QuakeCoRE and OpenSees (Year 2): Initiatives and Activities to Reduce Barriers to Entry and Reduce Time to Solution

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1. Background and Objectives

The OpenSees finite element platform (**Open S**ystem for **E**arthquake **E**ngineering **S**imulation) developed through the University of California Berkeley is the principal collaborative software identified by **QuakeCoRE Technology Platform 4** for use in detailed seismic response modelling of individual infrastructure components. OpenSees was selected for this purpose due to its capabilities as an open-source platform for sequential and parallel analysis of both geotechnical and structural systems. OpenSees is one of the few tools available with all of these attributes, and due to this unique combination of features it meets all three of the underlying principles identified for QuakeCoRE Technology Platform 4: it is **open-source**, it is **scalable** (able to make use of HPC resources), and it is **flexible** (works for variety of problem types and able to work with other QuakeCoRE software modules).

The primary objectives of OpenSees development under Technology Platform 4 coincide with the overall objectives of the tech platform. These two objectives are somewhat intertwined, but specific OpenSees-related tasks/objectives are noted for each.

- **Reducing entry barriers:** As OpenSees has been adopted as the primary seismic response analysis tool for QuakeCoRE, it is important to take steps that can accelerate the process of learning and working with this tool for new researchers.
  - ○ **Training for new users** of OpenSees to provide a headstart and build overall knowledge base of community
  - ○ Encourage and provide arena for **community involvement** among researchers performing OpenSees analysis

- **Reducing time to solution:** It is also important to provide an optimised workflow infrastructure that reduces the time/effort spent in pre-processing, analysis, and post-processing so researchers can move from idea to results in an efficient manner.
  - ○ **Establish standardized pre- and post-processing workflows** for problem types identified by the OpenSees user community, including model generation scripts, interfaces with GUI tools, and standardized post-processing.
  - ○ **Optimise implementation** of OpenSees on NeSI high-performance computing (HPC) resources and establish links with international HPC resources such as the NEHRI DesignSafe-CI.
  - ○ Examine the parallelization of the OpenSees source code to **improve HPC scalability** and enable more efficient analysis for very large computational models.

2. OpenSees Development in QuakeCoRE Year 2

To facilitate the use of the OpenSees finite element platform by QuakeCoRE researchers, and to meet the primary strategic objectives (reduce barrier to entry and time to solution), several key activities and initiatives have been undertaken during QuakeCoRE year 2. Some are new initiatives and some are carried over from year 1.

- **User Development:** Provide a starting point for new users and enhance the capabilities of comfortable and advanced users. Encourage community engagement and provide forum for community development.
  - ○ **OpenSees Training Workshops:** Training workshops for new to advanced users of OpenSees for both structural and geotechnical analysis. Held in Christchurch on 16-17 March, and Auckland on 27-28 March. Content ranged from beginning topics such as an anatomy of an OpenSees model file to advanced topics such as parallel computing with OpenSees.
  - ○ **Monthly OpenSees Community Webconferences:** To provide a place where researchers can share their work with the QuakeCoRE research community, to hold presentations about OpenSees topics of interest from researchers in NZ and worldwide, and to generally facilitate collaboration and sharing within the community.

- **Computational Development:** Efforts to implement and optimise OpenSees on National e-Science Infrastructure (NeSI) HPC resources, to optimise workflows for running parallel OpenSees simulations on NeSI resources, and to develop a suite of pre- and post-processing tools to streamline OpenSees use for QuakeCoRE (and all) researchers.
  - ○ Established **development group** for ongoing development of OpenSees capability within QuakeCoRE and have identified and established key international collaborations with OpenSees users/developers in the US and Europe.
  - ○ Procurement of Allinea MAP code profiling tool for **assessment of performance of OpenSees source code**
  - ○ **Pre- and post-processing development** for OpenSees:
    - • Development and dissemination of general pre-processing tools in form of tcl/python scripts and GUI interface tools.
    - • GUI interface tools for post-processing and visualisation of results.

3. Optimised OpenSees Analysis Workflow: Pre-processing ⇒ Analysis ⇒ Post-Processing and Visualisation

Pre-Processing Tasks for Model Generation

Code blocks for common modelling tasks

Python and tcl model creation scripts

Script converts GUI input to tcl model file

Model development using GUI tools

Ghofrani et al. (2016)

Model Assessment and Analysis

Parallel analysis tools and algorithms

Consider/examine complex meshes

Ghofrani et al. (2016)

Post-Processing and Visualisation

Standard plots for identified problem types

McGann (2013)

Standard plotting scripts

Scripts to format output for use in GUI visualisation tools

Visualisation using GUI tools

Horizontal Displacement (cm)

0.0   25.0   50.0   75.0   100.0

northeast abutment

90 cm
60 cm
30 cm
0.0

Ghofrani et al. (2016)

McGann (2013)