

Modelling the seismic response of New Zealand wharves: Case history application

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Outline

- Introduction
- CQ3 Model
- Fragility Modelling
- Conclusions



INTRODUCTION

Research Motivation

- Ports infrastructure critical to economy
- 99% of all imports and exports by volume
- Lifeline as specified by CDEM Act
- Needed for recovery after natural hazard
- Do we understand their seismic response?





San Antonio Port
2010 Chile Earthquake



Lyttelton Port
2011 Christchurch Earthquake

Research Objectives

1. Collect information on New Zealand ports and review the hazard exposure.
2. Develop database of New Zealand wharves
3. Model the seismic response of key wharf at Lyttelton Port
4. Conduct fragility analysis on key wharf at Lyttelton Port
5. Develop models to study seismic performance of wharf configurations.



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LYTTELTON PORT

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Lyttelton Port



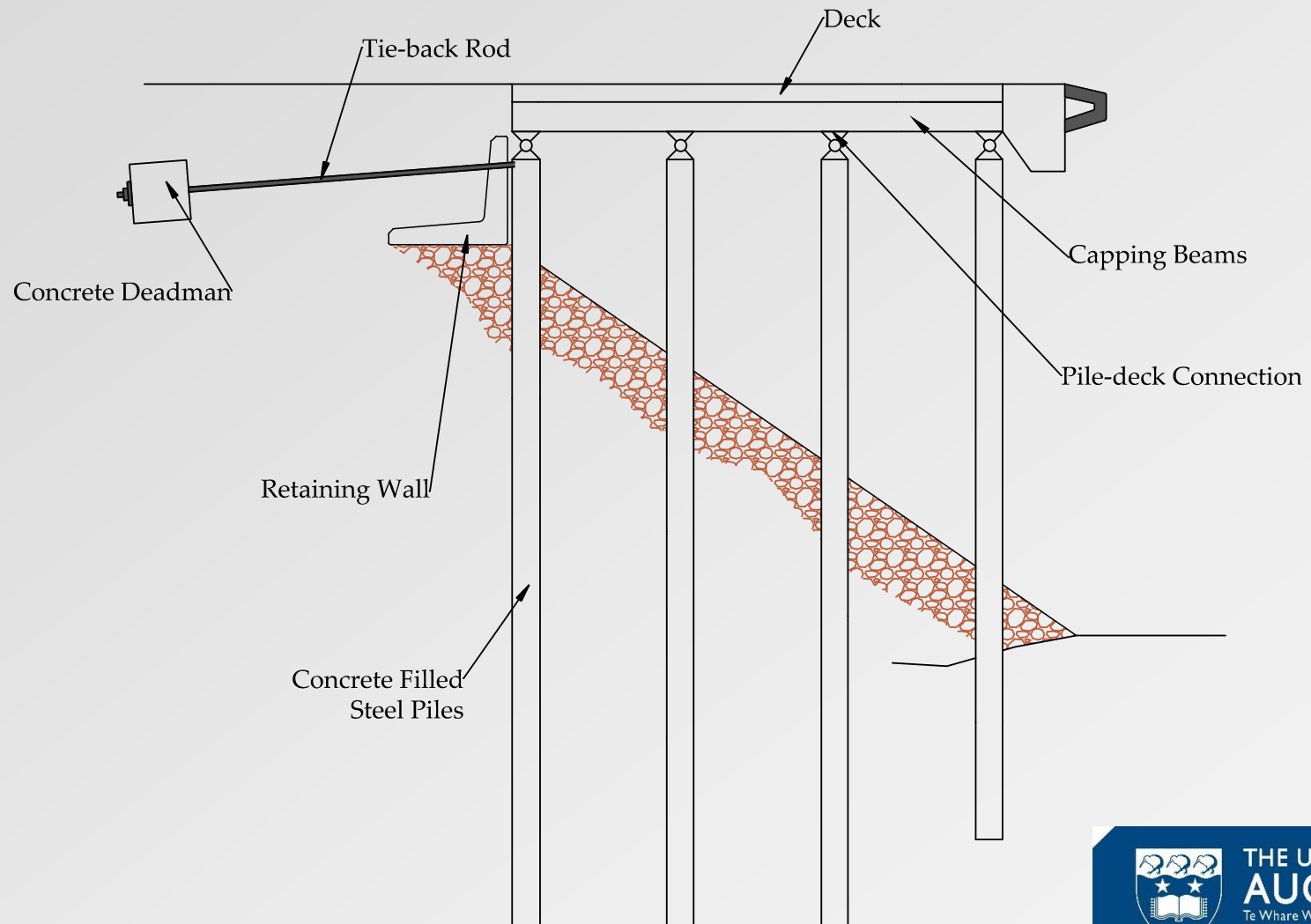
200 m

Cashin Quay 3

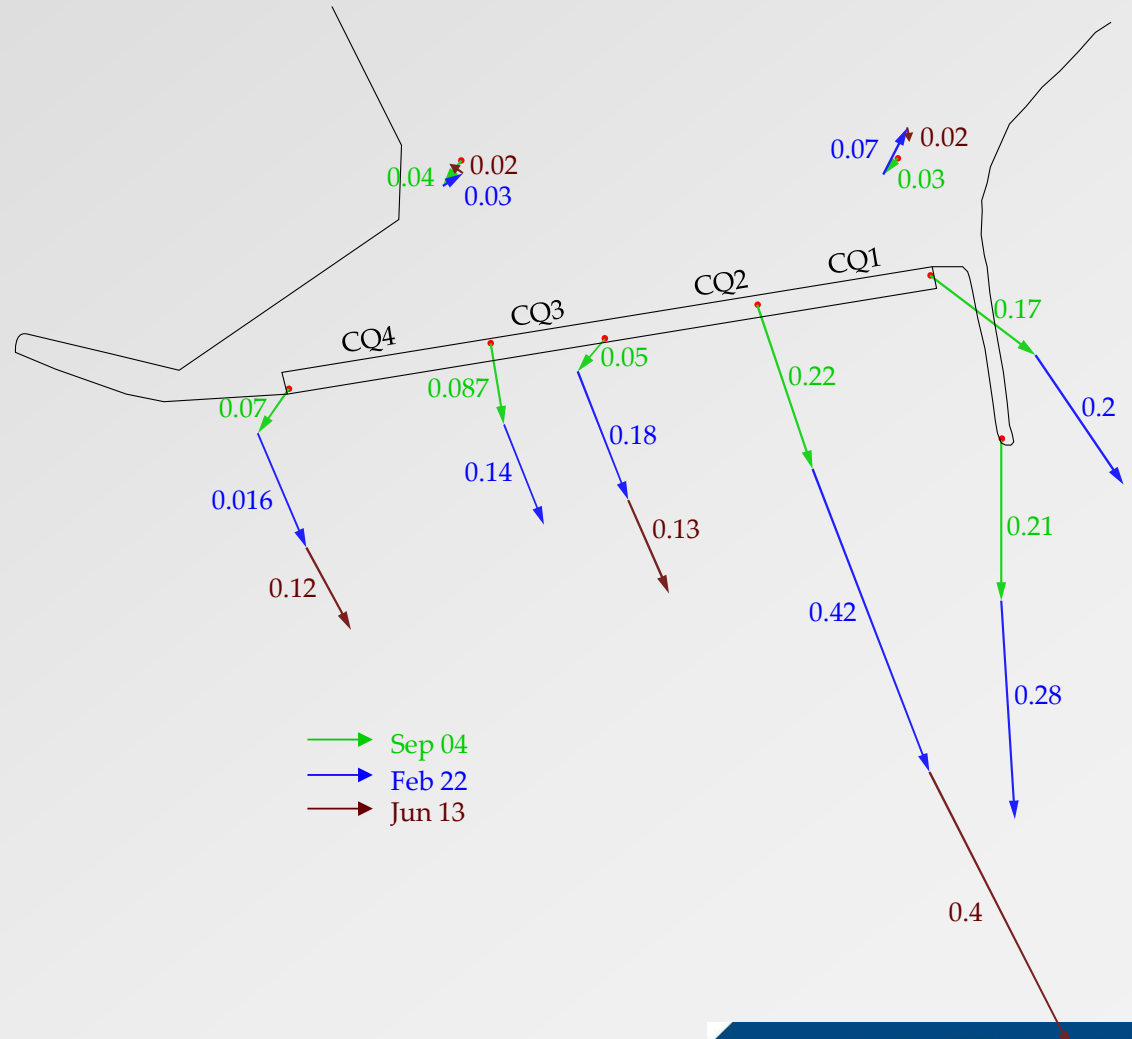


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NEW ZEALAND

CQ3 Wharf



Damage Characteristics

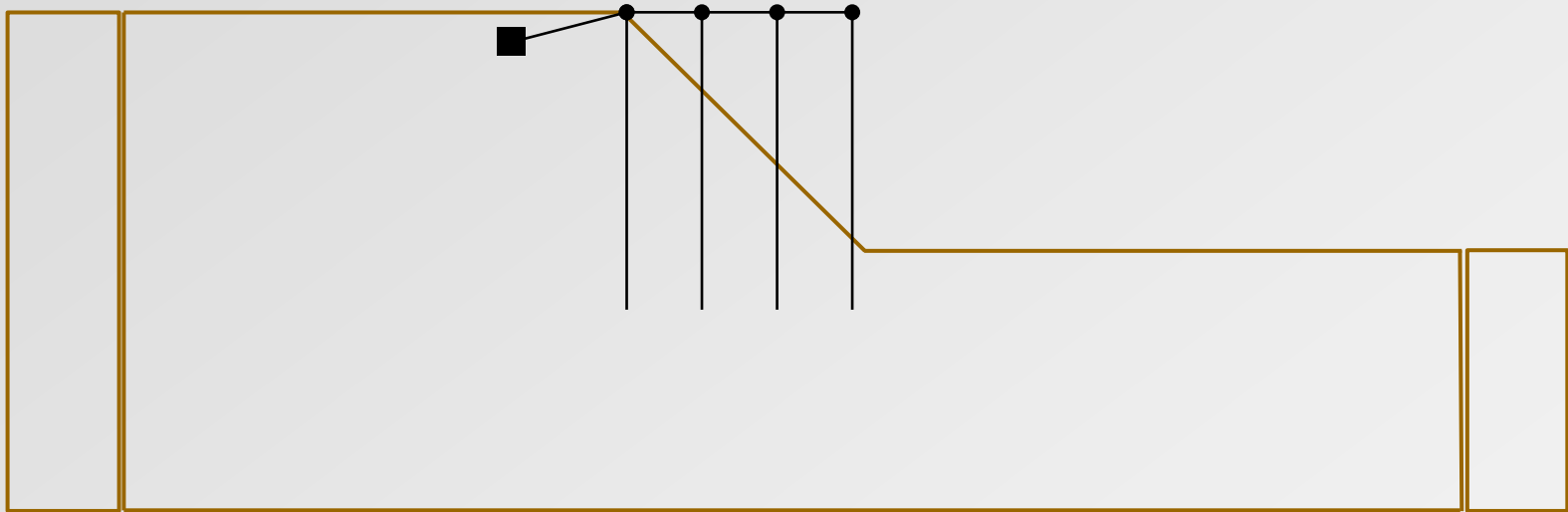


Computational Modelling

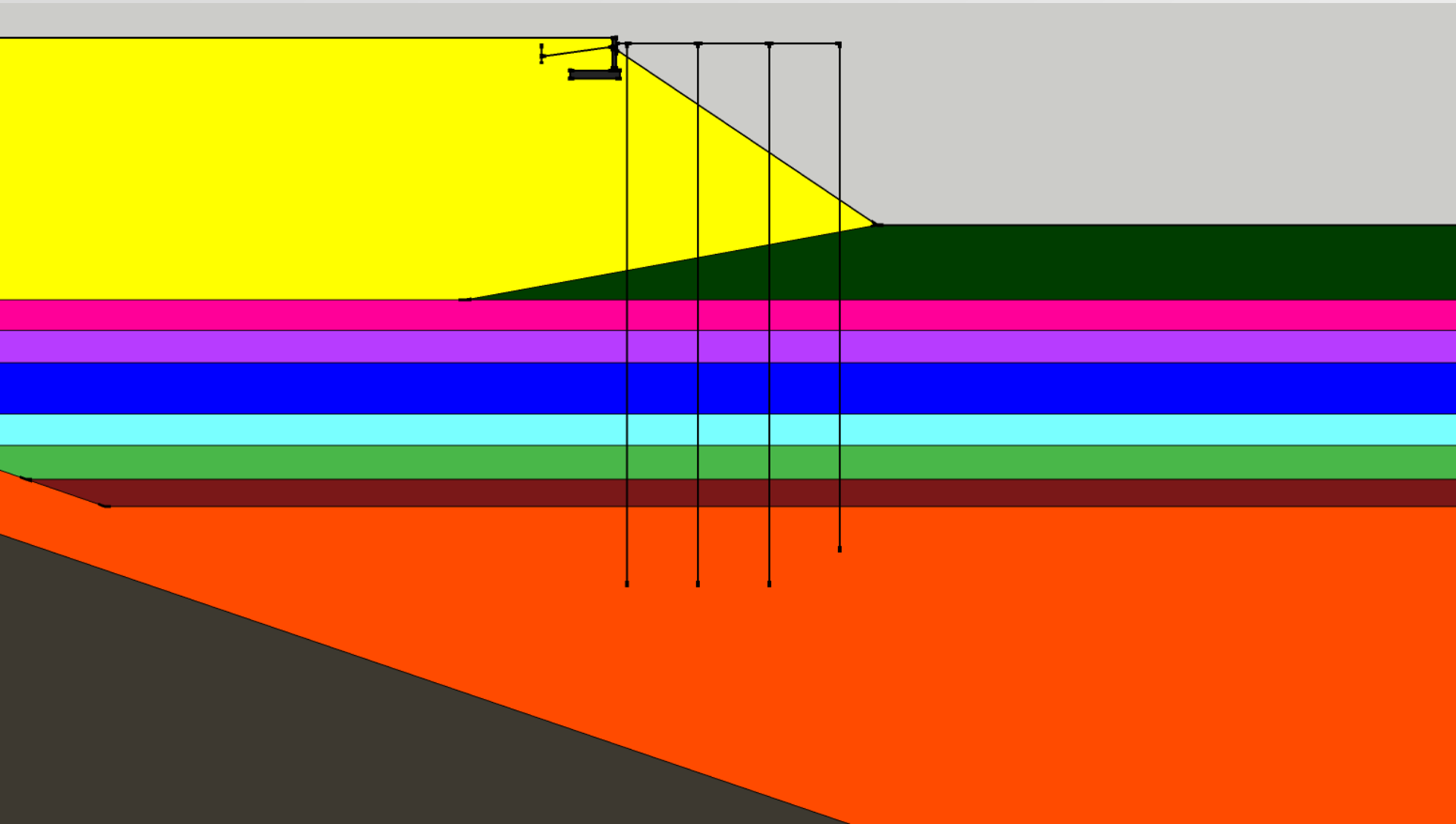
- Nonlinear dynamic analysis
- Captures soil-structure interaction
- Kinematic loading due to soil movement



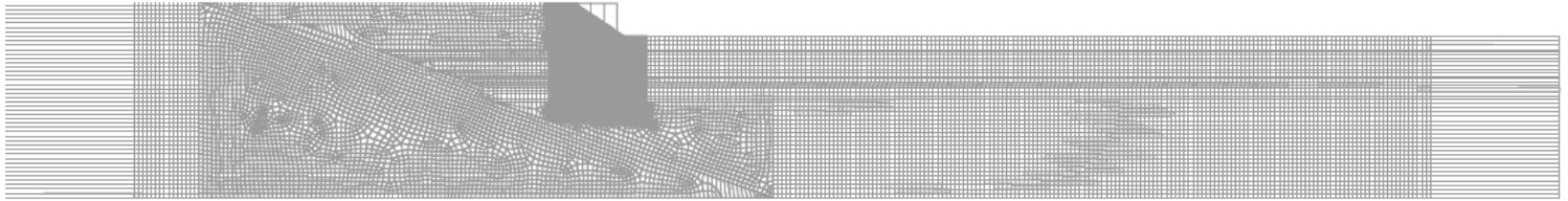
CQ3 Numerical Model



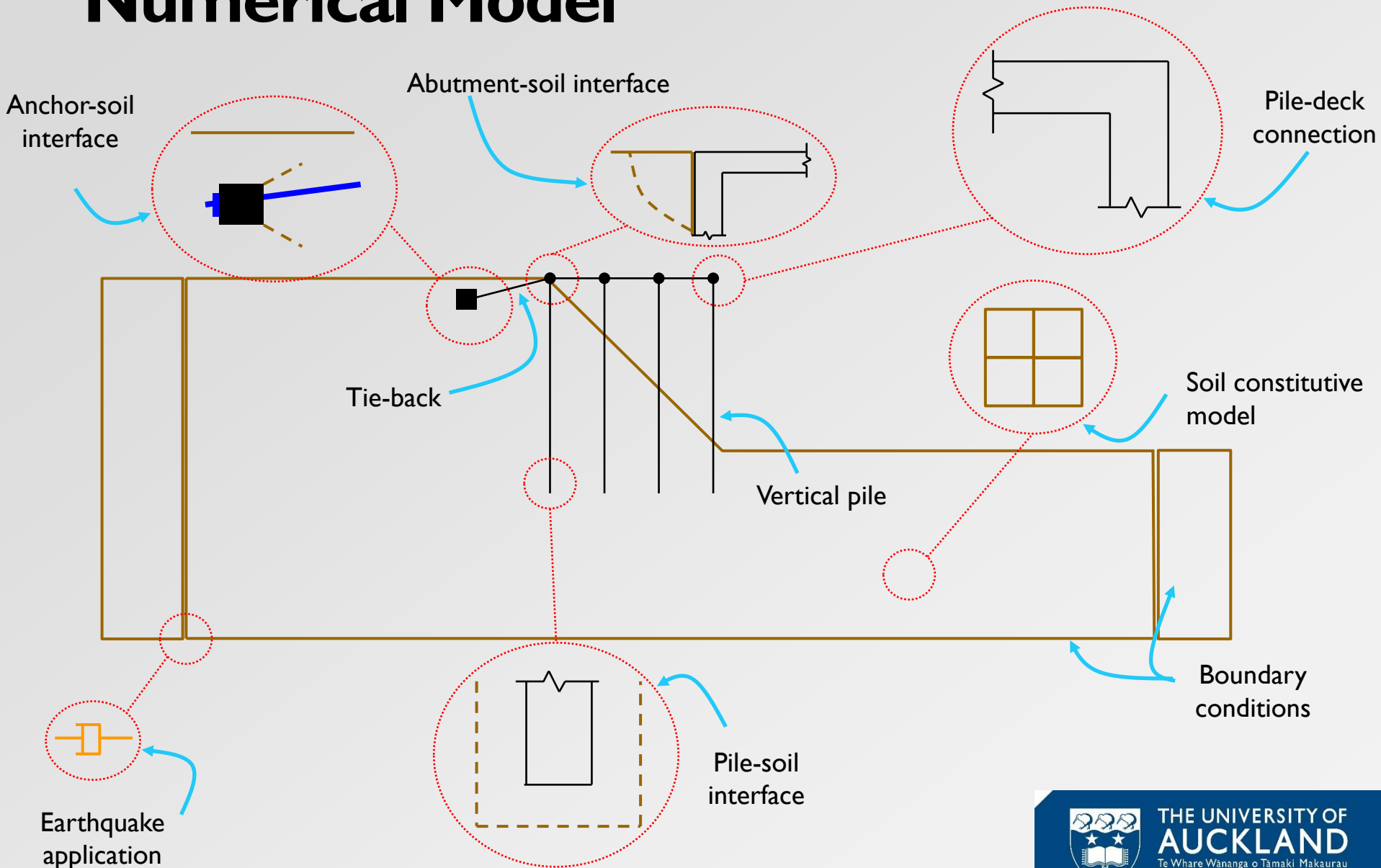
Soil Layers



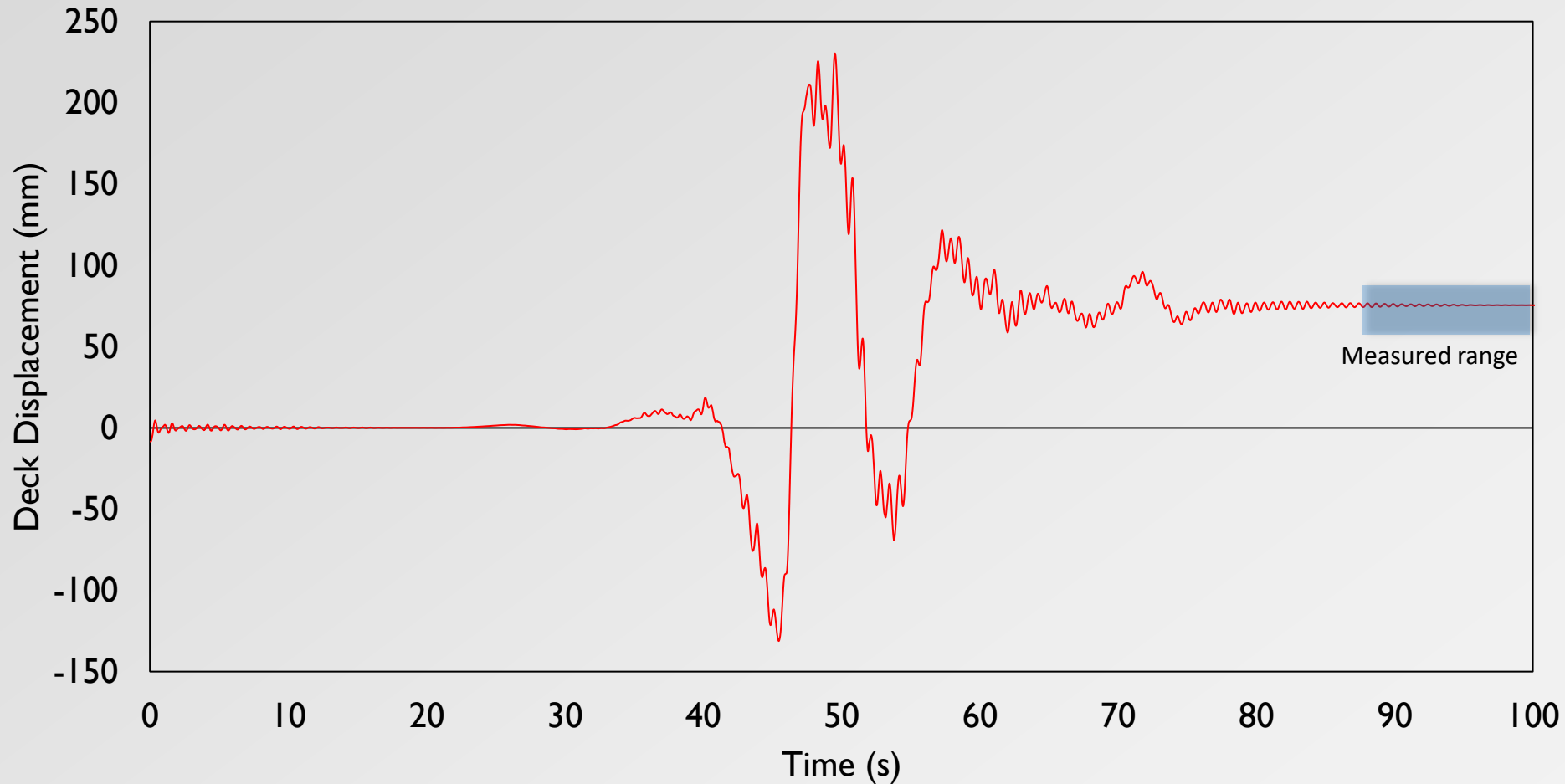
Numerical Model



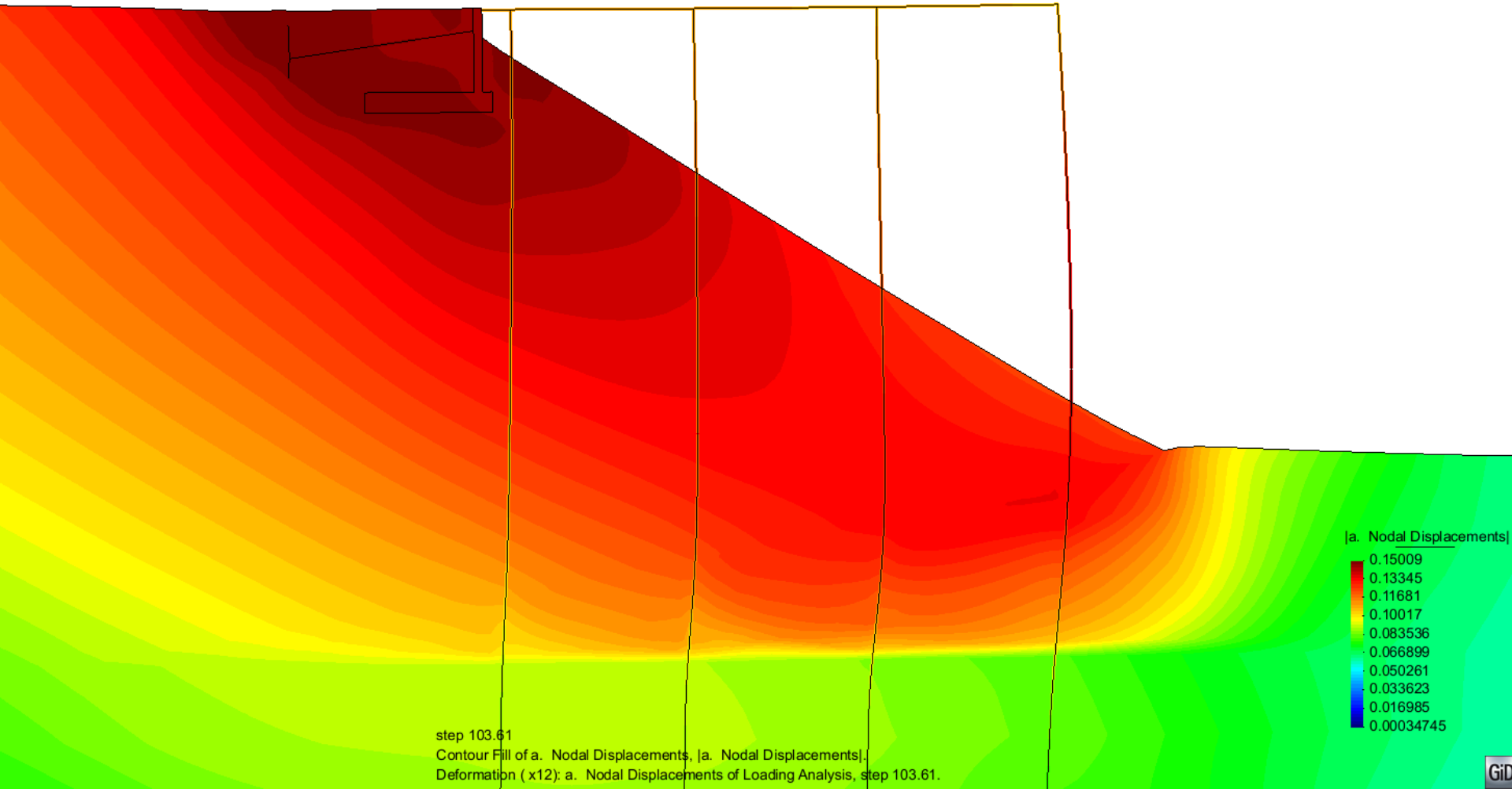
Numerical Model



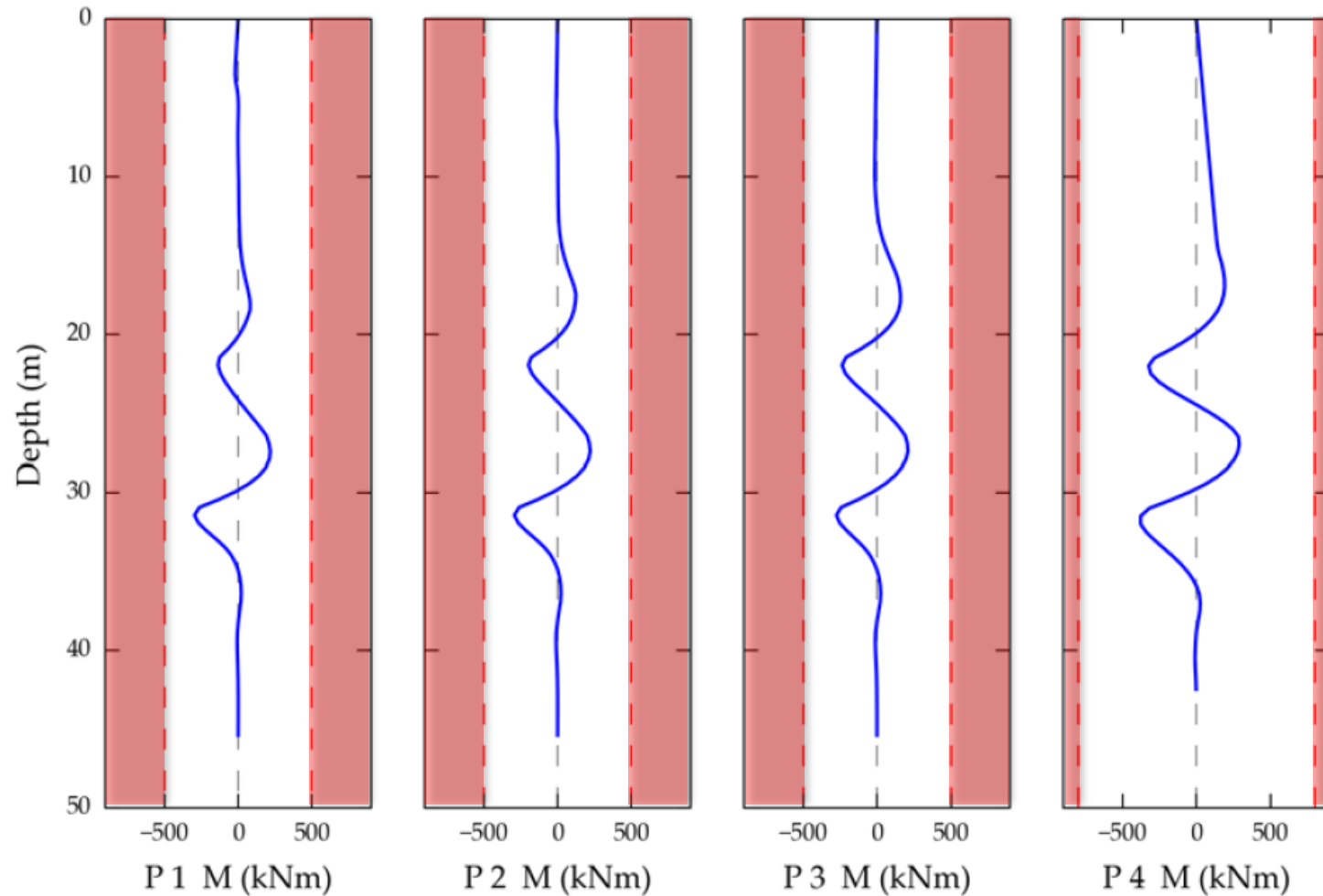
Darfield EQ - Deck Displacement



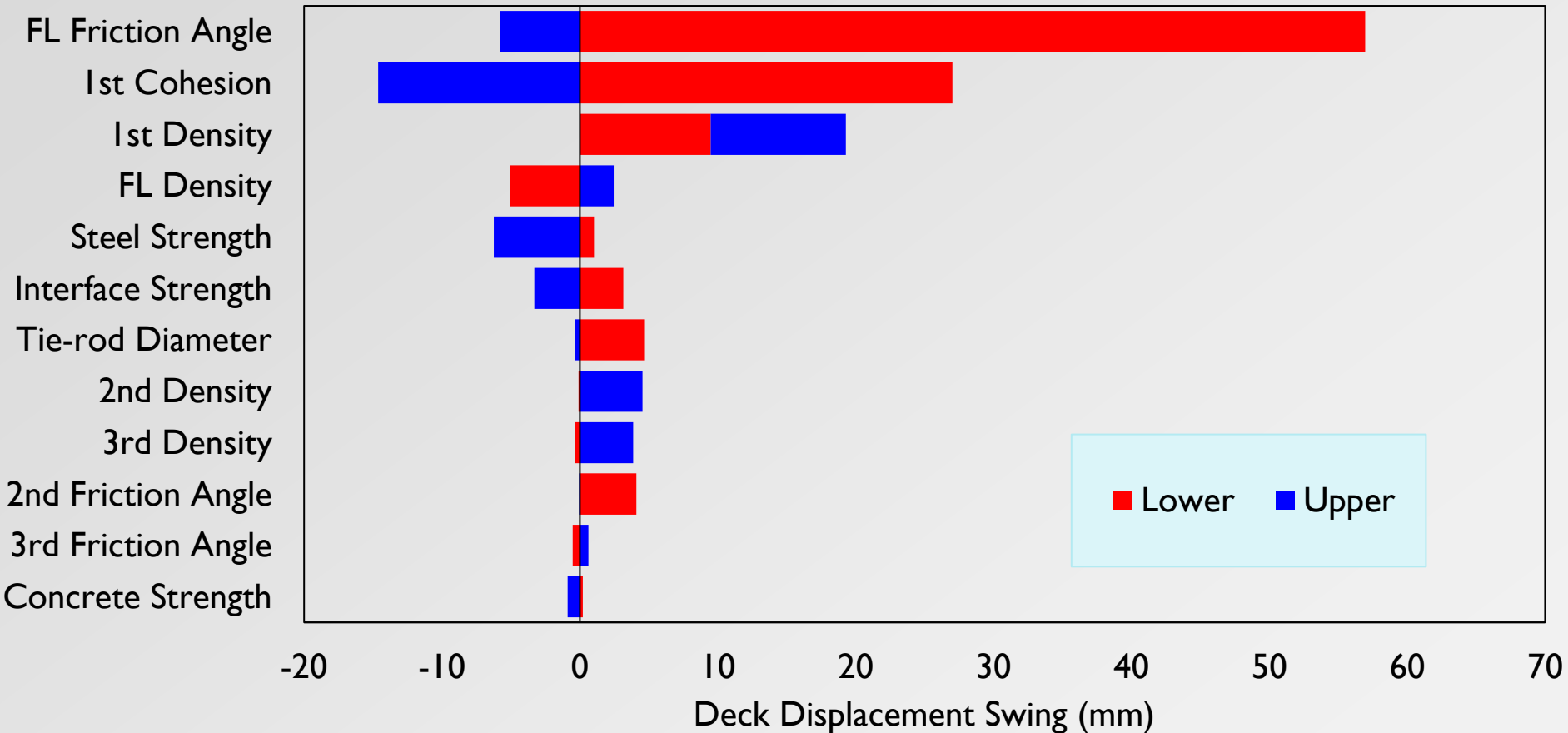
Darfield EQ - Slope Displacement



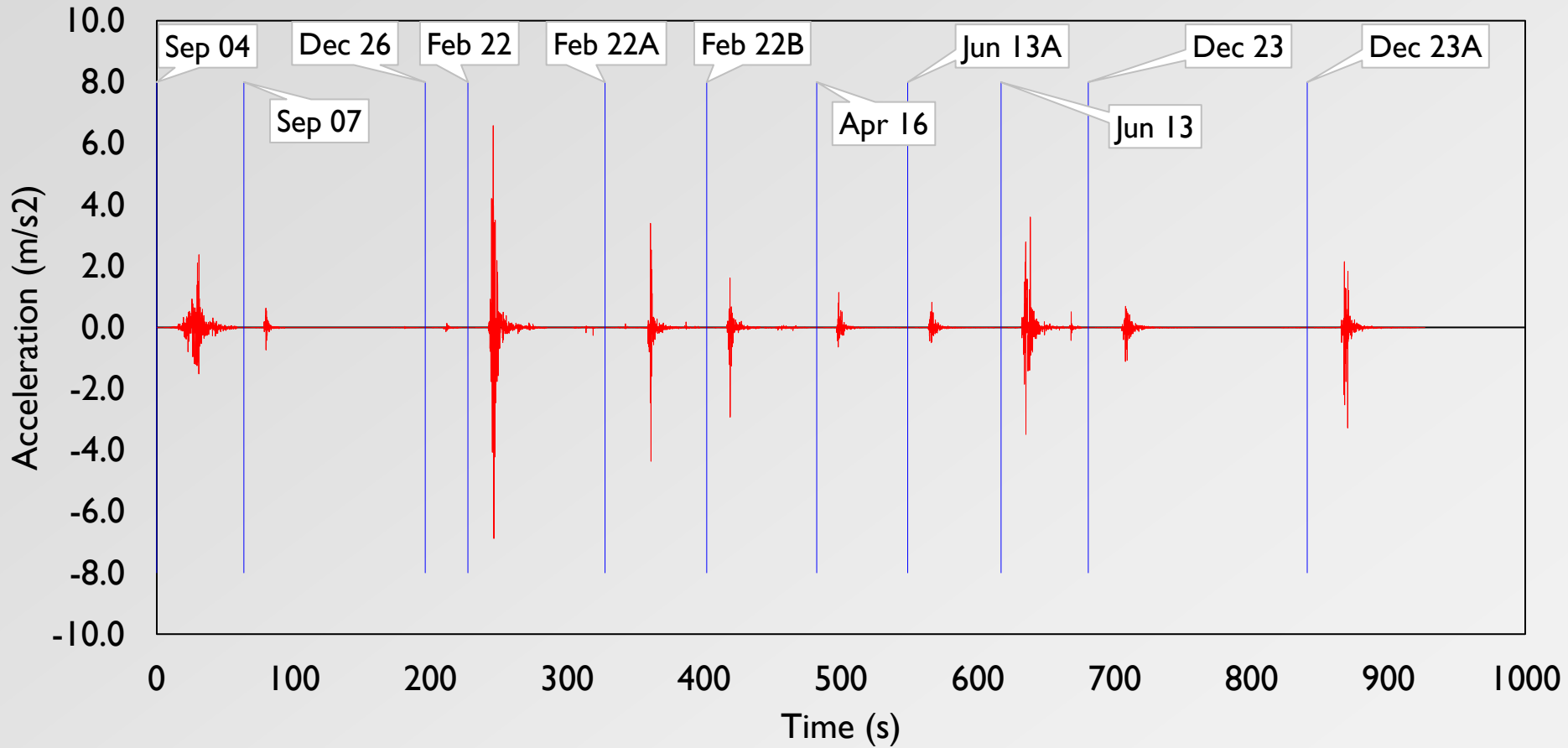
Darfield EQ - Piles



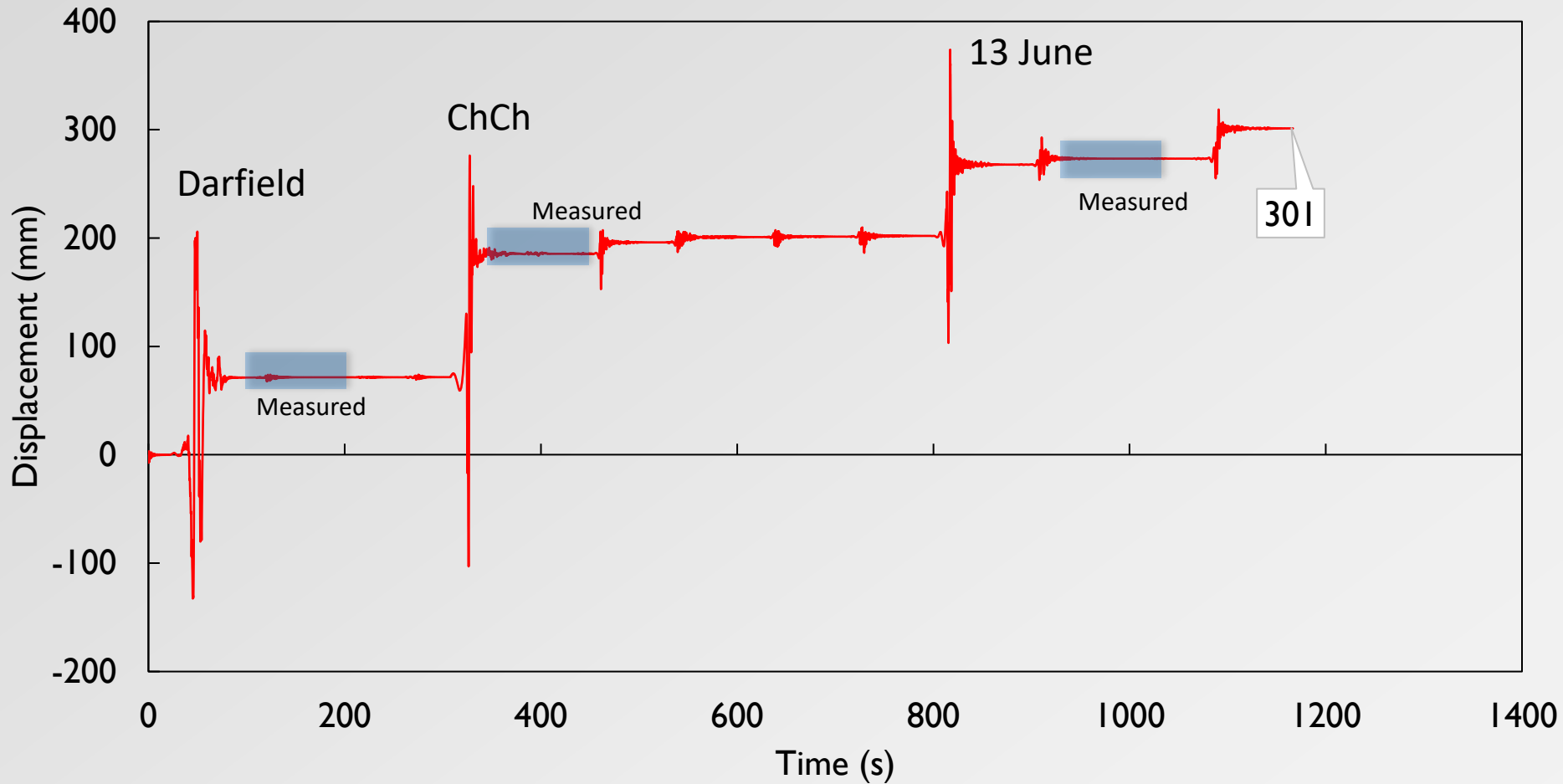
Sensitivity Analysis



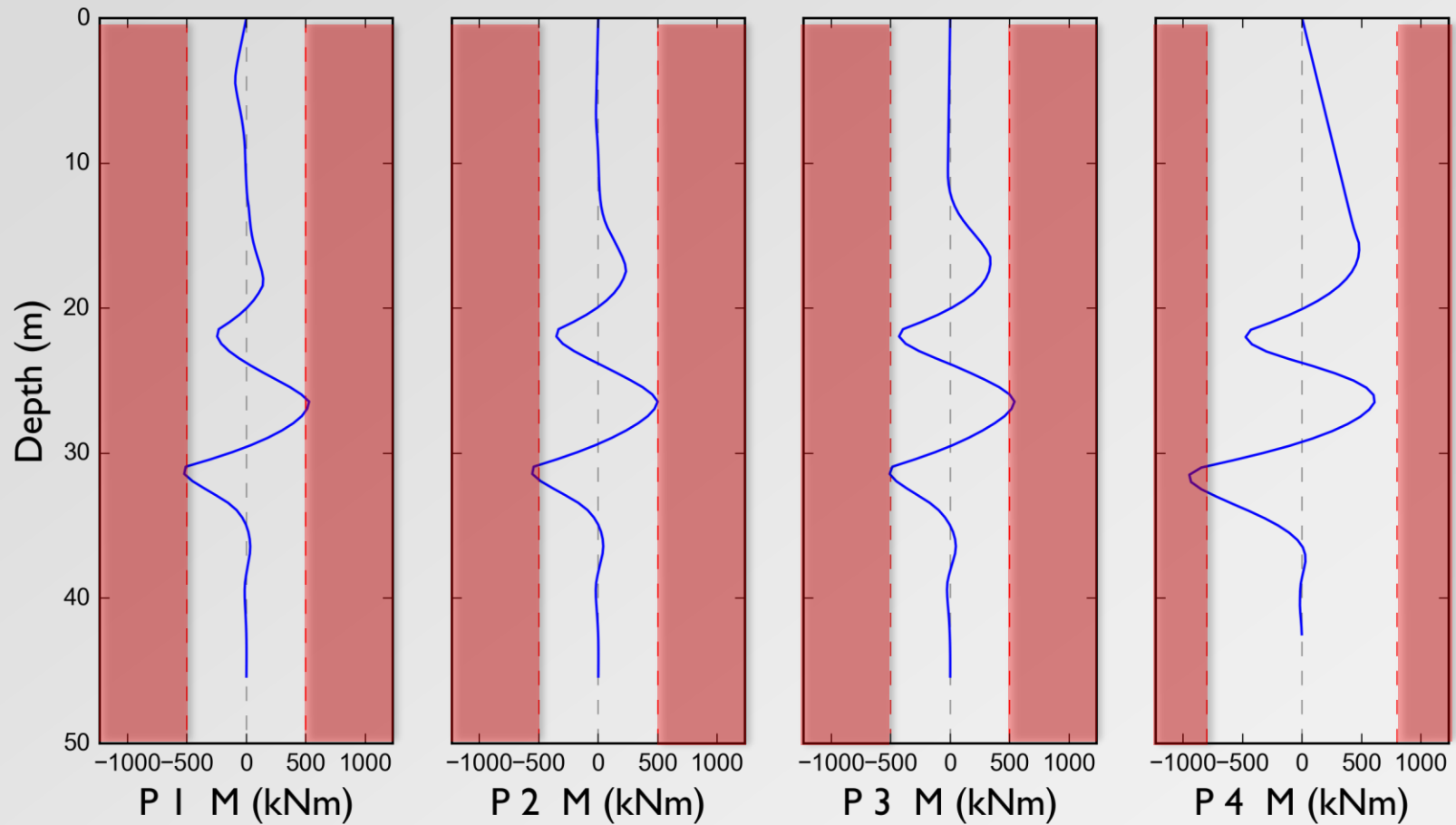
EQ Sequence



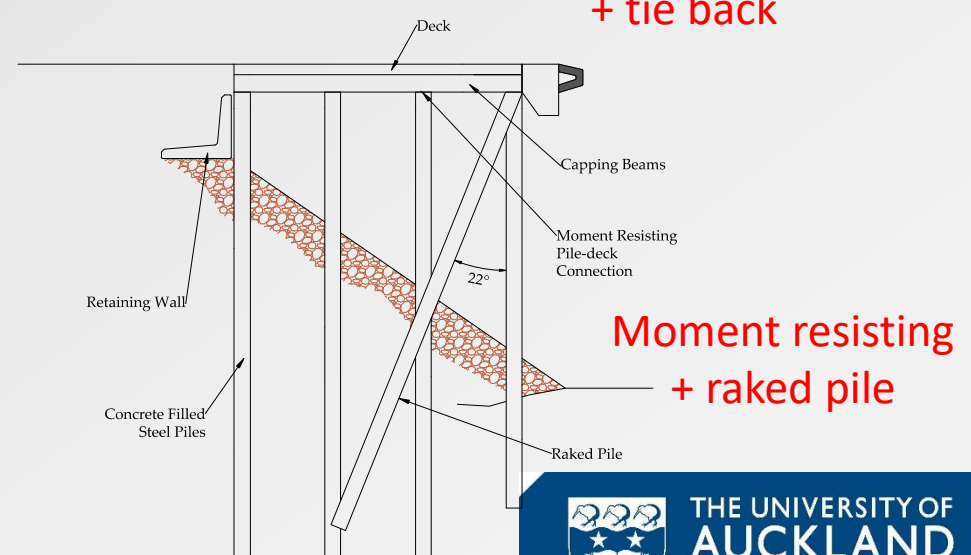
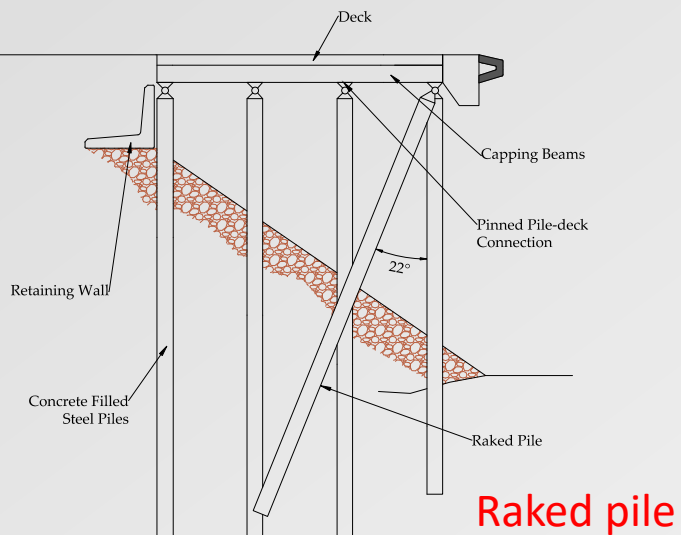
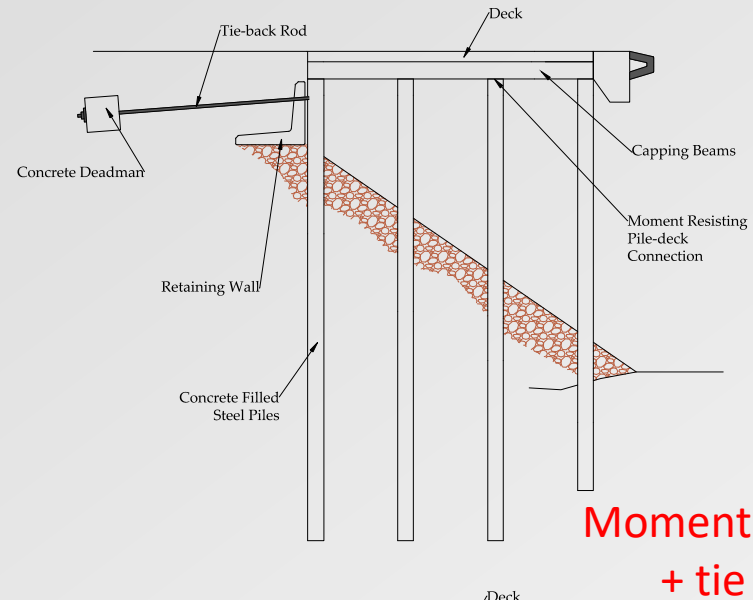
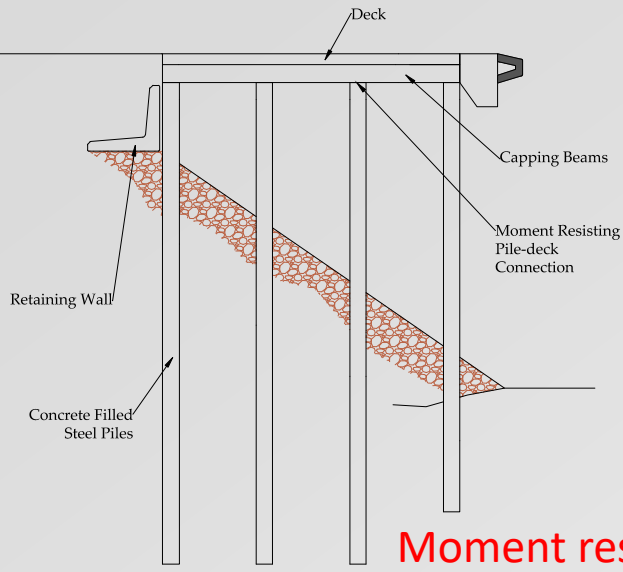
EQ Sequence



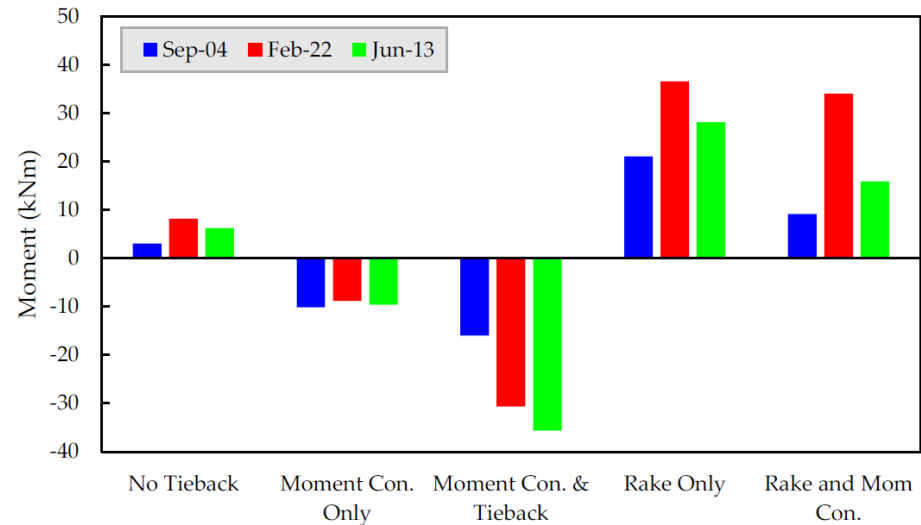
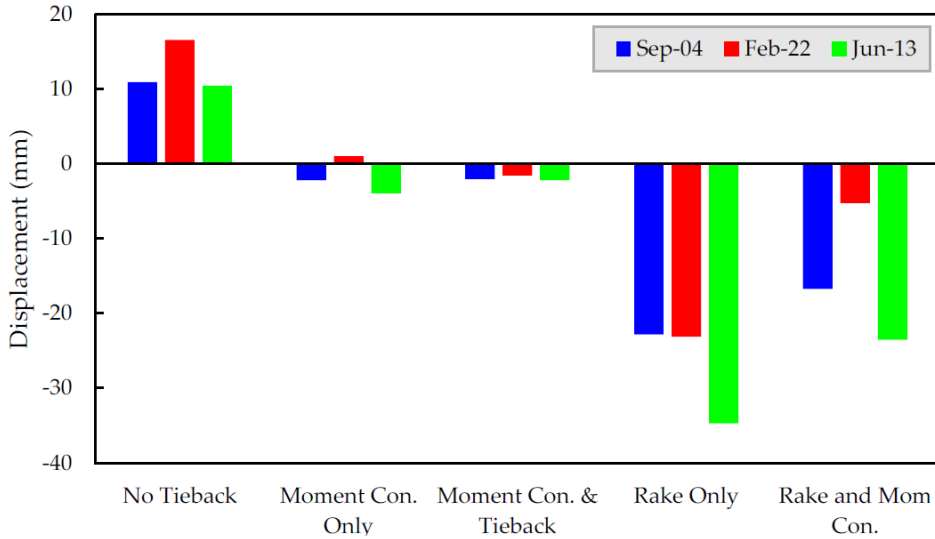
Pile Bending Moment



Effect of Structural Form



Effect of Structural Form



FRAGILITY MODELLING

Relationship between hazard intensity and probability of damage

Fragility Analysis Framework

CQ3 Numerical Model

Scaled ground motion suite (PGV)

Dynamic analysis simulation

Defined damage states

Generate curves

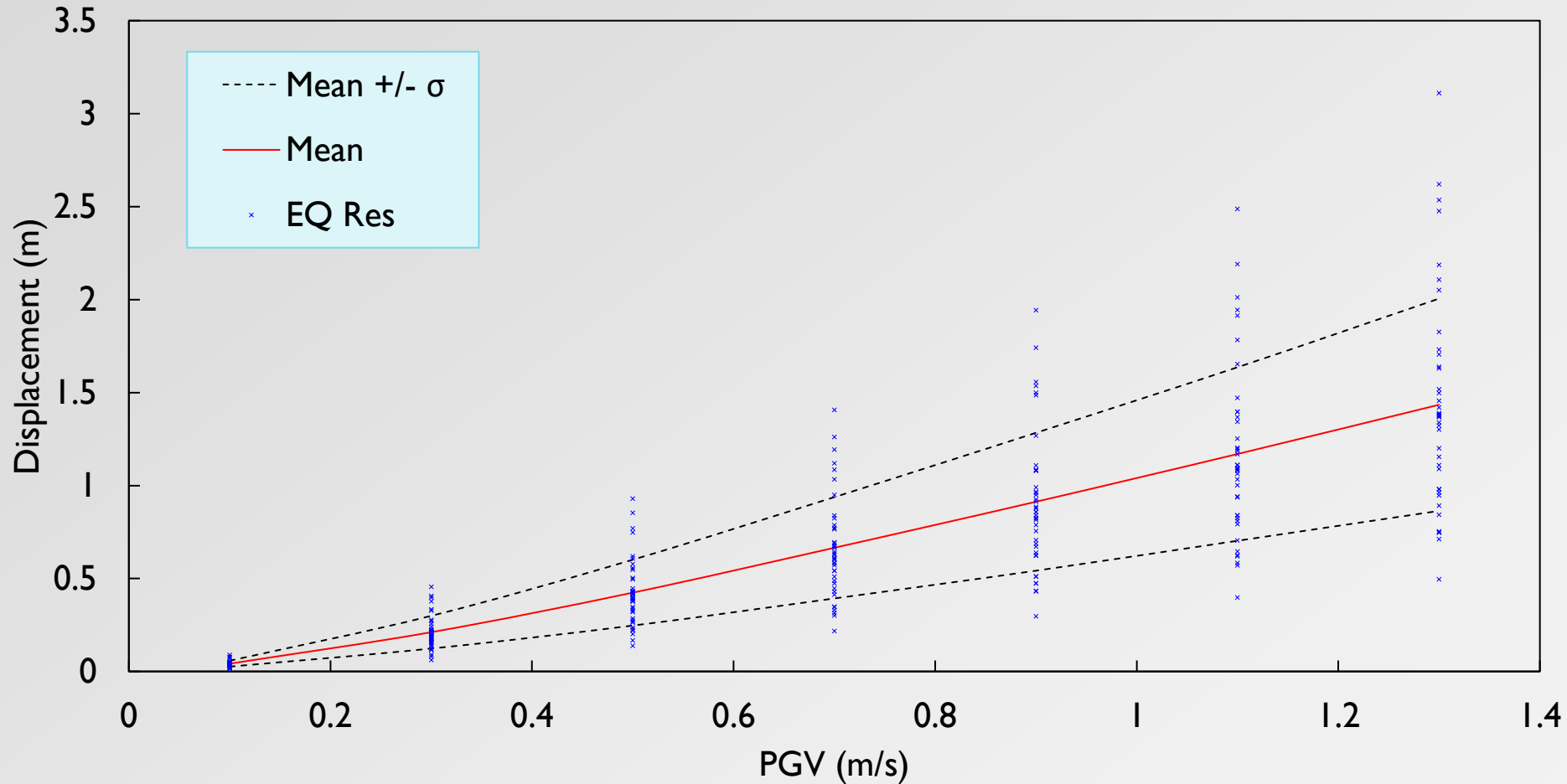


Engineering Demand Parameters

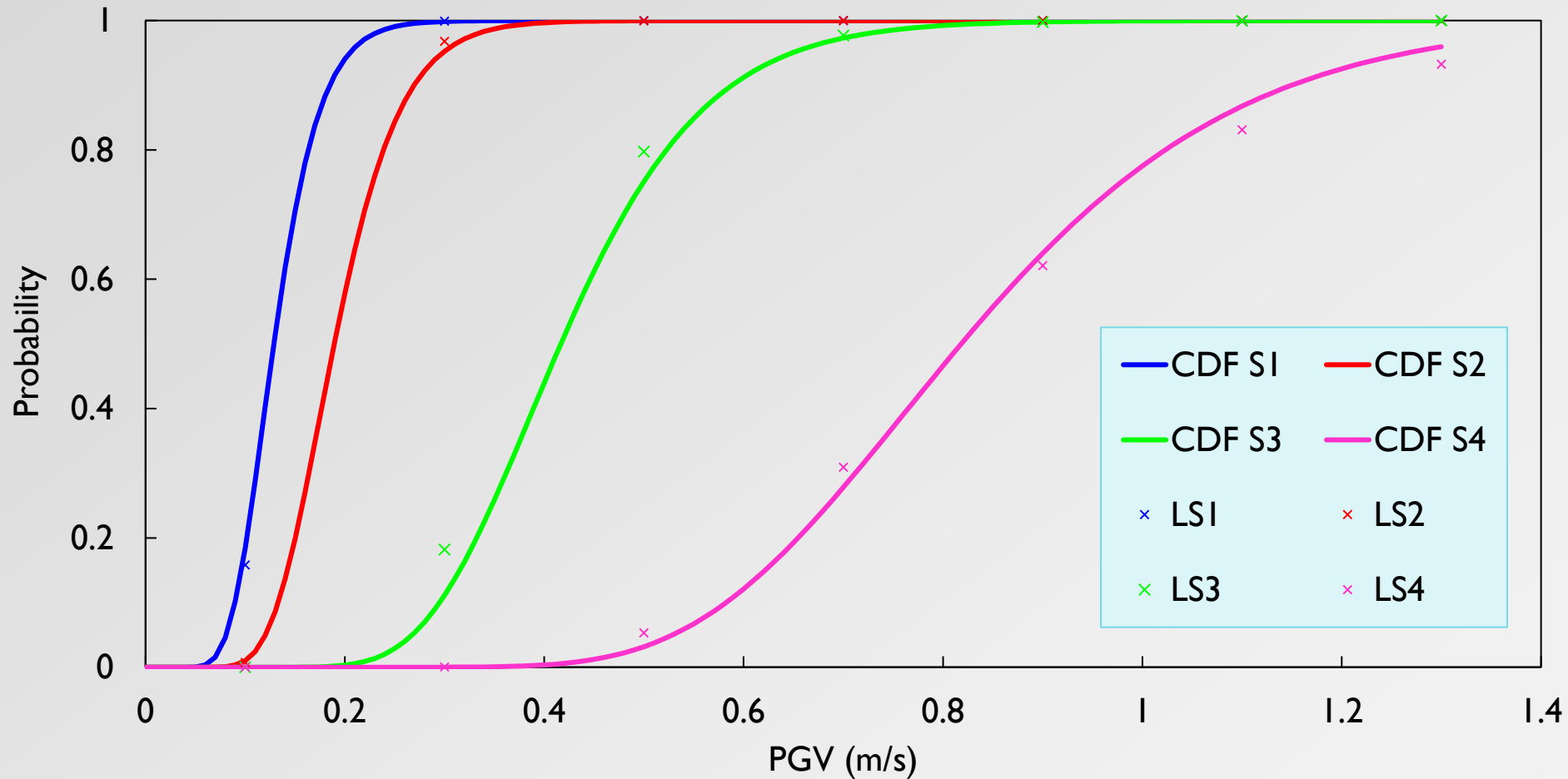
- Residual deck displacement
- Maximum pile bending moment
- Residual ground displacement
- Four limit states defined for each EDP



Statistical Analysis – EDP I



Fragility Curve – EDP I



Damage States

- Minor
 - Cracking or no structural damage
 - Small settlement
- Moderate
 - Spalling and onset of yielding
 - Significant pavement cracks from slope movement

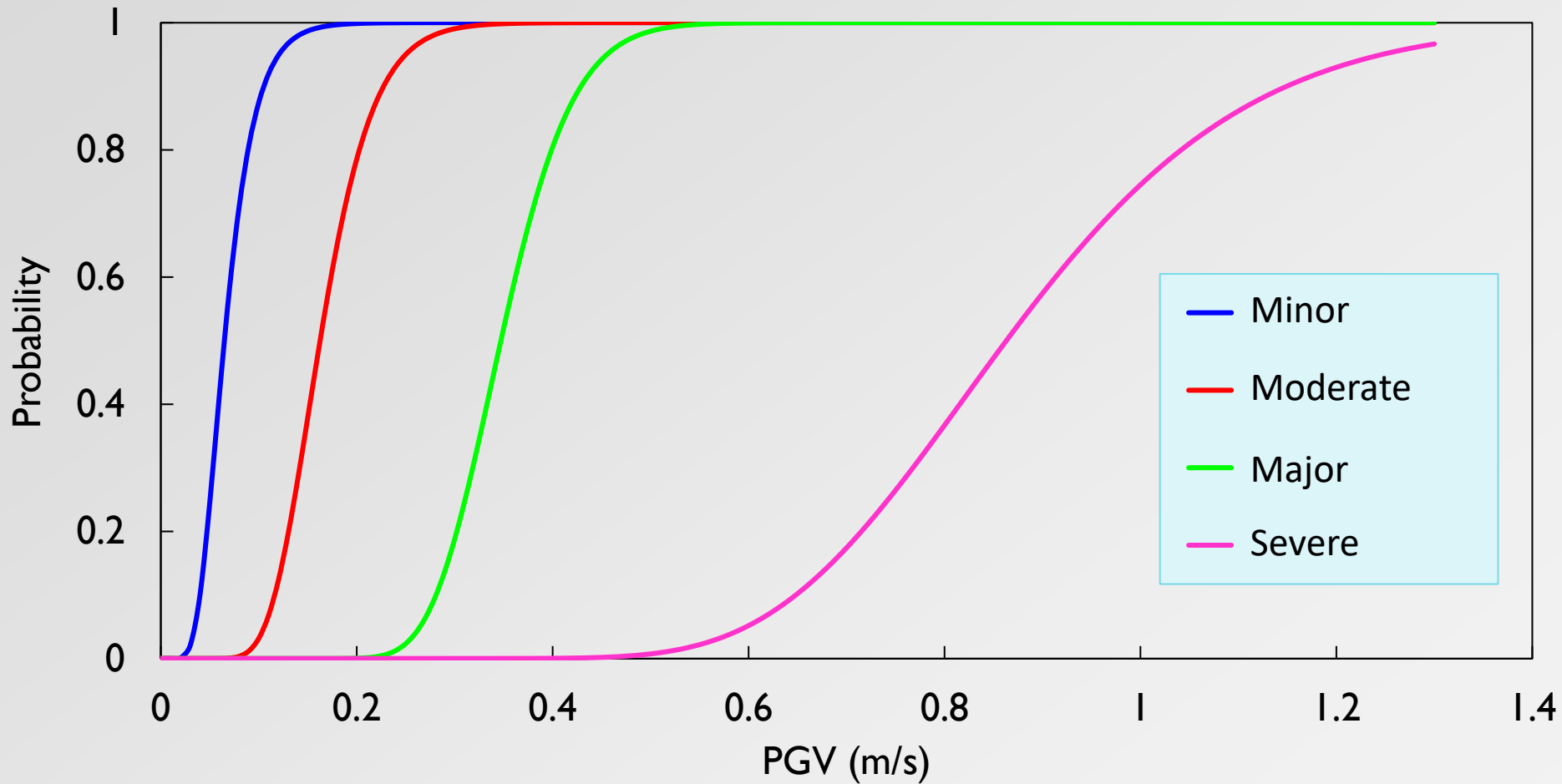


Damage States

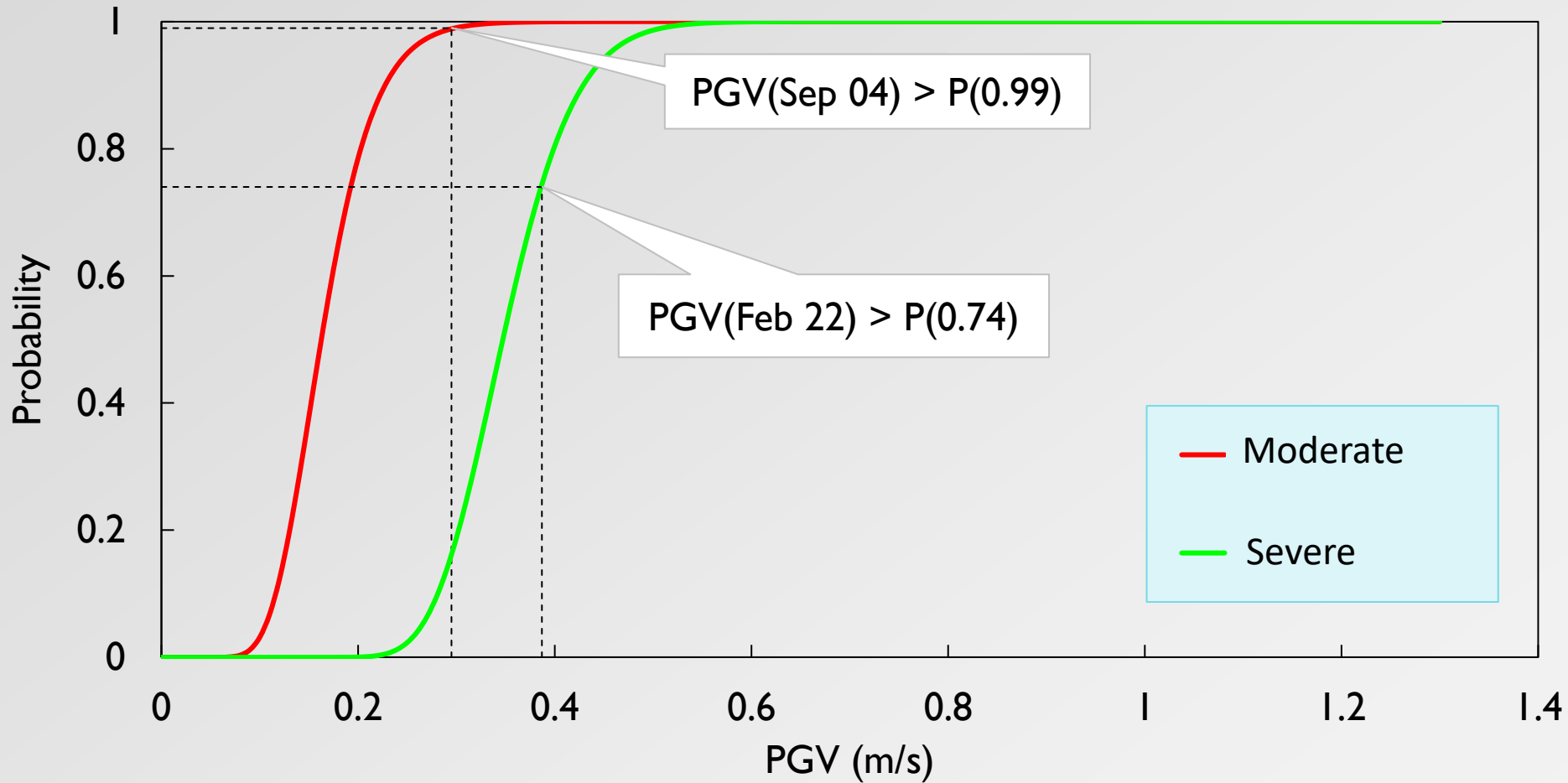
- Major
 - Structural element yielding
 - Significant slope movement
- Severe
 - Degradation of structural strength
 - Significant slope failure
 - Loss of retaining wall capacity



Fragility Curve



Sep 04 and Feb 22 Events



CONCLUSIONS

Conclusions

- CQ3 model was capable of capturing kinematic and inertial loading
- Validated against the recorded velocity time histories and residual deck displacements
- Sensitivity analysis showed friction angle and cohesion of the fill and 1st layer caused the greatest variation
- Greatest pile bending moment at interface between stiff and weak layer



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- Framework developed for generating fragility curves
- Three EDPs adopted in this study
- Four damage states defined Serviceable, Repairable, Near Collapse and Collapse
- Fragility curves validated using the results from the Sep 04 and Feb 22 events
- Fragility curves can be used for quantifying probability of damage at each intensity level



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THANK YOU

QUESTIONS?