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NZ Centre for Earthquake Resilience
Te Hiranga Rū

Recent Developments in the System Response of Liquefiable Deposits

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Introduction

System response refers to the consideration of the soil deposit as a system of layers interacting with each other in their dynamic response (e.g. liquefaction effects on the ground motion) and through pore water pressure redistribution and water flow (e.g. seepage effects) [1].

The present study examines key factors affecting the triggering of system response mechanisms and their contribution to liquefaction-induced damage.

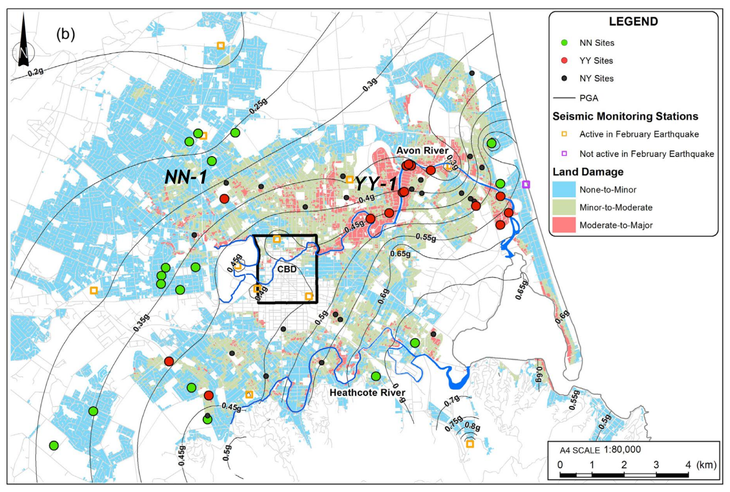


Figure 1. Land damage caused by soil liquefaction in 22 February 2011 Christchurch earthquake; severe damage occurred in the eastern suburbs along the Avon River whereas areas west and south of CBD remained largely unaffected. This spatial variability in the surface manifestation of liquefaction appears to be related to differences in the deposit characteristics between the eastern (YY-1 deposit type) and western suburbs (NN-1 deposit type). In fact, the system responses of YY-1 and NN-1 deposits are characterized by cascading mechanisms that work in opposite directions with regard to liquefaction manifestation.

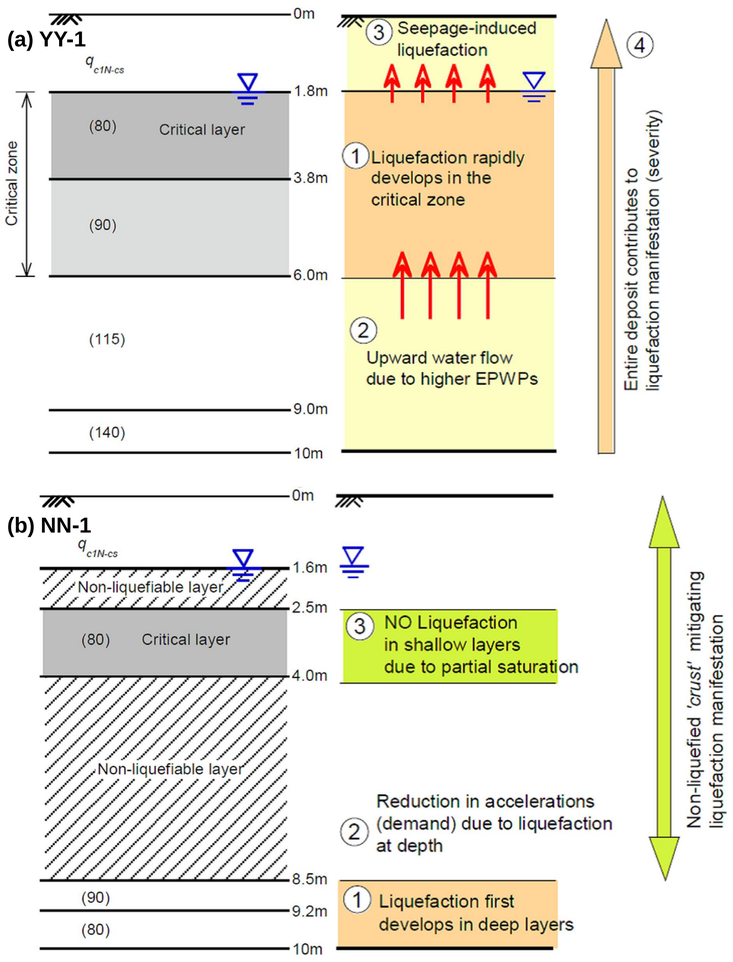
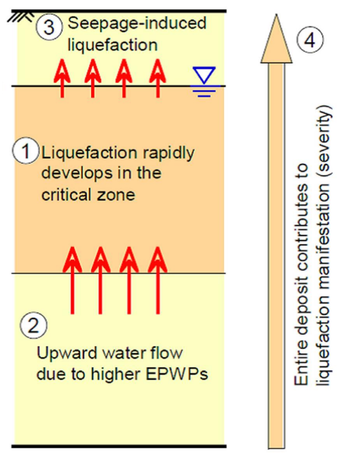


Figure 2. Schematic illustration of typical soil profiles and associated key processes in the system response: (a) YY-1 deposit (typical of soil deposits along the Avon River); (b) NN-1 deposit (encountered west and south of CBD).

Influencing factors

The activation of each of these mechanisms depends on the overall configuration of the soil profile and the intensity of shaking. We can approach the problem by answering two main questions:

1. Does the soil deposit have the potential to activate system-response mechanisms?
2. What the intensity of shaking required to actually trigger these mechanisms?

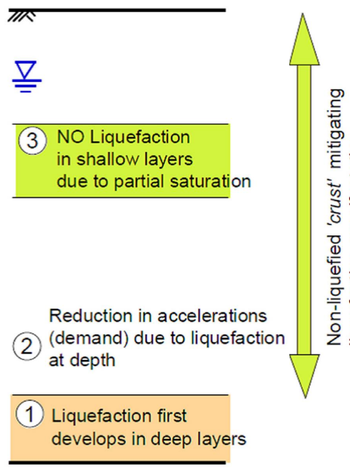


Mechanism 3 (Surface soils):
- susceptible to liquefaction
- relatively low permeability and low compressibility

Mechanism 1 (Critical layer):
- critical layer has the lowest cyclic resistance in the deposit

Mechanism 2 (Deeper soils):
- susceptible to liquefaction
- relatively high permeability
- absence of non-liquefiable soils

Figure 3. Deposit criteria for potential intensification of liquefaction manifestation.



Mechanism 3 (Critical layer):
- Partially saturated ($V_p^{CL} \lesssim 800$ m/s)

Mechanism 2 (Below CL) :
- large thickness of liquefied layer at depth
- laterally continuous non-liquefiable soils below critical layer

Mechanism 1 (Deeper soils):
- resistance equal or lower than that of the critical layer

Figure 4. Deposit criteria for potential mitigation of liquefaction manifestation.

Examples

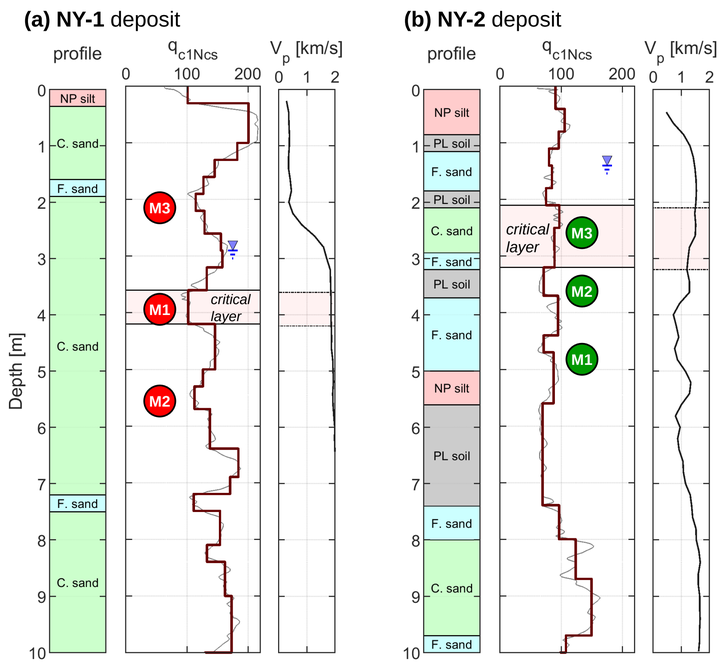


Figure 5. Potential for activation of system response mechanisms in (a) NY-1 and (b) NY-2 deposits; NY-1 falls within the YY-1 deposit type, intensifying mechanisms 1, 2 and 3 can potentially be activated; NY-2 falls within the NN-1 deposit type, mitigating mechanisms 1,2 and 3 are possible.

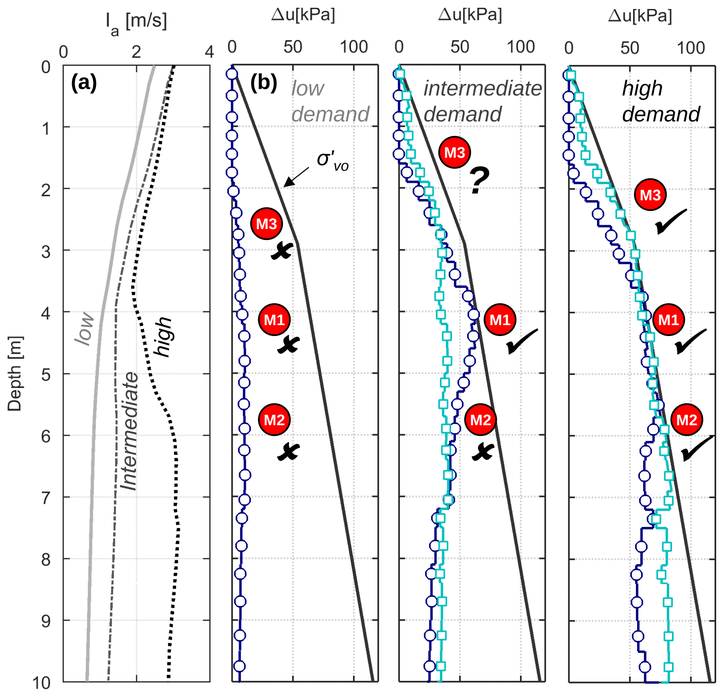


Figure 6. Results from effective stress analyses with varying intensity of the input motion illustrating key response characteristics throughout the depth of the **NY-1 deposit**: (a) Arias intensity, I_a; (b) excess pore water pressures, Δu, at the time of liquefaction triggering (blue lines) and end of shaking (cyan lines). The mechanisms activated in each analysis case are also indicated.

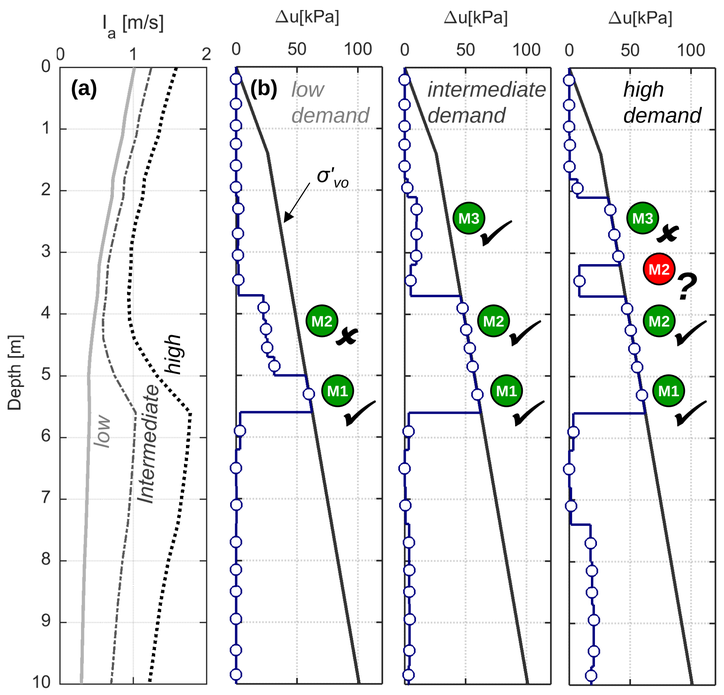


Figure 7. Results from effective stress analyses with varying intensity of the input motion illustrating key response characteristics throughout the depth of the **NY-2 deposit**: (a) Arias intensity, I_a; (b) excess pore water pressures, Δu, at the end of shaking. The mechanisms activated in each analysis case are also indicated.

Future work

System response mechanisms often play a key role in the severity of liquefaction manifestation and associated damage [1]; particularly so when certain conditions with respect to soil profile and intensity of shaking are satisfied.

Future work will focus on defining appropriate measures and associated thresholds for activation of each mechanism as well as measures to account for the combined effects of different mechanisms. The possibility of incorporating the system-response concept into the simplified methods for liquefaction assessment will also be examined.

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References

1. Cubrinovski, M., Rhodes, A., Ntritsos, N., and van Ballegooy, S. (2019). System response of liquefiable deposits. *Soil Dynamics & Earthq. Eng.,* 124, 219-229 https://doi.org/10.1016/j.soildyn.2018.05.013