Breakout Sessions #2
Energy Facilities

John Cobb, ORNL
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Swaminathan Krishnan, Caltech (**Recorder**)
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5: Japan; 3: USA

Issues to Discuss

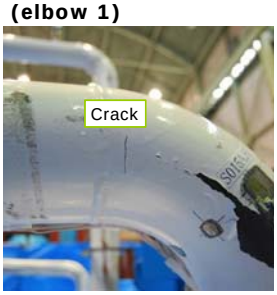
1) Comments and suggestions to Japanese projects from US

- Japanese researchers presented results from tests of piping systems with effects of aging.
- Pre-test numerical simulations were able to predict the failure modes in pipes that were sound.
- Post-test numerical simulations were able to replicate the failure modes in aged pipes.
- The failure modes are quite different.
- Next set of tests are planned for 2012 on a piping system that is connected to a water tank.
- The effect of support flexibility will be studied. Two models, one with rigid supports, and another with flexible supports will be tested.

Failure modes

Sound system (elbow 3)

Degraded system (elbow 1)



ASME PVP2010-25839

Mode analysis of piping system

Mode1
Sound: 4.63 Hz
Thinned: 3.49 Hz

Elbow 3 subjected to in-plane bending

Mode2

Elbow 1 subjected to in-plane and out-of-plane bending

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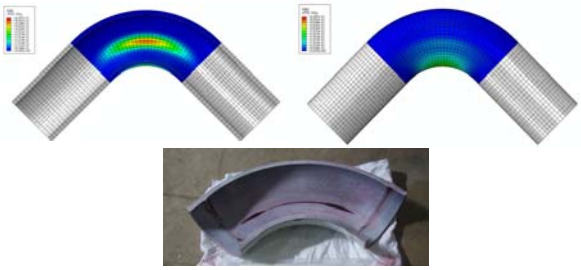
FEA result (sound elbow 3, 7.5 times)

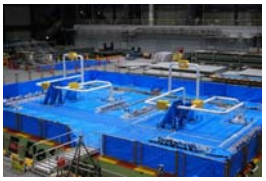
Accumulated equivalent plastic strains after the shake table test

Inner side **Outer side**



Outline of the test models

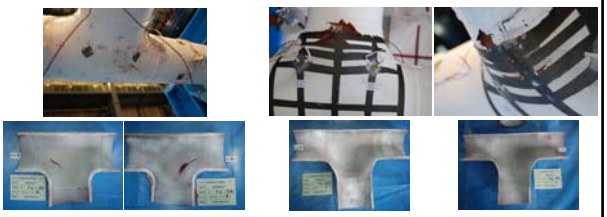
- Model configuration
  - 3-D piping system models with nine elbows and two tees
- Name and condition of test models
  - AP3_EA01:Model without wall thinning
  - AP3_EC01: Model with full circumferential wall thinning at four elbows and one tee



Setup of the excitation test
Left: AP3_EA01 / Right: AP3_EC01

Test results – failure mode

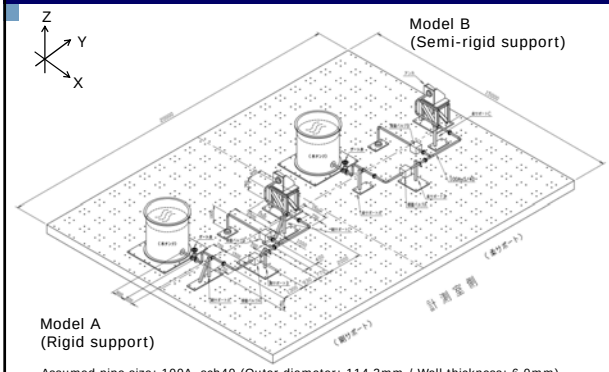
- The failure mode of both test models was the failure at Tee2.
  - The failure aspects were different;
    - AP3_EA01: Fatigue cracks occurred at the body of the pipe joint
    - AP3_EC01: Remarkable ratchet deformation and nearly burst



AP3_EA01
Diameter increase: ~9%

AP3_EC01
Diameter increase: ~21%

Draft design of 2012 experiment



Assumed pipe size: 100A, sch40 (Outer diameter: 114.3mm / Wall thickness: 6.0mm)

9th NEES/E-Defense planning meeting, Aug. 26-27, 2011

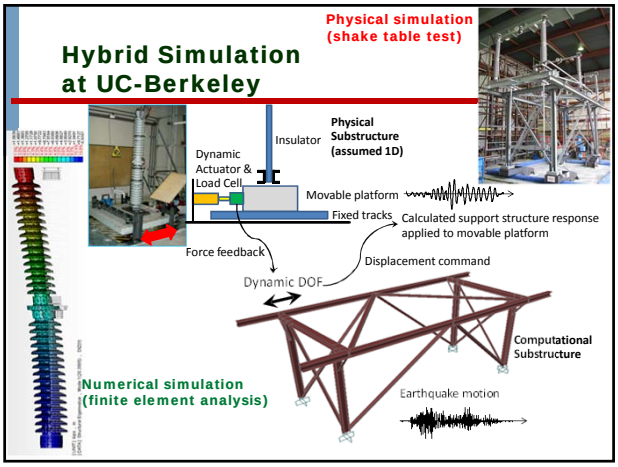
Issues to Discuss

2) Research plans in US and comments from Japan

- Research on electric substations was presented by the US researchers.
- Many complex failure modes exist in these systems, tipping-over, bushing fracture, circuit breaker collapse, transmission tower collapse, … etc.
- Such structures are highly suitable for hybrid simulations where support structures are the computational substructures and, e.g., the post insulators are the physical substructures to be tested.
- Hybrid simulations physical substructure models are typically idealized as simple stick-mass models, whereas high-fidelity models are used for numerical simulations.
- The next step would be to test a substation system with the support structure included. E-Defense shake table would be ideal for such testing.

Hybrid Simulation of Disconnect Switch on Support

Hybrid Simulation at UC-Berkeley

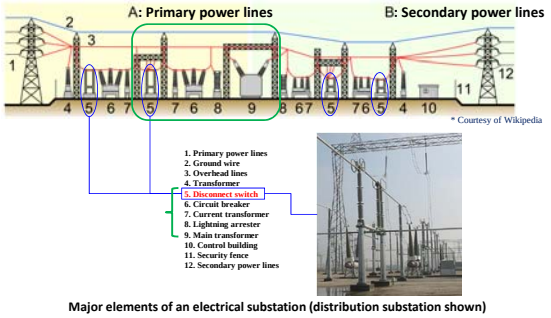


Issues to Discuss

3) Possible issues for collaboration

- A substation system test was proposed by the US side to be conducted at E-Defense in 2015.
- The Japan side was very receptive to this idea since severe damage from ground shaking did occur in substations during the March 11 Great East Japan earthquake.

Seismic Evaluation of Electrical substations



Major elements of an electrical substation (distribution substation shown)

Earthquake damage due to interaction

Interaction between connected equipment is recognized as a likely cause of failure in past earthquakes

Issues to Discuss

4) Complementary research strategies

- The strategy would be to start with a joint China-Japan-US workshop, which will include presentations of research being carried over in all three countries.
- A plan would be formalized to carry out smaller experiments and numerical studies to prepare for the 2015 experiment.
- The Japanese side would need some time to study the Japanese designs of substations. A few representative designs will be studied through small experiments and numerical simulations before putting together a joint NEES/E-Defense proposal.
- We need to involve a number of people from the industry to better understand industry needs and formalize the most pressing problem statement.
- We need to collect substation damage data from the March 11 Great East Japan earthquake to motivate the research plan.

Damage of Great East Japan Earthquake

Power line tower (Minami-soma, Fukushima)

Electric transmission facility (Otsuchi, Iwate)

Electric substation (Kami, Miyagi)

Haramachi thermal power plant (Minami-soma, Fukushima)

(by Tohoku Electric Power, http://www.tohoku-epco.co.jp/)

9th NEES/E-Defense planning meeting, Aug. 26-27, 2011

Issues to Discuss

5) Other comments

- Energy facilities have the greatest impact on society's ability to respond and recover from a disaster.
- US may see a nuclear renaissance. There has been major thrust to consider smaller modular reactors. This will result in important siting considerations. Quantifying and assessing seismic hazard should be important. While there are major activities in optimizing the reactor structures, additional research is needed on the earthquake engineering front.
- Substation systems research: Cable vibration and the coupling of towers present an interesting and important analytical challenge.
- Effect of nonlinearity in the supporting structure reducing the response of equipment is important aspect that could be studied.
- Research could be the performance of buried pipelines, or partially buried and partially suspended pipelines under strong earthquake shaking.

Resolutions

Resolution 1: Plan a joint China-Japan-US workshop on seismic response of electric substations with strong participation from academia and industry.

Resolution 2: Collect and analyze information about damage to the energy infrastructures that occurred due to the March 11 Great East Japan earthquakes and augment it to similar data available from China and US.

Resolution 3: Collaborate for the 2015 E-Defense shaking table test on electric substations.