ToDo While Waiting

1. *Go to:* nees.org *and register*
2. *Submit a ticket and ask: "Need HPC access for OpenSeesDays"*

Day 1 – Getting Started With OpenSees

8:30 - 9:00	**Welcome and Introduction to OpenSees**	Frank McKenna
9:00 - 9.45	**Getting Started with OpenSees**	Frank McKenna
9:45 -10:15	**Unknown (Use of OpenSees in Research)**	Reagan Chandramohan
10:15 -10:30	**OpenSees & Output**	Frank McKenna
10.30-11:15	**Basic Modeling & Analysis by Example**	Frank McKenna
11:15-12:15	**Introduction to Nonlinear Analysis**	Prof. Filip Filippou
12.00-1.00	Lunch	
1:00 - 1:45	**Nonlinear Analysis With Examples**	Frank McKenna
1:45 - 2:15	**Introduction to NEEShub**	Anup Mohan
2:15 - 2.45	**OpenSees on NEEShub**	Frank McKenna
2:45 - 4:30	**Hands on Examples (bring a working laptop)**	
4:30-5:00	**BuildingTcl**	Dr. Silvia Mazzoni
5:00-5:30	**OpenSees Navigator**	Dr. Andreas Schellenberg

NEES / PEER
OpenSees Days 2013

Presented by the OpenSees Community

August 26-27, 2013

Sponsored by:

NEES through NEEScomm

Pacific Earthquake Engineering Research Center

National Science Foundation

http://opensees.berkeley.edu/wiki/index.php/OpenSeesDays2013

On behalf of the:
George E. Brown Network for Earthquake Engineering Simulation
(NEES)
and the
Pacific Earthquake Engineering Research Center
(PEER)

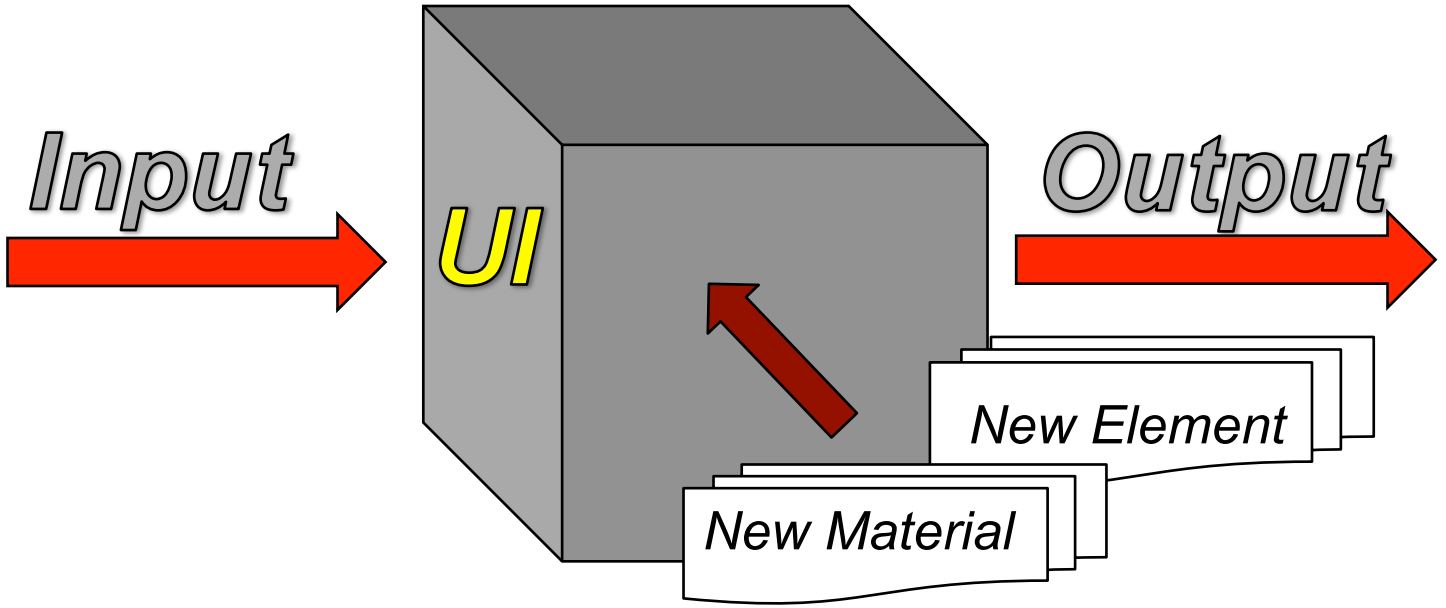
WELCOME

PEER: OpenSees Goals (1998):

Dean Gregory Fenves
UT Austin

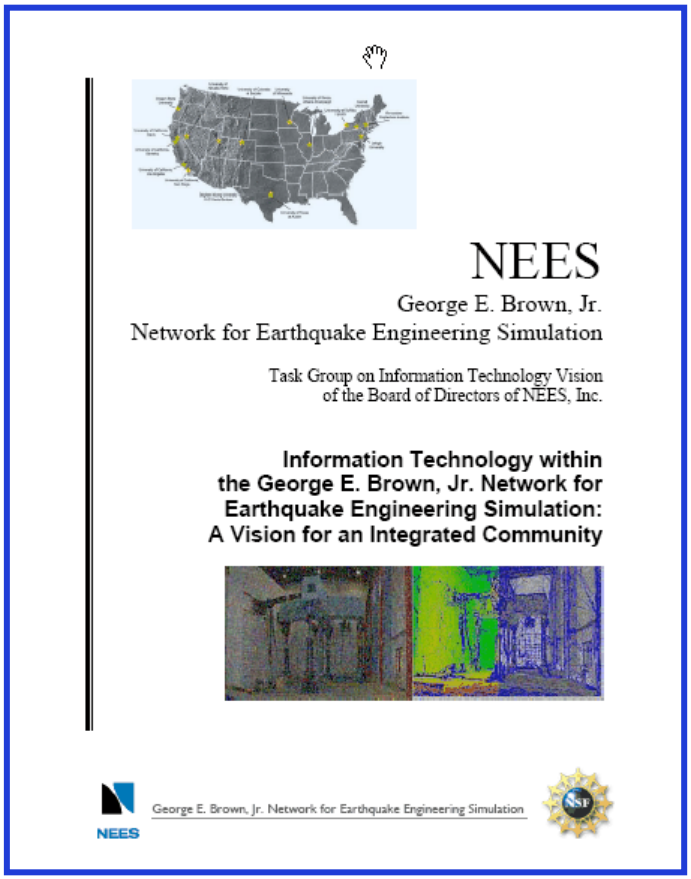
1. *To use **modern software techniques** to evolve an extensible open-source finite element software platform for earthquake engineering that would encompass both **structural & geotechnical** engineering.*
2. *To provide **a common analytical research framework** for PEER researchers **to educate students & share** new knowledge.*
3. *To foster a mechanism whereby new research developed through PEER could be **disseminated to industry** for testing and implementation.*

What Was Wrong With Existing Software



- Tight binding of models in research and commercial codes is an impediment to new research and implementation of models for professional practice.
- Embedding of computational procedures in codes makes it difficult to experiment and take advantage of computing technology (Parallel & Grid Computing)
- “Closed-source” is the norm, whereas other fields have adopted “open-source” software for communities users.

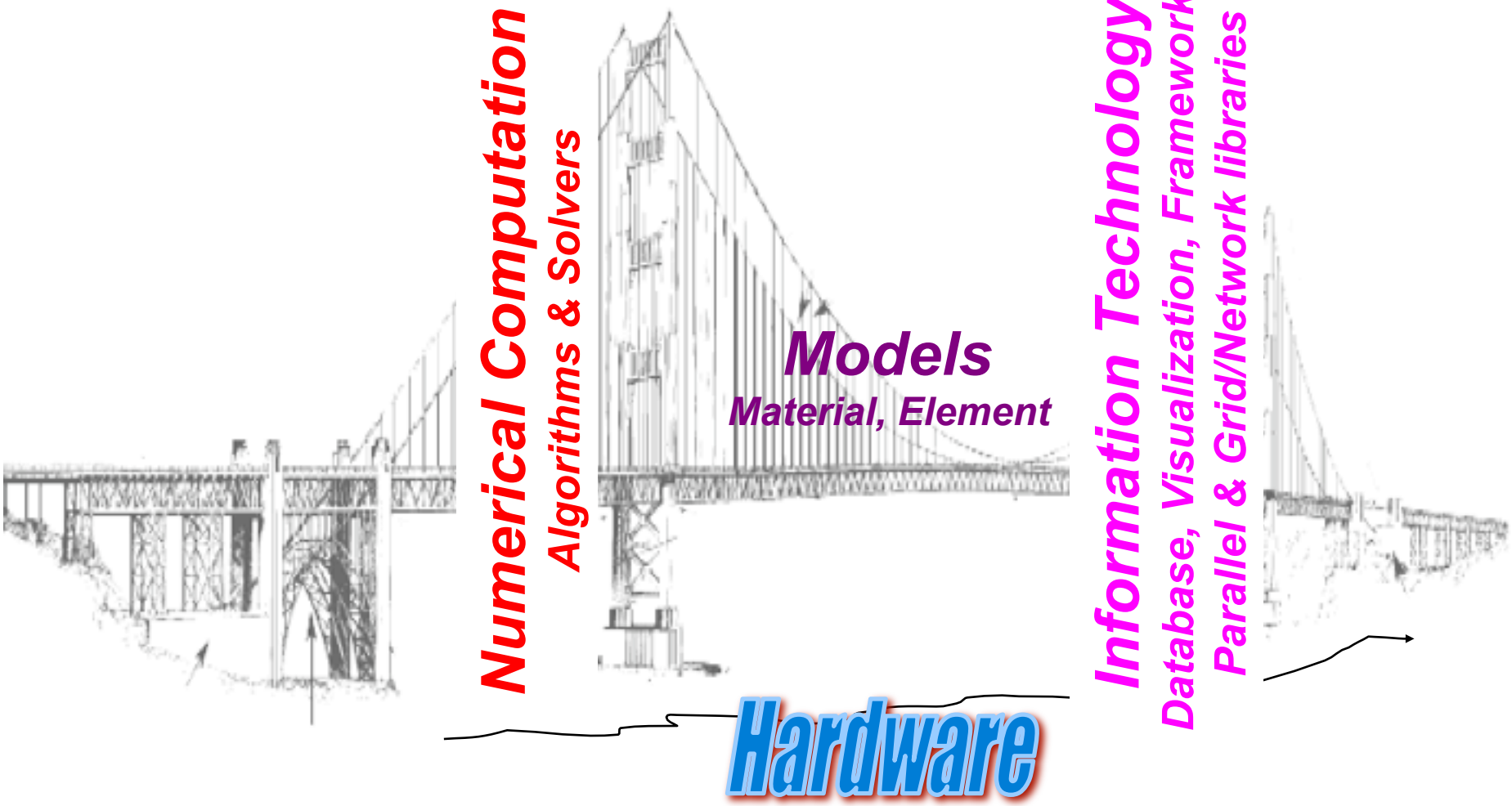
Vision for Simulation



Computational modeling and simulation is central to the vision of NEES to transform the development of new earthquake engineering solutions from being primarily based on experiments to a balanced use of simulation and experimentation using computational models validated by experimental data.

A close integration of modern computational models and simulation software with other NEES applications and services will provide the earthquake engineering community, and broad engineering users, new capabilities for developing innovative and cost-effective solutions.

Building Blocks for Modern Simulation Code



Open-Source - Leave it out there for community

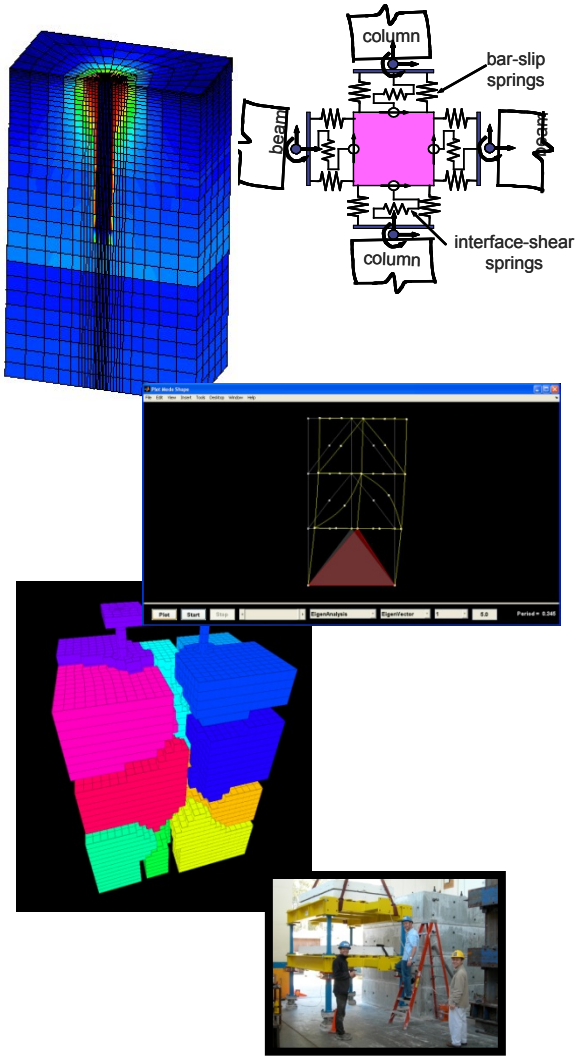
OpenSees — Open System for Earthquake Engineering Simulation
Pacific Earthquake Engineering Research Center

- Source Code started in 1995 so I could do my research.
- OpenSees has been under development at PEER since 1998.
- NEES has supported integration and maintenance since 2003.
- Open-Source and royalty free license for non-commercial use and internal commercial use.
- License must be obtained for software developers including OpenSees code in their applications if they sell it.
- Written in C++, C and Fortran (C++ being the main language)

http://opensees.berkeley.edu

OpenSees Approach to Simulation

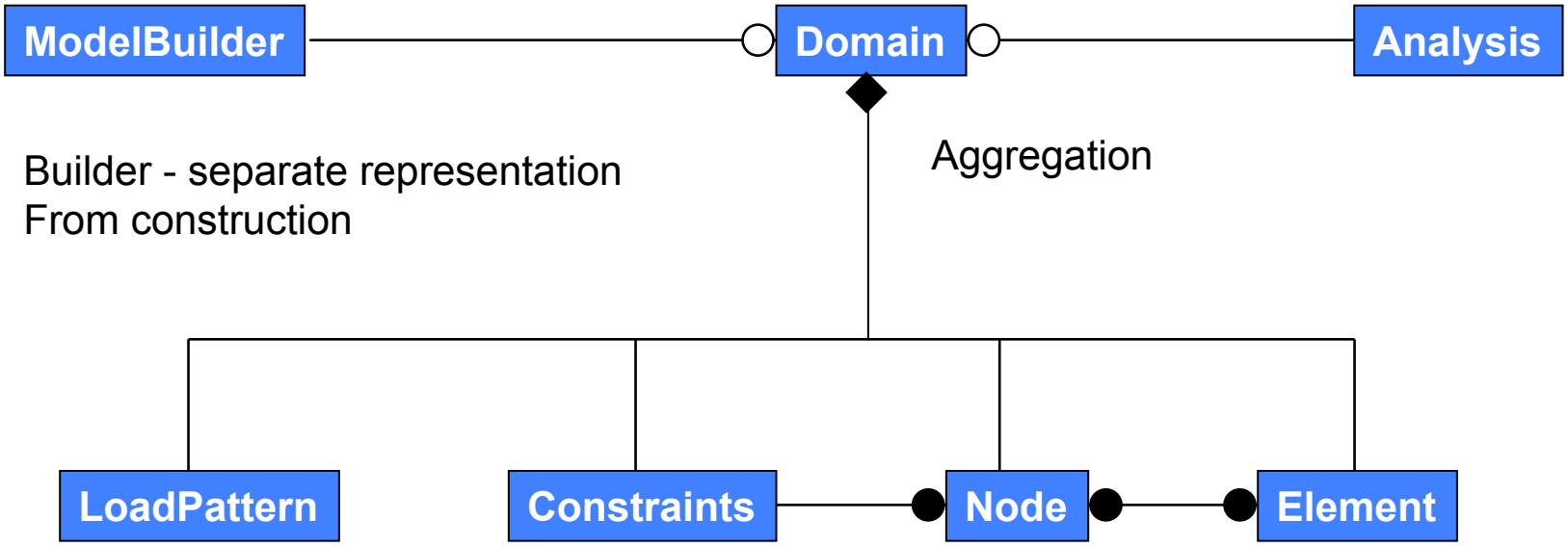
- Basic approach:
  - Modular software design for implementing and integrating modeling, numerical methods, and IT for scalable, robust simulation
  - Focus on capabilities needed for performance-based engineering
  - Programmable interfaces
- Most users: a "application" for nonlinear analysis. Fully scriptable.
- Generally: a software framework for developing simulation applications.



What is OpenSees?

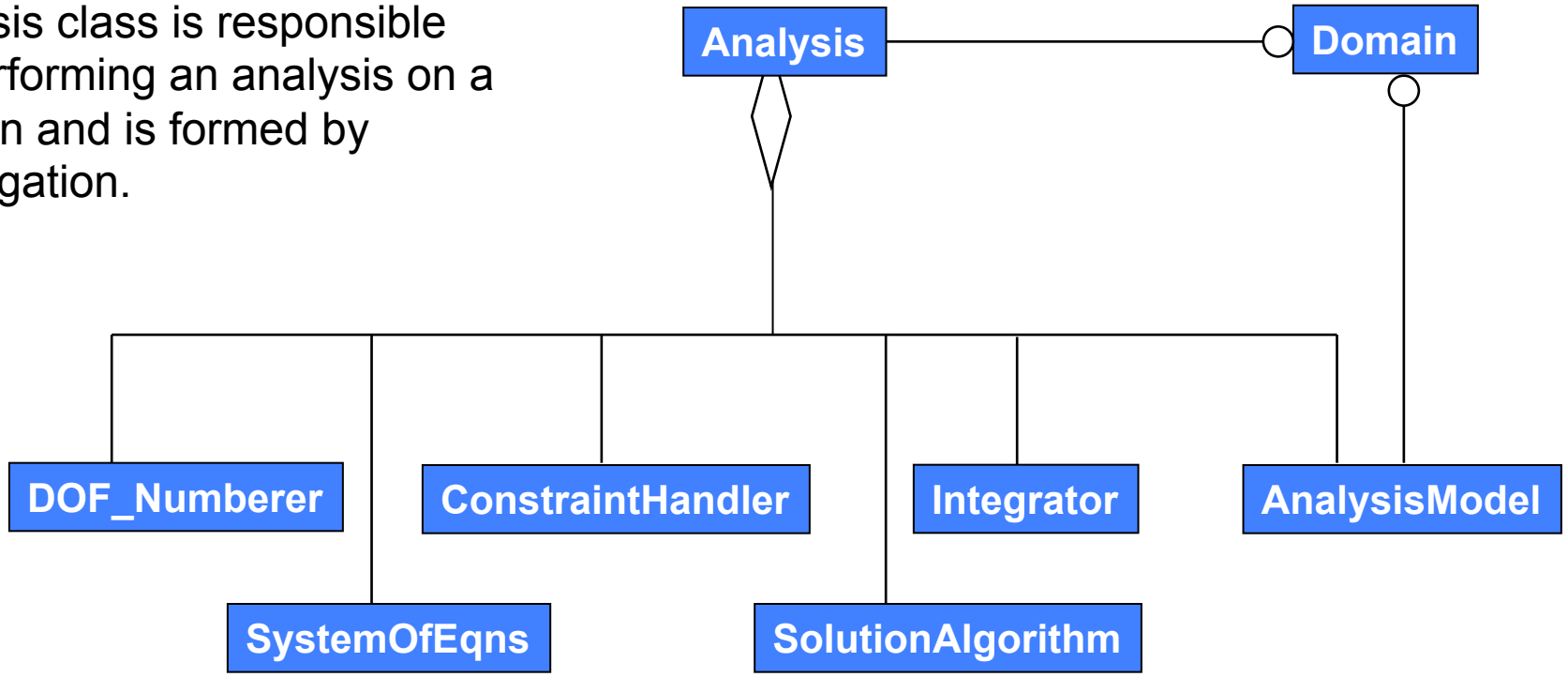
- A software *framework* for simulation applications in earthquake engineering using finite element methods. OpenSees is not an application.
- A communication mechanism for exchanging and building upon research accomplishments.
- As open-source software, it has the potential for a community code for earthquake engineering.

Structural Models as Aggregation Pattern

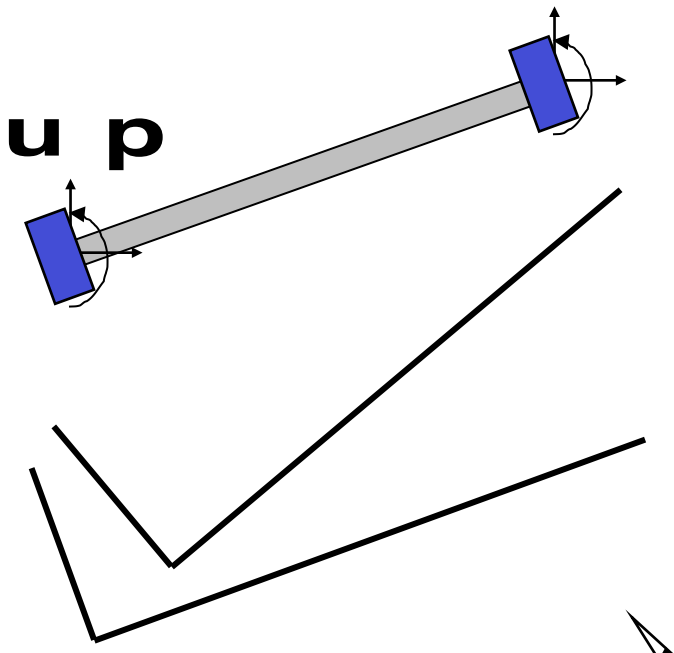


Analysis Class for Simulation

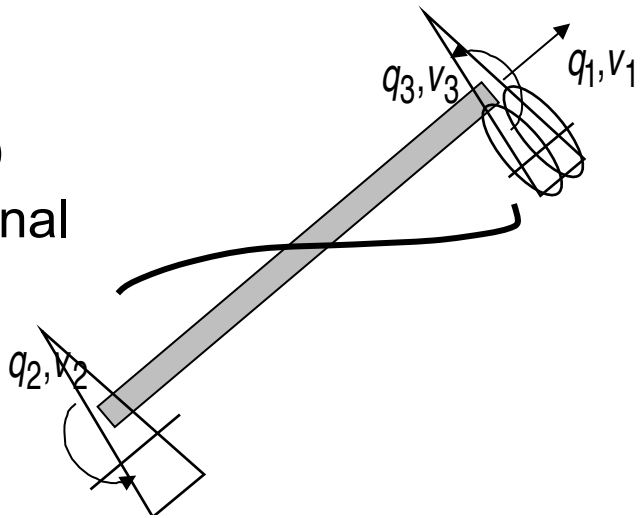
Analysis class is responsible for performing an analysis on a domain and is formed by Aggregation.

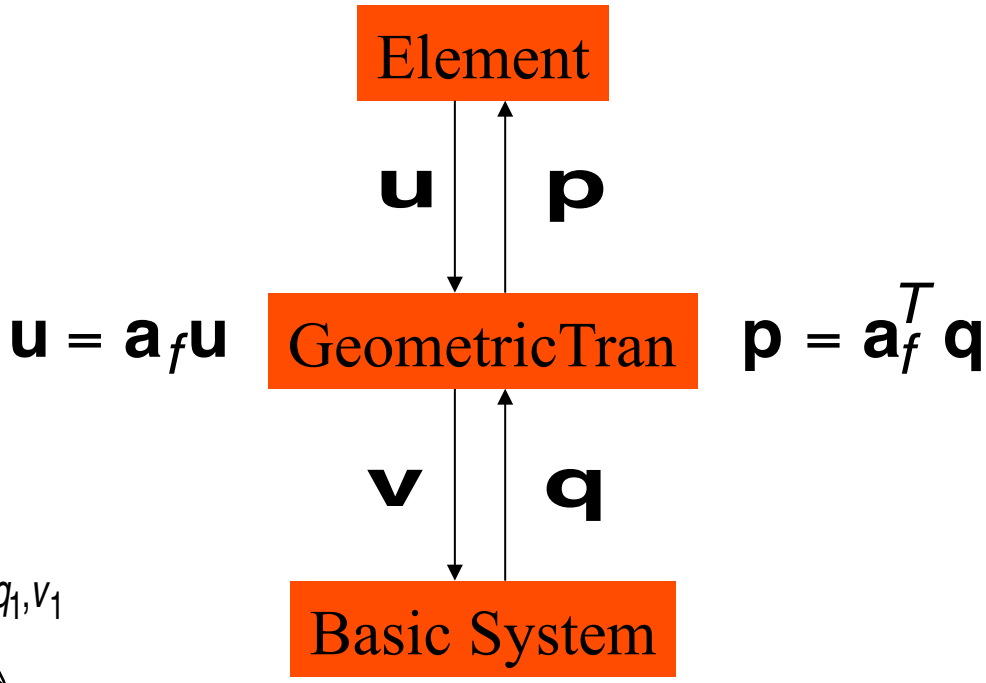


Beam-Column Models I

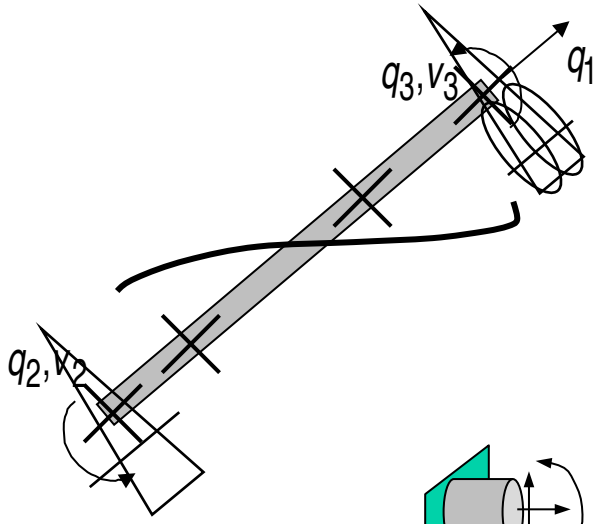


Linear
LinearPD
Corotational





Beam-Column Models II

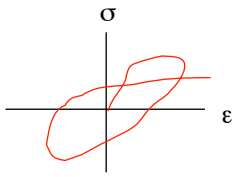


Displacement

$$\mathbf{e} = \mathbf{a}\mathbf{v}$$

$$\mathbf{q} = \int_0^L \mathbf{a}^T \mathbf{s}\, dx$$

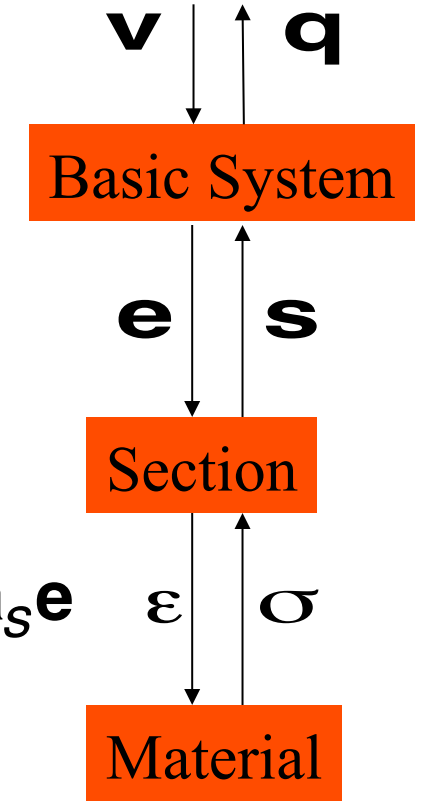
e, s



Force

$$\mathbf{s} = \mathbf{b}\mathbf{q}$$

$$\mathbf{v} = \int_0^L \mathbf{b}^T \mathbf{e}\, dx$$



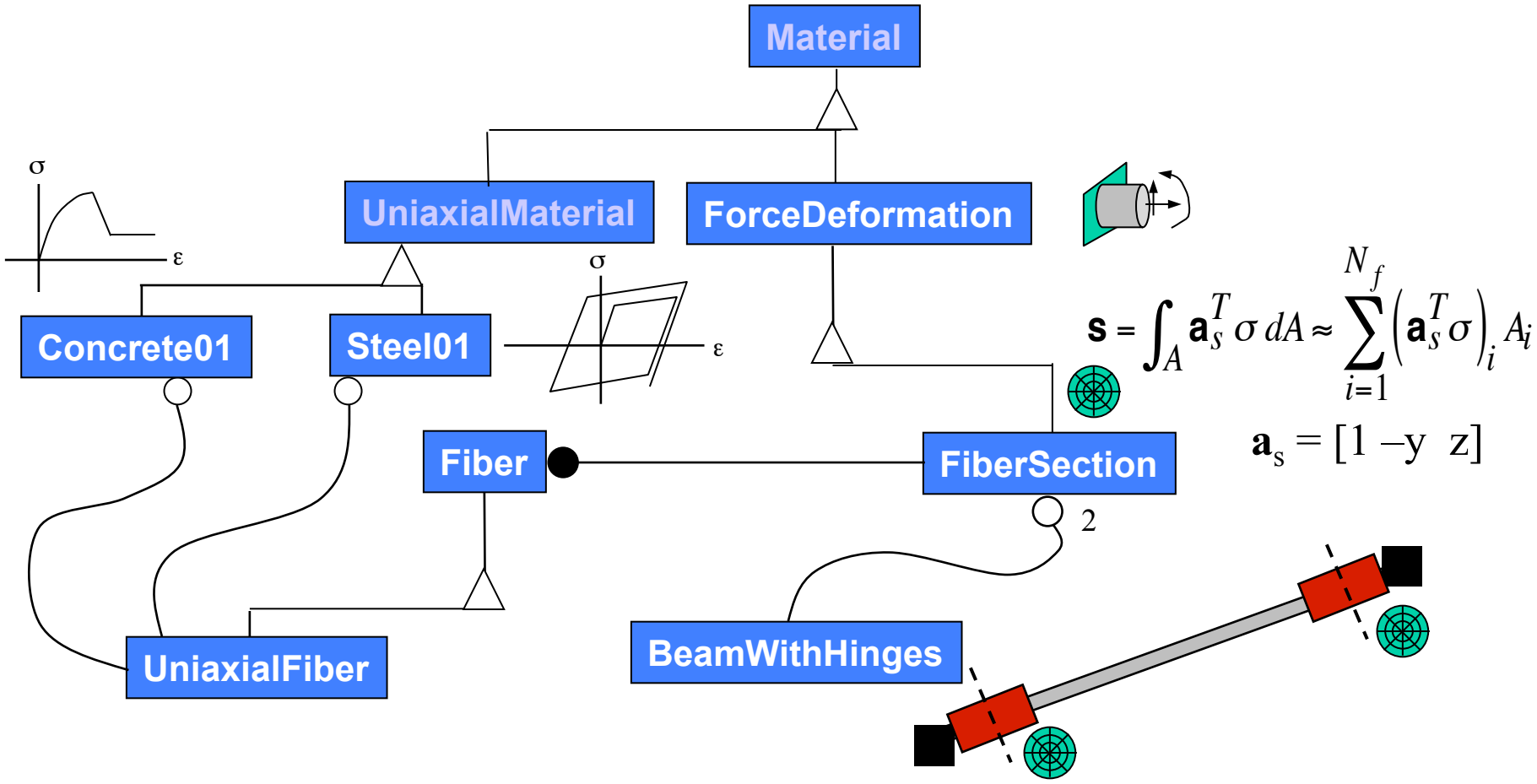
$$\varepsilon = \mathbf{a}_s \mathbf{e}$$

$$\mathbf{s} = \int_A \mathbf{a}_s^T \sigma\, dA$$

$$\sigma = \sigma(\varepsilon)$$

No assumptions are made on section or material behavior; each level in the hierarchy can be defined independently of other levels

Form Follows Mechanics



OpenSees Scripting

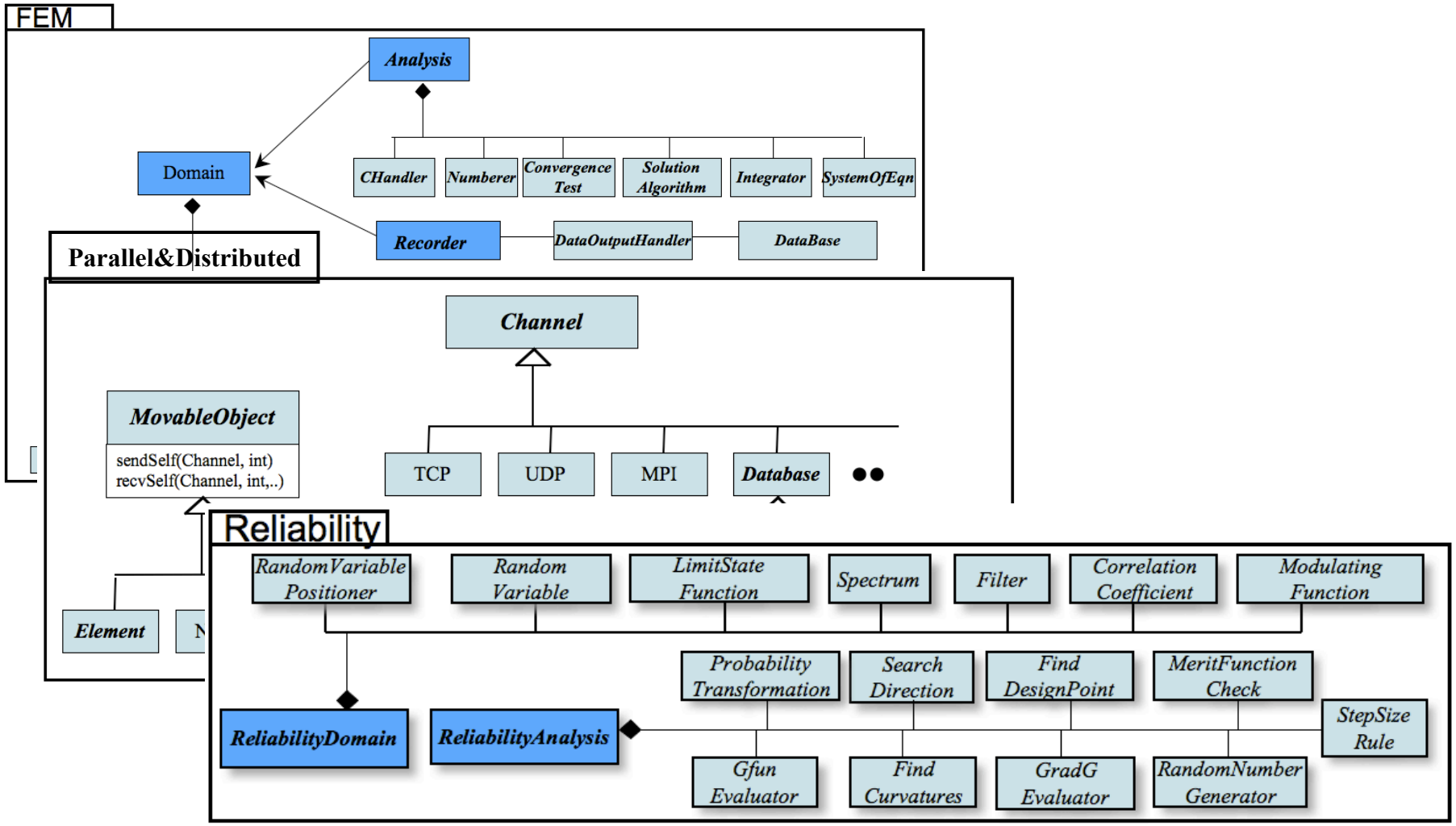
```
1.  wipe
2.  source Units.tcl;                          # define units
3.  source ParamList.tcl;                      # load up parameter values
4.  source GMFiles.tcl;                        # load up ground-motion filenames

5.  foreach Xframe $iXframe Hcol $iHcol Lcol $iLcol Lbeam $iLbeam
                Glblc $iGlblc GrhoCol $iGrhoCol GPcol $iGPcol GMfact $iGMfact {
6.      source Static.tcl;      # load procedure for static analysis
7.      source Dynamic.tcl; # load procedure for dynamic analysis
8.      puts FRAME$Xframe.....FRAME$Xframe.....
9.      puts STATIC_ANALYSIS
10.     Static $Xframe $Hcol $Lcol $Lbeam $Glblc $GrhoCol $GPcol $GMfact ;
11.     puts DYNAMIC_ANALYSIS
12.     foreach GroundFile $iGroundFile {
13.         puts GroundMotion$GroundFile
14.         Dynamic $Xframe $Hcol $Lcol $Lbeam $Glblc $GrhoCol $GPcol $GMfact $GroundFile;
15.     }
16. }
```

FRAME

GROUND MOTION

OpenSees has more capabilities than the typical FE Application

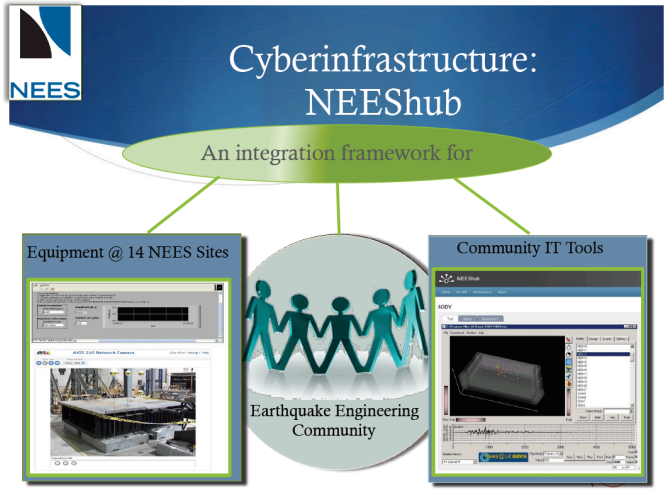


NEES

The Network for Earthquake Engineering Simulation (NEES) is a shared national network of 14 experimental facilities, collaborative tools, a centralized data repository, and earthquake simulation software.

NEEShub

- The power behind NEES at http://nees.org
- Maintained and developed at Purdue by NEEScomm
- A science gateway for education and research in earthquake engineering

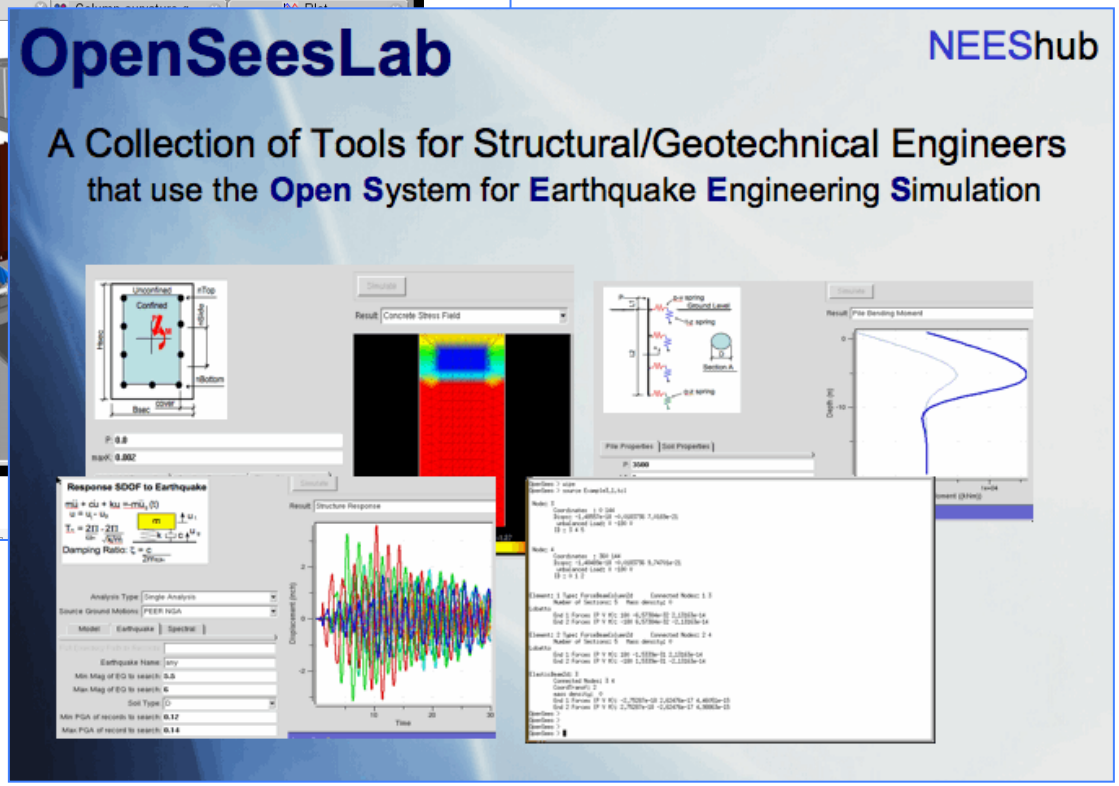


Through a browser engineers can:

- Upload and view experimental data
- Browse online seminars and courses
- Launch sophisticated tools using remote computational resources (OpenSeesLab)

NEEShub Tools and Resources

Simulation



Data Management

Objective of OpenSees Days

- Describe modeling and analysis capability, including hierarchy of system, element, section, material
- Overview of applications, structural and geotechnical
- Show specific examples of nonlinear analysis
- Provide hands-on starting-point for simulation tools
- Introduce NEEShub capabilities using OpenSees
- Motivation to use OpenSees for your simulation problems….

What Should be Your Expectations?

- OpenSees is primarily a research tool at this time, but fairly stable and is used in professional practice
- As with any nonlinear analysis, it requires careful consideration of model and interpretation of results
- It is under continual development by students, faculty and other researchers
- User interface development lags behind computational technology
- It is not bullet-proof
- An investment of time and learning is required

All that said

OpenSees
is
Something Students
LEARN to **LOVE**

(most hate it initially!)

Used Worldwide (2013)

Visitors

83,663

% of Total: **100.00% (83,663)**

Visits

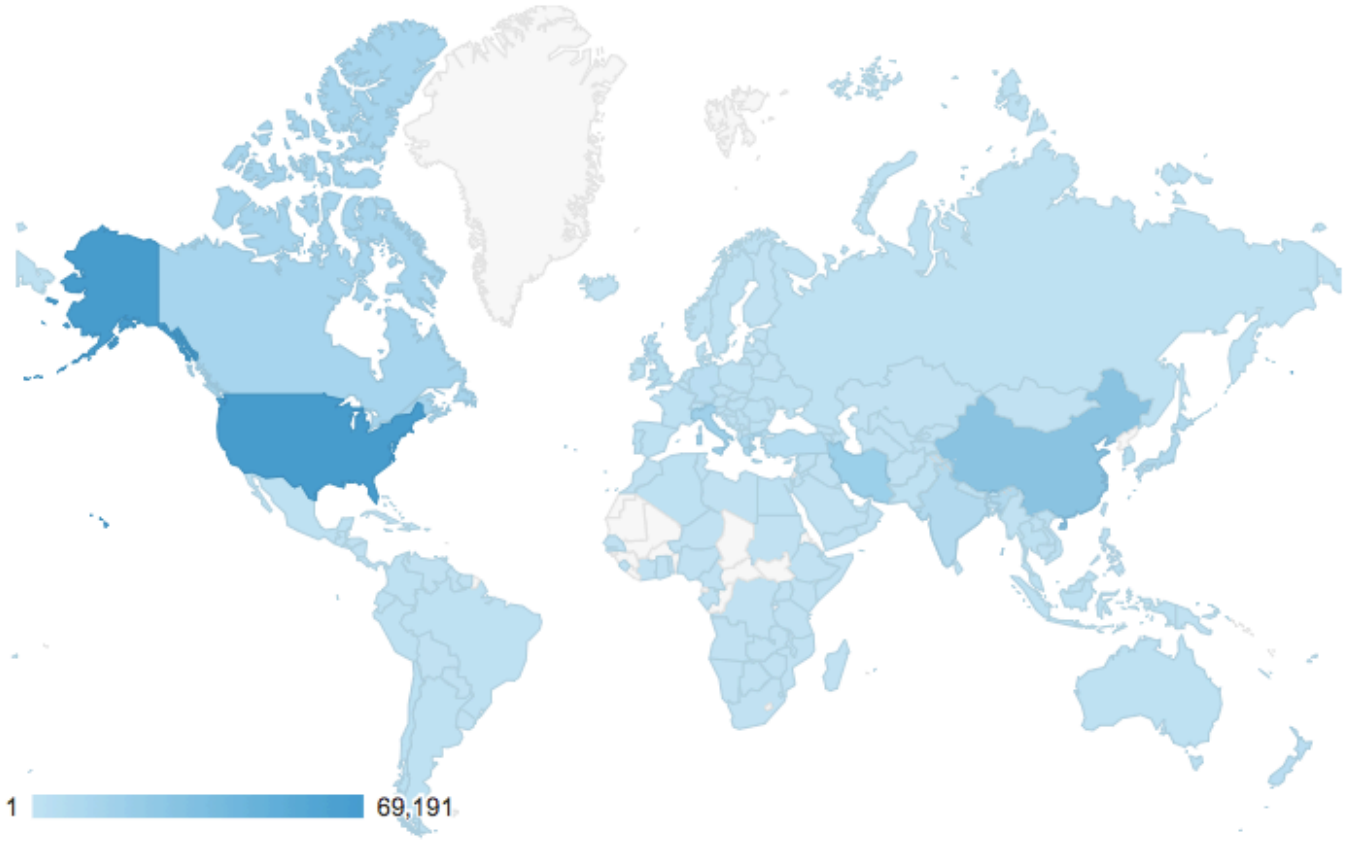
249,630

% of Total: **100.00% (249,630)**

Pageviews

1,492,715

% of Total: **100.00% (1,492,715)**



1. United States
2. China

Contributions Worldwide (2013)

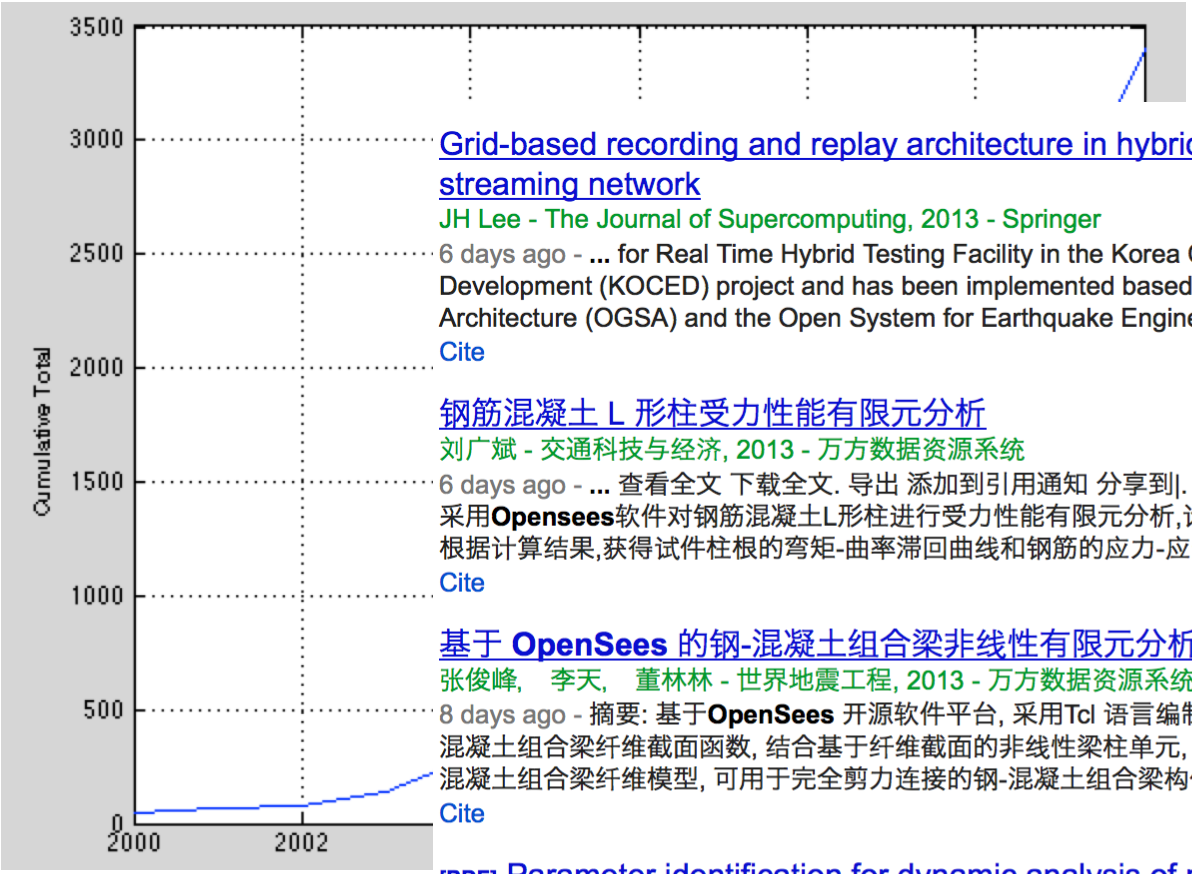
- *A hysteresis model for high damping rubber bearings. M.Kikuchi (Hokkaido University, Japan) and I. Aiken (Seismic Isolation Design, Inc)*
- *A number of stabilized single-point integration elements for use in continuum models: SSP_Quad, SSP_Brick, SSPquad_UP, SSPbrick_UP,, C McGann, P Mackenzie-Heinwein, and P. Arduino, University of Washington.*
- *New multi-spring elements. M.Kikuchi (Hokkaido University, Japan) and I. Aiken (Seismic Isolation Design, Inc)*
- *A new contact element. A. Zaghi and M.Cashany (University of Connecticut)*
- *ElasticOrthotropic material. (ElasticOrthotropic, ElasticOrthotropic3D) M. Scott (Oregon State)*
- *Additional elastometric Bearings elements (ElastomericBearing, ElastomericBearingBoucWen, ElastomericBearingPlasticity). A. Schellenberg (UC Berkeley)*
- ***SteelBRB Q.Gu (Xiamen University, P.R. China**)*
- *A number of deterioration models for use in modeling of structural frames using concentrated plasticity approach. ModIMKPeakOriented,ModIMKPeakPinching, Bilin D.Lignos, McGill*

Others contd.

- *BeamContact2D, BeamContact3D, BeamEndContact3D C McGann, P Mackenzie-Heinwein, and P. Arduino, University of Washington.*
- *Triple Friction Pendulum Element , N. Dao and K. Ryan, University of Nevada - Reno.*
- ***CapPasticity Q.Gu (Xiamen University, P.R. China)***
- *ManzariDafalias ND materials (3D, PlaneStrain) Alborz Ghofrani and P.Arduino*

Similar to Usage: Researchers in US and P.R. China main contributors to OpenSees

Primarily in Research



Google Scholar

[Grid-based recording and replay architecture in hybrid remote experiment using distributed streaming network](#)
JH Lee - The Journal of Supercomputing, 2013 - Springer
6 days ago - **...** for Real Time Hybrid Testing Facility in the Korea Construction Engineering Development (KOCED) project and has been implemented based on the Open Service Grid Architecture (OGSA) and the Open System for Earthquake Engineering Simulation (**OpenSees**) **...**
Cite

[钢筋混凝土 L 形柱受力性能有限元分析](#)
刘广斌 - 交通科技与经济, 2013 - 万方数据资源系统
6 days ago - **...** 查看全文 下载全文. 导出 添加到引用通知 分享到|. 下载PDF阅读器. doi： 摘要： 采用**Opensees**软件对钢筋混凝土L形柱进行受力性能有限元分析,计算结果与试验结果吻合较好. 根据计算结果,获得试件柱根的弯矩-曲率滞回曲线和钢筋的应力-应变滞回曲线 **...**
Cite

[基于 **OpenSees** 的钢-混凝土组合梁非线性有限元分析](#)
张俊峰, 李天, 董林林 - 世界地震工程, 2013 - 万方数据资源系统
8 days ago - 摘要: 基于**OpenSees** 开源软件平台, 采用Tcl 语言编制了钢-混凝土组合梁纤维截面函数, 结合基于纤维截面的非线性梁柱单元, 集成了钢-混凝土组合梁纤维模型, 可用于完全剪力连接的钢-混凝土组合梁构件及结构在竖向荷载及 **...**
Cite

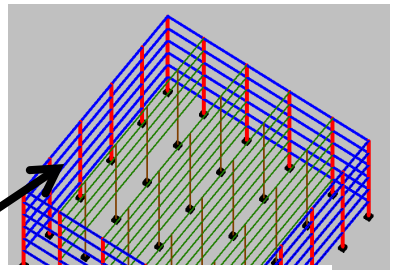
[PDF] [Parameter identification for dynamic analysis of pile foundation using non-linear py method](#)
J Simon - devmarabu.omikk.bme.hu
11 days ago - **...** girder bridges. As the first step, a numerical model is built in **OpenSEES** FEM software based on the idea of Beam on Non-Linear Winkler Foundation method. An overview **...** Numerical model in **OpenSEES** The numerical model of **...**
Cite More

[Research on System Reliability of Plane Steel Truss](#)
ZZ Wang, HJ Li - Applied Mechanics and Materials, 2013 - Trans Tech Publ
12 days ago - **...** Abstract. More and more attentions are paid on reliability and sensitivity of space structure in recently years. To investigate the mechanical characteristics of plane steel truss, **OpenSees** is utilized to evaluate component and system reliability plane steel truss. **...**

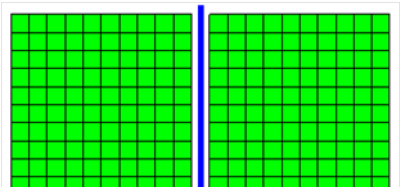
Example Usage

Perimeter Moment Resisting Frame

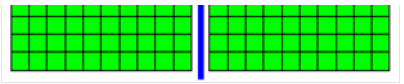
Interior Gra Fra

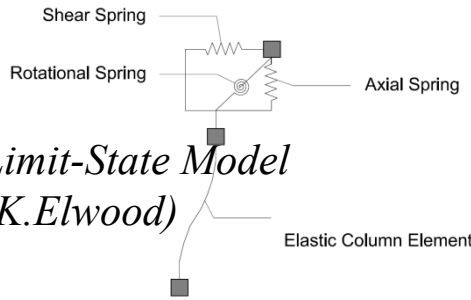


STRUCTURAL

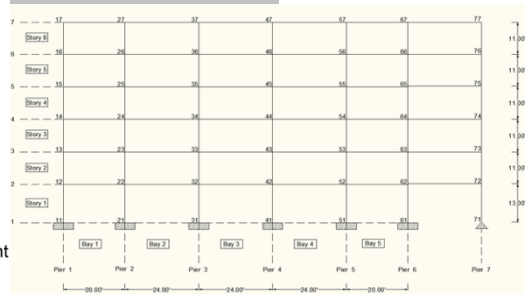


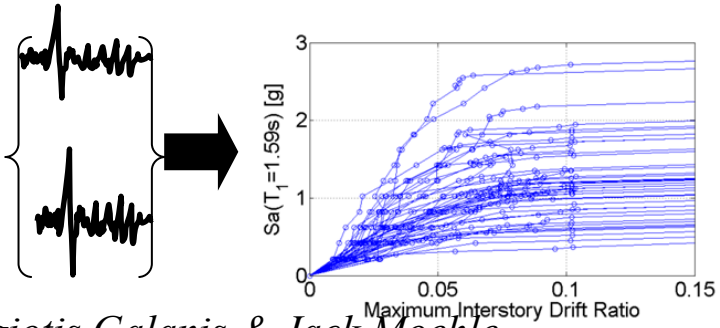
GEOTECHNICAL





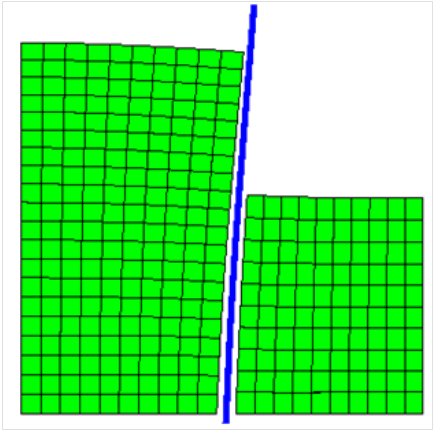
Limit-State Model (K.Elwood)





Panagiotis Galanis & Jack Moehle

ATC 78: Assessment of Collapse Risk of Existing Reinforced Concrete Buildings

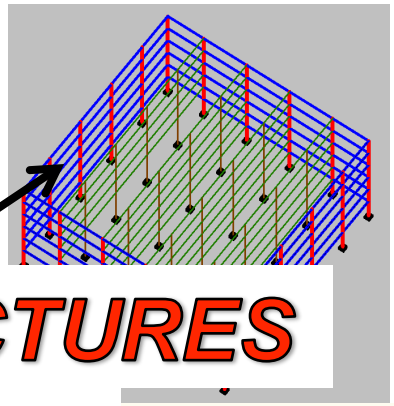


Pedro Arduino

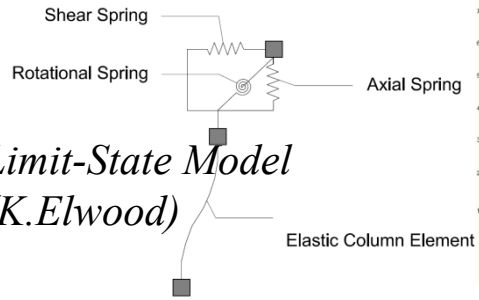
Example Usage

Perimeter Moment Resisting Frame

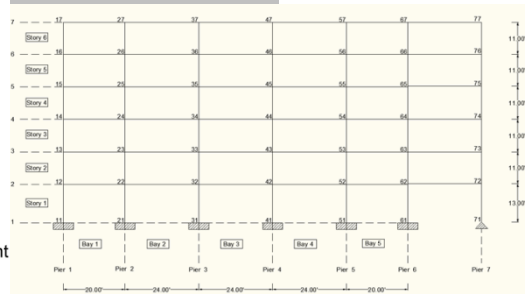
Interior Gra Fra

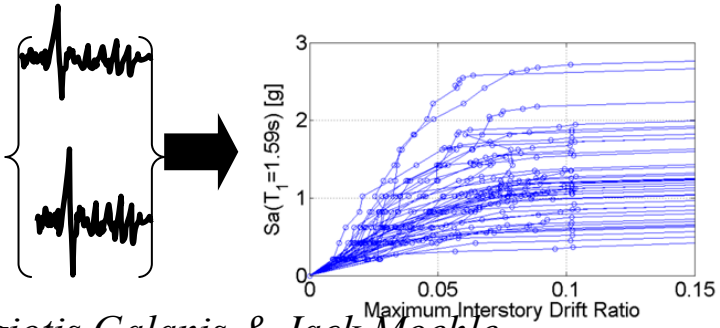


STRUCTURES



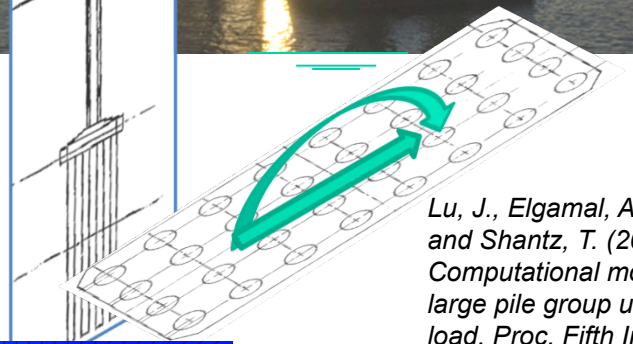
Limit-State Model (K.Elwood)

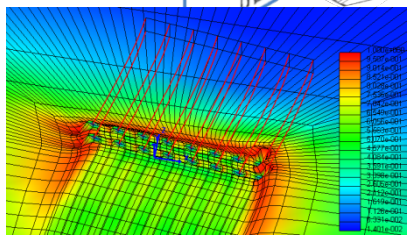


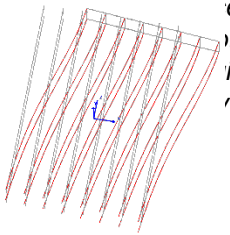


Panagiotis Galanis & Jack Moehle

ATC 78: Assessment of Collapse Risk of Existing Reinforced Concrete Buildings



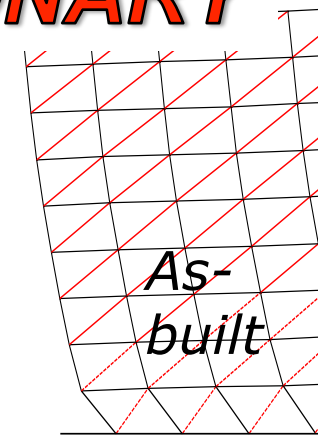


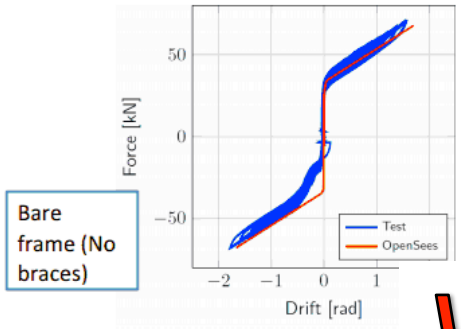


Lu, J., Elgamal, A., Sikorsky, C., and Shantz, T. (2010). Computational modeling of a large pile group under lateral load, Proc. Fifth Intl. Conf. on ent Advances in technical Earthquake ineering and Soil Dynamics, 24-29, San Diego, CA

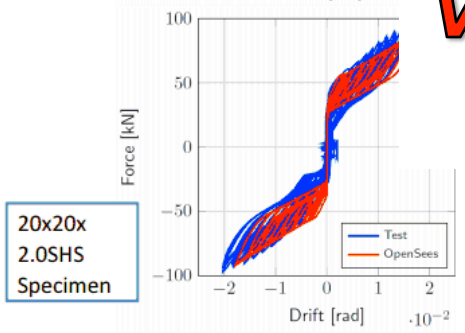
Jinchi Lu & Ahmed Elgamal

MASONARY





Bare frame (No braces)



20x20x 2.0SHS Specimen

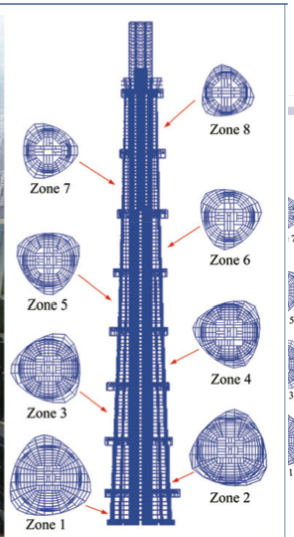
- Testing on bare frame demonstrated the bilinear elastic behavior of the frame and the OpenSees predicts the behavior very well.
- Testing with a 20x20x2.0SHS specimen showed the energy dissipation and self-centering of the frame and also that the OpenSees modeling predicts the behavior accurately.

VALIDATION

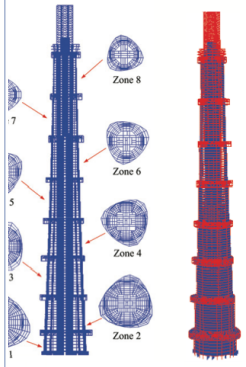
M.Talaat & K.Mosalam

NUI Galway
OÉ Gaillimh
IRISH RESEARCH COUNCIL
COMHAIRLE TAIGHDE na hÉIREANN

Comparison

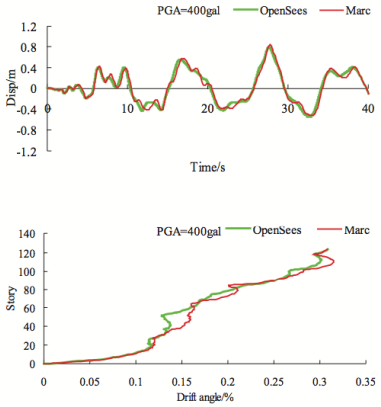


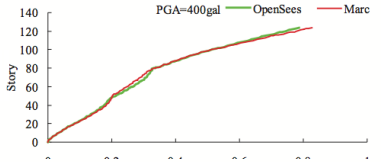
TBI Building 2 & Shanghai Tower

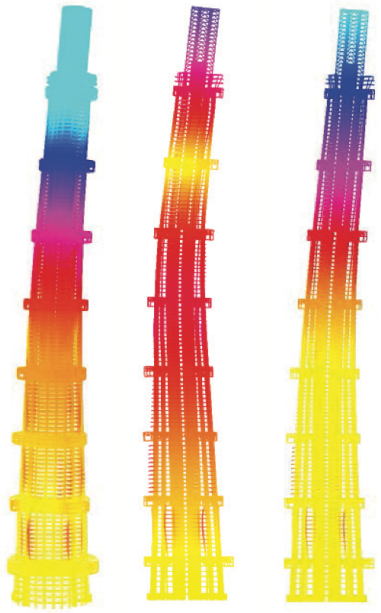


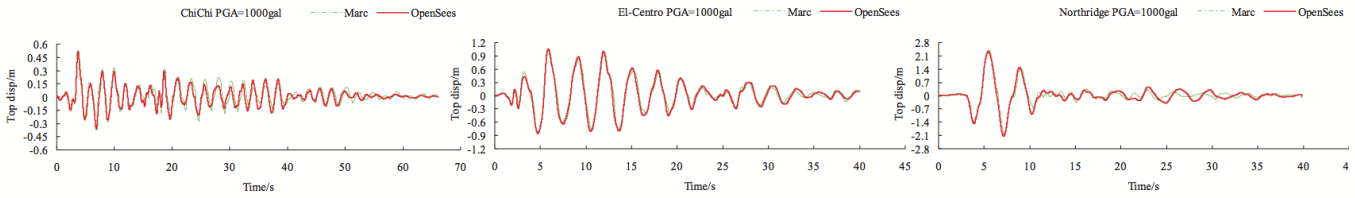
Shanghai Tower

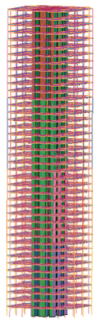
- H=632m, 124 stories
- 53,006 nodes
- 88,089 elements
- 48,774 fiber beam elements
- 39,315 multi-layer shell elements

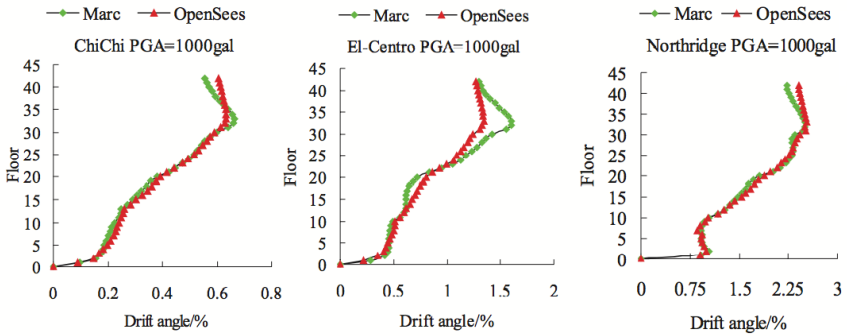












TBI Building-2

- H=141m, 42 stories
- 8,469 nodes
- 14,451 elements
- 9,744 fiber beam elements
- 39,315 multi-layer shell elements
- Memory used: 1.3GB

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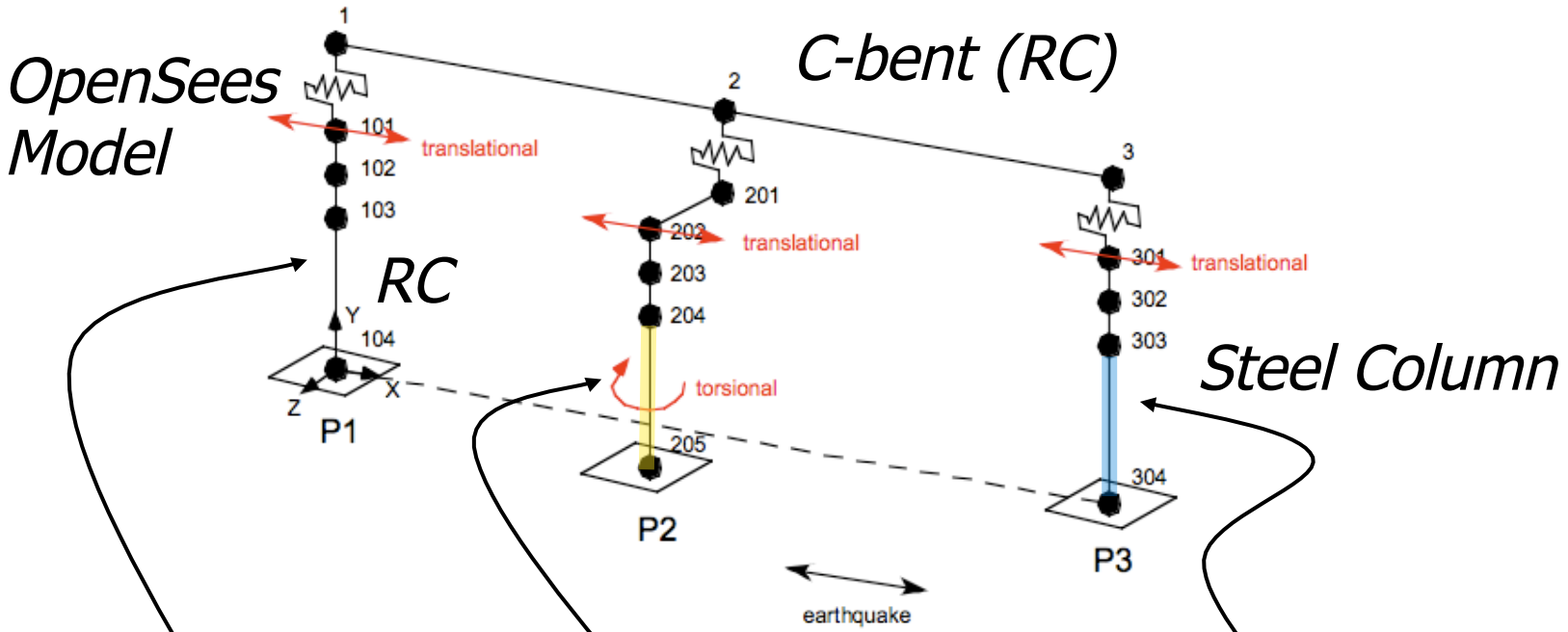
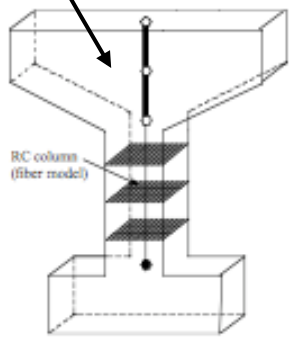
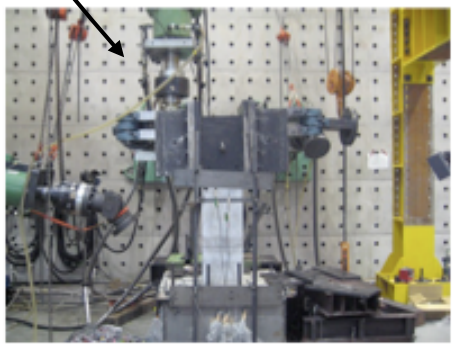
HYBRID SIMULATION

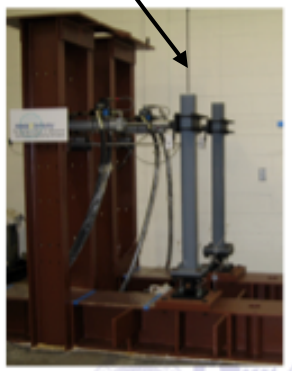




Numerical Component
at Kyoto University



Experimental Component
at Kyoto University



Experimental Component
at nees@berkeley

Kyoto/Berkeley

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