Effect of Partial Saturation on Liquefaction Triggering

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CHRISTCHURCH SOILS

- Analyses of 7000 case histories (Fig. 1) from the Canterbury Earthquake Sequence (CES) indicate commonly competing simplified liquefaction evaluation methods are often overly conservative (Maurer et al. 2014).
- Liquefaction evaluation methods predicted moderate-to-severe liquefaction over large areas of Christchurch where no liquefaction manifestation was observed.

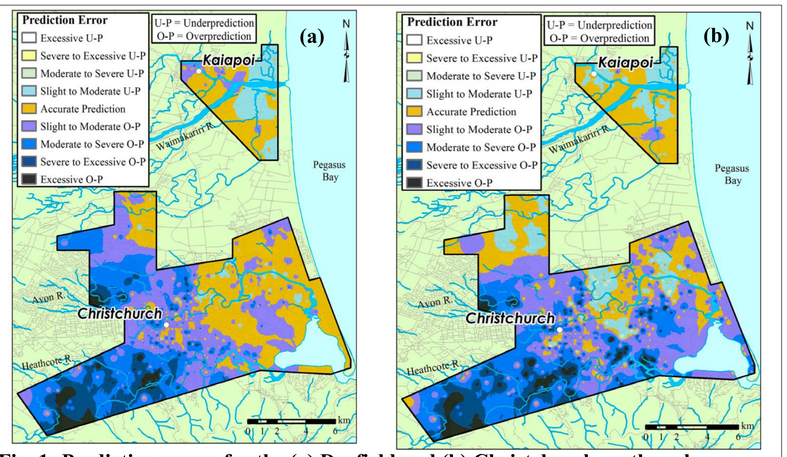

Fig. 1: Prediction errors for the (a) Darfield and (b) Christchurch earthquakes (Maurer et al. (2014))

EFFECT OF PARTIAL SATURATION

- Degree of saturation, S_r can be determined through measurement of the P-wave velocity, V_p **in the laboratory**. As V_p can also be measured **in the field**, S_r in the field can be inferred using S_r-V_p relationship of same soil (e.g. Fig. 2).
- Christchurch soil deposits in some areas contain layers of fines-containing sandy soils or non-liquefiable soils (e.g. clayey silts). In some locations, the top part of the deposit is partially saturated even 1.0 m below the water table, and in some cases over larger depths (Fig. 3).

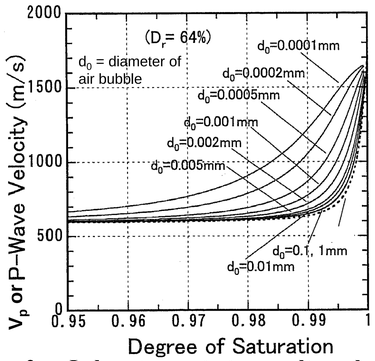

Fig. 2: Laboratory test results showing relationship between V_p and S_r of Toyoura sand (modified, Tamura et al. 2002)

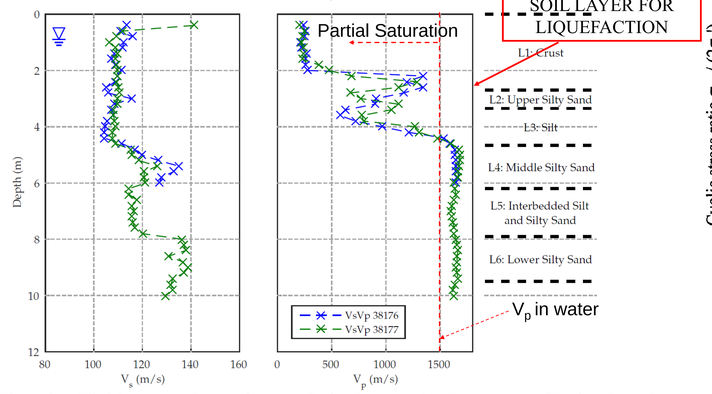

Fig. 3: Field test data from Gainsborough Reserve, Christchurch indicates partially saturated silty sands (V_p less than 1500 m/s measured in the field indicates partial saturation). (Stringer et al. 2016)

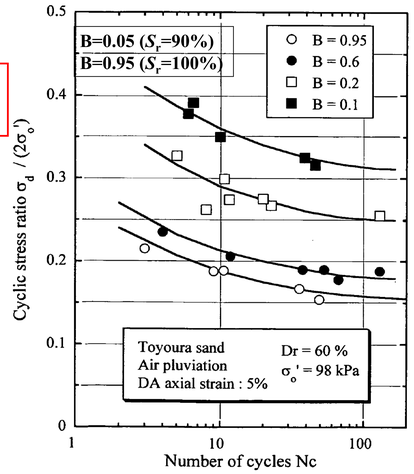

Fig. 4: Effect of partial saturation of clean sand (Tsukamoto et al. 2002)

- It is well known that partially saturated sands exhibit greater liquefaction resistance than fully saturated sand (e.g. Fig. 4).

MEASUREMENT of V_p

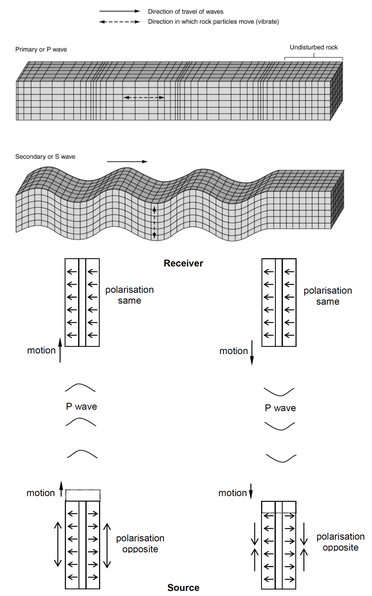

Fig. 5: P-wave transmission (GDS handbook)

Fig. 6: Bender elements

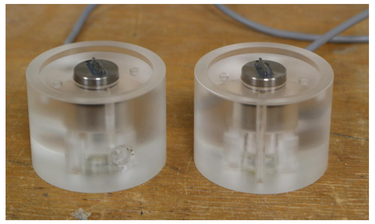

Fig. 7: Modified platens and bender elements for V_p measurement in triaxial device

EXPECTED RESEARCH OUTCOMES

- ✓ Quantification of partial saturation effects on liquefaction resistance of characteristic Christchurch soils.
- ✓ Methodology for laboratory testing of partially saturated soils.
- ✓ Reduction of undue conservatism in liquefaction evaluation.
- ✓ Better quantification of NZ liquefaction hazard at regional level.

ACKNOWLEDGEMENT

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RESEARCH AIMS

- To correlate liquefaction resistance with degree of saturation for characteristics Christchurch soils including sands with fines and silts.
- To incorporate the effects of saturation in simplified procedures for liquefaction assessment.
- Provide basis for quantifying the effects of partial saturation in advanced seismic analysis.

EXPERIMENTAL PROGRAM

- Three types of typical Christchurch soils will be tested.
- Fines content varies between 0 and 60%.
- Soil will be tested at varying S_r covering from 60% to 100%.
- V_p will be measured at different stages of testing allowing us to estimate the degree of saturation during the testing.

REFERENCES

GDS handbook, The GDS Bender Elements System Hardware Handbook for Vertical and Horizontal Elements

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