Research Project Highlight

Calibration and verification of OpenSees models for simulating the response through collapse of nonplanar RC walls

TSRP Topic T2 – Tools for non-linear elements and materials

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Abstract
Planar and nonplanar reinforced concrete walls are used commonly to resist lateral loads in buildings and transportation structures located in regions of high seismicity. However, the models used typically in research and practice to simulate the earthquake response of these components provide relatively crude representation of the interaction of flexure and shear actions and three-dimensional response modes. This research will employ an extensive experimental data set[1] to calibrate and validate the concrete continuum models and layered shell elements available in the OpenSees platform. In addition to OpenSees, the calibration and validation effort will employ Jupyter notebooks, the quoFEM software tool developed by the NHERI SimCenter, and computing and software resources available through NHERI DesignSafe. The validated models will enable researchers to better understand the behavior of structures comprising three-dimensional wall systems as well as provide opportunities for professional engineers to practically and economically simulate the nonlinear response of wall systems to support seismic design of new and evaluation of existing concrete structures.

Deliverables
A PEER report, a conference presentation, and a journal paper describing the research activities and results. Additionally, all Jupyter notebooks and OpenSees scripts will be published via GitHub and/or the DesignSafe DataDepot, as appropriate.

Research Impact
The proposed research will provide researchers and practitioners with a calibrated and validated modeling approach for planar and nonplanar concrete walls that enables accurate and computationally

[1] Shegay et al. (2021) "PRJ-2430 | UoA-UW Reinforced Concrete Wall Database" 10.17603/ds2-r12q-t415

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efficient simulation of load-deformation response as well as stress, strain, and damage fields using the OpenSees software platform. Currently, a number of approaches exist for use in simulating the nonlinear response of reinforced concrete walls; however, most have significant limitations: i) fiber-type beam-column elements ignore flexure-shear interaction and multiple-vertical-line-element models (MVLEMs) employ simplifying assumptions with respect to this interaction, ii) beam-column elements and MVLEMs require significant assumptions for modeling non-planar walls, iii) solid-element models are typically too computationally intensive for most design and evaluation projects, iv) proprietary software has significant constraints with respect to output variables, load patterns, and solution algorithms, v) few models have been calibrated to provide accurate and mesh-independent simulation of strength loss, and vi) few software include parallelized solution algorithms to support simulations with many degrees-of-freedom. These limitations are not present in the proposed OpenSees modeling approach, which employs layered shell elements (*ShellMITC4*[2] and *ShellNLDKGQ*[3]), the *PlaneStressUserMaterial*[4] for concrete, and parallelized solution algorithms as needed. Jupyter notebooks and OpenSees scripts will published to enable users to rapidly introduce the modeling approach into their workflows.

Model calibration and sensitivity analysis will be accomplished using the quoFEM software developed by the NHERI SimCenter, which utilizes HPC resources as well as the Dakota[5] software provide by NHERI DesignSafe. Project results will include recommendations for using quoFEM for this type of practical model calibration as well as Jupyter notebooks and analysis scripts to facilitate similar model calibration activities by researchers and practitioners.

[2] https://opensees.berkeley.edu/wiki/index.php/Shell_Element
[3] https://opensees.berkeley.edu/wiki/index.php/ShellNLDKGQ
[4] http://www.luxinzheng.net/download/OpenSEES/En_THUShell_OpenSEES.htm
[5] https://dakota.sandia.gov/

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Project Image

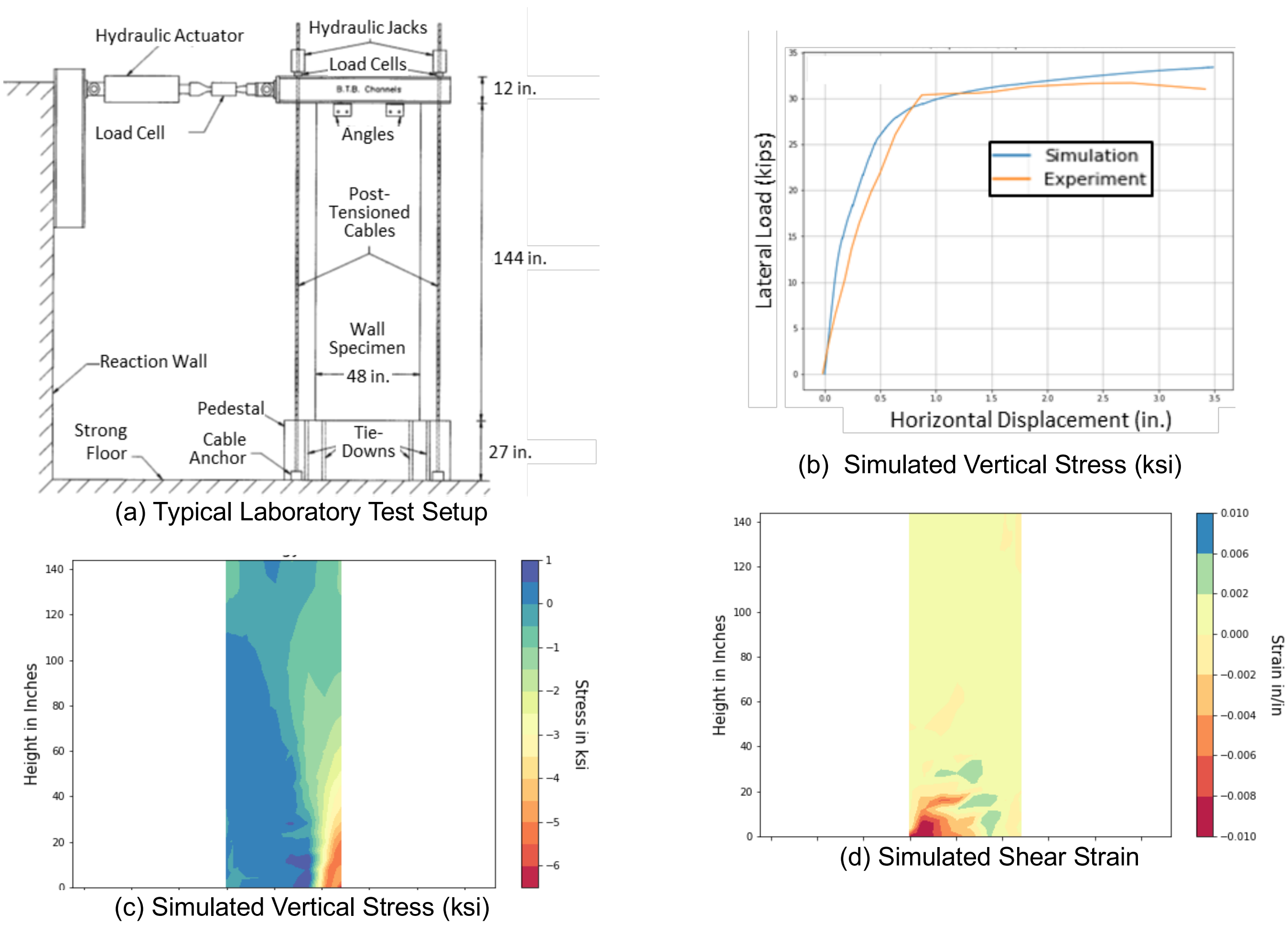

Figure 1: Preliminary results of a calibration study for a typical planar wall; note that in (b) experimental data represent the envelope to the measured-load displacement history and simulation results are from a monotonic displacement history.