

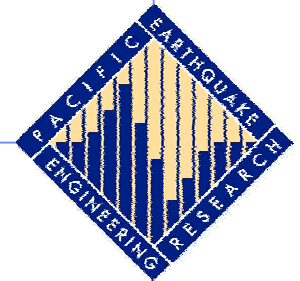


# OpenSees Update

Silvia Mazzoni, Frank McKenna,  
Gregory L. Fenves  
*University of California, Berkeley*



**PEER Annual Meeting  
San Francisco 2006**



## OpenSees activities

- ◆ Software development and maintenance
- ◆ Material & Element development by the OpenSees community
- ◆ Parallelization and distributed-computing effort
- ◆ Pre/Post-processing tools development by the OpenSees community
- ◆ Applications
- ◆ User Support

# OpenSees activities

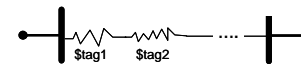
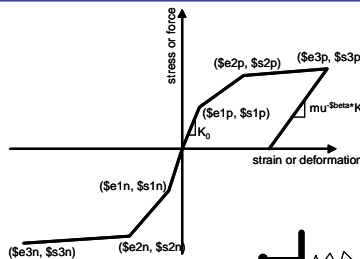
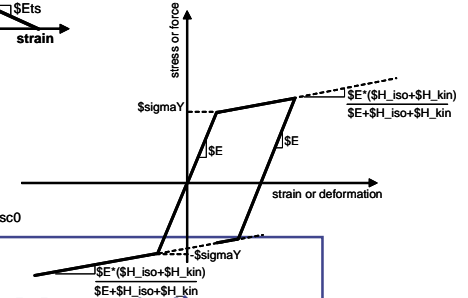
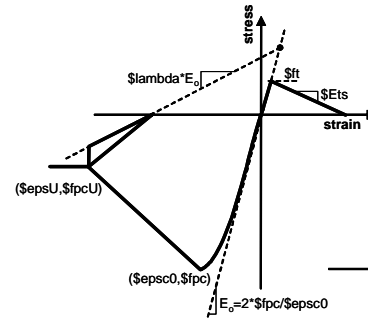
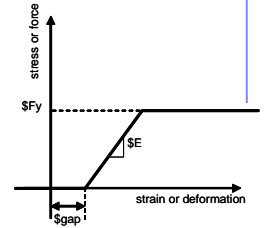
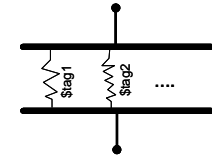
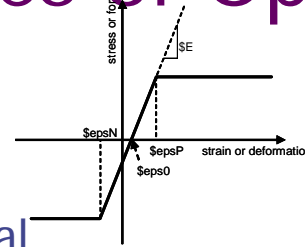
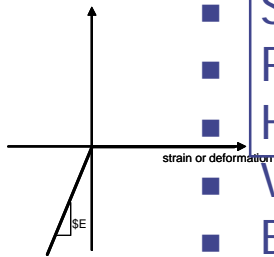
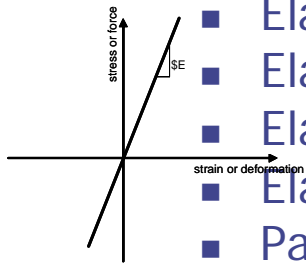
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- ◆ User Support

# Documented Capabilities of OpenSees



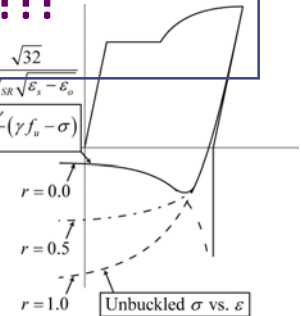
## Uniaxial Materials Library:

- Elastic Material
- Elastic-Perfectly Plastic Material
- Elastic-Perfectly Plastic Gap Material
- Elastic-No Tension Material
- Parallel Material
- Series Material
- Hardening Material
- Concrete01 Material -- Zero Tensile Strength
- Concrete02 Material -- Linear Tension Softening (Fedea's Material)
- Concrete03 Material -- Nonlinear Tension Softening (Fedea's Material)
- Concrete04 Material -- Popovics Concrete Material (for Mander Model)
- Steel01 Material
- Steel02 Material -- Giuffrè-Menegotto-Pinto Model w/ Isotropic Hardening
- Reinforcing-Steel Material ← **New and ready to try!!!!**
- Hysteretic Material
- Viscous Material
- BARSLIP Material
- Bond01 Material
- Bond02 Material
- PINCHING4 Material
- PyTzQz Uniaxial Materials



$$\Omega_b = \beta \frac{\sqrt{32}}{3\pi I_{SR} \sqrt{\epsilon_u - \epsilon_o}}$$

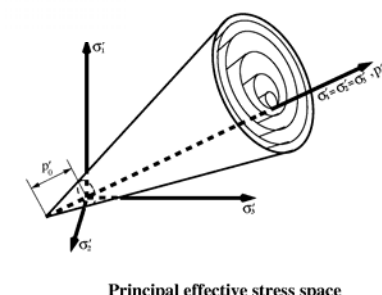
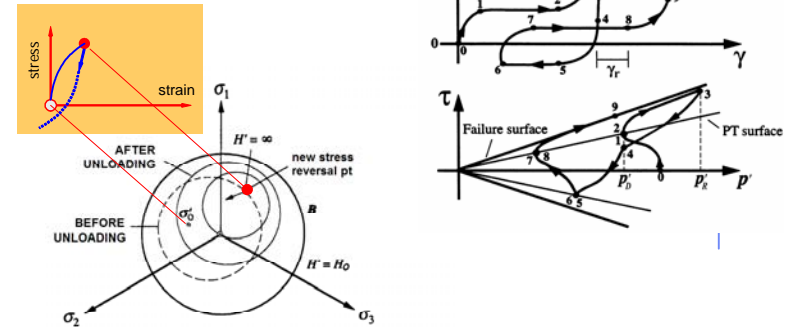
$$\sigma_b = \gamma f_u - \frac{\Omega_b + \gamma}{1 + \gamma} (\gamma f_u - \sigma)$$



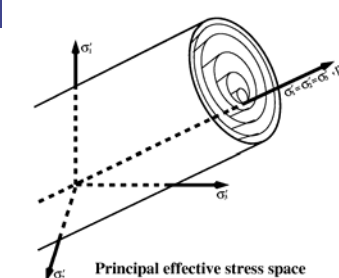
# Documented Capabilities of OpenSees

## ◆ nD Materials Library:

- Elastic Isotropic Material
- J2 Plasticity Material
- Plane Stress Material
- Plate Fiber Material
- Template Elasto-Plastic Material
- FluidSolidPorousMaterial Material
- PressureIndependMultiYield Material
- PressureDependMultiYield Material



Principal effective stress space

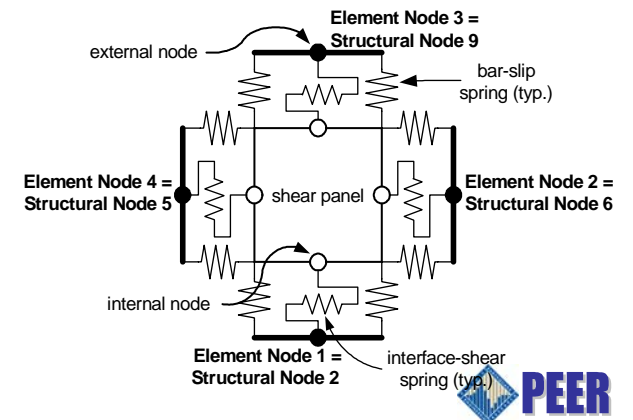


Principal effective stress space

# Documented Capabilities of OpenSees

## ◆ 1D & 2D Elements

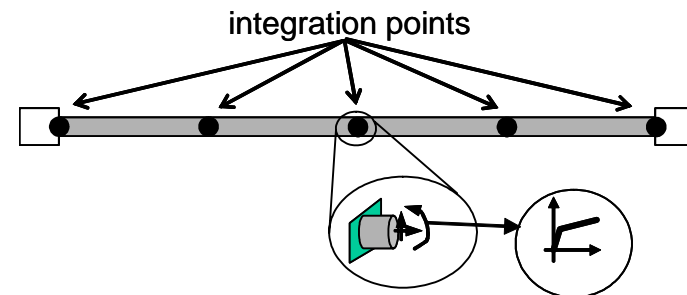
- Truss Element
- Corotational Truss Element
- Elastic Beam Column Element
- Nonlinear Beam Column Elements
  - ◆ Force-Based Nonlinear Beam Column Element
  - ◆ Force-Based Beam With Hinges Element
  - ◆ Displacement-Based Beam-Column Element
- Zero-Length Elements
  - ◆ Zero-Length Element
  - ◆ Zero-Length ND Element
  - ◆ Zero-Length Section Element
- BeamColumnJoint Element



# Force-Based Nonlinear Beam-Column Elts

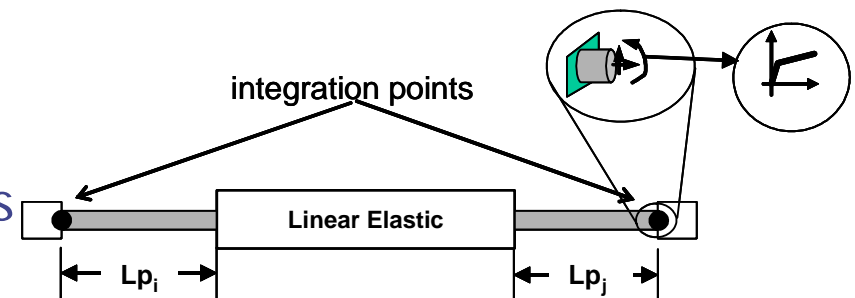
## ◆ Force-Based Nonlinear Beam Column Element

- considers the spread of plasticity along the element
- useful for distributed loads along element



## ◆ Force-Based Beam With Hinges Element<sup>1</sup>

- considers the spread of plasticity to be concentrated over specified hinge lengths at the element ends
- useful for softening/localization problems
- useful for local deformation measures



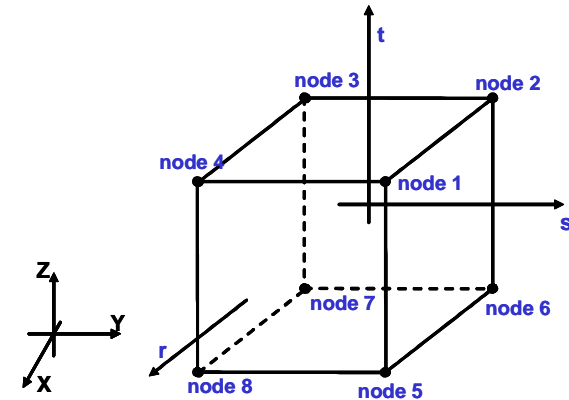
<sup>1</sup> Scott, M.H. and G.L. Fenves. "Plastic Hinge Integration Methods for Force-Based Beam-Column Elements", ASCE Journal of Structural Engineering, 132(2):244-252, February 2006.

# Documented Capabilities of OpenSees

## ◆ 3D Elements

### ■ Quadrilateral Elements

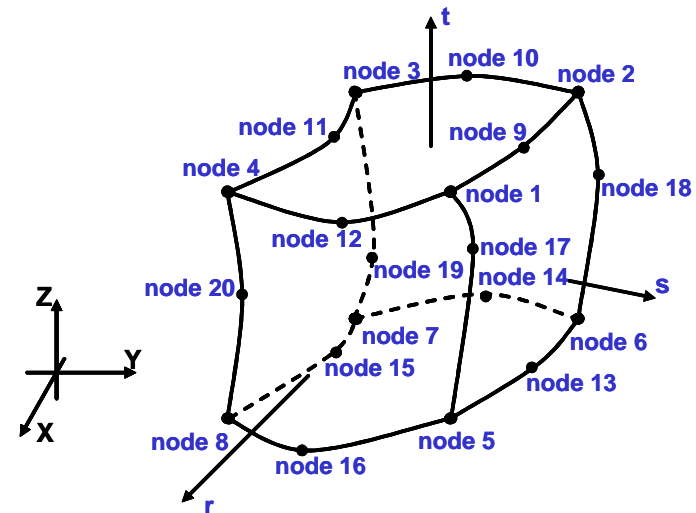
- ◆ Quad Element
- ◆ Shell Element
- ◆ Bbar Plane Strain Quadrilateral Element
- ◆ Enhanced Strain Quadrilateral Element



### ■ Brick Elements

- ◆ Standard Brick Element
- ◆ Bbar Brick Element
- ◆ Eight Node Brick Element
- ◆ Twenty Node Brick Element
- ◆ u-p-U element

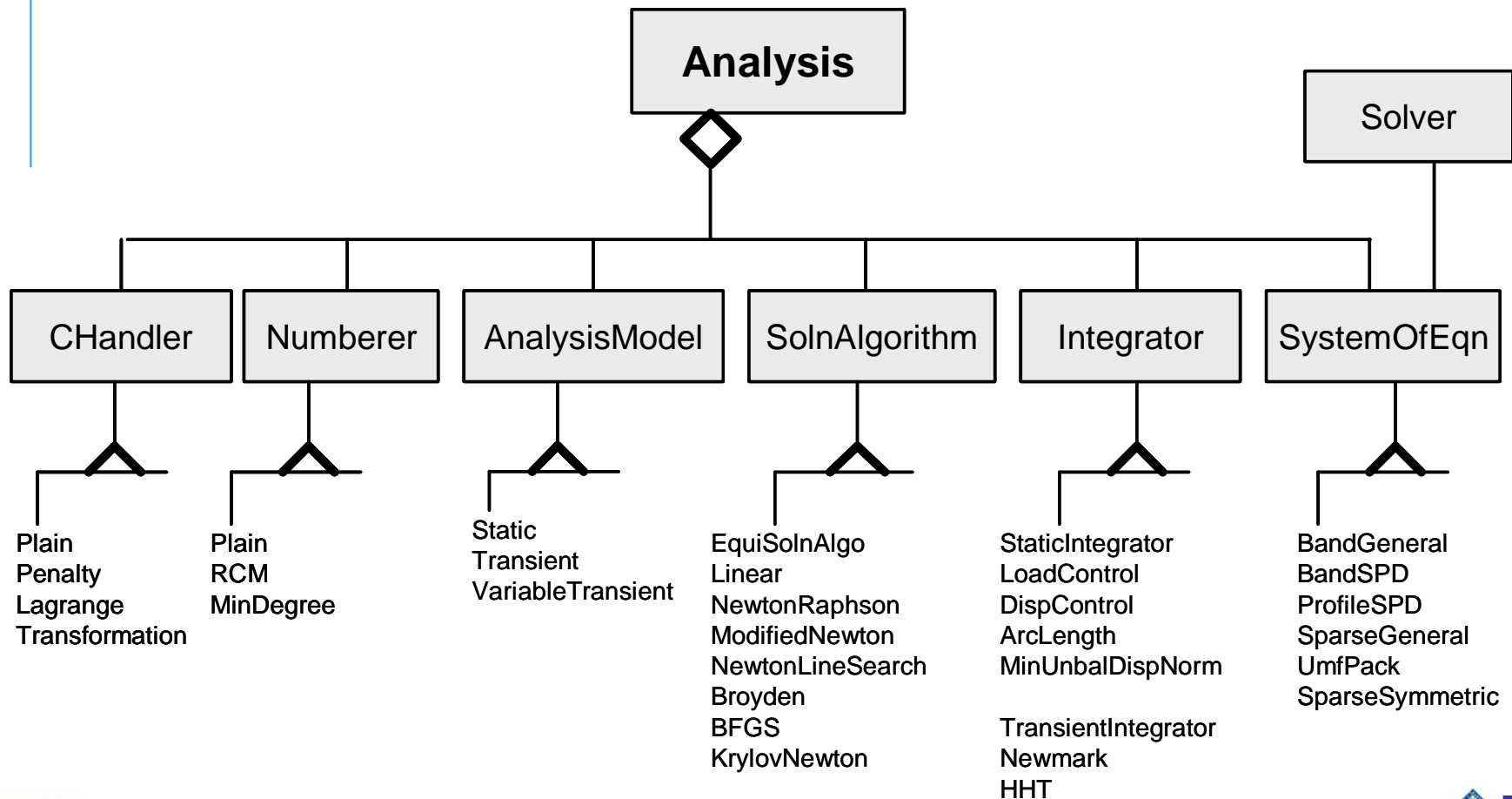
### ■ FourNodeQuadUP Element





# Documented Capabilities of OpenSees

- ◆ The analysis/solution process is transparent
  - User can tailor the procedure to the specific problem to optimize solution process



# OpenSees activities

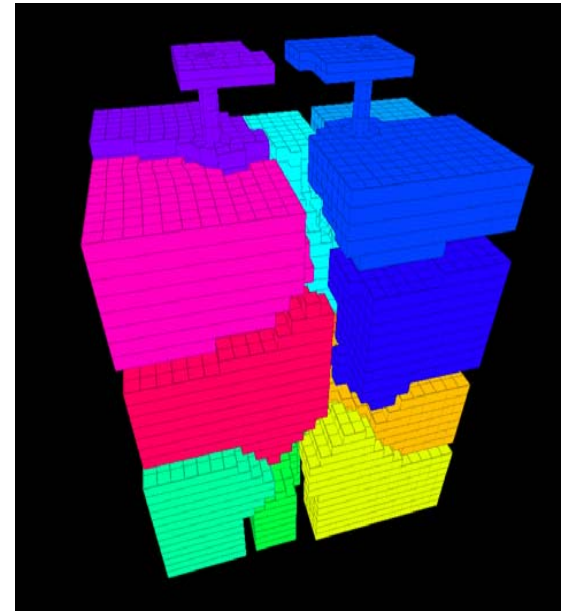
- ◆ Software development and maintenance
- ◆ Material & Element development by the OpenSees community
- ◆ Parallelization and distributed-computing effort
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- ◆ Applications
- ◆ User Support

# Plastic Domain Decomposition Parallel OpenSees

**Boris Jeremic**

UC Davis

The Plastic Domain Decomposition (PDD) OpenSees implements parallel computational methodology designed for efficient and scalable computations with inelastic (elastic-plastic) finite element on distributed memory parallel computers.



# Geotechnical Capabilities and Applications

Dr. Liangcai He

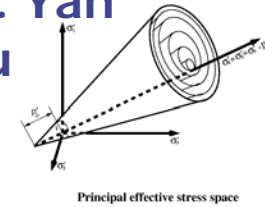
Dr. Zhaohui Yang

Prof. Ahmed Elgamal

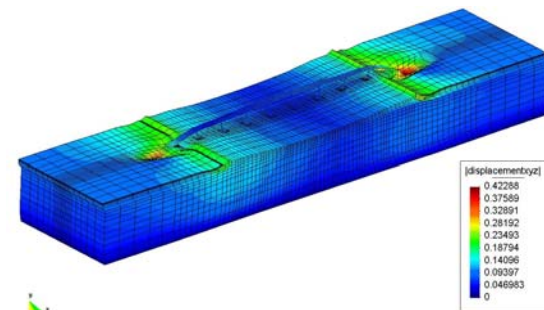
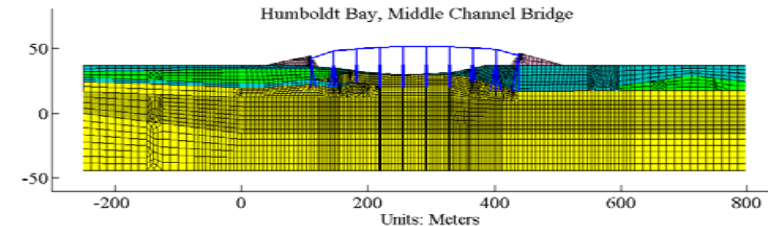
UC San Diego

Mr. James L. Yan

Mr. Jinchi Lu



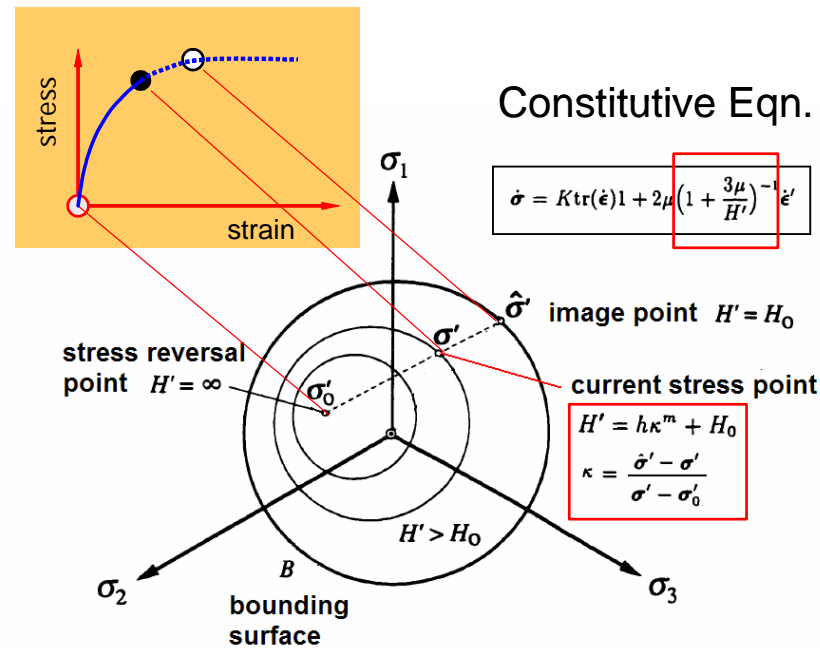
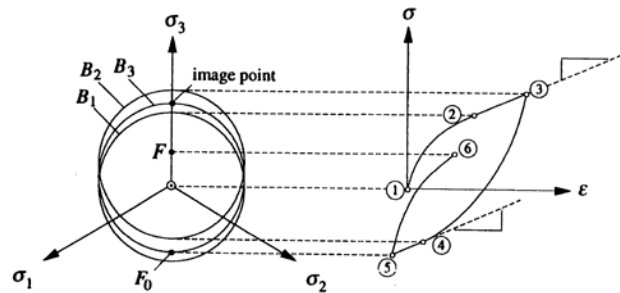
- ◆ Material Models
  - Solid-Fluid Fully Coupled Elements Implemented in OpenSees
  - Pressure Dependent Soil Model (for Sands and Silts)
  - Pressure Independent Soil Model (for Clays and Silts)
  - Undrained Material Model
- ◆ OpenSees analysis of bridge-ground interaction effects
  - OpenSees Model of Humboldt Bay Bridge
- ◆ 3D OpenSees Bridge Model
  - Defining Spatially Varying Ground Motion using Domain Reduction Method (Bielak et al. 2003)
- ◆ OpenSees analysis of liquefaction-induced lateral spreading effects on piles
  - Shake-table and Soil Box used in the Experiments
  - 3D Finite Element Study



# A Cyclic Soil Model & its Application in Soil-Pier Interaction Under Axial Load

- ◆ Dynamic Soil-Pile-Structure System
- ◆ Nonlinear Cyclic Soil Response
- ◆ Bounding Surface Cyclic Soil Model (R. Borja)
  - Hardening Rule
  - Loading/Unloading Criterion
  - Unloading

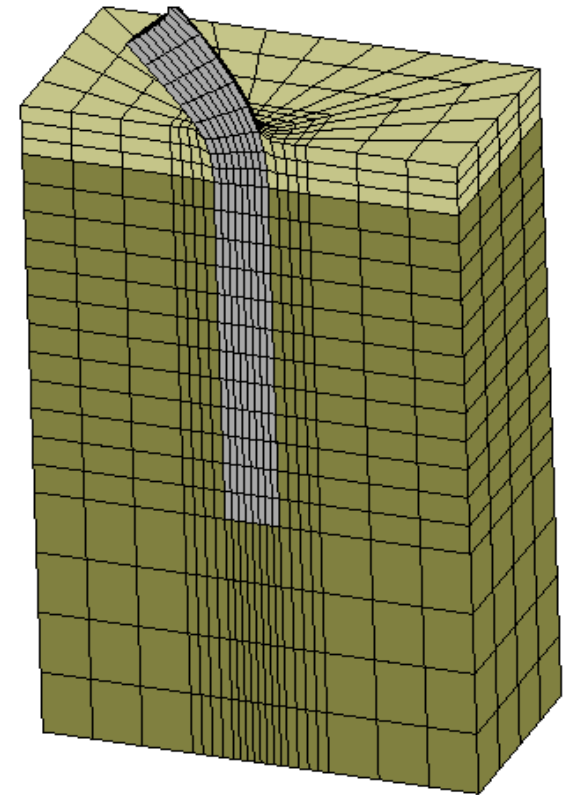
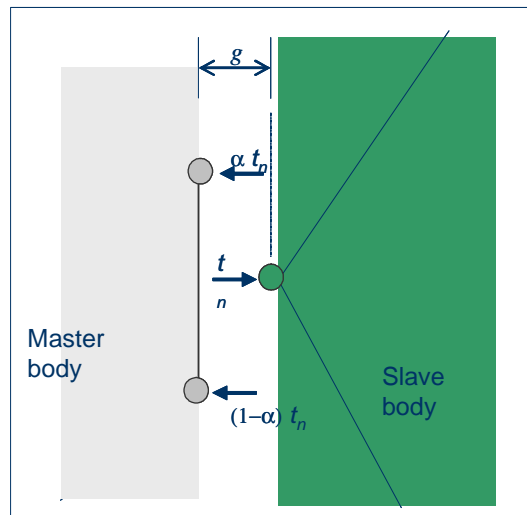
Gang Wang  
 Nicholas Sitar  
 UC Berkeley



# Two and Three-Dimensional Contact Element Implementation for Geotechnical Applications

- ◆ Realistic soil-pile interaction
- ◆ Consideration of complex soil models
- ◆ Alternative pile modeling approaches
- ◆ Pile-soil interaction: stick, slip, debonding, and rebonding behavior
- ◆ Contact element applies a geometric constraint to the system that relates a slave node to a master contact line segment or surface.

**Kathryn Petek**  
**Pedro Arduino**  
**Peter Mackenzie-Helnwein**  
University of Washington

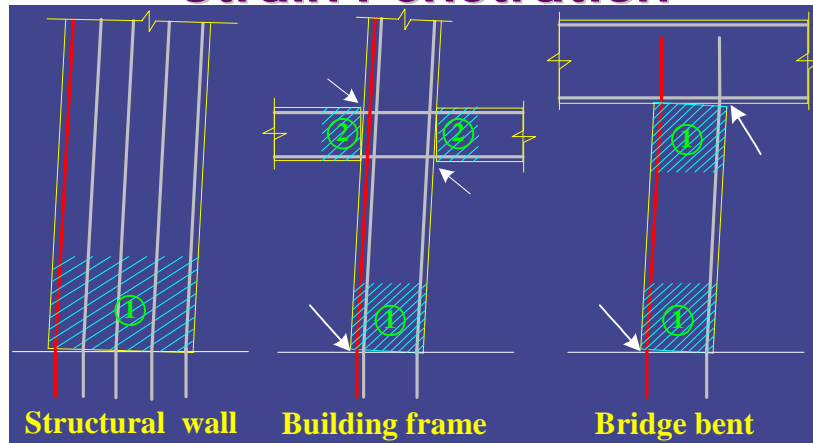


# Bond-SP01: Bond-slip model to Capture Strain Penetration Effects in OpenSees

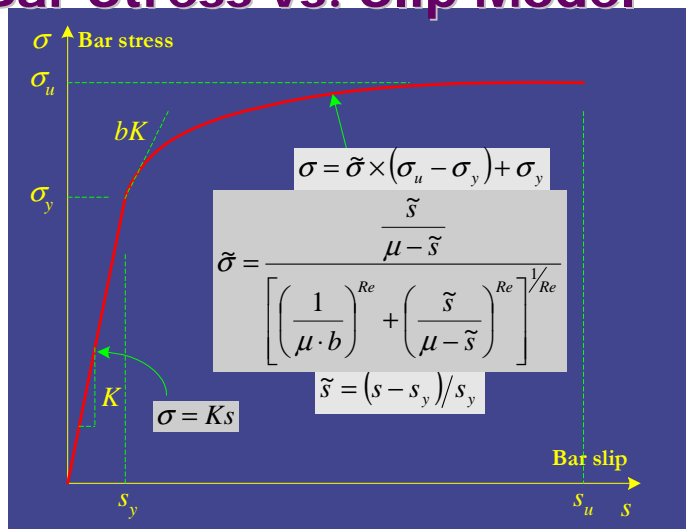
Sri Sritharan  
Iowa State University

Jian Zhao  
University of Wisconsin - Milwaukee

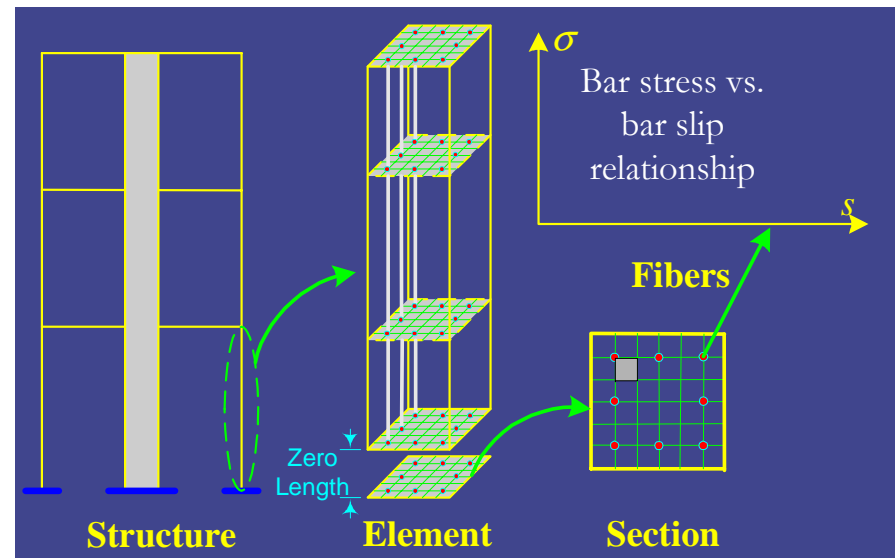
## Strain Penetration



## Bar Stress vs. Slip Model



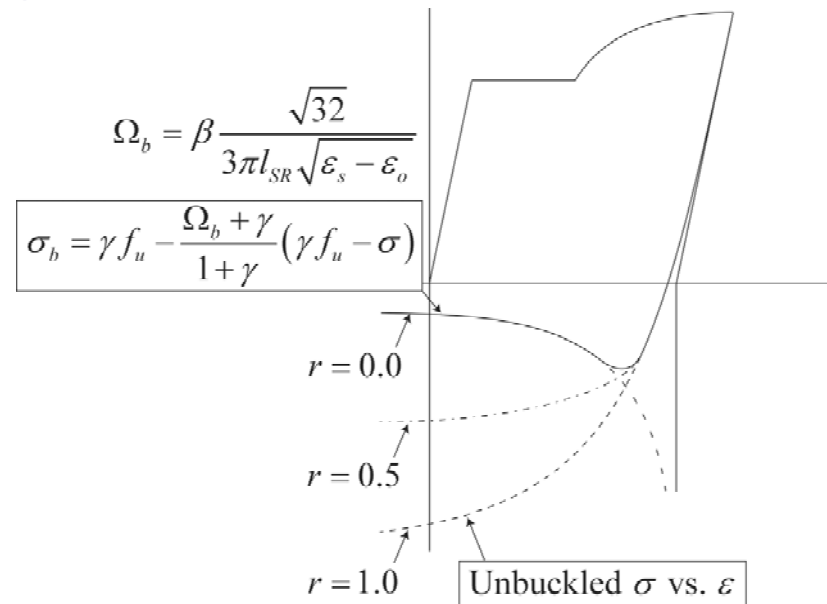
## Zero-length Section Element



# Uniaxial Material Model for Reinforcing Steel Incorporating Buckling and Low-Cycle Fatigue

Jon Mohle, Sashi Kunnath  
UC Davis

- ◆ Buckling Behavior
- ◆ Low-Cycle Fatigue and Fracture
- ◆ Cyclic Degradation



uniaxialMaterial ReinforcingSteel \$matTag \$fy \$fu \$Es \$Esh \$esh \$eult  
<\$lsr> <\$beta \$r \$gamma> <\$Cf \$alpha \$Cd>



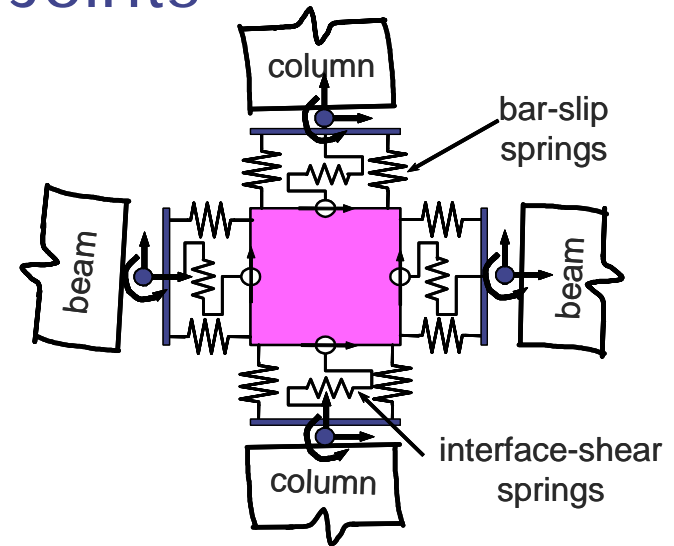
# OpenSees Development and Validation

Laura N. Lowes

University of Washington

## ◆ Modeling RC Beam-Column Joints

- Element Development
- Material Model Development
  - ◆ Pinching4 Material Model
  - ◆ Bar-Slip Material Model
- Validation Study



## ◆ Modeling RC Bridge Columns for PBEE

- Concrete Material Model
- Variable Plastic-Hinge Length Model
- Plastic-Hinge Length Calibration Study

# Application of Shape Memory Alloys Using OpenSEES

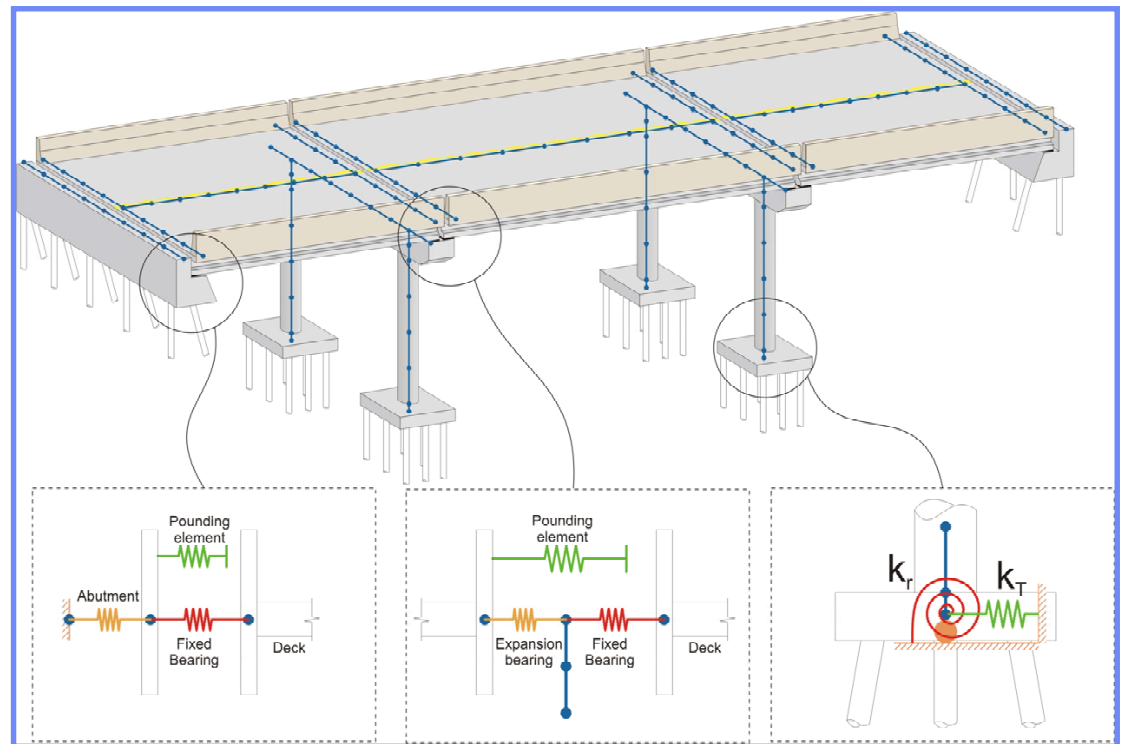
Reginald DesRoches  
Georgia Tech

## ◆ Applications

- Bridge Restrainers
- Braced-Frame Steel Buildings
- SMA Beam Column Connections

## ◆ OpenSEES Development Work

- PR Connections
- SMA Connections
- Energy Recorders



# Nonlinear Stochastic Dynamic Analysis

Kazuya Fujimura

Armen Der Kiureghian

University of California, Berkeley

## ◆ Stochastic characterization of ground motion

Define the ground motion as a stochastic process, consistent with the characteristics of the local site and given *im*.

## ◆ Nonlinear random vibration analysis

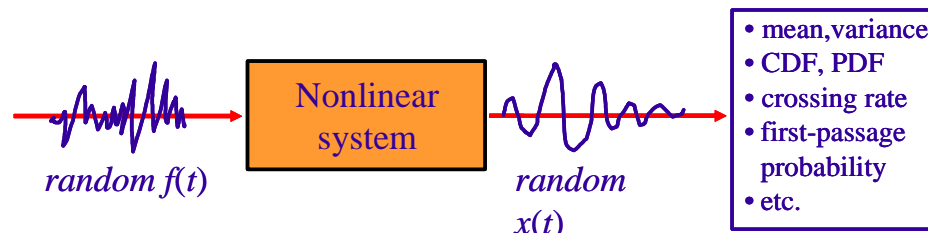
Compute the statistics of *EDP* by nonlinear random vibration analysis and first-passage probability.

## ◆ New method being implemented in OpenSees:

- *Tail-Equivalent Linearization Method* (TELM)

$$v(DV) = \int \int \int G(dv | dm) | dG(dm | edp) | \boxed{dG(edp | im)} | dv(im) |$$

$$G(edp | im) = \Pr(EDP > edp | im)$$

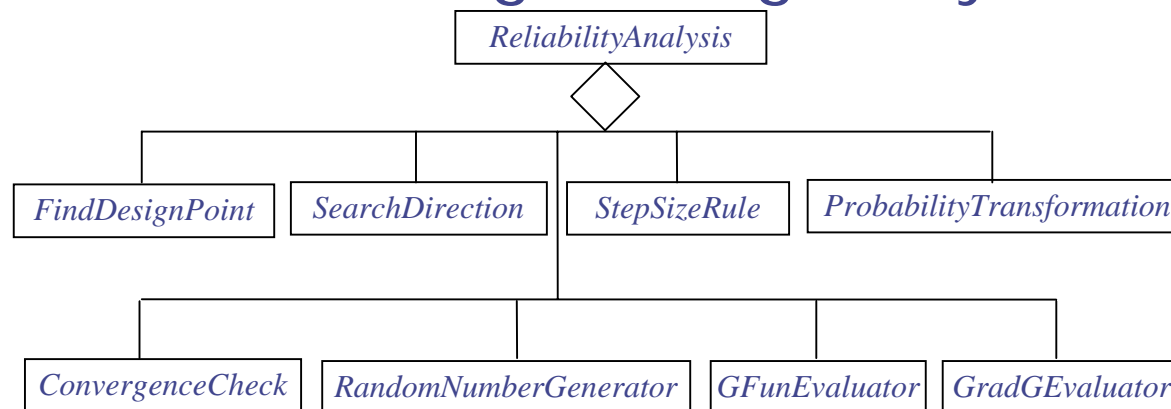


# Reliability-based Design Optimization in OpenSees

Terje Haukaas

UBC, Vancouver

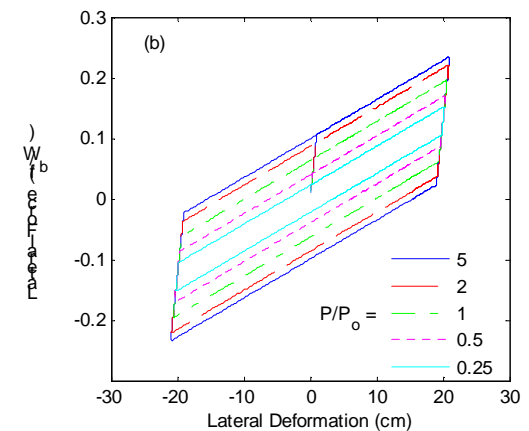
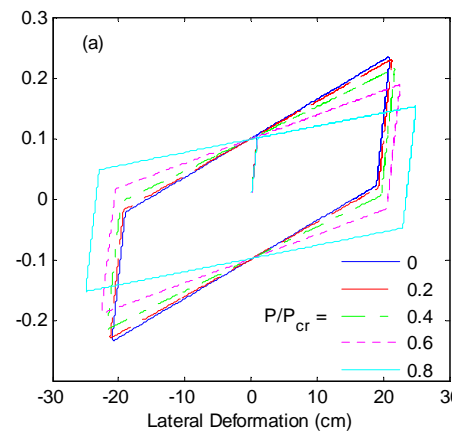
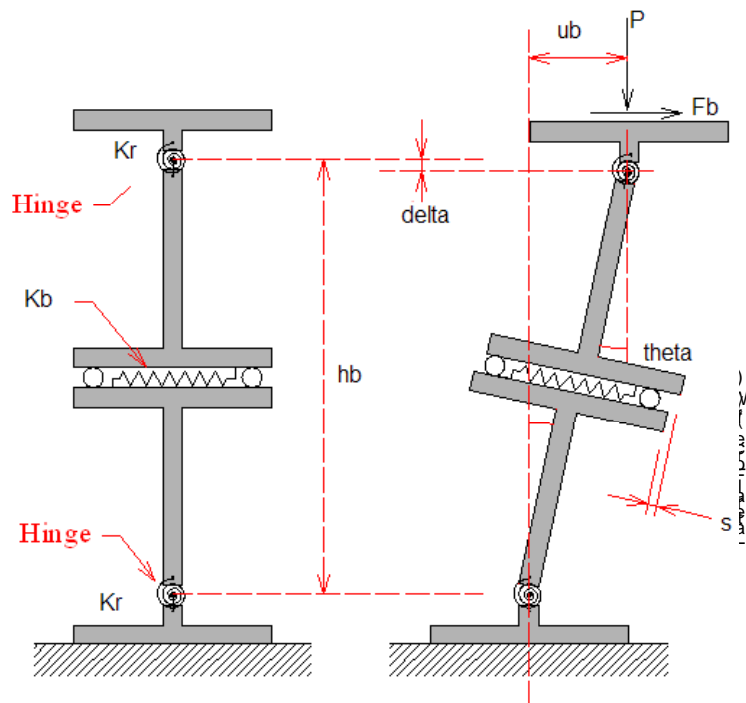
- ◆ Reliability-based Optimal Design
- ◆ Determination of Costs and Probabilities
- ◆ Objective:
  - Implement *Reliability-based design optimization* (RBDO) analysis capabilities in main-stream engineering analysis software



# Isolator2spring Section – Model to include buckling behavior of an elastomeric bearing

Keri L. Ryan  
Utah State University

- ◆ buckling behavior of an elastomeric bearing for two-dimensional analysis in the lateral and vertical plane



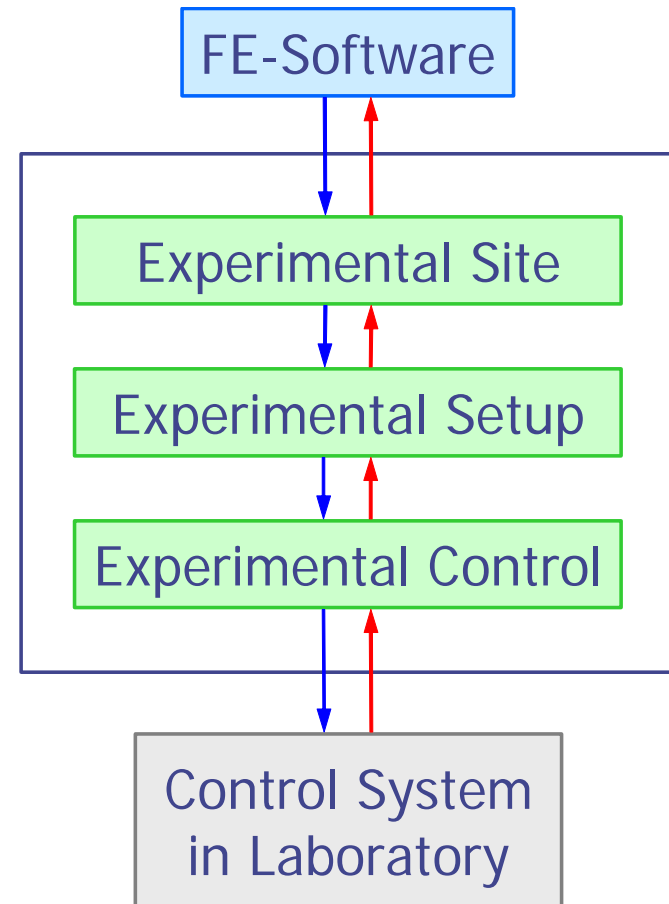
# OpenFRESCO

<http://opensees.kuciv.kyoto-u.ac.jp/fresco/>

**Yoshikazu Takahashi**  
Kyoto University, Japan

**Andreas Schellenberg**  
UC Berkeley

- ◆ FRESCO is the object-oriented software framework for experimental setup and control to develop software to manage distributed experimental tests for structural systems.

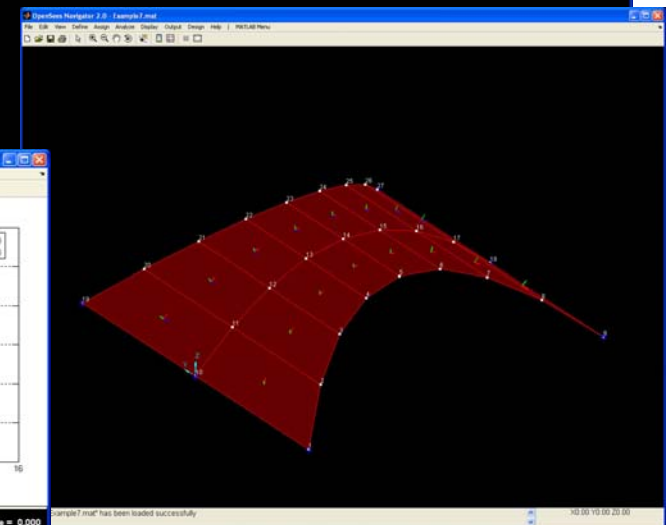
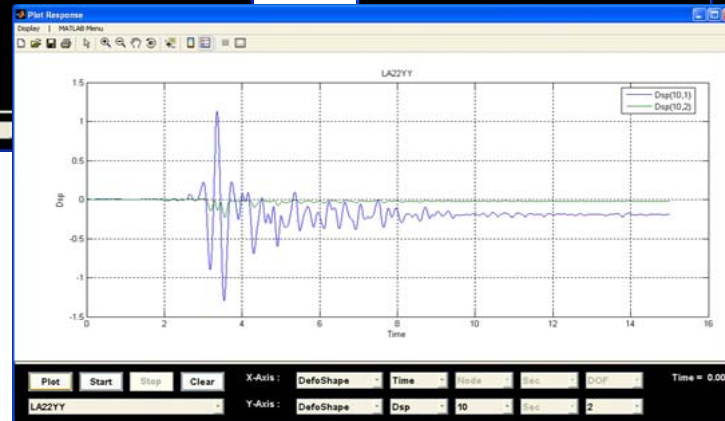
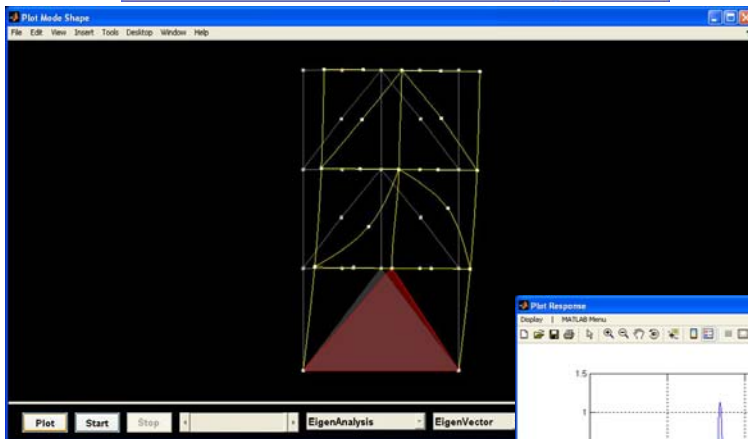
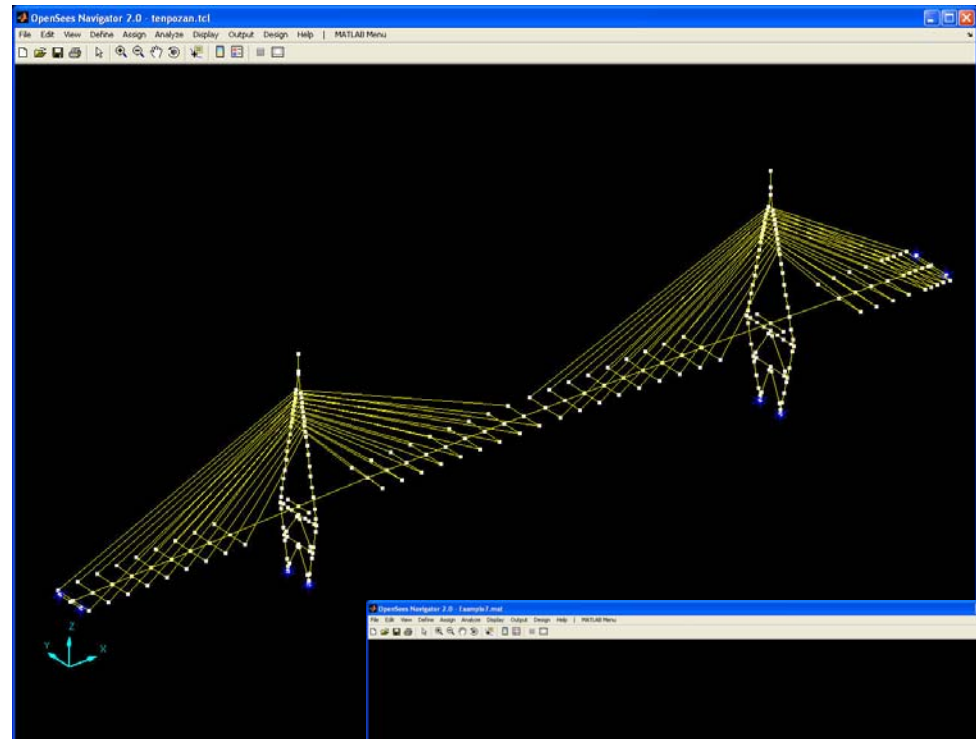
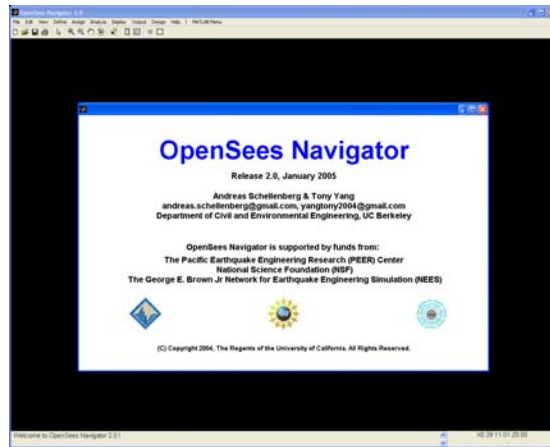


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# OpenSees Navigator

<http://peer.berkeley.edu/OpenSeesNavigator/>





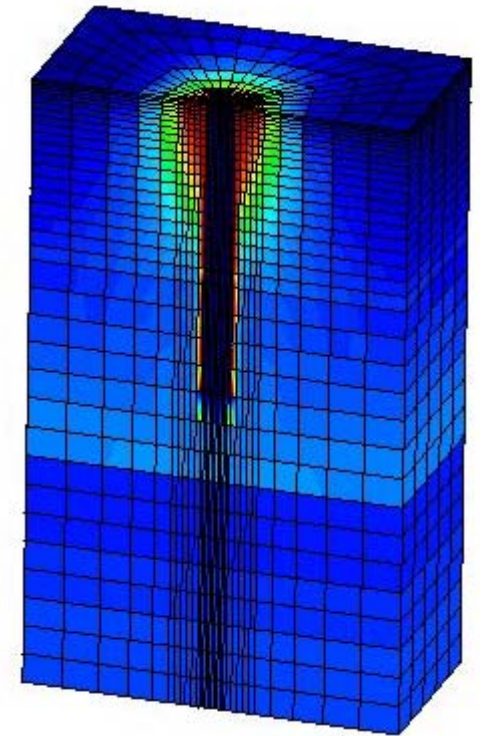
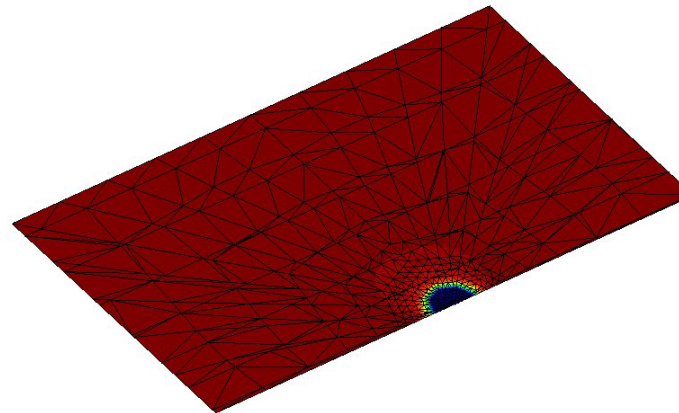
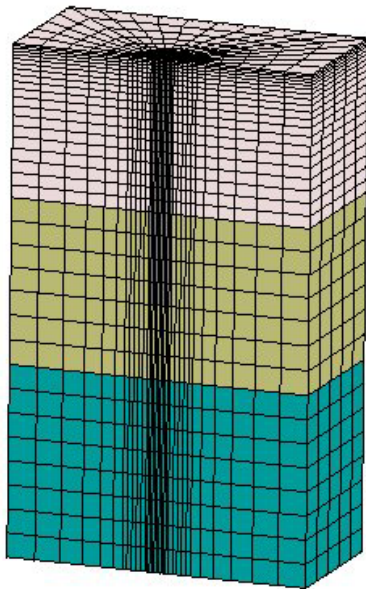
# University of Washington



## GiD-applications Development

Developed pre- and post-processing tools using commercial software GiD

- Model creation
- Mesh generation
- Results visualization



# OpenSees Tcl Editor, Stanford University

The screenshot displays the OpenSees Tcl Editor interface. The main window shows a Tcl script with syntax highlighting. The script defines beam-column elements and their geometry. A table lists the elements and their parameters:

	tag	ndI	ndJ	A	E	Iz
element elasticBeamColumn	1	39	40	1e06	3e04	1e06
element elasticBeamColumn	2	41	42	1e06	3e04	1e06
element elasticBeamColumn	3	43	44	1e06	3e04	1e06
element elasticBeamColumn	4	45	46	1e06	3e04	1e06
element elasticBeamColumn	5	47	48	1e06	3e04	1e06
element elasticBeamColumn	6	49	50	1e06	3e04	1e06

The interface includes a menu bar (File, Edit, View, Help), a toolbar, and a command summary window at the bottom. The command summary window provides context-sensitive help for the `elasticBeamColumn` command, listing its arguments and their meanings.

OpenSees interface

Syntax highlighting

Command reference

Context sensitive help

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# OpenSEES user resources

◆ <http://OpenSEES.berkeley.edu/>

- Both an executable version and the source code are publicly available
- User Command Manual
- Examples Manual
- e-mail technical support
- The OpenSEES Community Forum

◆ Annual User Workshops

# http://OpenSEES.berkeley.edu/

The screenshot shows a Netscape browser window displaying the OpenSees website. The browser's address bar shows the URL <http://opensees.berkeley.edu/index.html>. The website header features the OpenSees logo and the text "Open System for Earthquake Engineering Simulation" and "Pacific Earthquake Engineering Research Center". A "Quick Links" dropdown menu is visible, listing "Main Page", "About", "Projects", "User Pages", and "Developer Pages". The main content area includes a "Welcome" section, a "Register!" section, a "Need Support?" section, and a "Latest News" section. The "Welcome" section states: "Welcome to the website for OpenSees, a software framework for developing applications to simulate the performance of structural and geotechnical systems subjected to earthquakes." The "Register!" section says: "For information about new releases we encourage you to register with us at the [OpenSees Registration Center](#)." The "Need Support?" section says: "If you need assistance or have any bugs to report, send an e-mail to [technical support](#)." The "Latest News" section has two entries: "January 31, 2005 Finally, the [Workshop Material](#) presented at the September workshop is available for download." and "Nov 30, 2004 A Version 1.6.1 [binary](#) is now available." The footer of the browser window shows the Windows taskbar with the Start button and several open applications, including "2005\_02Feb\_11\_Ste...", "Open System for Ear...", "Outstanding attenda...", "Microsoft PowerPoint...", and "Open System for E...". The system clock shows "12:05 PM".


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

Quick Links

- ◆ [Main Page](#)
- ◆ [About](#)
- ◆ [Projects](#)
- ◆ [User Pages](#)
- ◆ [Developer Pages](#)

◆ [FAQ](#)

◆ [Related Links](#)

  
Pacific Earthquake Engineering Research Center

### Welcome

Welcome to the website for OpenSees, a software framework for developing applications to simulate the performance of structural and geotechnical systems subjected to earthquakes.

The goal of the OpenSees development is to improve the modeling and computational simulation in earthquake engineering through open-souce development.

OpenSees is in under continual development, so users and developers should expect changes and updates on a regular basis. In this sense, all users are developers so it is important to [register](#). More information on [Open Source](#) is available.

The development and application of OpenSees is sponsored by the [Pacific Earthquake Engineering Research Center](#) through the [National Science Foundation](#) engineering and education centers program.

OpenSees has been selected as the simulation component for the [George E. Brown, Jr. Network for Earthquake](#)

### Register!

For information about new releases we encourage you to register with us at the [OpenSees Registration Center](#).

### Need Support?

If you need assistance or have any bugs to report, send an e-mail to [technical support](#)

### Latest News

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**Nov 30, 2004**  
A Version 1.6.1 [binary](#) is now available.

**Sent 1, 2004**

# OpenSEES user resources

◆ <http://OpenSEES.berkeley.edu/>

- Both an executable version and the source code are publicly available
- User Command Manual
- Examples Manual
- e-mail technical support
- The OpenSEES Community Forum

◆ Annual User Workshops

# OpenSEES user resources

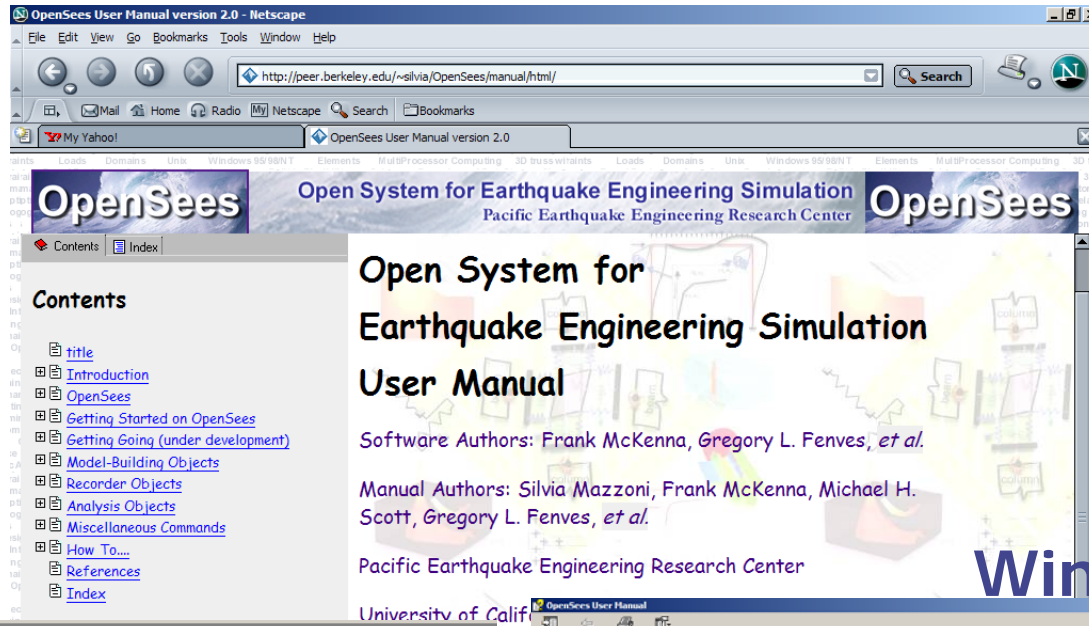
◆ <http://OpenSEES.berkeley.edu/>

- User Command Manual -- *A document providing the syntax and description of OpenSEES commands in 3 formats:*
  1. **HTML Manual** – on-line HTML document, residing on OpenSEES server. Always going to be the most current.
  2. **MS Word** – downloadable and printable Word document in PDF format
  3. **Offline Windows** – downloadable .chm file. it is similar to the HTML format, but the file resides on your computer.



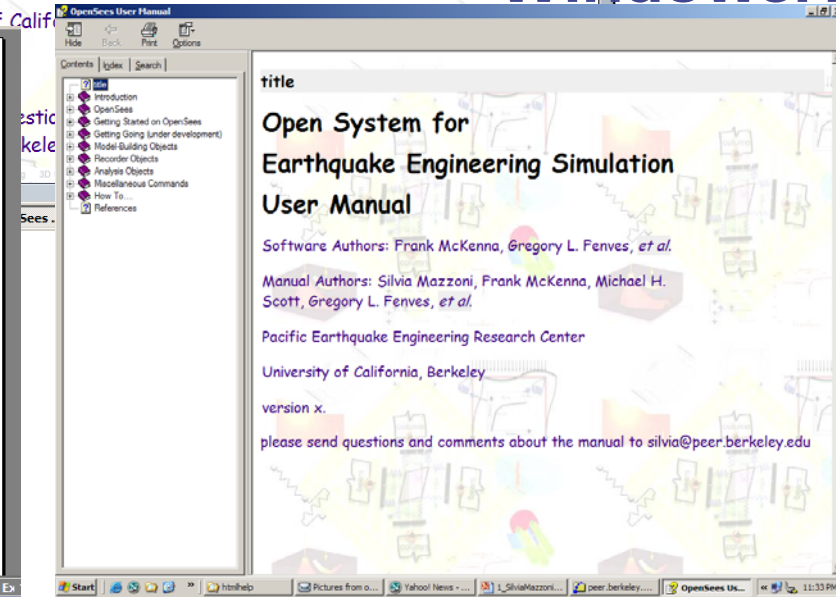
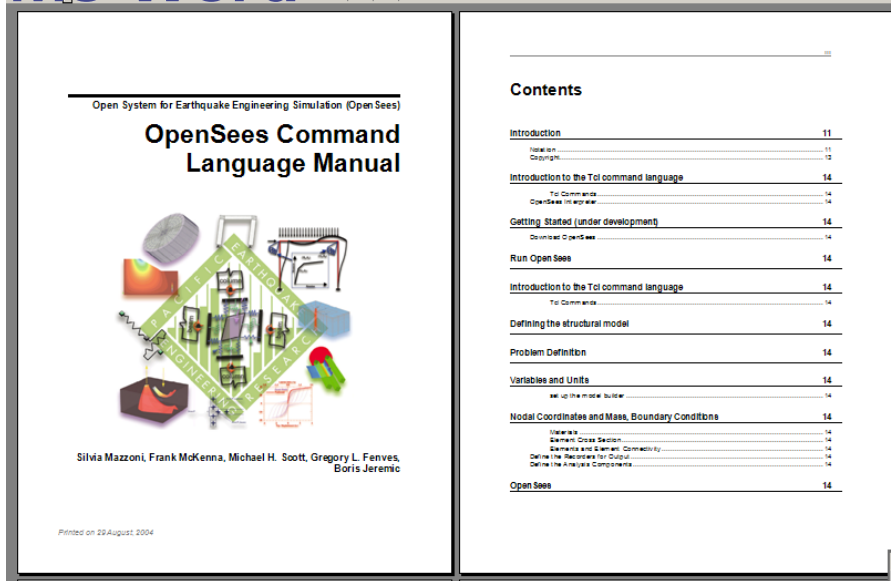
# OpenSEES User Manual

HTML



Windows Help

MS Word





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# OpenSEES examples manual

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

**Contents**

- [Introduction](#)
- [EXAMPLE 1 - Truss Example](#)
- [EXAMPLE 2 - Moment-Curvature Analysis](#)
- [EXAMPLE 3 - Portal Frame Examples](#)
- [EXAMPLE 4 - Multibay Two Story Frame](#)
- [EXAMPLE 5 - Three-Dimensional Rigid Frame](#)
- [EXAMPLE 6 - Simply Supported Beam](#)
- [EXAMPLE 7 - Dynamic Shell Analysis](#)
- [EXAMPLE 8 - Cantilever Beam](#)
- [Reinforced Concrete Plane Frame Example](#)
- [Steel Plane Frame Examples](#)
- [Rigid Floor Diaphragm Example](#)
- [Zero Length Element Examples](#)
- [Section Analysis Example](#)
- [Quad Examples](#)
- [Brick Examples](#)
- [Reliability Examples](#)
- [Script Utilities Library](#)
- [Index](#)

## EXAMPLE 1 - Truss Example

The first example is a simple truss structure. The purpose of this example is to show that model generation in OpenSees can resemble typical finite element analysis programs with the definition of nodes, materials, elements, loads and constraints. The example also demonstrates how an analysis object is 'built' from component objects.

This example is of a linear-elastic three bar truss, as shown in the figure, subject to static loads.

**Files Required**

Example1.1.tcl

**Model**

The model consists of four nodes, three truss elements, a single load pattern with a nodal load acting at node 4, and constraints at the three support nodes. Since the truss elements have the same elastic material, a single Elastic material object is created.

$E=3000 \text{ ksi}$   
 $A_1=10 \text{ in}^2$   
 $A_{2,3}=5 \text{ in}^2$

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redirect to:



# opensees.berkeley.edu/community/index.php

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

Quick Links

## The OpenSees Community

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**The OpenSees Community Forum Index** [View unanswered posts](#)

Forum	Topics	Posts	Last Post
<b>OpenSees</b>			
<b>OpenSees.exe Users</b> Forum for OpenSees users to post questions, comments, etc. on the use of the OpenSees interpreter, OpenSees.exe	438	1498	Thu Jan 19, 2006 9:16 am <a href="#">silvia</a> →
<b>Documentation</b> For posts concerning the documentation, errors, omissions, general comments, etc.	47	125	Tue Jan 10, 2006 10:02 am <a href="#">silvia</a> →
<b>Framework</b> For developers writing C++, Fortran, Java, code who have questions or comments to make.	67	212	Thu Jan 12, 2006 2:40 pm <a href="#">fmk</a> →
<b>Useful Scripts.</b> If you have a script you think might be useful to others post it here. Hopefully we will be able to get the most useful of these incorporated in the manuals.	6	10	Wed Nov 23, 2005 1:59 pm <a href="#">silvia</a> →
<b>Future Directions</b> A forum dedicated to the future direction of OpenSees, i.e. what would you like, what do you need.	15	35	Wed Oct 12, 2005 3:32 pm <a href="#">fmk</a> →

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### Who is Online

Our users have posted a total of **1880** articles  
We have **385** registered users  
The newest registered user is [KontupeR47238](#)

In total there are **2** users online :: 1 Registered, 0 Hidden and 1 Guest [ [Administrator](#) ] [ [Moderator](#) ]  
Most users ever online was **26** on Tue Oct 25, 2005 4:11 am

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◆ Annual Workshops – 3 days in 2005

# annual workshop announcement



NEESit & PEER announce:

[The OpenSees Developer Symposium – Aug 24, 2005](#)

[The OpenSees Developer Workshop – Aug 25, 2005](#)

[The OpenSees User Workshop – Aug 26, 2005](#)

UC Berkeley, Richmond Field Station

*The OpenSees Developer Symposium* – A one-day symposium with presentations and discussions of on-going development of the OpenSees framework. Presentations will be made by the OpenSees team as well as by current developers of OpenSees.

*The OpenSees Developer Workshop* – A one-day workshop for beginning and intermediate developers. The workshop will focus on how to introduce a new material and a new element into the OpenSees framework with hands-on exercises.

*The OpenSees User Workshop* – The annual one-day workshop on how to use OpenSees. The workshop is intended for both those who are interested in starting to use OpenSees and also for intermediate users.

Students, researchers, and practitioners are welcome to attend any of the days. Registration is free, lunch is provided, but space is limited, so please register on time at: <http://it.nees.org/training>.



# OpenSees Days 2006

- ◆ Tentatively scheduled for June 2006
- ◆ Three days may not be enough
- ◆ We would like to increase attendance from industry representatives

finally, the fine print

## What Should be Your Expectations of OpenSees?

- ◆ As with any nonlinear analysis, it requires careful consideration of model and interpretation of results
- ◆ An investment of time and learning is required
- ◆ It is under continual development by students, faculty and other researchers
- ◆ The OpenSees *open-source community* requires contributions for the community to succeed.



# Questions, or statements!

The OpenSees Community Forum:

<http://opensees.berkeley.edu/community/index.php>