Full Computer Simulation of a Hybrid Test

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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

Diagram showing a shear wall with dimensions labeled as $h_w$ and $l_w$. The text explains the need for dynamic testing due to limited knowledge about the behavior of these walls.
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

\[
M \ddot{u} + C \dot{u} + P_r(u) = P(t)
\]

Discretize the structure:
\[
M \ddot{u}_i + C \dot{u}_i + r_i = P_i
\]

Discretize time:

Quasi-Static Loading
- Seismic
- Wind
- Blast/Impact
- Wave
- Traffic
1) Input asynchronous ground accelerations & calculate displacements

2) Impose displacements from FE model

3) Measure restoring force and recalculate displacements

Computer FE model

\[
[M] \ddot{u} + [C] \dot{u} + [K] u = \mathbf{F}(u) \]

Physical Test Specimen

- Load cells

Time history result

\([u, \dot{u}, \ddot{u}]\)
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

OS → OF → Simulink → PID Controller → Simulink Actuator → OS
Simulink → OF
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 80xK, 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


Theon, B. UCB PC Simulation Simulink Model, MTS Systems.
Thank you!!