

Re-evaluation of Liquefaction Potential Index based on Christchurch Data

Project Number: 23
Group: Geotechnical

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Introduction

The 2010-2011 Canterbury earthquake sequence caused significant damage to the urban areas of Christchurch due to widespread liquefaction, especially as a result of the M6.3 earthquake on 22 February 2011. Following the earthquakes, extensive ground investigations have been conducted for the subsequent rebuild efforts. The liquefaction potential index (LPI) is often used to quantify and/or estimate liquefaction-induced damage following a seismic event.

Objectives

- Determine the applicability of current LPI equation in assessing damage in Christchurch.
- Recommend modifications to the LPI concept that best quantifies the damage observed.

Methodology

- From the Canterbury Geotechnical Database (CGD), 106 CPT data between 22 February - 13 June were collected, together with information on peak ground accelerations and ground water tables at the sites.
- The original LPI equation is given by:

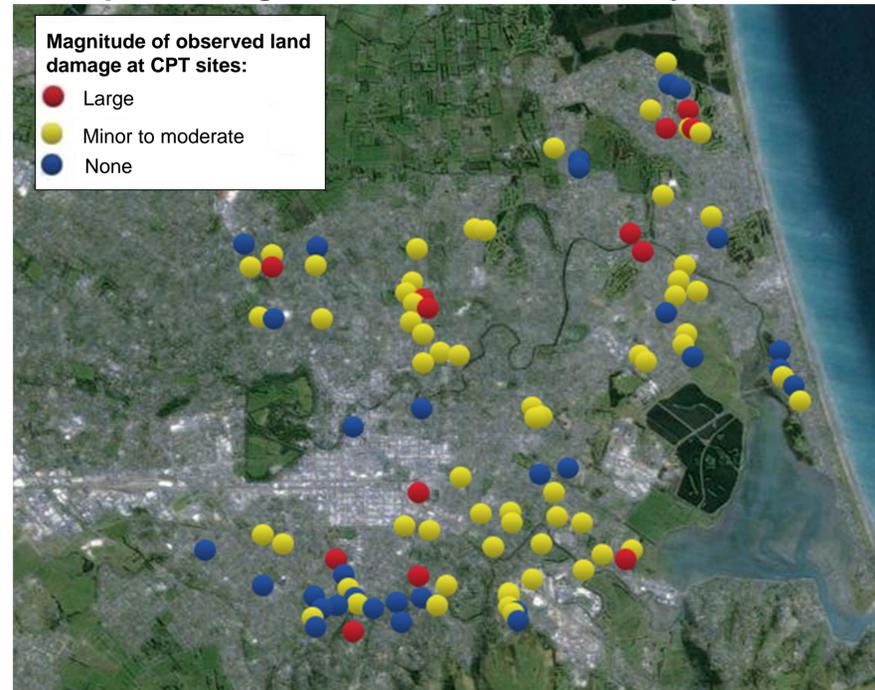
$$LPI = \int_0^{20} F(z) \cdot w(z) dz \quad \text{Where: } F(z) = \begin{cases} 1-FS & FS < 1.0 \\ 0 & FS \geq 1.0 \end{cases}$$

$$w(z) = 10 - 0.5z$$

- Classification: $LPI > 15$: severe liquefaction; $5 \leq LPI \leq 15$: moderate liquefaction; $LPI < 5$: no liquefaction.
- Recalibration of the original LPI classification: $LPI > 21$: severe liquefaction; $14 \leq LPI \leq 21$: moderate liquefaction; $LPI < 14$: no liquefaction.
- The Factor of Safety (FS) was calculated using Boulanger & Idriss (2014) method.
- The following modifications to LPI were considered:

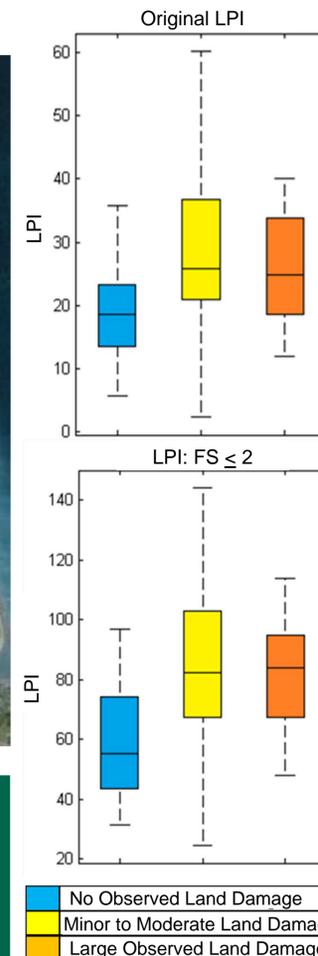
LPI Modification	Equation changes	New LPI thresholds for expected damage		
		None	Minor to moderate	Major
a) LPI_{2a}	$F(z) = \begin{cases} 2-FS & FS < 2.0 \\ 0 & FS \geq 2.0 \end{cases}$	0 - 52	52 - 84	>84
b) LPI_{2b}	As a) and: $LPI_{2b} = \int_0^{20} F(z) \cdot \frac{DF_c}{20} \cdot w(z) dz$ Where: $DF_c = \begin{cases} 12 - 0.6 \cdot d_L & FS < 1.0 \\ 16 - 0.8 \cdot d_L & FS \geq 1.0 \end{cases}$ $d_L = \text{depth to first liquefiable layer}$	0 - 8	8 - 13.2	>13.2
c) LPI_{2c}	As a) and: $d_z = 3 \cdot d_L$ $LPI_{2c} = LPI_{2a} \cdot \left(0.4 + \frac{\int_{d_L}^{d_z} F(z) \cdot dz}{10 \cdot (d_z - d_L)}\right)$	0 - 23	23 - 43	>43

Map showing CPT Sites Used in Analysis

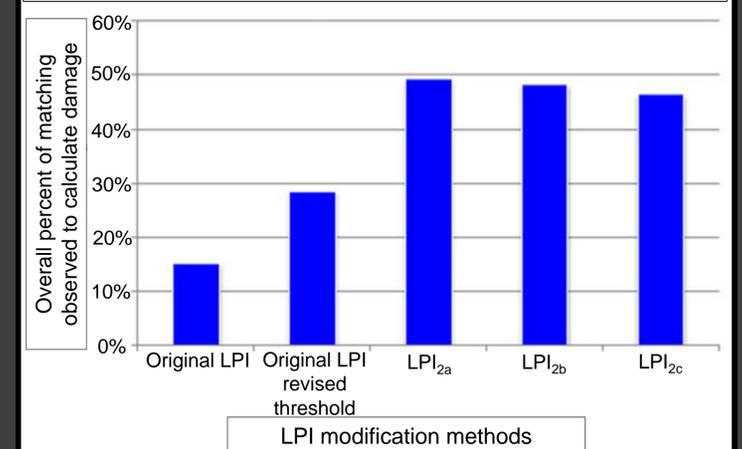


New Modified LPI Equation

Among the modifications proposed, LPI_{2a} was the best fit equation. It had the highest percent of LPI's that matched to the observed when allowing for a maximum 10% underestimation in damage.



Overall Percent matching of observed damage to calculated LPI



Analysis and Discussion

- When compared to observed damage, the original LPI has the lowest accuracy (only 15%).
- Recalculation of damage severity ranges for the original LPI resulted in increased accuracy.
- Modifying the LPI equation to include $FS \leq 2$ showed the highest accuracy in predicting surface damage (49%). This is possibly due to effect of generation/dissipation of pore water pressure for $1 < FS \leq 2$.
- Cumulative effects of the earthquake sequence may have over-estimated the damage observed at the CPT sites.

Conclusions

- Original LPI equation is not applicable in assessing liquefaction-induced damage in Christchurch.
- The modified LPI equation (LPI_{2a}) best reflect the observed damage in Christchurch.

Recommendations for future work

- The number of CPT data used was just a small fraction of the CGD database. More CPT should be analysed.
- Only one method was used to calculate FS. Other evaluation methods are recommended.

Acknowledgements

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Reference

Boulanger, R. W., & Idriss, I. M. (2014). CPT and SPT based liquefaction triggering procedures. Report No. UCDC/GM-14/01. Center for Geotechnical Modeling, Dept of Civil & Environmental Engineering, UC Davis.

Performance of various LPI modifications when compared with actual damage

