3-Pier Hybrid Simulation Using Zeus-NL and Matlab

Patricia AuBuchon
Home University: The University of Central Florida
Email: paraboloid1@hotmail.com

Host University: University of Illinois Urbana-Champaign
PI: Dr. Bill Spencer
Graduate Students: Thomas Frankie and Adel Abdelnaby

INTRODUCTION

- Earthquakes have a disastrous effect on regions, demanding in depth research to allow the design of safer building, bridge, and port components. Not only does this require large-scale specimen testing but also the use of a unified system of both computational and experimental testing models.
- Hybrid Simulations can allow for more accurate and controllable testing by using strong computational data and experimental data while testing (Frankie, 2009).

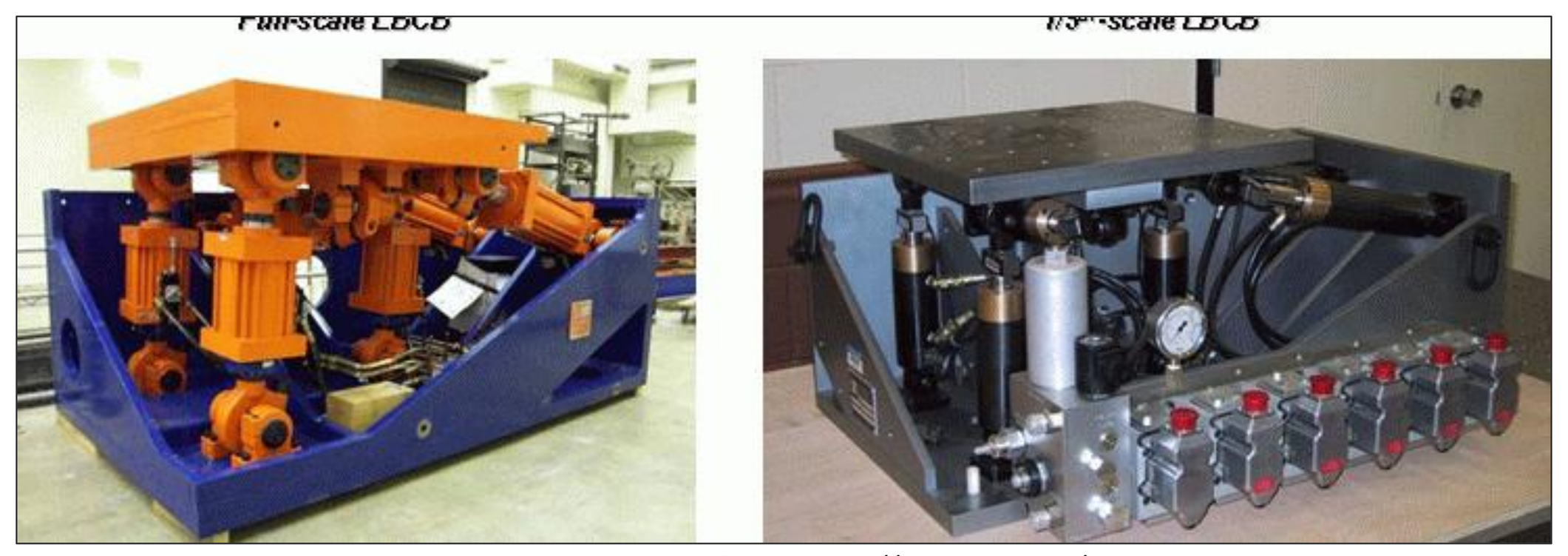


Photo courtesy of NEES@UIUC, http://nees.uiuc.edu/

- The University of Illinois at Urbana-Champaign (UIUC) will be employing such techniques to study spiral reinforced concrete columns. The NEES@UIUC facility is unique largely due to it's L-shaped strong wall with two LBCBs (Loading and Boundary Condition boxes) with hydraulic actuators which allow for 6-degrees of freedom in specimen testing and can exert up to one million pounds of force.

ZEUS-NL METHODS

One of the computational resources being employed is the software Zeus-NL, developed at UIUC. The user-friendly interface allows the user to perform eigenvalue, static pushover, static time-history and dynamic analysis.

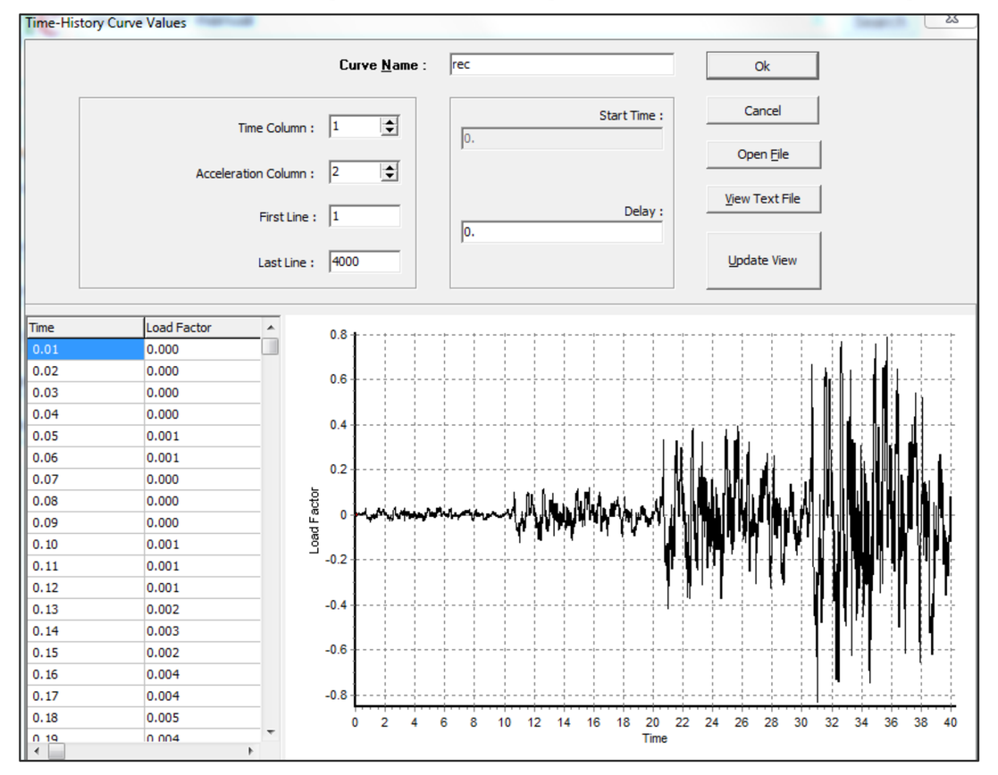


Photo of earthquake data imported into Zeus-NL

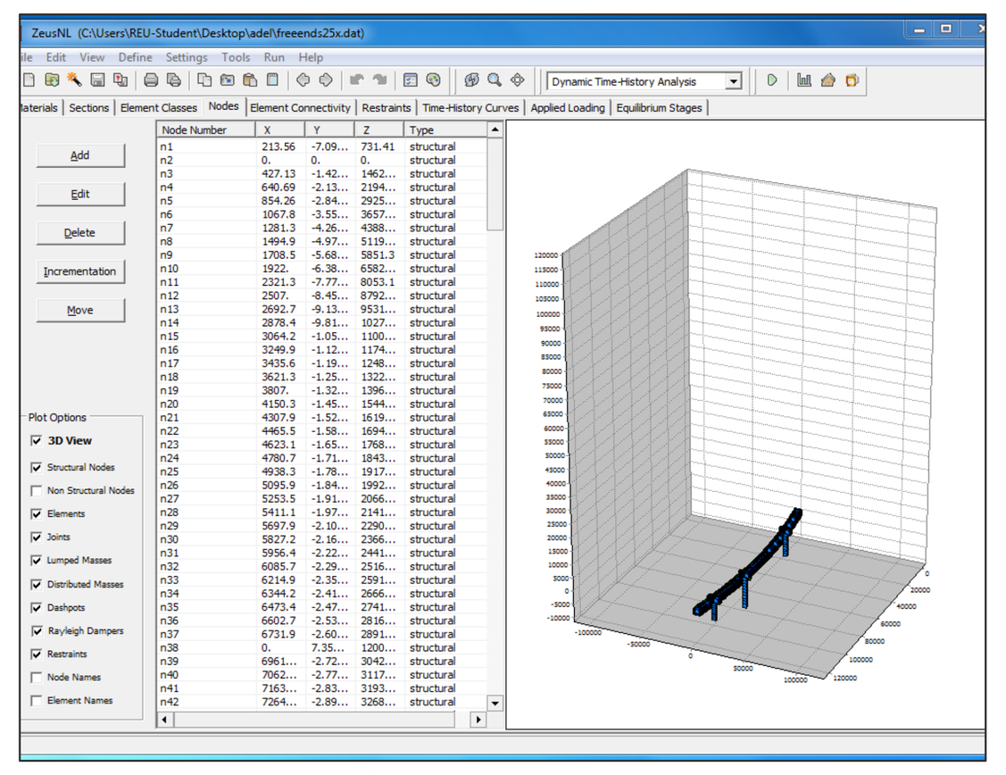


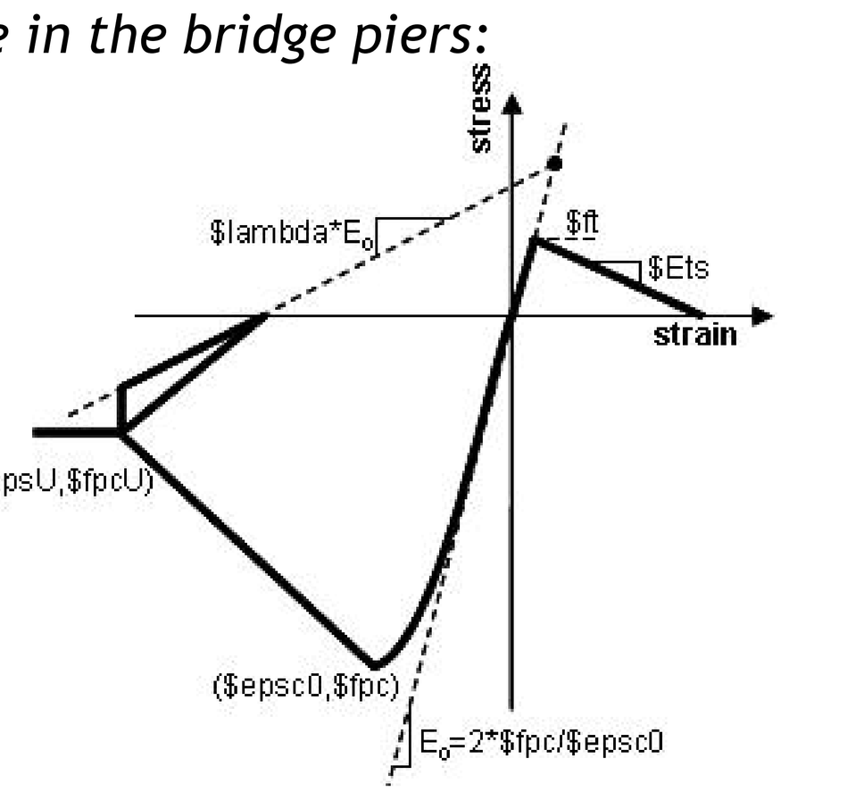
Photo of bride design in Zeus-NL

Inside Zeus-NL there is a large library of materials and elements. Applied loading can be constant or variable forces, displacements, and accelerations making it a great choice to model the torsional testing (Moon and Gencturk, 2010).

Characteristics of the concrete in the bridge piers:

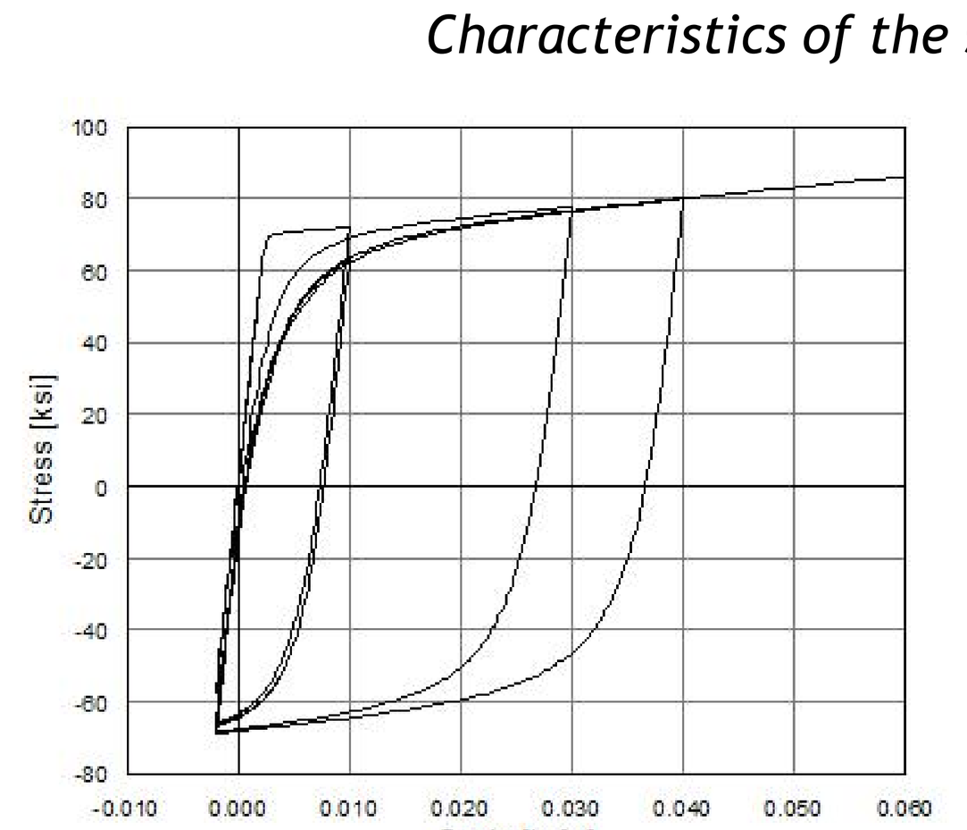
	Confined	Unconfined
f'c	1.2*-6500 psi	-6500 psi
e'c	2*f'c/E_c	-.003
f'cu	.2*f'c	.2*f'c
e'cu	20*e'c	-0.01
lambda	0.1	0.1
f_t	-0.14*f'c	-0.14*f'c
Ets	f_t/0.002	f_t/0.002

OpenSees concrete specs, courtesy of Thomas Frankie

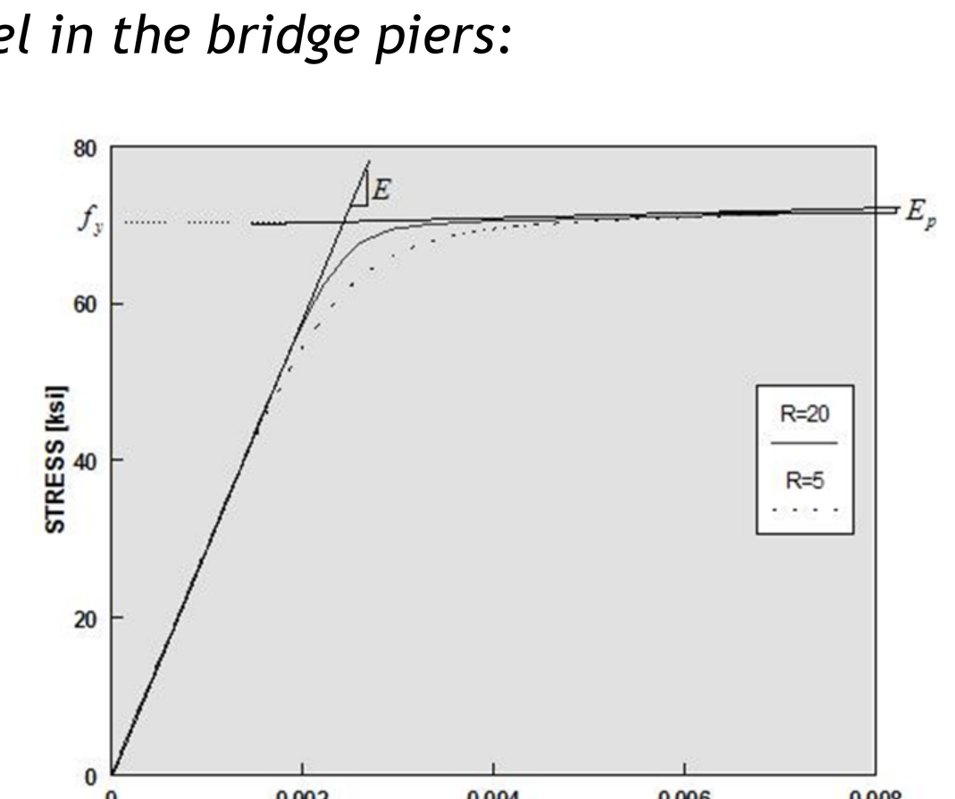


OpenSees concrete diagram, courtesy of Thomas Frankie

Characteristics of the steel in the bridge piers:



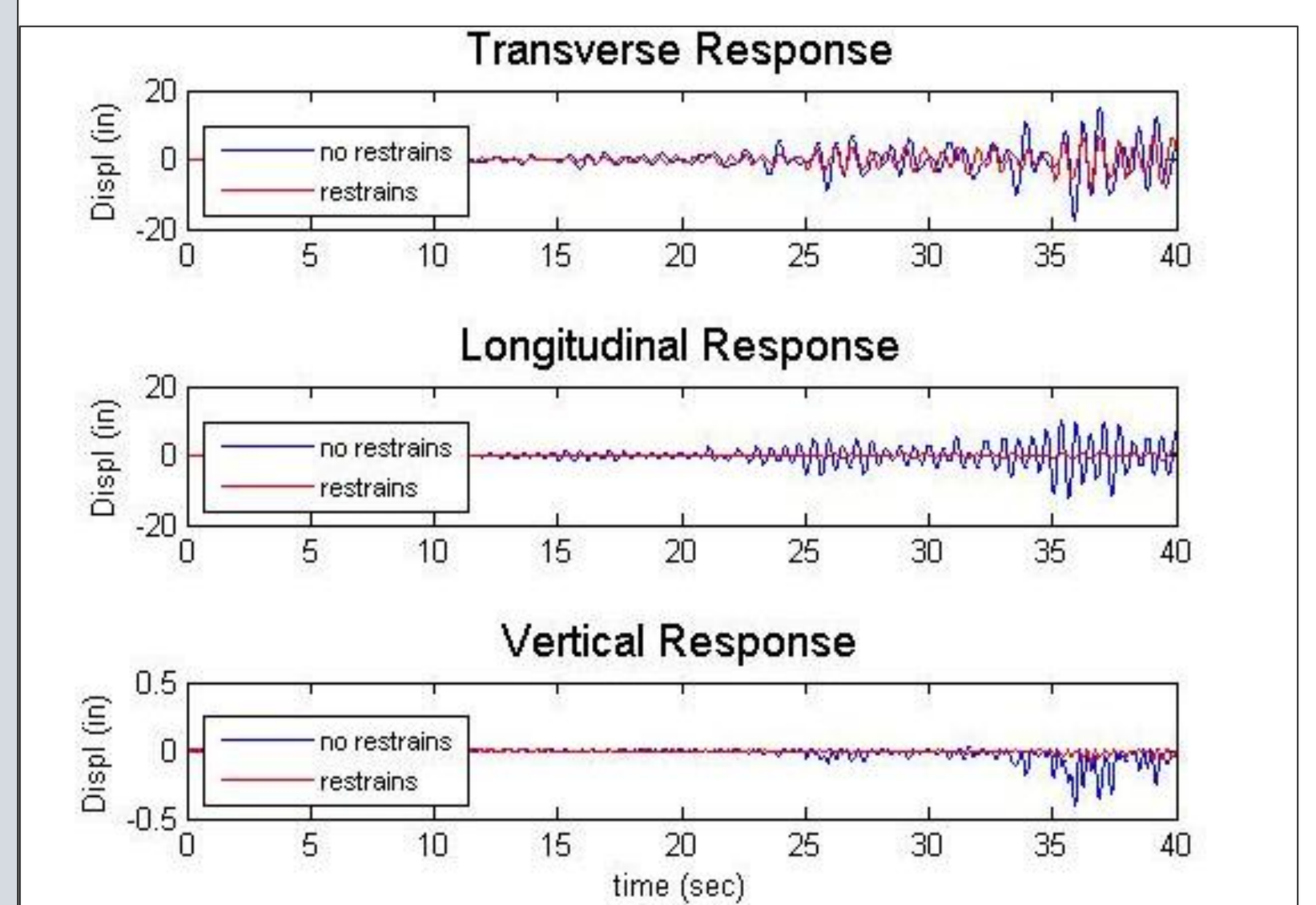
OpenSees concrete diagram, courtesy of Thomas Frankie



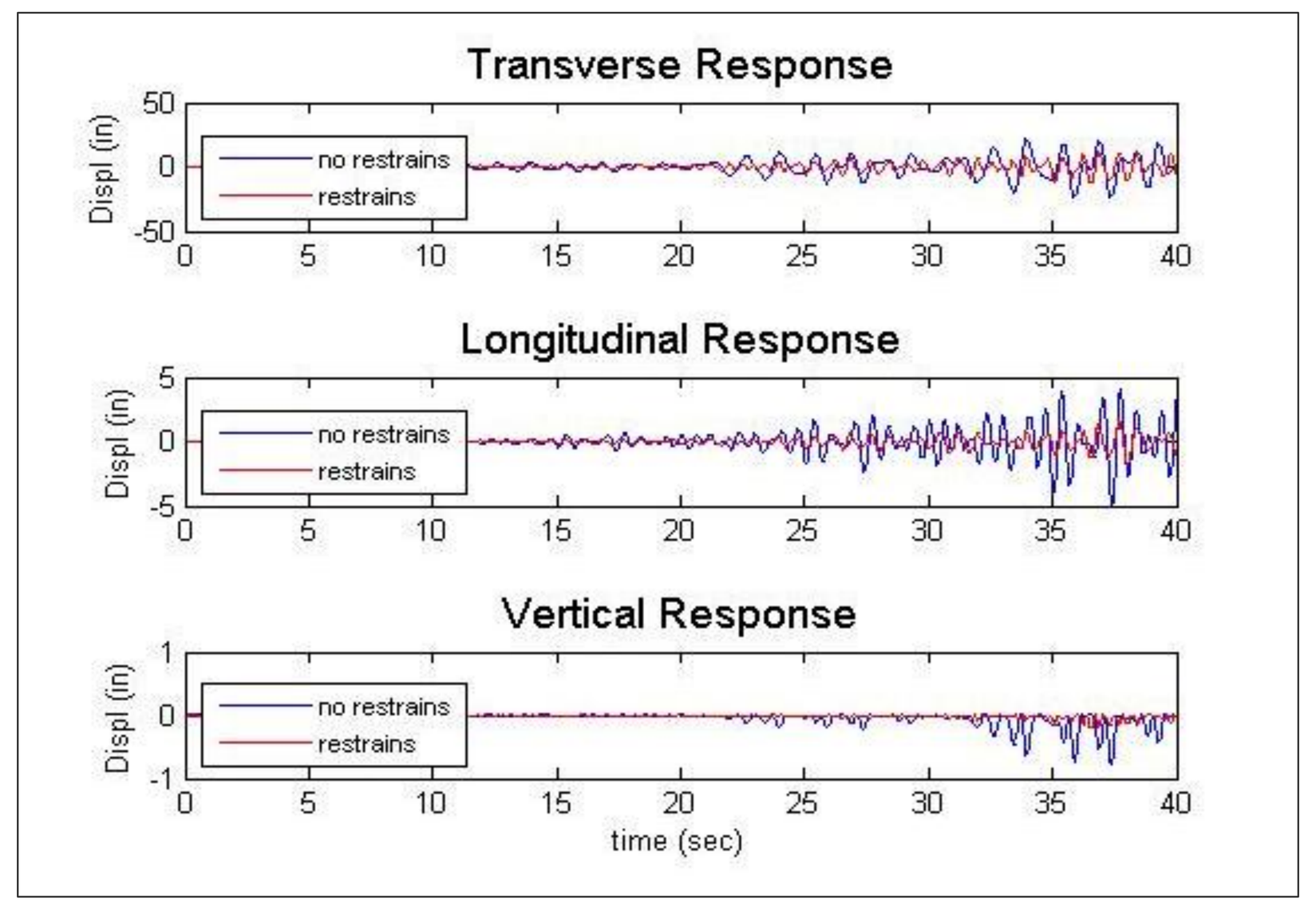
OpenSees steel diagram courtesy of Thomas Frankie

ZEUS-NL RESULTS

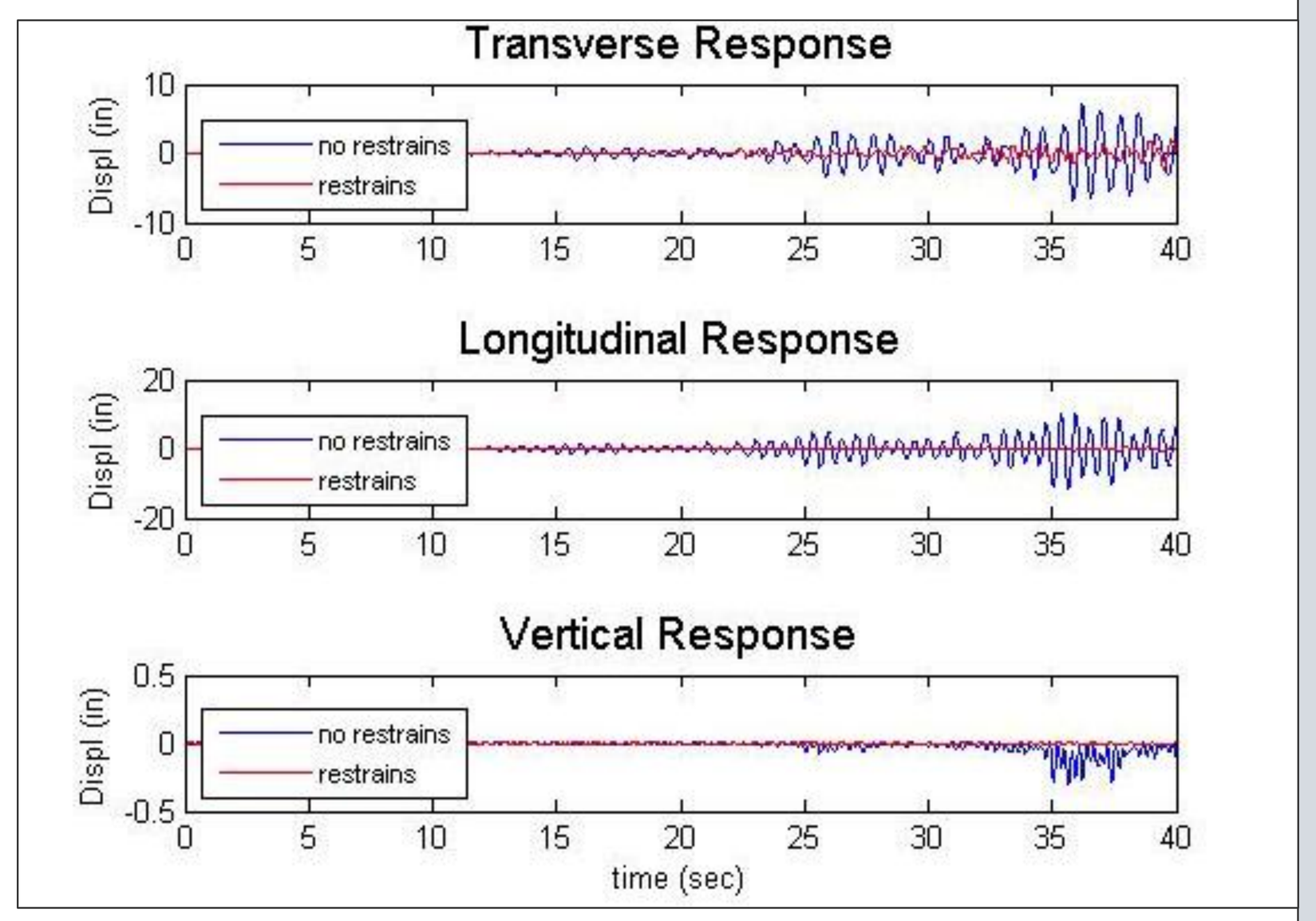
Once the bridge is meshed and the earthquake forces combined the interstory drift of the piers and also the rotations along the tops in the x, y, and z directions can be calculated. With the same simulation run with different magnitudes along the axis of the bridge, different reactions along the axis as confined vs. unconfined were plotted and the results compared. The reactions of the more simple design were expected and can be used as a reference of accuracy during hybrid testing.



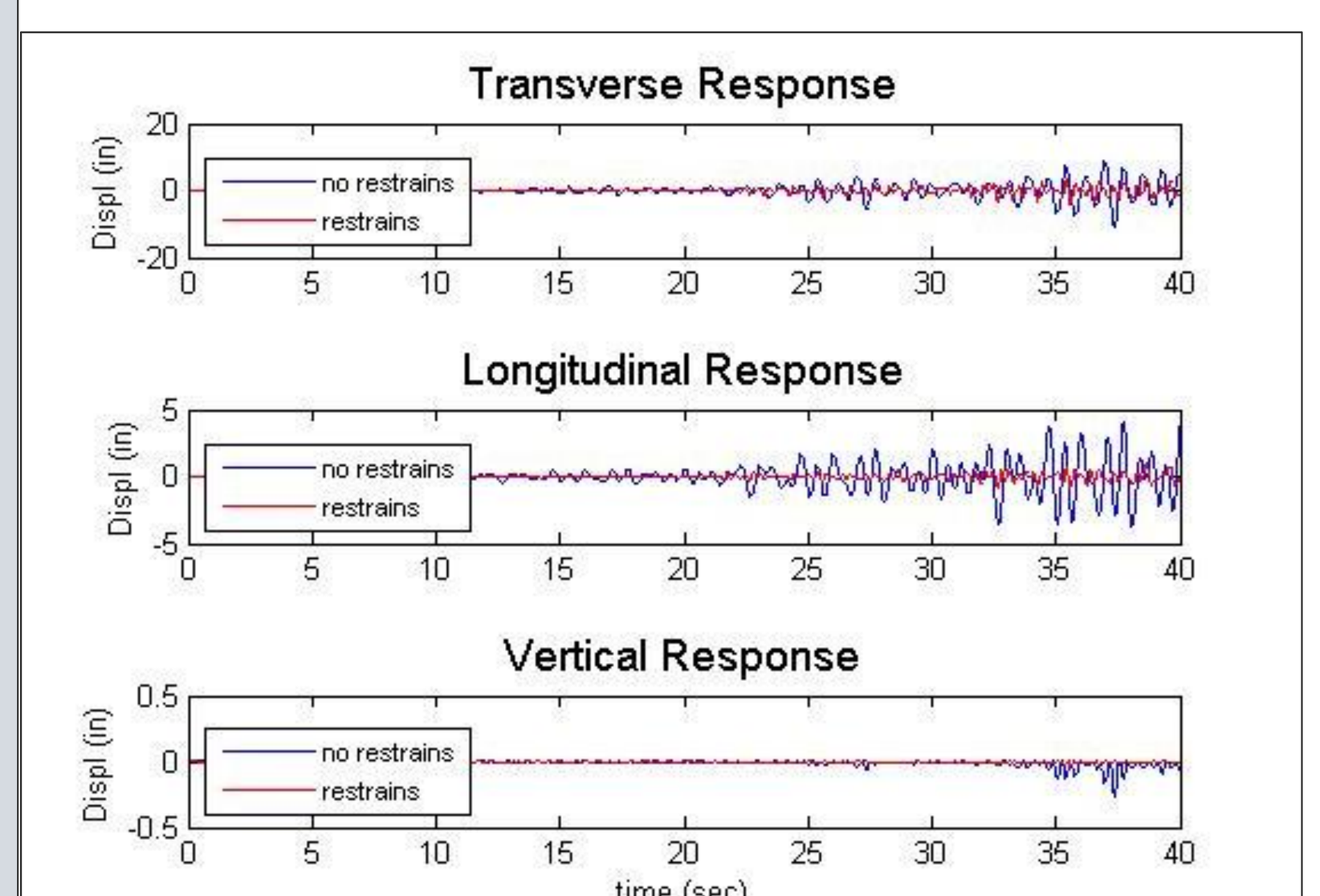
Pier-1 with 25% dampening in the x direction



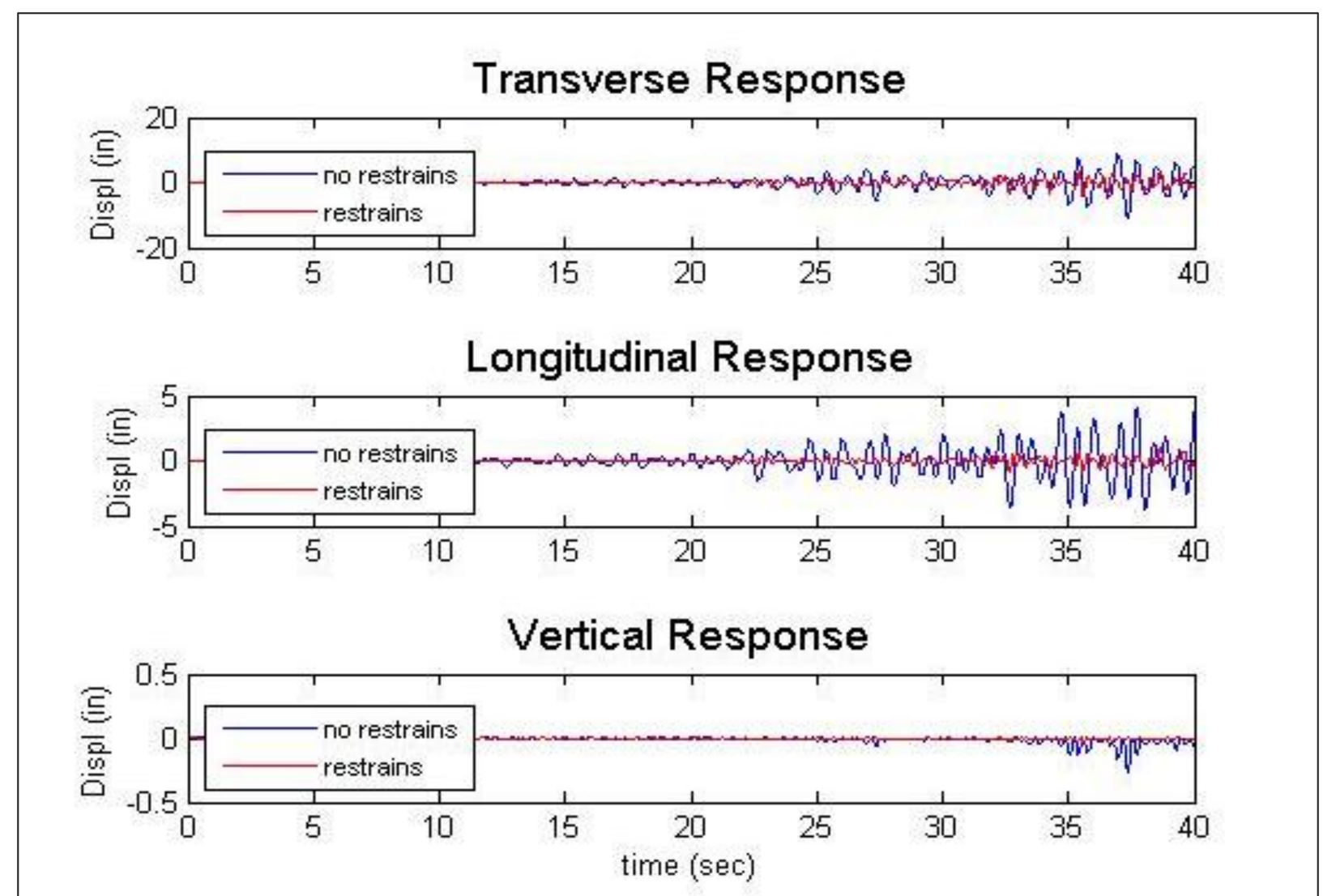
Pier-1 with 25% dampening in the z direction



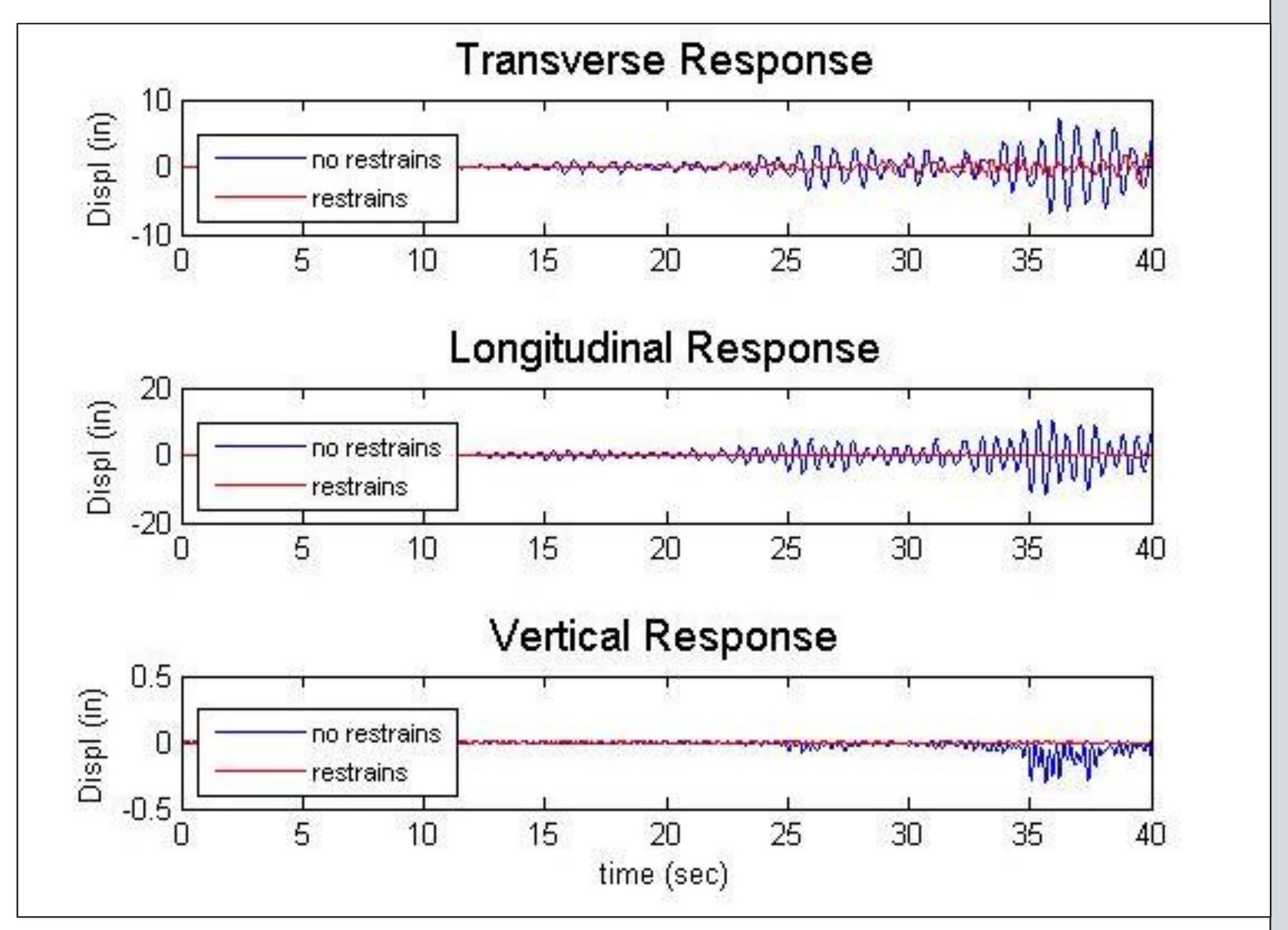
Pier-2 with 25% dampening in the x direction



Pier-2 with 25% dampening in the z direction

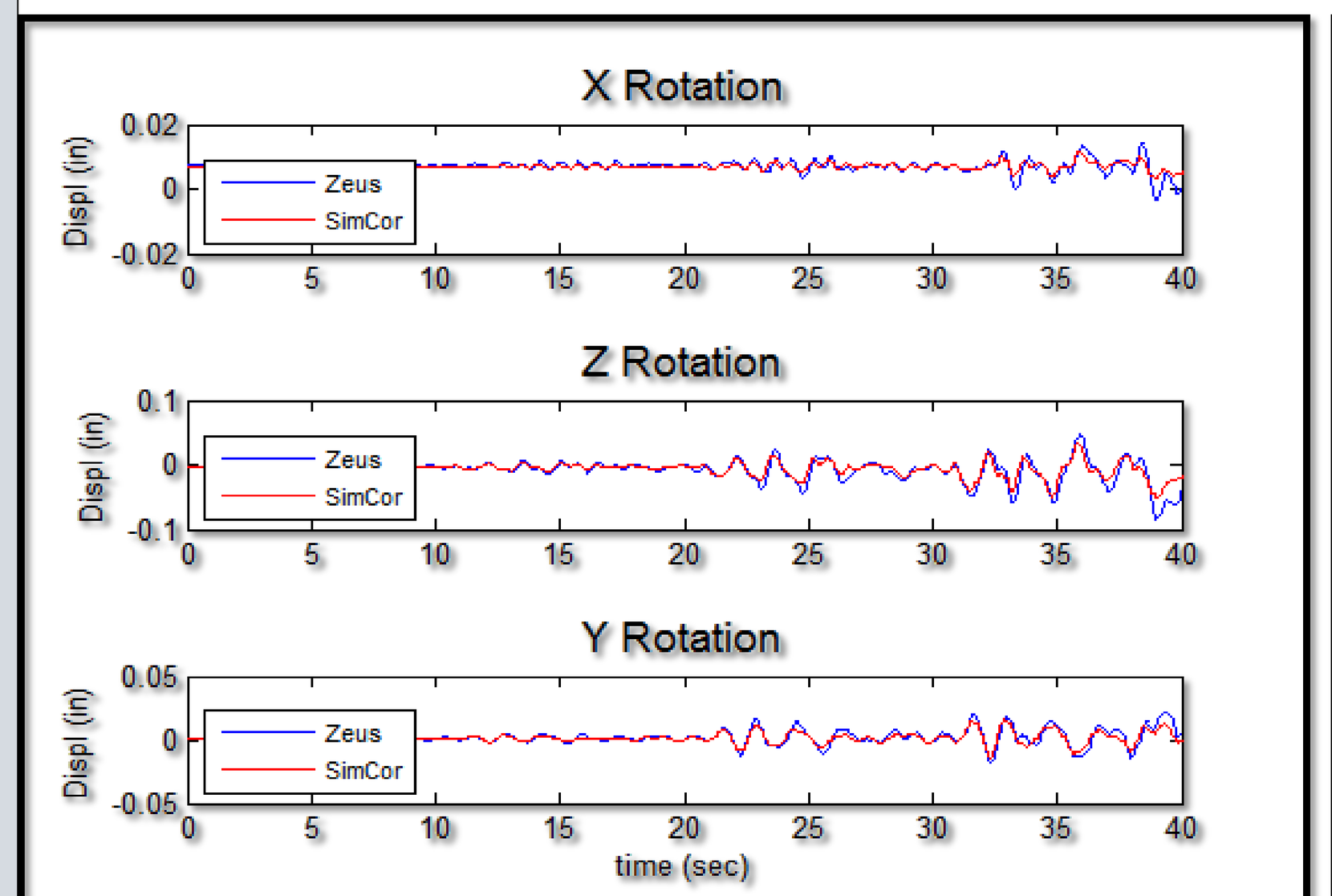


Pier-3 with 25% dampening in the x direction

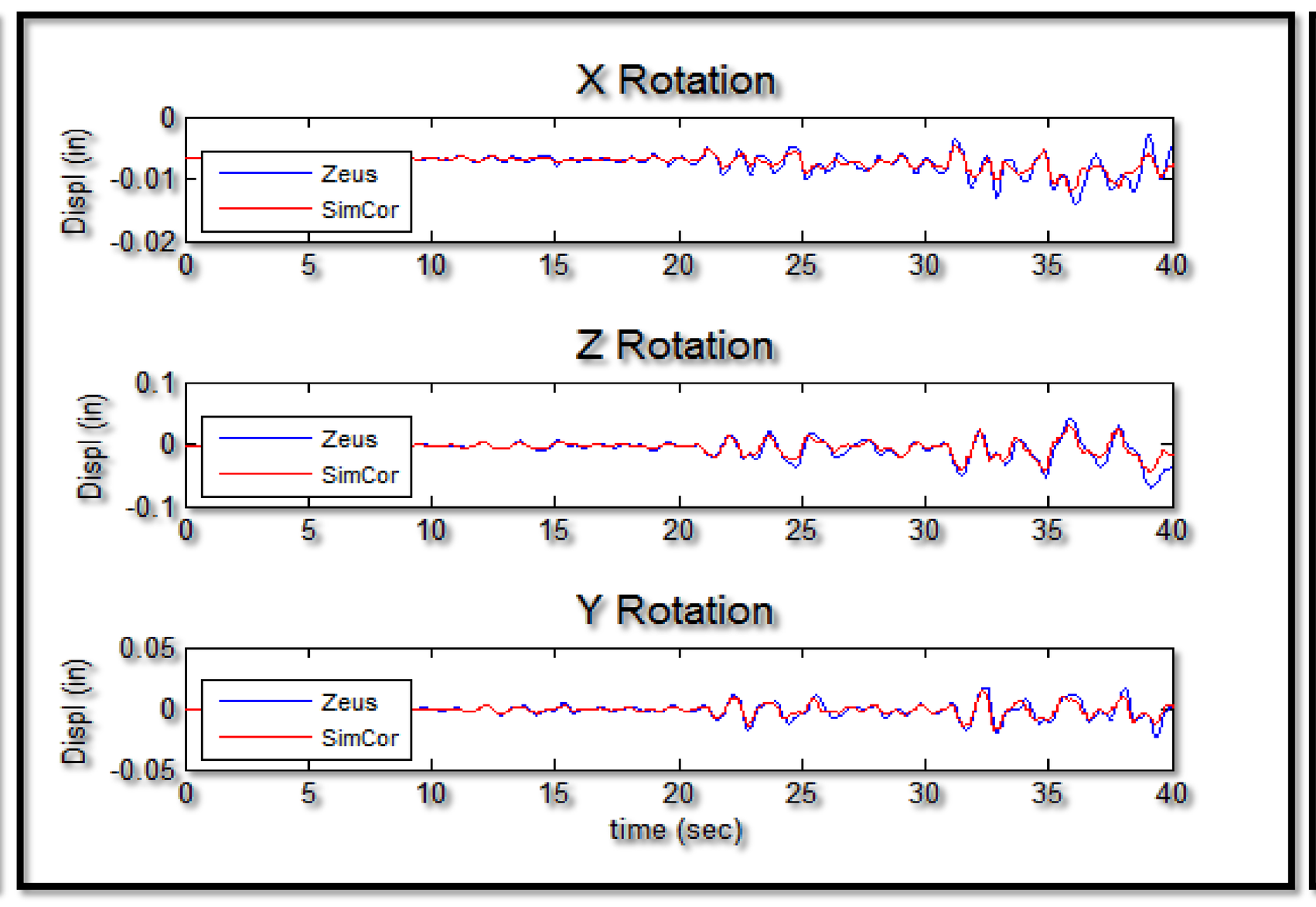


Pier-3 with 25% dampening in the z direction

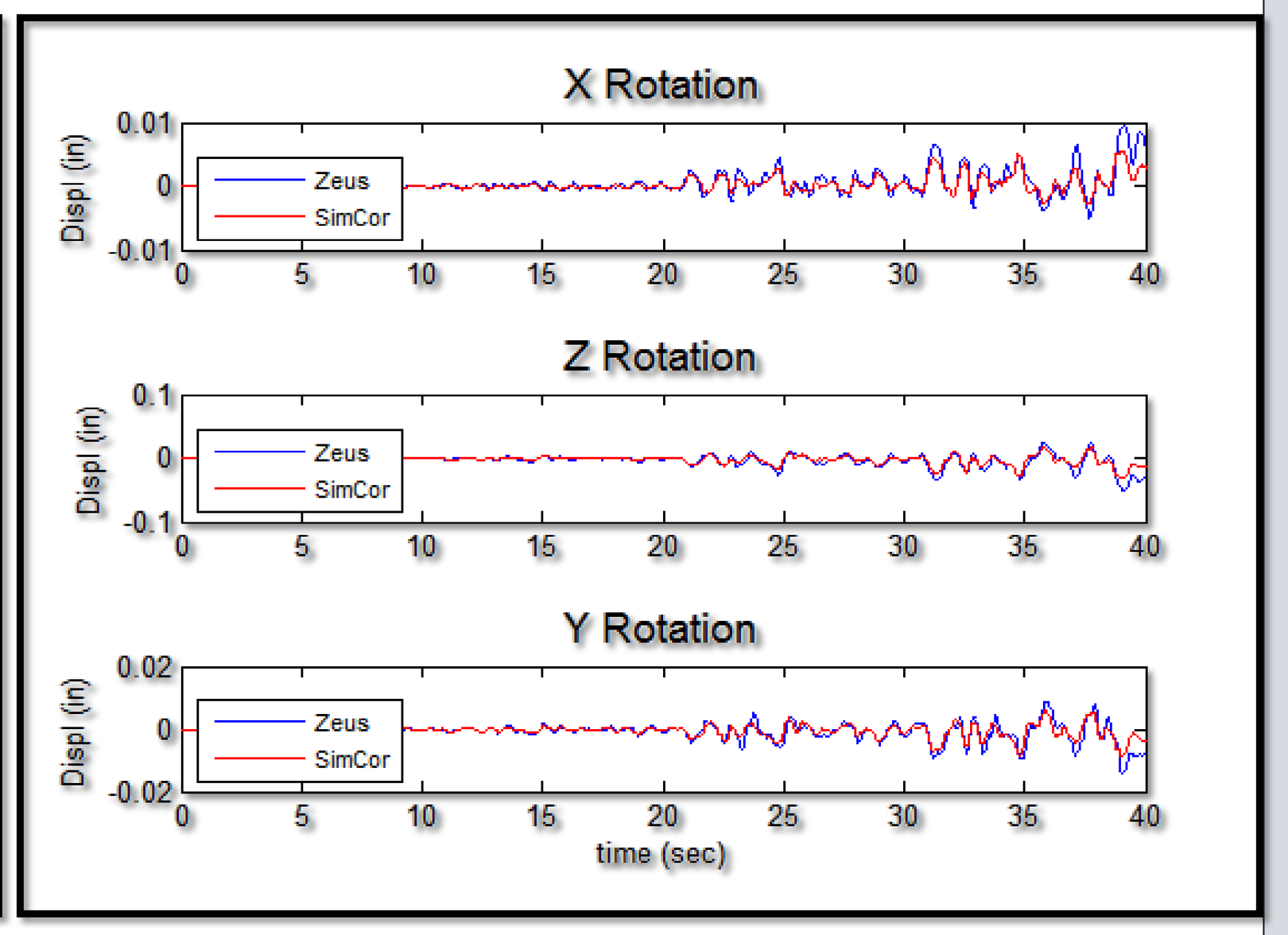
After the unconfined vs. unconfined results are verified a Zeus-NL simulation can be run and plotted against Sim-Cor data (experimental vs computational) to see the accuracy of Zeus-NL in predicting responses.



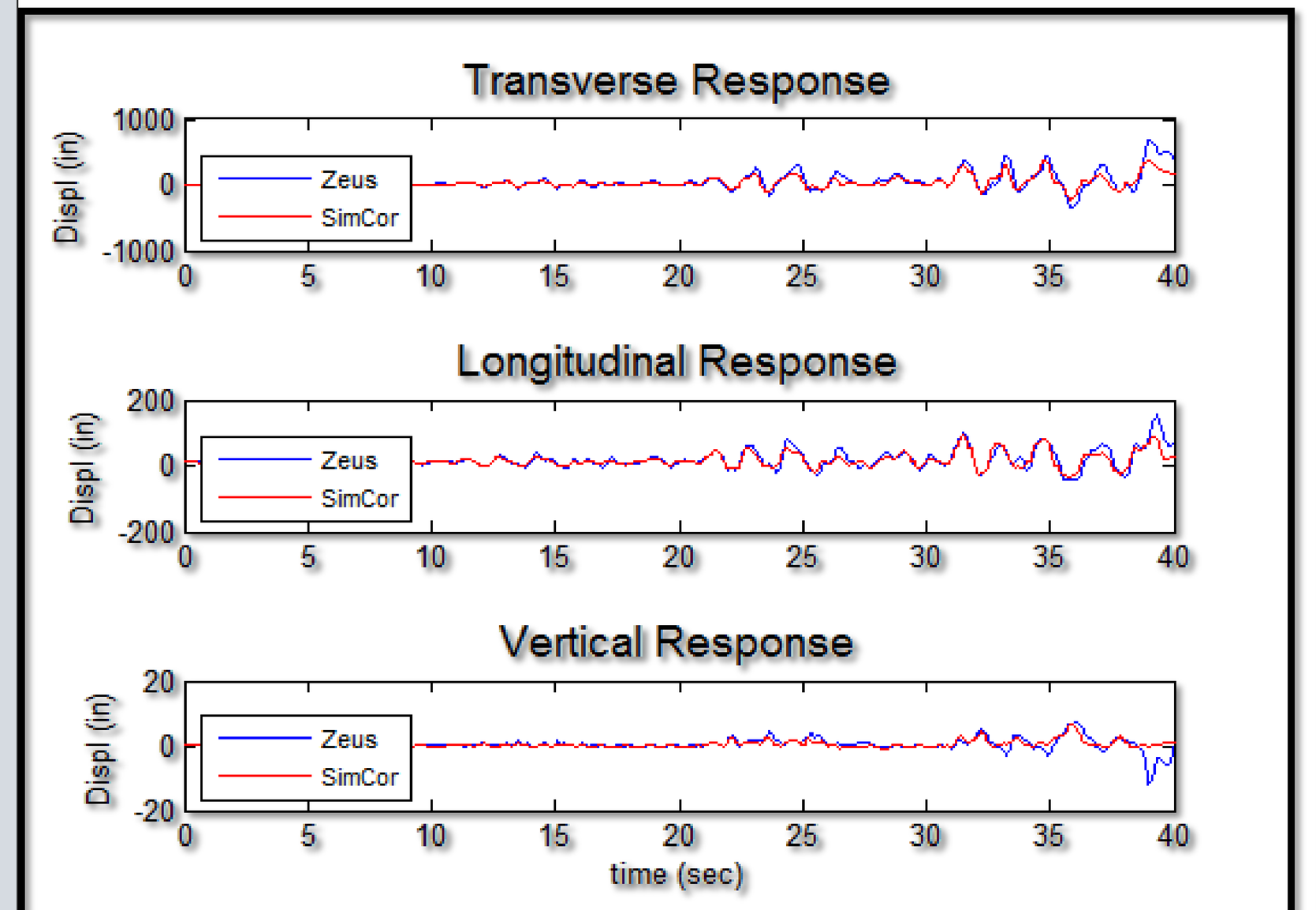
Pier-1 rotation in the x-direction



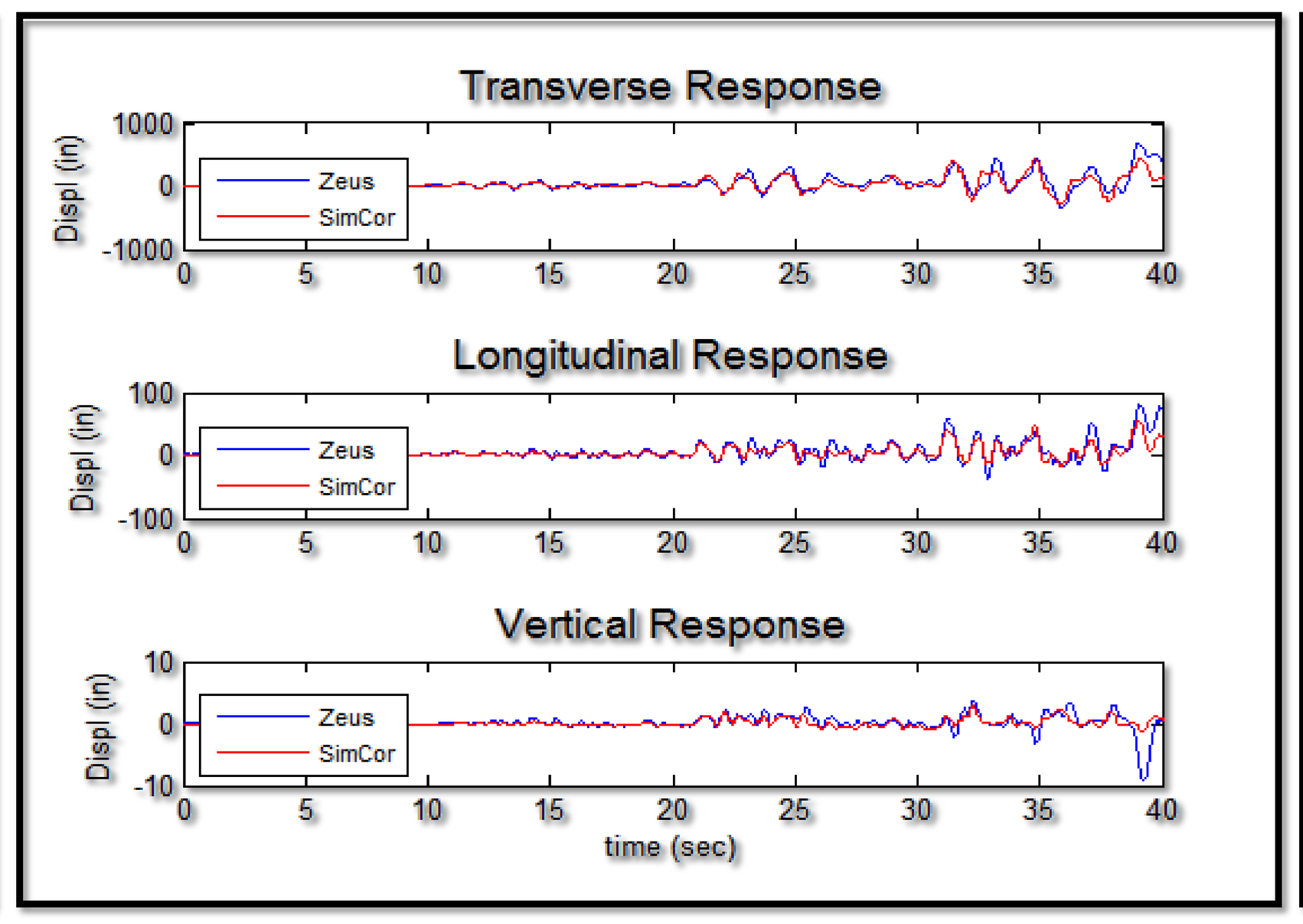
Pier-2 rotation in the y-direction



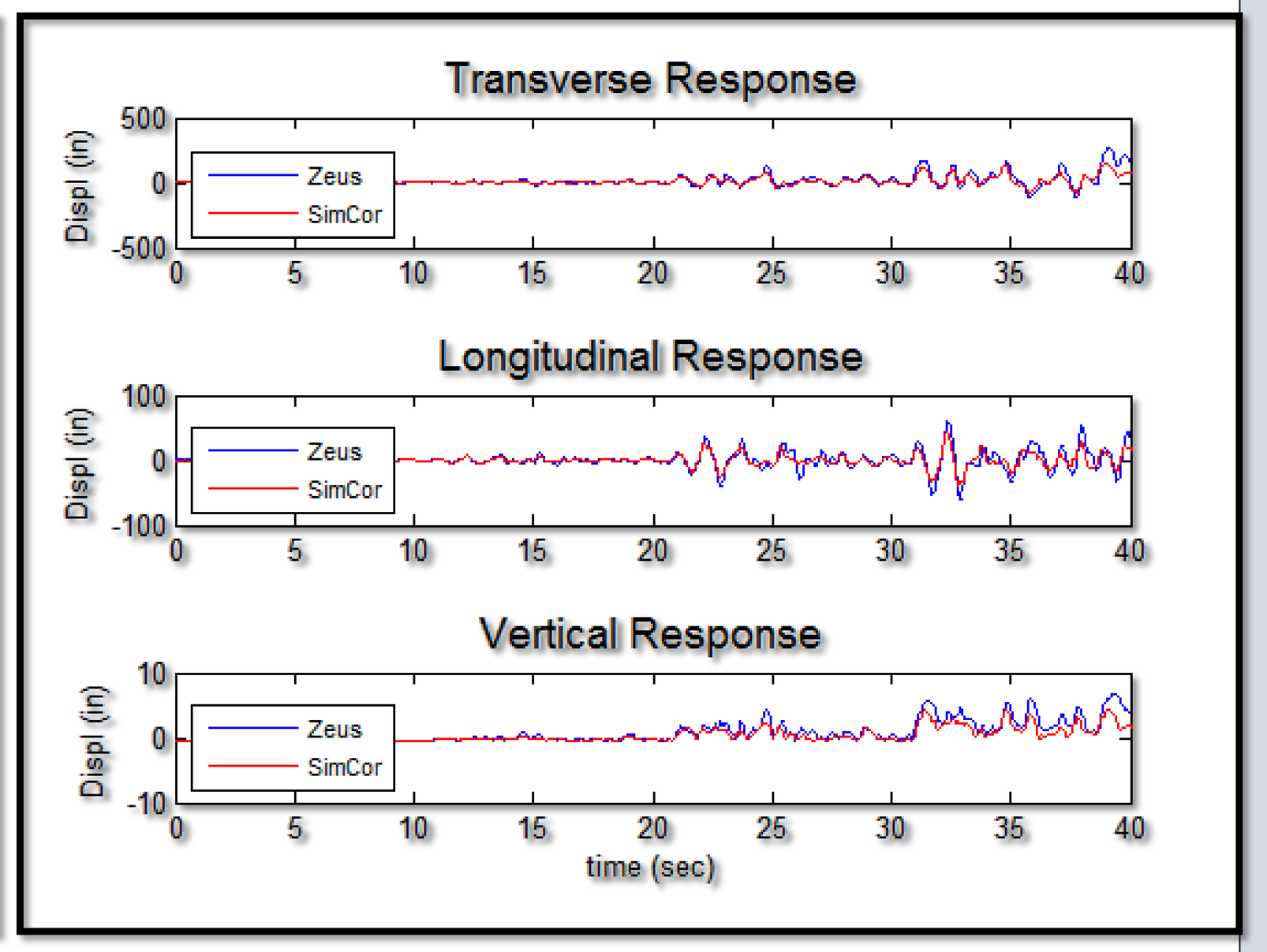
Pier-3 rotation in the z-direction



Pier-1 interstory drift in the x-direction



Pier-2 interstory drift in the y-direction

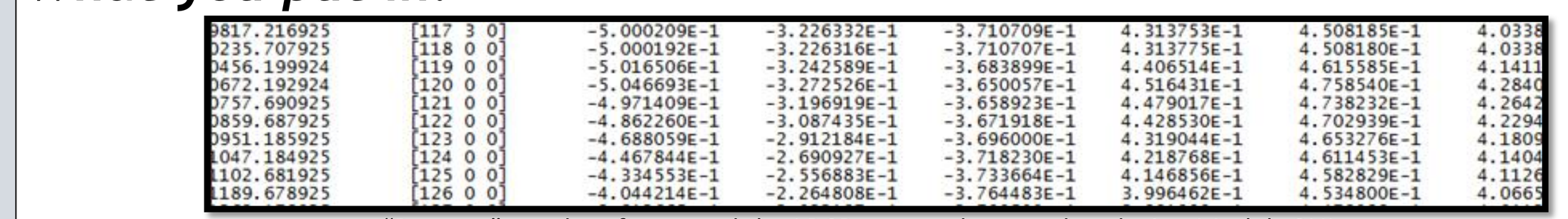


Pier-3 interstory drift in the z-direction

MATLAB PROCESSING OF LBCB DATA

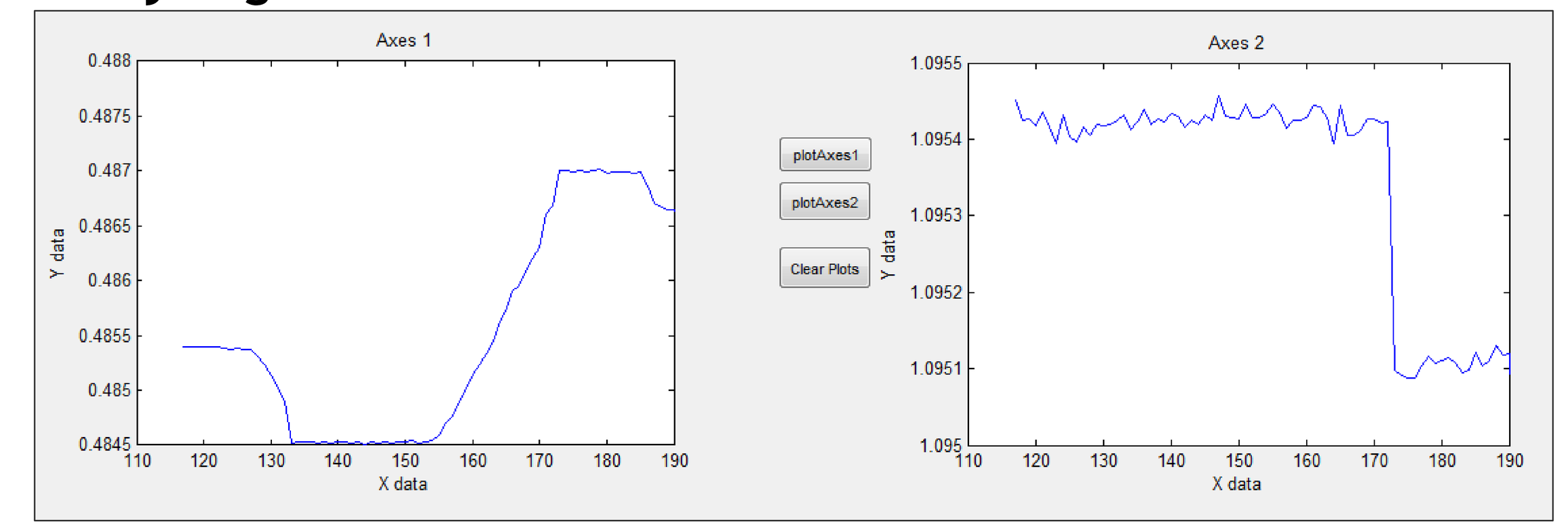
A Graphical User Interface (GUI) can be created in Matlab to help with the post-processing of data.

What you put in:



"Dummy" .txt data formatted the LBCB output data used to design Matlab GUI

What you get out:



Matlab GUI graph of part of the above "dummy" data

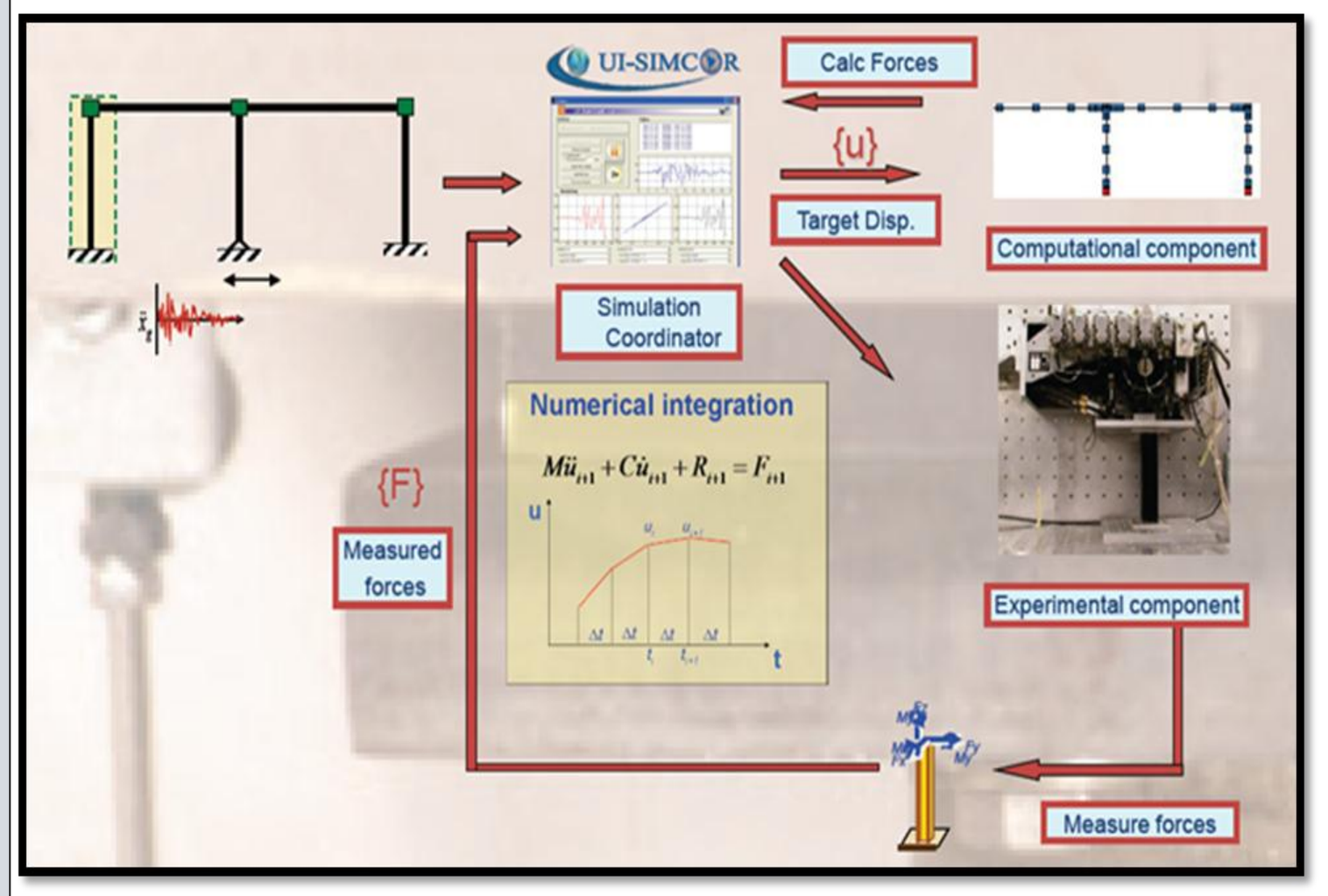
This specific GUI can graph 7 different columns of the data versus time (the first column). The data is composed of such things as actuator displacement measured by various strain gages.

```
cd('C:\Users\REU-Student\Desktop\DUMMY111\CONT\DAQ')
temp=ls('DisplacementSensor*');
data= load(char(temp(1,:)));


sensors_used=[1 2 3 4 5 6 7 8];
indices=sensors_used+1;

for p=1:20
    Stress(p,1) = mean(data(p,indices))*57500*sqrt(5800);
    Forces(p,1)=Stress(p,1)*(120*6+2*6*42)/1000;

end

save my_data.out A -ASCII
dlmwrite('my_data.out',Forces)
```

Matlab command script used to import all displacement sensor data

The simple command to the left can import all the text files from the displacement sensors. The "*" in Matlab script allows the program to pull up all files with the same beginning characters, which in this case is displacement sensors.

Future Work



Hybrid testing diagram, courtesy of Thomas Frankie

Future testing can investigate responses from experiments in realtime. This will involve one pier being physically tested. During each time step the recorded acceleration is fed into SimCor where it passes into the same Zeus-NL bridge structure that has the third pier missing (the one being tested).

Simcor knows the forces associated with a given acceleration which Zeus then knows as a certain displacement based on the predefined stiffness of the structure. It then sends target displacements to the computational and experimental targets. Then, the computational component calculates forces which it feeds into the experiment. The experimental forces are actually measured, calculated, and then sent back to Simcor where it does a numerical time integration to balance the numerical integration equation. Simcor will send more displacement targets to get to the target force that gets the equation sufficiently close to equilibrium then moves to next time step.

REFERENCES

Frankie, T. (2009), "Hybrid Simulation," *CEE561-Behavior and NL Modeling of RC Structures Final Report*

DoSoo Moon; Bora Gencturk (2010), "*ZEUS-NL*," https://nees.org/resources/zeus.

McKenna, F. T., and Fenves, G. L. (2001), "The OpenSees command language manual, Version 1.2," Pacific Earthquake Engineering Research Center, Univ. of California, Berkeley, Calif.

Quach, Q. (2007, October 31). *Matlab gui tutorial - plotting data to axes*. Retrieved from http://blinkdagger.com/matlab/matlab-gui-tutorial-plotting-data-axes/

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