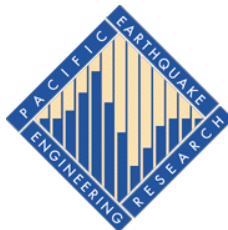


Bridge PBEE Numerical Simulation Framework

Ahmed Elgamal, Jinchu Lu
University of California, San Diego
Kevin Mackie
University of Central Florida



CYCLIC1D Liquefaction Model - Microsoft Internet Explorer

Back Forward Stop Refresh Home Search Favorites History Channels Fullscreen Mail Fonts Print Ec

Address <http://cyclic.ucsd.edu/>

File Edit View Go Favorites Help

Cyclic 1D

Internet-based Computer Simulation Of Site Earthquake Response and Liquefaction

Welcome to *Cyclic 1D* !

- Main
- Introduction
- Model Builder
- Results
- References
- Sponsors
- Contact

Water table

Inclination angle

Loose sand

Medium clay

Dense sand

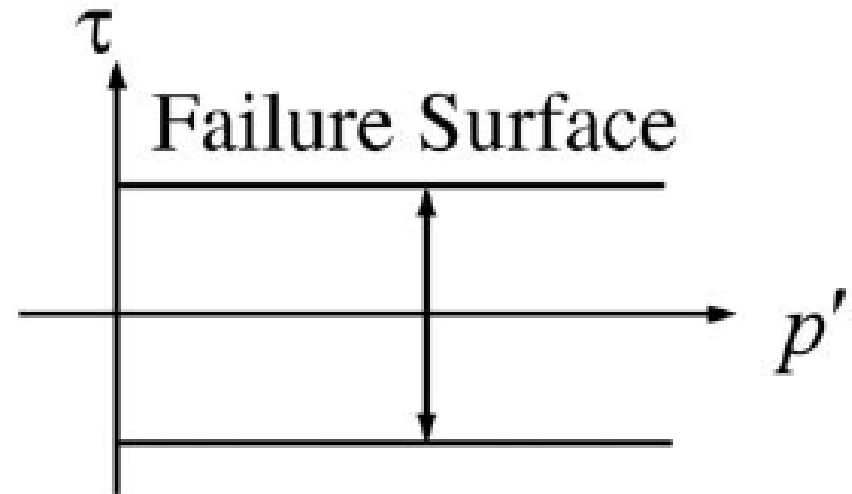
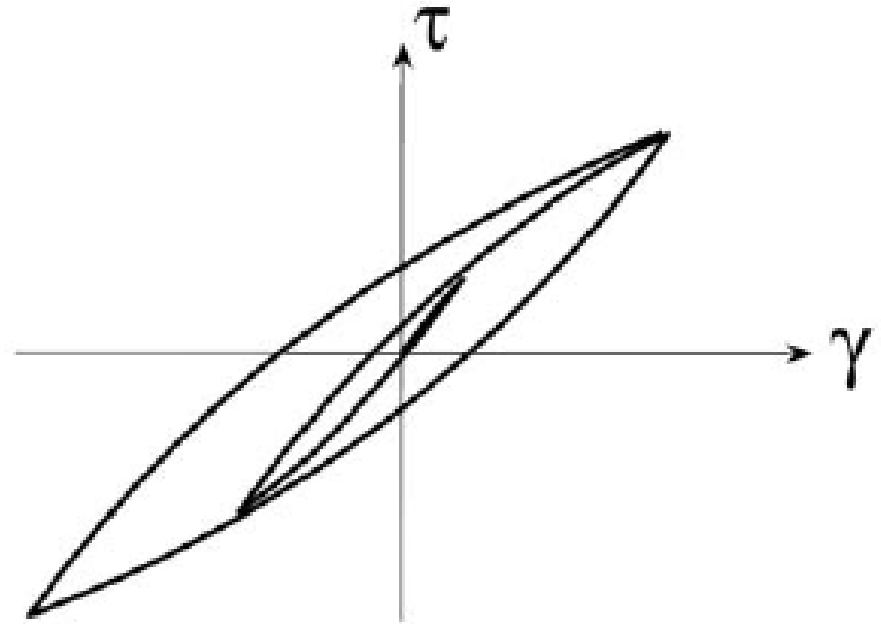
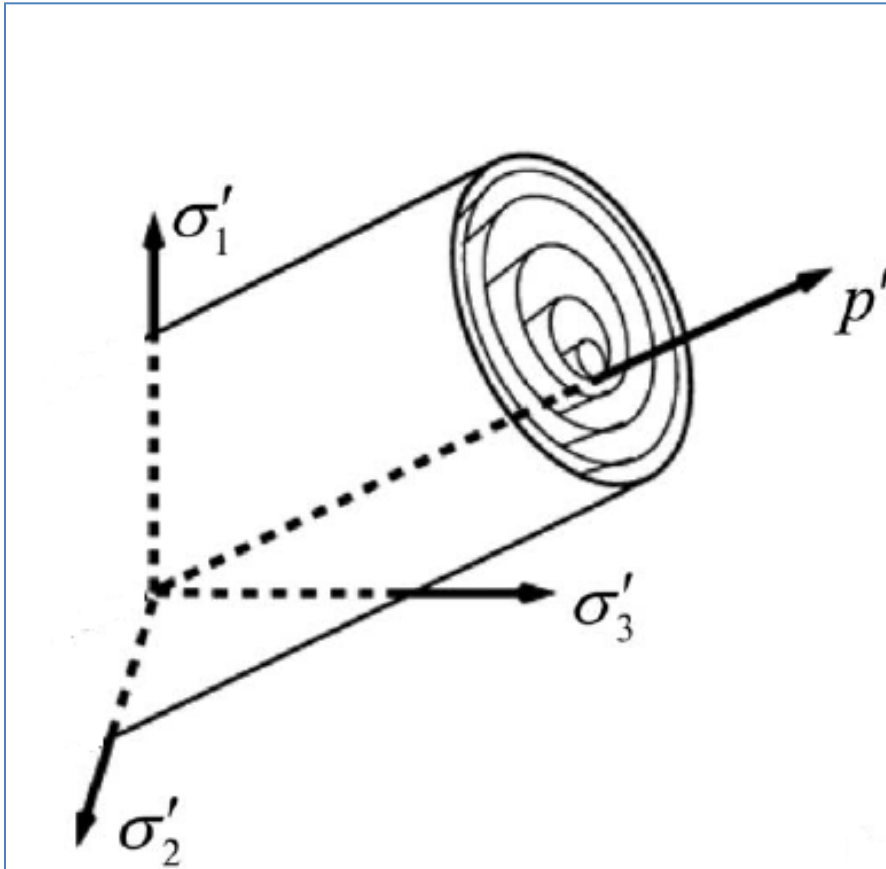
Bedrock

Input motion

Cyclic 1D is an Internet-based nonlinear Finite Element program for execution of one-dimensional site amplification and liquefaction simulations (for level as well as mildly inclined sites). Here, You can build and analyze your own soil profiles, and view and

Internet zone

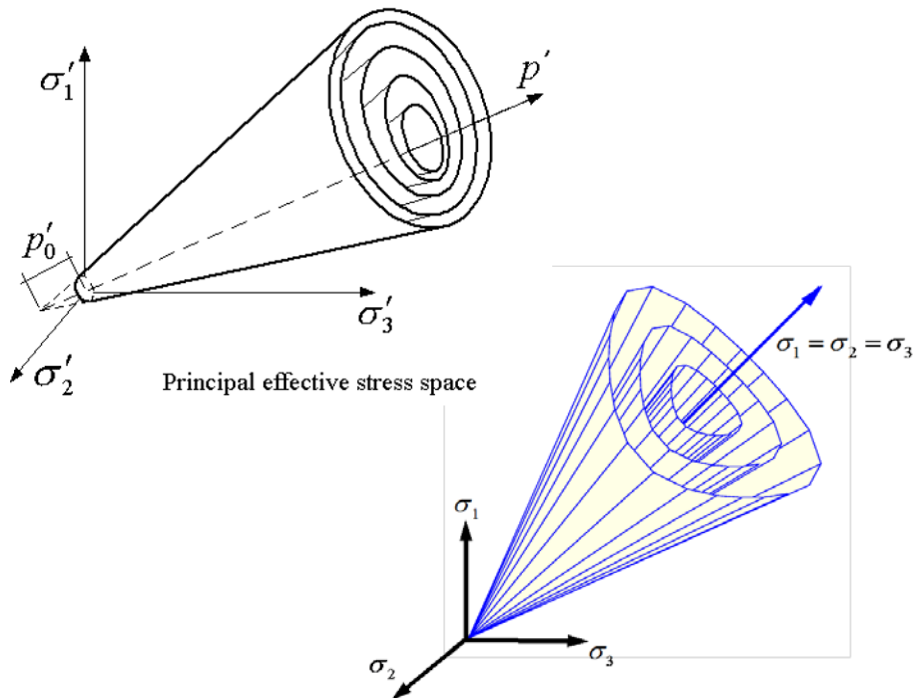
Nonlinear hysteretic Model



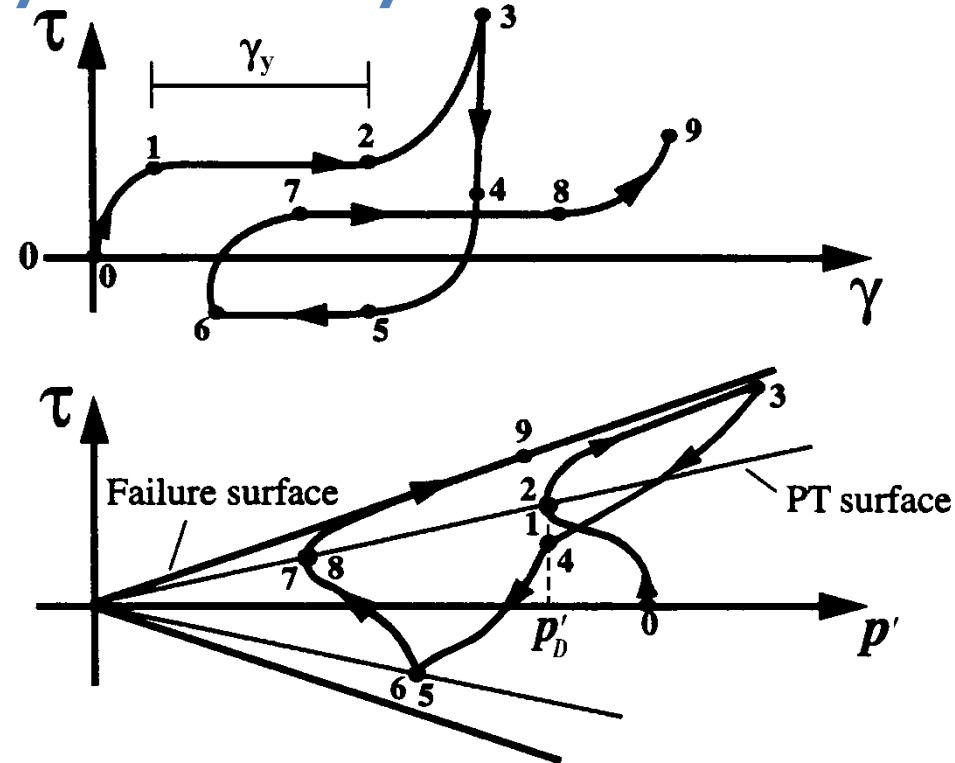
Note: Also available with Tension Cut-off for interface between structure and soil

Soil Constitutive Model

- Multi-yield surface plasticity model (based on Prevost 1985)
- Incorporating dilatancy and cyclic mobility effects



Conical yield surfaces for granular soils (Prevost 1985; Elgamal et al. 2003; Yang and Elgamal 2008)



Shear stress-strain and effective stress path under undrained shear loading condition (Parra 1996, Yang 2000, Yang and Elgamal 2002)

OpenSees at UC Berkeley

for Earthquake Engineering Simulation - Home Page - Mozilla Firefox

History Bookmarks ScrapBook Yahoo! Tools Help

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

Google

OpenSees

PEER NEES NEESit

HOME USER DEVELOPER PROJECTS SUPPORT PARALLEL SITE MAP

About News Calendar Registration

HOME MESSAGE BOARD USER DOC DOWNLOAD SOURCE CODE BUG REPORT	OpenSees 2.0.0 Released Version 2.0.0 of the OpenSees binary is now available for download. Here is the change log. Parallel Version Released	Register For information about new releases we encourage you to register with us at the OpenSees Registration Center. News 2008-04-22 Version 2.0.0
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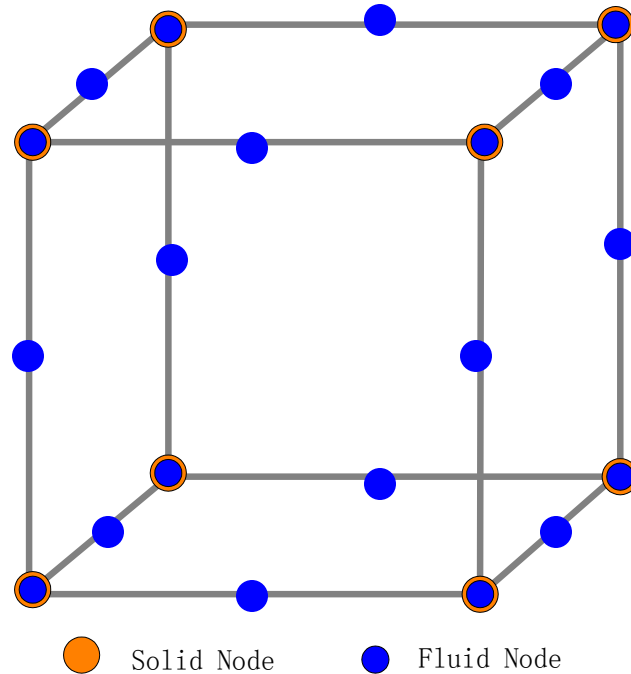
OpenSees

<http://opensees.berkeley.edu/>

PEER Center, UC Berkeley, Prof. Gregory Fenves



Open-source platform



Solid-Fluid Fully Coupled
Element for Saturated Soil



Beam Element
for Pile

OpenSeesPL - Untitled

File Meshing Analyze Display View Options Help



Model Input

Model Definition

Pile Parameters...

Soil Parameters...

Mesh Parameters...

Analysis Options...

Load

☒ Pushover

Define Pattern...

☐ Base Shaking

Boundary Condition Type Shear Beam

Input Motion

☒ Longitudinal (X) ☐ Transverse (Y) ☐ Vertical (Z)

X Tapered 0.2g sinusoidal motion

Y Tapered 0.2g sinusoidal motion

Z Tapered 0.2g sinusoidal motion

	X	Y	Z
Frequency (0.5-5Hz)	1	1	1
Number of Cycles (3-30)	10	10	10
Scale Factor (0.01-1)	1	1	1

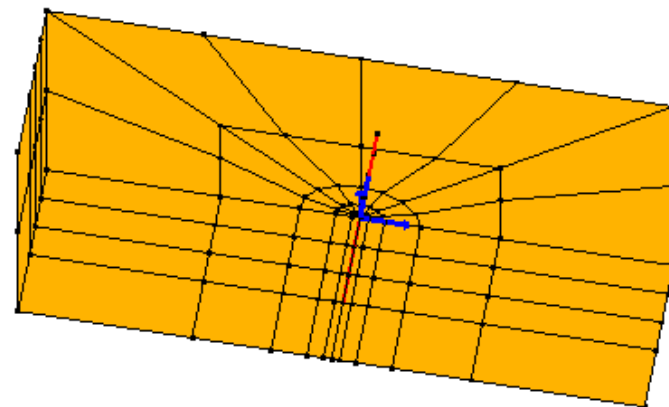
Model Inclination along Longitudinal Direction

Ground Surface Inclination Angle (0-30 deg)

Whole Model Inclination Angle (0-10 deg)

Finite Element Mesh

OpenSeesPL Graphical User Interface
<http://cyclic.ucsd.edu/openseespl>



OpenSeesPL: <http://cyclic.ucsd.edu/openseespl>

File

Pile

Pile Type

Circular

Pile Diameter (D)

1

[m]

Total Pile Length

12

[m]

Pile Height Above Surface

6

[m]

Pile Head

☒ Fixed ☐ Free/Pinned

Pile Head Mass

0

[ton]

Axial Load

0

[kN]

☐ Pile Group

Group Info

X-Dir.

Y-Dir.

Number of Piles

3

3

Spacing (xD)

3

3

☐ w/ Brick Deck at Pile Head (Single Pile Only)

Deck Geometry

Length (Longitudinal Direction)

10

[m]

Width (Transverse Direction)

5

[m]

Thickness (Vertical Direction)

0.5

[m]

Deck Material Properties

Young's Modulus

30000000

[kPa]

Poisson's Ratio

0.2

Mass Density

0

[ton/m3]

☐ Linear Beam Element

Linear Beam Properties

Young's Modulus

30000000

[kPa]

Mass Density

0

[ton/m3]

Moment of Inertia

0.0490873

[m4]

Re-Calculate

☒ Nonlinear Beam Element

Nonlinear Beam Properties

☒ Aggregator Section

My & Mz:

Flexural Rigidity EI

158600

[kN-m2]

Yield Moment

1200

[kN-m]

Kinematic Hardening Parameter

0

[kN-m]

Isotropic Hardening Parameter

0

[kN-m2]

Vy & Vz:

Shear Rigidity GA

3378000

[kN]

T:

Torsional Rigidity GJ

42200

[kN-m2]

P:

Axial Rigidity EA

8785000

[kN]

☐ Fiber Section

Modify...

OK

Cancel

8

Pile

Pile Type

Circular

Pile Diameter (D)

1

[m]

Total Pile Length

12

[m]

Pile Height Above Surface

6

[m]

Pile Head

Fixed

Free/Pinned

Pile Head Mass

0

[ton]

Axial Load

0

[kN]

☐

Pile Group

Group Info

	X-Dir.	Y-Dir.
Number of Piles	3	3
Spacing (xD)	3	3

☐

w/ Brick Deck at Pile Head (Single Pile Only)

Deck Geometry

Length (Longitudinal Direction)	10	[m]
Width (Transverse Direction)	5	[m]
Thickness (Vertical Direction)	0.5	[m]

Deck Material Properties

Young's Modulus	30000000	[kPa]
Poisson's Ratio	0.2	
Mass Density	0	[ton/m3]

Linear Beam Element

Linear Beam Properties

Young's Modulus	30000000	[kPa]
Mass Density	0	[ton/m3]
Moment of Inertia	0.0490873	[m4]

Re-Calculate

Nonlinear Beam Element

Nonlinear Beam Properties

Aggregator Section My & Mz:	Flexural Rigidity EI 158600 [kN-m2]	Kinematic Hardening Parameter 0 [kN-m]
	Yield Moment 1200 [kN-m]	Isotropic Hardening Parameter 0 [kN-m2]
Vy & Vz:	Shear Rigidity GA 3378000 [kN]	
T:	Torsional Rigidity GJ 42200 [kN-m2]	P: Axial Rigidity EA 8785000 [kN]

Fiber Section

Modify...

OK

Cancel



Moment-Curvature Analysis

Material: Concrete

	Core	Cover	
Compressive Strength	-29000	-22332	[kPa]
Strain at Max. Strength	-0.004	-0.002	
Crushing Strength	-22332	0	[kPa]
Strain at Crushing Strength	-0.014	-0.006	

Material: Steel

Yield Strength	1860000	[kPa]
Initial Elastic Tangent	200000000	[kPa]
Strain-hardening Ratio	0.01	

Patch

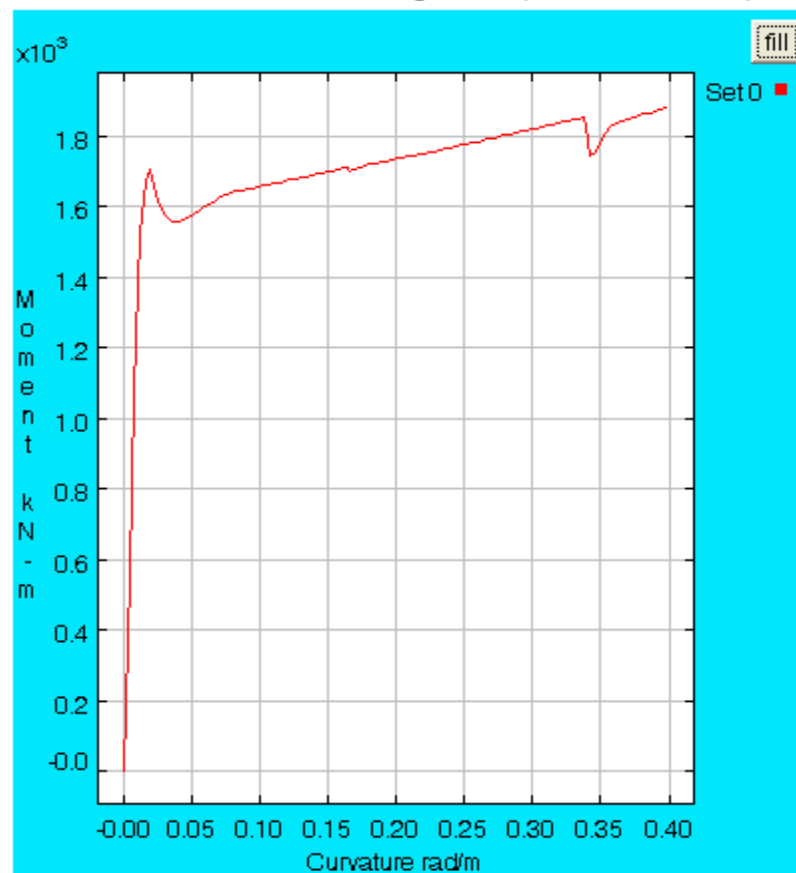
	Core	Cover	
Number of Fibers in Circumferential Direction	16	16	
Number of Fibers in Radial Direction	4	4	
Internal Radius	0	0.457	[m]
External Radius	0.457	0.61	[m]

Layer

Number of Reinforcing Bars along Layer	16	
Area of Individual Reinforcing Bar	0.00014	[m ²]
Radius of Reinforcing Layer	0.457	[m]

Axial Load	0	[kN]
Maximum Curvature	0.3937	[rad/m]
Number of Analysis Increments to Max. Curvature	100	

Moment-Curvature Response (File: [mcFile.txt](#))



Re-calculate Response

OK

Cancel

Soil Strata



Soil Layer # (From topdown)	Thickness [m]	Soil Type	Residual Shear Strength [kPa]	P	L	C
1:	10	8: Cohesionless medium, sand permeability	0.2	☒	☐	☐
2:	0	1: Cohesionless very loose, silt permeability	0.2	☒	☐	☐
3:	0	2: Cohesionless very loose, sand permeability	0.2	☒	☐	☐
4:	0	3: Cohesionless very loose, gravel permeability	0.2	☒	☐	☐
5:	0	4: Cohesionless loose, silt permeability	0.2	☒	☐	☐
6:	0	5: Cohesionless loose, sand permeability	0.2	☒	☐	☐
7:	0	6: Cohesionless loose, gravel permeability	0.2	☒	☐	☐
8:	0	7: Cohesionless medium, silt permeability	0.2	☒	☐	☐
9:	0	8: Cohesionless medium, sand permeability	0.2	☒	☐	☐
10:	0	9: Cohesionless medium, gravel permeability	0.2	☒	☐	☐
		10: Cohesionless medium-dense, silt permeability	0.2	☒	☐	☐
		11: Cohesionless medium-dense, sand permeability	0.2	☒	☐	☐
		12: Cohesionless medium-dense, gravel permeability	0.2	☒	☐	☐
		13: Cohesionless dense, silt permeability	0.2	☒	☐	☐
		14: Cohesionless dense, sand permeability	0.2	☒	☐	☐
		15: Cohesionless dense, gravel permeability	0.2	☒	☐	☐
		16: Cohesive soft				
		17: Cohesive medium				
		18: Cohesive stiff				
		19: U-Sand1...				
		20: U-Sand2...				
		21: U-Clay1...				
		22: U-Clay2...				

☐ Include Liquefaction Effect

☐ Activate Pile Zone Material

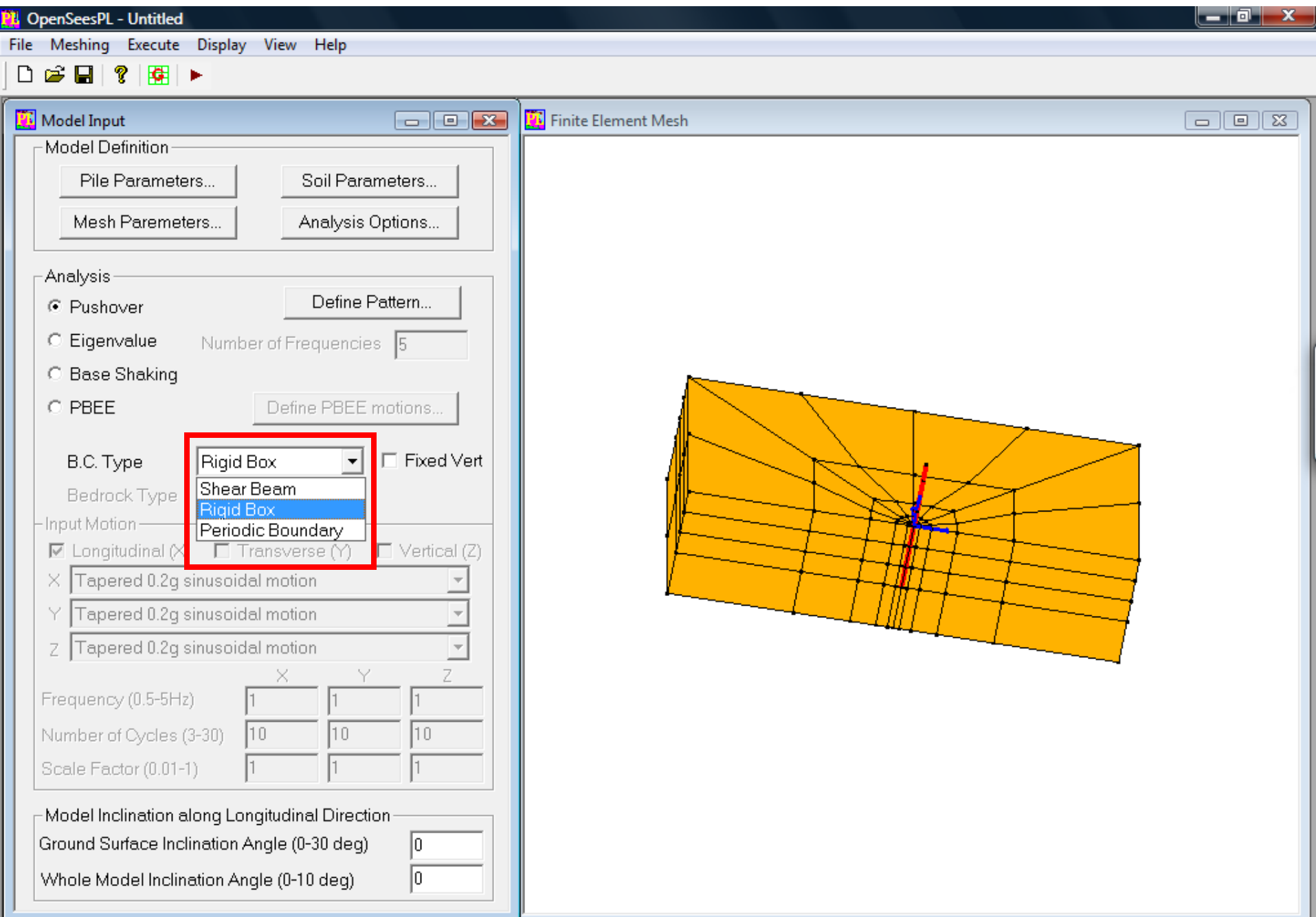
☐ Activate Pile-Soil Interface

10 [m]

Note: P, L and C represents Parabolic, Linear increasing and Constant variation of soil modulus with depth, respectively.

OK

Cancel



Pushover



Type

- ☒ Monotonic Pushover
☐ Cyclic Pushover (Sine Wave)
☐ U-Push

Define U-Push...

Method

- ☐ Force-Based Method
☒ Displacement-Based Method

Force Increment (Per Step)

Logitudinal (X) Force [kN]
Transverse (Y) Force [kN]
Vertical (Z) Force [kN]
Moment of X [kN-m]
Moment of Y [kN-m]
Moment of Z [kN-m]

Displacement Increment (Per Step)

Longitudinal Displacement [m]
Transverse Displacement [m]
Vertical Displacement [m]
Rotation around X [rad]
Rotation around Y [rad]
Rotation around Z [rad]

Sine Wave

Frequency (Hz)

Time

Total Number of Steps

OK

Cancel

U-Shake

Current User Defined Input Motion (U-Shake) File

Select/Change Input Motion File...

C:\Program Files\OpenSeesPL\motions\elcentro

Detail Motion Information

Number of Points	1559	
Time (seconds)		Acc. Value (g)
Starting Point	0.02	0.0063
Ending Point	31.18	0
Maximum Acc. Point	2.22	0.298
Minimum Acc. Point	2.04	-0.319

Please change if necessary

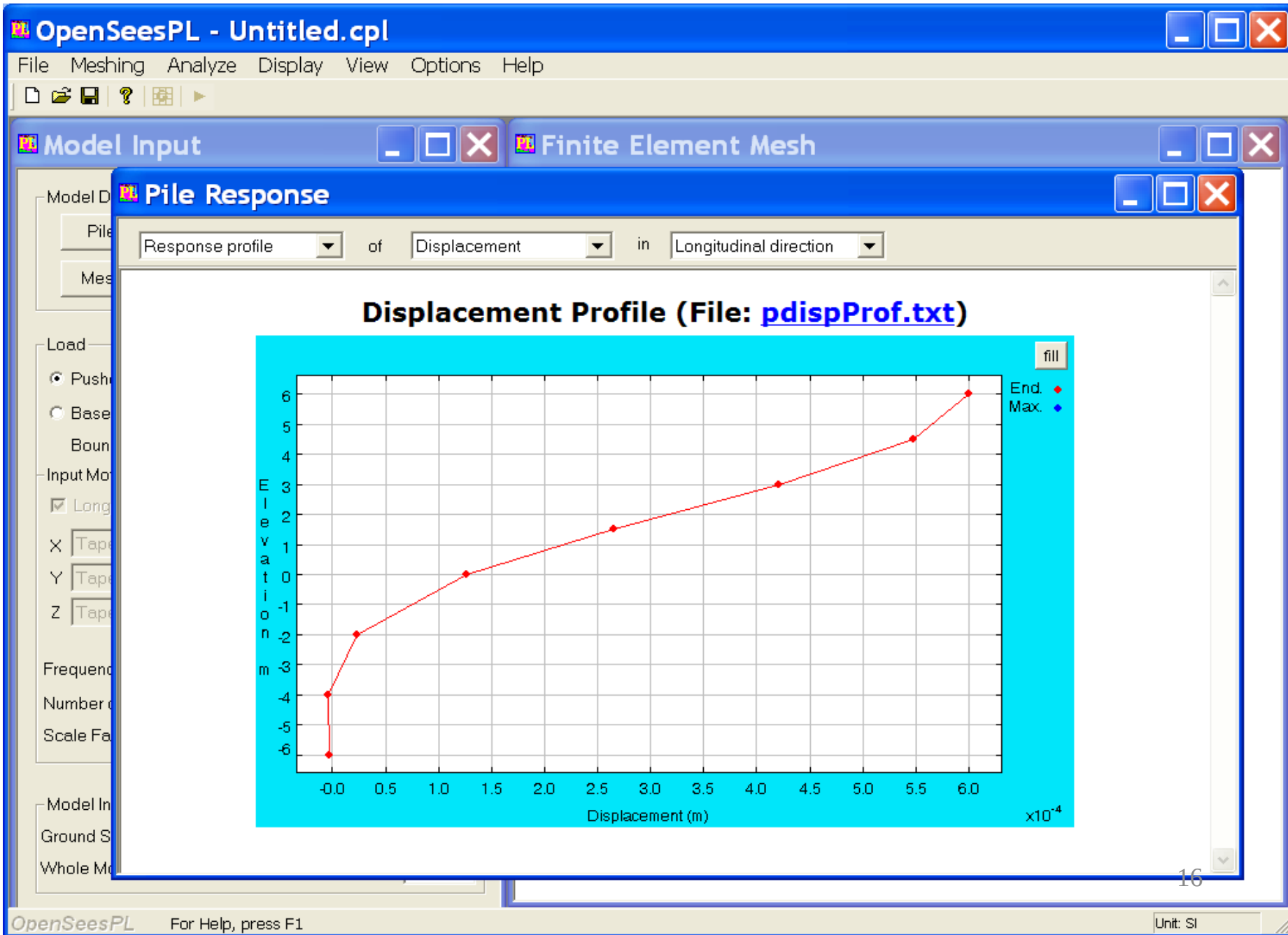
Response will be computed for 31.18 seconds.

Output at interval of 0.01 seconds.

View Motion

Horizontal axis: Time (second)
Vertical axis: Acc. (g)

OK Cancel

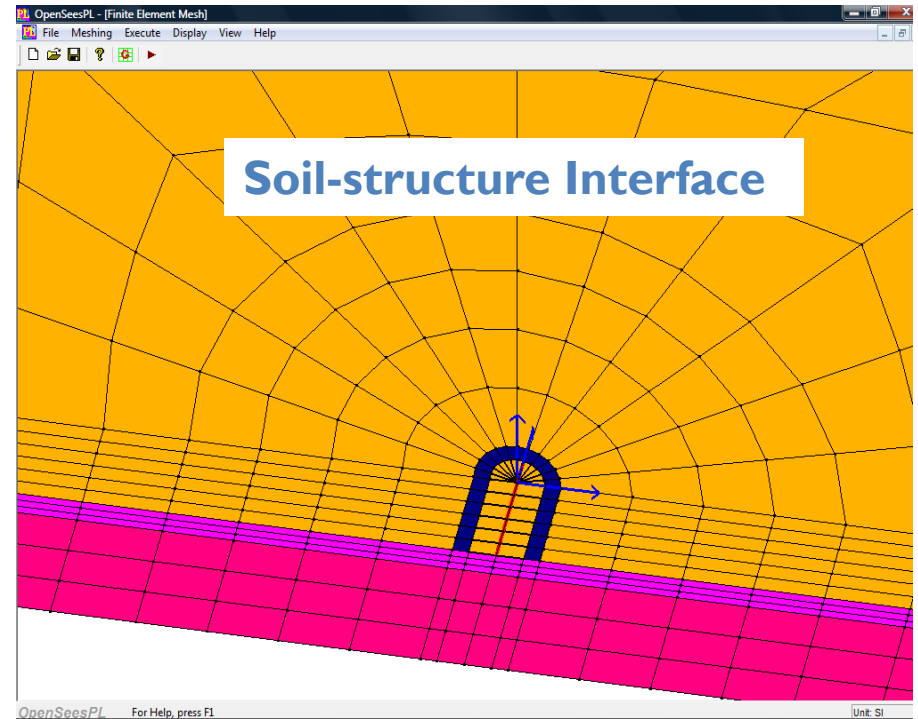
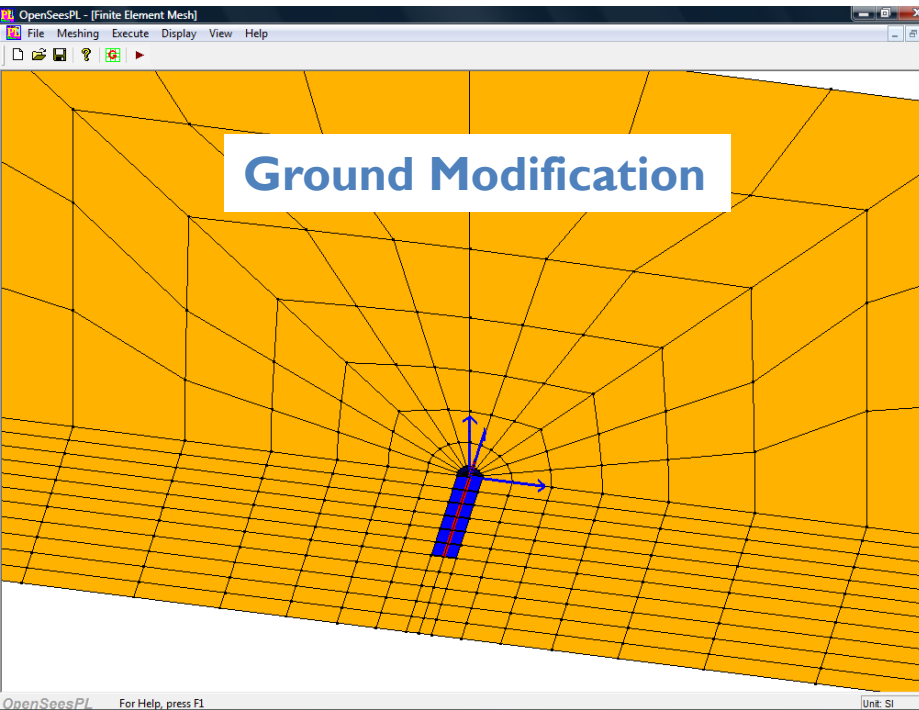


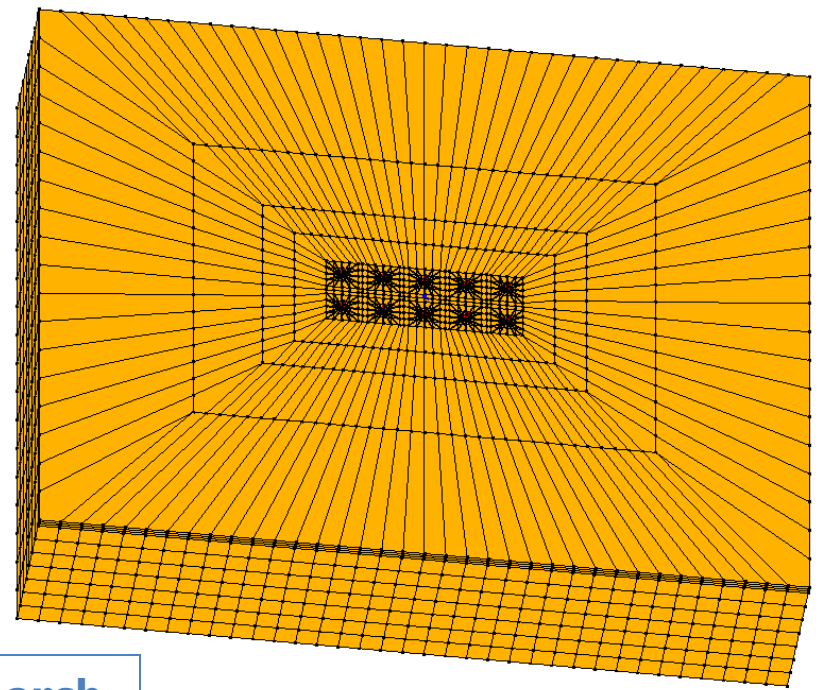
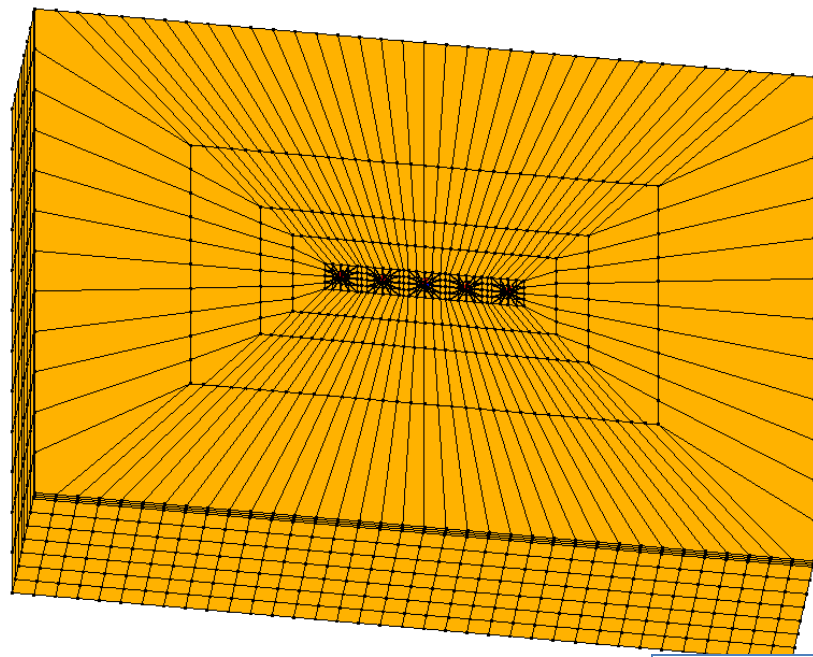
Shallow Foundation

Caisson

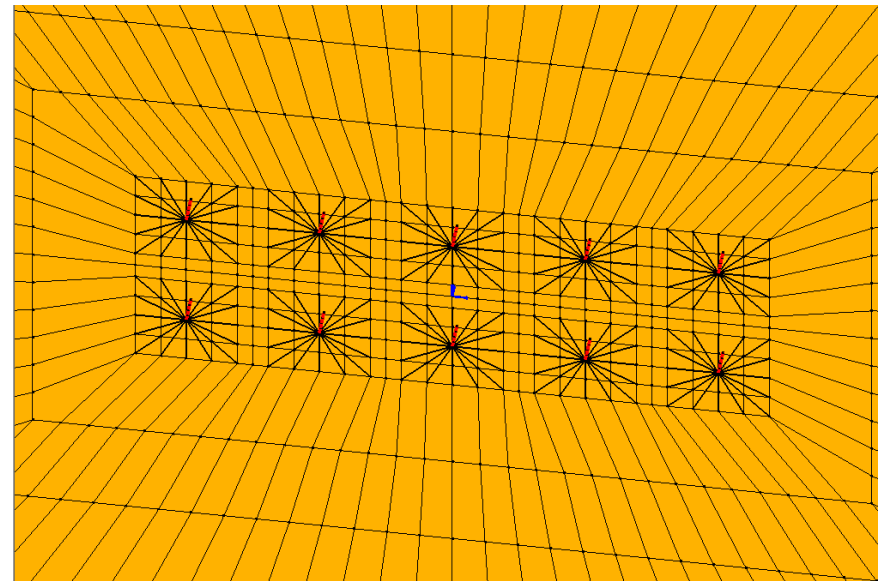
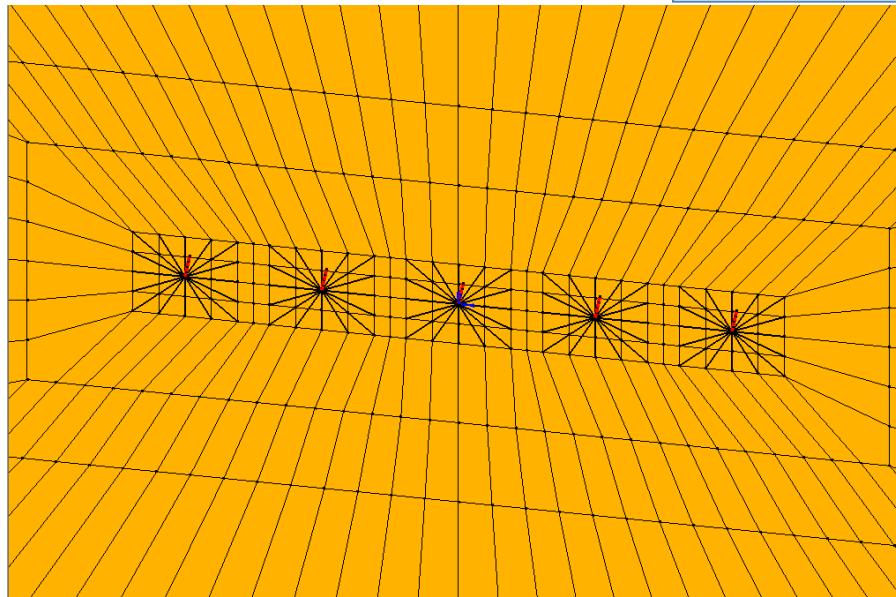
Ground Modification

Soil-structure Interface





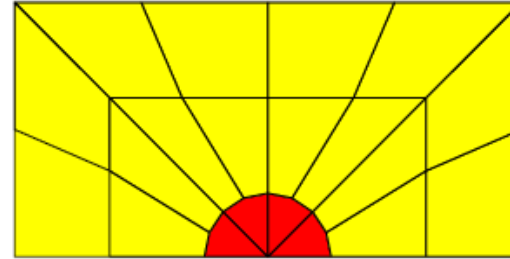
Ongoing Research



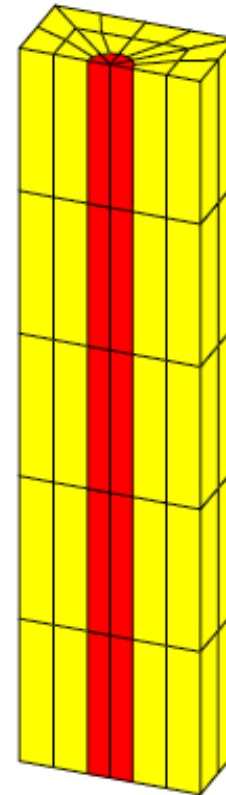
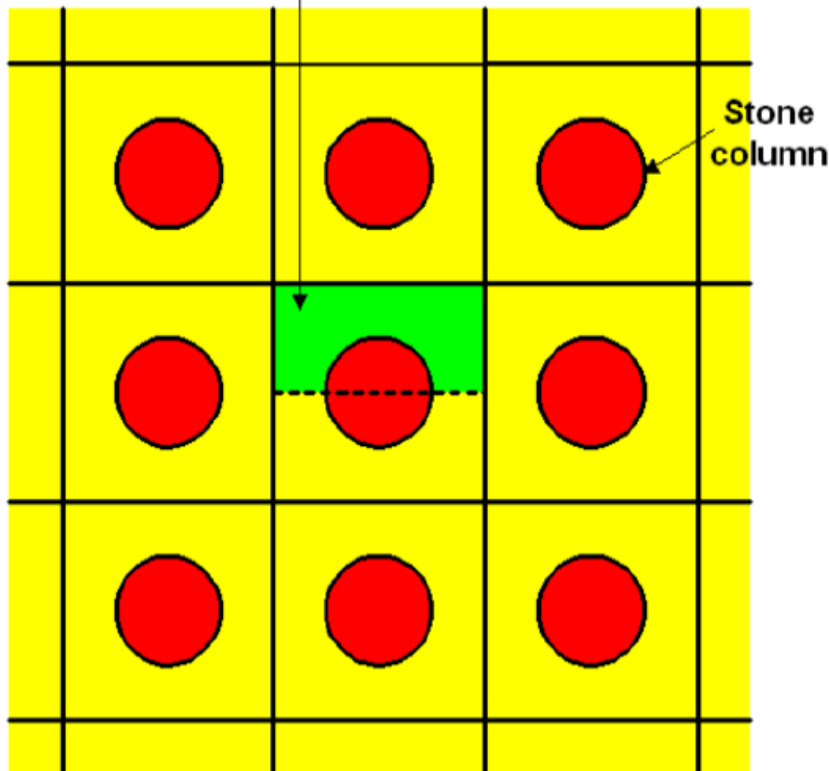


Ground Modification

- Gravel Drain/Stone column
- Pile Pinning



Half mesh within $S \times S$ "cell"



Schematic view
of stone column
or pile-pinning layout

10 m depth
Sand Layer
(or Silt Layer)

Mild Infinite Slope (4 degrees)

OpenSeesPL - Untitled

File Meshing Analyze Display View Options Help

Model Input

Model Definition

Pile Parameters...

Soil Parameters...

Mesh Parameters...

Analysis Options...

Analysis

Pushover

Eigenvalue

Base Shaking

Define Pattern...

Number of Frequencies: 5

B.C. Type: Laminar Container

Bedrock Type: Rigid Bedrock

Fixed Vert

Input Motion

Longitudinal (X)

Transverse (Y)

Vertical (Z)

X

Y

Z

Tapered 0.2g sinusoidal motion

Tapered 0.2g sinusoidal motion

Tapered 0.2g sinusoidal motion

Frequency (0.5-5Hz)

Number of Cycles (3-30)

Scale Factor (0.01-1)

X

Y

Z

1

10

1

1

1

1

Model Inclination along Longitudinal Direction

Ground Surface Inclination Angle (0-30 deg)

Whole Model Inclination Angle (0-10 deg)

0

0

Finite Element Mesh

σ'_1

σ'_2

σ'_3

p'_0

p'

Principal effective stress space

$\sqrt{\frac{3}{2}}\sigma'_1$

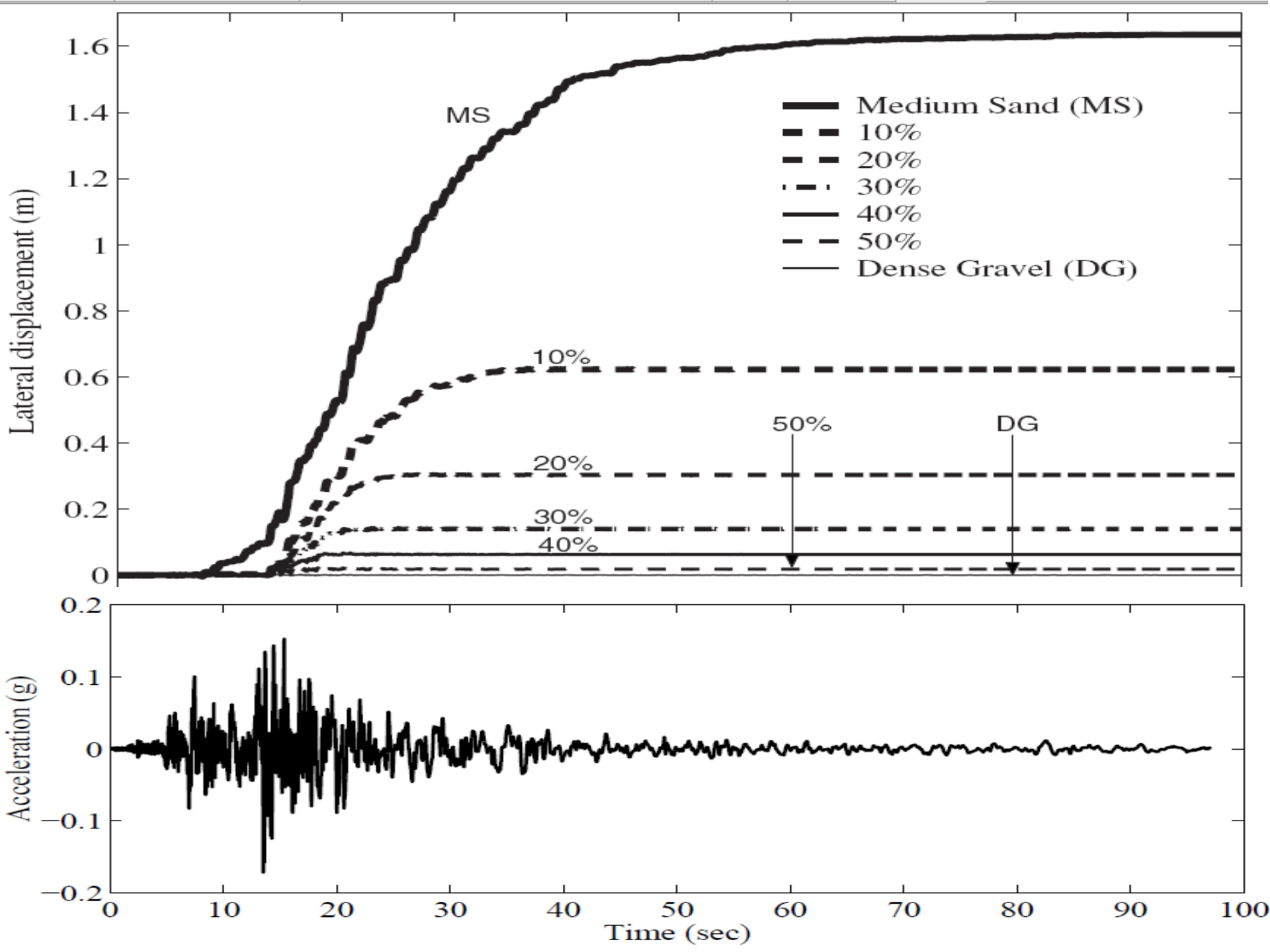
$\sqrt{\frac{3}{2}}\sigma'_2$

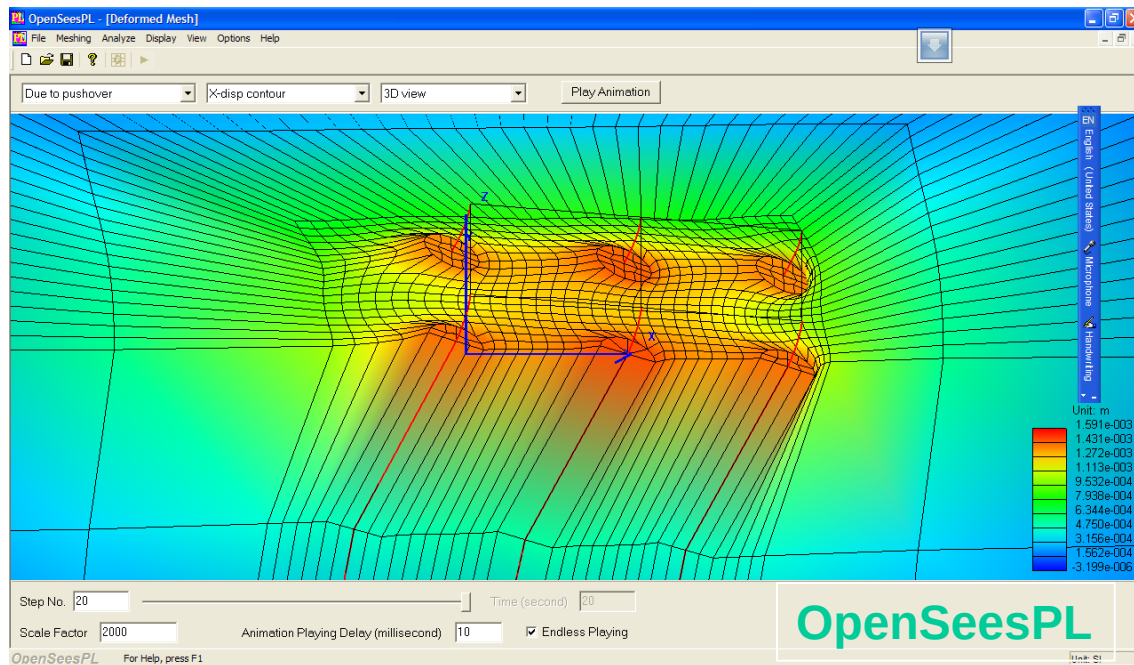
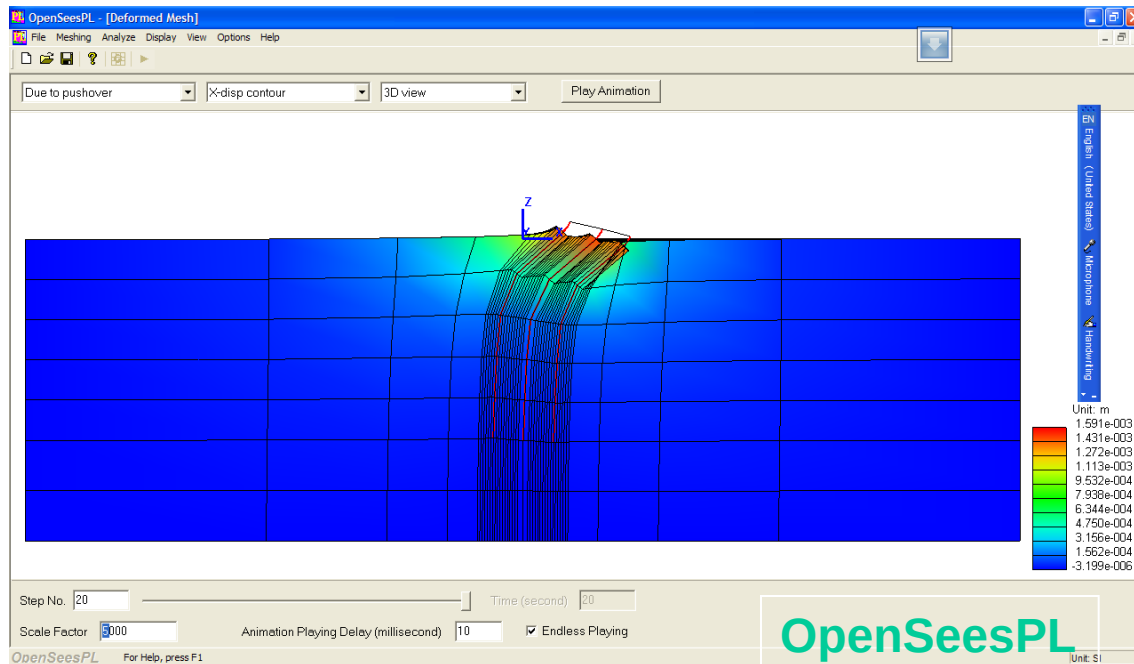
$\sqrt{\frac{3}{2}}\sigma'_3$

Deviatoric plane

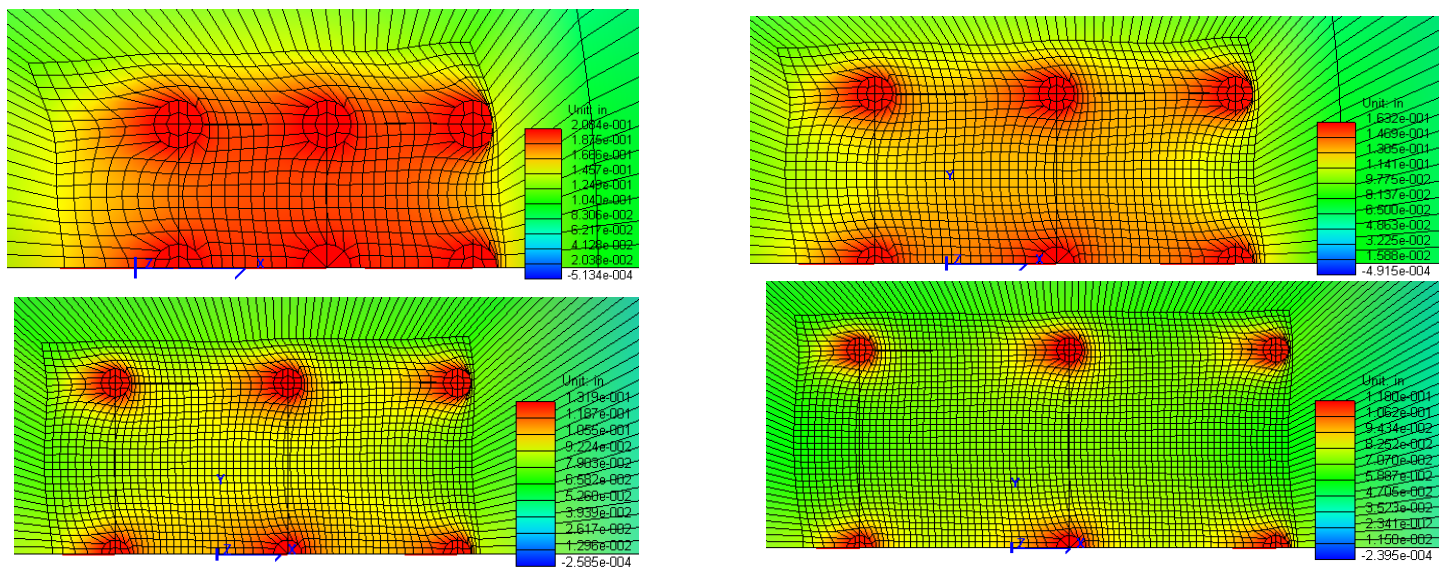
OpenSeesPL

For Help, press F1



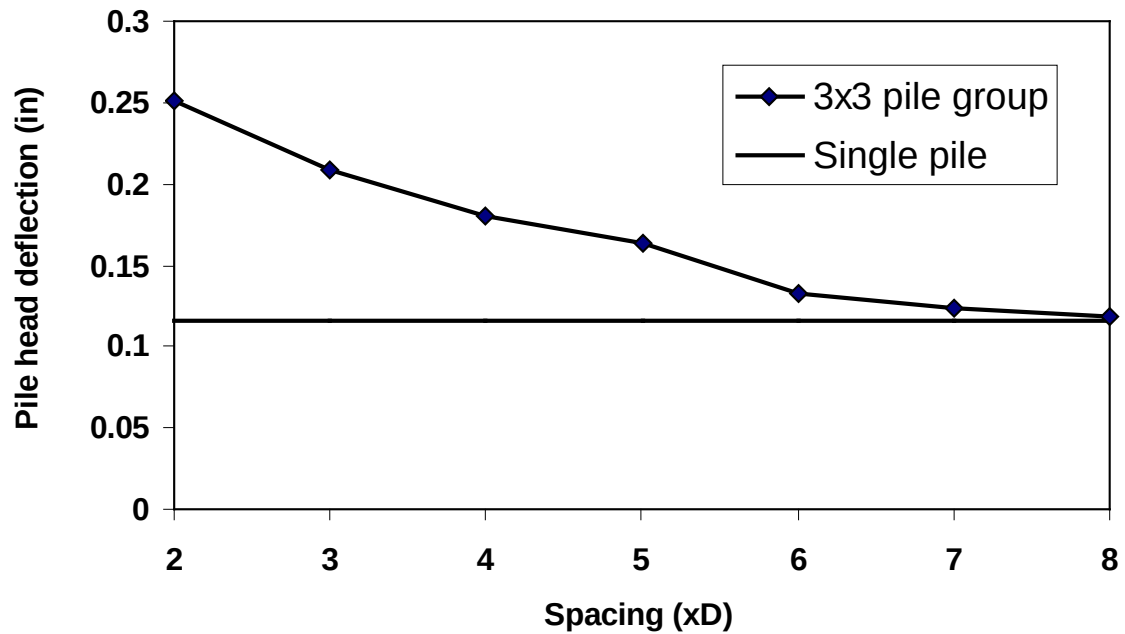


Elgamal, A. and Lu, J. (2009). "A Framework for 3D Finite Element Analysis of Lateral Pile System Response," Proceedings of the 2009 International Foundation Congress, ASCE GSP 186, M. Iskander, D. F. Laefer, and M. H. Hussein, Editors, Orlando, Florida, pp. 616-623.



OpenSees Computations through Graphical Interface OpenSeesPL

Pile group displacement of the 3x3 pile group (for different spacing) and the single pile under lateral loading.



http://en.wikipedia.org/wiki/File:DumbartonBridgeCA_and_Towers.jpg

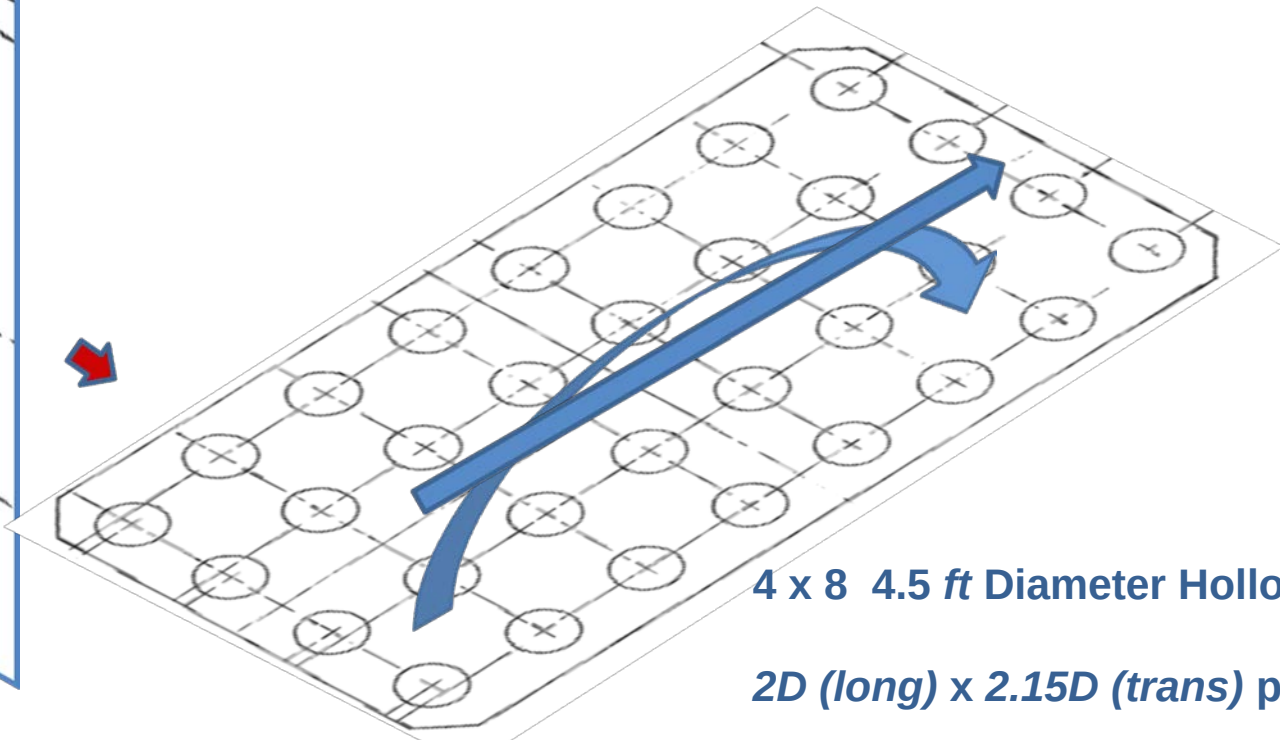
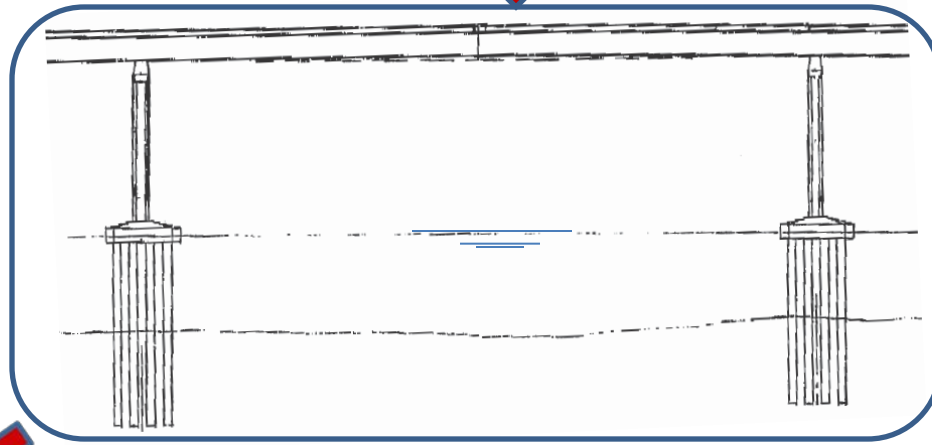




Dumbarton Bridge

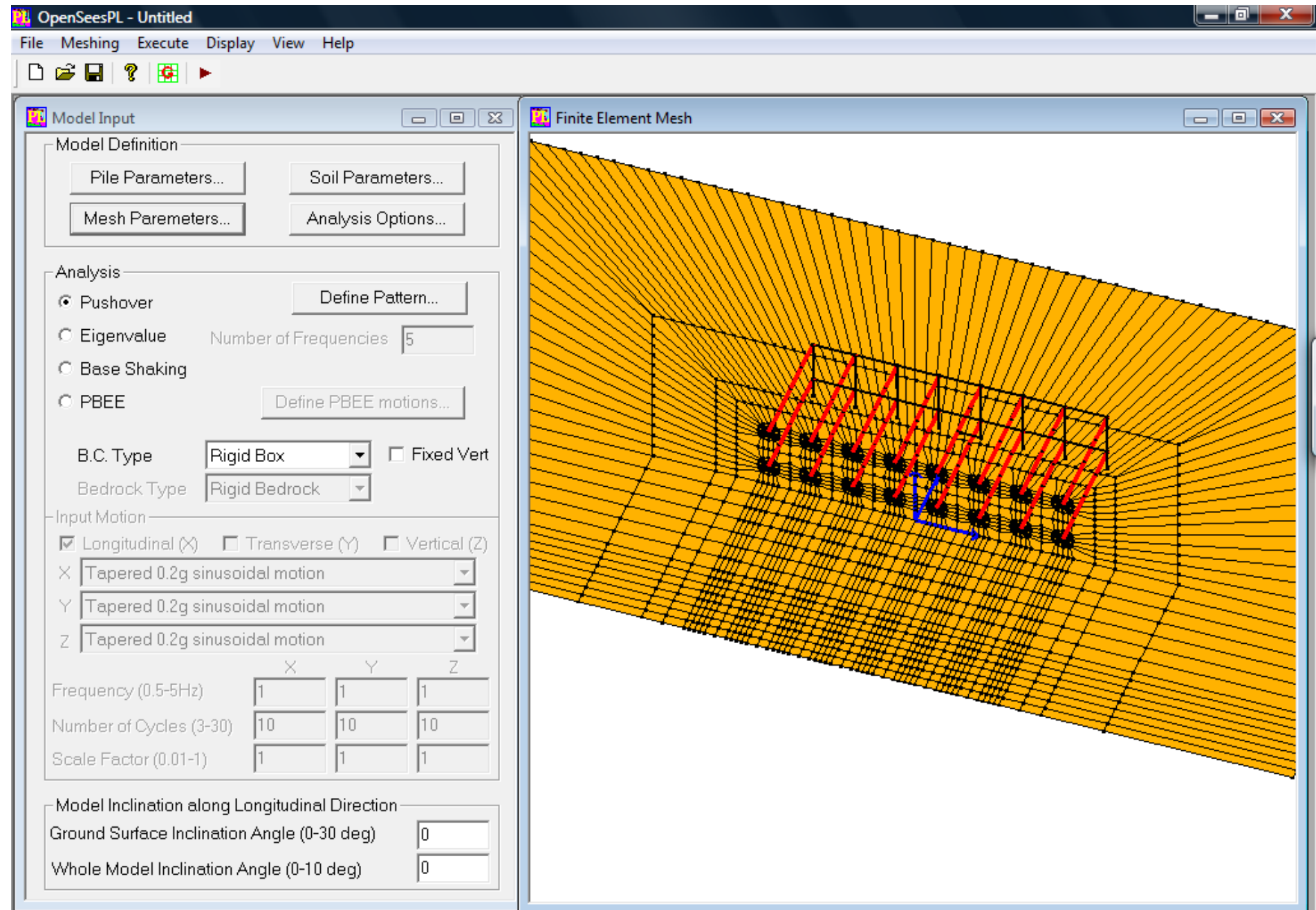
Pier 23

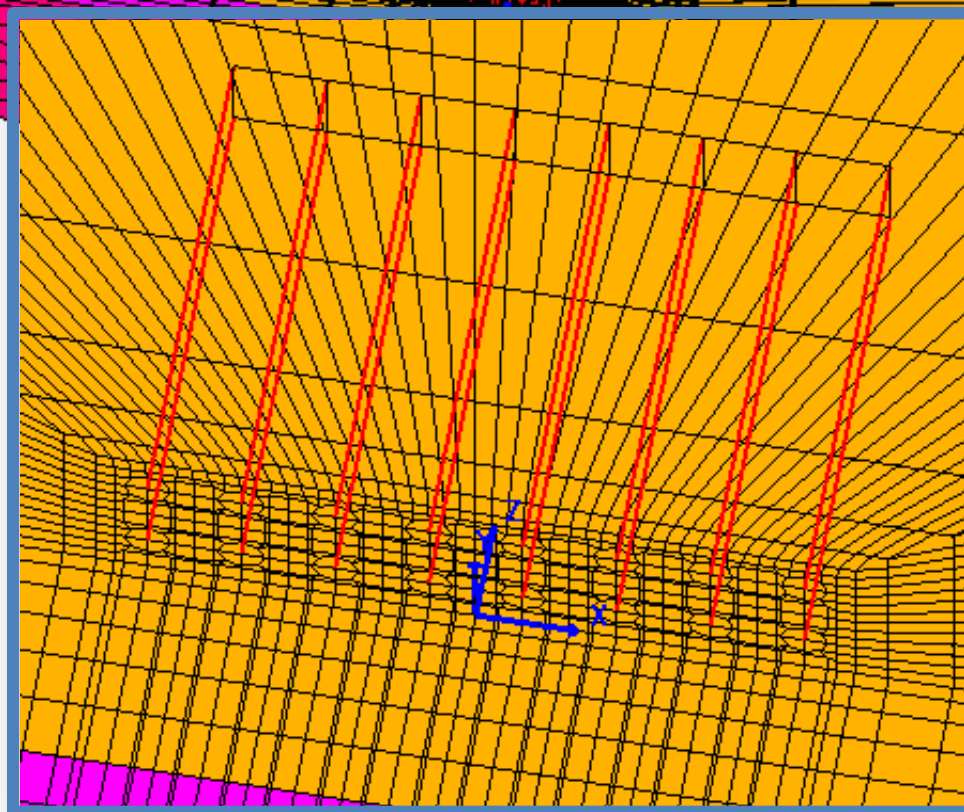
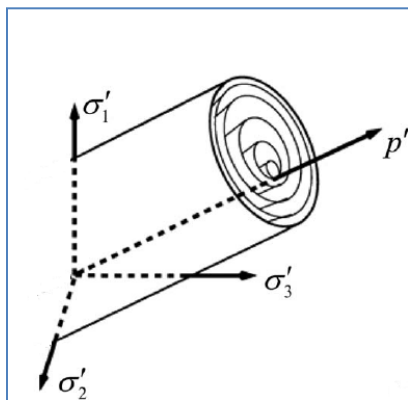
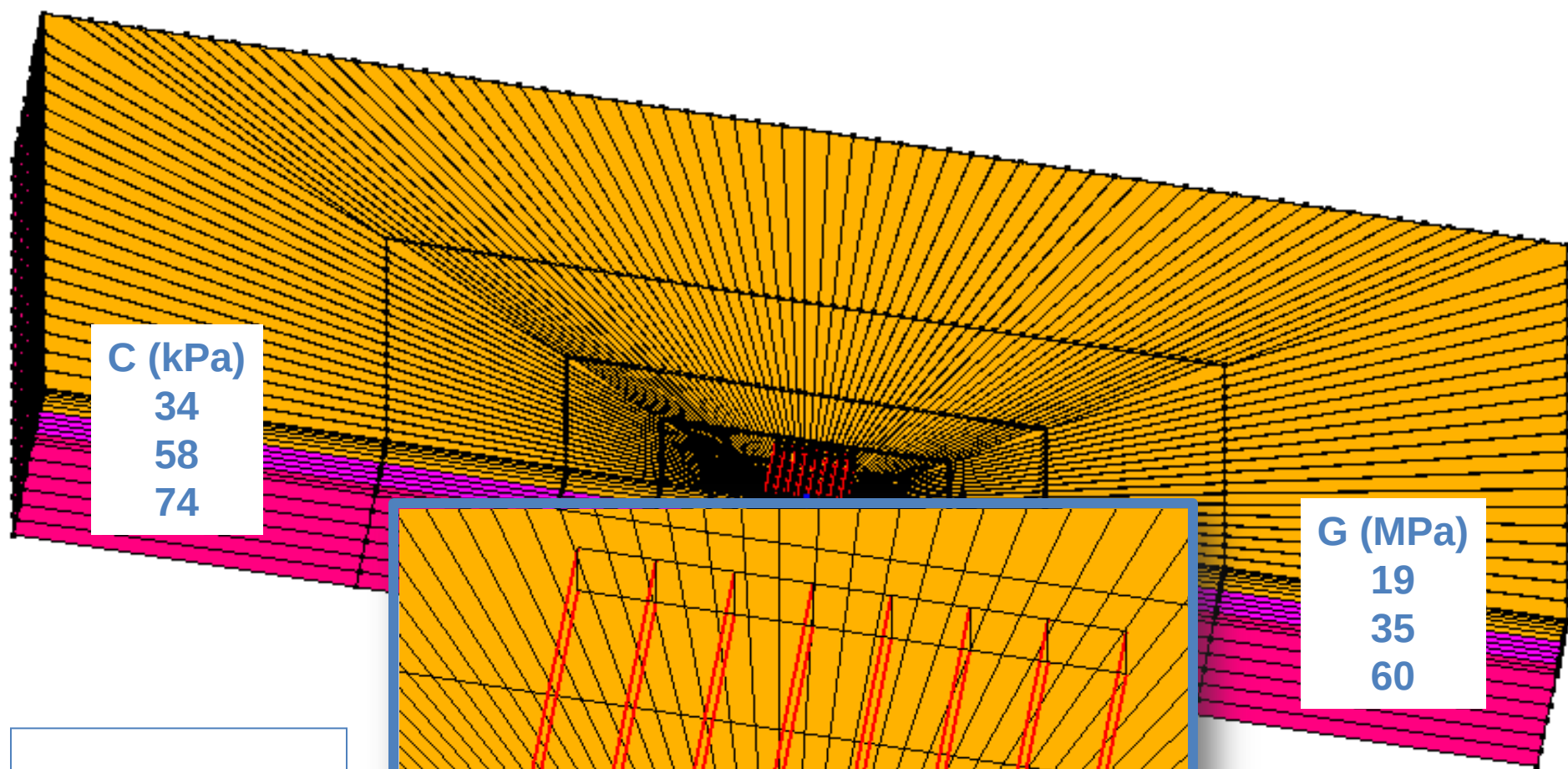
16 m 14 m 27 m



4 x 8 4.5 ft Diameter Hollow RC Piles

2D (long) x 2.15D (trans) pile spacing

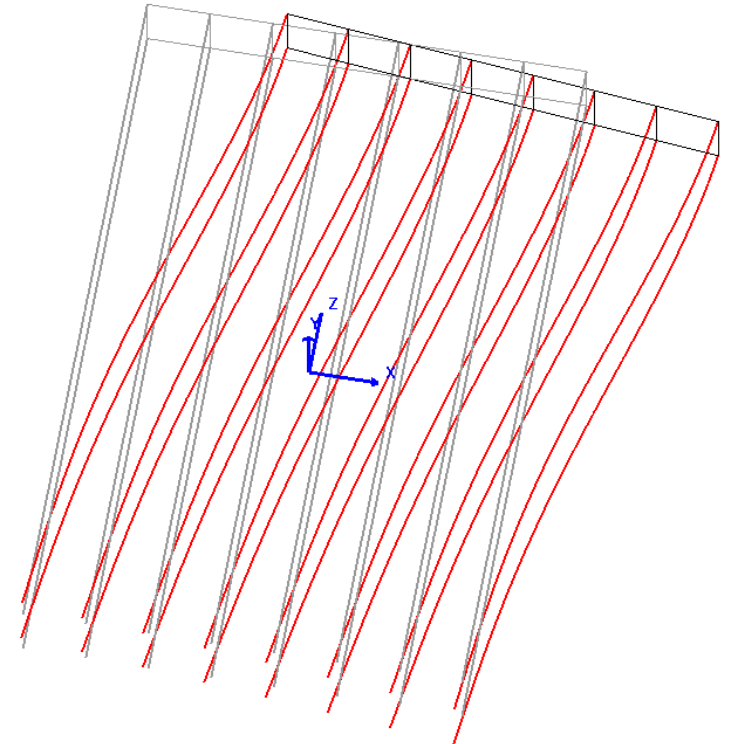
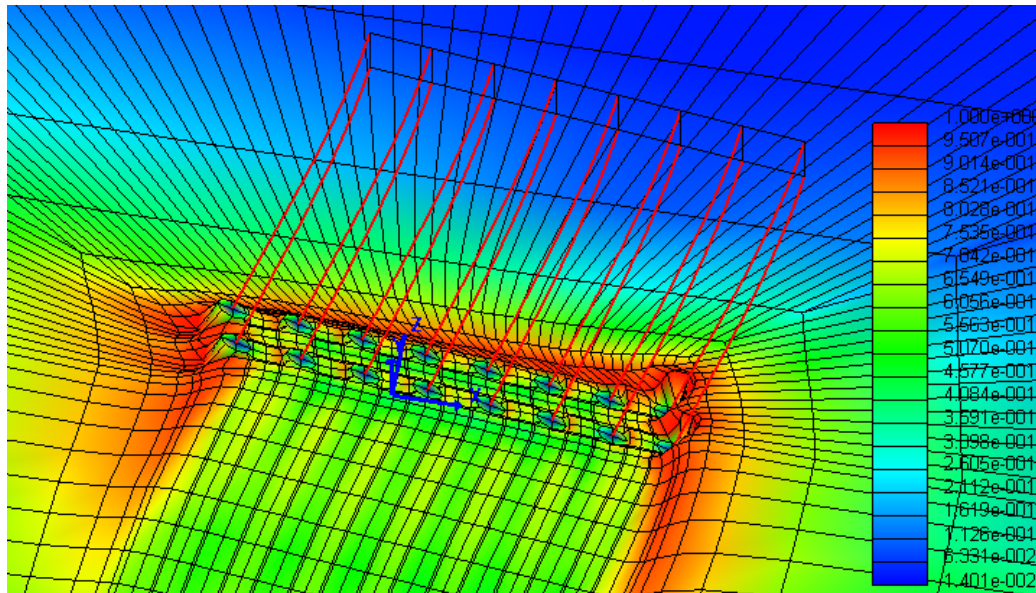
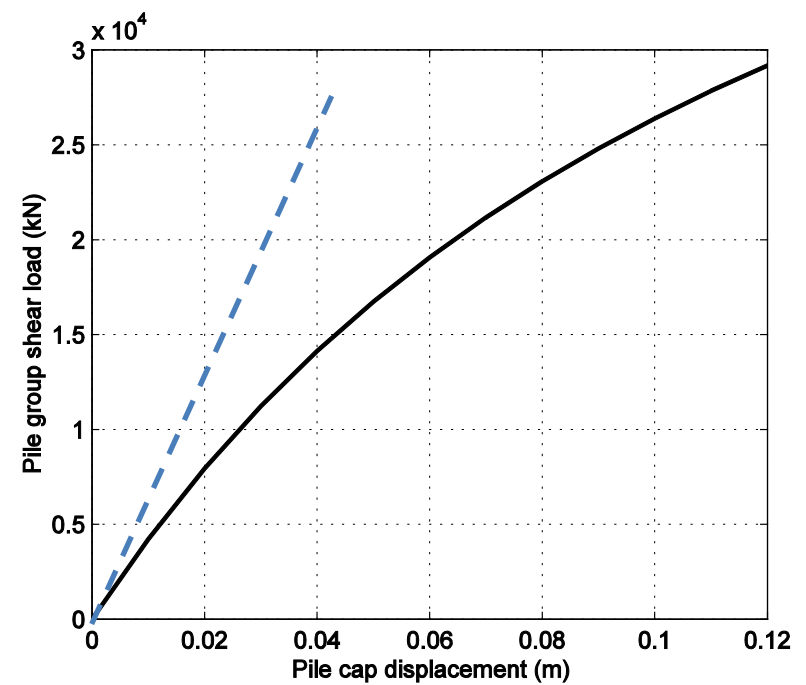


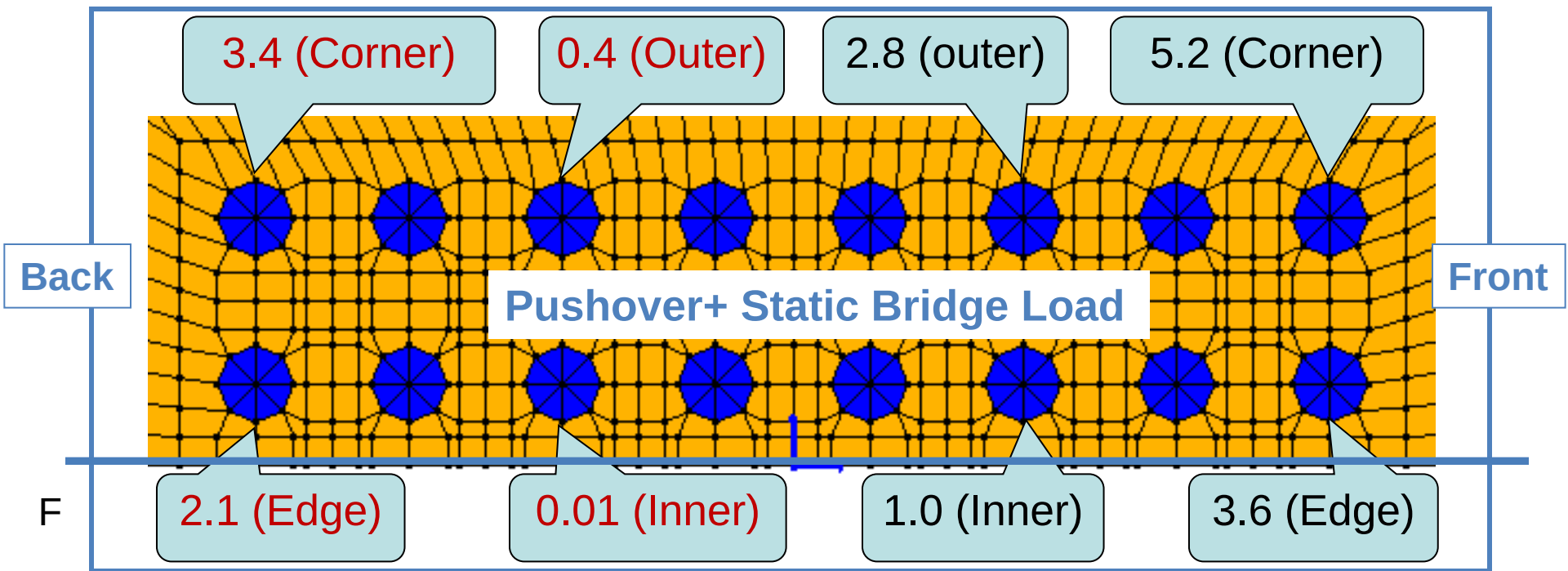
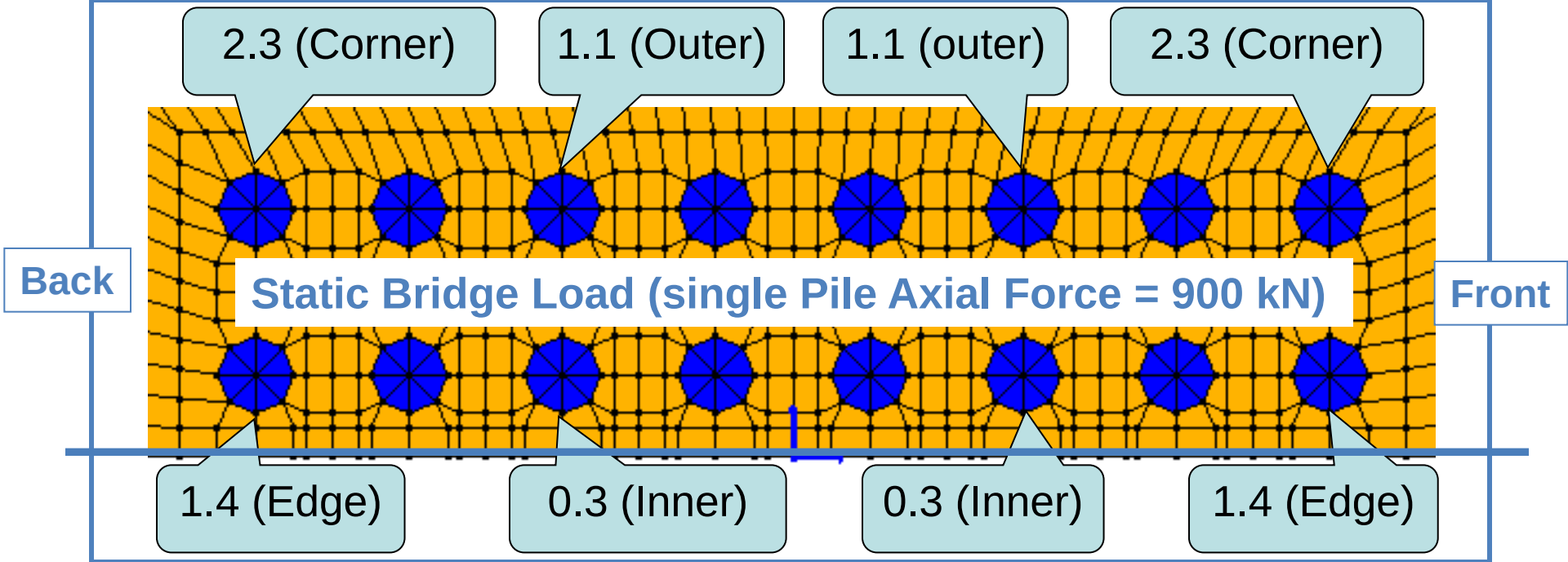


Applied Loads

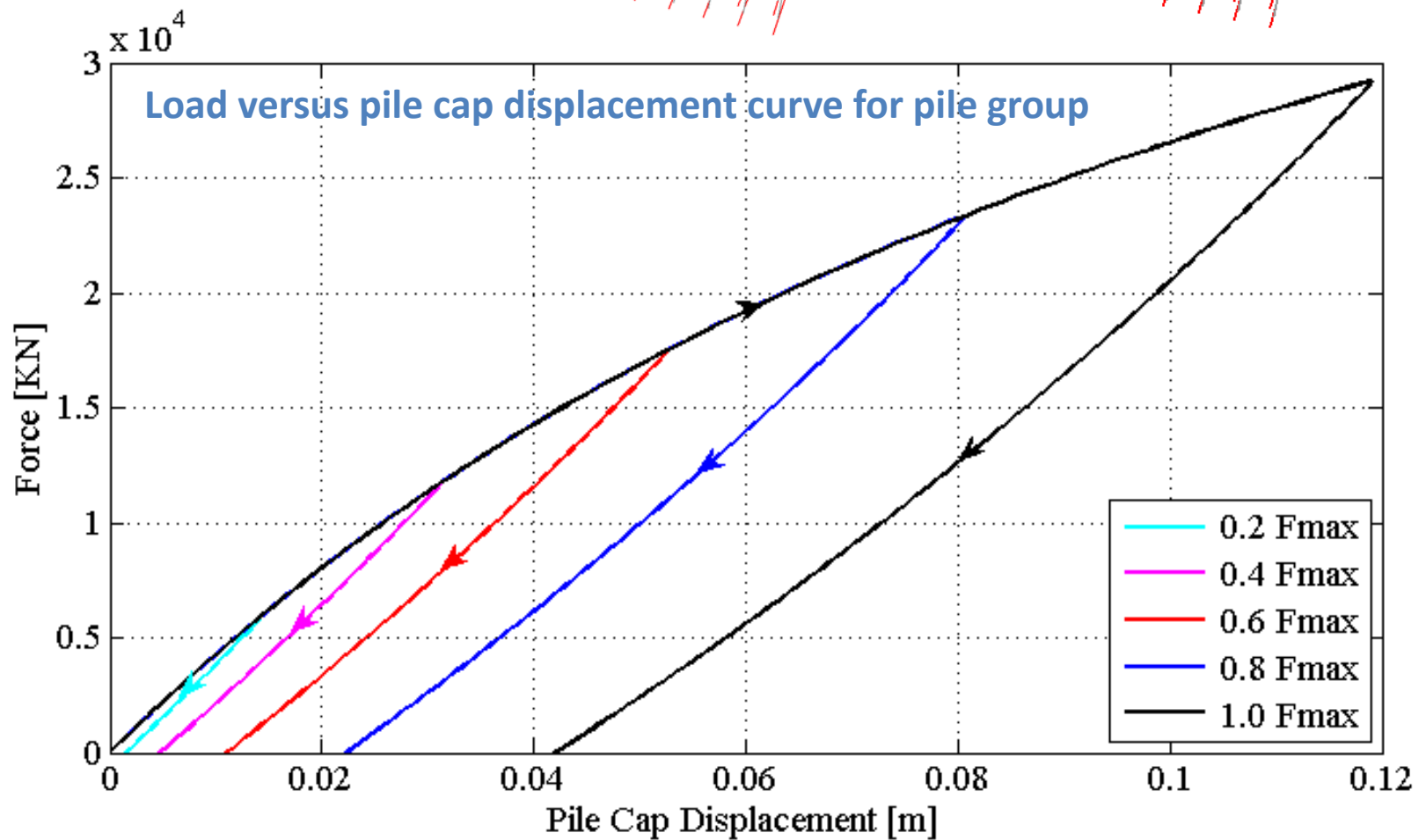
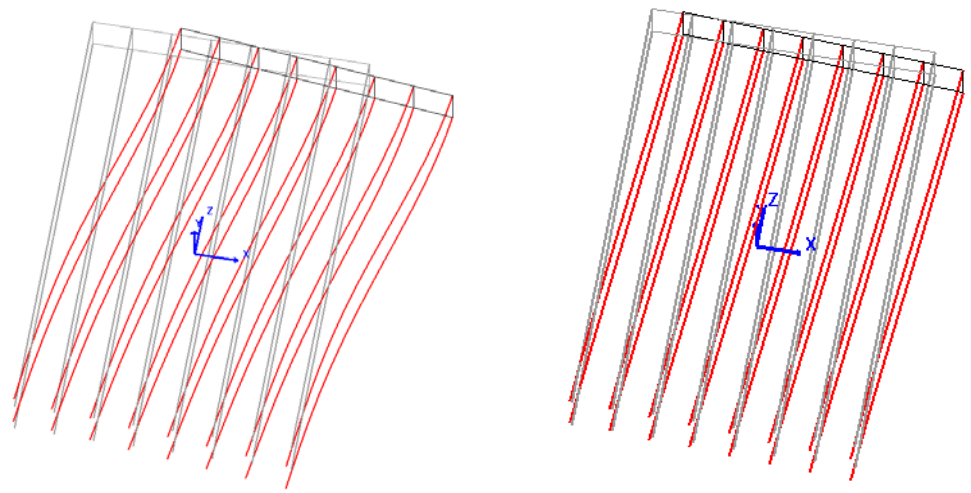
1. Bridge Own weight

2. Pushover analysis (1 g)

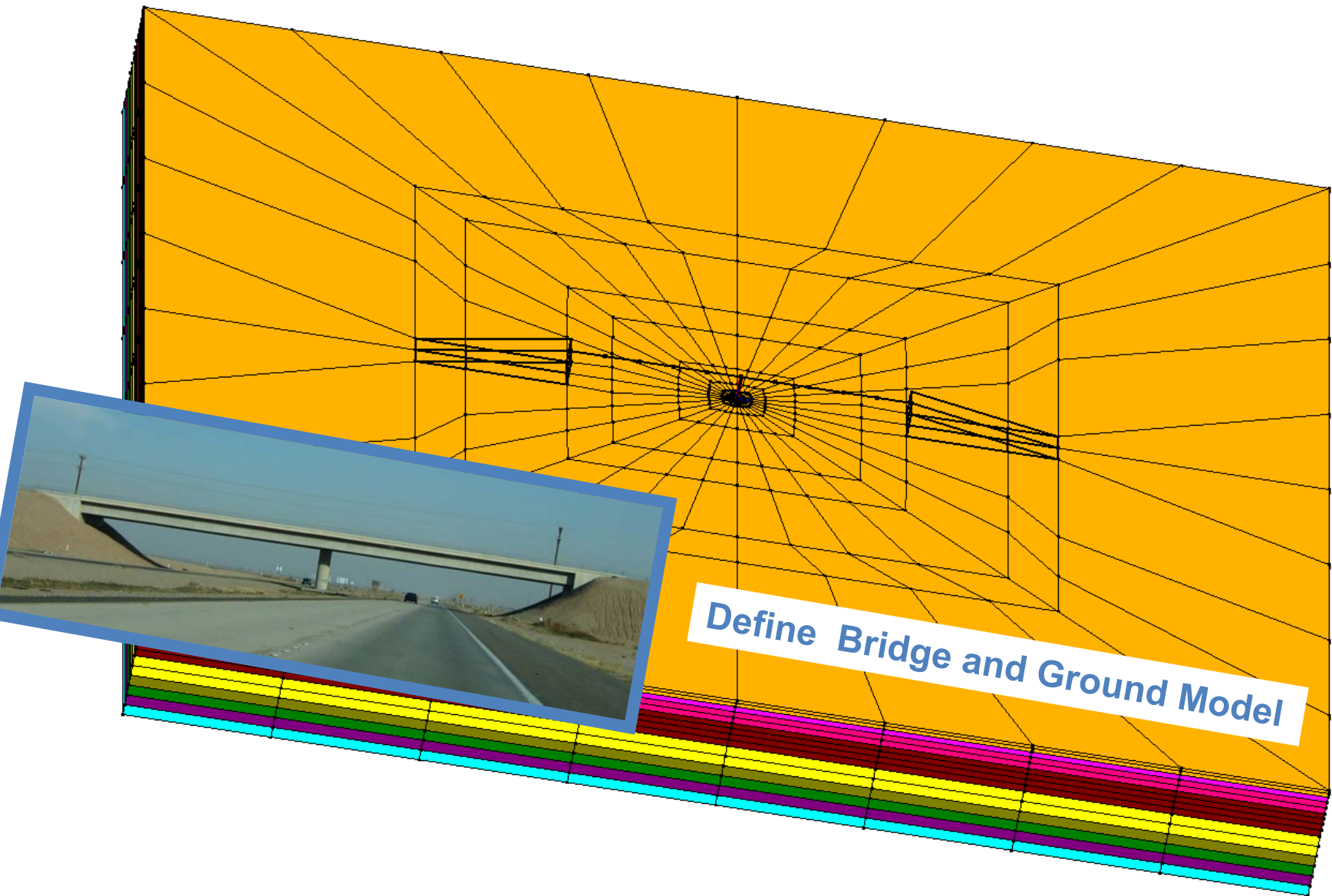




Permanent Deformation



OpenSeesPL Bridge-Ground Model for Performance-Based Earthquake Engng- with Prof Kevin Mackie



Firefox

PEERBridgePBEEWiki

+

http://peerbridgebee.net/index.php?title=Main_Page

★

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- OpenSeesPBEE
- Employed OpenSees Soil Elements/Models User Manual

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toolbox

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page discussion view source

Main Page

WELCOME!

OpenSeesPBEE is a PC-based graphical pre- and post-processor (user-interface) for conducting Performance-Based Earthquake Engineering (PBEE) studies for bridge-ground systems. The finite element computations are conducted using **OpenSees** of the Pacific Earthquake Engineering Research (PEER) Center. The analysis options available in OpenSeesPBEE include: 1) Pushover Analysis, 2) Single 3D Base Input Acceleration Analysis and, 3) Full Performance-Based Earthquake Engineering (PBEE) Analysis.

Note: It is best to use a relatively new Laptop or Desktop with a fast processor, and at least 2 Gig of memory.

The following steps describe how to download, install and run **OpenSeesPBEE**. For detailed documentation, please see [Step 5](#). In addition, A few demo examples are available in [Step 6](#).

Step 1: Install Tcl

If you have not installed **Tcl/Tk** on your computer, please download the **Tcl/Tk 8.5** installation file below and double-click it to install (**OpenSees** employs Tcl 8.5). You only need to do this step once for a given PC.

Tcl 8.5

Step 2: Install Java

Most likely you should already have **Java** installed on your computer. If you don't, please download the installation file below and install the **Java** software.

Java

Step 3: Install OpenSeesPBEE

Please download the installation file below, and then double-click on the icon and follow the simple installation instructions (you may wish to visit this site periodically to check for updates).

Download OpenSeesPBEE_Setup.exe (Ver 0.8.6, updated 5/1/11)

Step 4: Run OpenSeesPBEE

1) After installing the software on your computer, double-click the **OpenSeesPBEE** icon to start.

Model Input

STEP 1: DEFINE MODEL

Analysis Type

☒ Pushover

Define Pattern...

☐ Eigenvalue

Number of Modes 5

☐ Base Shaking

Input Motions...

PBEE Analysis:

☐ Ground Shaking

PBEE Motions...

Model Definition

Bridge Parameters...

Soil Parameters...

Mesh Parameters...

Analysis Options...

Boundary Conditions

B.C. Type

Shear Beam

☐ Fixed Vert

Bedrock Type

Rigid Bedrock

STEP 2: EXECUTE FE ANALYSIS

Save Model & Run Analysis

STEP 3: COMPUTE REPAIR COST

PBEE Analysis

Finite Element Mesh

Re-Generate

☐ Bridge Only

Zoom In

Out

Frame

XY

YZ

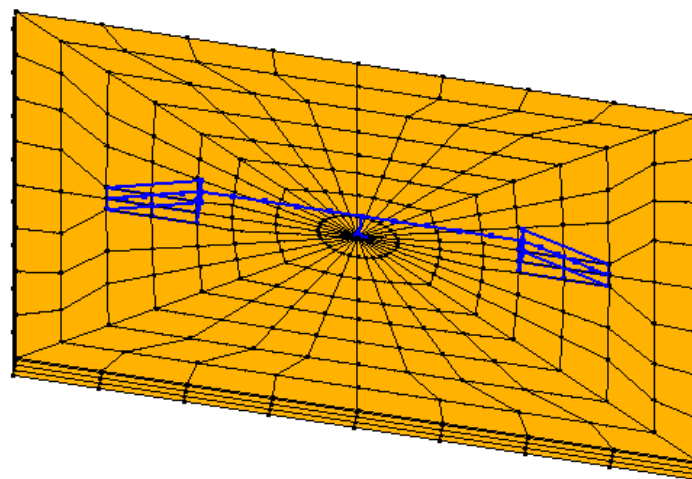
XZ

3D

<-

->

Up





Transportation Research Program

Pacific Earthquake Engineering Research Center

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Publications & Data

Ground Motions for PEER Transportation Research Program

by Nirmal Jayaram, Shrey Shahi and Jack Baker, 2010

The following files document selected ground motions for use in the PEER transportation systems research program. Documentation

[Report on PEER Systems Workshop1.doc](#)

Documentation

The following are presentations given in the process of developing these ground motions:

- [January 21st draft report documenting selected ground motions and the methods used to select them.](#) (PDF file - 752 KB)

Set #1a: Broad-band ground motions ($M = 7$, $R = 10$ km, soil site)

See the report above for background regarding the selection of these ground motions.

- [Spreadsheet documenting selected ground motions.](#) Worksheets are provided to list a summary of the selected ground motions' metadata, their response spectra, and comparisons of the ground motion set's mean, standard deviation to comparable values predicted by ground motion models. (Excel file - 676 KB)
- [Zip file containing acceleration time histories for the 40 selected ground motions.](#) Fault-normal, fault-parallel and vertical components are included. (Zip file - 7 MB)

Set #1b: Broad-band ground motions ($M = 6$, $R = 25$ km, soil site)

See the report above for background regarding the selection of these ground motions.

- [Spreadsheet documenting selected ground motions.](#) Worksheets are provided to list a summary of the selected ground

Ensemble of 160 3-D Earthquake Excitation Records (Jack Baker, Stanford)

Select/Change...

Display Intensity Measures

Input Motions (100 Records in Total)

Record#	Bin	Motion	#Points	Timestep (Sec)	Duration (Sec)
1	LMLR	BORREGO/A-ELC	4000	0.0100	40.0000
2	LMLR	LOMAP/AZE	7990	0.0050	39.9500
3	LMLR	LOMAP/FMS	7949	0.0050	39.7450
4	LMLR	LOMAP/HVR	7990	0.0050	39.9500
5	LMLR	LOMAP/SJW	7990	0.0050	39.9500
6	LMLR	LOMAP/SLC	7915	0.0050	39.5750
7	LMLR	NORTHR/BAD	3499	0.0100	34.9900
8	LMLR	NORTHR/CAS	3979	0.0100	39.7900
9	LMLR	NORTHR/CEN	2999	0.0100	29.9900
10	LMLR	NORTHR/DEL	3536	0.0100	35.3600

☒ Compute Response to Entire Record Length☐ Compute Response for seconds

OK

Cancel

Model Definition

Bridge Parameters...

Mesh Parameters...

Boundary Conditions

B.C. Type Bedrock Type

Model Inclination along L

Ground Surface Inclination

Whole Model Inclination

Current Motion 4: HVR Run 4 of 4: Base shaking...



8%

Current Motion 5: SJW Run 4 of 4: Base shaking...



7%

Current Motion 6: SLC Run 4 of 4: Base shaking...



8%

Current Motion 7: BAD Run 4 of 4: Base shaking...



8%

Current Motion 8: CAS Run 4 of 4: Base shaking...



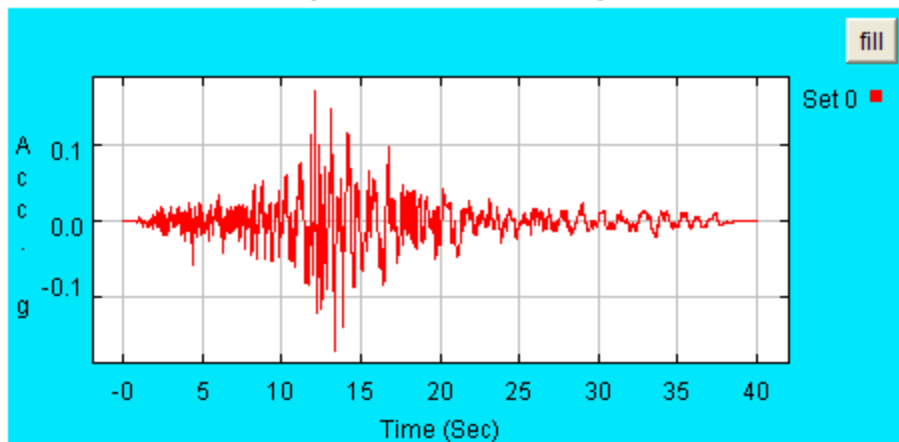
8%

Intensity Measures

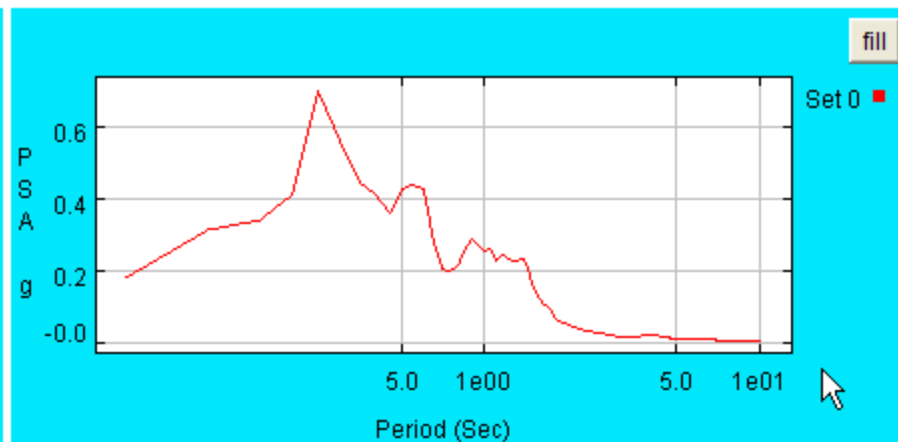
	Horizontal 1	Horizontal 2	Horizontal SRSS	Vertical
PGA (g)	0.170558	0.138501	0.181953	0.095212
PGV (cm/sec)	13.712202	11.527482	17.248343	3.759779
PGD (cm)	3.891637	5.643364	5.753599	2.382868
D(5-95) (sec)	31.530000	30.845000		36.905000
CAV (cm/sec)	616.701389	508.981512		323.320389
Arias Intensity (cm/sec)	40.190139	27.553230		9.283904

Acceleration Time Histories and Pseudo-Spectral Acceleration (PSA)

Horizontal 1 Acceleration (g) (Motion File:
A2E000.AT2.data)
(File: [motionX.txt](#))



Horizontal 1 Pseudo-Spectral Acceleration (g) (File:
[spectralAccX.txt](#))

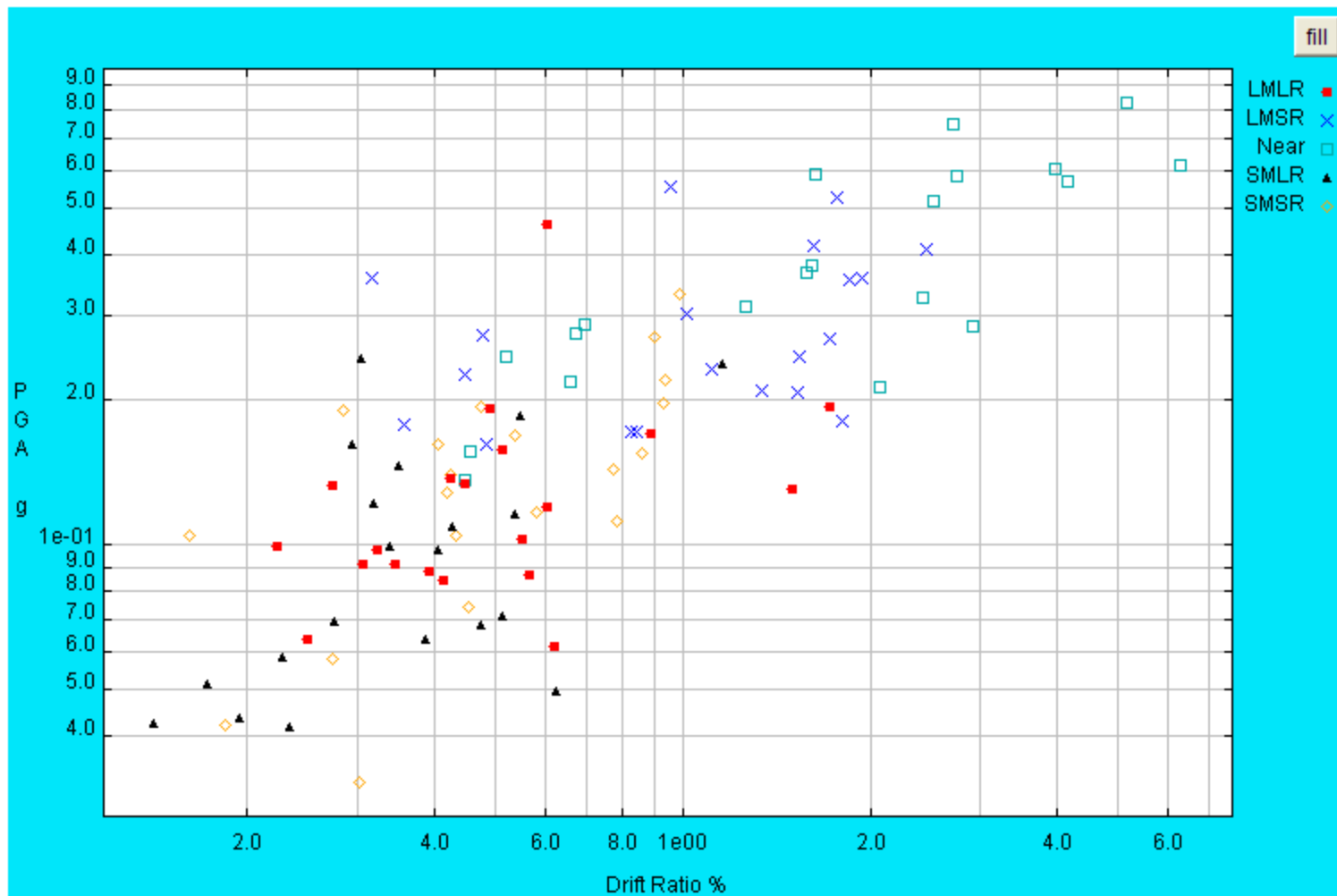


Horizontal 2 Acceleration (g) (Motion File:
A2E000.AT2.data)

Horizontal 2 Pseudo-Spectral Acceleration (g) (File:

Maximum & residual of Drift ratio in Longitudinal direction with respect to PGA

Maximum Drift Ratio (%) (File: [bentMaxDriftRatio.txt](#))



Unit Costs

OpenSeesPL - PBEE.opl

File Meshing Execute Display View Help

Model Input

Analysis Type

Single Analysis:

☐ Pushover

☐ Eigenvalue

☐ Base Shaking

PBEE Analysis:

☐ Ground Shaking

☒ Repair

Model Definition

Bridge Parameters...

Mesh Parameters...

Boundary Conditions

B.C. Type

Bedrock Type

Model Inclination along Long

Ground Surface Inclination Ang

Whole Model Inclination Angle

PBEE: Unit Costs

Item#	Item Name	Unit	UC mean	UC std dev
1	Structure excavation	CY	\$ 165	\$ 33
2	Structure backfill	CY	\$ 220	\$ 44
3	Temporary support (superstructure)	SF	\$ 38	\$ 7.6
4	Temporary support (abutment)	SF	\$ 38	\$ 7.6
5	Structural concrete (bridge)	CY	\$ 2225	\$ 445
6	Structural concrete (footing)	CY	\$ 520	\$ 104
7	Structural concrete (approach slab)	CY	\$ 1625	\$ 325
8	Aggregate base (approach slab)	CY	\$ 325	\$ 65
9	Bar reinforcing steel (bridge)	LB	\$ 1.35	\$ 0.27
10	Bar reinforcing steel (footing, retaining w...	LB	\$ 1.2	\$ 0.24
11	Epoxy inject cracks	LF	\$ 215	\$ 43
12	Repair minor spalls	SF	\$ 300	\$ 60
13	Column steel casing	LB	\$ 10	\$ 2
14	Joint seal assembly	LF	\$ 275	\$ 55
15	Elastomeric bearings	EA	\$ 1500	\$ 300
16	Drill and bond dowel	LF	\$ 55	\$ 11
17	Furnish steel pipe pile	LF	\$ 55	\$ 11
18	Drive steel pipe pile	EA	\$ 2050	\$ 410
19	Drive abutment pipe pile	EA	\$ 9000	\$ 1800
20	Asphalt concrete	TON	\$ 265	\$ 53
21	Mud jacking	CY	\$ 380	\$ 76
22	Bridge removal (column)	CY	\$ 3405	\$ 681
23	Bridge removal (portion)	CY	\$ 2355	\$ 471
24	Approach slab removal	CY	\$ 1000	\$ 200
25	Clean deck for methacrylate	SF	\$ 0.4	\$ 0.08
26	Furnish methacrylate	GAL	\$ 85	\$ 17
27	Treat bridge deck	SF	\$ 0.55	\$ 0.11
28	Barrier rail	LF	\$ 2	\$ 0.4
29	Re-center column	EA	\$ 100	\$ 20

OK

Cancel

PBEE Analysis

Damage States

Repair

Unit Costs

Production Rates

Intensity Measure (SRSS)

PGV

PGA

PGV

PGD

D(5-95)

CAV

Arias Intensity

SA (Period = 1 sec)

SV (Period = 1 sec)

SD (Period = 1 sec)

PSA (Period = 1 sec)

PSV (Period = 1 sec)

Free-field PA

Free-field PV

Free-field PD

Free-field D(5-95)

Free-field CAV

Free-field Arias Intensity

Free-field SA (Period = 1 sec)

Free-field SV (Period = 1 sec)

Free-field SD (Period = 1 sec)

Free-field PSA (Period = 1 sec)

Free-field PSV (Period = 1 sec)

Display Results as a Function of Intensity Measure (SRSS)

Intensity Measure (SRSS)

Hazard Level for 2% of Probability

Hazard Level for 5% of Probability

Hazard Level for 10% of Probability

Interval (in Year)

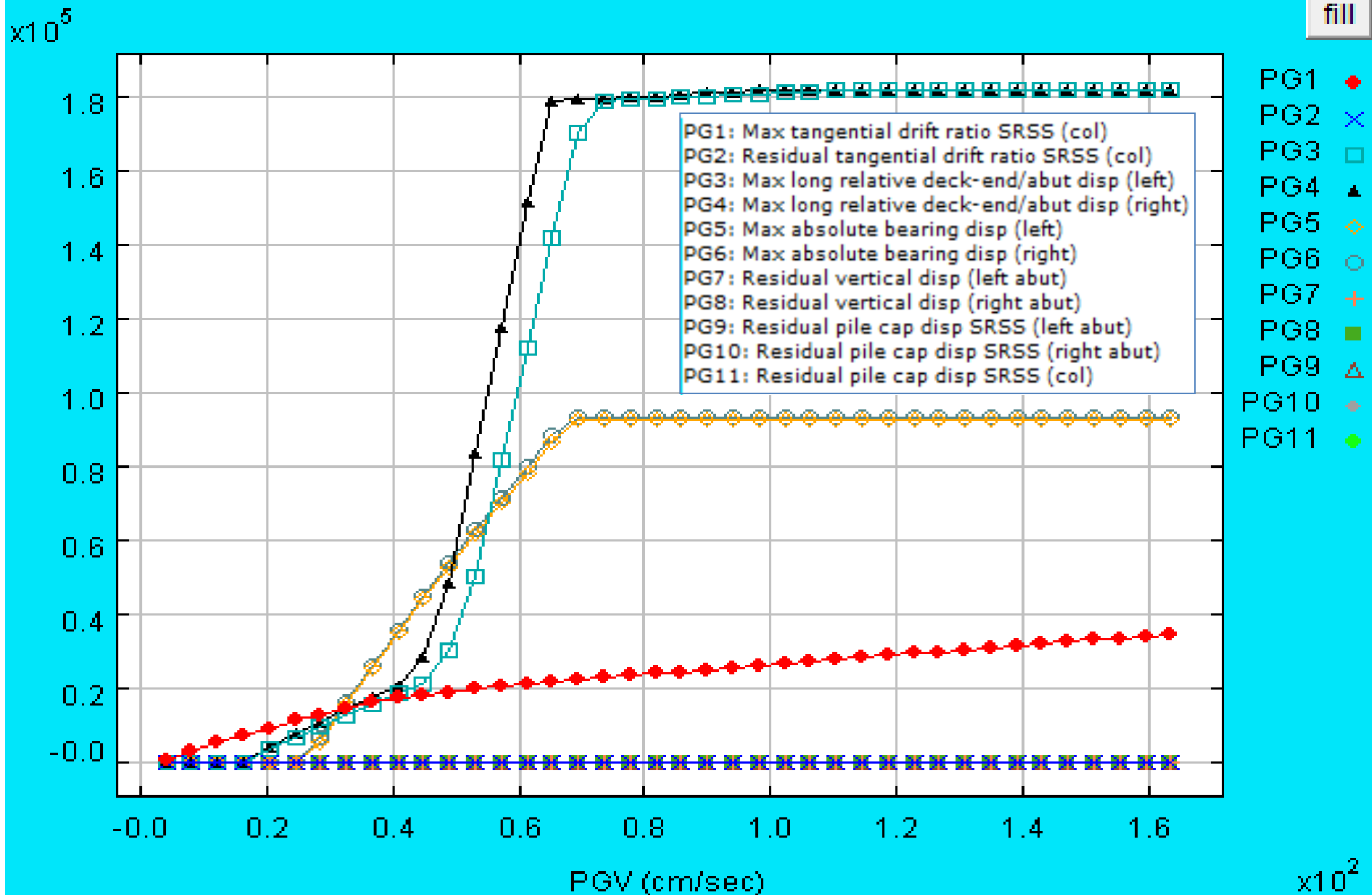
[cm/sec]

[cm/sec]

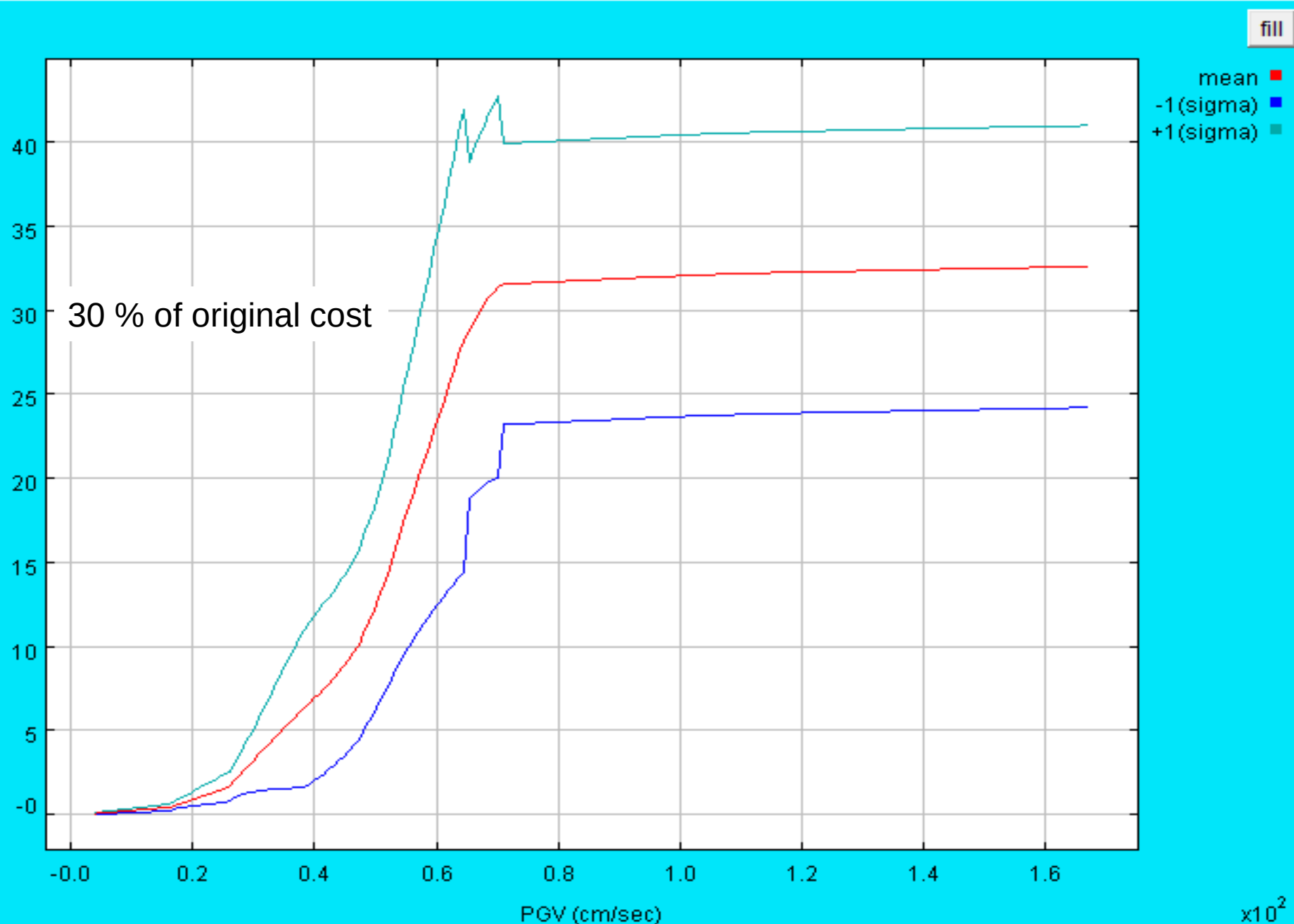
[cm/sec]

[Year]

Contribution to expected repair cost (\$) from each performance group (File: [PGsens_E.txt](#))

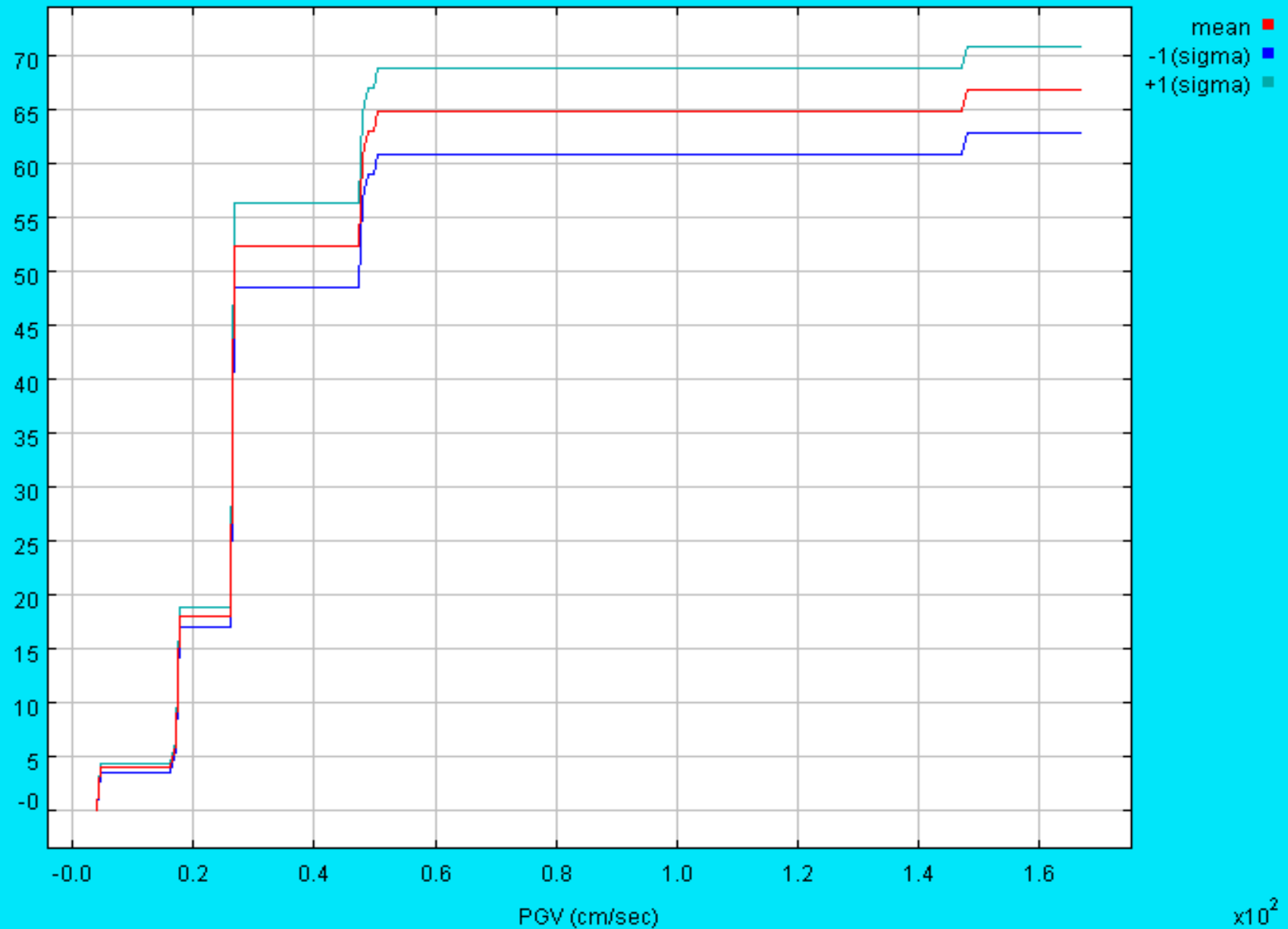


Total repair cost ratio (%) (File: [RCR_Model.txt](#))



Total repair time (CWD) (File: [RT_Model.txt](#))

Crew Working Days (CWD)



Definition of Hazard Level at Specific Bridge Location

PBEE Quantities

Define PBEE Quantities

Damage States

Repair

Unit Costs

Production Rates

Choose IM & Define Hazard Levels

Intensity Measure (Longitudinal Component)

PGV

Hazard Level for 2% of Probability of Exceedance

160

[cm/sec]

Hazard Level for 5% of Probability of Exceedance

80

[cm/sec]

Hazard Level for 10% of Probability of Exceedance

10

[cm/sec]

Interval (in Years)

50

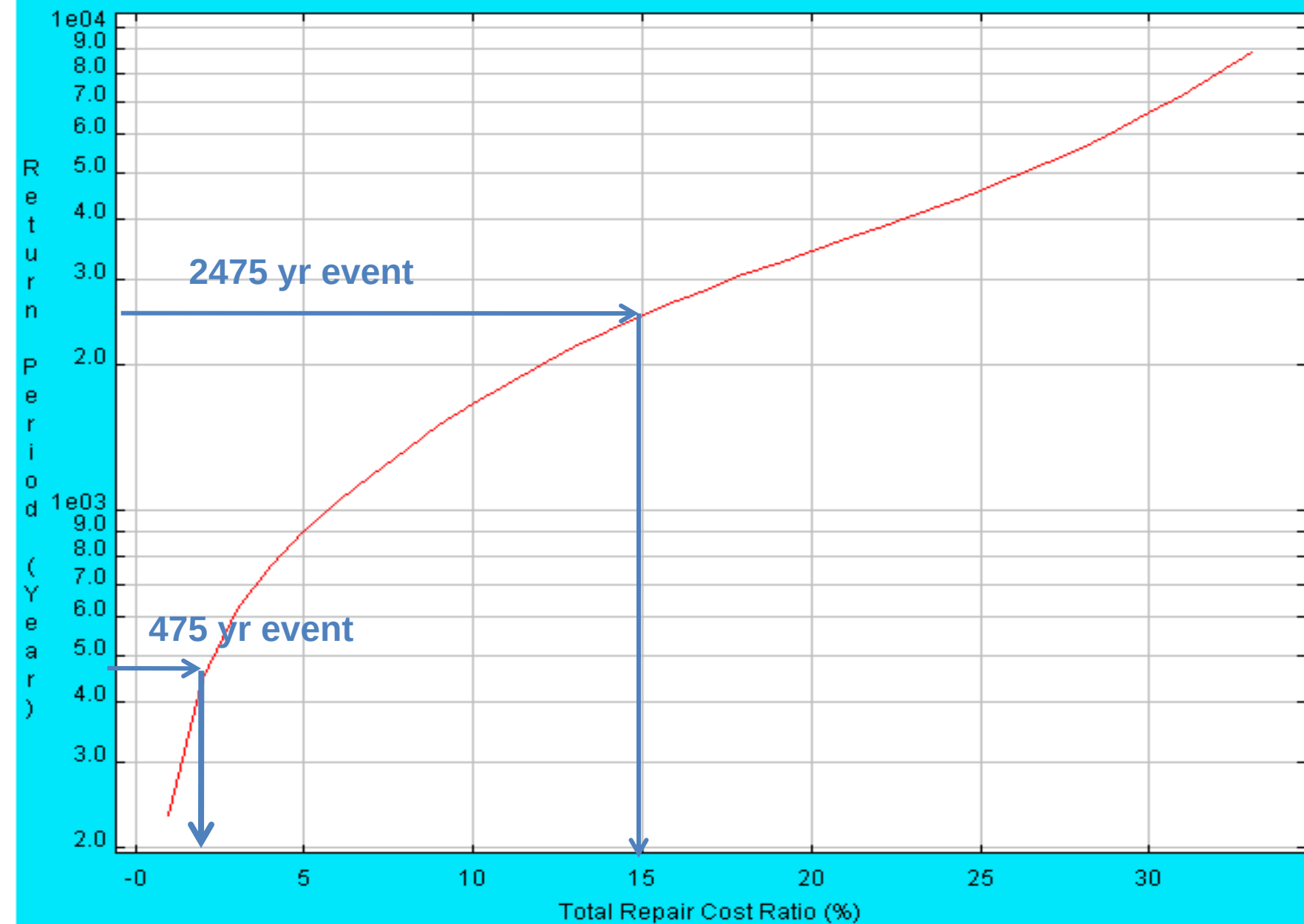
[Yr]

Compute Repairs

Return Period (File: [ReturnPd.txt](#))

fill

Set 0 ■



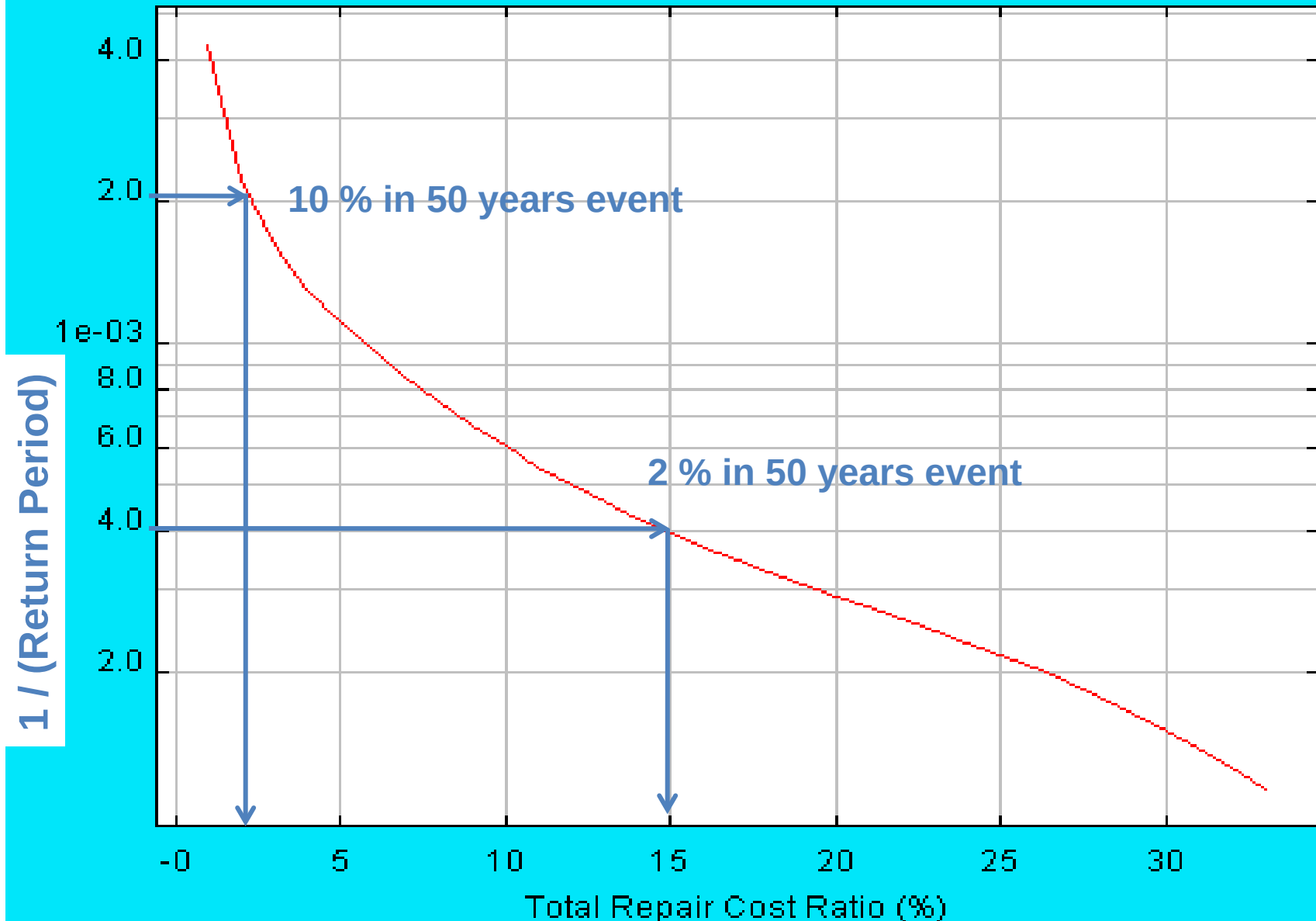
Mean Annual Frequency of Exceedance (Loss) (File: [HazardDV.txt](#))

(Mean Annual Total Repair Cost Ratio = 0.018613%)

(Mean expenditure per year on repairs is 0.0002 of cost of structure)

fill

Set 0



Bridge Model

Column

☒ Circular ☐ Rectangular ☐ Oblong

Diameter [m]

Total Column Length [m]

Column Length above Grade [m]

Column Properties

☐ Linear Column

☐ Use Different Properties for Column below Grade

Column below Grade

Diameter [m]

Youngs Modulus [kPa]

Deck

Deck Length [m]

Deck Width [m]

Deck Depth [m]

Deck Properties

OK

Embankment

Embankment Length [m]

Depth of Embankment Foundation [m]

Total Weight of Embankment [kN]

☐ Activate Abutment Pile

Abutment Pile

Pile Length [m]

Diameter [m]

☒ Properties Same as Column

Define...

Abutment

Abutment Model

Define...

Number of Bearing

Bearing Height

Number of Shear K

Elastic
Roller
Simplified (SDC 2004)
Spring (SDC 2004)
SDC 2010 Sand
SDC 2010 Clay
EPP-Gap
HFD Model

Cancel

- What links here
- Related changes
- Special pages
- Printable version
- Permanent link

The elastic abutment model consists of a simple 6 elastic springs in each dof: longitudinal, transversal, vertical displacements and across longitudinal, transversal and vertical rotations. By default the rotations are set with zero value.

Roller Model

The roller abutment model consists of a simple boundary condition module that applies single-point constraints against displacement in the vertical direction (vertical support), as seen in Fig. 1. This model can be used to provide a lower-bound estimate of the longitudinal and transverse resistance of the bridge, captured through a pushover analysis. For more details, see [1]

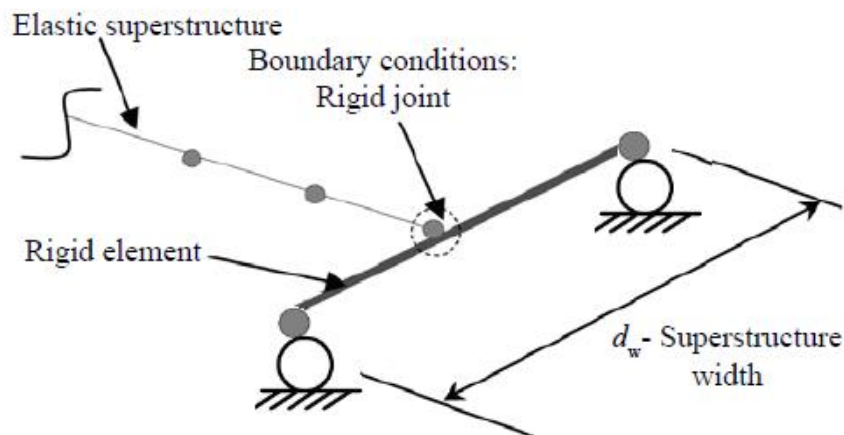


Fig. 1 General scheme of the Roller abutment model

Simplified Model

The simplified abutment model consists of a simplification of the spring abutment model. The general scheme of the simplified model is presented in Fig. 2. It consists of a rigid element of length d_w (superstructure width), connected through a rigid joint to the superstructure centerline, with defined longitudinal, transverse and vertical nonlinear response at each end. In the longitudinal direction, a series system is defined (see Fig. 3), consisting of a rigid element with shear and moment releases, a gap element with boundary conditions at each end allowing only longitudinal translation, and a zero-length element. The latter element is assigned an elastic-perfectly-plastic (EPP) backbone curve with abutment stiffness (K_{abt}) and ultimate strength (P_{bw}) obtained from section 7.8.1 of the Caltrans SDC (2004), see fig. 4. The longitudinal response defined for the simplified model accounts only for the gap and the embankment fill response, where passive pressures are

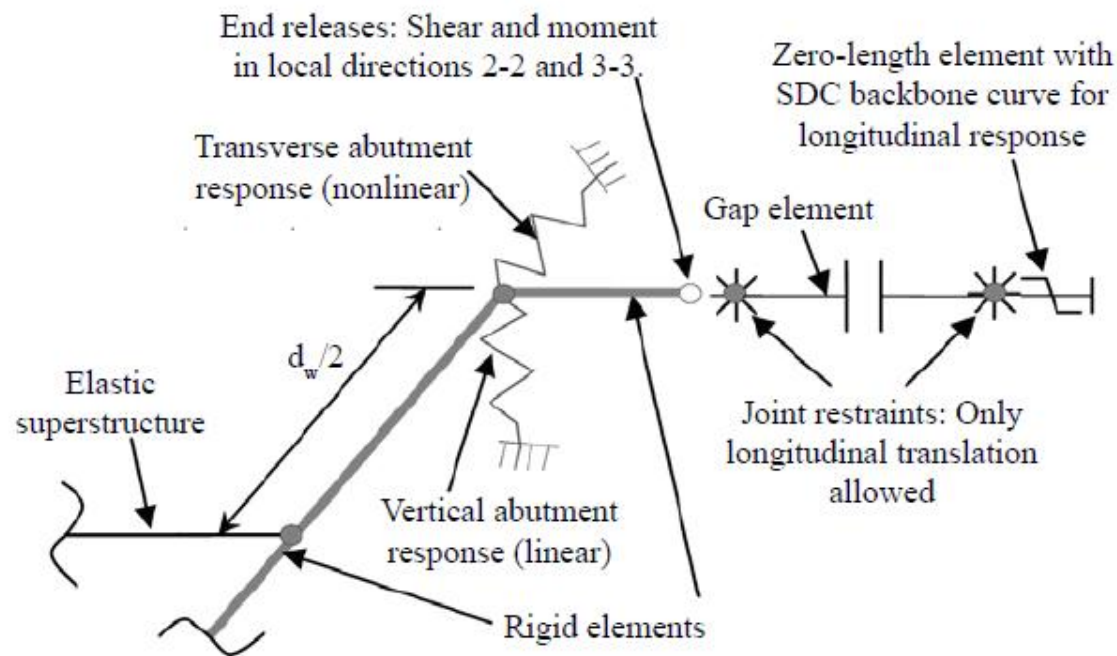
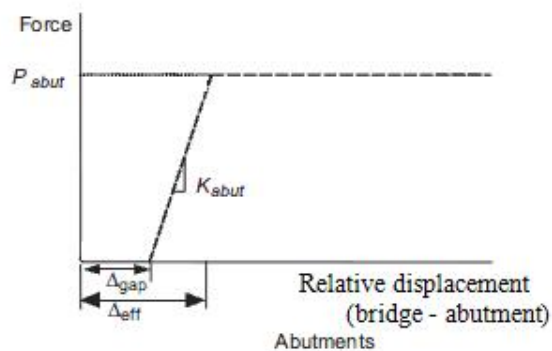


Fig. 3 Series system of the longitudinal simplified abutment response



presented in Fig. 2. It consists of a rigid element of length d_w (superstructure width), connected through a rigid joint to the superstructure centerline, with defined longitudinal, transverse and vertical nonlinear response at each end. In the longitudinal direction, a series system is defined (see Fig. 3), consisting of a rigid element with shear and moment releases, a gap element with boundary conditions at each end allowing only longitudinal translation, and a zero-length element. The latter element is assigned an elastic-perfectly-plastic (EPP) backbone curve with abutment stiffness (K_{abt}) and ultimate strength (P_{bw}) obtained from section 7.8.1 of the Caltrans SDC (2004), see fig. 4. The longitudinal response defined for the simplified model accounts only for the gap and the embankment fill response, where passive pressures are produced by the abutment back wall. The shear resistance of the bearing pads is ignored. In the transverse direction, a zero-length element is defined at each end of the rigid link with an assigned EPP backbone curve representing the backfill, wing wall and pile system response. The resistance of the brittle shear keys and distributed bearing pads is ignored in this model for simplicity. In the vertical direction, an elastic spring is defined at each end of the rigid link, with a stiffness corresponding to the bearing pads stiffness k_v . The stiffness of the pads in compression and tension is assumed to be identical. Each bearing is assumed to have a cross-sectional area as specified on the plans. The distribution of the bearing pads along the stem wall and the vertical embankment stiffness are not accounted for in the model, assuming rigid soil conditions. For more details, see [*]

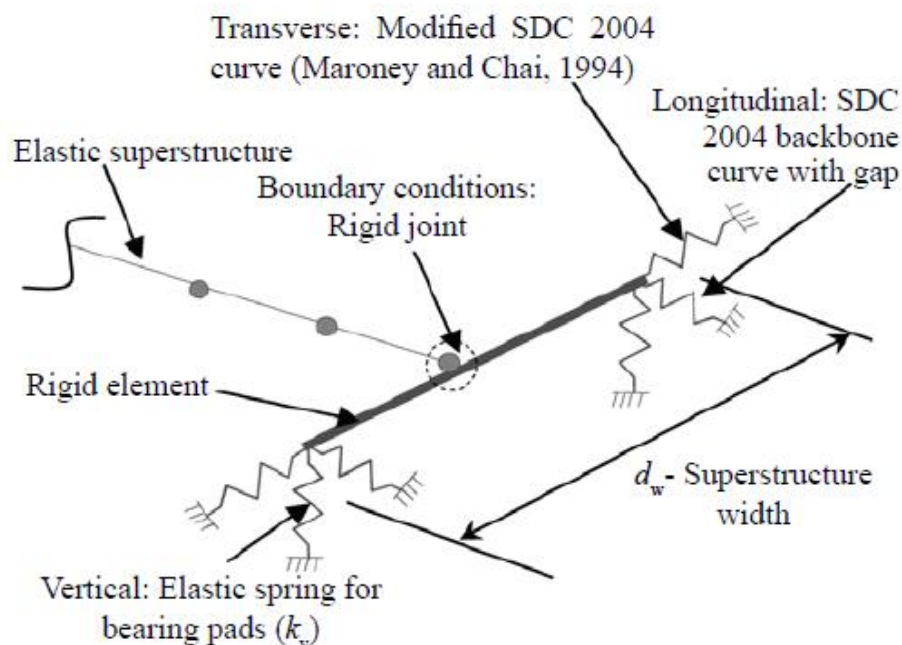
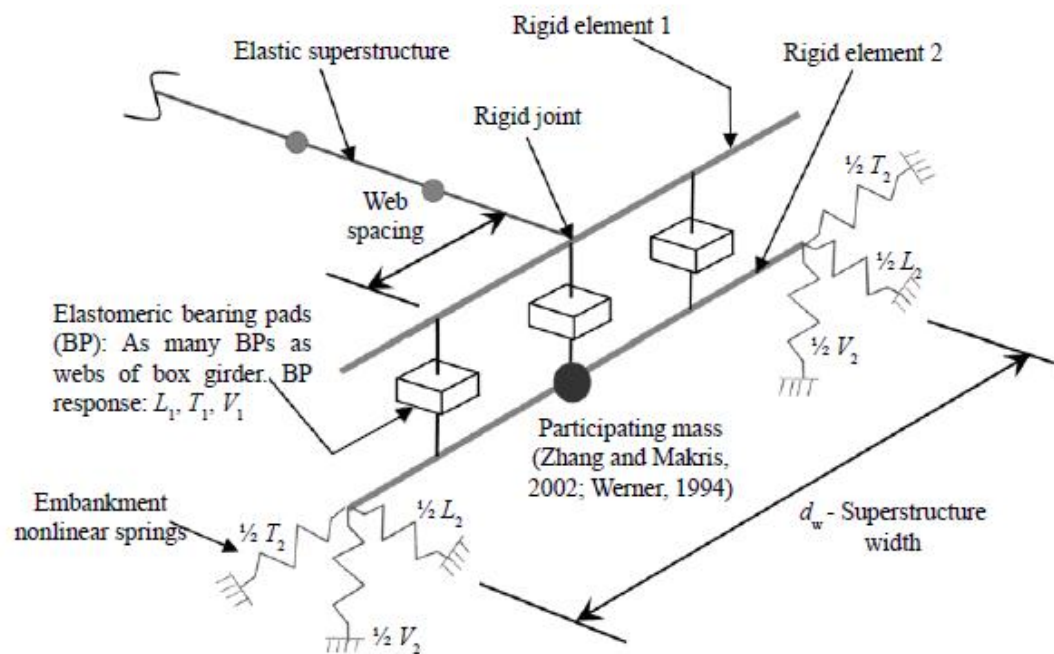


Fig. 2 General scheme of the Simplified abutment model

superstructure dead load at the abutment, including a contribution from structural concrete as well as the participating soil mass. An average of the embankment lengths obtained from Zhang and Makris (2002) and Werner (1994) is included in the calculation of the participating mass due to the embankment of the abutment. For more details, see [4]

Specifically, the user can modify the vertical tensile force factor for the bearing pads.



Bearing pads response:

- Longitudinal L_1 : BP shear resistance and backwall gap contact element in parallel.
- Transverse T_1 : BP shear resistance and brittle shear keys (extreme BPs only) in parallel.
- Vertical V_1 : BP vertical stiffness and contact element for stem wall in parallel.

Embankment response:

- Longitudinal L_2 : SDC (2004) backbone curve.
- Transverse T_2 : Modified SDC (2004) backbone curve.
- Vertical V_2 : Embankment vertical stiffness.

Fig. 5 General scheme of the Spring abutment model

Shamsabadi's HFD Model

Longitudinal Gap [m]
 Skew Angle [degree]

Wall Height/Deck Depth [m]

Soil Type

- ☒ Sand
☐ Clay
☐ User-Defined

View Parameters
for HFD Model

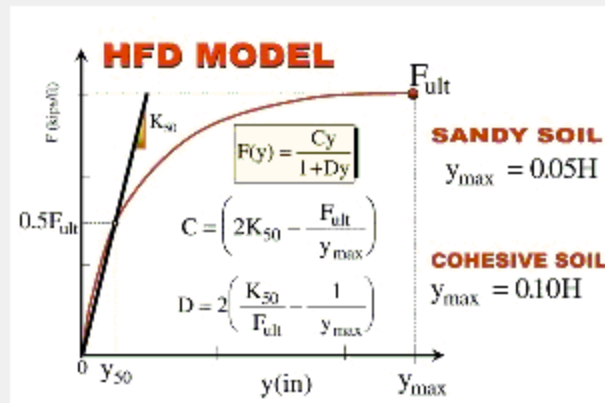
Max Displacement (ymax) [m]
 K50 [kN/m/m]
 Ultimate Pressure (Fult) [kPa]

Re-Calculated Constants C & D

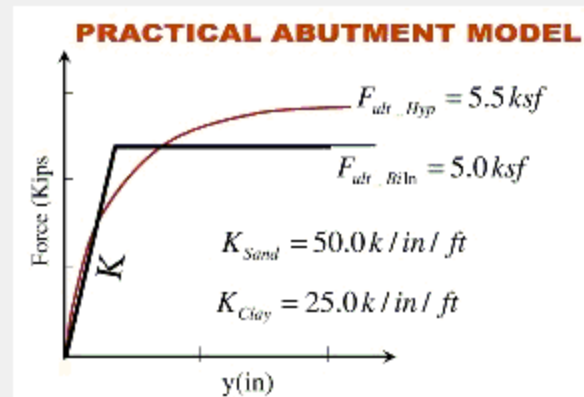
Calculated Curve Constants

Constant C
 Constant D

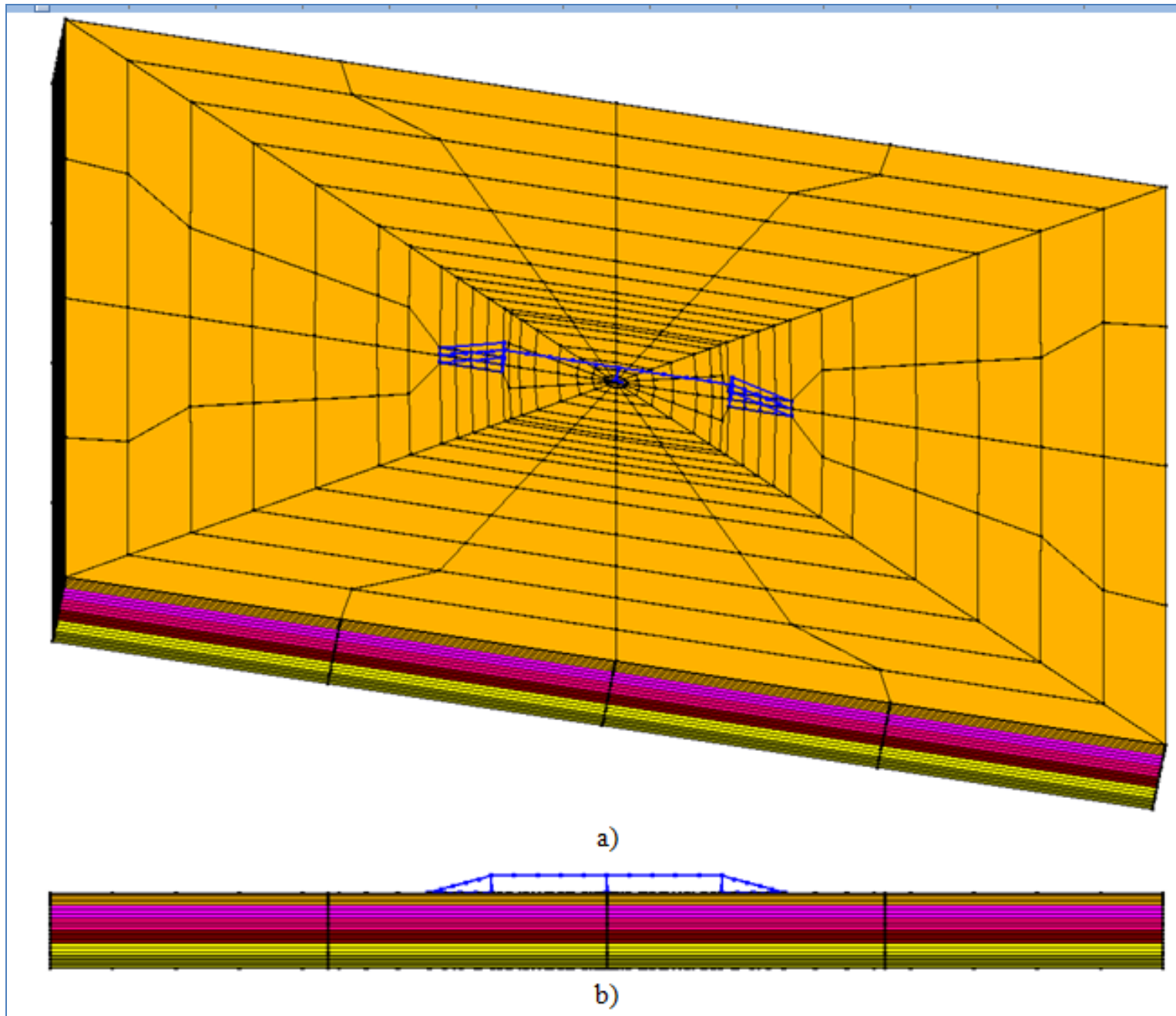
OK



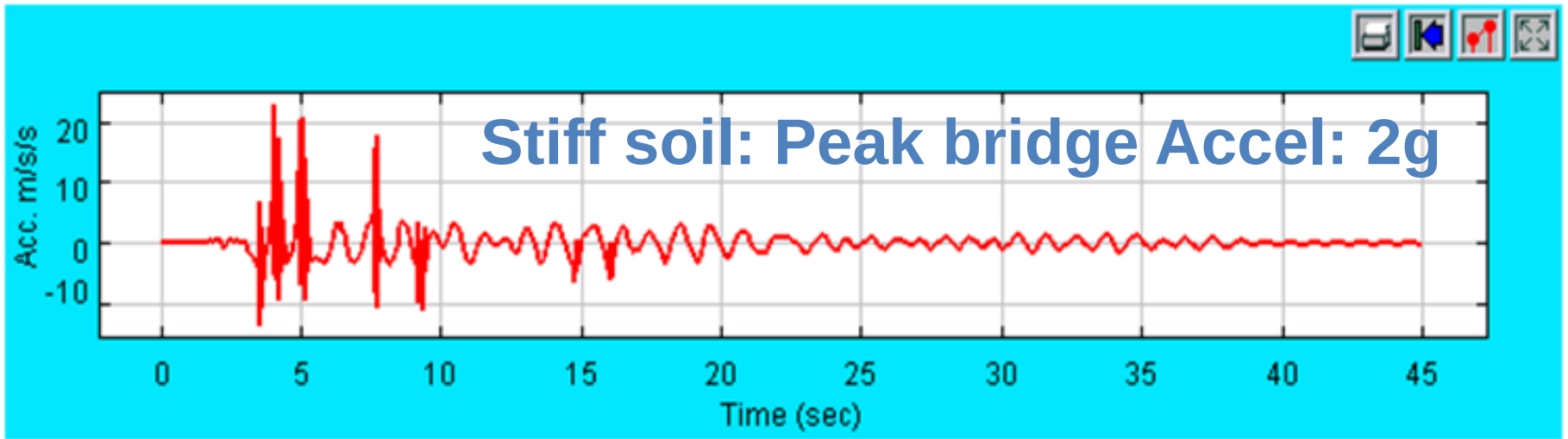
(Shamsabadi et al. 2007)



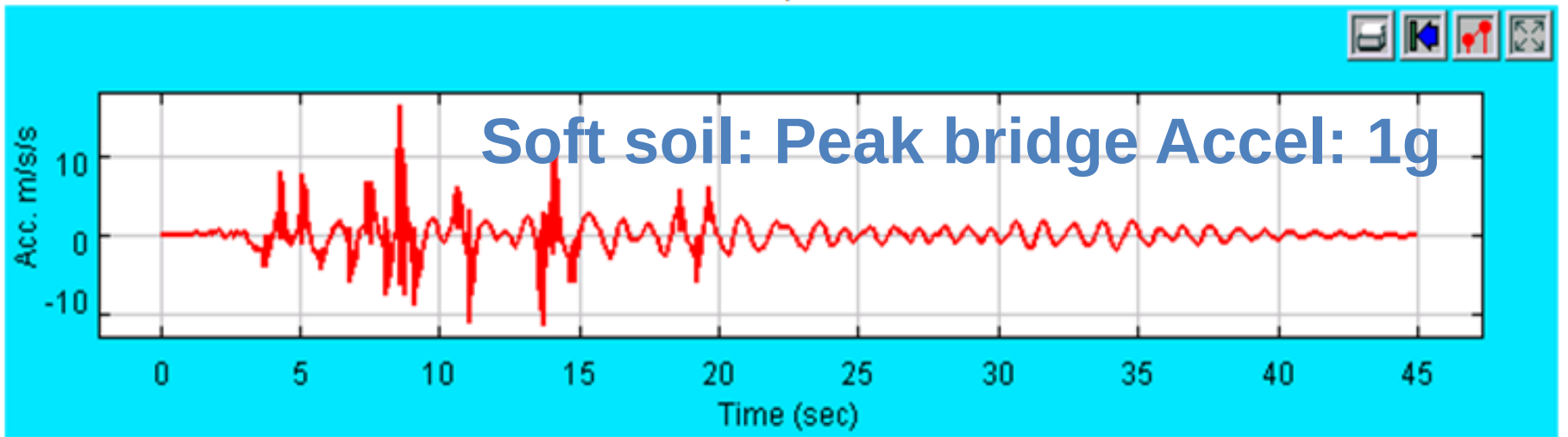
Cancel



Case 1: Stiff soil and Case 2: Soft soil

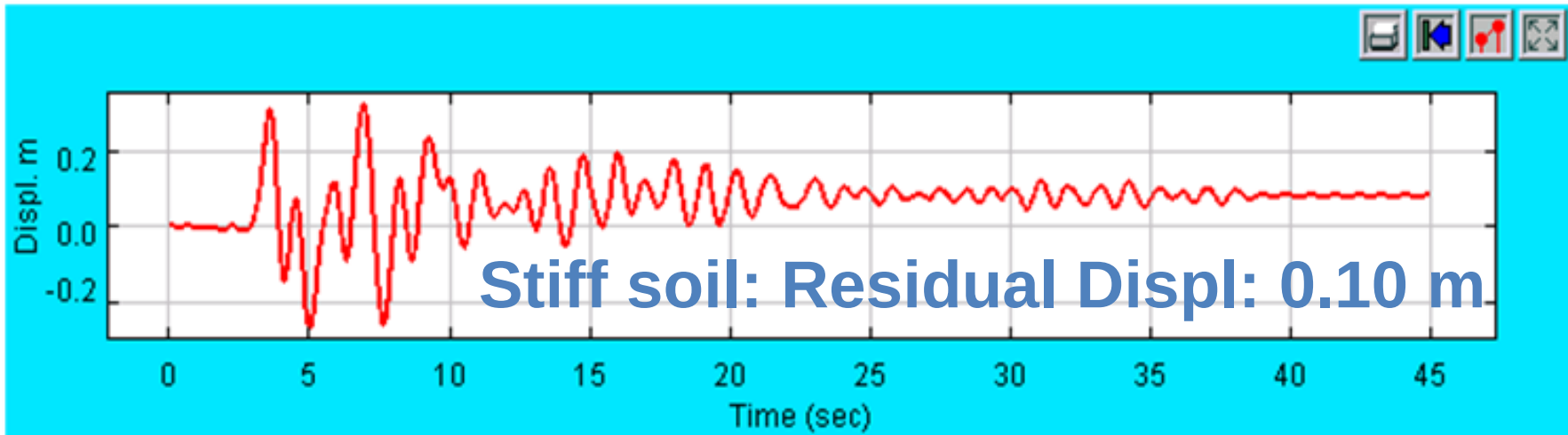


a)

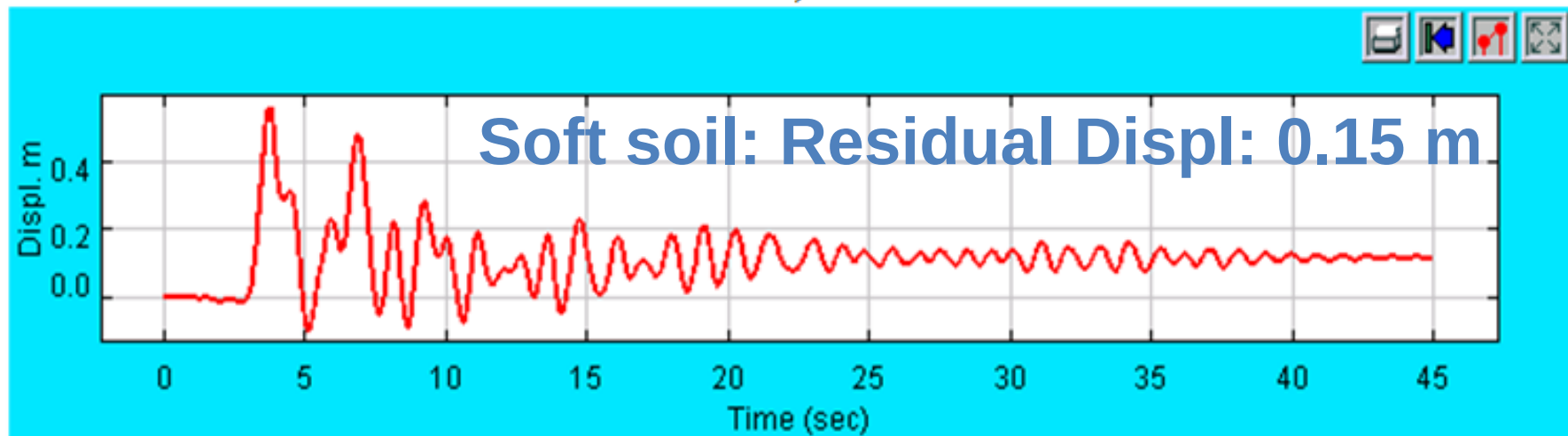


b)

Fig. 11. Column top longitudinal acceleration time histories: a) Case 1; b) Case 2



a)



b)

Fig. 7. Column top longitudinal displacement time histories: a) Case 1; b) Case 2

Fine mesh: Comparison of total repair cost ratio (%) for Cases 1 & 2

