1. Contents

2. Subject Introduction

2.1. Components of Soil

- **Solid**
- **Air**
- **Water**

2.2. Examples in Geotechnical Engineering

- Landslide and ground subsidence
- Earth retaining structures
  - Gravity
  - Cantilever
  - Semi-gravity
- Ground improvement
- Foundations
- Excavations
- Land reclamation
- Dams
- Tunnels and underground space
- Mining
- Environmental geotechnics

3. Laboratory Testing: Soil and Rock (AS 1289.0)

Laboratory testing may be required if **in-situ tests** are **insufficient** or **not possible** or the importance of the project deems the additional testing necessary (relying on empirical relationships may not be feasible)

3.1. Basic concepts

3.1.1.1. Soil phase relationships

The **weight** and **volume** of a soil sample will **depend** on the

- Specific gravity of soil grains (solids)
- Size and space between soil grains (voids and pores)
- Volume of void space filled with water

Soil **properties** include

- Moisture content (w)
- Specific gravity (G_s)
- Unit weight (γ)
- Porosity (n)
- Void ratio (e)
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- Weight-volume **relationships**
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- Soil identities
- $G_s w_n = S\ e$
- $\gamma_T = G_s \gamma_w \left(\frac{1+w_n}{1+e}\right)$
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- **Limiting unit weight** (solid phase only, w=e=0)
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- $\gamma_{solid} = G_s \gamma_w$
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- **Dry Unit weight** (w = 0, all air in void space)

  $$\gamma_d = \frac{G_s \gamma_w}{1+e}$$
- **Moist unit weight** (variable amounts of air and water)

  $$\gamma_T = G_s \gamma_w \left(\frac{1+w_n}{1+e}\right)$$
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- **Saturated unit weight** (all voids with water, S = 1)
  $$\gamma_{sat} = \gamma_w \left(\frac{G_s + e}{1 + e}\right)$$

3.1.1.2. *Load-deformation process*
As the amount of **water** in the voids **increases**, the **pore water pressures** on the soil grains will **increase** and the **intergranular** contact **forces** will be **reduced**
→ if the sample is **saturated**, the **water** filling the voids will be **forced out** and the **soil particles** will **consolidate** (if saturated and low permeability, deformation is slow and there will be in increase in pore water pressure initially before deformation)

Deformation will **depend on** the
- **Intergranular forces** (grain to grain contact)
- The **volume of water** in the voids (higher void ratio increases possibility of deformation)

3.1.1.3. *Principles of effective stress*
For **partially saturated** soils **effective stress** will be **influenced** by the **soil structure** and **degree** of **saturation**

For soils **below** the **water table** (soil is saturated)
$$Total\ stress\ (\sigma) = \gamma_{sat} z$$
$$Pore\ water\ pressure\ (u) = \gamma_w z_w$$
$$Effective\ stress\ (\sigma') = \sigma - u$$

3.1.1.4. *Overburden pressure*
Soils are **affected** by the **weight** of the **soil above** (overburden stress)
→ when a **sample** is removed the **overburden stress** is **relieved** (need to re-establish in-situ stress conditions)
→ **unit weight** is **determined/estimated** from density tests, shear wave velocity, SPT/CPT or other in-situ test

$$Total\ overburden\ stress\ (\sigma_{v0}) = \int \gamma_T dz \approx \Sigma \gamma_T \Delta z_i$$
$$Effective\ overburden\ stress\ (\sigma'_{v0}) = \sigma_{v0} - u_0$$
$$Effective\ horizontal$$
Soil elements **above** the **water table**

Completely Dry: $u_0 = 0$
Full capillarity: $u_0 = \gamma_w(z - z_w)$

Soil elements **below** the **water table**

$$u_0 = \gamma_w(z - z_w)$$

3.2. Index properties
Several **index properties** are **obtained** from **laboratory tests**
- Moisture content
- Specific gravity
- Unit weight
- Sieve analysis
- Atterberg limits
- Moisture-density relationship
- pH of soils
- **Organic content** (important to know as properties of soil can change over time - may give desirable engineering properties now but this can change, e.g. additional settlement following decomposition)

3.2.1.1. *Sieve analysis*
Used to determine the **particle size distribution** which is useful in evaluating engineering characteristics (permeability, susceptibility to frost action)

3.2.1.2. *Hydrometer analysis*
Use to determine the **distribution** of **particles** that are **smaller** than the **no. 200 sieve** (75µm)
→ Identifies silt, clay and colloids percentages

3.2.1.3. *Atterberg limits – AS 1289.3*
Used to describe the **consistency** and **plasticity** of **fine-grained** soils with **varying** degrees of **moisture content**
→ portion of the soil **passing no. 40 sieve** is considered to identify **3 stages** of soil behaviour.

1. **Liquid Limit (LL)**
2. **Plastic Limit (PL)**
3. **Shrinkage Limit (SL)**
   Plasticity Index (PI) = LL – PL

3.2.1.4. *Moisture-density relationships*

Used to determine **moisture content** and **max. dry density** for a given soil and specific **compactive effort** (used for the design and construction of earth structures – embankments, dams, structural foundations and fills)
→ a dry density vs. moisture content plot is obtained and the relationship is determined from performing tests on a given soil at varying water contents

3.3. Strength tests

The **selection** of **strength parameters** will depend on the **context** (construction type, foundation design, intensity type and duration of loads, soil materials)

The **strength parameters include**

- Effective strength envelope: assumed to be constant for a particular soil
- c': cohesion
- φ': angle of shear resistance
- Effective shear strength: $\tau_{max} = c' + \sigma_N \tan(\varphi')$
- Total or undrained shear strength: S_u or c_u

3.3.1.1. *Unconfined compressive strength (q_u)*

Can find the **undrained shear strength** from the unconfined compressive stress and axial strain relationship

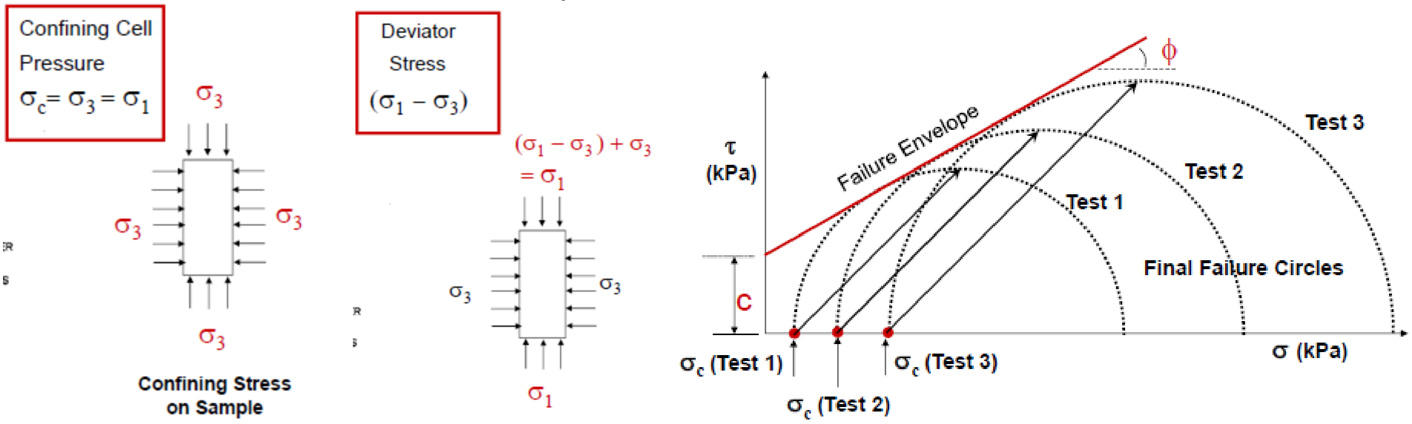
$$\rightarrow q_u = 2c_u = 2S_u$$

3.3.1.2. *Triaxial Tests*

A 38mm diameter **soil sample** is placed in a **rubber membrane** that sits in a **cell** with a given **confining pressure** where the confining pressure should approximately simulate in-situ state of effective stresses (e.g. original overburden pressure σ'_{v0}, anticipated max. vertical pressure in future, an intermediate pressure)
→ a **deviator stress** is applied vertically to the soil sample until the sample fails
→ the **pore water pressure (u)** is **controlled** by a **drainage connection**

Drainage: $\Delta u = 0$
No Drainage: $\Delta u > 0$

→ σ_3 is held constant while σ_1 is increased through the deviator stress until failure (considered to have failed when the deviator stress reaches its peak)
→**final failure Mohr circle** and the **failure envelope** can be found by **repeating** the test for **different σ_c**
→ the **shear strength parameters c'** and **φ'** can be determined graphically



There are **several types** of **triaxial tests**
→ CU, CUPP and CD tests are used to develop strength envelopes by the use of Mohr circles

1. ***Unconsolidated Undrained (UU):*** Samples not allowed to drain or consolidate prior or during testing, results will depend on degree of saturation ($s = 0 \rightarrow \varphi' = 0$)
   → does not produce reliable results for saturated granular soils
2. ***Consolidated Undrained (CU):*** Specimen allowed to consolidate but drainage is blocked when axial stress is applied (pore water pressure will increase)
   → used or lower permeability soils