

Full Computer Simulation of a Hybrid Test

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CE291F Final Project
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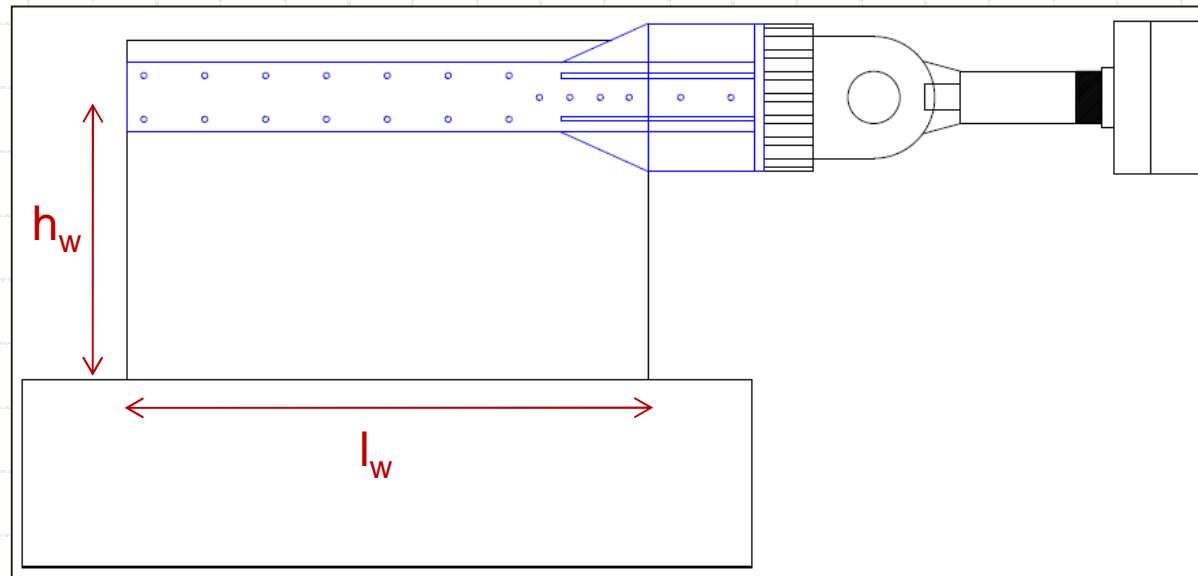
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PhD Project Goals

- ◆ Dynamic testing of shear walls in nuclear reactors
- ◆ Limited knowledge about behavior of such walls since they are very difficult to test



Experimental Testing Methods

◆ Shake table testing

- Usually very small scale
- Large amount of additional mass required to satisfy similitude

◆ Hybrid Simulation

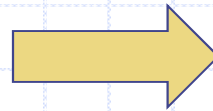
- Divides structure into numerical and physical substructures
- Physical specimen can be full scale
- Mass contained in numerical model

Structural Modeling

Distributed Parameter System:

Continuous system represented by PDEs

Structure has infinite number of degrees of freedom



Lumped Parameter System:

Discrete system represented by ODEs

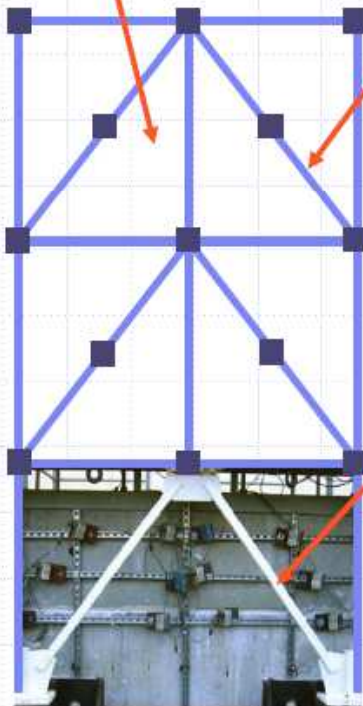
Structure has finite number of degrees of freedom

Hybrid Model

$$\mathbf{M} \cdot \ddot{\mathbf{u}} + \mathbf{C} \cdot \dot{\mathbf{u}} + \mathbf{P}_r(\mathbf{u}) = \mathbf{P}(t)$$

Quasi-Static Loading
Dynamic Loading

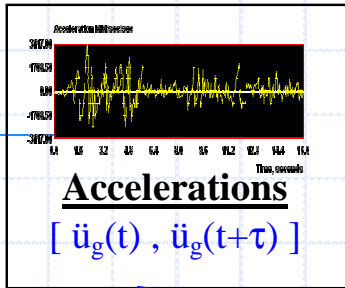
- Seismic
- Wind
- Blast/Impact
- Wave
- Traffic



◆ Discretize the structure:
 $M\ddot{u}(t) + C\dot{u}(t) + r(t) = P(t)$

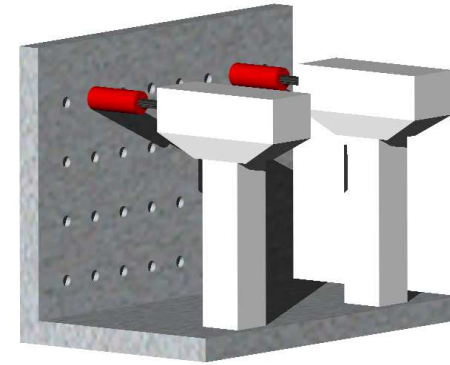
◆ Discretize time:

$$M\ddot{u}_i + C\dot{u}_i + r_i = P_i$$



1) Input asynchronous ground accelerations & calculate displacements

2) Impose displacements from FE model



Physical Test Specimen

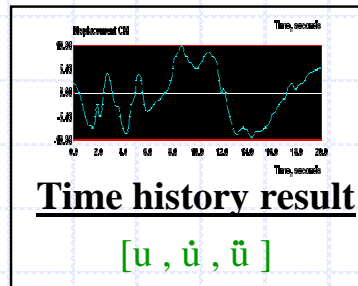
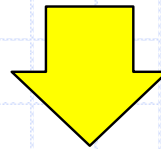
• Load cells $\rightarrow F([u])$

3) Measure restoring force and recalculate displacements



Computer FE model

$$[M] \ddot{u} + [C] \dot{u} + F([u]) = [M] \ddot{u}_g$$



Goals for CE291F Project

- ◆ Create a full computer simulation of the entire hybrid test to investigate control methods
 - MTS Simulink model
 - OpenFresco
 - Specimen model: OpenSees/LS-Dyna

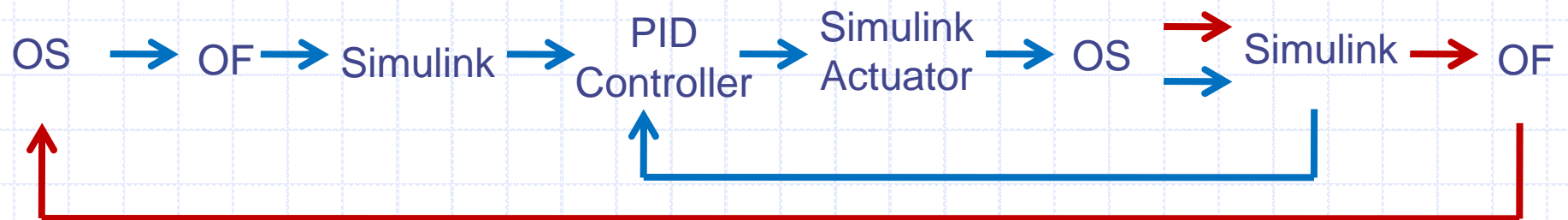
Program Interactions

OS=OpenSees

OF=OpenFresco

→ displacement

→ force

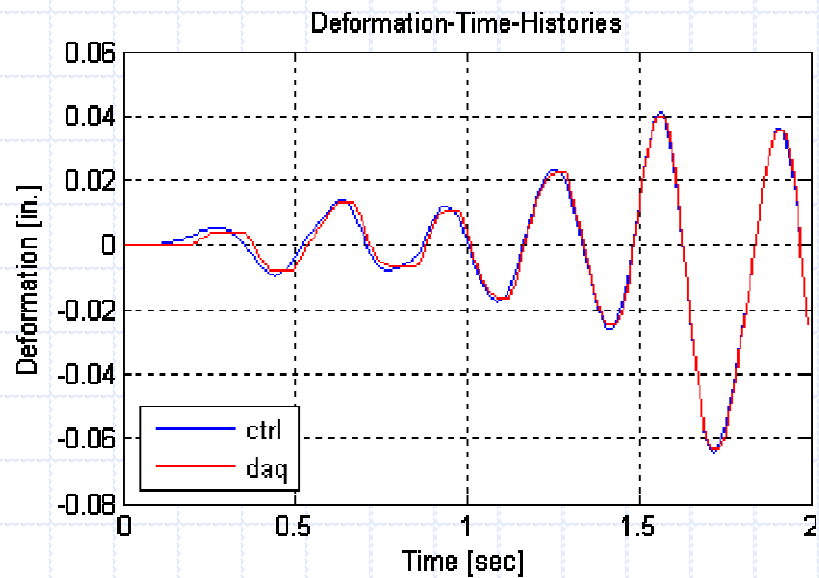


Stiff SDOF Cantilever Model

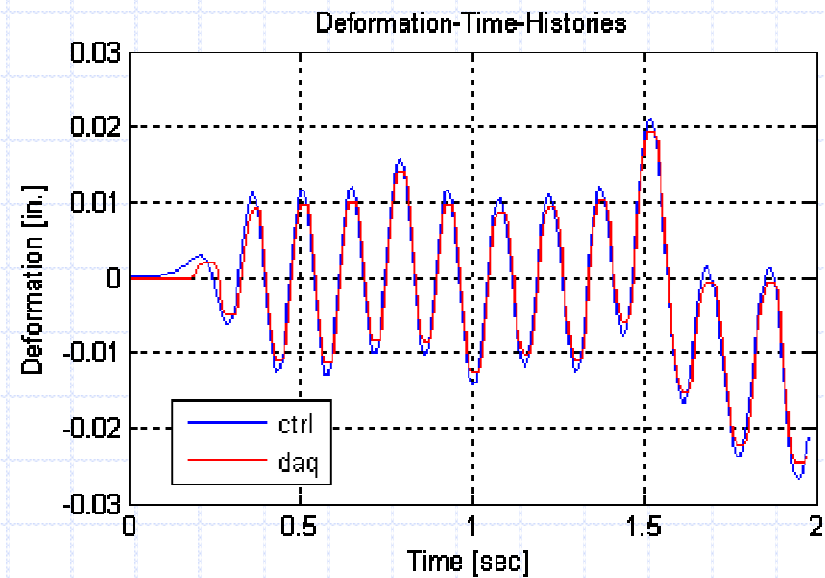
- ◆ S4x7.7
- ◆ 54" tall
- ◆ Mass=0.08 k-s²/in
- ◆ K=2.8 k/in
- ◆ Tabas Earthquake
- ◆ Increased stiffness to determine when controller would become unstable



SDOF Observations



10*K
Tracking Error=0.2936 in



70*K
Tracking Error=0.3019 in

SDOF Observations

- ◆ Tracking error remained fairly constant for increasing K
- ◆ Repeated simulation caused same scale of tracking error variation
- ◆ With $80 \times K$, finite element model to fail to converge
 - With an experimental element, this is a problem since it cannot revert back to the last stiffness value

Continuing Efforts on this Project

- ◆ Finalize results for SDOF stiff cantilever
- ◆ Complete OpenFresco – LS-Dyna communication
- ◆ Finish finite element model of shear wall in LS-Dyna and link to OpenFresco
- ◆ Investigate stability of controller with wall specimen
- ◆ Convert Simulink model to force control and similarly investigate stability

References

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Thank you!!



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