NZGS GEOTECHNICAL ENGINEERING BASICS
LIQUEFACTION AND LATERAL SPREAD

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3. ASSESSMENT

Susceptibility
• Geological criteria **(GNS Geology Map)**.
• Younger (Holocene) deposits and constructed fills are more likely to be susceptible to liquefaction.
• Older (Pleistocene) sediments are less likely to be susceptible to liquefaction but should be checked.
• Compositional criteria.
• Sands, non-plastic silts, gravels and their mixtures are susceptible to liquefaction.

Quantitative assessment of susceptibility
• Plasticity criteria – Atterberg Limits:
  – PI < 7   Susceptible
  – 7 ≤ PI ≤ 12   Potentially susceptible
  – PI > 12   Not susceptible
• CPT Soil Behaviour Classification (I_c):
  – Ic ≤ 2.6   Assumed susceptible
  – Ic > 2.6   Assumed not susceptible
• SPT N value:
  – Consider normalised SPT N60 value in assessment.
  – Typically N60>30 is not susceptible to liquefaction.
• Particle size distribution:
  – Compare to PSDs for liquefaction ejecta samples (e.g. Centreport, **Cubrinovski (2019)**).

Considerations
• Are there any observations of liquefaction (or no liquefaction) in previous earthquakes?
• Can aging factors be applied? Refer Section 5.2.1 **Module 3, 2021**.
• Are soils volcanic in origin? Refer Section 9 **Module 3, 2021**.

Triggering
Common methods of assessment:
1. Cone Penetrometer Test (CPT)
    – Simplified triggering procedure, **Idriss and Boulanger (2014)**.
2. Shear wave velocity testing
    – **Kayen et al. (2014)**.
3. Borehole (SPT-based)
    – SPT based simplified triggering procedure, **Idriss and Boulanger (2014)**.
4. Flat dilatometer test (DMT)
    – **Monaco et al. (2005)**, **Tsai et al. (2009)**.

Considerations
• Are soils gravelly, or poorly compacted fill? Refer Sections 5.2, 5.3 and 8 of **Module 3, 2021**.
• Are soils susceptible to cyclic softening? **I&B 2008**.
• Effect of fines content on CPT/SPT results and cyclic resistance.
• Effect of groundwater level on effective stress state.
• System response effects; **Cubrinovski (2019)**.
• Effect of interlayed soil profiles (inverse filtering approach); **Boulanger and DeJong (2018)**.

4. CONSEQUENCES

Physical manifestations
• Lateral spread and cyclic displacements.
• Free field settlement.
• Differential settlement.
• Ground cracking.
• Ejection of sand and water to the ground surface (sand boils).

Site Performance
For sites that are susceptible to liquefaction, the following parameters should be considered when determining a general performance level for the site.
• LPI – liquefaction potential index. **Iwasaki et al. (1978)**.
• LSN – liquefaction severity number **van Ballegooy et al. (2014)**.
• Non-liquefiable crust thickness.

Considerations for a structure
• Uplift pressures.
• Reduced support to foundations (e.g. punching failure).
• Damage to deep foundations from lateral movement, and settlement from downdrag (negative skin friction).
• Differential settlements.
• Damage to buried services.
• Lateral stretch of the building.

Lateral Spread
• Refer back to your ground model.
• Where is the free face? River channels? Seawalls? Batters/slopes?
• Is liquefaction in continuous layers, or just in pockets? How thick are the layers?
• What direction is the lateral spread likely to occur?
• Assessment methods
• Empirical methods: **Youd (2002)**, **Zhang (2004)**.
• Newmark sliding block: e.g. **Jibson (2007)**, **Ambraseys and Menu (1988)**, **Ambraseys and Srbulov (1995)**, **Bray et al (2018)**, **Bray and Macedo (2019)**.
• Understand limitations and uncertainties: **Palmer (2022)**.

1. INTRODUCTION

Liquefaction is a process which causes soil to behave more like a liquid than a solid. It can happen when earthquake shaking rearranges soil particles, causing high water pressures. An earthquake of sufficient duration and intensity will result in the generation of excess pore water pressures, leading to a loss of contact pressure between soil particles.
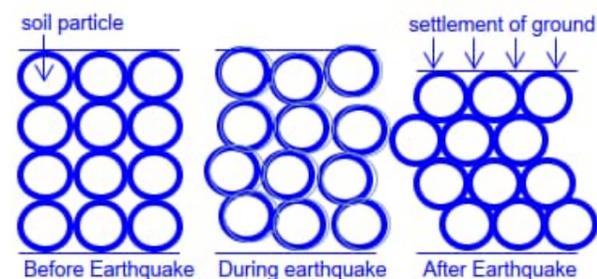
Liquefaction can repeatedly occur at the same site. Soils do not achieve an improved liquefaction resistance (increased cyclic strength, higher density) post-liquefaction.

2. GROUND MODEL AND SHAKING HAZARD

Ground Model
• Big picture – regional geological and geomorphological maps.
• Borehole and other investigations.
• Groundwater information.
• Lab testing data.
• SPT and CPT results.
• Historical cut / fill at the site.
• The **NZGD** has a wealth of information!
• A summary in **Table 3.2** of MfE and MBIE's "Planning and engineering guidance for potentially liquefaction-prone land" document.
• See NZGS Ground Model poster.

Ground Shaking Hazard
• What is the importance level and design life?
• Determine the design return period using **NZS1170.0**.
• Determine the design magnitude and PGA:
• Table A1 **MBIE Module 1, 2021** for routine projects.
• Probabilistic Seismic Hazard Assessment (PSHA) for projects of higher importance and complexity.
• **National Seismic Hazard Model, 2022**.
• Consider the ground shaking hazard beyond the design magnitude and PGA. **NZSEE, SESOC, NZGS (2022)**.

5. DESIGN MITIGATION AND REMEDIATION

• New build or existing (detailed seismic assessment)? Refer **Palmer (2019)** and **Section C4** of the assessment guidelines for existing buildings.
• Strength reduction factors – Refer **MBIE Module 4, 2021**.
• See NZGS Deep Foundations poster.
• See NZGS Shallow Foundations poster.
• Ground Improvement for liquefiable soils.
  – Refer **MBIE Module 5, 2021**.