Dynamic Site Characterisation:
Opportunities for Liquefaction Research

Andrew Stolte
Field Research Engineer

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UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

QuakeCoRE
NZ Centre for Earthquake Resilience
Te Hiranga Rū

Dynamic Site Characterisation → Seismic Geophysical Testing

Goals for dynamic site characterisation:

- Develop profiles of S-wave and/or P-wave velocity (V_S and V_P)
- Evaluate site period (T_0)

Invasive Testing Methods:

- Source and/or sensors placed beneath the ground surface
  - Conventionally, lowered into boreholes
  - More recently, directly pushed into the ground
- Localized measurements of V_S and V_P

Non-Invasive Testing Methods:

- Source and sensor arrays at the ground surface
- Spatial averaging of material properties

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Suited to liquefaction studies

V_S-based simplified liquefaction triggering procedures:

- Kayen et al. (2013)
- Andrus and Stokoe (2000)

Non-Invasive Testing Methods:

- Source and sensor arrays at the ground surface
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Invasive Testing Methods

Conventional, borehole-based methods:

- Downhole seismic testing (DH)
- Crosshole seismic testing (CH)
- PS suspension logging

Direct-push methods:

- Seismic cone penetration testing (SCPT)
  - Downhole equivalent
- Seismic dilatometer testing (SDMT)
  - Downhole equivalent
- **Direct-push crosshole seismic testing (DPCH)**
  - Crosshole equivalent

Direct Push Crosshole Testing (DPCH)

Well-suited to testing near-surface, soft soils

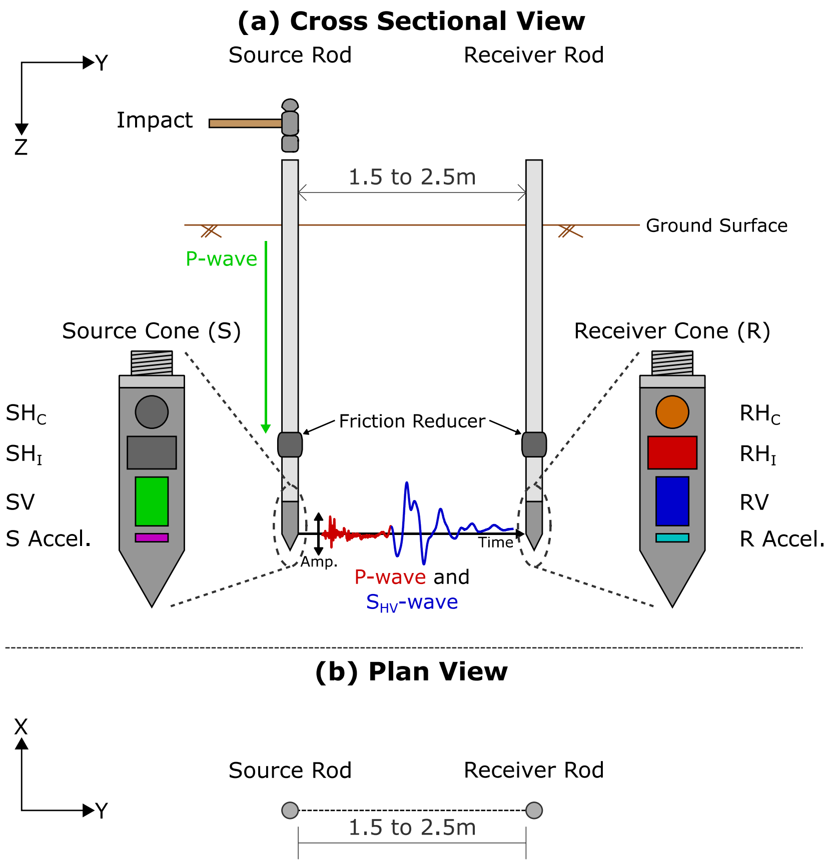
- Testing method outlined in Cox et al. (2018) and focus of my PhD research
- Rapid development and increased use following 2010-2011 Canterbury Earthquake Sequence:
    - Ground Improvement Trials
    - Liquefaction Case Histories

Source and receiver conical probes are directly advanced into the ground using CPT rigs

- Cone spacing: 1.5 to 2.5 m apart
- Depth intervals: 0.2 to 0.5 meters

Cone instrumentation:

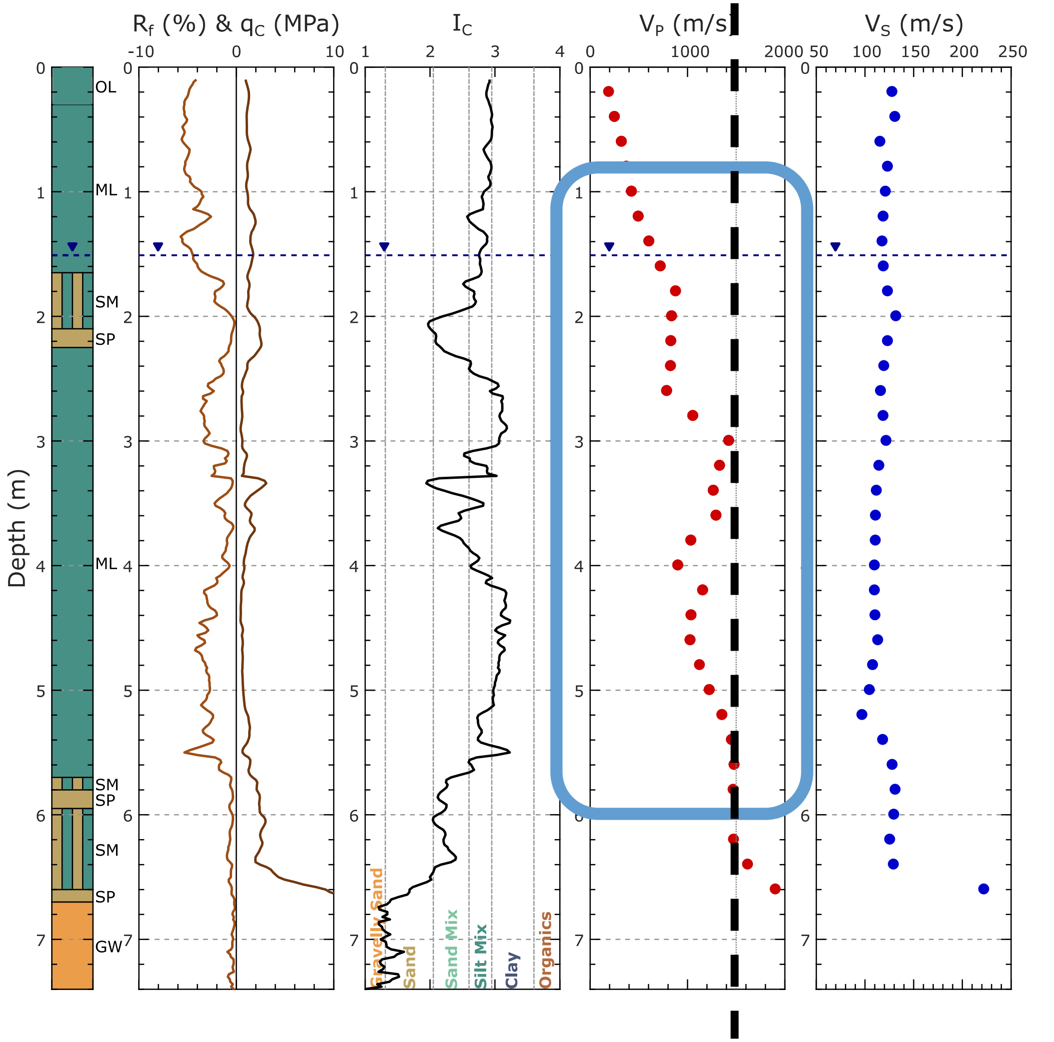
- Geophones to measure vibration
- Accelerometer to track cone deviation



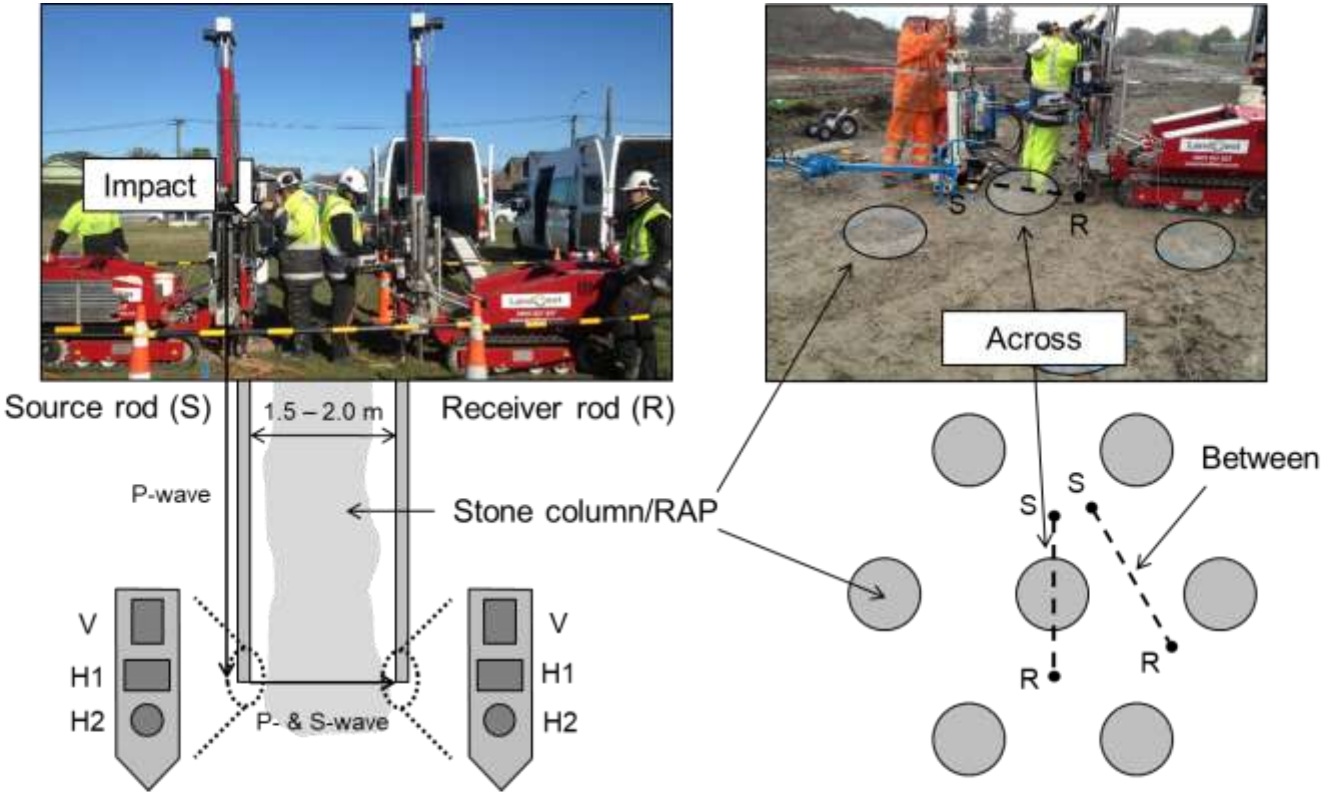
Example DPCH Data

Develop profiles of V_P and V_S with depth

Fully-saturated soils indicated by V_P > 1,500 m/s



DPCH Applications: Ground Improvements



Test unimproved ground & between and across ground improvement elements

Red Zone ground improvement trials and beyond:

> Alexander et al. (2019), Hwang et al. (2017), Wotherspoon et al. (2017), Stokoe et al. (2016), Wotherspoon et al. (2015), Stokoe et al. (2014)

DPCH Applications: Sample Disturbance

Shear wave velocity to evaluate disturbance of high-quality soil samples (e.g., gel-push samples)

- Bender element testing on laboratory specimens
- In-situ measurements from DPCH testing near borehole

DPCH Applications: V_S & V_P → Void Ratio?

Porosity Relationship (Foti et al. 2002)

- Based on the theory of linear poroelasticity (Biot 1956a & 1956b)

Comparison between DPCH $V_S V_P$ and CPT Dr relationships (Stolte et al. 2020)

- Sensitive to V_P
- Tend to under predict CPT-based relationships

Need comparisons between "undisturbed" soil samples and in-situ DCPH measurements