NEW ZEALAND GEOTECHNICAL SOCIETY INC
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NZGS GEOTECHNICAL ENGINEERING BASICS
DEEP FOUNDATIONS (PILE DESIGN)

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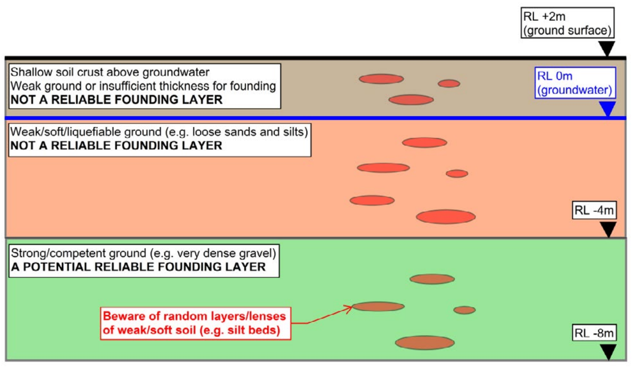
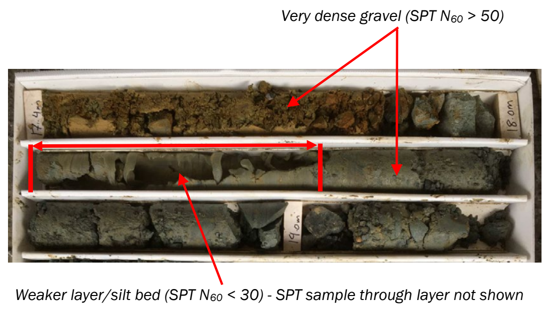
STEP 1: Geotechnical Ground Model

- Develop a site-specific ground profile with appropriate soil parameters by critically assessing available geotechnical information (e.g. BH, CPT, test pits, geophysical data, laboratory testing, geological maps etc.).
- Define upper and lower boundaries of soil parameters for the pile design to allow for 'best' and 'worst' case assessments in order to perform a site-specific sensitivity analysis.
- Define site-specific groundwater conditions. Always allow for continuous monitoring if possible (e.g. standpipe piezometer with level logger). Beware of measurements taken during drilling and seasonal effects. Allow for tidal effects sea level rise as appropriate.
- Refer example of ground profile with potential founding layers.
- See NZGS Ground Model poster.



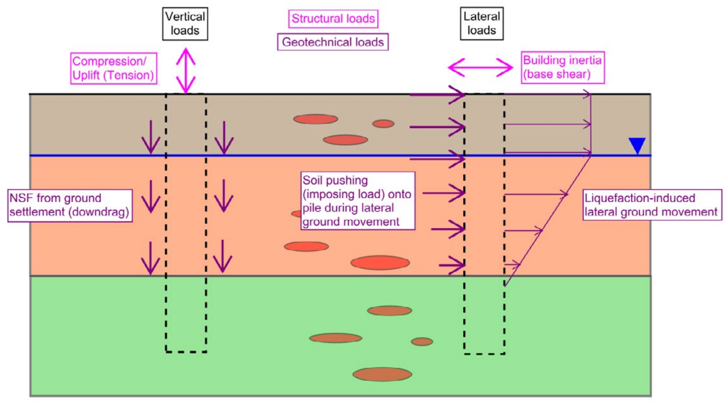
ABOVE Example ground profile.



ABOVE Example Borehole core showing embedded weaker layer inside very dense gravel.

STEP 2: Define geotechnical scope, hazards, load cases and general risks relevant for the pile design

- Typical considerations often include, but are not limited to:
  - Main component of load transfer (shaft friction/end-bearing).
  - Potential founding layer (Rock/dense/hard soil).
  - Pile loading (axial compression, tension, lateral, moment.
  - Select the relevant design standard.
  - Settlement of soft clay or loose sand can cause downdrag forces, i.e. negative skin friction (NSF).
  - Earthquake-induced ground shaking.
  - Liquefaction-induced lateral ground movement (e.g. lateral spread).
  - Liquefaction-induced ground settlement causing NSF.
  - Piles in slopes with risk of instability due to e.g. heavy rainfall and/or ground shaking.
- Note that not all these issues are necessarily present at any specific site.
- Assess pile performance as a result of these issues.
- Refer example of pile loading and pile damage.

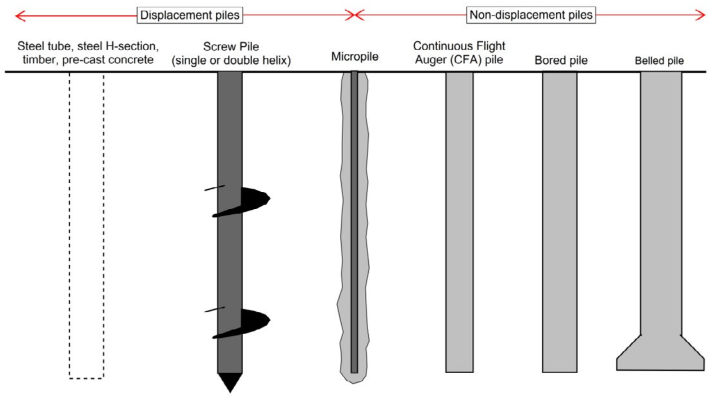


ABOVE Example pile loading: structural and geotechnical (due to identified issues).

ABOVE Example pile damage caused by lateral ground movement. Photo from: Hamada M (1991): Damage to Piles by Liquefaction-Induced Ground Displacements. 3rd U.S. Conference Lifeline Earthquake Engineering, ASCE, Los Angeles, USA, 1172-1181.

STEP 3 : Selection of pile types

- Consider structural requirements and demands of the individual piles, but also the entire foundation concept.
- Consider suitability of the pile type to suit the loading and ground conditions.
- Consider constructability and site constraints (e.g. low head-room, limited access, noise and vibration, etc.). Consider pile installation effects on adjacent structures.
- Consider sustainability impacts of the selected pile types.
- Consider Safety in Design.
- Jointly/collaboratively select preferred pile type with structural engineer, and contractor (if possible – otherwise just reach out to a colleague for some help).
- Refer examples of pile construction.

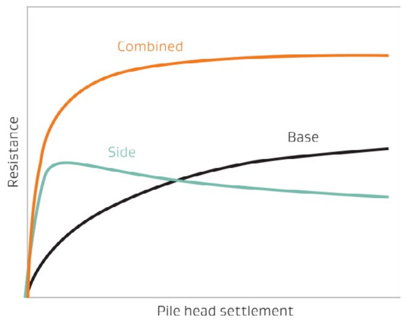


ABOVE Typical pile types used in New Zealand.

ABOVE Examples of construction: driven timber pile (left) and bored pile (right; photo by Martin Larisch).

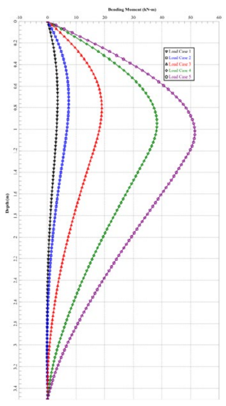
STEP 4 : Pile Design

- Axial pile design: consider where resistances are derived from (skin friction, end-bearing or combined?), including associated displacements. Apply appropriate Geotechnical Strength Reduction Factors (typically derived from AS2159) to assess the ultimate pile axial capacity using a risk-based approach. Consider pile group effects and potential downdrag forces.
- Lateral pile design: consider whether the ground is imposing a load (ground pushing against the pile) or providing resistance (pile pushing into ground). Assess the pile head fixity and check lateral displacement limits. Consider pile group effects.
- Perform soil-structure-interaction (SSI) analysis to assess the load/deflection behaviour of the pile under different load cases (collaboration between structural and geotechnical engineers is critical for this task). Note that several iterations may be required. Refer example pile actions from LPile.
- Develop pile sizes, which comply with geotechnical and structural requirements, codes and standards (e.g. pile material, size, diameter, spacing and required embedment depths).
- Consider Safety in Design.
- Prepare a producer statement (if required), a pile design report, including drawings, technical specification, general notes and pile schedule.



SIDE: Skin/shaft friction
BASE: End-bearing

ABOVE Example load (or resistance-displacement plot. Figure sourced from: NZGS Module 4 – Earthquake Resistant Foundation Design. Figure 6.2, Section 6.2, page 49.



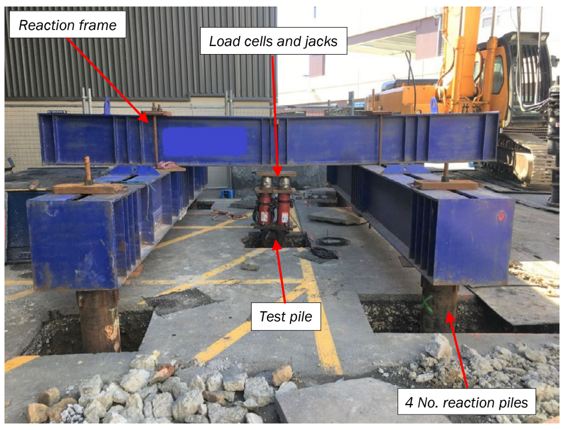
Plot colours indicate different load cases, e.g. lateral load applied at pile head.

ABOVE Example pile bending moment actions with depth from LPile.

- Standards, codes and guidelines, which can be used for pile design in New Zealand:
  - **NZ Building Code**
  - **AS 2159-2009 Piling – Design and installation**
  - **NZGS Module 4 – Earthquake Resistant Foundation Design**
  - **SESOC/ NZGS Piling Specification** (Construction specification)
- Selected software, which can be used for pile design:
  - **RSPile** by Rocscience (vertical, lateral and group analysis)
  - **AllPile** by Civiltech (vertical and lateral analysis)
  - **GROUP** by Ensoft (vertical pile group analysis)
  - **LPile** by Ensoft (lateral analysis)
  - **CPeT-IT** by GeoLogismiki (single pile vertical capacity calculation)
- **GRLWEAP** by Pile Dynamics (only for the assessment of pile drivability – not a design tool).

STEP 5 : Test Piles and Construction Monitoring

- Consider pile load and/or pile integrity testing for your project.
- Pile integrity testing (e.g. low strain integrity testing (PIT) or Cross hole sonic logging are used to assess the integrity of the pile shaft).
- Pile load testing can be used to:
  - Assess the load-settlement response of the tested pile on site under specific load conditions.
  - Increase the geotechnical strength reduction factor in the pile design (AS2159) as the pile resistance and load-settlement behaviour will be measured on site.
  - Assess pile design parameters (upfront testing on sacrificial piles) or verify the pile performance on working piles (verification testing).
- Construction monitoring is important to verify that pile construction was carried out in accordance with the design intent and for verification of foundation layers (e.g. rock socket material and locations).



ABOVE Example of static load test arrangement.

ABOVE Example of soil/rock samples collected from bored pile construction.

DISCLAIMER: This reference guide is not a standard. It is a 'rough guide' based on common practice in New Zealand. The recommended calculation process/analytical methods within this document are not intended to be codified nor does the document hold any legal requirement/standing in New Zealand. The accuracy of the process described below depends highly on the expertise of the geoprofessional regarding the modelling of the design, the understanding of various soil models and their limitations, the selection of material parameters, and the ability to judge the results. NOTE: Bold, underlined text contain hyperlinks to external sources. These hyperlinks are subject to failure should these posters be reviewed in print form.