The Unloading Modulus of Soft Soil:
A Field and Laboratory Study

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Background

Uncertainty in empirical relationships for estimating the unloading modulus and consolidation time

Scope

Field (and laboratory) testing to determine the unloading stiffness

Objective

Estimate the stress-strain characteristics for clay at unloading for more cost effective design
Instrumentation

Heave gauge

+12
+9
+5.6
+3
+/-0
--3
-11
-35.0
-21
-15.0
-35.0

Piezometers

Glötzl Extensometer

Fill

Clay

Heave [mm]

Hävning [mm]
Field results

- **Heave [mm]**
  - Extensometer 9 m depth (level +3 m)
  - Piling stage I and stage II

- **Pore pressure, ϕ [kPa]**
  - Piezometer 9 m depth (level +3 m)
  - Giötzl, 9 m depth (level +3 m)
  - Evaluated pore pressure
Laboratory tests
Jenny Persson, GeoEngineering

Lab and field results

\[
\frac{M_{ul}}{\sigma_c'} = 35 \exp \left( \frac{3.5}{OCR} \right)
\]
Recommended empirical model

\[ M_{ul} = 35 \cdot \exp\left(3.5/\text{OCR}\right) \]

- Normalized unloading modulus, \( M_{ul}/\sigma_c' [-] \)
- Normalized effective stress, \( 1/\text{OCR}=\sigma'_v/\sigma'_c [-] \)

Recommended empirical model

\[ M_{ul} = 35 \cdot \exp\left(3.5/\text{OCR}\right) \]
Conclusions

Unloading stiffness is large at small strains and decreases rapidly with decreasing stress level

- field measurements indicate stiffness twice as large as laboratory values (Bender Elements)
- stress history important when reconsolidating laboratory specimens
- creep rate affects the unloading stiffness

Long-term pore pressure distribution should be taken into account when predicting heave
Thank you for your attention!

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