Flagship 2 Coordinated Project 2019-2020

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Project Contributors

	QuakeCoRE PI/AI	QuakeCoRE Industry Affiliate	Others – Aligned Researchers, Stakeholders, Students etc
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2018-2020 TEC Contract for delivery by QuakeCoRE Flagship 2 Programme

Flagship 2:

This flagship will develop new approaches and methodologies for quantification of impacts of soil liquefaction on land and infrastructure through a fundamental understanding of onset and consequences of liquefaction; and use these methods to assess liquefaction impacts throughout New Zealand and their potential to be mitigated. These novel methods will represent a major advance in the field, and will provide means for a robust assessment and treatment of liquefaction hazards at both site-specific and regional levels. The key thrust areas are:

1. Development and improvement of liquefaction assessment methods (Liquefaction Evaluation: Beyond Current State-of-Art and Practice). Utilize the exceptional databases compiled during Canterbury and Kaikoura Earthquakes, and obtain additional high-quality data where needed, to develop new or improve existing liquefaction evaluation procedures (field, laboratory and analytical tools and methodologies) that will adequately address current and future society needs for performance of land and infrastructure during earthquakes.
2. Identify critical issues and ground conditions related to liquefaction impacts on infrastructure, including characterization of important but challenging New Zealand soils, and the development of adequate assessment procedures and cost-effective mitigation strategies.
3. Development of performance based criteria for micro systems (e.g. soil deposits; soil-foundation-building systems) and macro systems (urban areas; land use and development) and lifeline networks, integrating geotechnical engineering knowhow within cross-disciplinary tools and methodologies.

Thrust Areas	Key tasks/Deliverables	Start	Finish
FP2.1 Liquefaction Evaluation: Beyond Current State-of-Art-and-Practice	1. Develop methodologies for assessment of liquefaction susceptibility and triggering; liquefaction-induced ground deformation	1/01/2016	31/12/2020
	2. Integrate field, laboratory and computational tools to develop next-generation liquefaction evaluation methods and procedures	1/01/2016	31/12/2020
FP2.2 Liquefaction Vulnerability of New Zealand Land and Infrastructure	1. Examine, through field and laboratory investigation, typical New Zealand soils that are challenging for liquefaction assessment (silty soils, pumiceous soils and gravelly soils; soil composition, soil micro-structure, ground conditions, overall deposit characteristics)	1/01/2016	31/12/2019
	2. Compile, summarise and interpret historical evidence of liquefaction in New Zealand (paleo-liquefaction studies)	1/01/2016	31/12/2018
	3. Develop liquefaction assessment procedures for challenging soils	1/01/2018	31/12/2020
	4. Enhance observations from Canterbury and Kaikoura Earthquakes with experimental and analytical studies to improve performance assessment of characteristic infrastructure	1/01/2016	31/12/2020
FP2.3 Liquefaction Assessment and Mitigation: Systems Approach	1. Develop assessment methodologies for micro and macro systems: Soil-foundation-building system (shallow and pile foundations); building-soil-building systems; bridge system	1/01/2017	31/12/2020
	2. Evaluate liquefaction impacts on spatially distributed systems and networks (transportation networks; pipe networks)	1/01/2019	31/12/2020
	3. Develop a framework for performance based criteria incorporating planning, management, operational, owner and user's perspectives in engineering evaluations of liquefaction impacts	1/01/2019	31/12/2020

FP2 Coordinated Project Plan – 2019-20

Research Activities:

Activity 1: Advancement of Liquefaction Assessment Methodologies

Liquefaction assessment of land and infrastructure is commonly performed either using so-called simplified procedures (state-of-the-practice) or advanced dynamic numerical analyses (state-of-the-art). The latter approach is far superior in terms of its capacity to capture the complex liquefaction process and its effects on structures; however, it is seldom used because of the higher demands on the user and lack of user-friendly environment and support in its application to practice. This project aims to make available such computational tool(s)/framework for the NZ researchers and practicing engineers.

There are five on-going major research areas addressing key issues related to the liquefaction assessment methodologies and seismic performance of NZ specific soils:

1. *"System response of liquefiable deposits"*
   This a continuation of the "55 Christchurch sites". This project aims to make best use of field and laboratory data of well-documented case history sites and soils in order to improve current liquefaction assessment methods and explain their inconsistent predictions of liquefaction performance in Christchurch.

   - The specific objectives are:

- To identify system-response mechanisms in liquefiable deposits that, depending on the deposit characteristics, either intensify or mitigate liquefaction manifestation (and associated damage) at the ground surface;
- Quantify system-response mechanisms for characteristic types of liquefiable deposits;
- Improve liquefaction evaluation procedures through incorporation of system-response effects.

2. *"Liquefaction behaviour of Christchurch sands and silty soils in simple shear"*
   This an extension of the "Silty Soils" project, which focuses on the characterization of stress-strain behaviour and liquefaction resistance of characteristic fluvial sands and silty soils typical for Christchurch. It is a laboratory-based study on reconstituted and undisturbed samples exploring the effects of grain-size composition, fines content, fabric and micro-layering on the liquefaction resistance. This project focuses on direct simple shear (DSS) testing which reproduces most closely the mode of soil deformation induced by earthquakes in level ground free field deposits. Additional triaxial testing will be performed to allow 'translation' of data obtained from advanced DSS testing to conventional triaxial test data, and implementation to practice.
   - The specific objectives are:
     - To identify stress-strain characteristics of silty soils which differentiate their liquefaction resistance in relation to clean sands;
     - Quantify the effects of micro-laminated sand-silt structure on liquefaction resistance of sand-silt mixtures;
     - Evaluate the performance of wave velocities for estimating the in-sitiu void ratio of Christchurch soils.

3. *"Liquefaction characterization of gravelly fills"*
   This a continuation of the "Kaikoura Earthquake response - Centreport reclamations" project. It focuses on the liquefaction response of gravelly fills based on well-documented damage observations after the 2016 Kaikoura earthquake, and subsequent comprehensive field investigations including over 100 CPTs and V_s profiling of the reclamations at the Wellington port.
   - The specific objectives are:
     - To scrutinize the accuracy of conventional liquefaction evaluation procedures in predicting liquefaction triggering and associated damage for gravel-sand-silt mixtures;
     - Simulate the observed liquefaction of Centreport reclamations and develop case-history basis for constitutive model calibration of Wellington waterfront reclamations.

4. "NZ *Tools* and Procedures for Seismic Effective Stress Analysis"
   Liquefaction assessment of land and infrastructure is commonly performed either using so-called simplified procedures (state-of-the-practice) or advanced dynamic numerical analyses (state-of-the-art). The latter approach is far superior in terms of its capacity to capture the complex liquefaction process and its effects on structures; however, it is seldom used because of the higher demands on the user and lack of user-friendly environment and support in its application to practice. This project aims to make available such computational tool(s)/framework for the NZ researchers and practicing engineers.
   - Key Objective:
     To create computational and visualisation tools in which seismic effective stress analysis for the assessment of full system response is as simple for the user to run and evaluate as comparable simplified analytical tools (e.g. equivalent linear site response analysis, liquefaction potential/consequence evaluation). The end result will incorporate state-of-the-art soil constitutive models capable of 1D/2D/3D analysis, and consideration for the interface elements, boundary conditions, loading conditions, and other numerical features necessary for analysis of the seismic response of earth structures and soil-structure interaction problems with nonlinear super- and sub-structure elements.

5. *"Performance-based criteria for liquefaction evaluation: CentrePort Case Study"*
   This will use the results of "*Liquefaction characterization of gravelly fills"* activity and FP2 component of the Wellington case study project to estimate impacts of liquefaction on various engineering structures at CentrePort, and will develop a framework for performance-based evaluation of liquefaction for port land and structures.
   - The specific objectives are:

- To develop a framework for a systematic engineering evaluation of liquefaction hazards within the context of performance-based assessment that satisfies different perspectives of owners, stakeholders, users, engineers and community at large.

Activity 2: Dynamic Characterisation of Natural Pumiceous Deposits

This project will build on the outputs of previous works done to characterise systematically the dynamic and liquefaction characteristics of natural pumice deposits found in the central part of North Island.

Key Objectives:

- Further characterise various pumiceous sites in the region by performing field tests at designated sites through cone penetration tests, Vs-profiling and high-quality undisturbed soil sampling.
- Investigate the dynamic properties (Gmax and strain-dependent properties) and liquefaction characteristics of the undisturbed soil samples obtained, as well as those of reconstituted specimens, as functions of various parameters (confining pressure, initial state, etc.);
- Formulate methodology to quantify in-situ pumice contents, and determine how the pumice contents affect the laboratory-obtained properties;
- Through comparison between laboratory testing and field-based empirical determination, identify appropriate approach(es) for evaluating liquefaction triggering in pumiceous deposits.

Activity 3 : Historical Evidence of Liquefaction in NZ

There are records that liquefaction was triggered in at least 13 earthquakes in NZ between 1848 and 2016. The observation records available from these earthquakes along with the extensive geotechnical investigation data available in the New Zealand Geotechnical Database (NZGD) and from archives from engineering consultants and councils allow the ground conditions where liquefaction did and did not manifest to be examined and characterised. This will be then used to scrutinize the simplified procedures for liquefaction triggering and evaluation of liquefaction vulnerability parameters. The aim of this work is to improve the suite of liquefaction prediction tools available to practitioners, so that the liquefaction hazard can be better managed.

Key Objective:

- Determine areas where liquefaction has previously occurred and also areas where liquefaction has not occurred in New Zealand from observational records, published accounts, and reports.
- Identify areas (soils) of interest that were subjected to high seismic demand, but did not liquefy.
- Identify the areas where the simplified SPT and CPT-based liquefaction analyses are either consistent with, or inconsistent with observations. Determine common subsurface sediment characteristics, geomorphic settings, and paleo-depositional settings where the liquefaction analyses performed well and where they over-predicted or under-predicted the liquefaction relative to the observations.

For further details please contact the Flagship Leader