NEW ZEALAND GEOTECHNICAL SOCIETY INC
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NZGS GEOTECHNICAL ENGINEERING BASICS
STATIC SETTLEMENT

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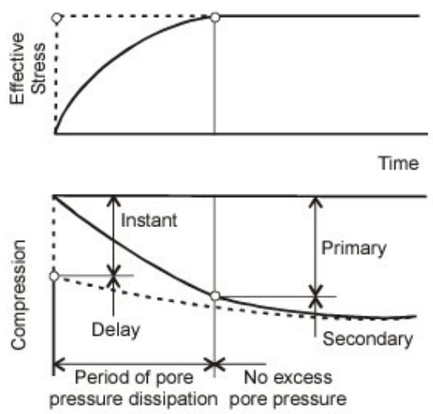
1. PRELIMINARY APPRAISAL

Desktop study
- Site description, site geology, geomorphology, and topography, historical development and risk assessment,
  e.g. local council GIS and hazard maps, LINZ, LiDAR, Google Earth Pro
- Historical site investigations, e.g. NZGD, available instrumentation data etc.
- Proposed developments and loadings, e.g. development plans & liaison with project structural engineer (the effect of live load is normally ignored, except in cases where the live load is sustained over long periods of time and shall be partially considered)
- Survey/contour information
- Geological cross sections or 3D model, e.g. gINT, Leapfrog Works, CAD

Site-specific investigation
- Site walkover / hazard mapping
- Boreholes & sampling – provide soil logging and samples
  for lab testing
- Seismic / Cone Penetration Test (CPTu or sCPTu) & dissipation test interpret soil behavior and parameters from qc, fs, u
- Seismic / Dilatometer Marchetti Test (DMT or sDMT) correlate soil stiffness or modulus with measured pressure
- Oedometer test
- Site specific seasonal groundwater monitoring, e.g. standpipes, Vibrating Wire Piezometers (VWPs), levelogger

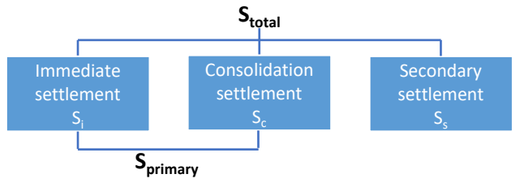
Refer to NZGS Developing an Engineering Geological Model poster



(Bjerrum, L. 1967)

2. REQUIRED SOIL PARAMETERS

Introduction to settlement



S_i Time independent settlement. Although non-elastic, generally calculated using elastic theory for cohesive soil.
S_c A time-dependent process of dissipation of excess pore-pressure and increase of effective stress after load application.
S_s Time dependent process and occurs at constant effective stress.

Required parameters

For fine grained soil, $S_{total} = S_i + S_c + S_s$
- Undrained Young's modulus E_u with Poisson's ratio ν_u of 0.5
  (Applied to saturated soil when calculating S_i)
  - CU Triaxial Test (be cautious of using the derived E_u because of differences in the stress history)
  - $E_u/Su \approx 300$, **J Atkinson (2008)**

- Compression index C_c , recompression index C_r , overconsolidation ratio OCR, and void ratio e
  - Oedometer test
  - Correlations based on CPT or DMT

- Coefficient of volume compressibility m_v or coefficient of consolidation C_v
  - Oedometer test
  - In-situ dissipation test

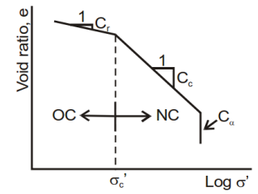
- Secondary compression index C_α
  - Oedometer test
  - Correlations with C_c, **Table 16.1 of Terzaghi, Peck and Mesri (1996)**

For coarse grained soil, $S_{total} = S_i + (S_c + S_s)$
(S_c is fast due to the high permeability that it is generally included with S_i . S_s is negligible.)

- Drained Young's modulus E' with Poisson's ratio ν ' ~0.3
  - DMT, e.g. **Technical Committee TC16 (2001)**, or CPT
  - CD Triaxial Test (be cautious of using the derived E')

3. STAGES OF DESIGN PROCESS

Simplified theories
- Conventional 1D consolidation settlement analysis, Terzaghi (1943) (be cautious of 3D deformation and horizontal drainage effects not captured in 1D)
  - From C_c and C_r (non linear):



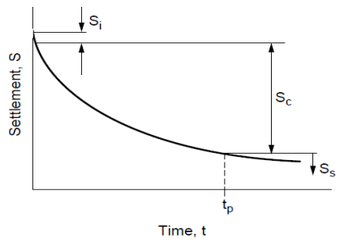
(Frantisek, H. 2004)

- From m_v (linear)

$$S = \sum_{i=1}^{layers} (m_v)_i H_i (\Delta\sigma_v)_i$$

Numerical analysis
- Site-specific models can be created using:
  - Settle 3 (Rocscience)
  - RS2/3 (Rocscience)
  - Plaxis 2D/3D (Bentley) etc.

Assessment of settlement time



(Patrick J. Fox 2003)

- Coarse grained soil – From a practical viewpoint, settlement duration is not important as it occurs relatively quickly.

- Fine grained soil – For S_c , time required to reach a certain degree of consolidation depends on C_v and time factor (i.e. T90). For S_s , the variation of e with time is a logarithmic curve and depends on C_α

Note: Sensitivity assessment to material properties, groundwater levels and loads shall be part of design process. Correlation checks can be performed by back calculating the site settlement monitoring data or analysing the data from similar sites.

4. DESIGN REQUIREMENTS

Common settlement requirements
- **Bridge Manual – 3rd Edition**
  - Residual settlement < 50 mm for roads (Table 6.1)
  - Residual settlement < 25 mm for shallow foundation and bridge foundation (Section 2.1.8)
  - Differential settlement for road and bridge (Table 6.1)

- **Building Code B1/VM4**
  - Differential settlement < 25 mm over 6 m for residential development (Appendix B)

Note: Settlement is inherently difficult to estimate accurately. Uncertainty shall be considered when working against settlement limits, with settlement risk mitigated accordingly e.g. apply uncertainty factor to design settlement values and/or develop a contingency plan for larger than expected settlements.

Mitigation measures
- Excavate & replace
- Preload
- Installation of vertical drains
- Soil improvements, e.g. stone column
- Custom foundation design
- Consider Safety in Design

Monitoring requirements
- A Groundwater and Settlement Monitoring Plan may be required, and should include
  - a monitoring location plan showing the layout and type of all monitoring instrumentation
  - timing and frequency
  - alert trigger levels and actions

- The monitoring shall commence from the initial baseline measurements prior to construction, until the time when all the specific design criteria has been met. Long term, post construction groundwater and settlement monitoring may be required.

- Back calculation of consolidation parameters from the site monitoring data and verification of existing settlement models are essential for the better understanding of the site settlement characteristics and prediction of the future settlement on the site.