Discovering OpenSees: Introduction to OpenFresco*Express*

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OpenFresco

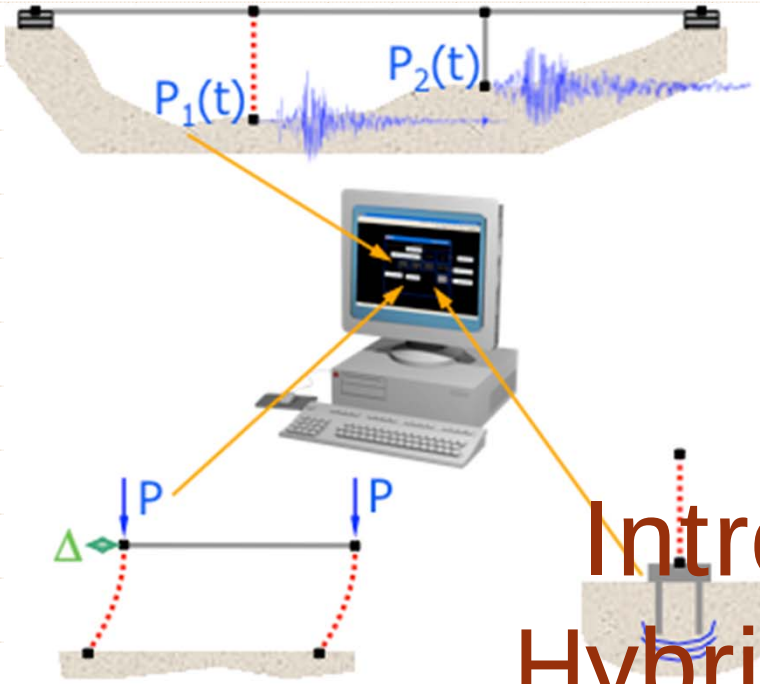
Introduction

- Populations of seismically active regions grow denser
- Greater odds for large-scale catastrophes (Haiti 01/2010, Chile 02/2010, New Zealand 02/2011, Japan 03/2011)
- Improve knowledge and understanding of the complex nonlinear response and behavior of new and existing civil structures during seismic events

→ Experimental testing of structures is the cornerstone of earthquake engineering

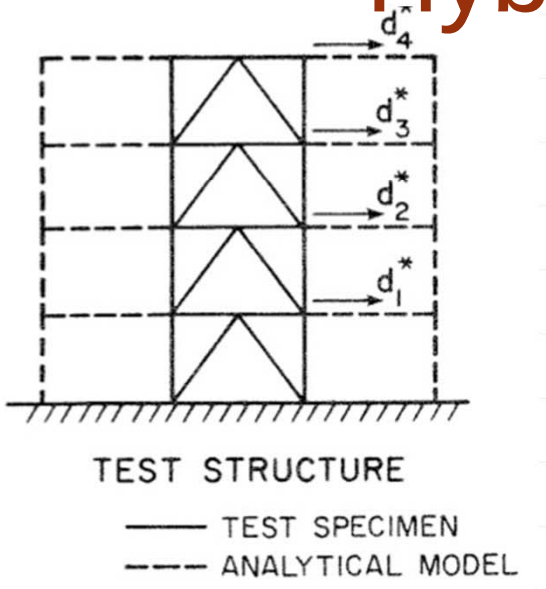
Outline of Presentation

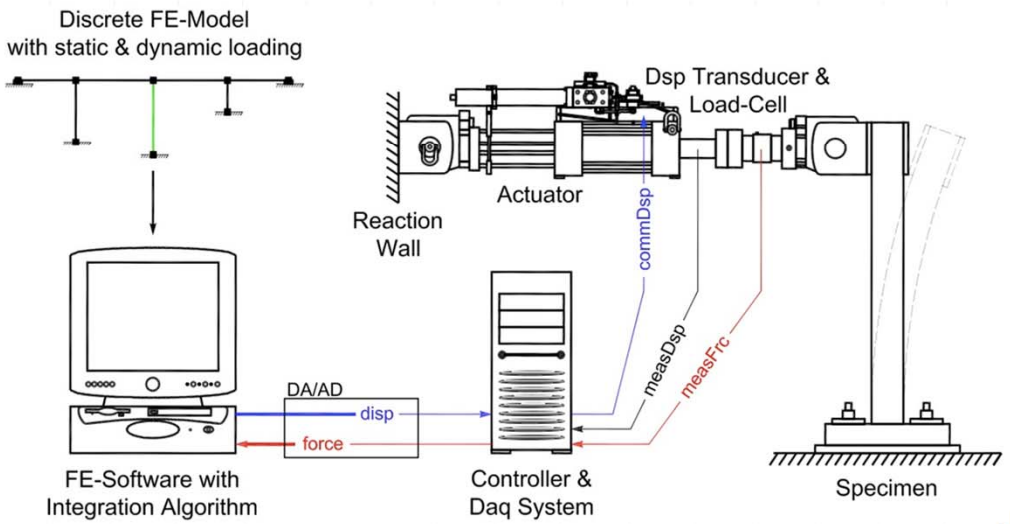
1. Introduction to Hybrid Simulation
2. Downloading and Installing
3. Example 1: Building first Hybrid Model
4. Simulated vs. Real Controllers
5. Error Monitors
6. Example 2: Two Story Building
7. Other Resources
8. Summary & Conclusions



$$\cdot\ddot{\mathbf{u}} + \mathbf{C}\cdot\dot{\mathbf{u}} + \mathbf{P}_r(\mathbf{u}) = \mathbf{P}(t)$$

Introduction to Hybrid Simulation





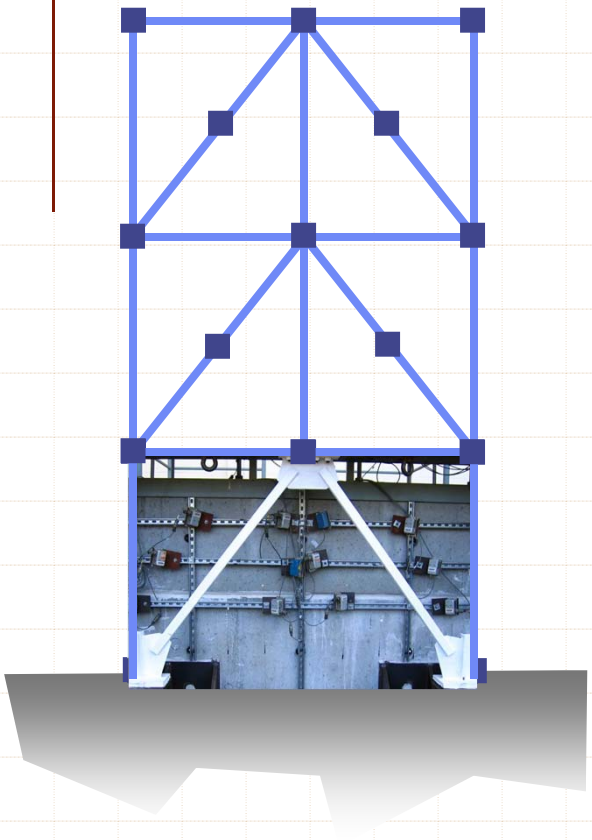
Comparison of Exp. Test Methods

	Quasi-Static	Shaking Table	Hybrid Simulation
Dynamics	NO	YES	YES
Strain Rate Effects	NO	YES	YES (if real-time test)
Large- or Full-Scale	YES	NO (limited by table)	YES

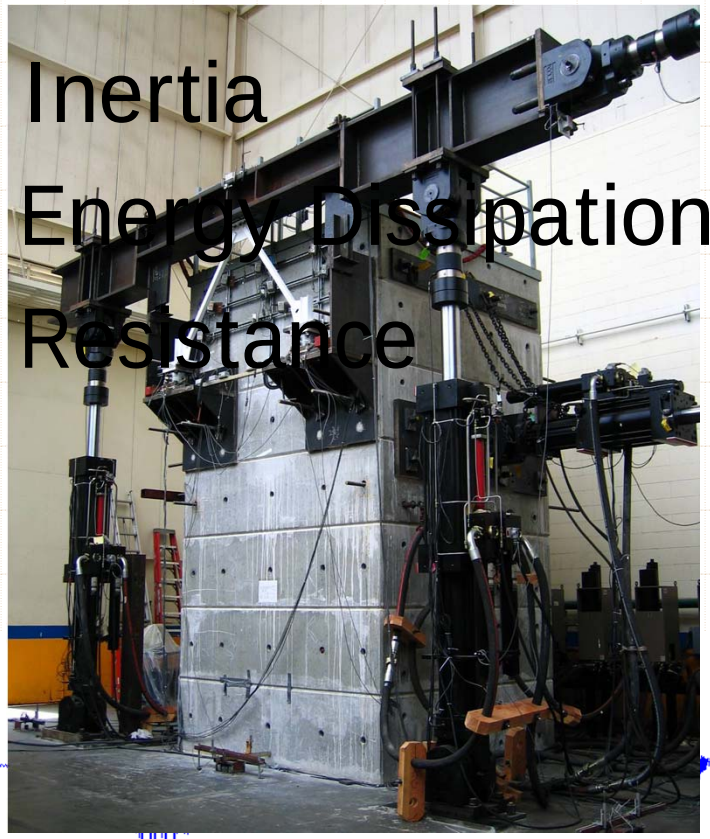
- First Hybrid Simulation (Online Test) in 1975 by Takanashi et al.

Hybrid Simulation

$$\mathbf{M}\cdot\ddot{\mathbf{u}}+\mathbf{C}\cdot\dot{\mathbf{u}}+\mathbf{P}_r(\mathbf{u})=\mathbf{P}(t)$$

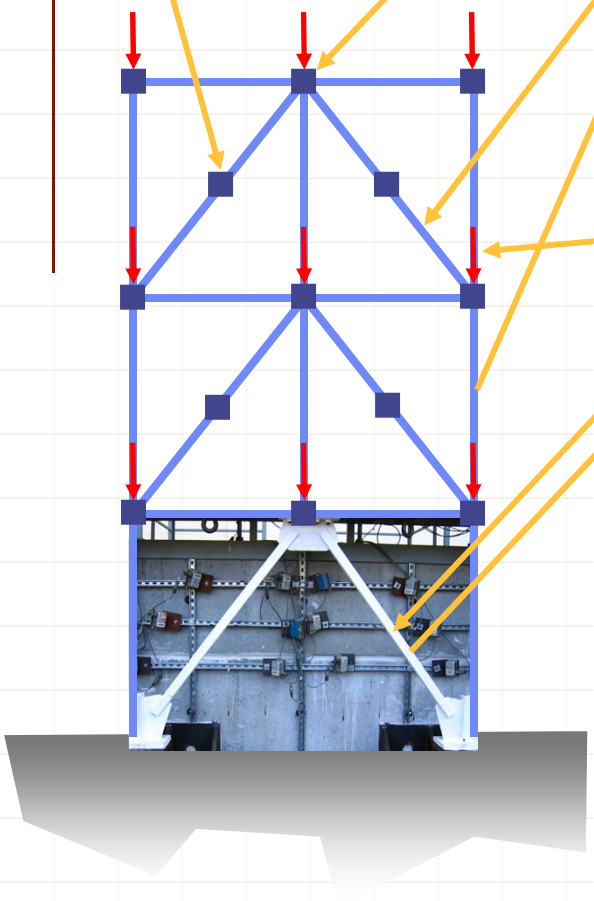


- Inertia
- Energy Dissipation
- Resistance



Hybrid Simulation

$$\mathbf{M}\cdot\ddot{\mathbf{u}}+\mathbf{C}\cdot\dot{\mathbf{u}}+\mathbf{P}_r(\mathbf{u})=\mathbf{P}(t)$$



Dynamic Loading:
- Seismic
- Wind
- Blast/Impact
- Wave
- Traffic

Static Loading:
- Gravity
- Prestress

analytically add nonlinear geometric effects to measured resisting forces

analytical model of structural energy dissipation and inertia

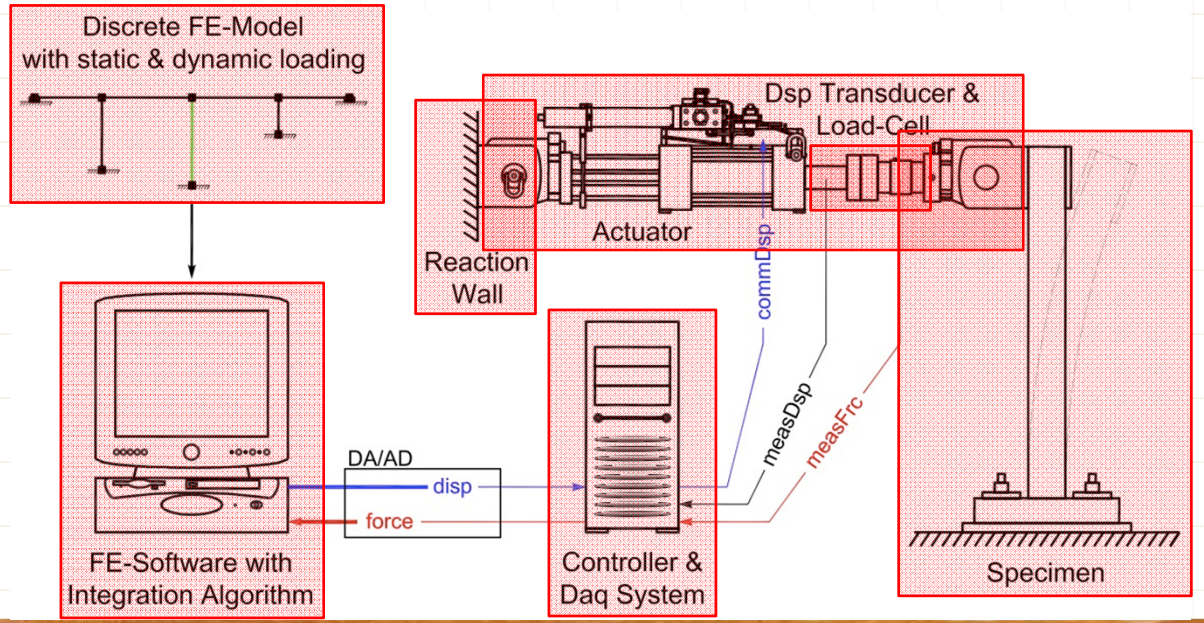
physical model of structural resistance

Hybrid Simulation

- Model the well understood parts of a structure in a finite element program on one or more computers
- Leave the construction and testing of the highly nonlinear and/or numerically hard to model parts of the structure in one or more laboratories
- Can be considered as a conventional finite element analysis where physical models of some portions of the structure are embedded in the numerical model

Required Components

1. Discrete model of the structure to be analyzed, including the static and dynamic loading
2. Servo-hydraulic control system with static or dynamic actuators
3. Physical test specimen, including a reaction-frame
4. Data acquisition system with instrumentation



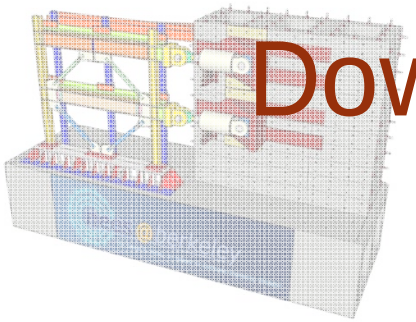
What is OpenFresco?

- Open source Framework for Experimental Setup and Control
- Secure, object oriented, network enabled "middleware" -- Pairs computer analysis software with laboratory control systems and other software to enable hybrid and collaborative computing:

- Computational Drivers
  - OpenSees
  - OpenFresco*Express*
  - Abaqus
  - LS-DYNA
  - Matlab
  - Simulink
  - Ansys
  - UI-SimCor
- Control Systems
  - dSpace
  - MTS
    - STS family
    - Flextest/CSI
    - Flextest/Scramnet
  - National Instruments
  - Pacific Instruments
  - ADwin

What is OpenFresco *Express*

- Graphical user interface that is designed to simplify the running of hybrid simulations
- Guides the user through a step-by-step process to define the key parameters in a hybrid simulation
- Plots test data and error monitors in real time for checking the validity of results
- Allows the user to perform ground motion or free vibration tests



Downloading and Installing OpenFresco*Express*

http://openfresco.berkeley.edu

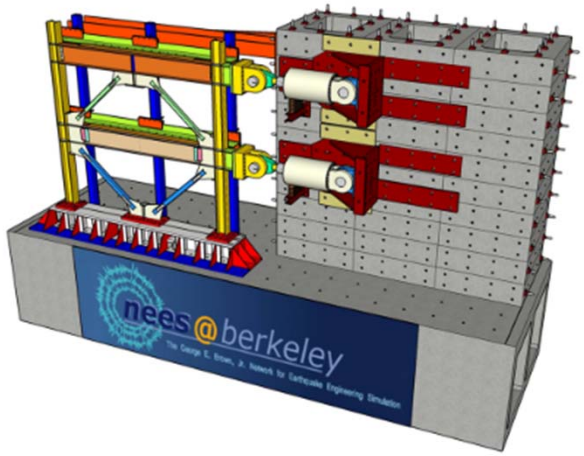
OpenFresco

HOME | USERS | DEVELOPERS | DOCUMENTATION | REFERENCES | COPYRIGHT

HOME

OpenFresco (the Open-source Framework for Experimental Setup and Control) is an environment-independent software framework, that connects finite element models with control and data acquisition systems in laboratories to facilitate hybrid simulation of structural and geotechnical systems.

Hybrid simulation is an experimental testing technique where a test is executed based on a step-by-step numerical solution of the governing equations of motion for a hybrid model, formulated considering both the numerical and physical portions of a structural system. In order for the earthquake engineering community to take full advantage of this technique, OpenFresco standardizes the deployment of hybrid simulation and extends its capabilities to applications where advanced numerical techniques are utilized, boundary conditions are imposed in real-time, and dynamic loading conditions caused by wind, blast, impact, waves, fire, traffic, and, in particular, seismic events are considered. Accordingly, the architecture of the OpenFresco software package provides a great deal of flexibility, extensibility, and re-usability to the researcher or developer interested in hybrid simulation.



Search

Search

Menu

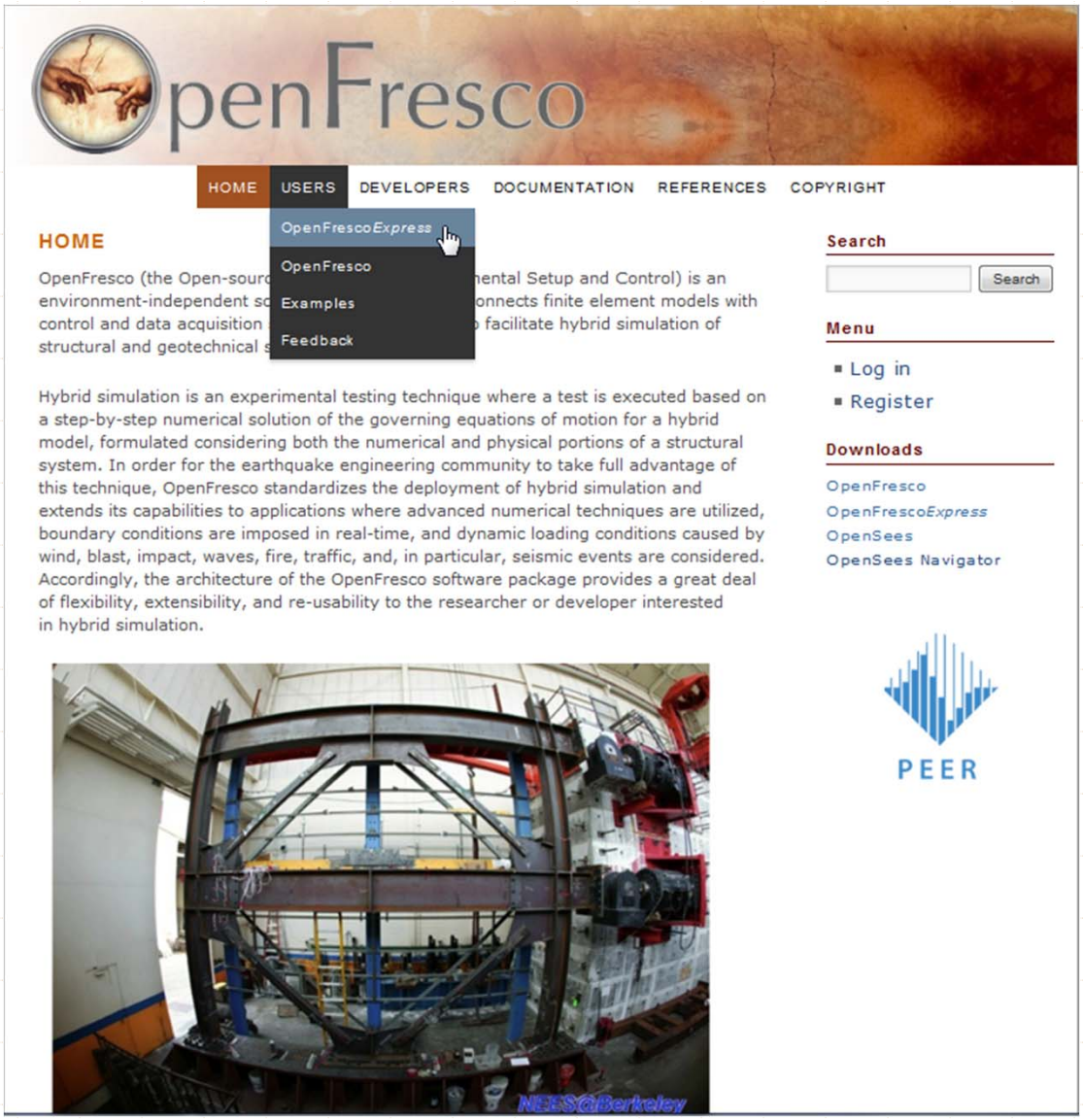
- Log in
- Register

Downloads

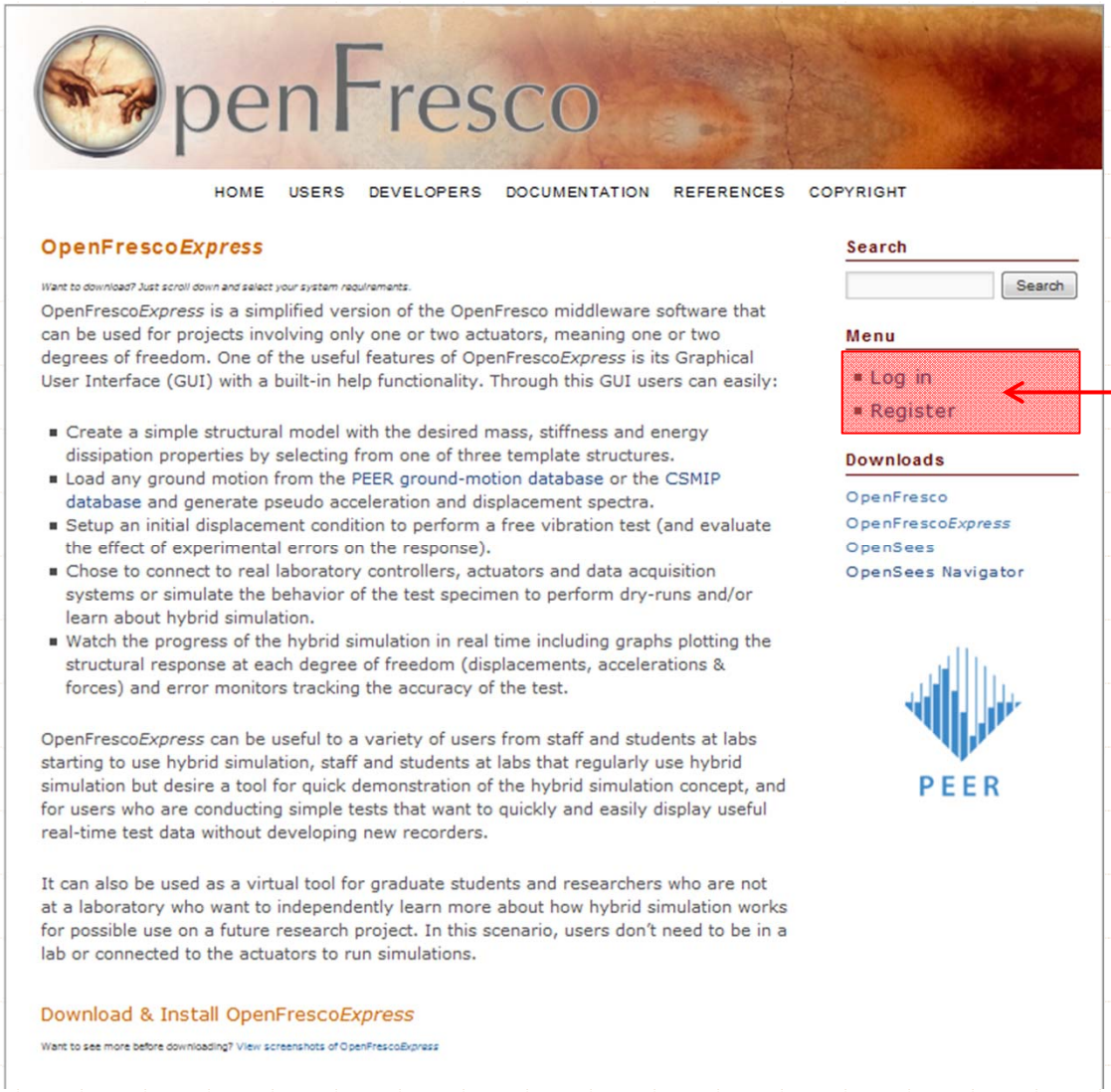
OpenFresco
OpenFrescoExpress
OpenSees Navigator

PEER

http://openfresco.berkeley.edu/users/express/

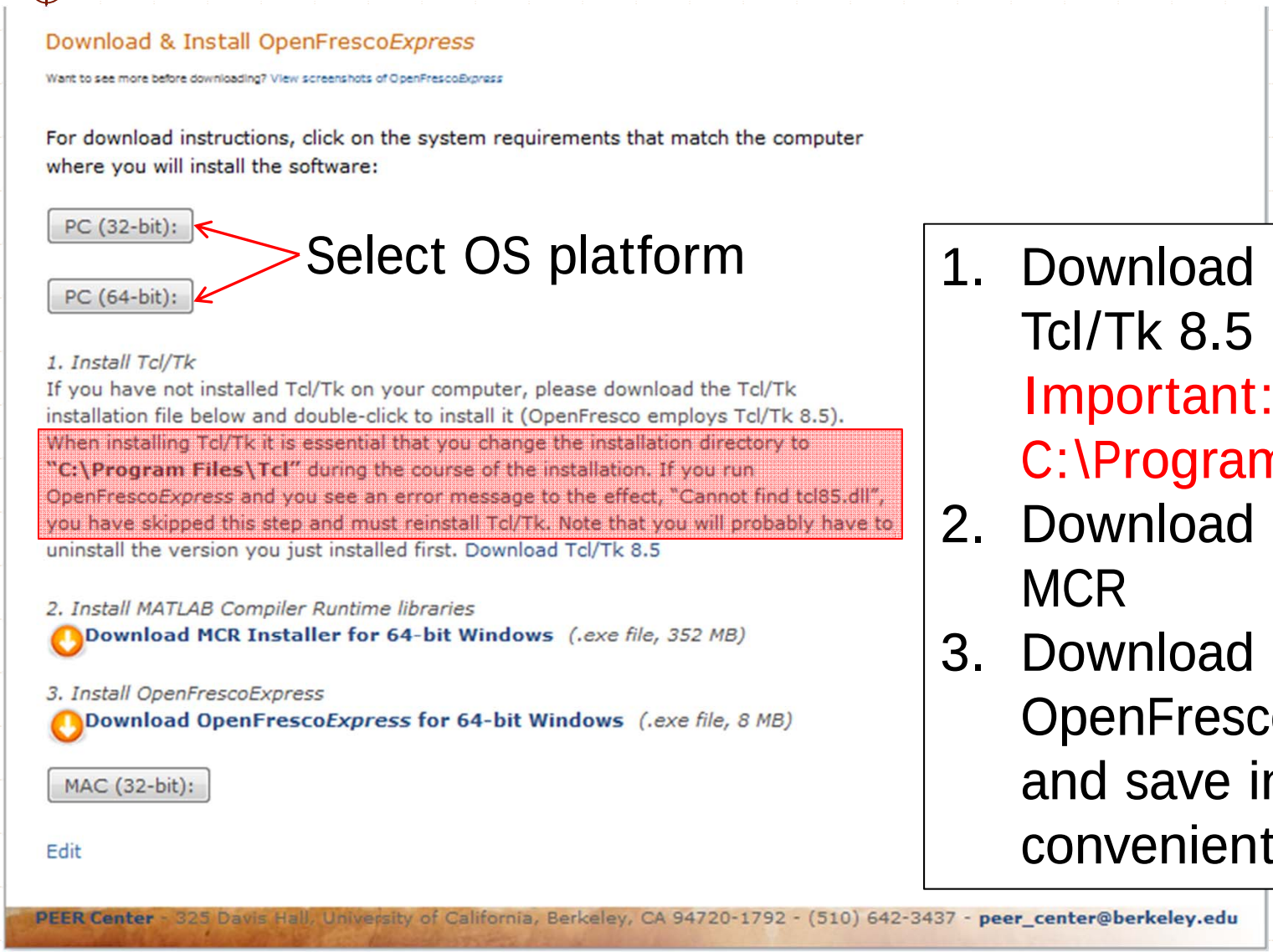


Login or Register



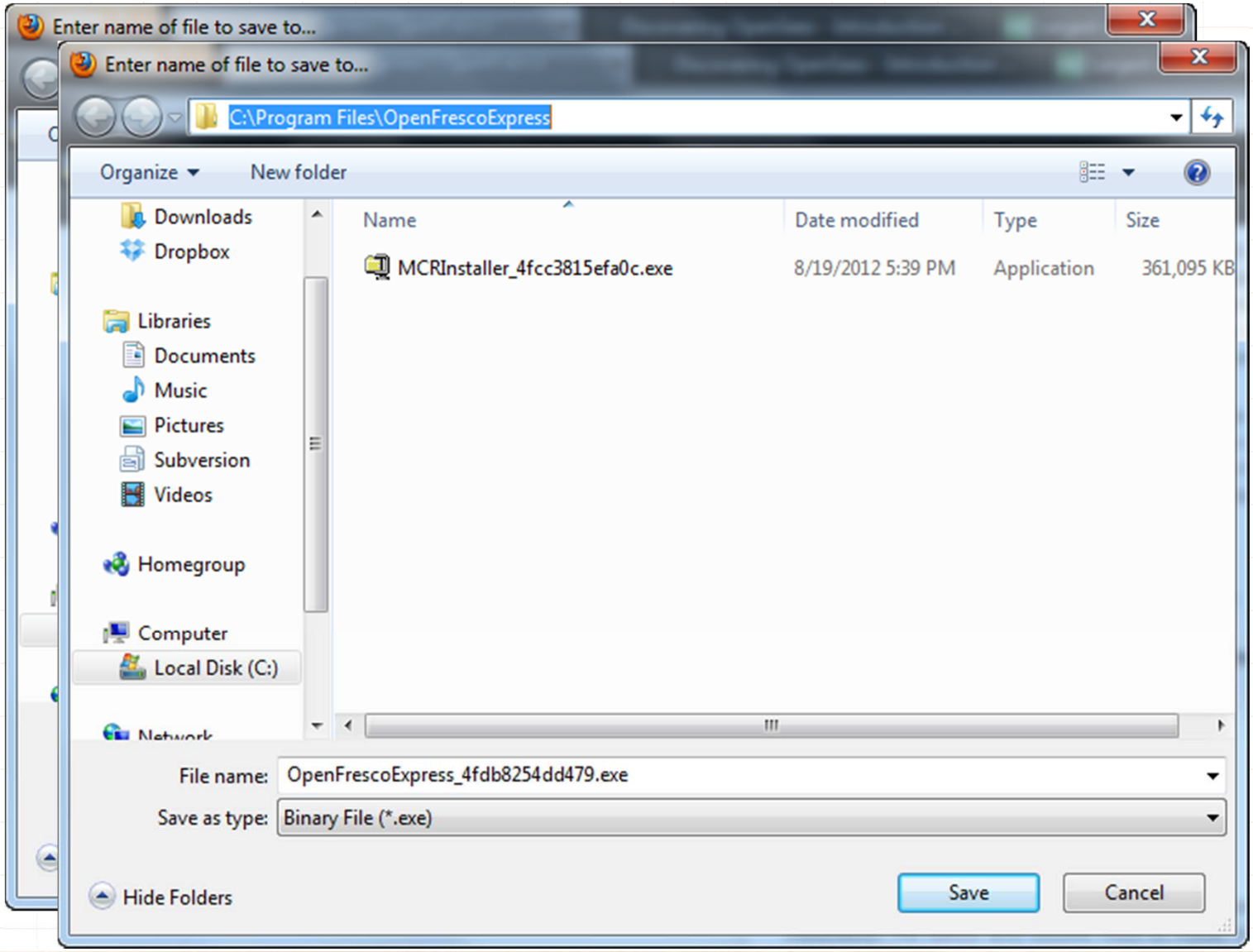
First, log in if you already have an account or register for a new account

Download Files

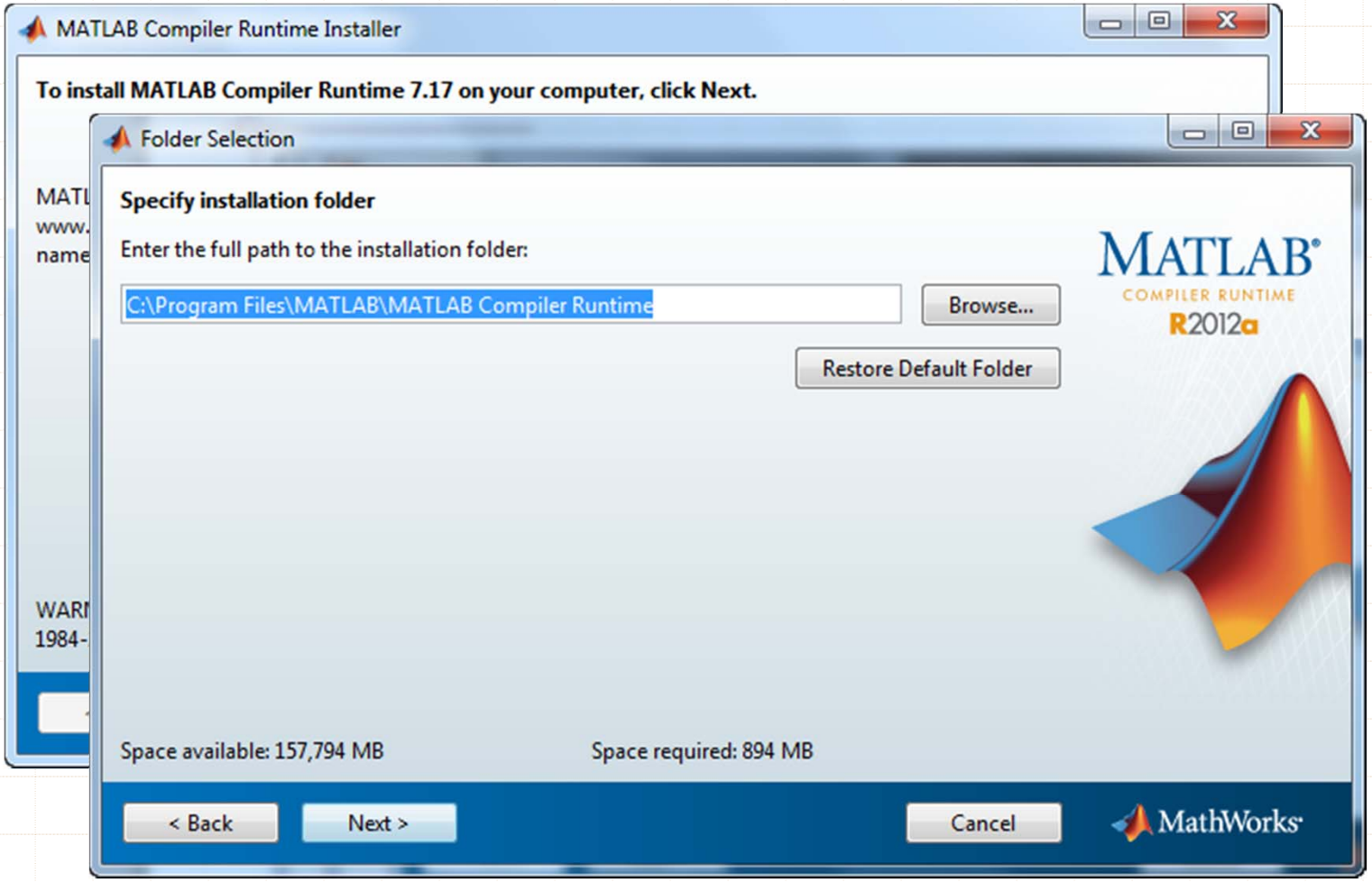


1. Download and install Tcl/Tk 8.5
   Important: install in C:\Program Files\Tcl
2. Download and install MCR
3. Download OpenFresco*Express* and save in a convenient directory

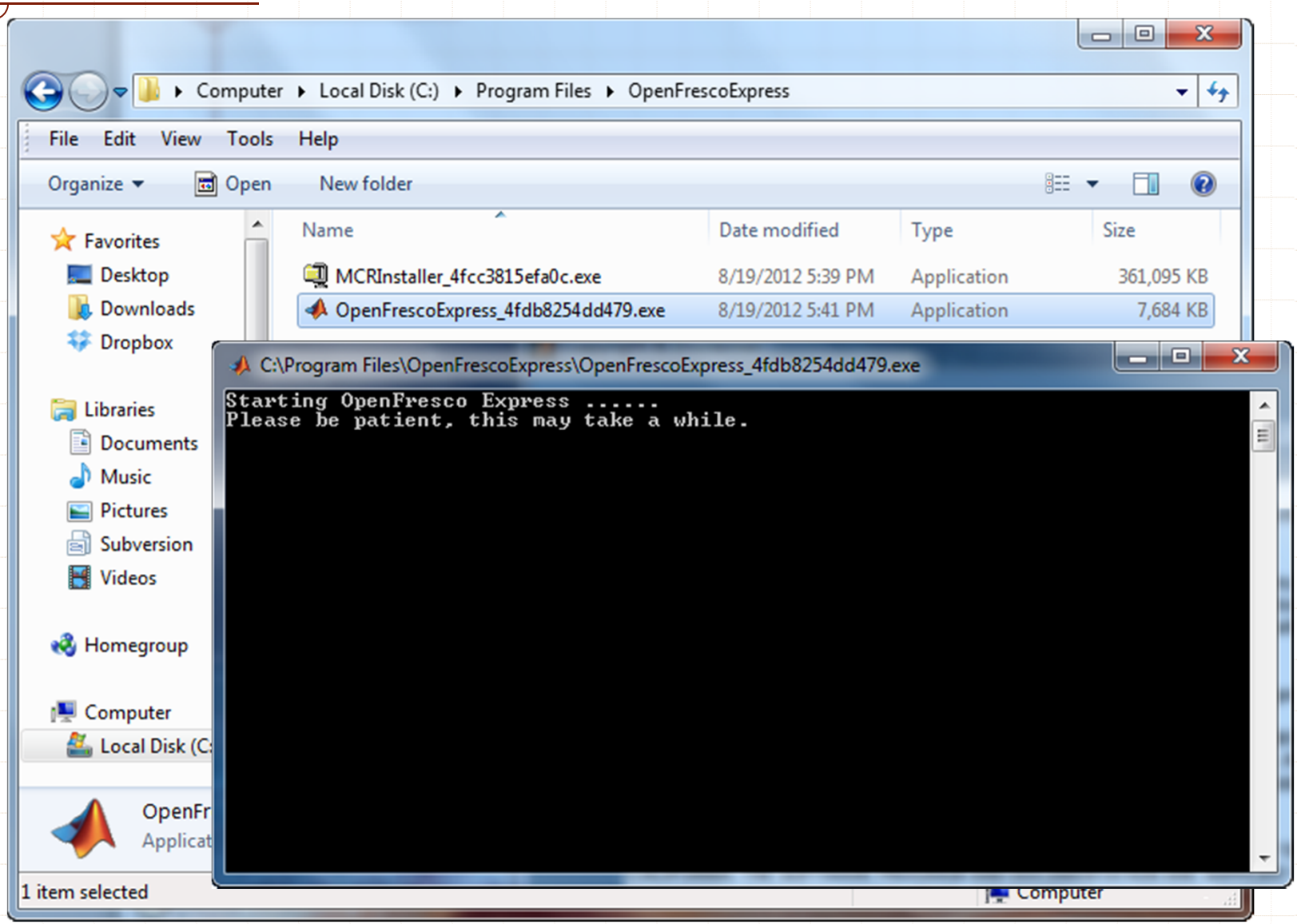
Save files in convenient directory



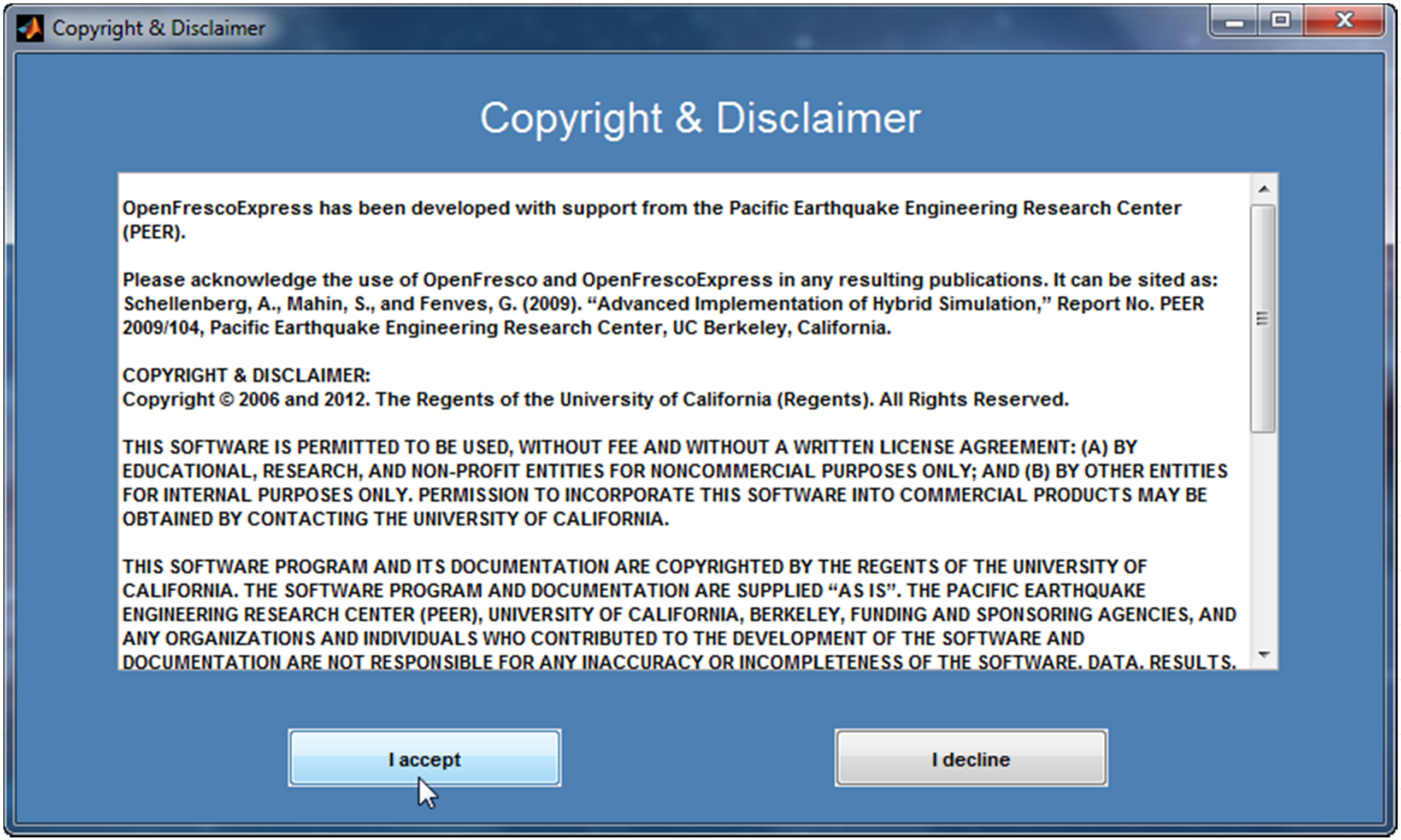
Install Matlab Compiler Runtime



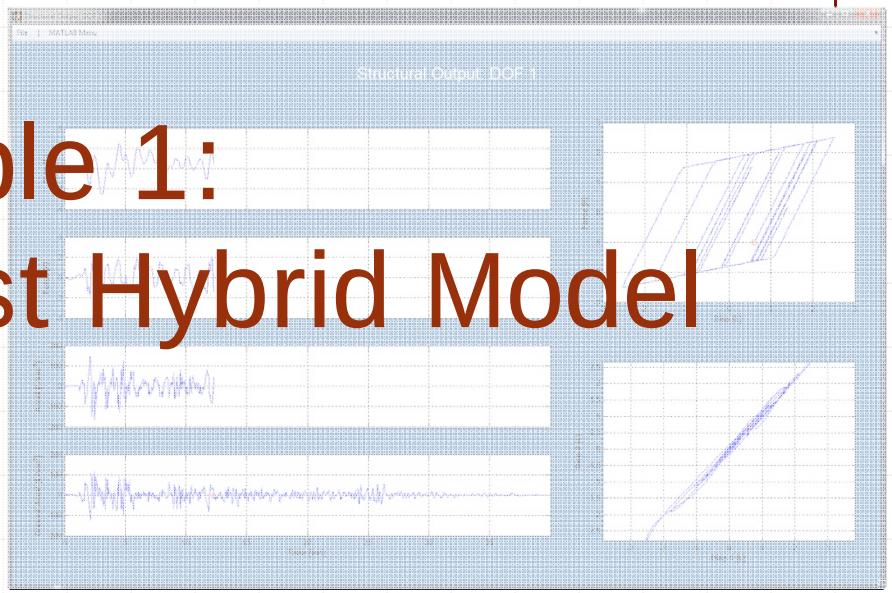
Start OpenFresco *Express*



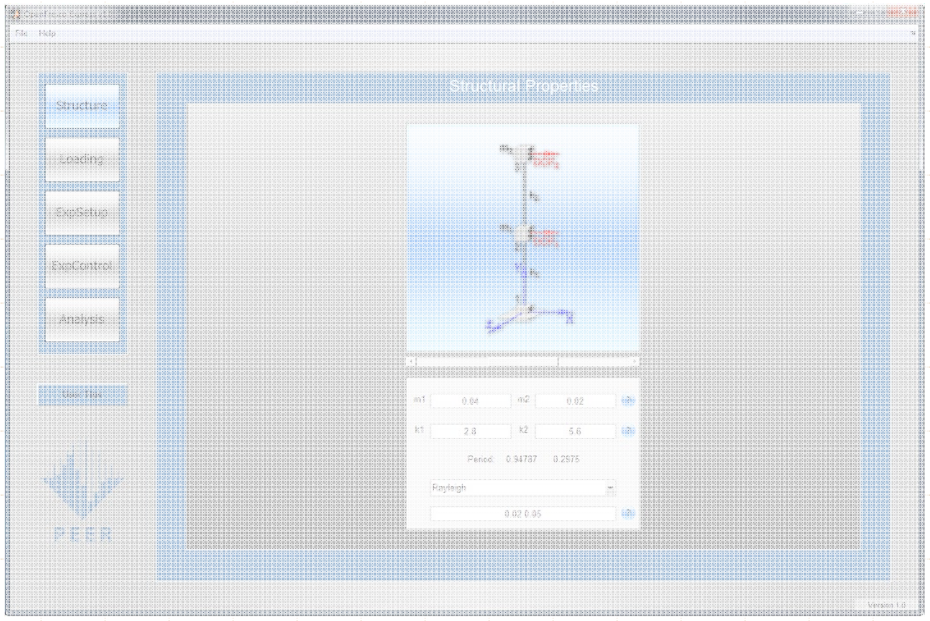
Read and Accept Copyright



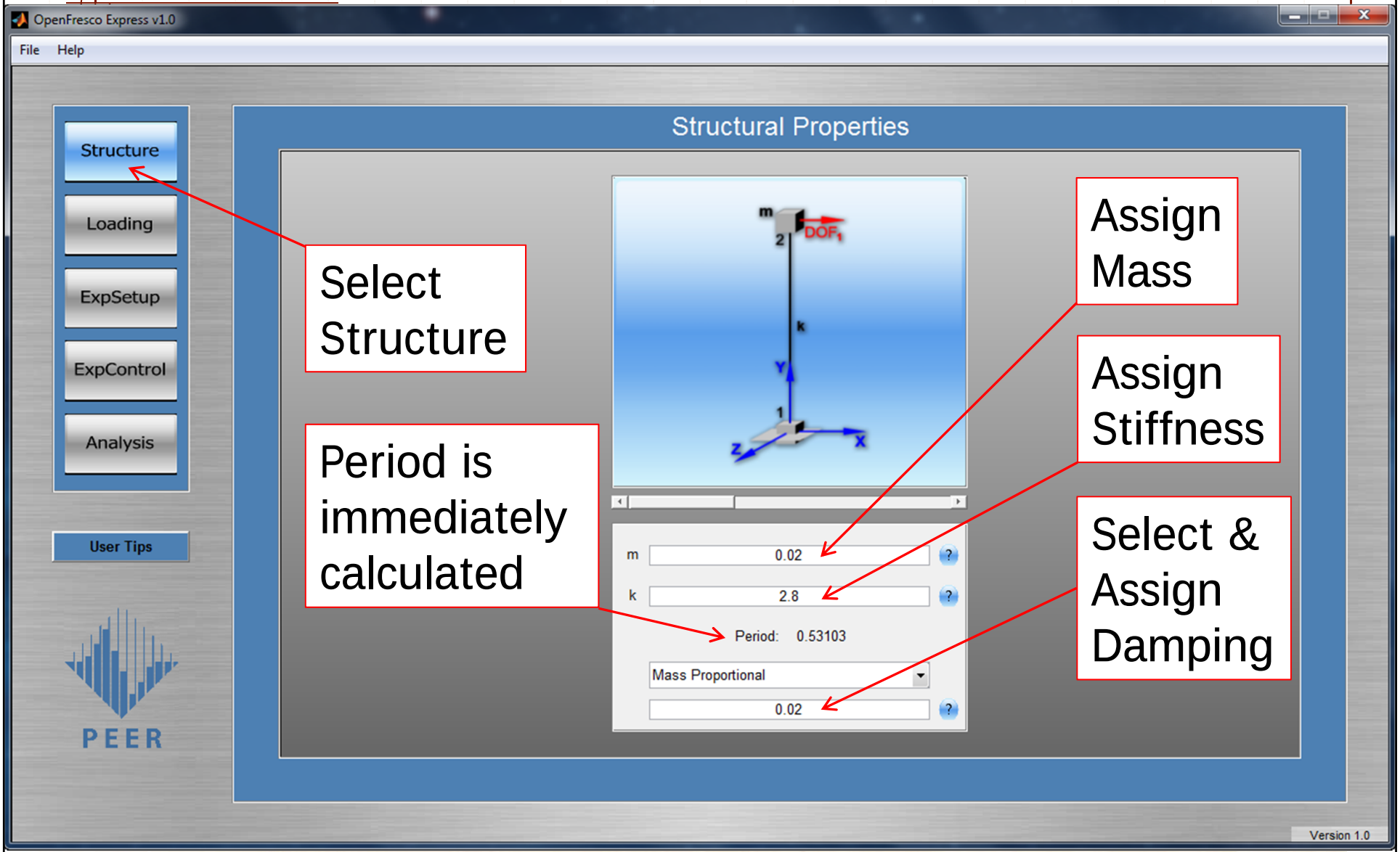
Splash Screen



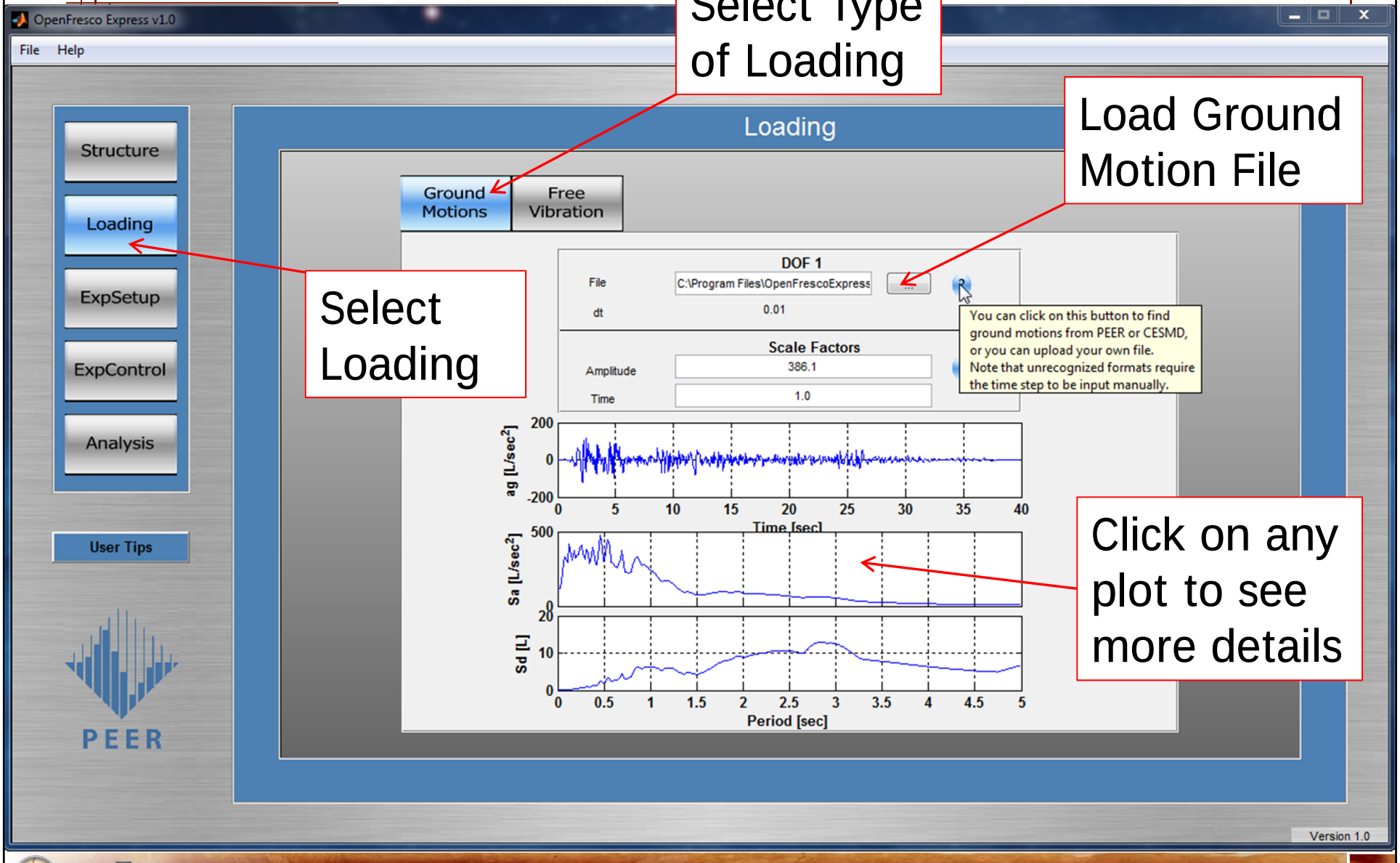
Example 1:
Building your first Hybrid Model



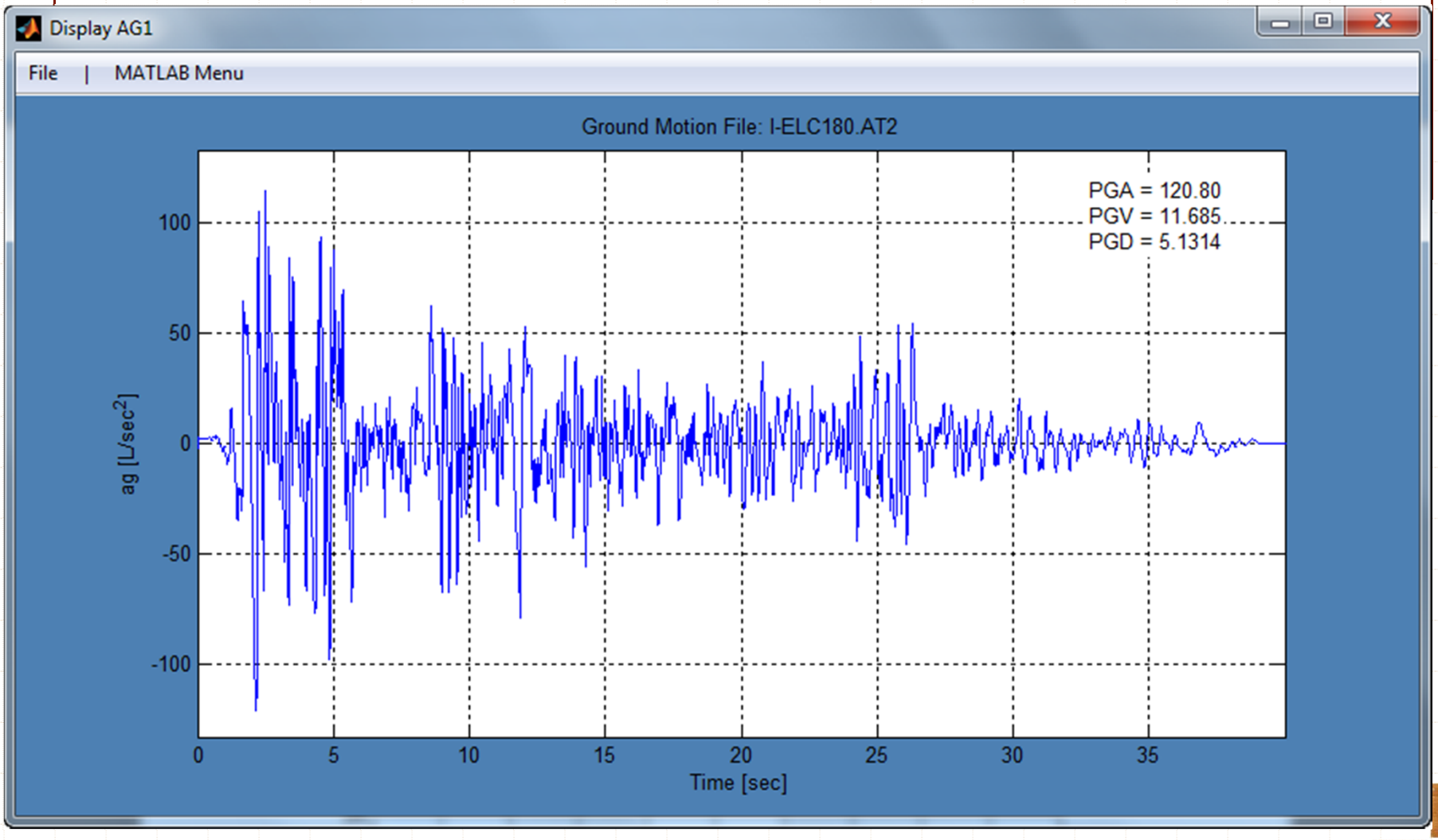
Define Structural Properties



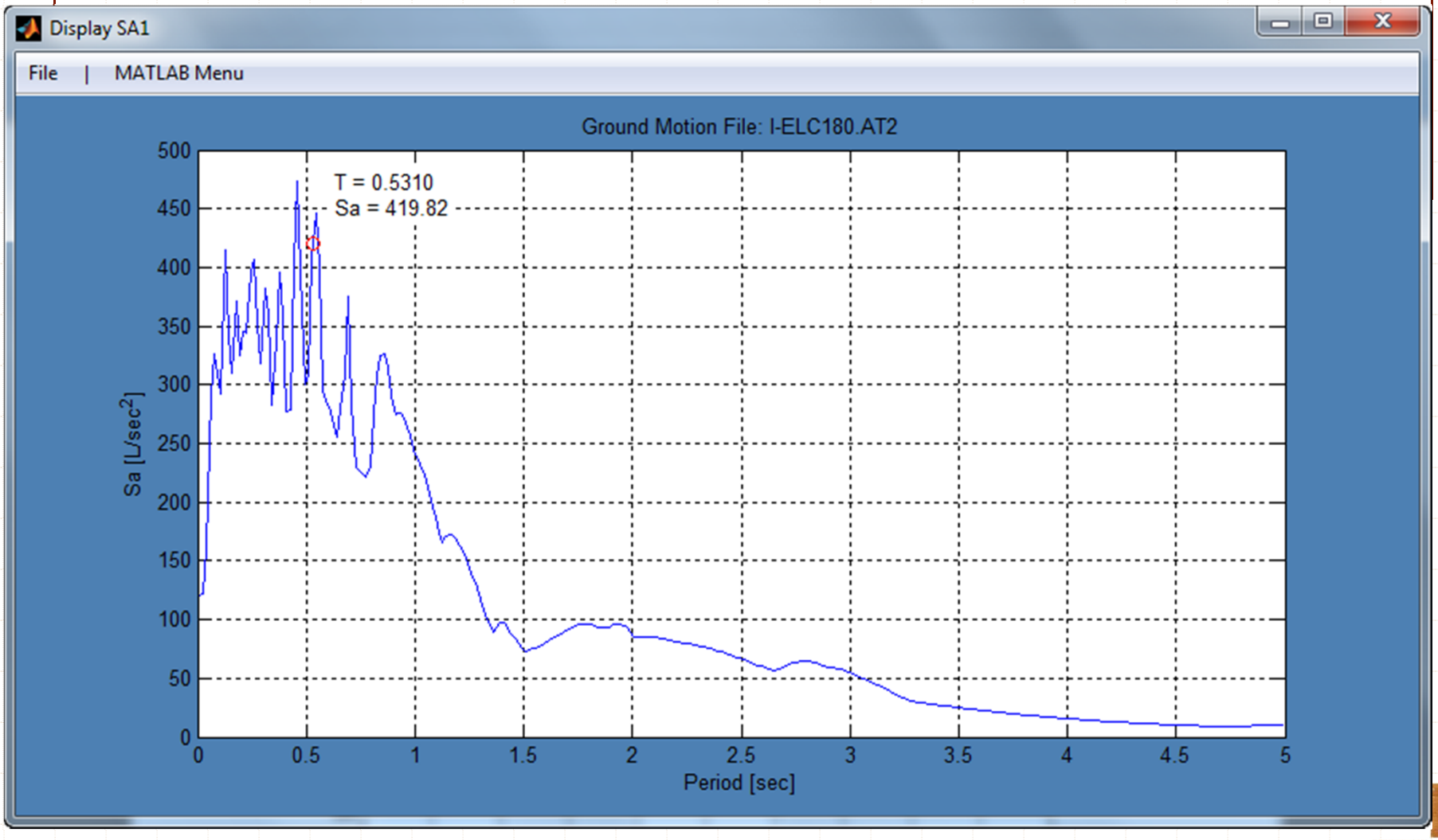
Define Loading



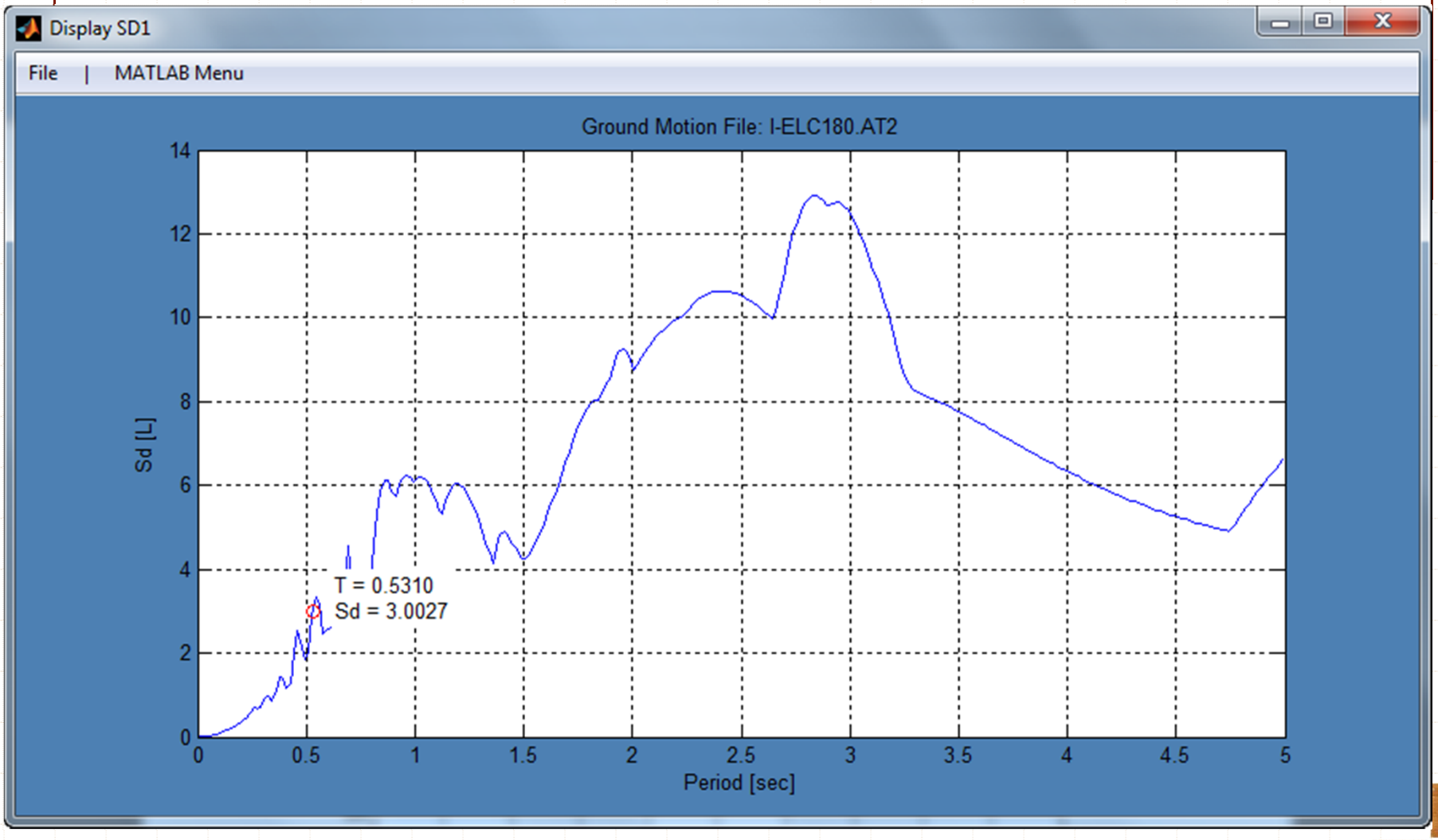
Ground Acceleration History



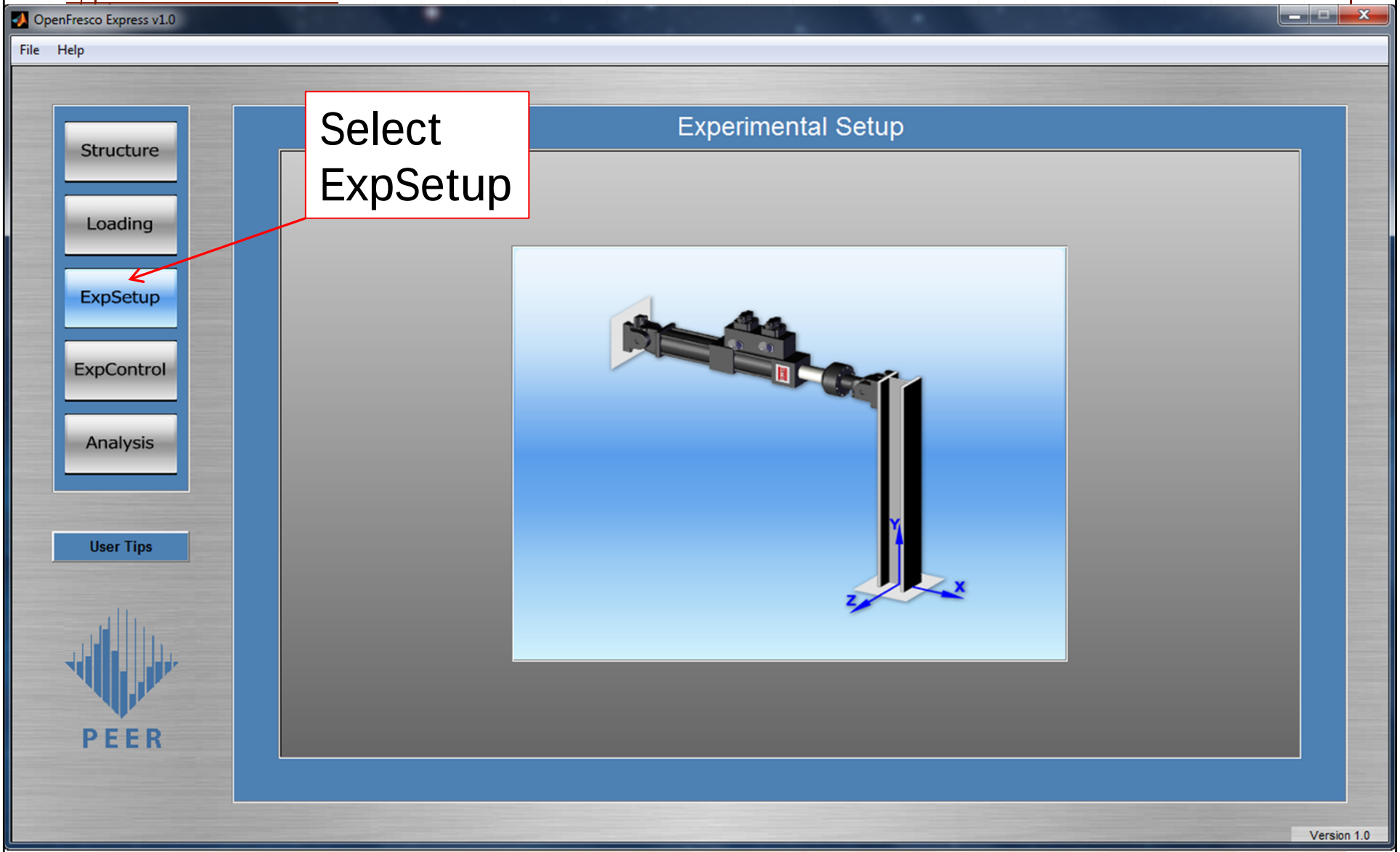
Pseudo Acceleration Spectra

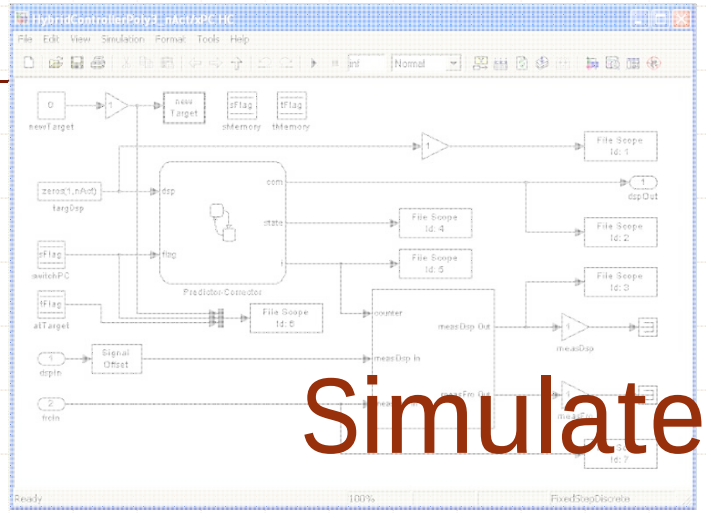


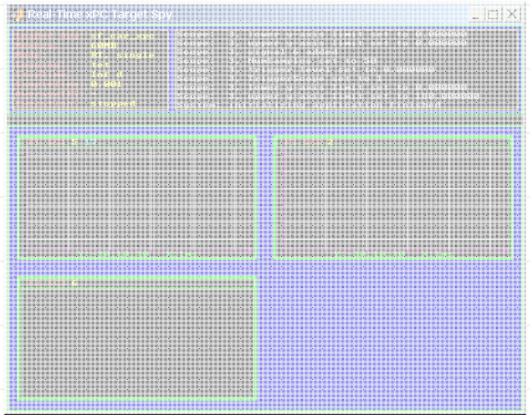
Displacement Spectra



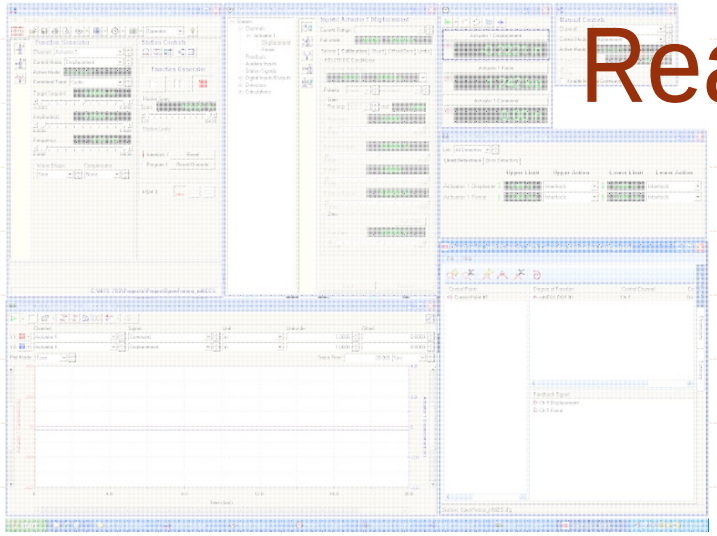
Experimental Setup

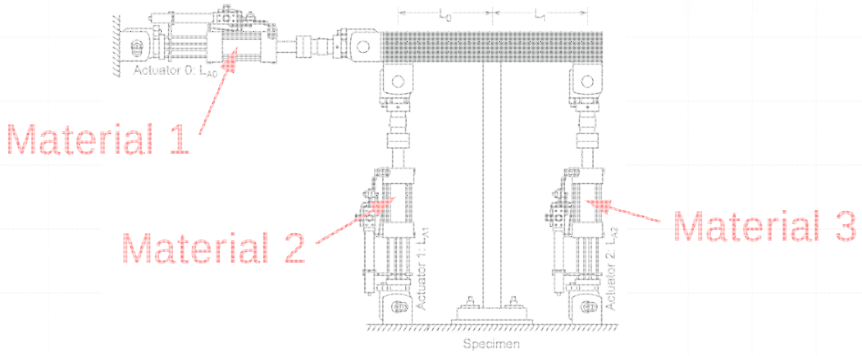




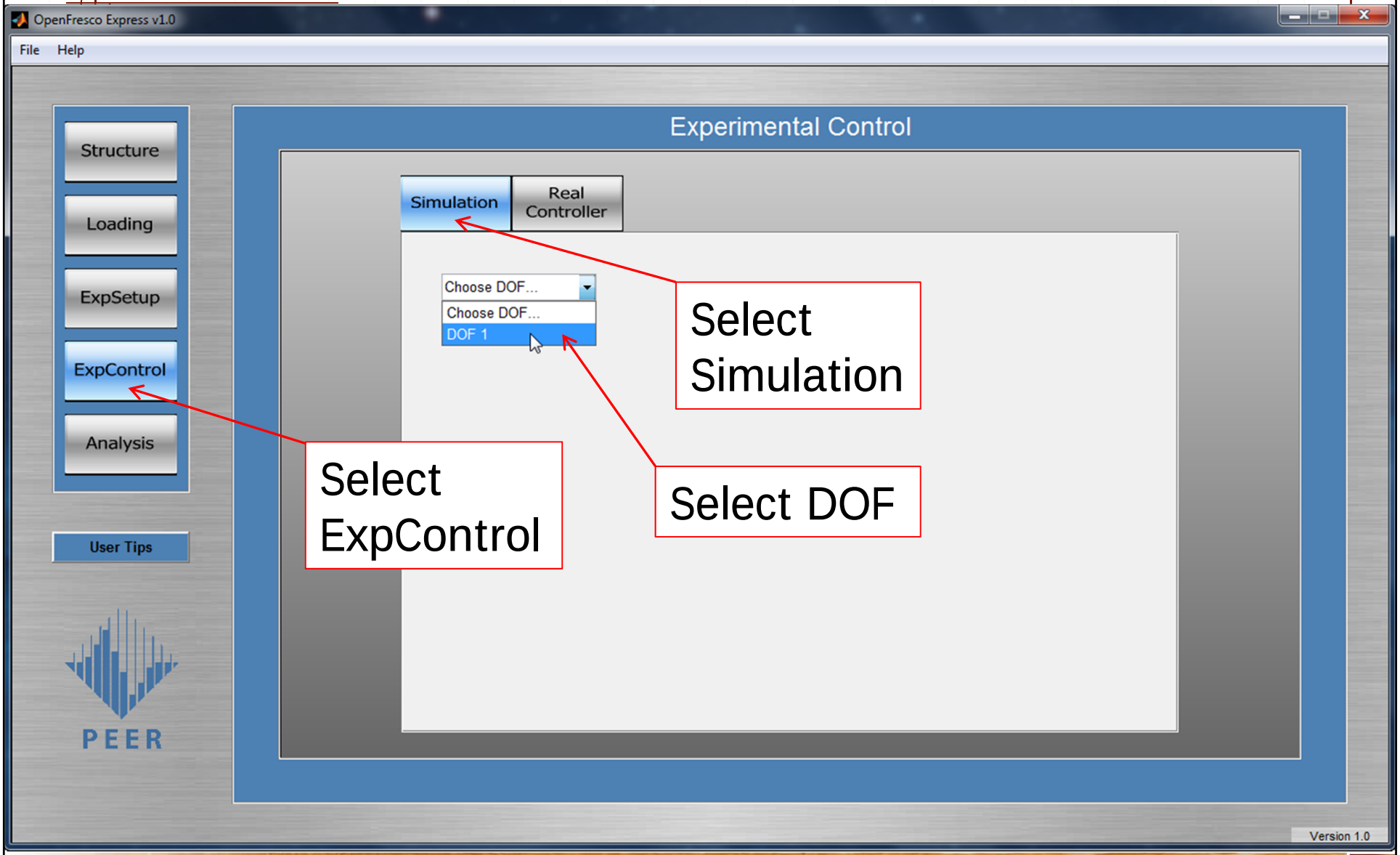


Simulated Controllers vs. Real Controllers

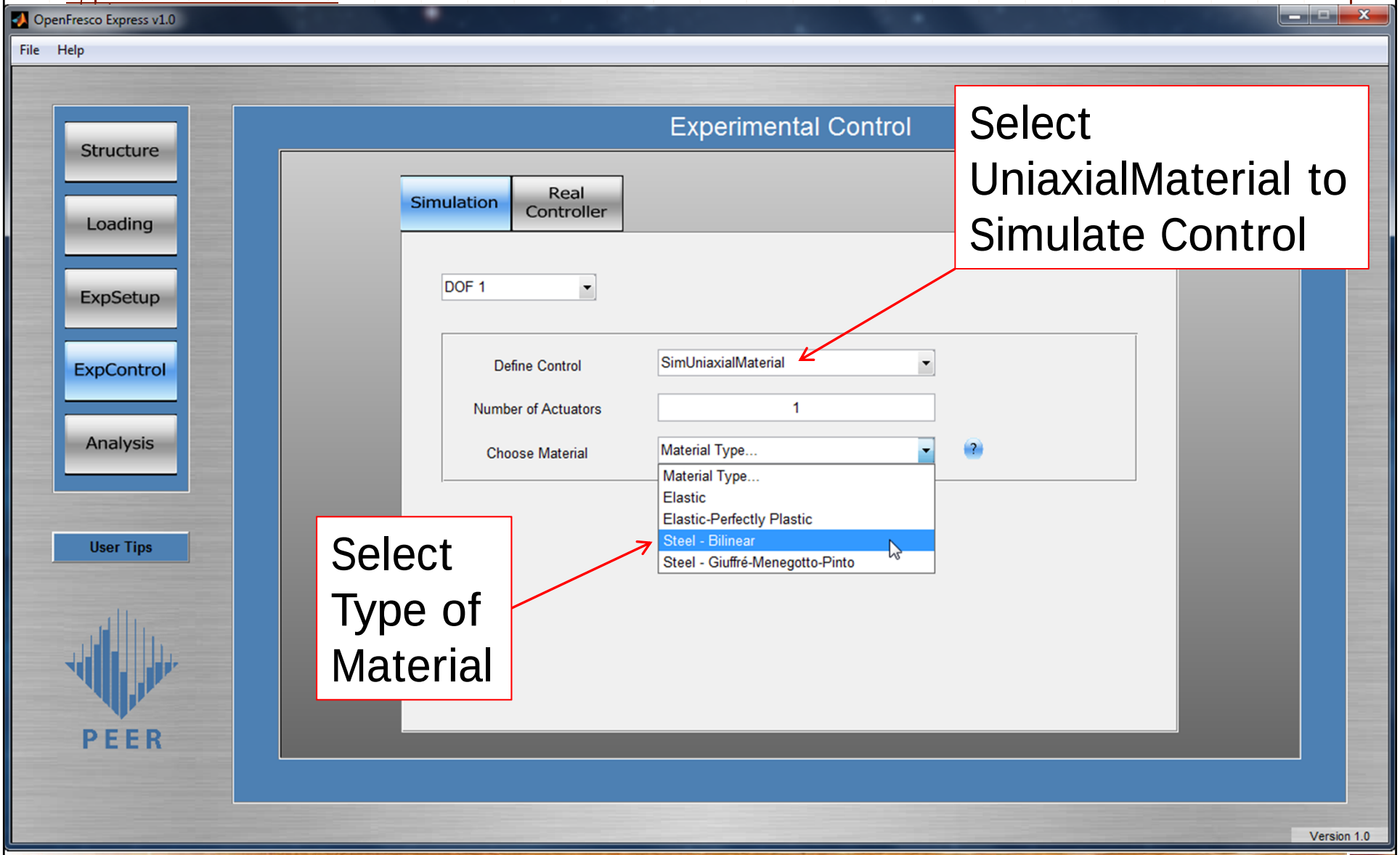




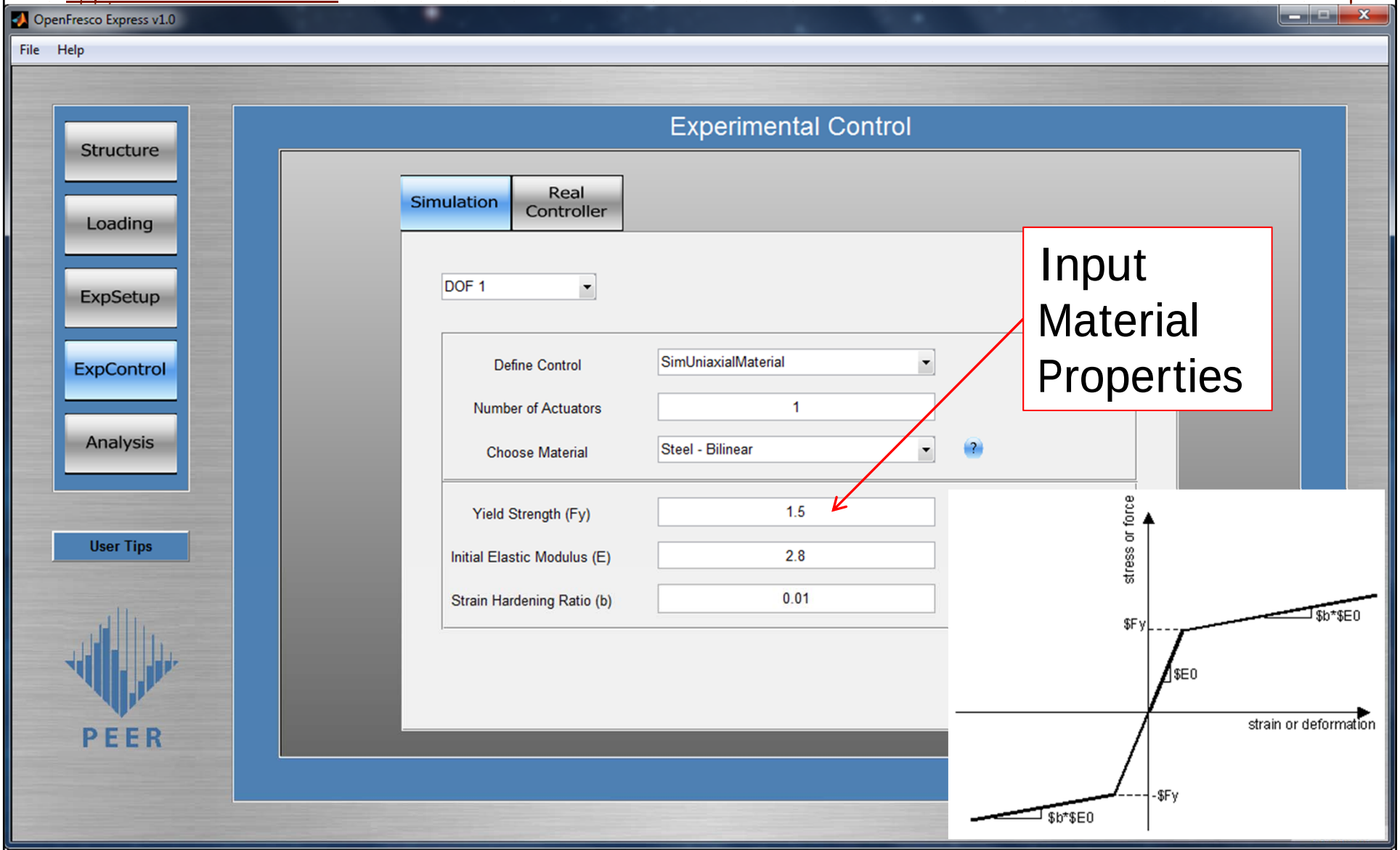
Simulated Experimental Control



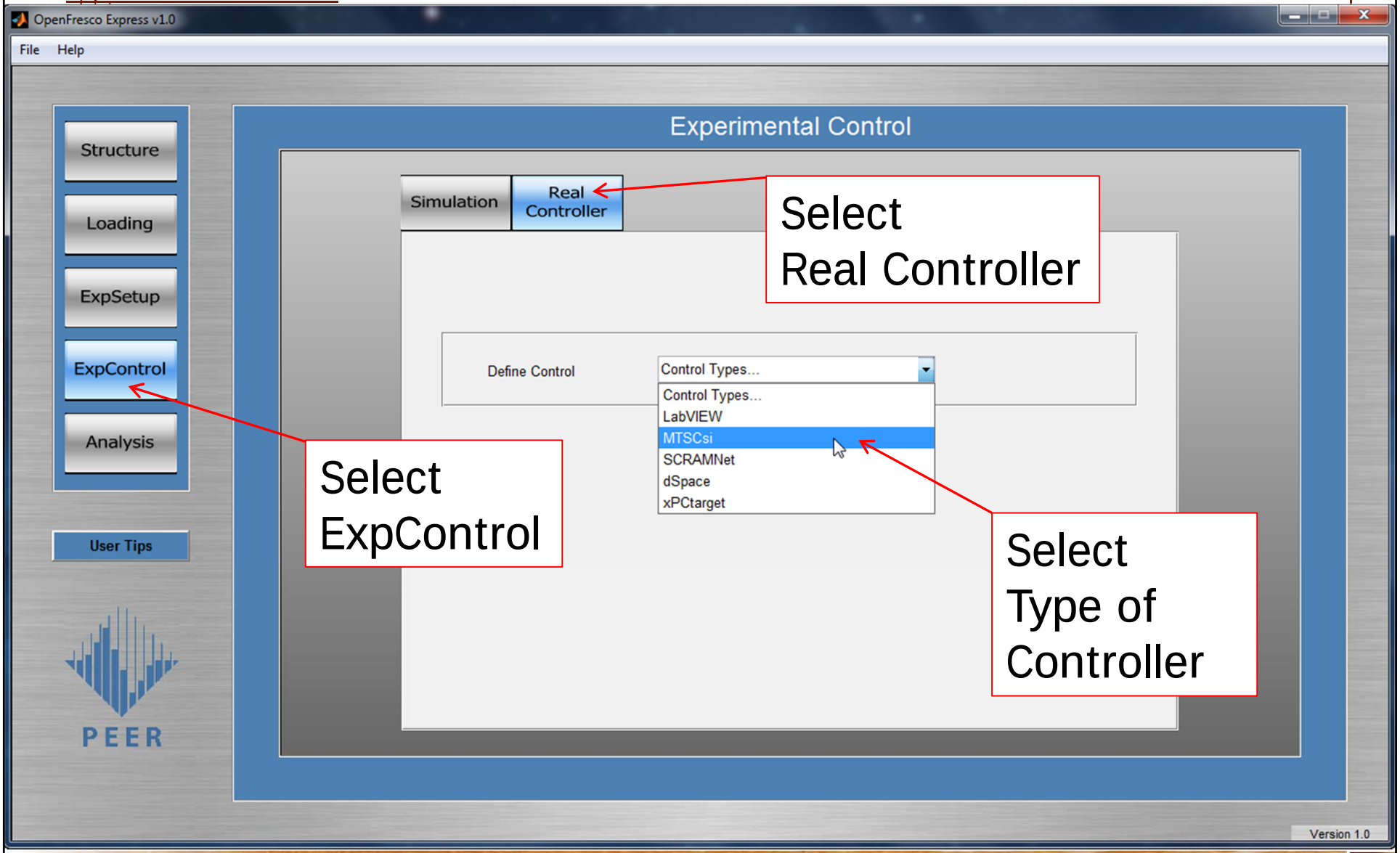
Simulated Experimental Control



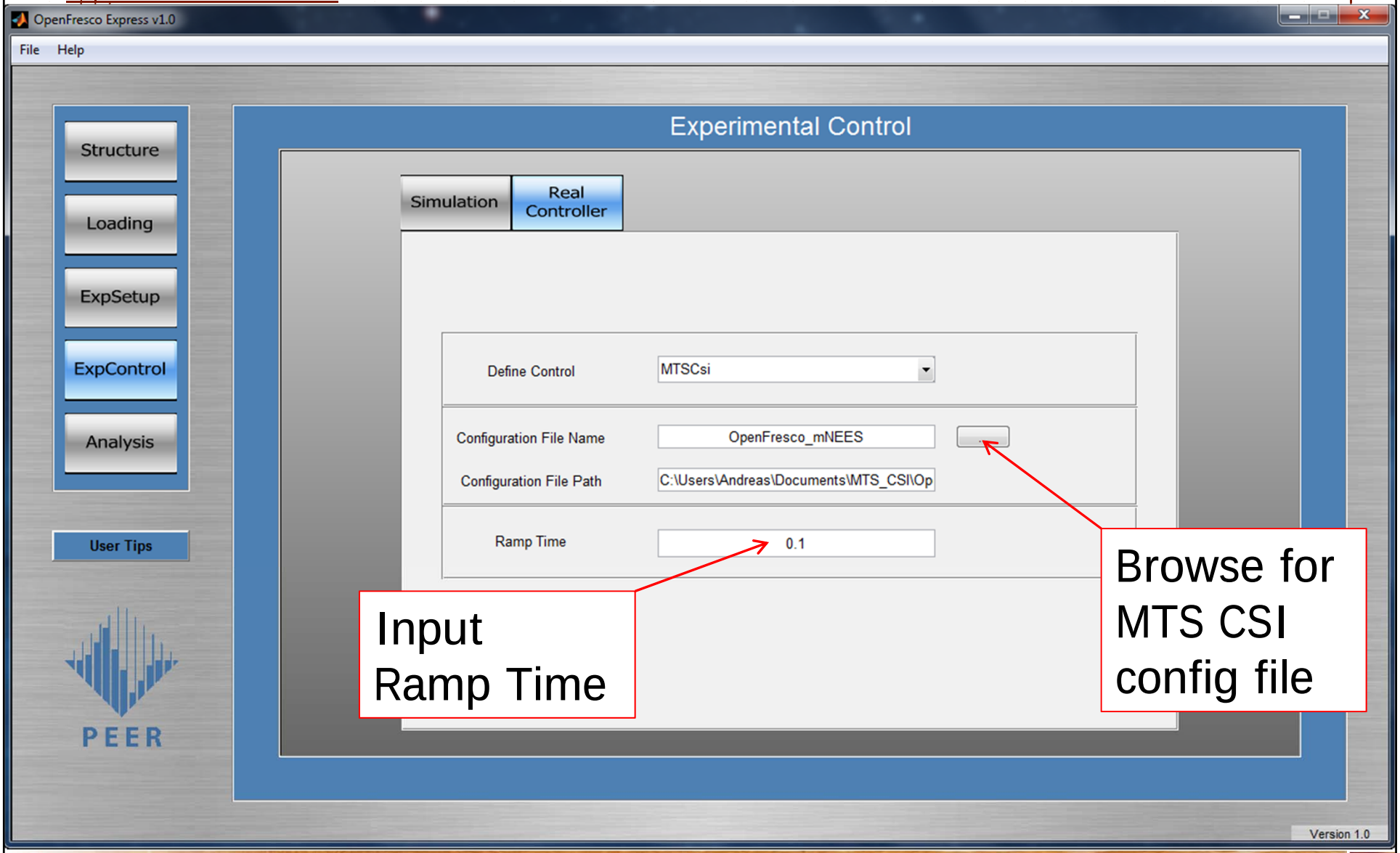
Simulated Experimental Control

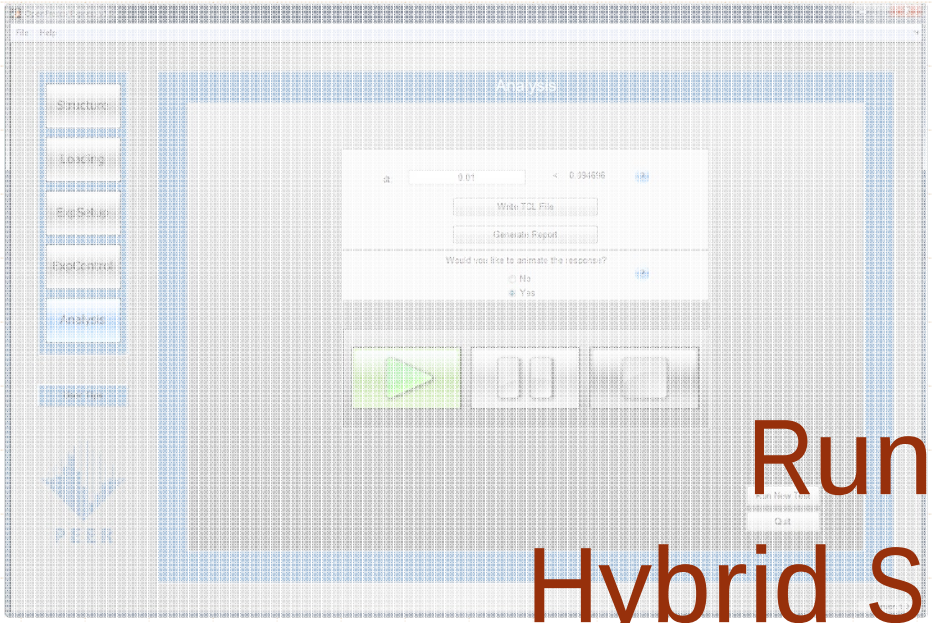


Real Experimental Control

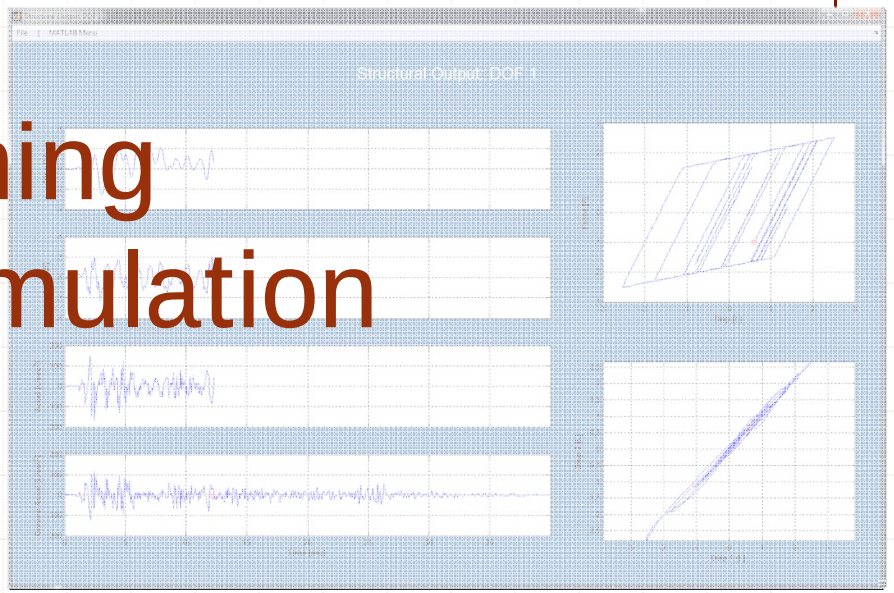


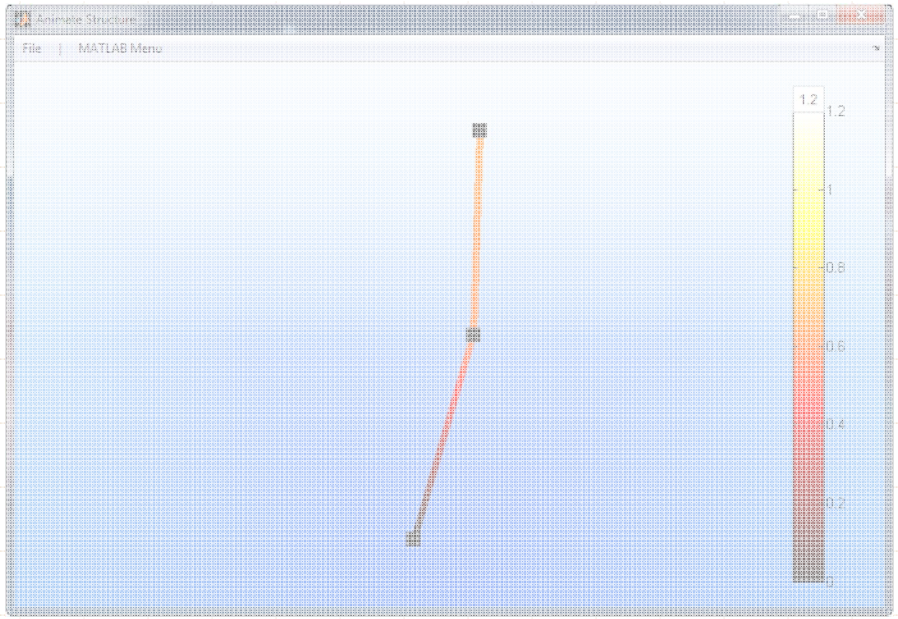
Real Experimental Control



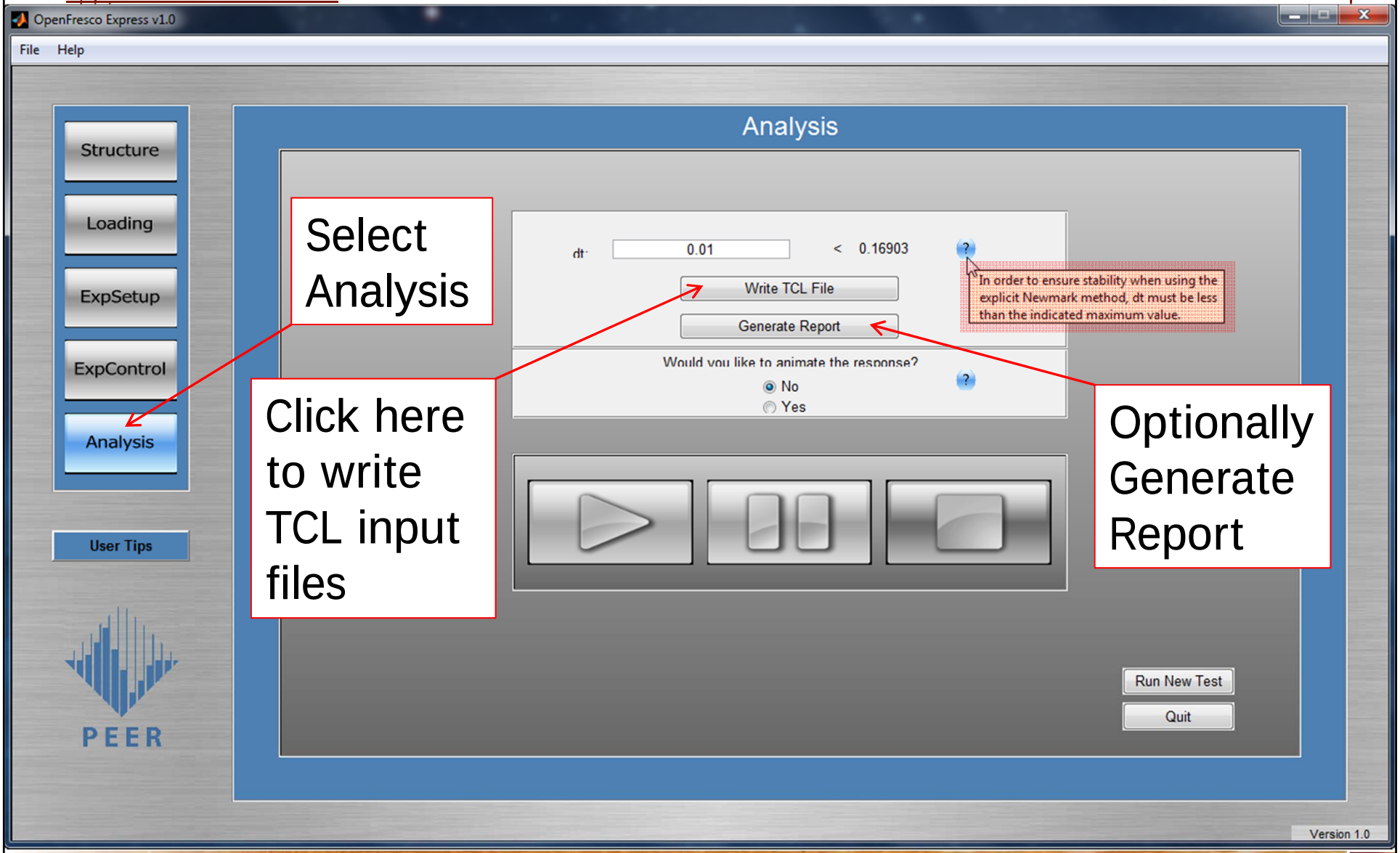


Running Hybrid Simulation

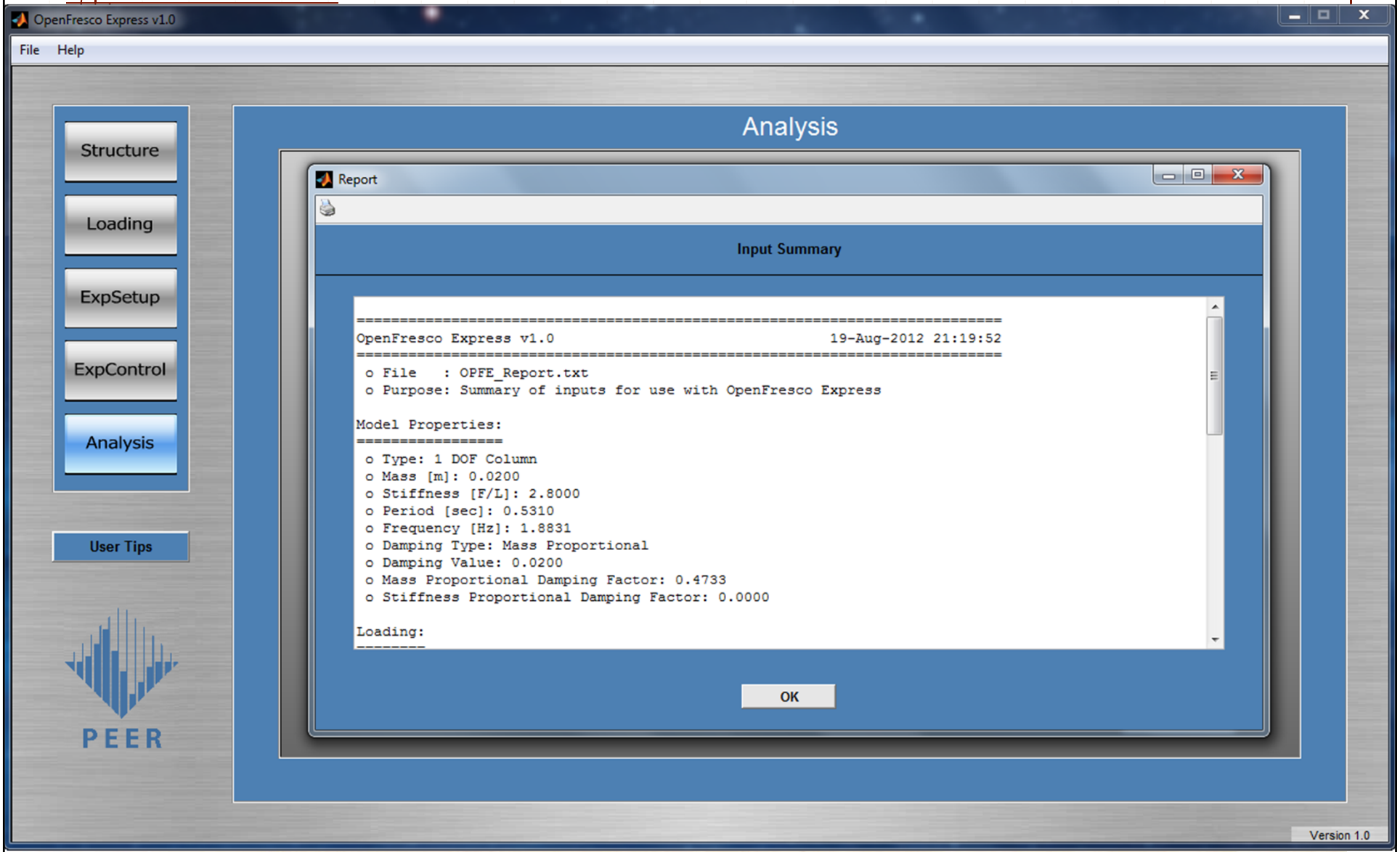




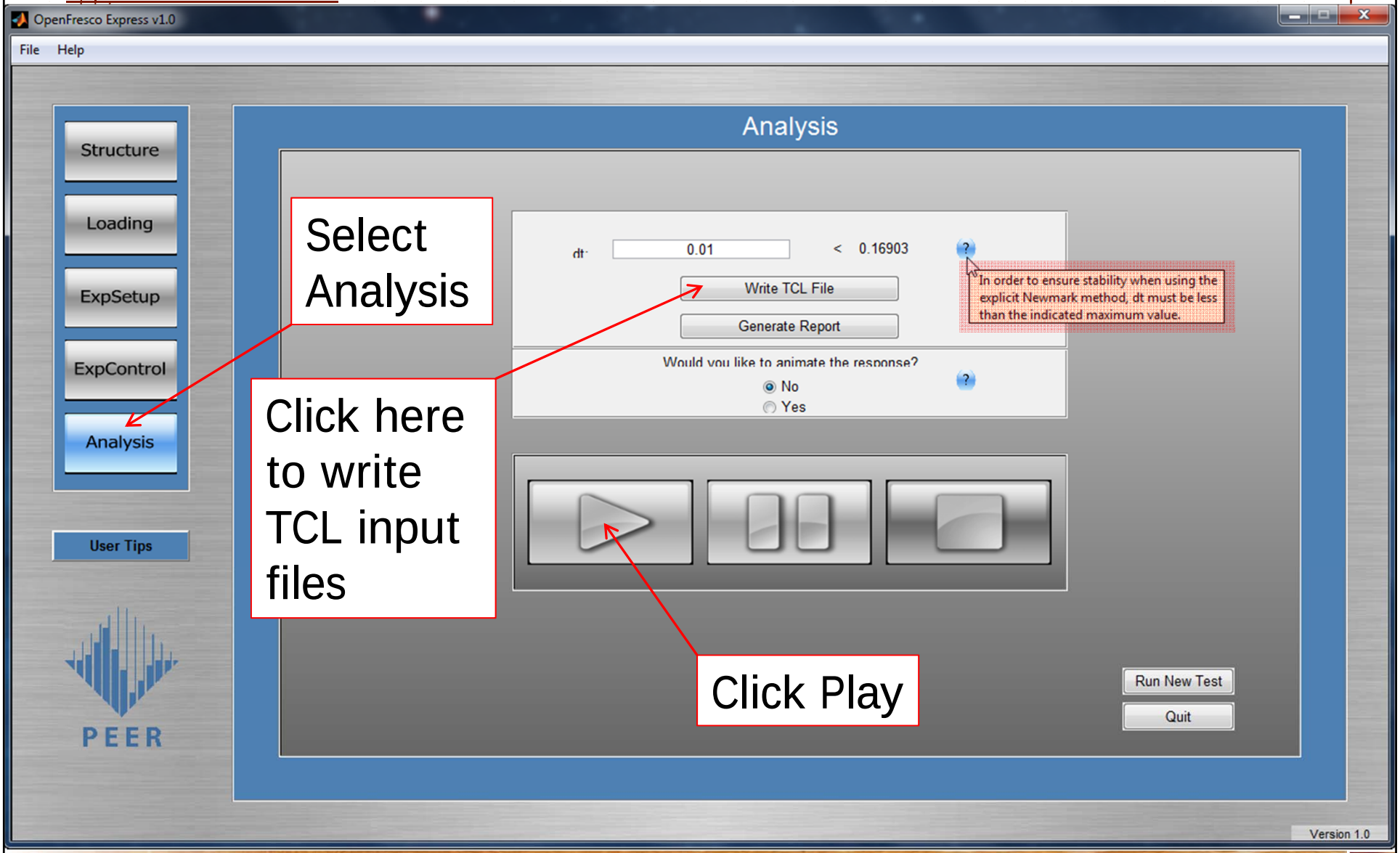
Analysis


OpenFresco Express v1.0
File
Help
Structure
Loading
ExpSetup
ExpControl
Analysis
User Tips
PEER
Analysis
Select Analysis
dt
0.01
< 0.16903
Write TCL File
Generate Report
In order to ensure stability when using the explicit Newmark method, dt must be less than the indicated maximum value.
Would you like to animate the response?
No
Yes
Click here to write TCL input files
Optionally Generate Report
Run New Test
Quit
Version 1.0

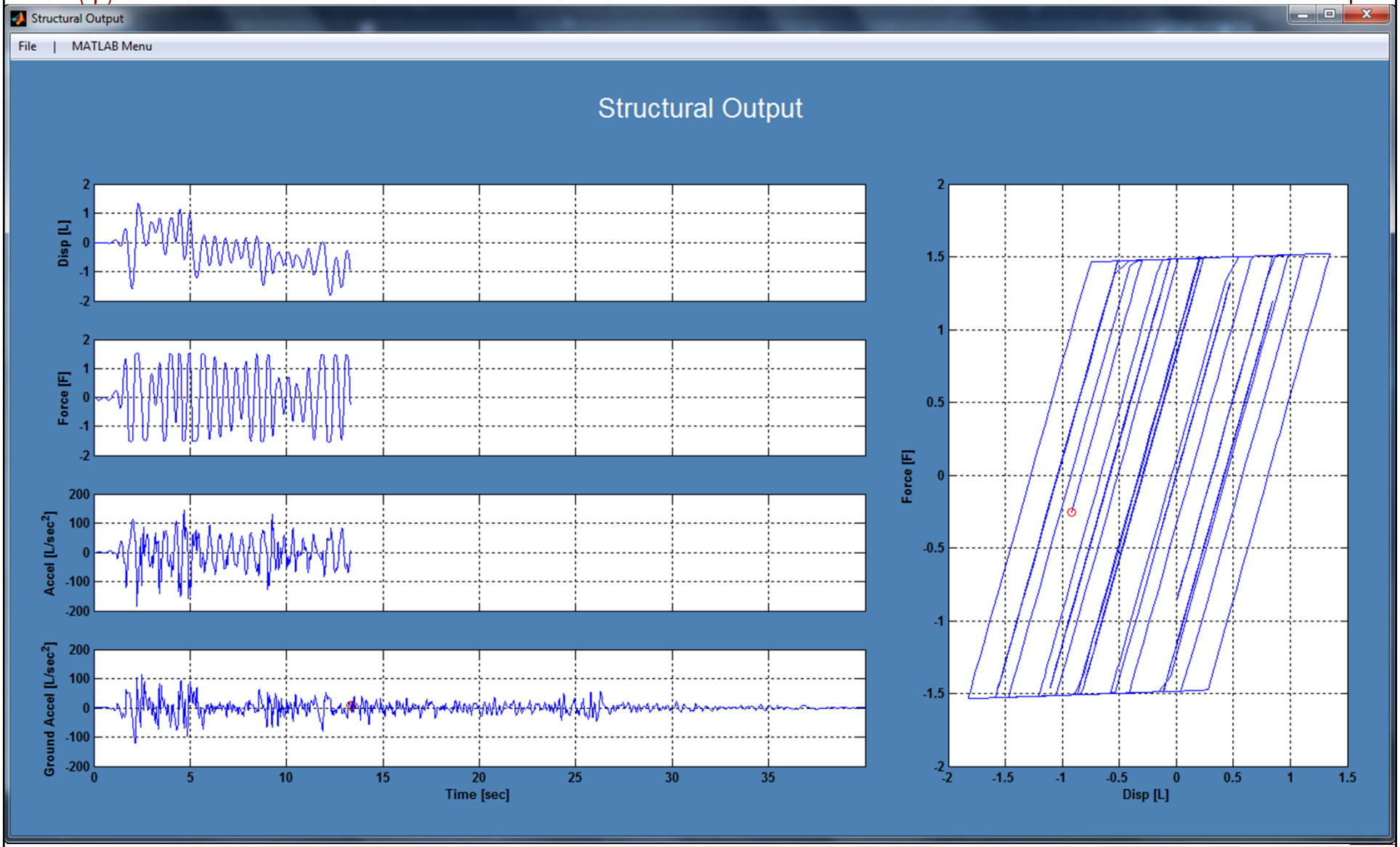
Report/Input Summary



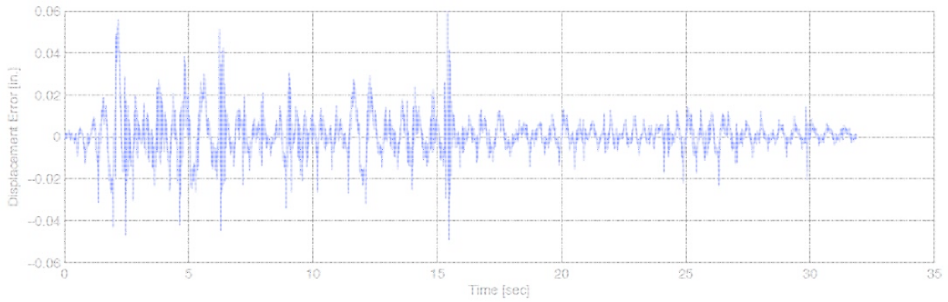
Analysis: Start Hybrid Simulation

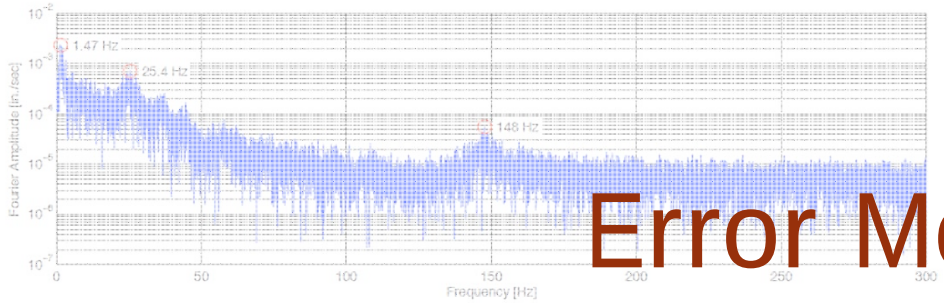


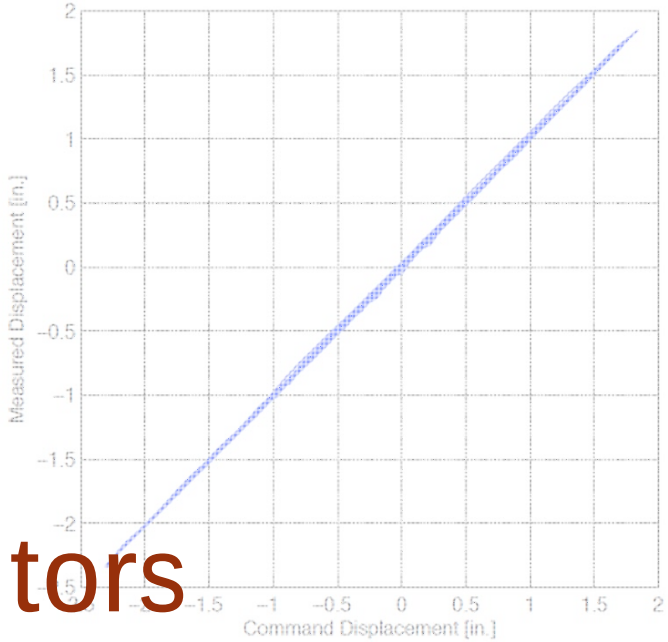
Structural Output

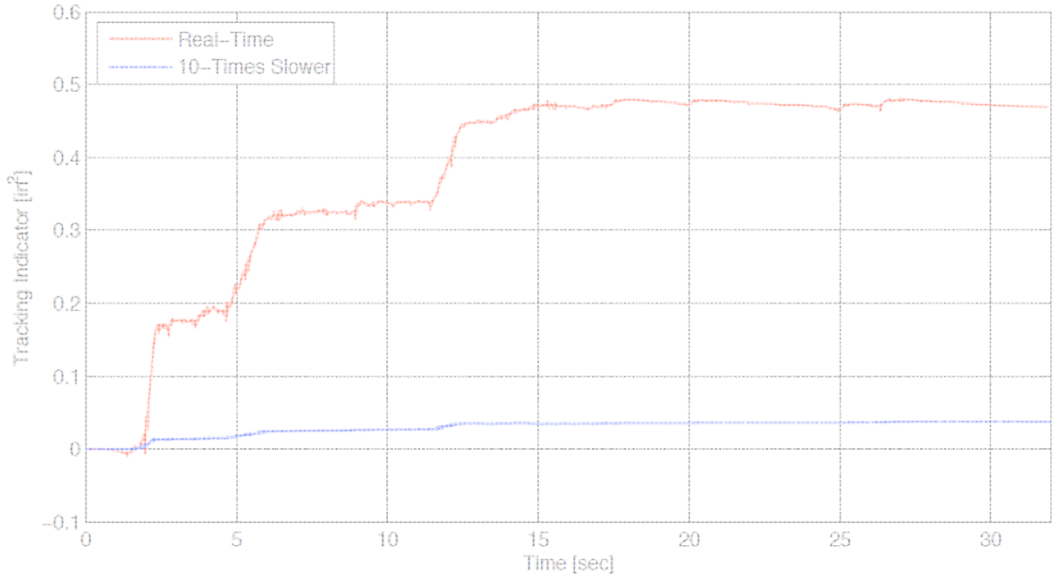


Error Monitors

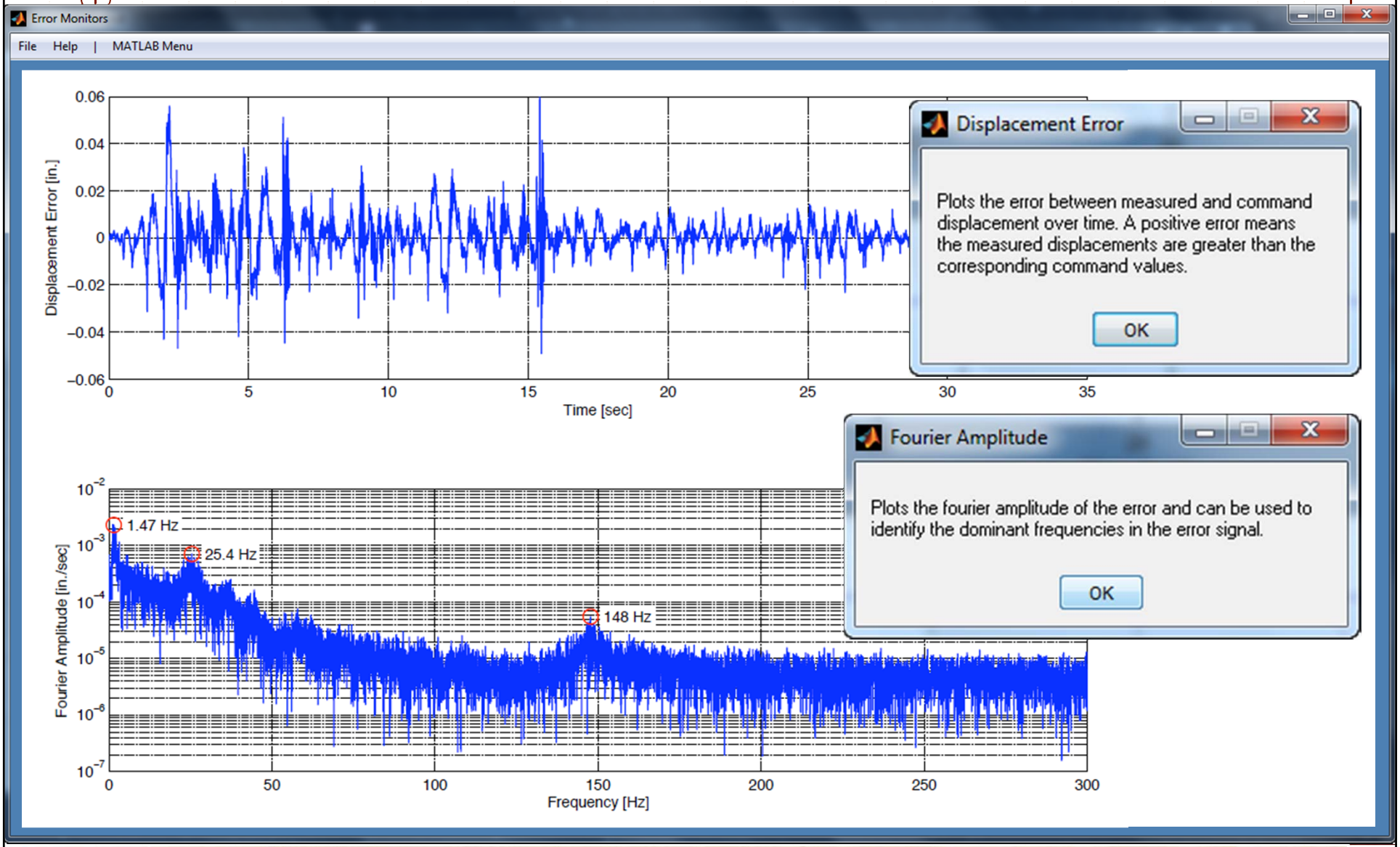




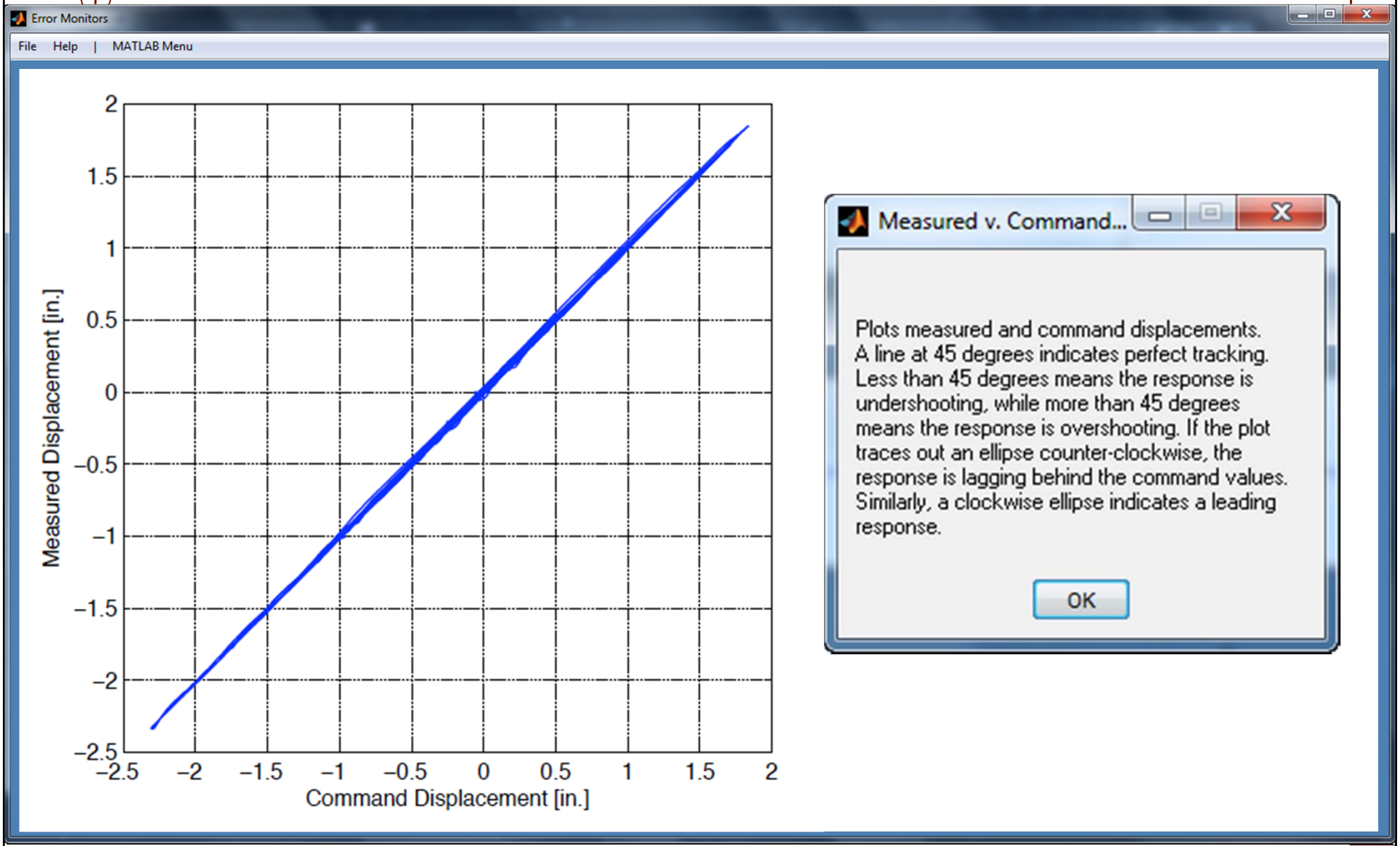




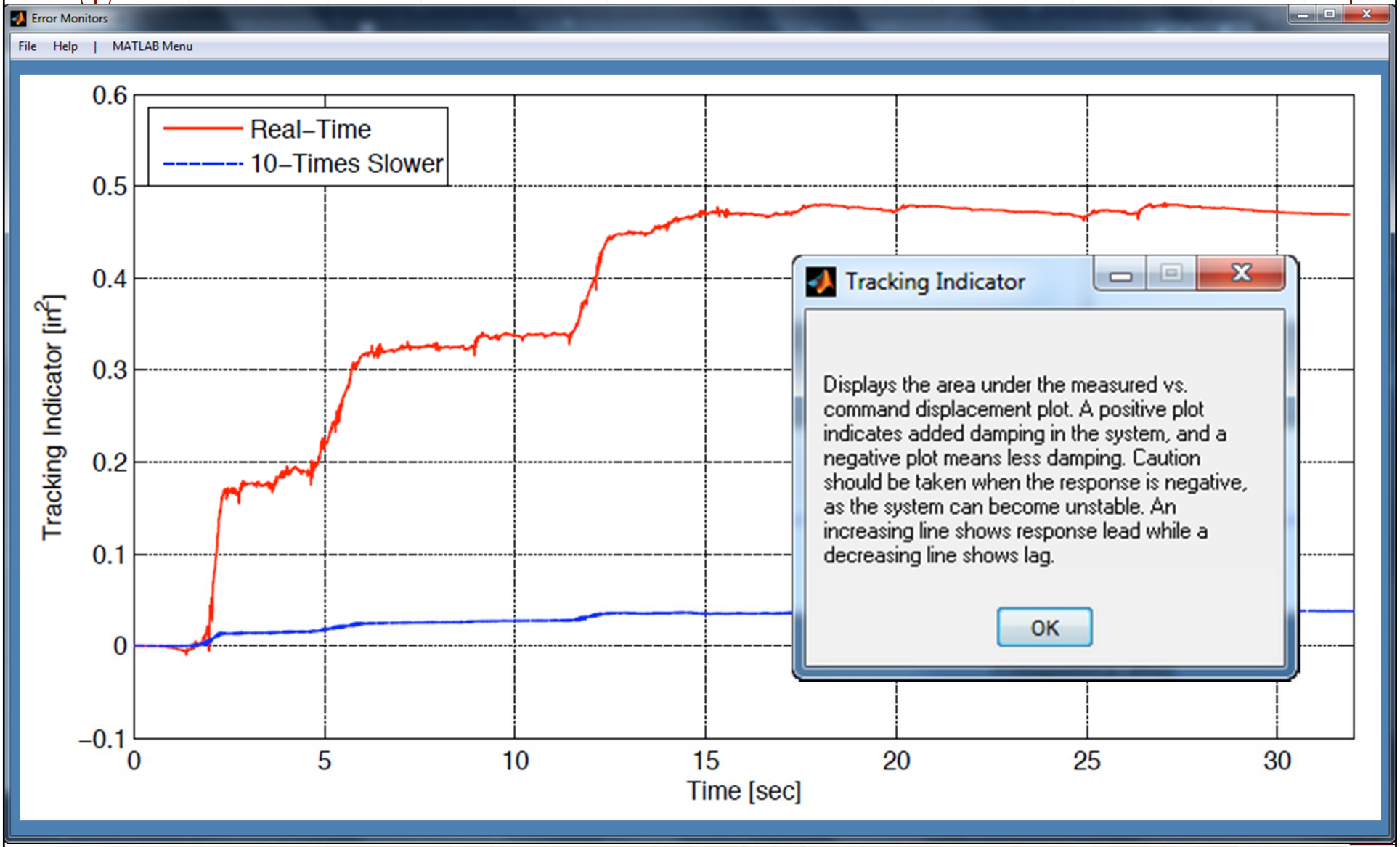
Error Monitors: dispError and FFT

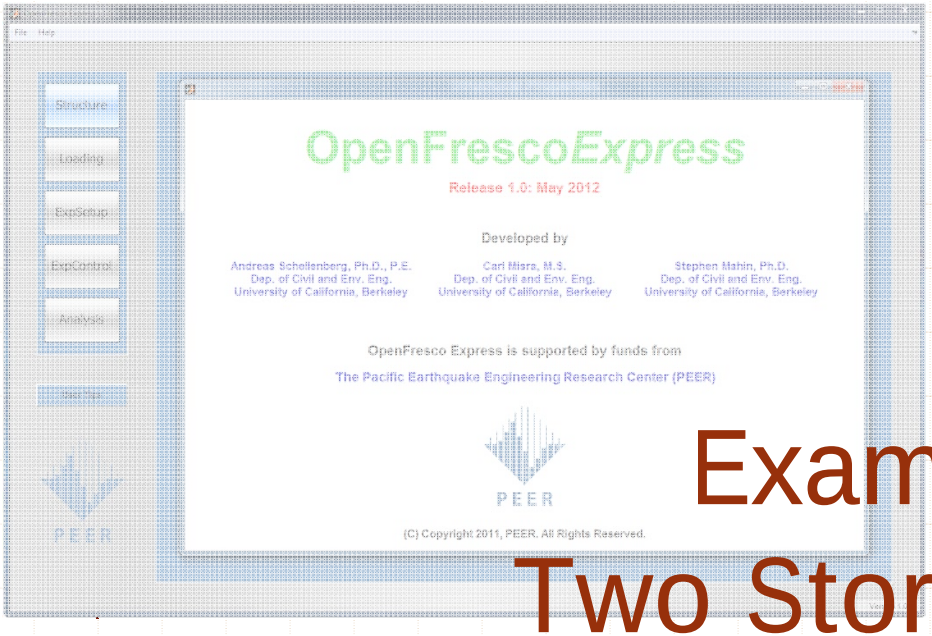


Error Monitors: Subspace Plot

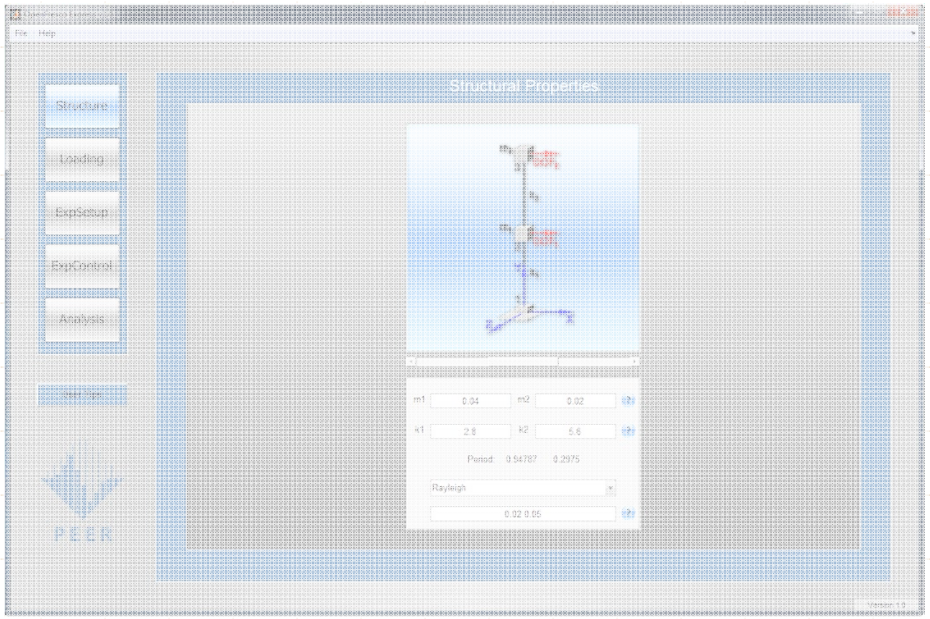


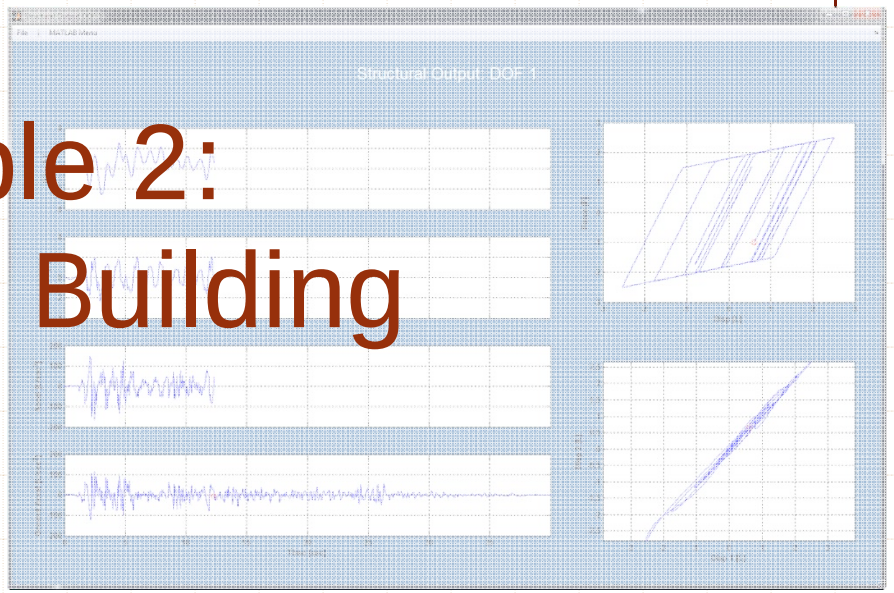
Error Monitors: Tracking Indicator



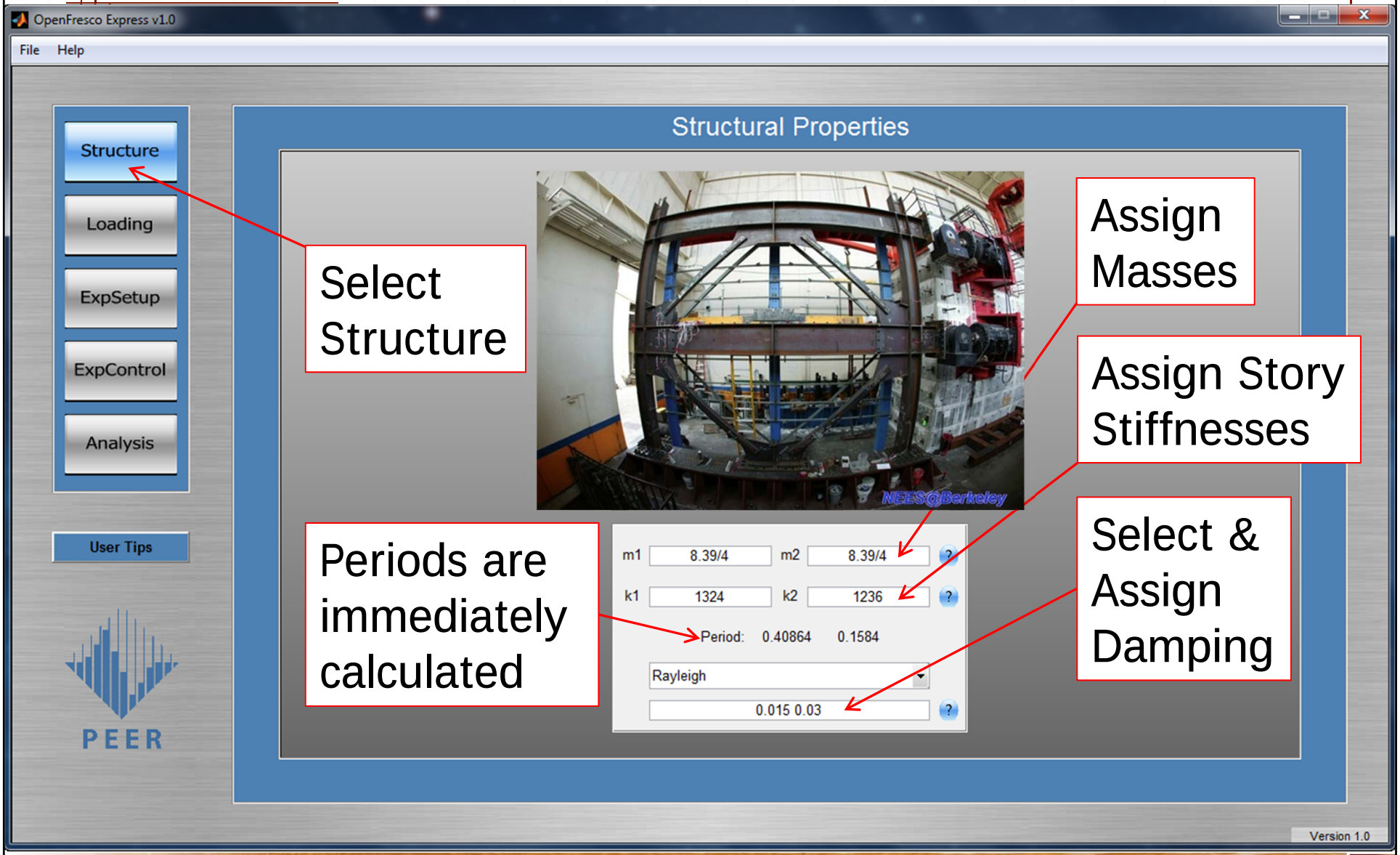


Example 2: Two Story Building

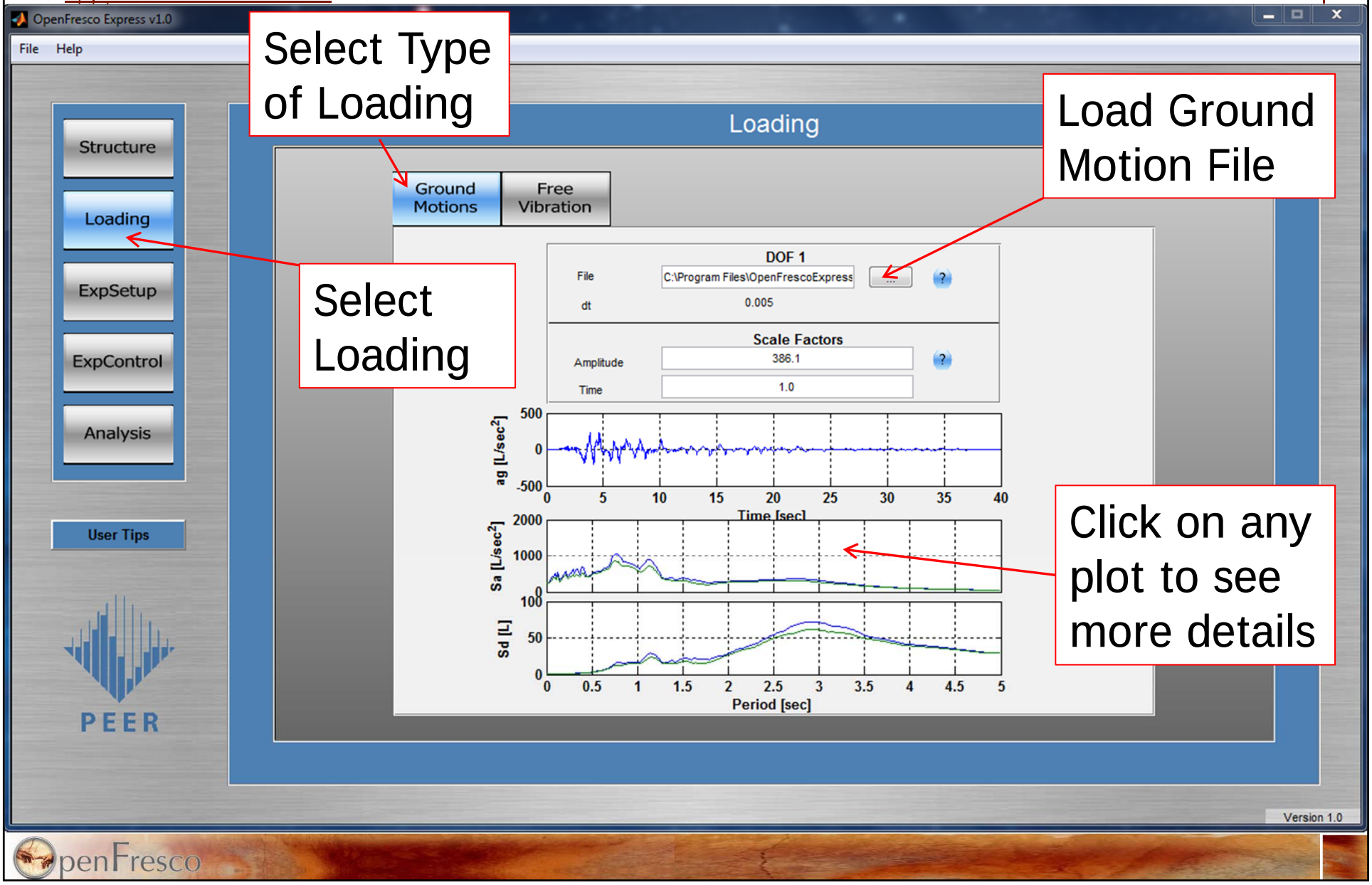




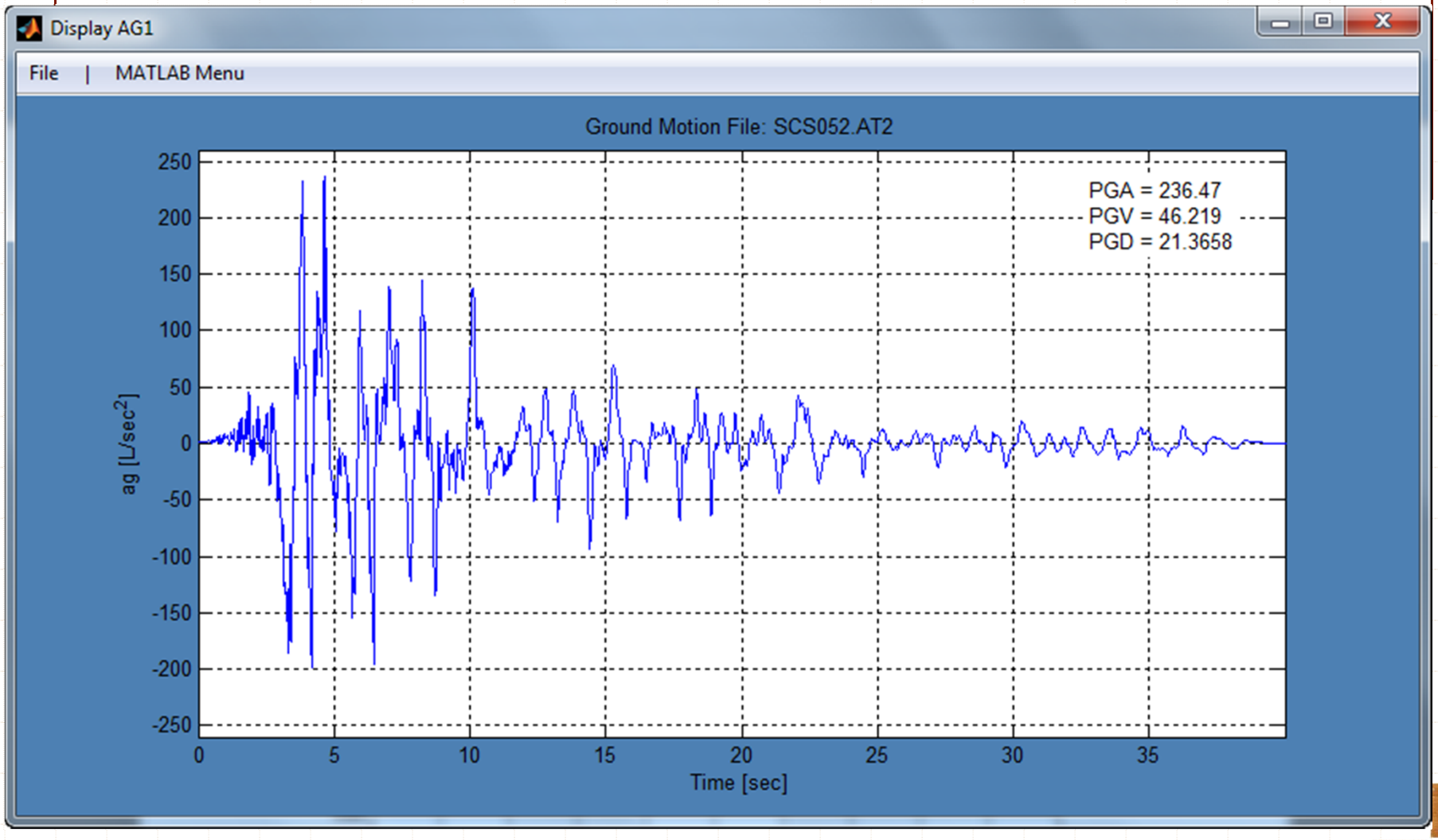
Structural Properties



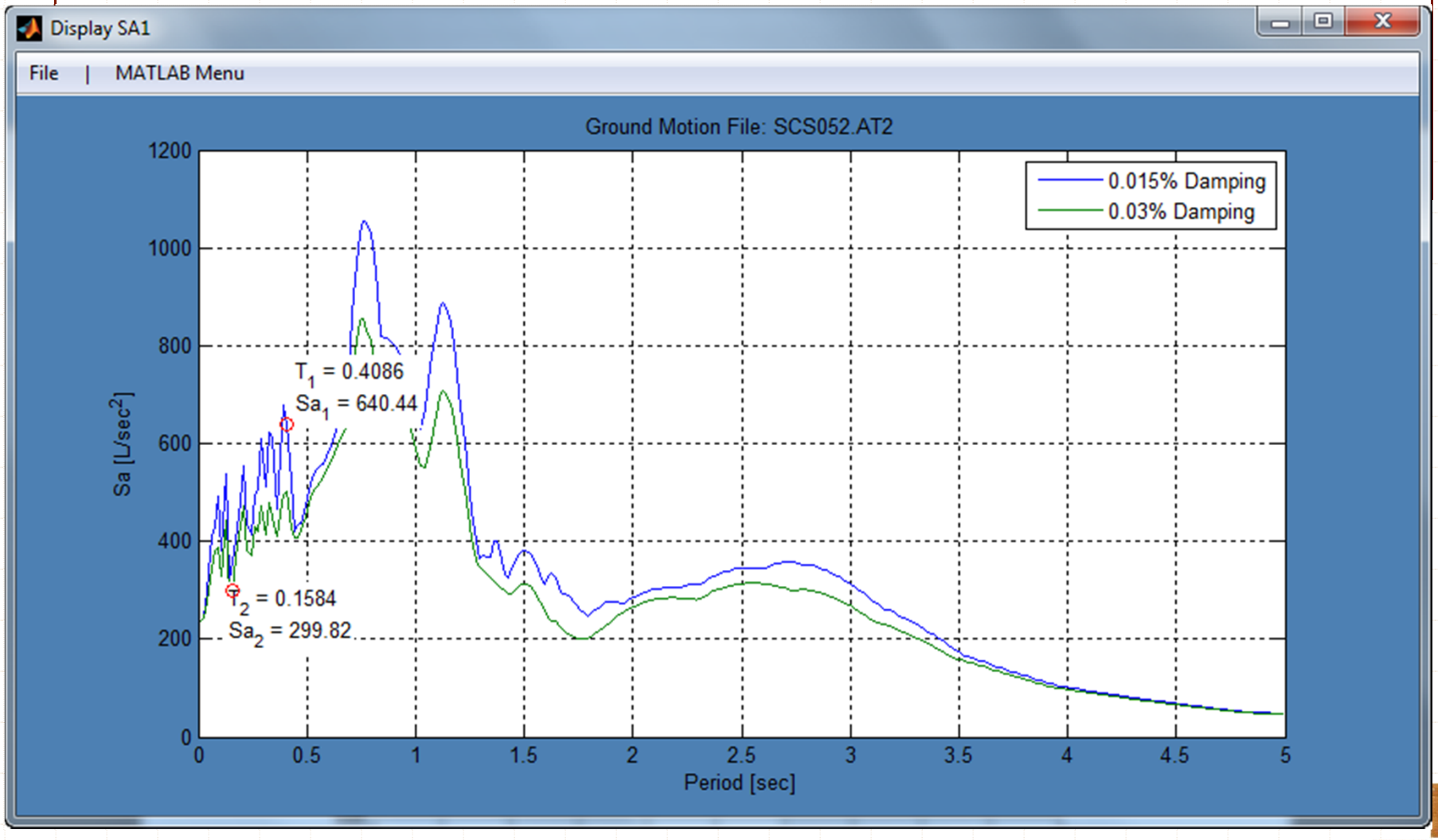
Define Loading: 1994 Northridge



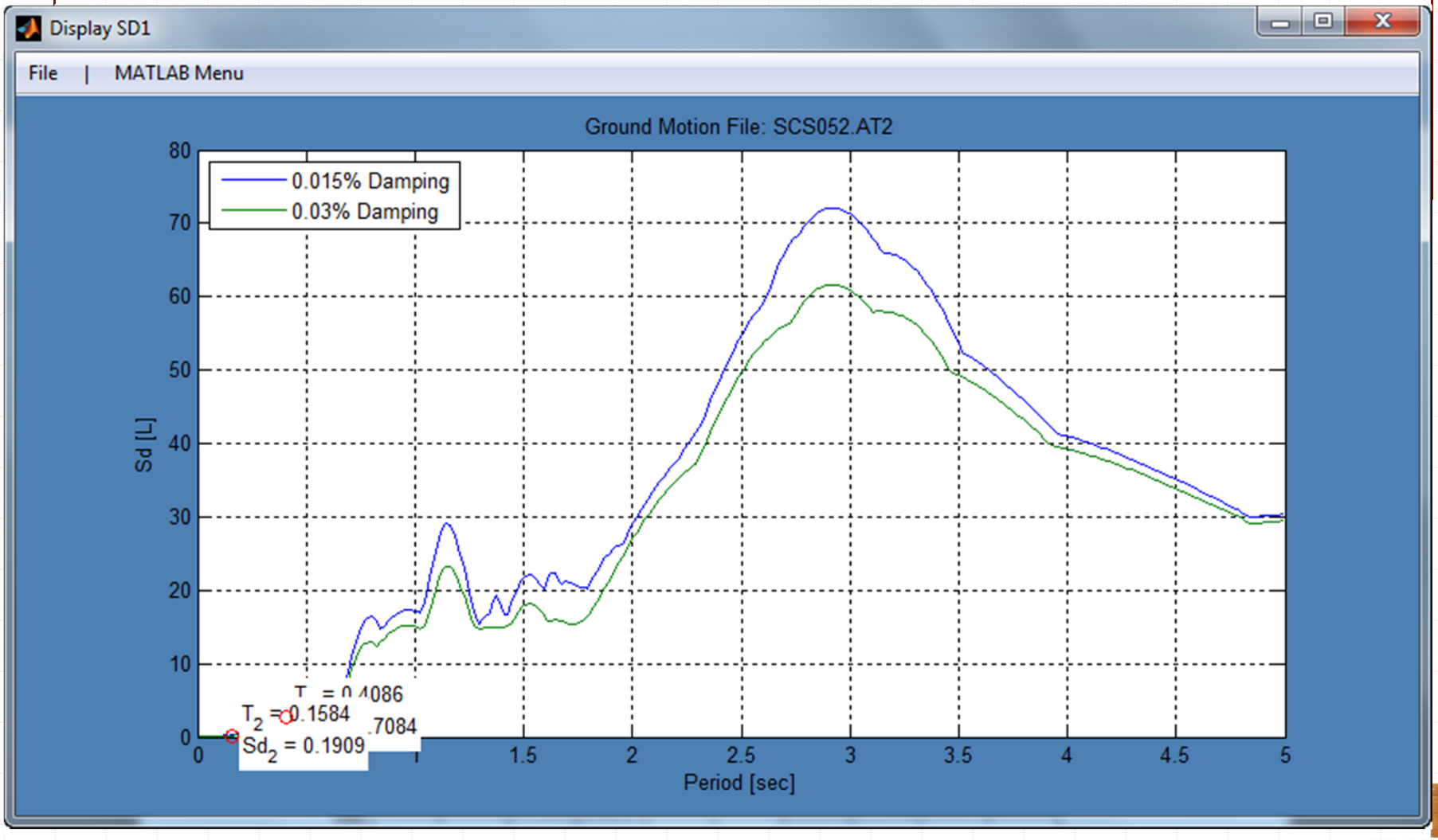
Ground Acceleration History



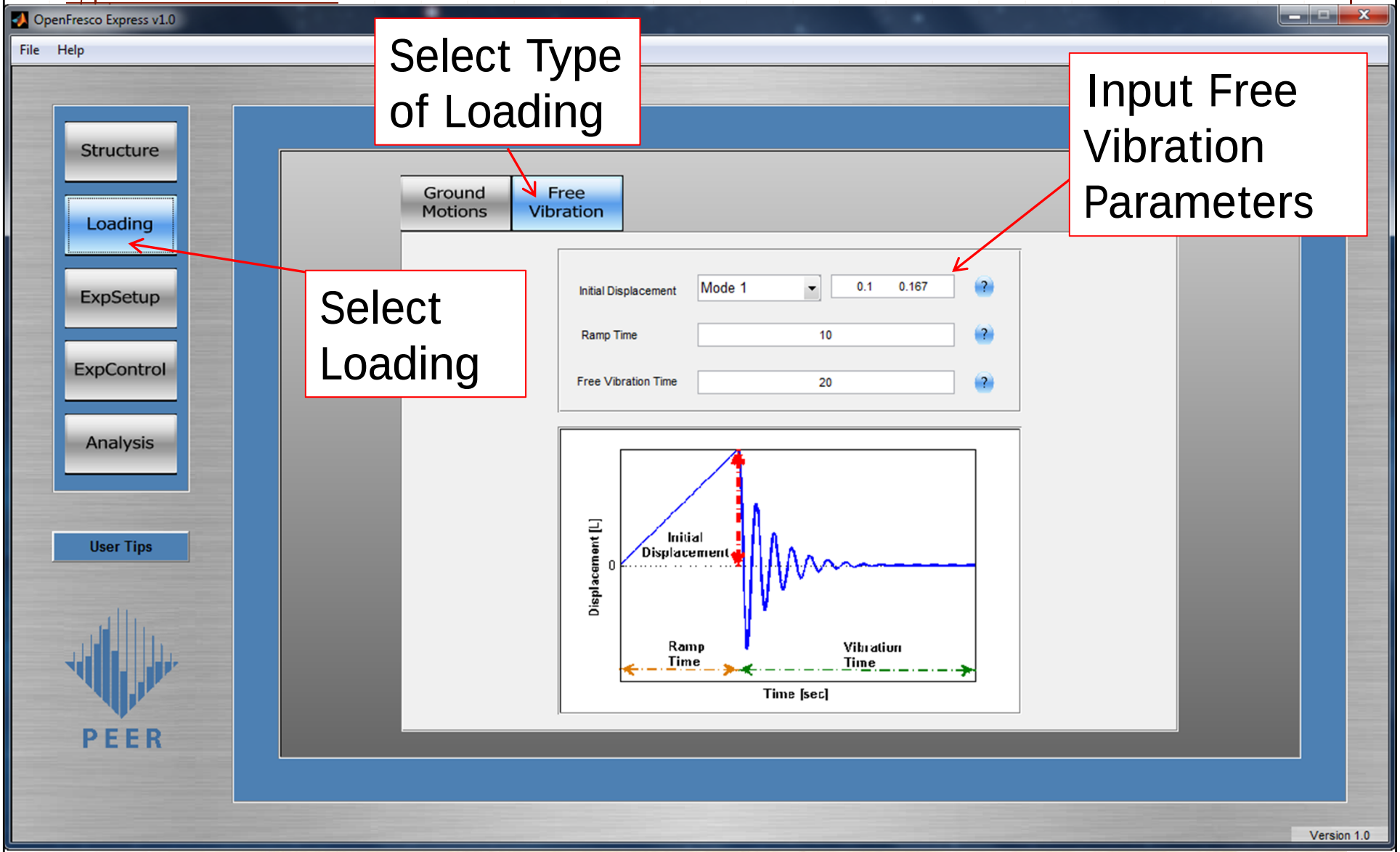
Pseudo Acceleration Spectra



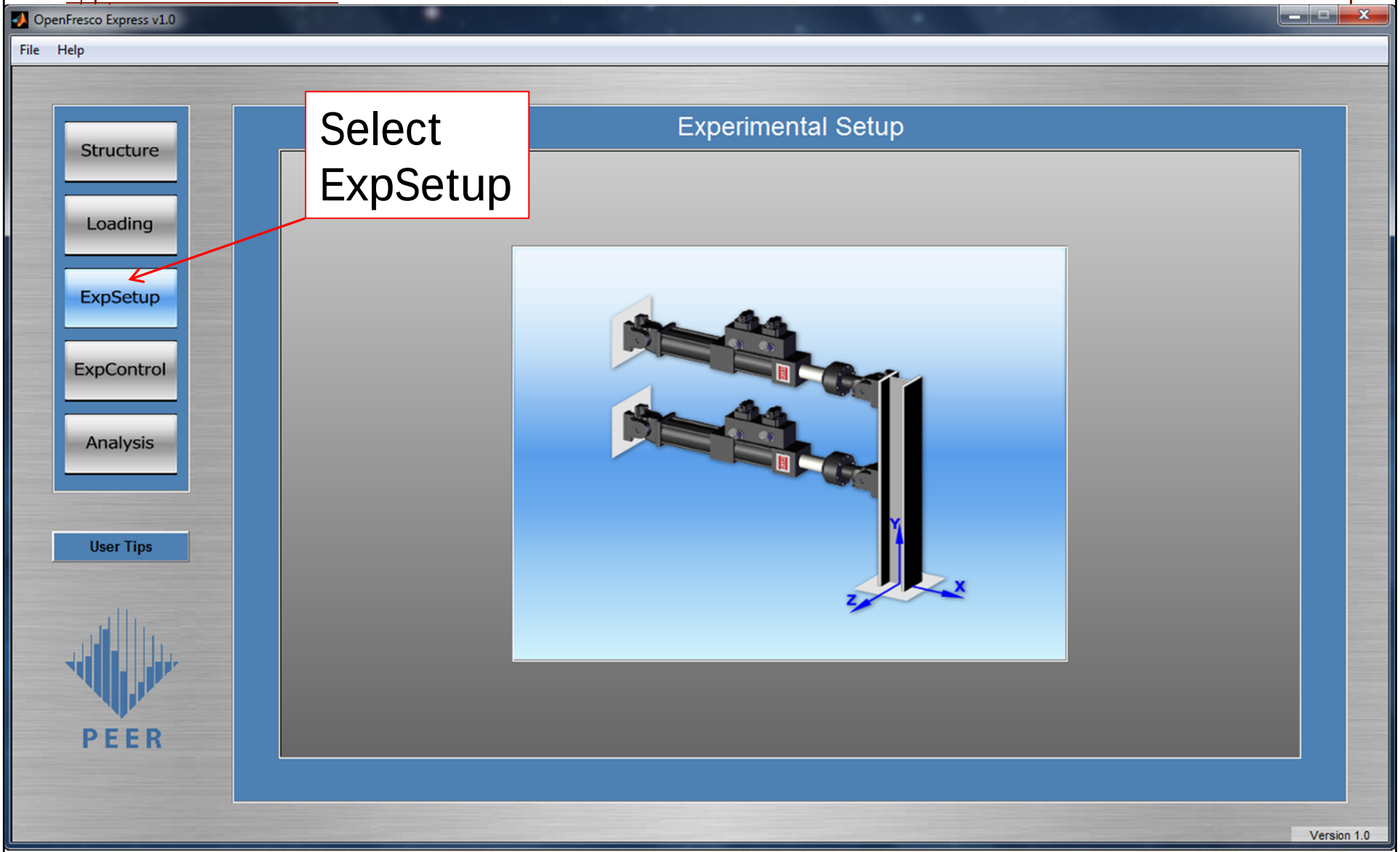
Displacement Spectra



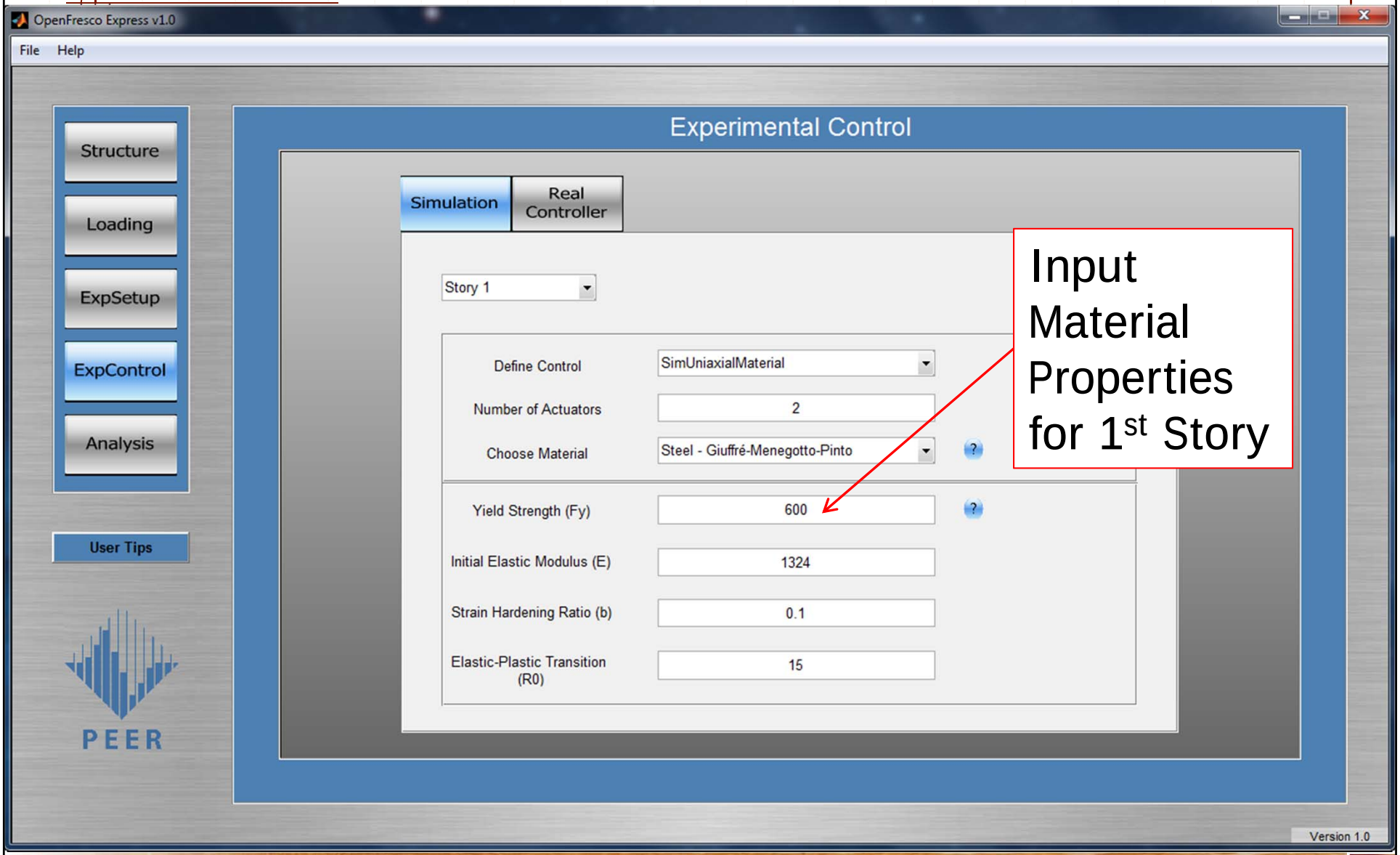
Define Loading: Free Vibration



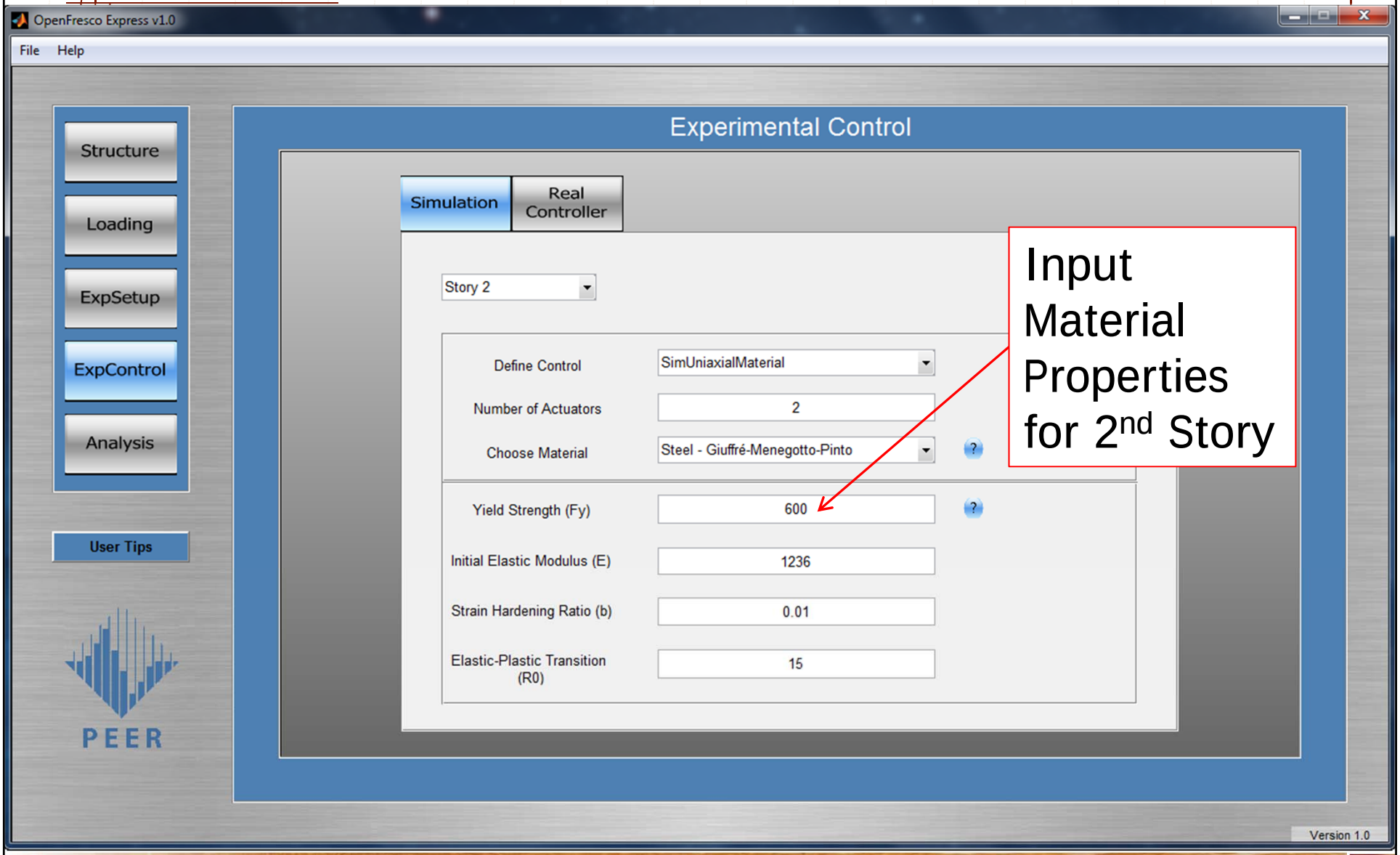
Experimental Setup



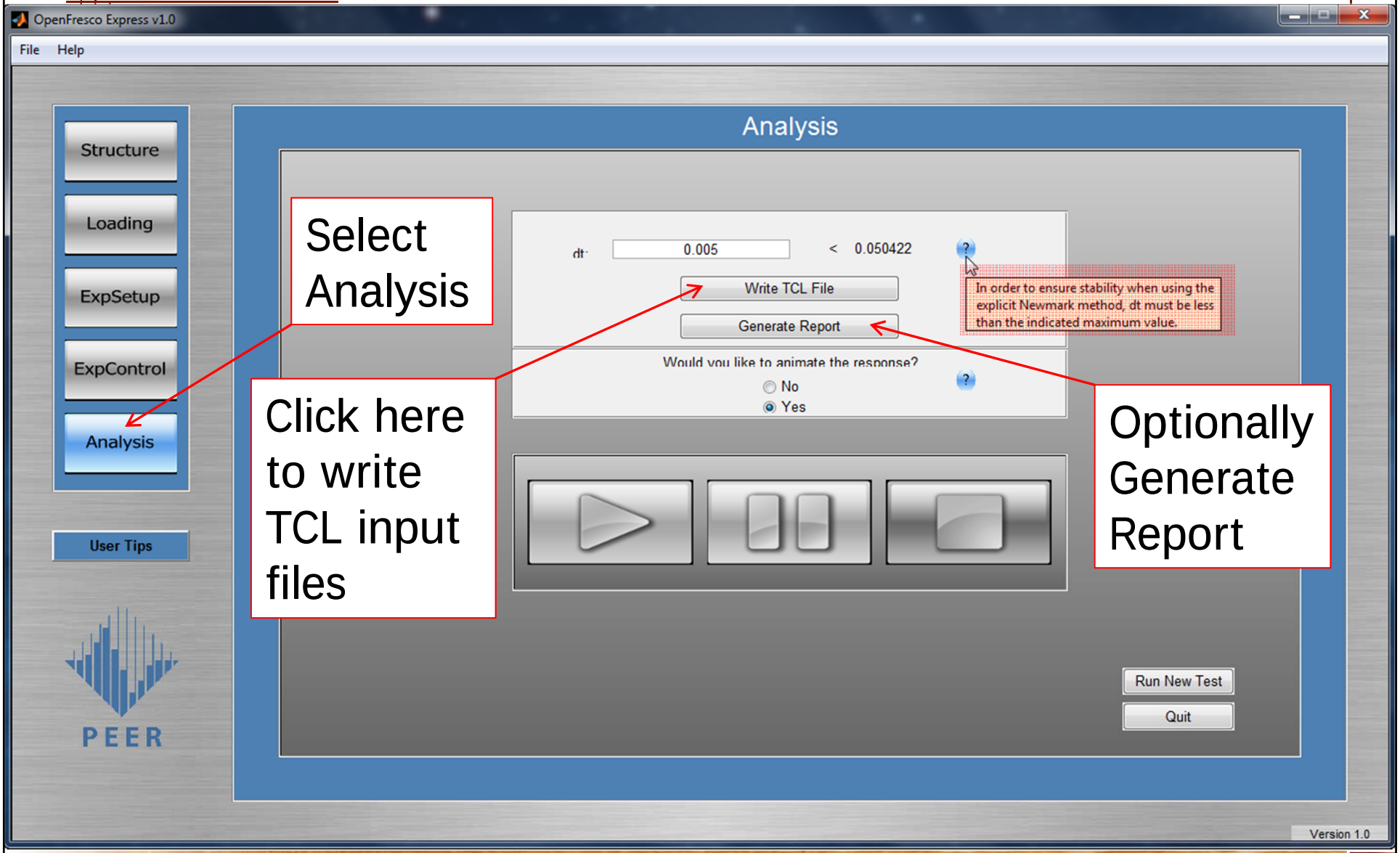
Experimental Control: Story 1



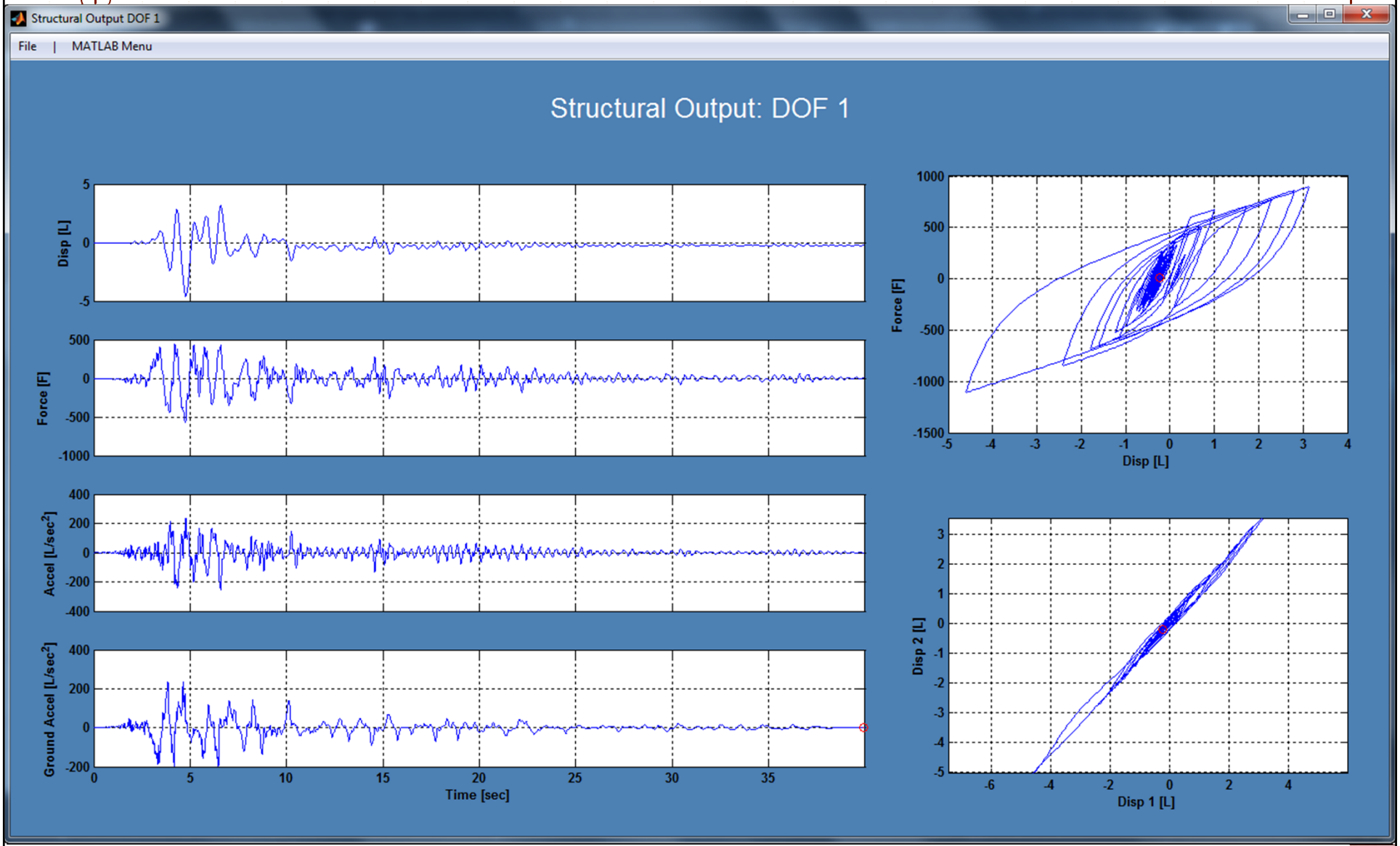
Experimental Control: Story 2



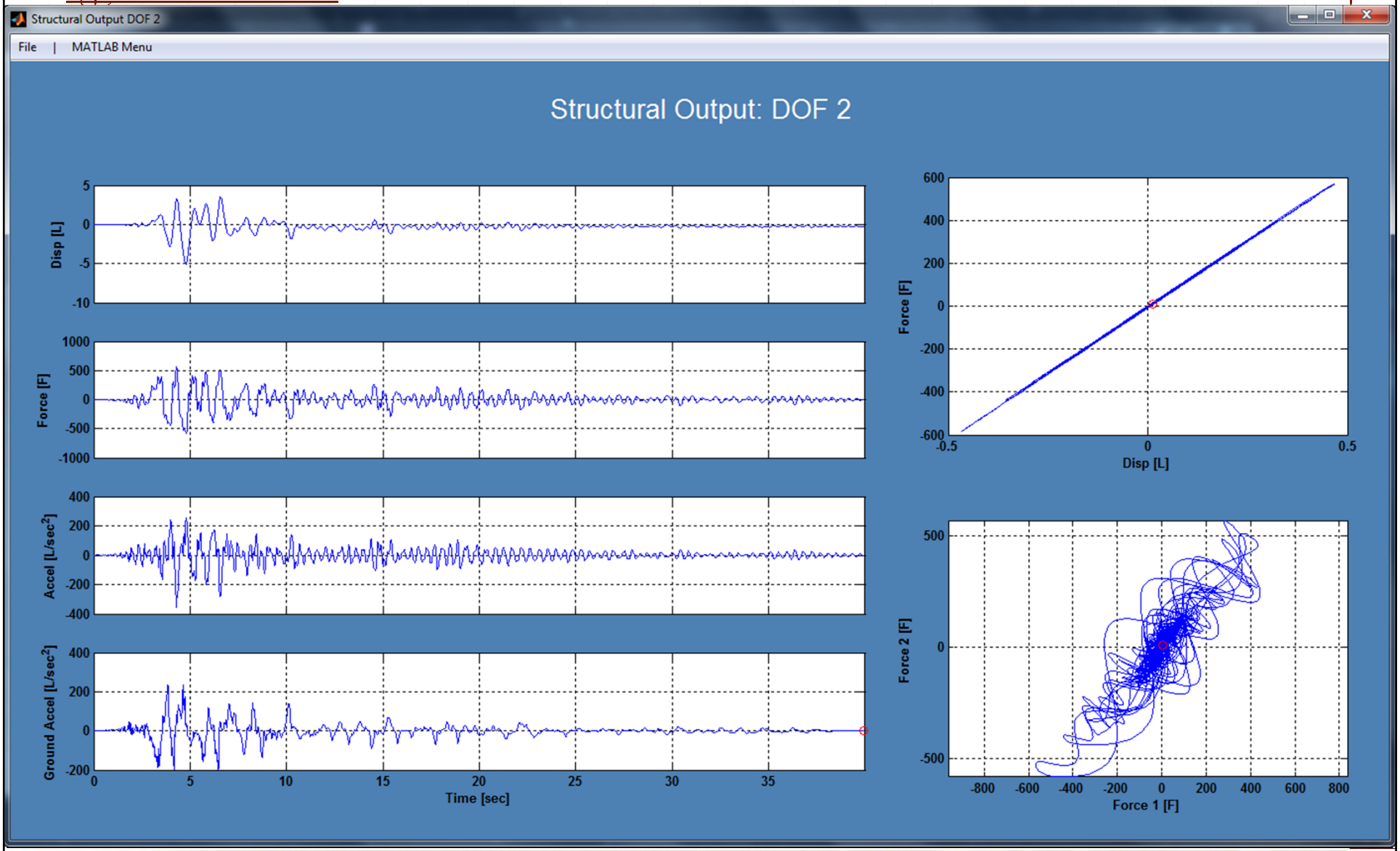
Analysis


OpenFresco Express v1.0
File
Help
Structure
Loading
ExpSetup
ExpControl
Analysis
User Tips
PEER
Analysis
Select Analysis
dt
0.005
<
0.050422
Write TCL File
Generate Report
In order to ensure stability when using the explicit Newmark method, dt must be less than the indicated maximum value.
Would you like to animate the response?
No
Yes
Click here to write TCL input files
Optionally Generate Report
Run New Test
Quit
Version 1.0

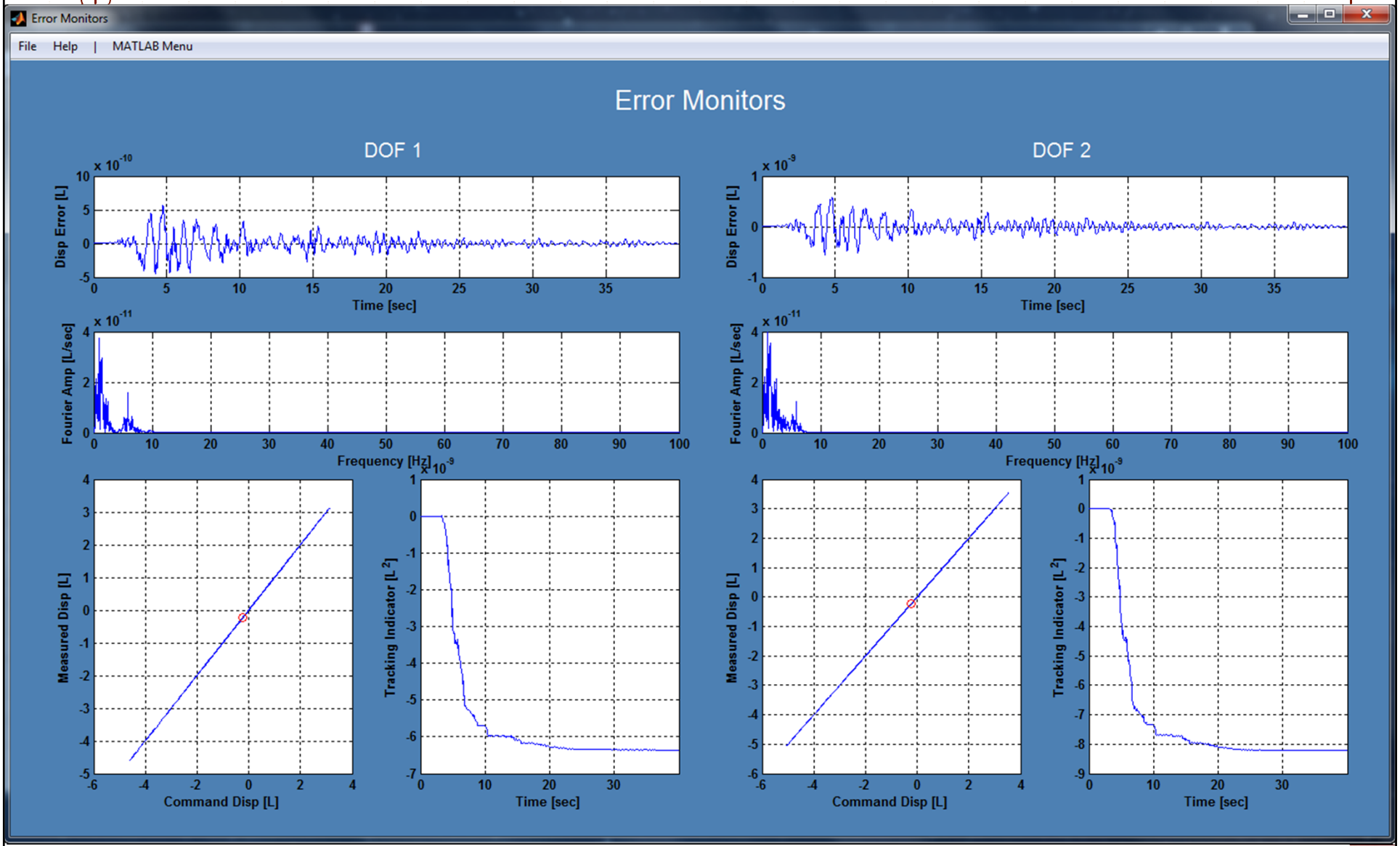
Structural Output: 1st Story



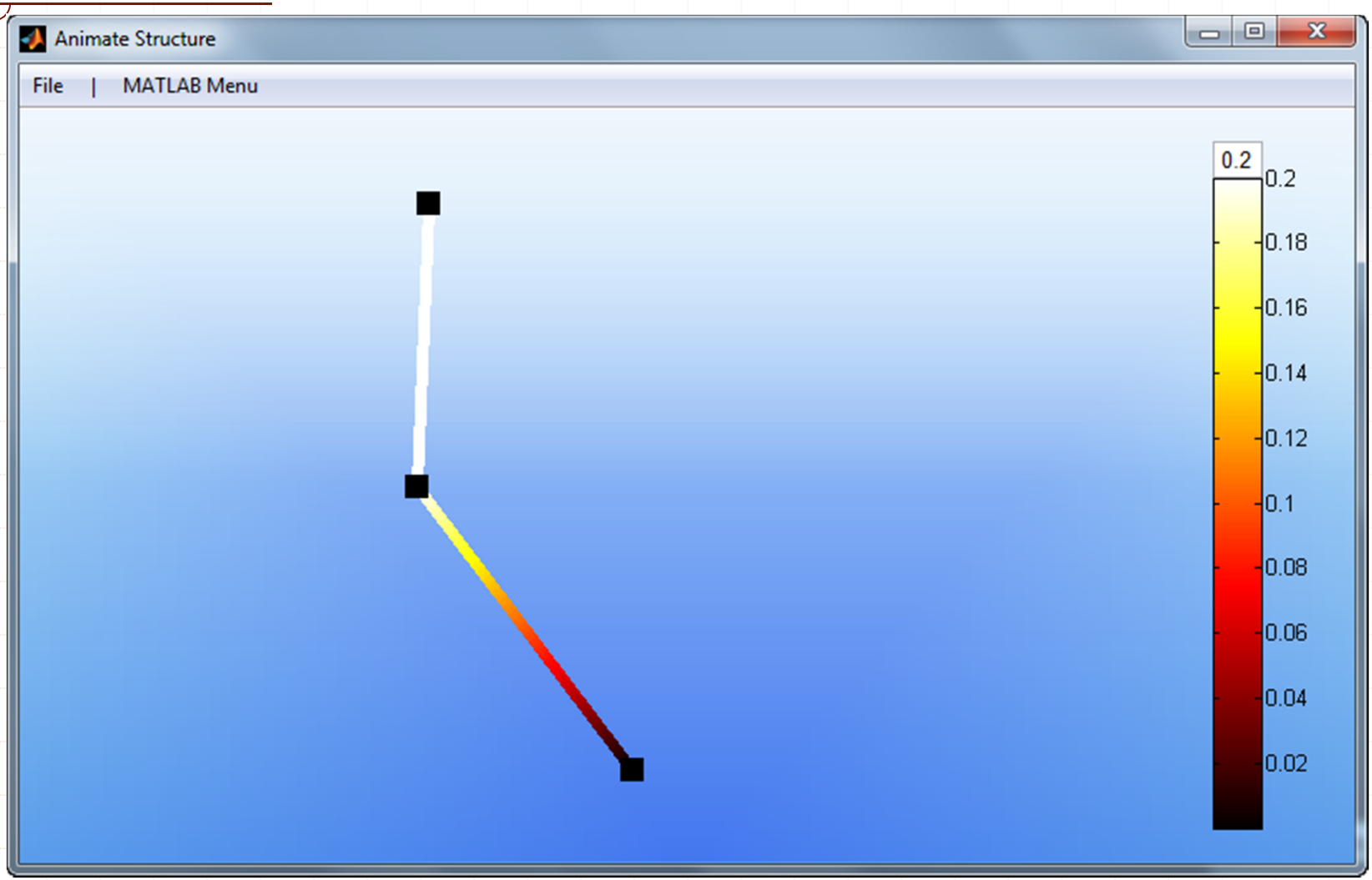
Structural Output: 2nd Story



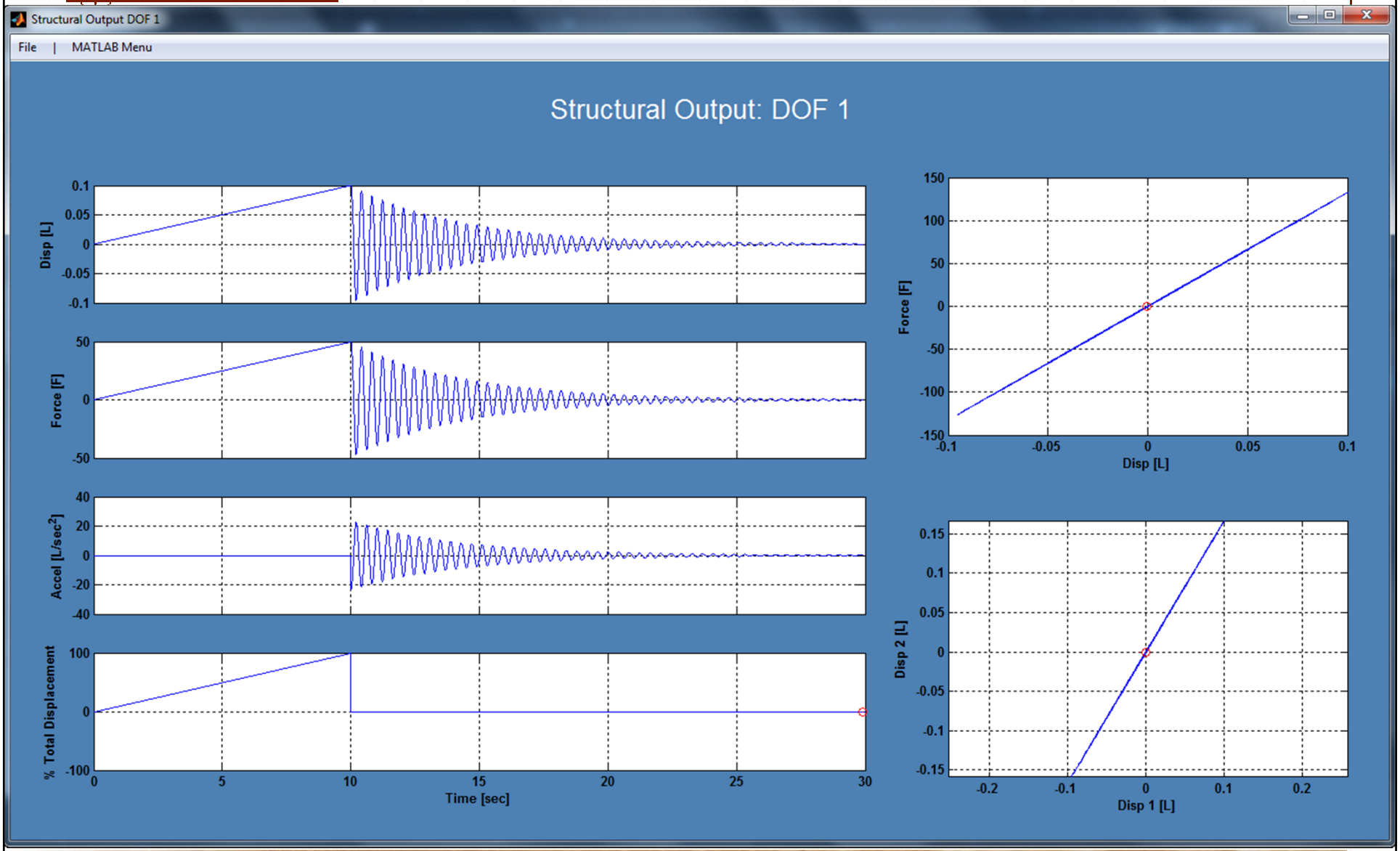
Error Monitors

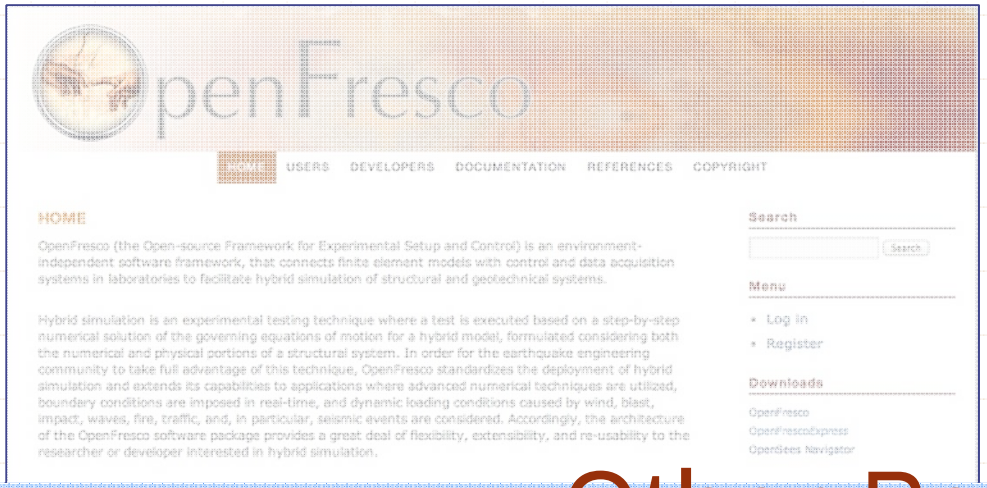


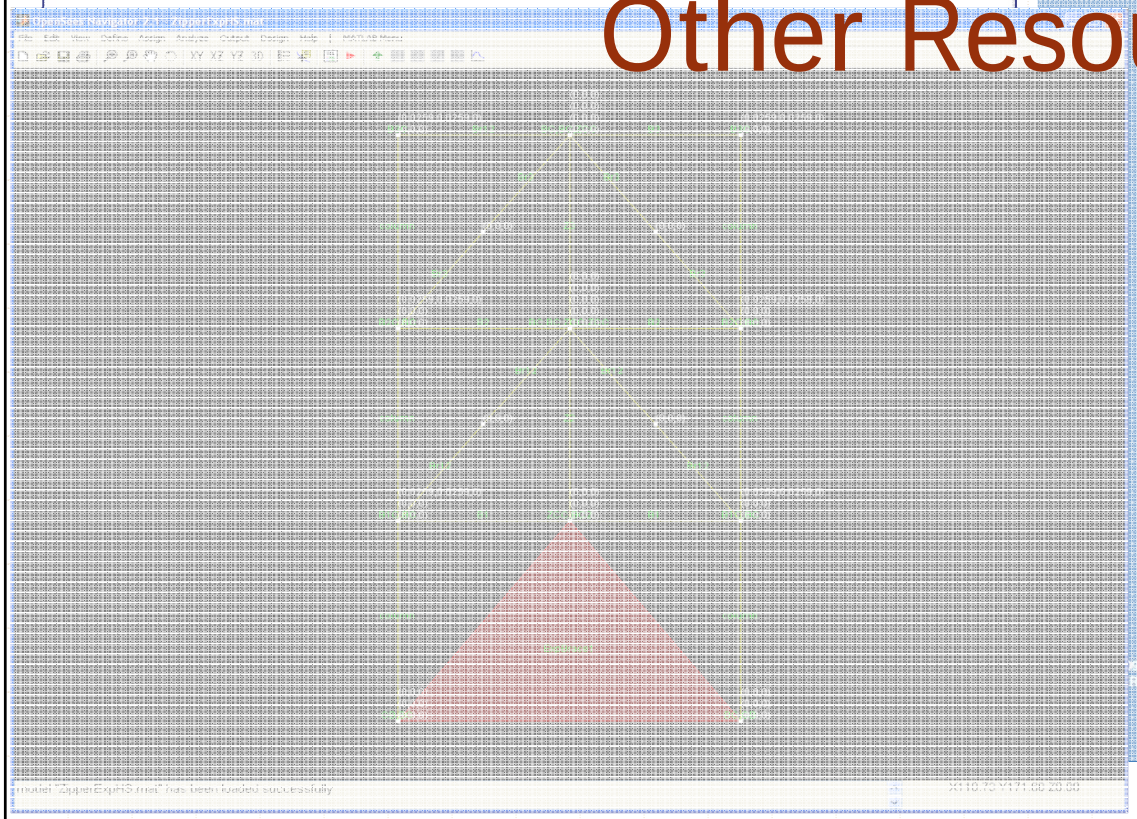
Animation of Model



Free Vibration Response







Other Resources

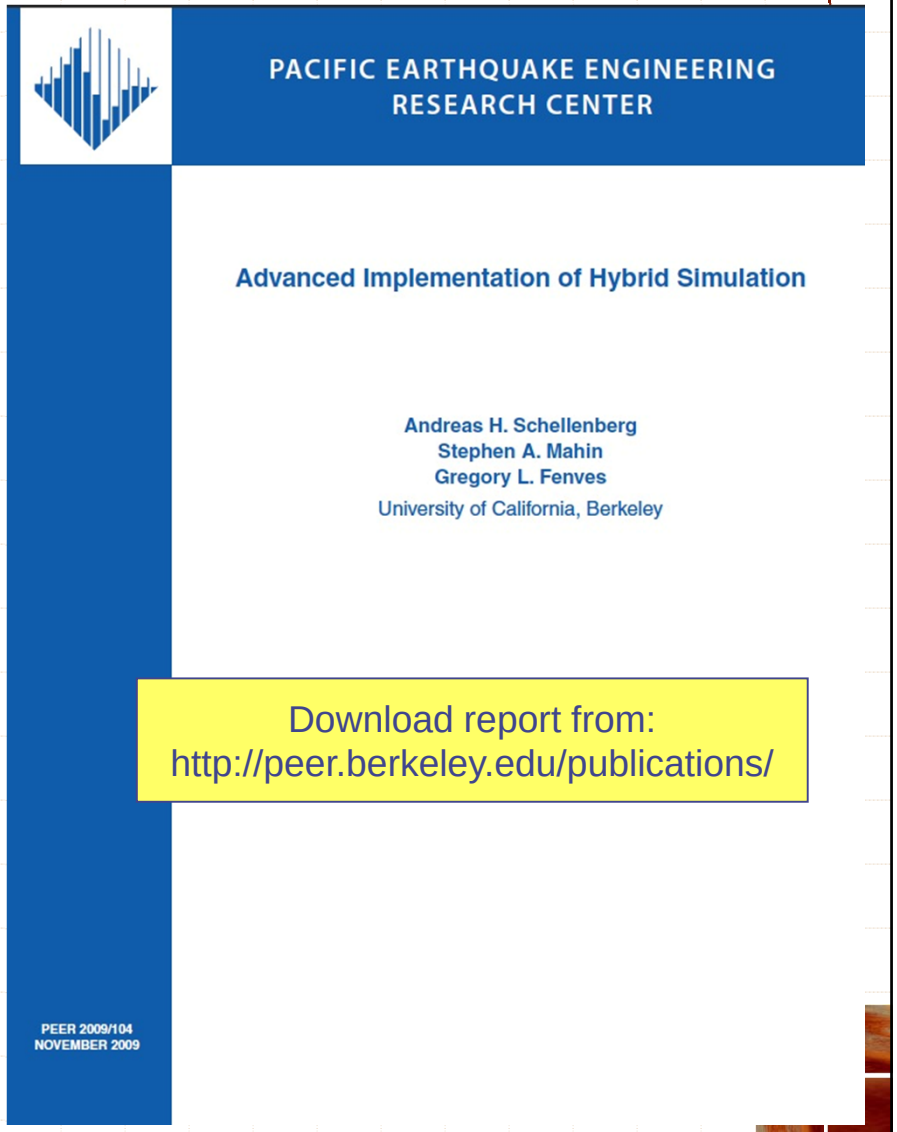
PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Advanced Implementation of Hybrid Simulation

Andreas H. Schellenberg
Stephen A. Mahin
Gregory L. Fenves
University of California, Berkeley

More Information

Download documentation and software:
http://openfresco.berkeley.edu



Download report from:
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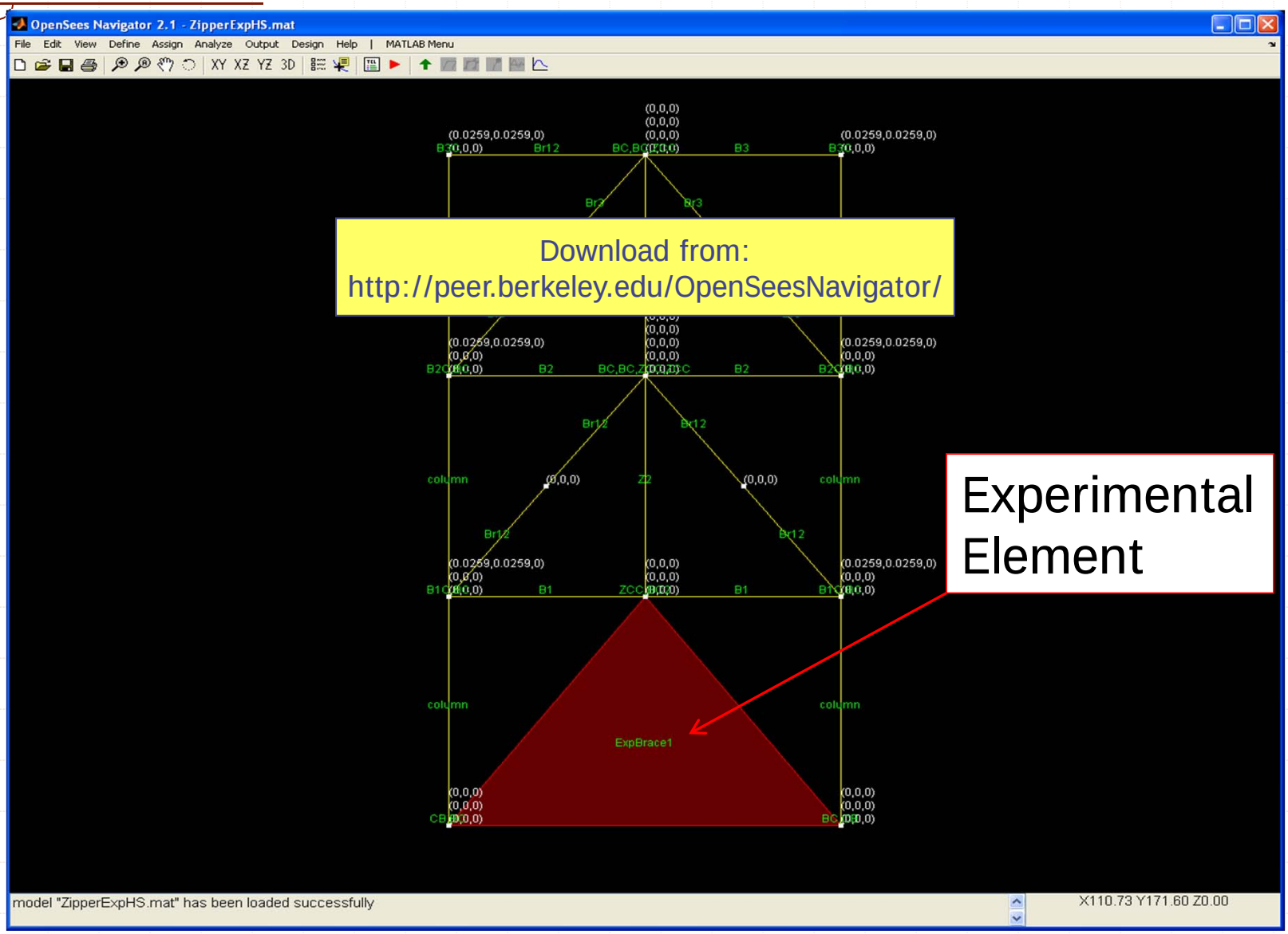
OpenSees Navigator



Summary & Conclusions

- OpenFresco*Express* is a simplified version of the OpenFresco middleware software for 1DOF and 2DOF systems
- Easy to graphically setup hybrid model
- Ground motion and free vibration HS
- Chose to connect to real laboratory controllers, actuators and data acquisition systems or simulate the behavior of the test specimen to perform dry-runs and/or learn about HS

Summary & Conclusions

- Watch the progress of the HS in real time including graphs plotting the structural response and error monitors tracking the accuracy of the test
- For more advanced problems you can use OpenFresco with the computational driver of your choice
- If you like to use a graphical user interface for more advanced problems try OpenSees Navigator

Questions?
Thank you!

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The development of OpenFresco*Express* has been sponsored by the Pacific Earthquake Engineering Research Center (PEER)