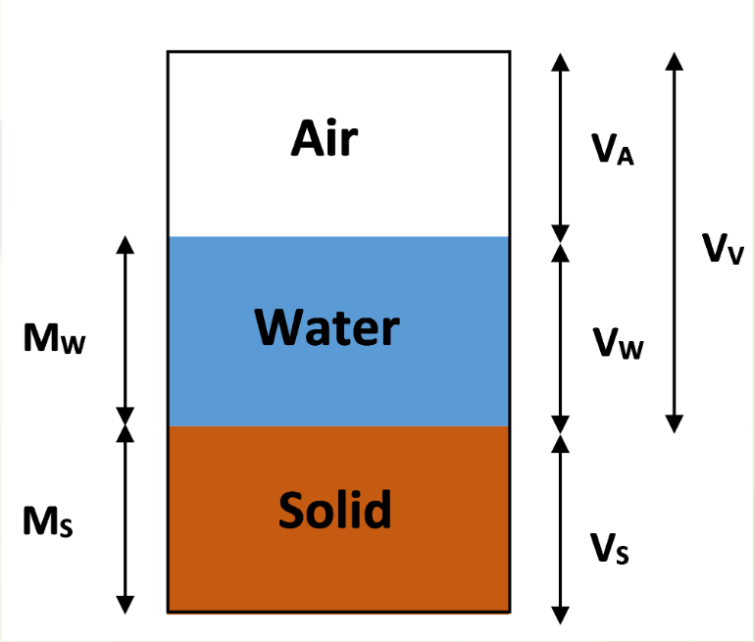
Fig: Transported soil (Alluvial) [Source: *constructor.org*]

Three Phase System of Soil

- Soil consists of solid, liquid (water) and air. Hence, soil is said to be **three phase system.**
- Water and air space fills up the voids in the solid. Hence, water and air together constitute **void space.**
- **Dry Soil:** Voids contains no water (i.e., only air is in the voids)
- **Saturated Soil:** Voids contain no air (i.e., only water in the voids)

Volumetric Relationship:

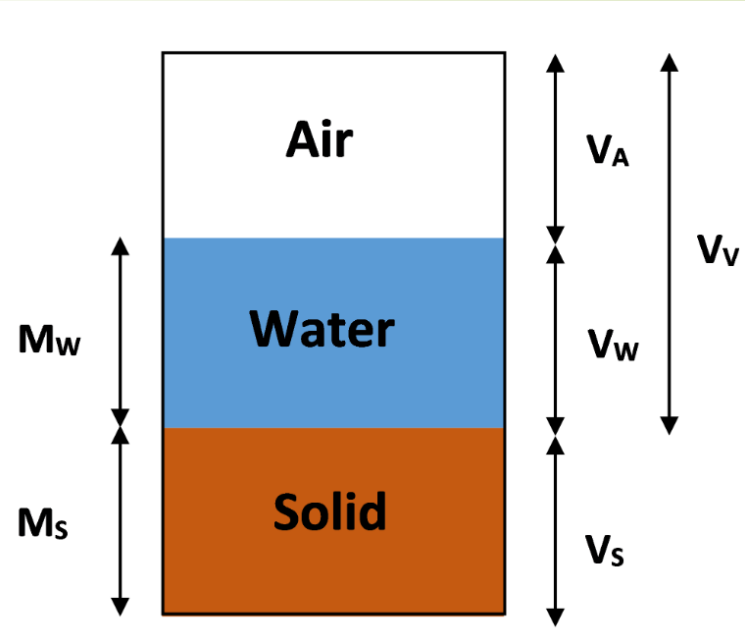
- Voids Ratio (**e**) = $\frac{V_v\ (Volume\ of\ voids)}{V_S\ (Volume\ of\ solids)}$; (can be > 1)
  - Generally, **e** for (coarse grained soil < fine grained soil).
- Porosity (**n**) = $\frac{V_v (Volume\ of\ Voids)}{V\ (Total\ Volume)}$
  - Expressed as percentage **($0 \leq n \leq 100$)**



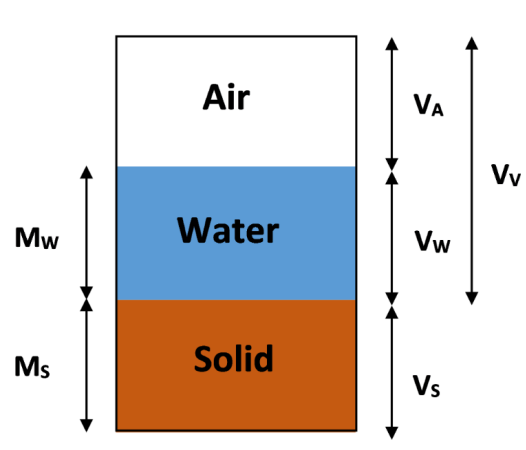
Relation:

$$\frac{1}{n} = \frac{V}{V_v} = \frac{V_s+V_v}{V_v} = 1 + \frac{V_s}{V_V} = 1 + \frac{1}{e} = \frac{1+e}{e} \quad \textbf{Hence, } n = \frac{e}{1+e}$$

- **Degree of Saturation: (S or S_r)**
  - $S = \frac{V_w}{V_v} \times 100\% = \frac{Volume\ of\ water}{Volume\ of\ voids} \times 100\%$
  - For Fully saturated soil, $V_w = V_v$; Hence S=100% or 1.
  - For Perfectly Dry Soil, $V_w = 0$; Hence S=0 or 0 %
  - For Partially Saturated Soil (General Case): $0 \leq S \leq 100$
- **Air Content (a_c)**
  - $a_c = \frac{V_a}{V_v} = \frac{Volume\ of\ air\ voids}{Volume\ ot\ total\ voids} = 1 - S$
  - $a_c + S = 1$
- **Percentage Air Voids (n_a)**
  - $n_a = \frac{Volume\ of\ air\ voids}{Total\ volume\ of\ soil\ mass} = \frac{V_a}{V}$
  - Relation:
    - $n_a = \frac{V_a}{V} = \frac{V_a}{V_v} \times \frac{V_v}{V} = a_c \times n \Rightarrow \boldsymbol{n_a = n\ a_c}$
- **Water Content (w)**
  - $\boldsymbol{w = \frac{Weight\ of\ water}{Weight\ of\ Solids} \times 100 = \frac{W_w}{W_s} \times 100}$
  - For dry soil, w = 0%
  - In General; w ≥ 0%;(with no upper limit)



- **Unit Weight (γ)** of soil is its weight per unit volume.
  - **Bulk Unit Weight** (γ *or* γ_t) $= \frac{Total\ weight\ of\ the\ soil\ mass\ (W)}{Total\ Volume\ of\ soil\ mass\ (V)} = \frac{W_s+W_w}{V_s+V_w+V_a} = \frac{W_s+W_w}{V_s+V_v}$; $(w_a = 0)$
  - **Dry Unit Weight** (γ_d) $= \frac{Weight\ of\ Solids}{Total\ Volume} = \frac{W_s}{V}$
    - Dry unit weight indicates denseness of soil. Higher the dry density, more dense is the soil.



  - **Saturated Unit Weight** (γ_{sat}) $= \frac{Total\ weight\ of\ saturated\ sample\ (W_{sat})}{Total\ Volume\ of\ Soil}$
    - It is Bulk Unit Weight when the sample is fully saturated.
  - **Submerged Unit Weight** (γ_{sub} *or* γ' $= \frac{Submerged\ weight\ of\ soil\ solids}{Total\ Volume} = \frac{W_{sub}}{V}$
    - When a soil mass is submerged below **GWT,** a buoyant force acts on the soil solids which is equal in magnitude to the weight of water displaced by the solids.
    - Mathematically, $(\gamma_{sub}\ or\ \gamma' = \gamma_{sat} - \gamma_w)$; $\gamma_w = Unit\ Weight\ of\ Water$ = 9.81 kN/m^2
  - **Unit Weight of Solids** (γ_s) $= \frac{W_s}{V_s}$

- **Specific Gravity (or Specific Gravity of Soil Solids)**
  - $G_s = G = \frac{Weight\ of\ given\ \textbf{volume of solids}}{\textbf{Weight of equal volume of water at } 4^0C} = \frac{W_s}{V_s\gamma_w} = \frac{\gamma_s}{\gamma_w}$ [γ_w=9.81 kN/m^3 or 1 gm/cc]
  - Typical Values of Specific Gravity:

Soil Types	Specific Gravity
Clean Sand and Gravel	2.65-2.68
Silt and Silty Sands	2.66-2.70
Inorganic Clays	2.70-2.80
Soil high in mica, iron	2.75-2.85
Organic Soil	Quite Variable; May fall below 2.0

MCQ Questions Preparation

BDCCDCCD

1. The term Soil Mechanics was coined by:
   a. Kray
   b. Karl Tergazhi
   c. Leygue
   d. Fellenius
2. Pick up the correct sequence of geological cycle of formation of soil?
   a. Transportation-Upheaval-Deposition-Weathering
   b. Transportation-Deposition-Weathering- Upheaval
   c. Weathering- Upheaval- Deposition- Transportation
   d. Weathering-Transportation- Deposition- Upheaval
3. If the soil stays at a place above the parent rock where it is produced, then it is called:
   a. Stationary soil
   b. Static Soil
   c. Residual Soil
   d. Immobile Soil
4. The soil transported by the running water is called:
   a. Aeolian soil
   b. Marine soil
   c. Alluvial soil
   d. Lacustrine soil

5. **Glacial soils are those soils which are:**
   a. Deposited in sea water
   b. Deposited in lakes
   c. Transported by running water
   d. None of these

6. Loess is
   a) Over consolidated clay
   b) Fine Sand
   c) Wind Borne Soil
   d) Marine Soil

7. Soil is considered as
   a. Single phase system
   b. Two Phase system
   c. Three Phase System
   d. None of the above

8. Soils are derived from:
   a. Igneous rock
   b. Sedimentary rock
   c. Metamorphic rock
   d. Any one of these

BDBC

9. The relation between the air content (a_C) and the degree of saturation (s) is :
    a. (a_C)=s
    b. (a_C)=1-s
    c. (a_C)=1+s
    d. (a_C)=1/s
10. The degree of saturation for fully saturated soil is:
    a. 0.25
    b. 0.50
    c. 0.75
    d. 1.00
11. The ratio of volume of voids to the total volume of soil mass is called:
    a. Water Content
    b. Porosity
    c. Void Ratio
    d. Degree of Saturation
12. The ratio of the unit weight of the soil solids to that of the water is called:
    a. Void Ratio
    b. Porosity
    c. Specific Gravity
    d. Degree of Saturation

13. Water content of soil can
    a. Never be greater than 100%
    b. Take values only from 0% to 100%
    c. Be less than 0%
    d. Be greater than 100%
14. Valid range for the degree of saturation (S) of soil in percentage is
    a. $S > 0$
    b. $S \leq 0$
    c. $0 < S < 100$
    d. $0 \leq S \leq 100$
15. Valid range for percentage air voids n_a is
    a. **$0 < n_a < 100$**
    b. $0 \leq n_a \leq 100$
    c. $n_a > 0$
    d. $n_a \leq 0$
16. Select the correct range of density index (I_D)
    a. $I_D > 0$
    b. $I_D \geq 0$
    c. $0 < I_D < 1$
    d. $0 \leq I_D \leq 1$

17. Residual soils are formed by
    a. Glaciers
    b. Wind
    c. Water
    d. None of the above

18. When the degree of saturation is zero, the soil mass under consideration represents
    a. One phase system
    b. Two phase system with soil and air
    c. Two phase system with soil and water
    d. Three phase system

19. When the degree of saturation is one, the soil mass under consideration represents
    a. One phase system
    b. Two phase system with soil and air
    c. Two phase system with soil and water
    d. Three phase system

20. In wet soil mass, air occupies one-seventh of its volume and Water occupies one- eighth of its volume. What will be the ratio of volume of voids with respect to the total volume?
    a. 0.329
    b. 0.279
    c. 0.432
    d. 0.268

Some Relationship:

- Relation between **e** and **n**
  - $\frac{1}{n} = \frac{V}{V_v} = \frac{V_s+V_v}{V_v} = 1 + \frac{V_s}{V_V} = 1 + \frac{1}{e} = \frac{1+e}{e}$ **Hence,** $n = \frac{e}{1+e}$ or $e = \frac{n}{1-n}$
- Relation between **e, w, G** and **S:**
  - $w = \frac{W_w}{W_s} = \frac{\gamma_w}{\gamma_s}\frac{V_w}{V_s} = \frac{1}{G}\frac{V_w}{V_s}$ [G= $\frac{\gamma_s}{\gamma_w}$]

    $= \frac{1}{G} * (\frac{V_w}{V_v} * \frac{V_v}{V_s}) = \frac{1}{G} * S * e$
  - Hence: [**Se=Gw]**
- Relation between γ_t, G, e, w *and* γ_w**:**
  - $\gamma_t = \frac{W}{V} = \frac{W_s+W_w}{V_s+V_v} = \frac{W_s(1+{}^{W_w}/_{W_s})}{V_s(1+{}^{V_v}/_{V_s})} = \frac{\gamma_s(1+w)}{(1+e)} = \frac{G\gamma_w(1+w)}{(1+e)}$
  - $\gamma_t = \frac{G\gamma_w(1+w)}{(1+e)} = \frac{G\gamma_w(1+Se/G)}{(1+e)} = \frac{\gamma_w(G+Se)}{(1+e)}$
- Saturated Unit Weight $(\gamma_{sat}) = \frac{\gamma_w(G+e)}{(1+e)}$ [Since; S=1]
- Dry Unit Weight $(\gamma_d) = \frac{G\gamma_w}{(1+e)}$ [Since; S=0]
- Submerged Unit Weight $(\gamma_{sub}$ *or* $\gamma' = (\gamma_{sat} - \gamma_w) = \frac{\gamma_w(G+e)}{(1+e)} - \gamma_w = \frac{\gamma_w(G+e-1-e)}{(1+e)} = \frac{\gamma_w(G-1)}{(1+e)}$

Most remember these formula on Day 02

- Relation between γ_t, w and γ_d:
  - $\gamma_t = \frac{W}{V} = \frac{W_s + W_w}{V} = \frac{W_s(1 + {}^{W_w}/_{W_s})}{V} = \gamma_d(1 + w) \Rightarrow \gamma_d = \frac{\gamma_t}{1+w}$
- Relation between γ_d, G, w and n_a
  - $V = V_s + V_w + V_a$
  - $1 = \frac{V_s + V_w + V_a}{V} = \frac{V_s}{V} + \frac{V_w}{V} + \frac{V_a}{V} = \frac{V_s}{V} + \frac{V_w}{V} + n_a$
  - $1 - n_a = \frac{V_s}{V} + \frac{V_w}{V} = \frac{w_s/G\gamma_\omega}{V} + \frac{w_w/\gamma_\omega}{V} = \frac{\gamma_d}{G\gamma_\omega} + \frac{wW_s/\gamma_\omega}{V} = \frac{\gamma_d}{G\gamma_\omega} + \frac{w\gamma_d}{\gamma_\omega} = \frac{\gamma_d}{\gamma_\omega}\left(\frac{1}{G} + w\right)$
  - $(1 - n_a)\,\gamma_\omega = \gamma_d\left(\frac{1}{G} + w\right) = \gamma_d\left(\frac{1+wG}{G}\right)$
  - $\gamma_d = \frac{G\gamma_\omega(1 - n_a)}{1+wG}$
- Relation between mass specific gravity, G_m and specific gravity of soil solids, G (at dry condition):
  - Mass specific gravity $(G_m) = \frac{\gamma}{\gamma_w}$ (for dry condition, $\gamma = \gamma_d$); So, $G_m = \frac{\gamma_d}{\gamma_w}$
  - $\gamma_d = \frac{G\gamma_w}{(1+e)} \quad \Leftrightarrow \frac{\gamma_d}{\gamma_w} = \frac{G}{(1+e)}$

$$G_m = \frac{G}{(1+e)}$$

Most remember these formula on Day 02