Review of Soil Mechanics

Concepts in foundation engineering

Description of soil properties

Definition of geotechnical terms

Soil mechanics

Index properties (water content, void ratio, unit weight etc)

Soil classification

Stress conditions (σ, σ', u)

Permeability (k)

Deformation properties (C, E, G, γ, ρ)

Shear strength (c, φ)

Theory

Foundation engineering

Soil mechanics

Experience

Geology

Application and limitations of the different methods.

Void ratio, e = \frac{V_s}{V}

Porosity, n = \frac{V_s}{V} \times 100 \%

Water content, w = \frac{V_w}{V} \times 100 \%

Unit weight, \gamma = \frac{V_s}{V} \text{ kN/m}^3

Dry unit weight, \gamma_d = \frac{V_d}{V} \text{ kN/m}^3

Unit weight of solids, \gamma_s = \frac{V_s}{V} \text{ kN/m}^3

Specific gravity, \rho_s = \frac{\gamma_s}{\gamma_w} \text{ (sand)}

Degree of saturation, S_s = \frac{V_s}{V} \times 100 \%
Determination of grain size distribution

Plasticity of soils

Plasticity chart

Distinction between clay and silt
Structure of clay

- Dispersed
- Positive
- Negative
- Flocculated

Standard Proctor compaction test

- Dry unit weight, $f_d$, kN/m$^3$
- Maximum dry density
- Optimum water content

Proctor's compaction tests

- 2.5 kg
- 4.5 kg
- Every layer 25 blows
- 1000 cm$^3$
- 305 mm
- 457 mm

Compaction curves

- $f_d$, kN/m$^3$
- Standard
- Modified
- Till
- Sand
- Silt
- Clay
Unified soil classification system

Gravel
- GW - Well graded
- GP - Poorly graded
- GM - Silty (mo)
- GC - Clayey

Sand
- SW - Well graded
- SP - Poorly graded
- SM - Silty (mo)
- SC - Clayey

Silt (mo) - ML
Clay - CL
Organic - OL
Silt (mo) - MH
Clay - CH
Organic - OH

Peat

Darcy's law

Permeameter for determination of laboratory permeability

Pumping test for determination of field permeability
Permeability of soils

\[ k, \text{cm/s} \]

- \(10^{-2}\) clean gravel
- \(10^{-3}\) clean sand
- \(10^{-4}\) silt, silty clayey soil, very dense clay
- \(10^{-5}\) clayey soil, very dense clay
- \(10^{-6}\) clayey soil, dense clay
- \(10^{-7}\) clayey soil, well compacted
- \(10^{-8}\) clayey soil, weathered
- \(10^{-9}\) clayey soil, well weathered
- \(10^{-10}\) clayey soil, weathered

Pumping test
Constant head permeability test
Falling head permeability test
Consolidation test

Flow net determination

Seepage pressure (negative pore water pressure)

Effective stress concept

\[ \sigma' = \frac{P'}{A} \]
\[ u = \frac{U}{A} = h \rho_w \]
\[ \sigma = \frac{P}{A} \]
\[ P = P' + U \]
\[ \sigma = \sigma' + U \]
Seepage pressure (positive pore water pressure)

Stress-strain relationship of soil

Hyperbolic stress-strain relationship

Modulus of elasticity
Shear modulus

\[ \gamma = \frac{T}{G} \]

Shear stress

Compression modulus

\[ \epsilon_1 = \frac{q'_f}{E} \]

Coefficient of lateral earth pressure at rest

1-D Consolidation Theory

Stage I: Initial compression

Stage II: Primary consolidation

Stage III: Secondary consolidation

Settlement, s

\[ \epsilon_0 = \frac{q_H}{K_{01}} \]

Primary settlement

Stability of footing on soil

Heave

\[ S_f = C' + (\overline{C} - C) \tan \phi' \]

Failure surface
**Coulomb-Mohr failure criterion**

\[ \tau = \sigma \tan \phi - c \]

Tennaghi-Hoerslev

\[ \tau = (\sigma - \sigma_y) \tan \phi' \]

Effective stress concept

\[ \Delta \sigma = \sigma - \sigma_y \]

\[ \Delta u = \begin{cases} \sigma_y & \text{Ambient stress} \\ \Delta \sigma & \text{Deviator stress} \end{cases} \]

\[ \Delta u = \frac{\Delta \sigma}{\Delta \sigma_y} \]

Mohr's stress circle

\[ \tau = \sigma_1 - \sigma_3 \]

Mohr's circle for clay soil

\[ \tau = \frac{1}{2} (\sigma_1 - \sigma_3) \]

\[ \sigma = \frac{\sigma_1 + \sigma_3}{2} \]
Stress path concept

Stress path concept, Kf failure line

Typical values of angle of internal friction of soils

Undrained shear strength of cohesive soils
c/p-ratio of clays

Short term stability of an excavation

Long term stability of an excavation

Effective stress analysis

\[ \sigma = c' + f' \tan \phi' \]

(From drained tests)

C-\phi analysis

For sand: \( c' = 0 \)

\[ s_f = f' \tan \phi' \]

\phi analysis
Total stress analysis

\[ \sigma_f = C_u + q \tan \phi_u \]

For saturated soils \( \phi_u = 0 \)

\[ \sigma_f = C_u \]

c-analysis, \( \phi = 0 \)-analysis

Determination of shear strength

\[ \sigma_f - q' = \sigma' \tan \phi' \]

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<th>Short term</th>
<th>Long term</th>
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<td>( q_d, (C_{yd} = 0) )</td>
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<td></td>
<td>( c, \varphi )-analysis</td>
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Laboratory tests for determination of shear strength of cohesive soils

Laboratory tests for determination of undrained shear strength

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<td>UU ( c_u ) only clay</td>
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<td>CU ( c_u, q_u ) only clay</td>
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<td>CD ( c_d, q_d )</td>
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<td>IU ( c_u, \varphi_u )</td>
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<td>Laboratory vane test ( c_u )</td>
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Field tests for determination of undrained shear strength

Testing method, Field tests
Field vane test \( c_u \)
Pressuremeter test \( c_u \)
Cone penetration test \( c_u = \frac{1}{6} + 0.20 q_c \)
Standard penetration test (SPT) \( (c_u) \)
Weight sounding test \( (c_u) \)