



Development of the UPRM Hybrid Simulation Facilities: Test Setup Design for Initial Calibration

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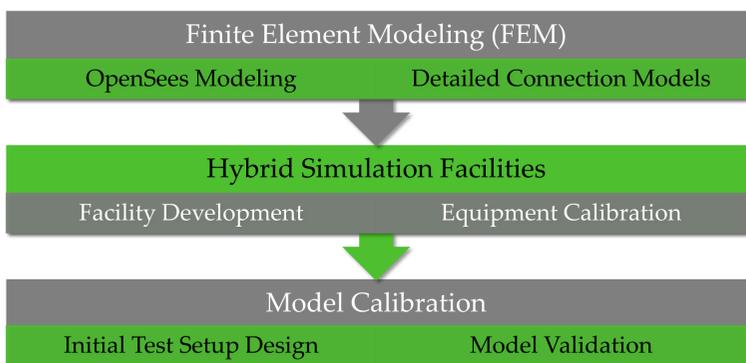


Abstract

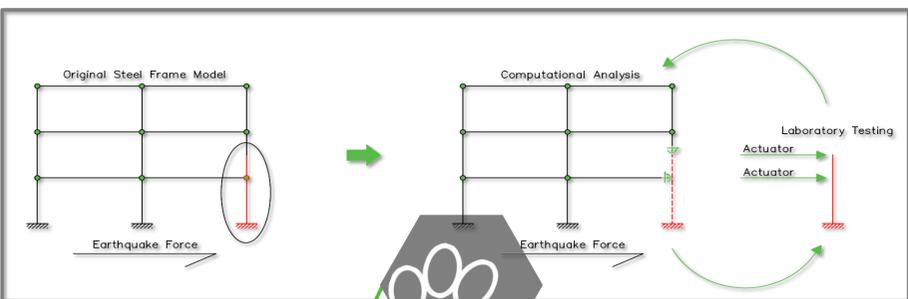
Conventional testing methods such as earthquake simulators (shaking tables) come with very strict size limitations that depend on the capacity of the facilities and the budget of the researcher. It's common practice to significantly scale down structures for testing due to these restrictions. This results in problems pertaining to the local response of the scaled-down structure, where there are significant differences with the response of the full-scale system. Currently, the Structural Engineering Laboratory facilities of the University of Puerto Rico at Mayagüez (UPRM) have a small, uniaxial shaking table powered by a single hydraulic actuator. Alternative methods must be employed to be able to perform larger scale tests. Hybrid simulation provides an effective alternative to conventional seismic simulation methods. Employing hybrid simulation cuts down on the cost and time needed to conduct simulations and opens up more ways of evaluating structure response and collapse due to seismic activity. A primary test setup is developed to allow for the calibration of the Hybrid Simulation equipment with aims of establishing the first facilities in Puerto Rico capable of performing these tests. A one and a half-story external column from a prototype is constructed in-lab while the rest of the prototype is run in a computer model, creating a close-loop control. The setup is subjected to the Canoga Park earthquake (1.0 magnitude) and the results are compared to an analytical coupled simulation of the complete structure.

Objectives

- Establish the first structural laboratory in Puerto Rico capable of performing state of the art Hybrid Simulation Tests.
- Build upon the Structural Engineering Laboratory to enable Hybrid Simulation Testing of various structural configurations.
- Design and conduct an initial large scale test of a steel frame in order to calibrate the hybrid simulation setup.
- Employ the use of hybrid simulation to research the behavior of structures undergoing collapse.



Hybrid Simulation and Test Setup Visualization

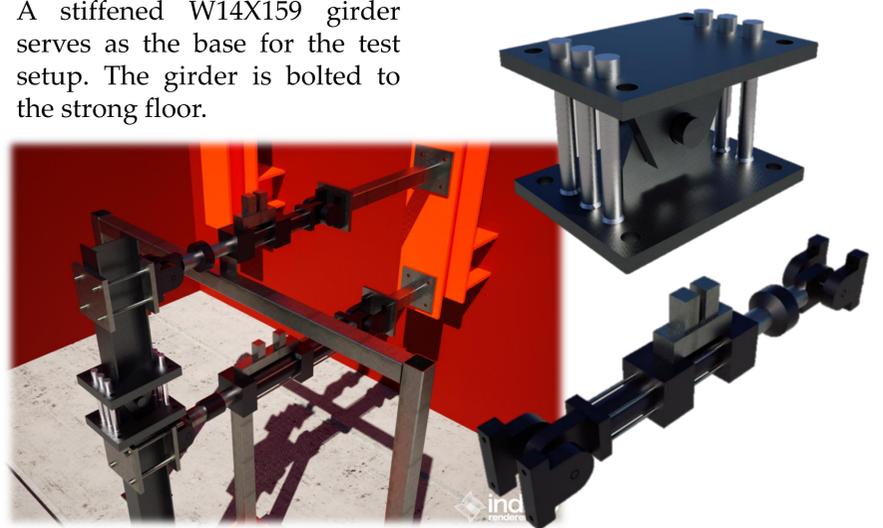


(Top) Diagram portraying the concept used in Hybrid Simulation. A section from the whole structure is chosen to be constructed in-lab and is subjected to seismic loads. The structure response is continuously fed back to the computer model running the analysis of the complete structure, which then calculates the loads to be applied to the in-lab section, creating a close-loop control.

(Bottom left and right) 3D renders depicting the proposed Test Setup corresponding to one and a half floors of a single column.

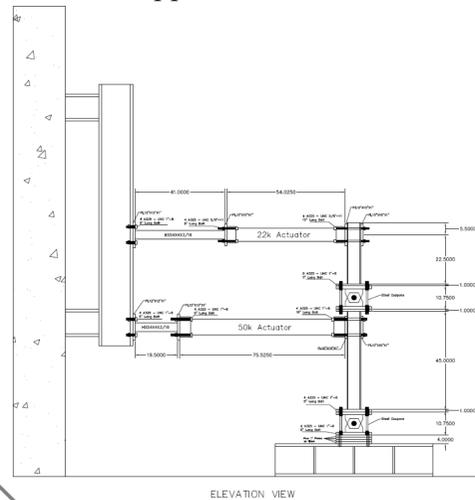
Test Setup Design Methodology

- One column from a steel building frame is built and tested in the lab.
- Scaling factor for test setup: 4.
- Test setup height is 8.125 ft., corresponding to 1.5 floors plus some room to place the actuators.
- Column specimen: W6X20.
- Two actuators are used to impose the earthquake loads. A 55kip actuator is placed at a height of 4.13 ft.; a 22kip actuator is placed at a height of 7.67 ft.
- A stiffened W14X159 girder serves as the base for the test setup. The girder is bolted to the strong floor.
- Steel clevises are used at the joints to simulate the formation of a plastic hinge in the column.
- The clevises hold bolted-on steel coupons which provide the moment reactions. This helps prevent damage done to the column and provides a way of performing multiple tests by only having to replace the steel deformed coupons.
- The clevises employ a modular design which allows multiple configurations of steel coupons to meet the needs of each test.



Test Setup Overview

Elevation View of the proposed Test Setup. Actuator bracings are not shown for clarity. The hydraulic actuators come in direct contact with the column, allowing it to pivot as needed when the column deforms due to the applied loads. Force and displacement at the actuators are measured by its Load Cell and Linear Variable Differential Transformer (LVDT) respectively. Both of these are to be calibrated to ensure good accuracy in the retrieved data.



Uniaxial strain sensors are placed on the clevises' steel coupons to measure their deformation. This data is used to determine the magnitude of the moment being applied at each joint.

Ongoing Research

An initial large scale test with the proposed test setup will be conducted and its results used to validate the accuracy of the Hybrid Simulation facilities. A subsequent test on a steel frame will be performed to further expand the range of structural systems that can be tested in-lab. The feasibility of utilizing other FEM tools such as Abaqus to perform hybrid simulation will be evaluated.

Future research shifts its focus to concrete structures to evaluate the feasibility of employing Hybrid Simulation for the analysis of nuclear facilities. Calibration tests will be performed for concrete systems and afterwards complex analyses of nuclear plant response and collapse will be pursued.

Acknowledgements

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