

State of the Practice of Nonlinear Response History Analysis

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New Technologies Group

Degenkolb Engineers

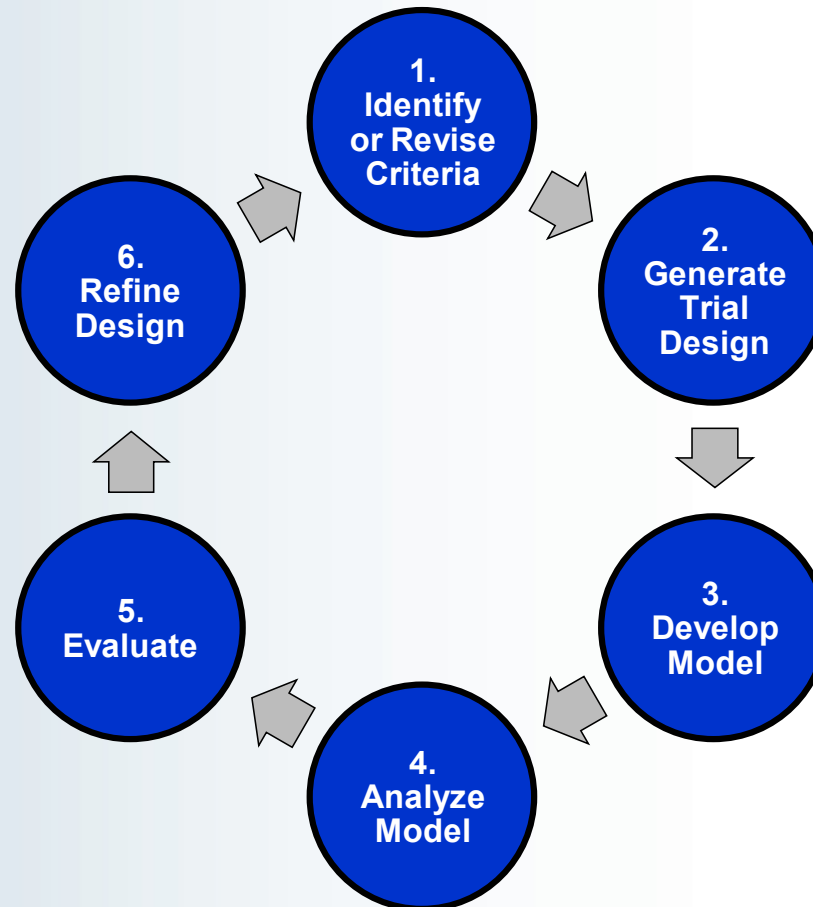
PEER annual Meeting, October 2012

Outline

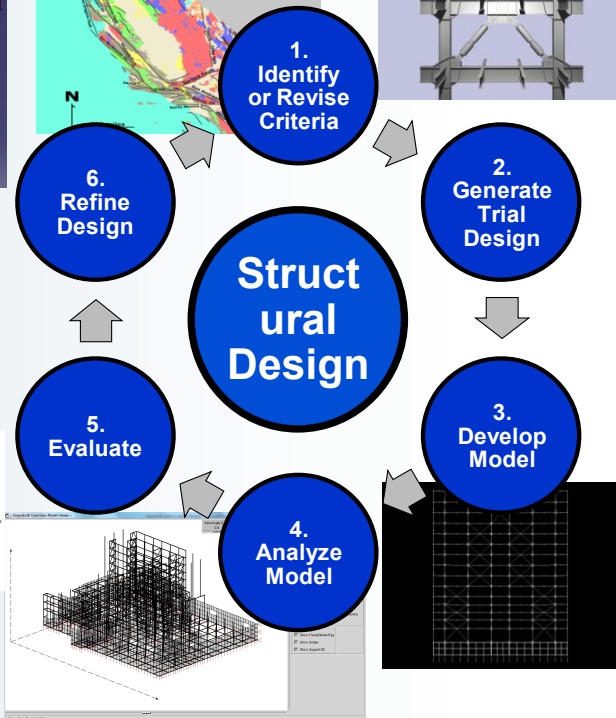
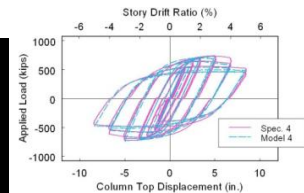
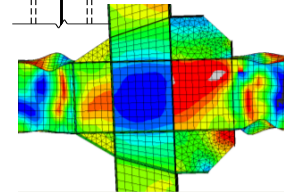
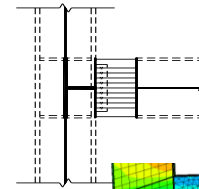
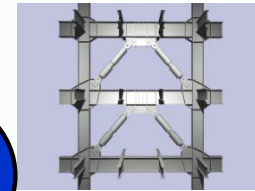
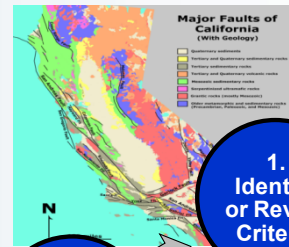
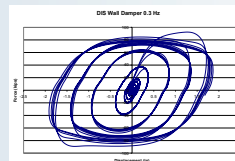
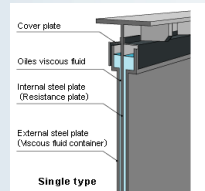
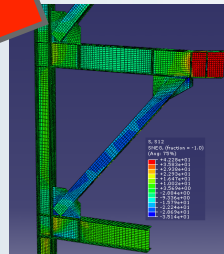
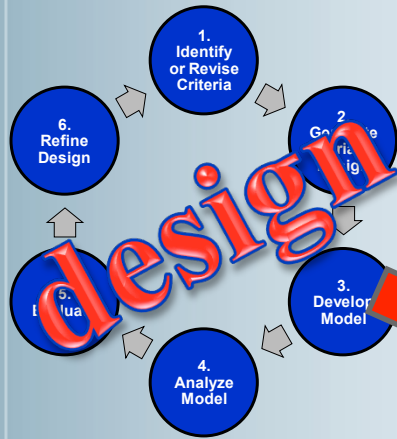
- What, Why & When NLRHA?
- Implementation NLRHA
- Simulation Needs & Challenges
- OpenSees Opportunities and Challenges
- Summary & Conclusion

practice

Design....



Design using Advanced Analysis



Why Nonlinear Response History Analysis (NLRHA)

Improve our prediction of the expected range of structural response by modeling 'realistic (not necessarily real) behavior'.

- *Reduce the uncertainties that we control.*
- *Understand those that we cannot.*

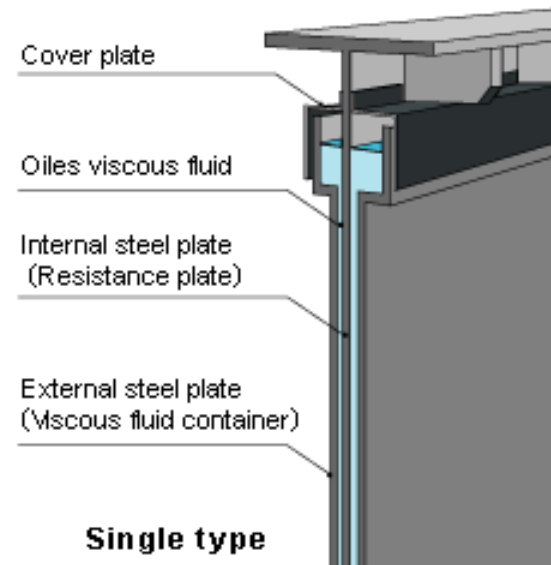
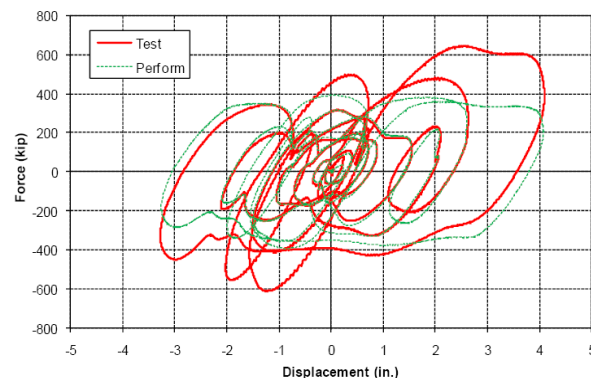
→ develop an efficient design

→ performance-based engineering paradigm)

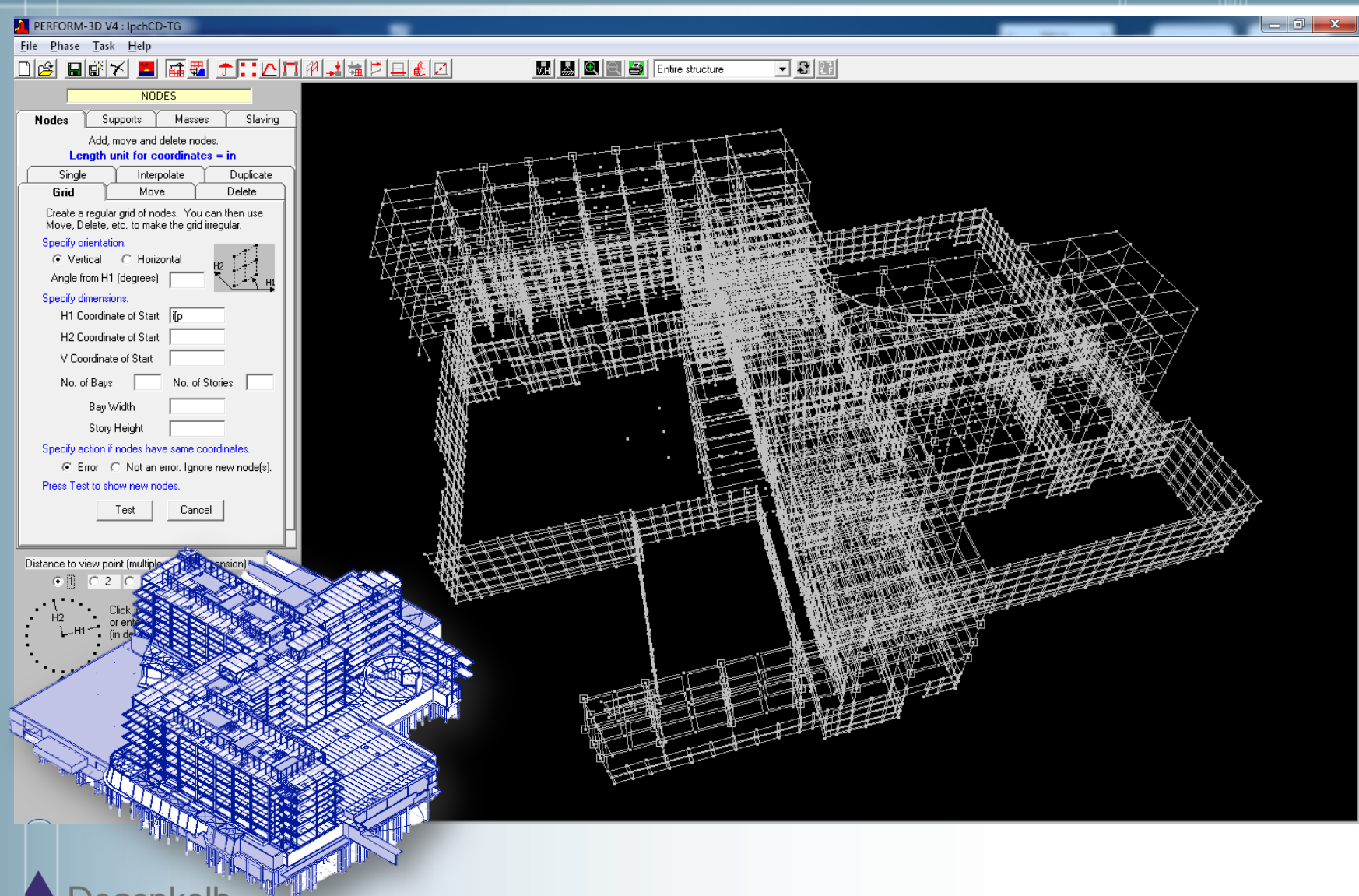
When to go to NLRHA?

- Is it required?
 - When taking a code exception
- Is it going to produce a better answer?
- Is it going to justify the increased cost?
- What is the purpose?
 - Evaluation & rehabilitation vs. design
- When a 'nonstructural' project advantage exists (e.g. reduced disruption)
- Can take advantage of higher code limits

New California-Hospital Design Using New Technologies

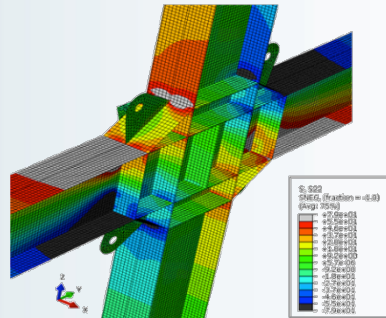
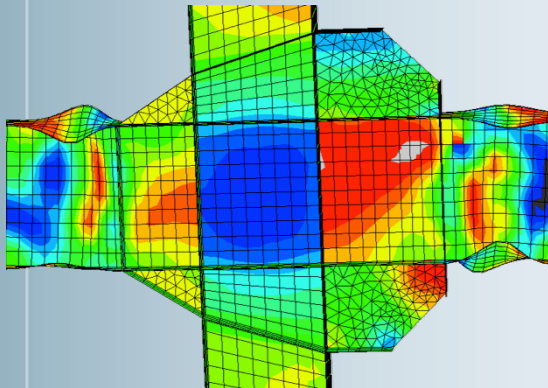


Perform 3D Model:

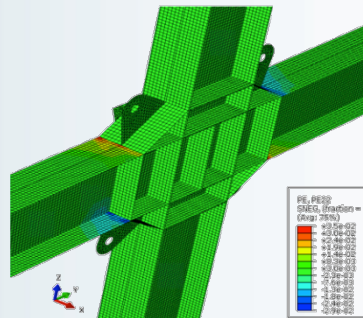
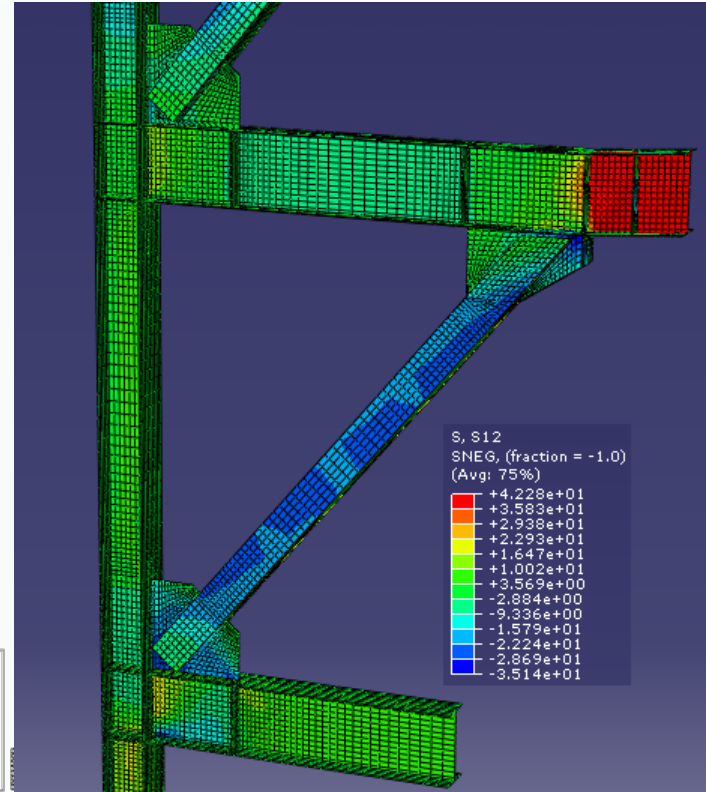


Component Finite Element Analysis

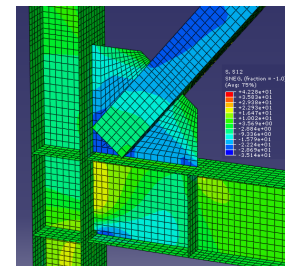
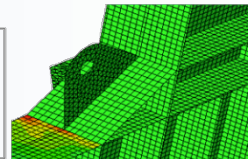
- Support testing programs
- Evaluate behavior of critical components



(a) Flexural Stress Contours



(b) Plastic Flexural Strain Contours



Issues in Implementation of NLRHA

Time-intensive

- 160 records (10 GM's x 16 cases)
- ~16 hours each record >100 days

Data-intensive

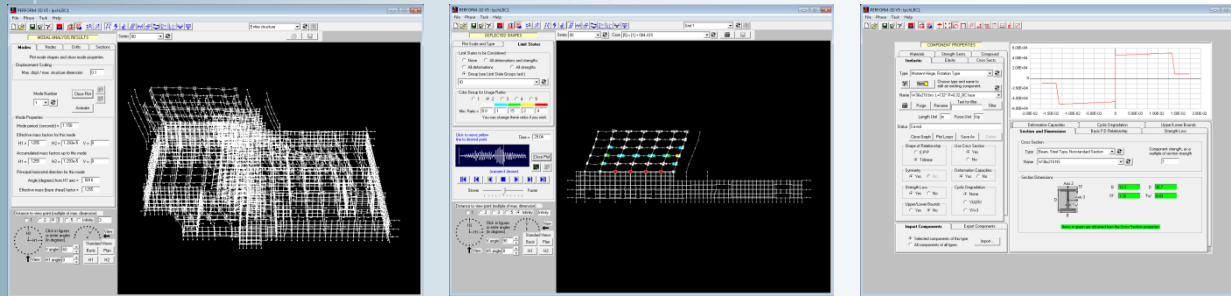
- Typical suite can generate up to 2 TB of data
- Includes displacements, drifts, member forces, hinge rotations, energy dissipation, etc. for every single time step

Labor-intensive

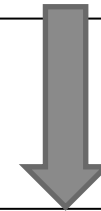
- Reduce data to only a few important results per element



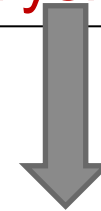
Improve Process Efficiency



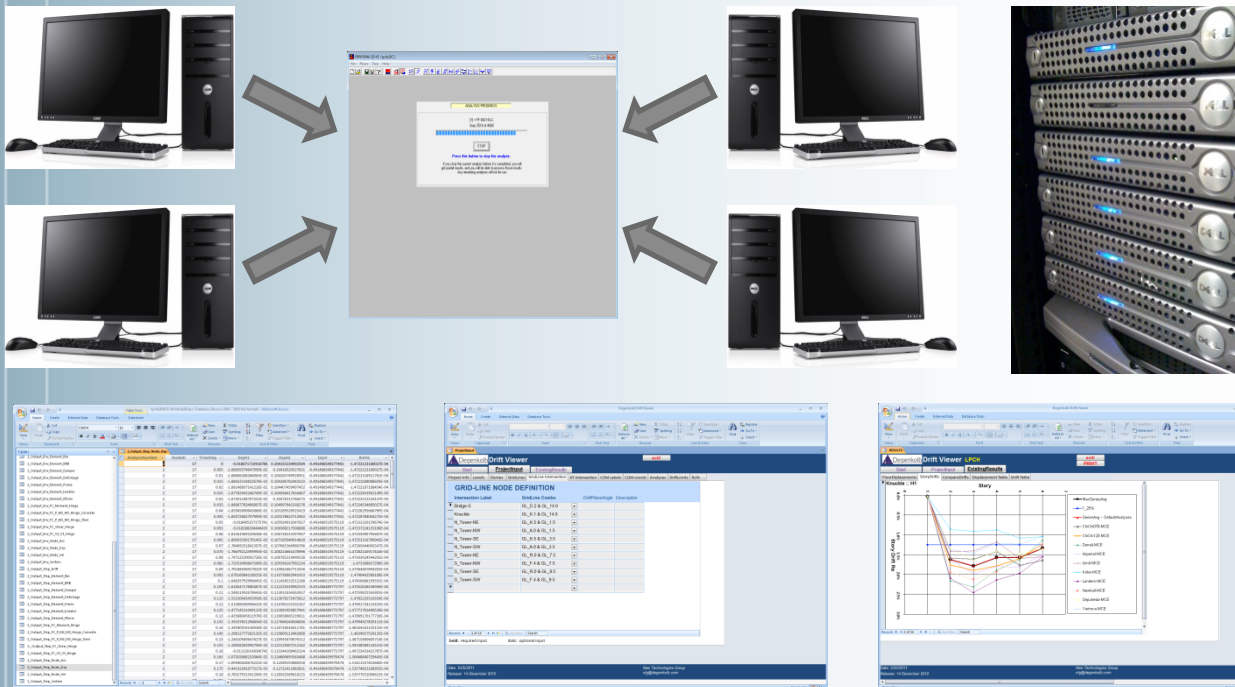
Rapid Model
Generation
Tools



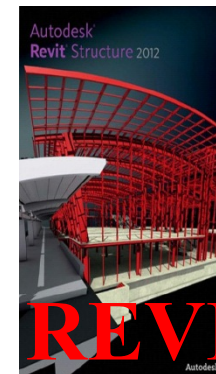
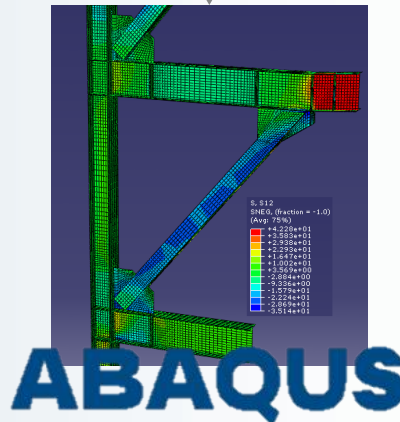
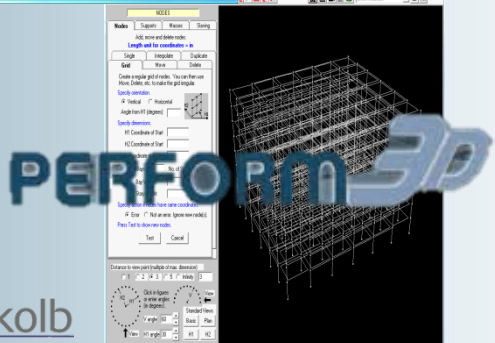
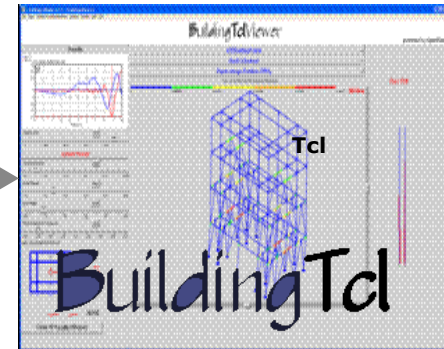
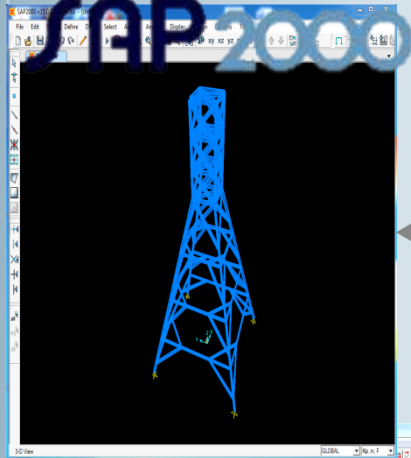
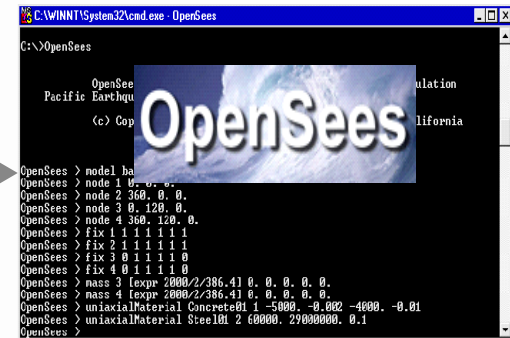
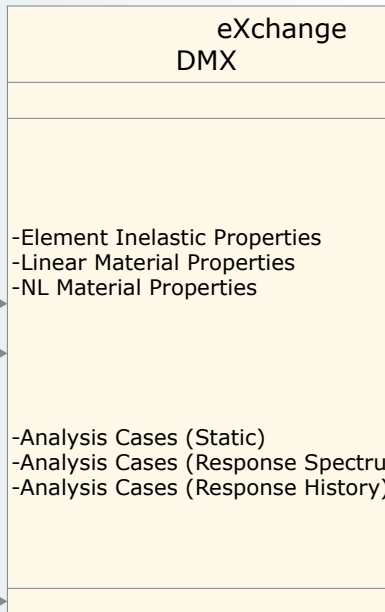
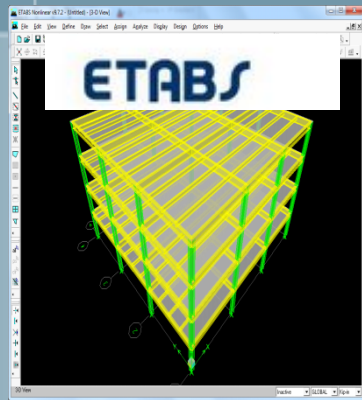
Multimachine
Analysis



Database Post-
Processing

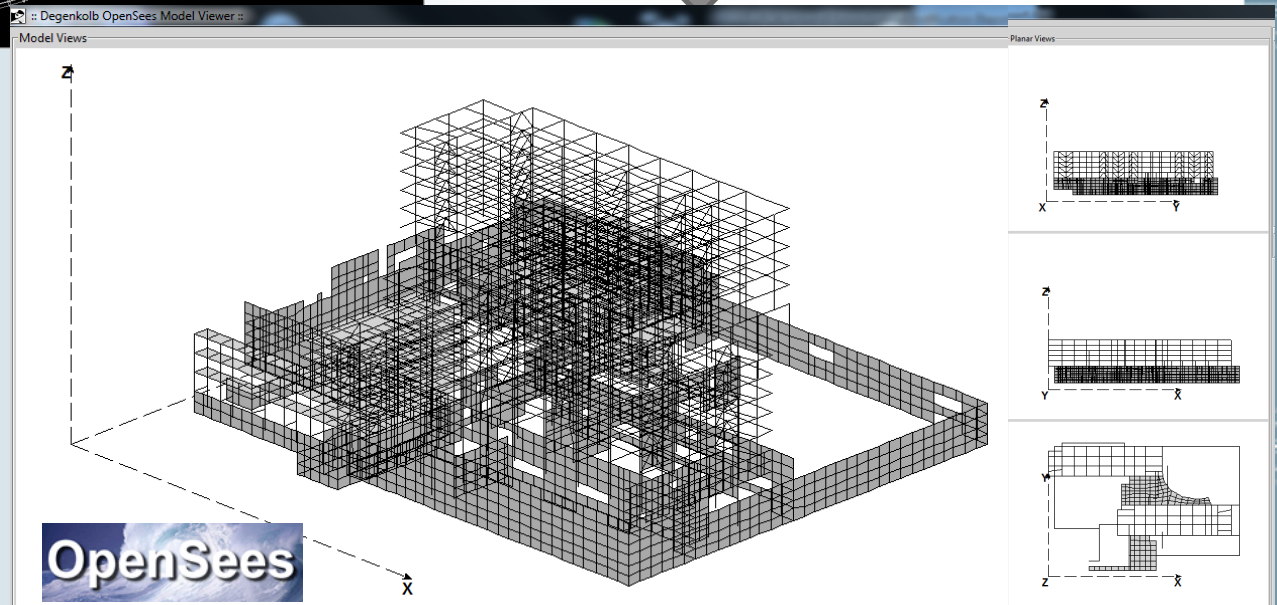
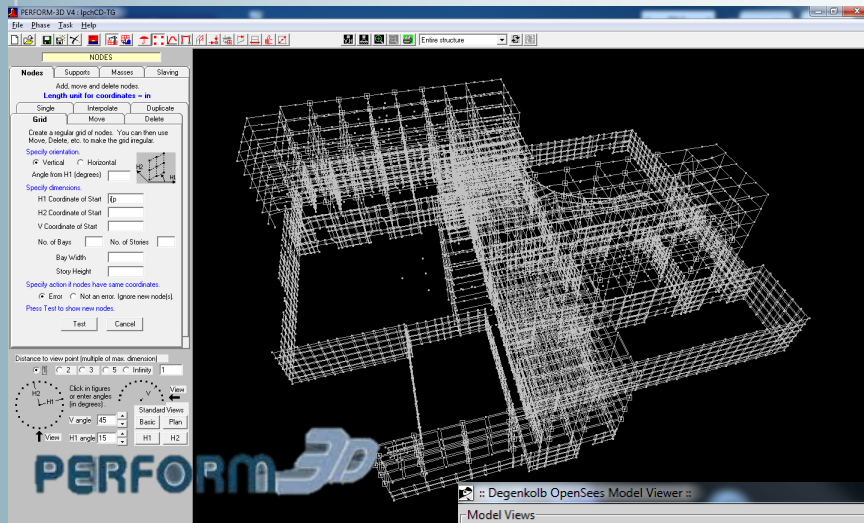


Model Management & Exchange Tool



Step 1. Model Conversion

Automated extraction of Perform Model into OpenSees



Continue development of BuildingTcl

a Real-Time Interface for Numerical Simulation in OpenSees

```
addModelData ModelLabel RCTestFrame2Story2BayBbraced
```

```
addModelData ModelDescription "RC MRF, 2-Story
```

```
addModelData ModelTypeLabel Elevation
```

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addSectionData SectionL
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addSectionData SectionM
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addSectionData E 3600e
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addSectionData B 600*1
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addSectionData H 480*1
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addSectionData
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```
addSectionData SectionModelLabel RCTest
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addSectionData H 30*1
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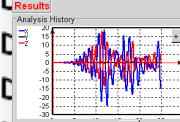
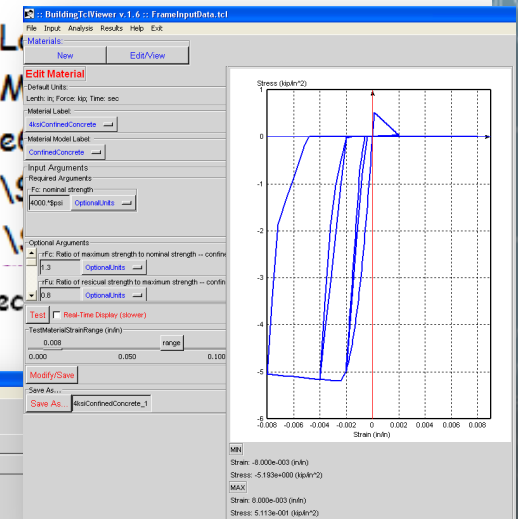
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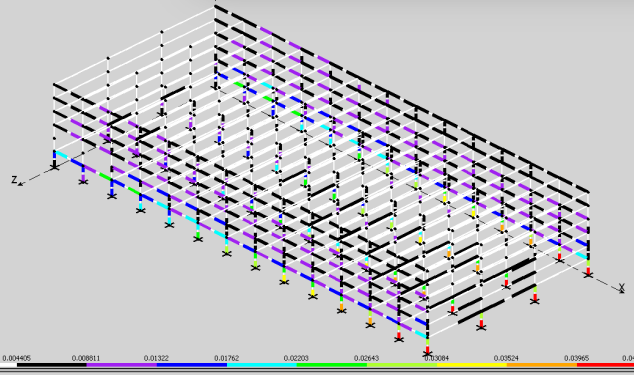
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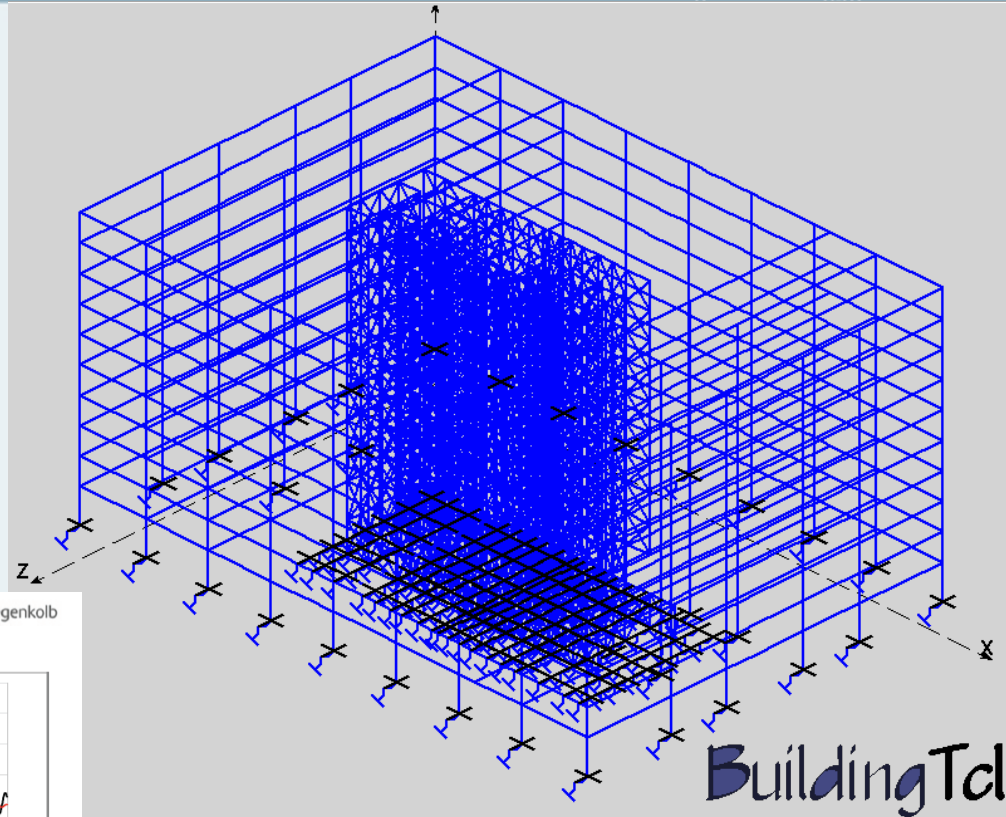


Plastic-Hinge Rotation OPHz

maxAbs

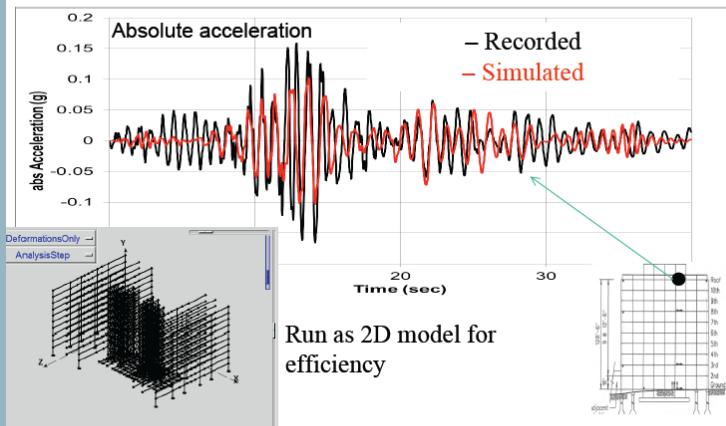


Involvement in ATC-83 Project: Soil-Structure Interaction

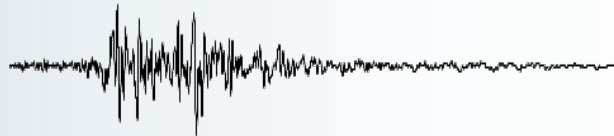
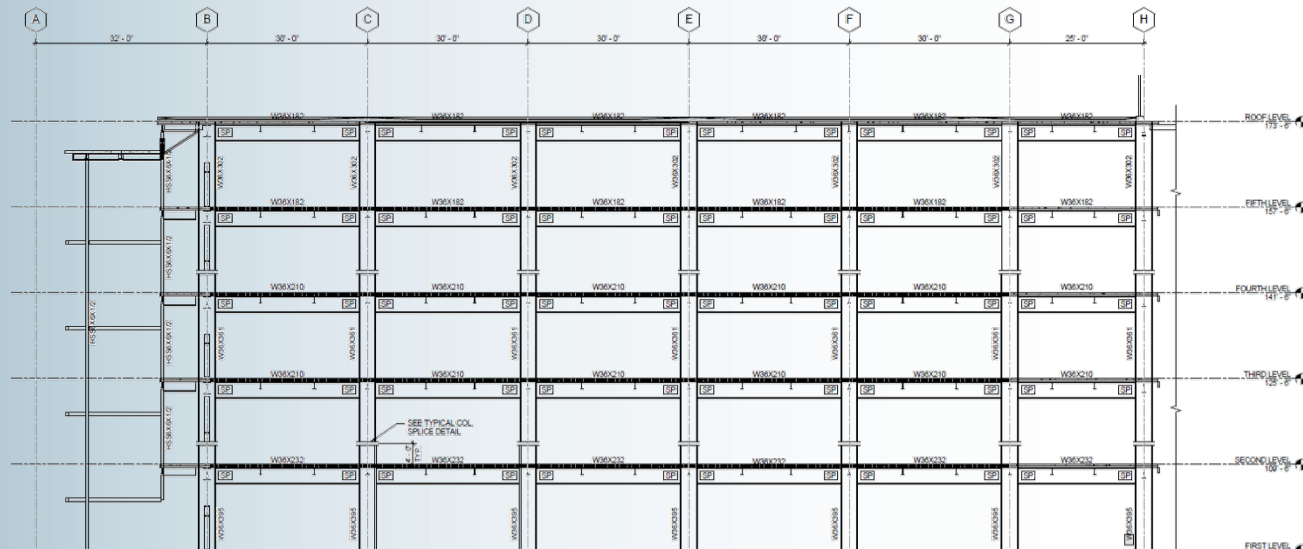


Simulation Validation – Loma Prieta

Degenkolb



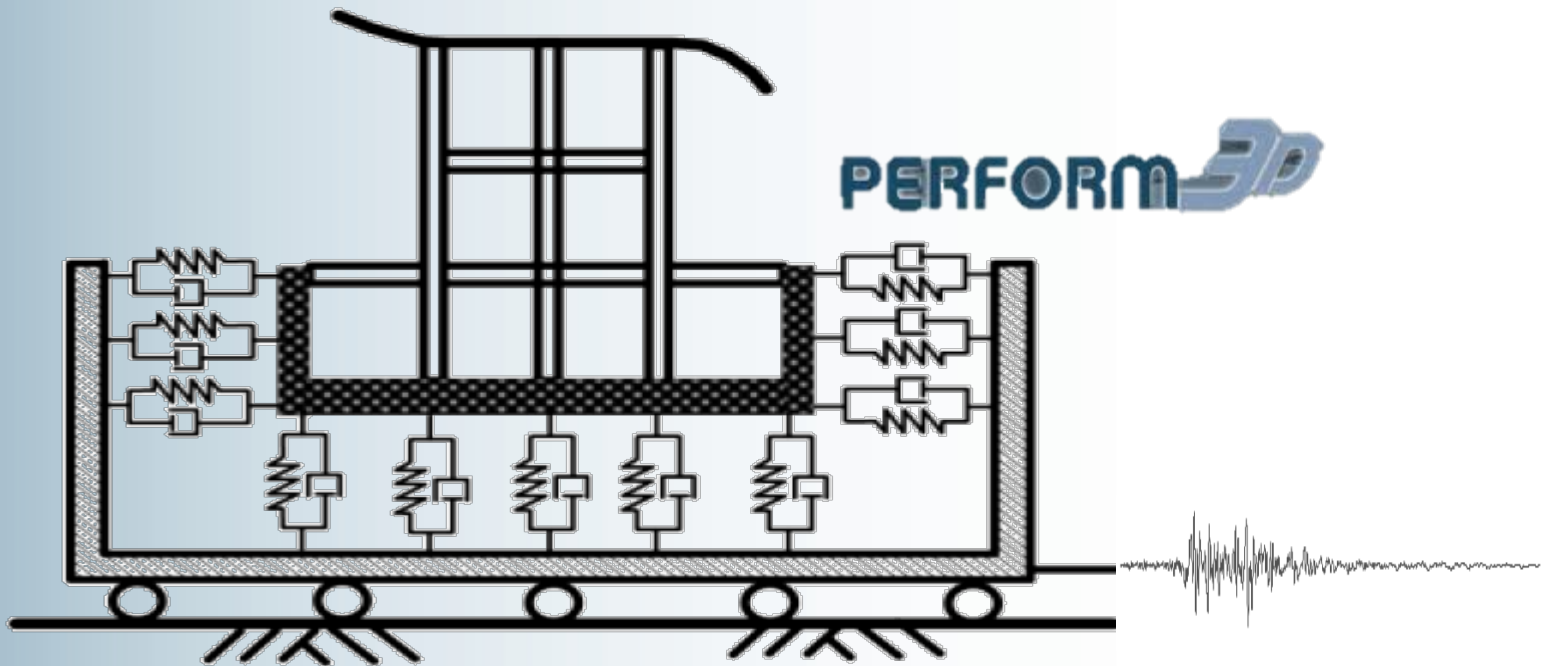
SFSI: State of the common practice:



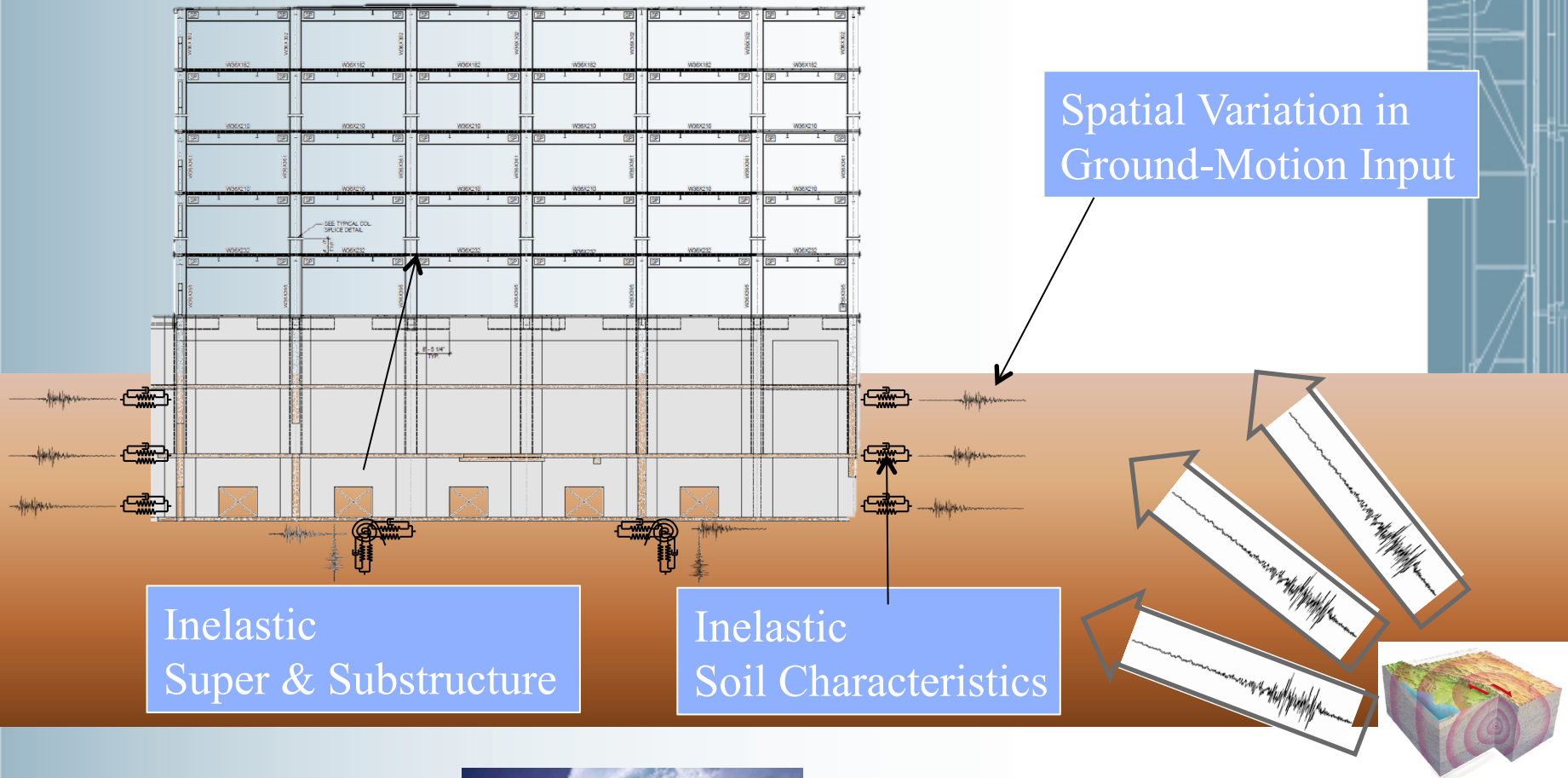
SFSI: Edge of the Practice:

Still Uniform-Support Excitation = bathtub model

- Model kinematic effects (spatial variation of ground motions) implicitly

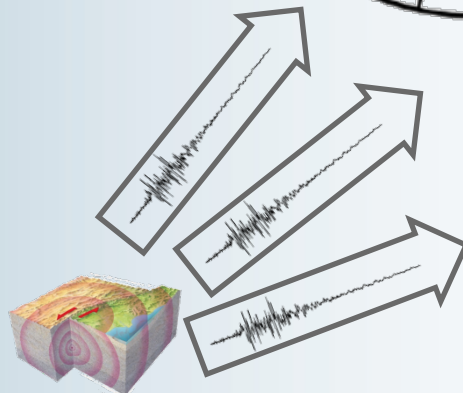
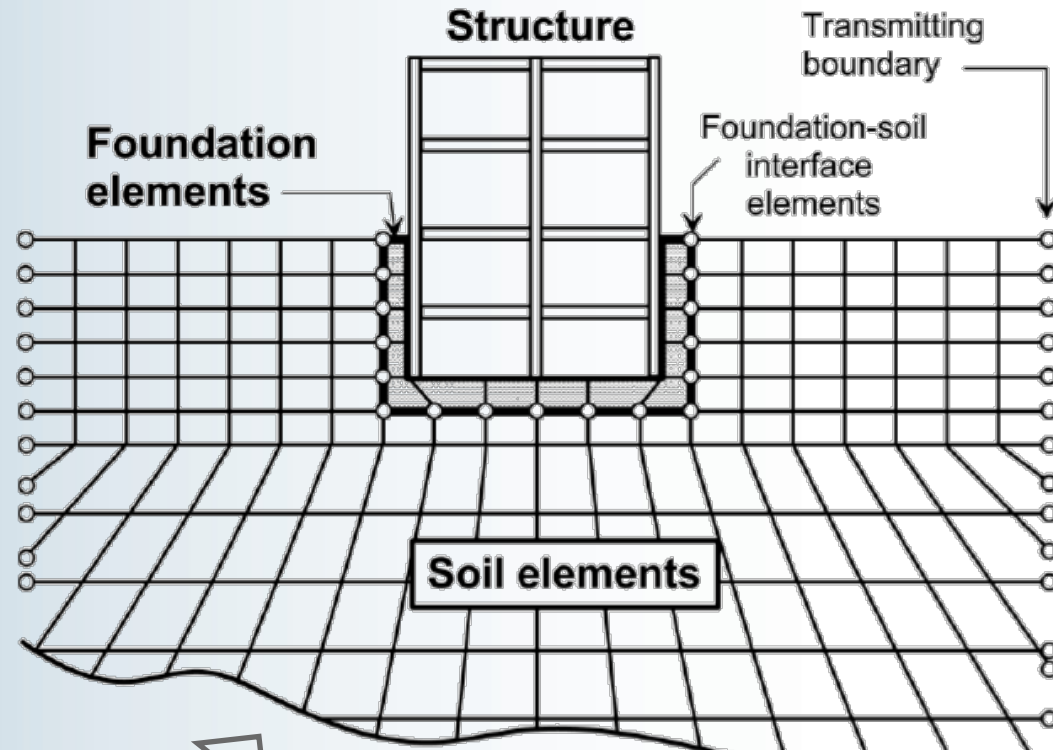


SFSI: Just beyond the edge...



➔ **OpenSees**

Direct Modeling of System Response



OpenSees

Simulation Needs in the Profession

- Project time is key → Optimize simulation
- Integration with BIM – model management, and synchronizing models between software (OpenSees <-> Revit <-> Etabs)
- Multi-analysis & multi-model management
- Model uncertainties, sensitivities & optimization
- Integration into design tools
- Distributed computing
- Smart solution algorithms

Simulation Needs (cont.)

- Validation & verification of models
- Education of engineers
- Move away from always using lumped-plasticity models!!!
- Data management & visualization
- Direct modeling of systems



OpenSees Opportunities/Benefits

- Open-Source
- Robust Solvers
- Latest research knowledge/models
- Can add user models/materials
- Multiple-support excitation
- SFSI / Soil modeling
- Parallel / Multi-Machine processing
- Customizable Output / Recorders
- Fiber models

OpenSees Limitations/Challenges

- Open-Source: Stability
- Latest Research: Model Stability/Robustness
- Lack of robust nonlinear RC wall elements (Promising developments by Prof. Filippou)
- Lack of some basic analysis tools used in design (modal analysis, etc..)
- Visualization



QUESTIONS?