

P.

2

P-Cares model

In an effort to have a better understanding of the Soil Structure Interaction of the AP1000 nuclear island, the staff developed a stick model in P-Cares for the shield building, one for the steel container, and one for the internal structures. This document will serve as a record for the work done with the AP1000 stick model.

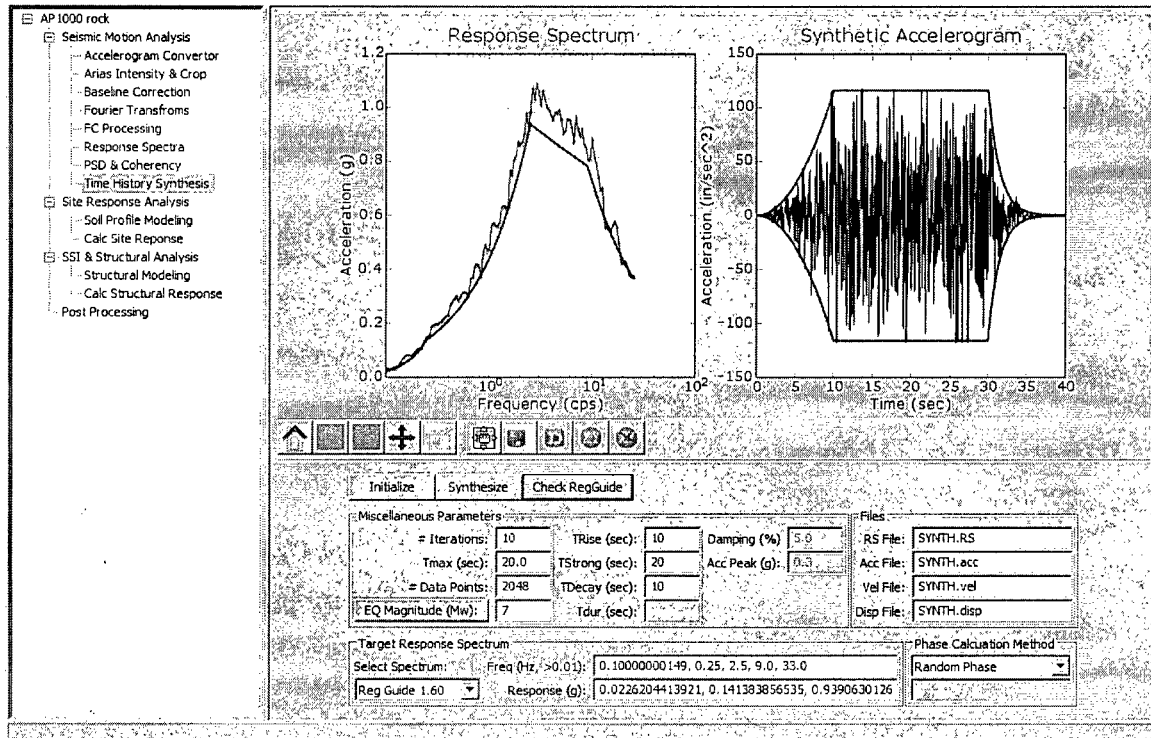
EPRI's "*Program on Technology Innovation: Validation of CLASSI and SASSI Codes to Treat Seismic Wave Incoherence in Soil-Structure Interaction (SSI) Analysis of Nuclear Power Plant Structures*" was used as a reference to compare input data and results. Also, NUREG/CR-6922 "*P-Cares: Probabilistic Computer Analysis for Rapid Evaluation of Structures*" was referred as guidance.

It is the final goal to use the output data in SASSI for the soil structure interaction analysis?????

11/1

Input data for the AP1000 stick Model

Seismic Motion Analysis (Input data) as shown below:



- 1- Enter TRise (sec): 10
- 2- Enter TStrong (sec): 20
- 3- Enter Tdecay (sec): 10

- 4- Select Spectrum: Reg Guide 1.60
- 5- For Reg Guide 1.60, use: Peak Ground Acceleration (g): 0.3
Damping (%): 5.0

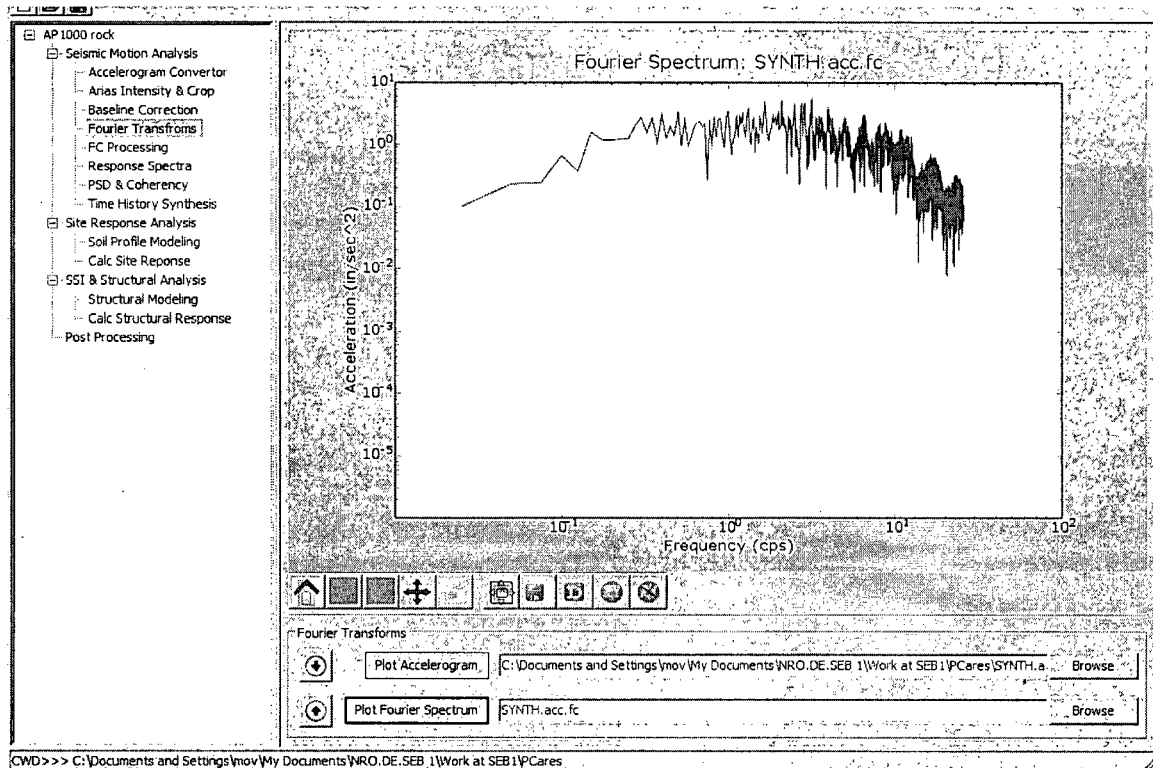
- 6- Click Initialize, Synthesize, and RegGuide

Then go to Fourier Transforms

Seismic Motion Analysis

- Fourier Transforms

- 1- Browse for the SYNTH.acc file
- 2- Click "Plot Accelerogram"
- 3- Click the yellow arrow pointing down
- 4- Click "Plot Fourier Spectrum", like the figure below:



Site Response Analysis

-Soil Profile Modeling as shown below:

AP1000 rock

- Seismic Motion Analysis
 - Accelerogram Convertor
 - Arias Intensity & Crop
 - Baseline Correction
 - Fourier Transforms
 - FC Processing
 - Response Spectra
 - PSD & Coherency
 - Time History Synthesis
- Site Response Analysis
 - Soil Profile Modeling**
 - Calc Site Response
- SSI & Structural Analysis
- Post Processing

General Info | Soil Layer Info | Correlation | Foundation

Project Name: AP1000 rock Tide: test

Soil Profile

Number of Soil Layers: 12 Soil Degradation Model: SEED-IDRISS 1970

Strain Calc Method: Frequency Ground Water Table: 99999.9

Rock Properties

Weight Density (pcf): 130.0 Shear Velocity (ft/s²): 10000.0 Damping Ratio (%): 5.0

Input Motion

☒ Seismic Input Fourier Component File: synth.acc.fc Location (Layer #): 0

☐ Sinusoidal Input Number of Frequencies: 0 Max Frequency (Hz): 0

Calculation Parameters

Cutoff Frequency (Hz): 50.0 Max Error (%): 5.0

Output Parameters

☐ Rock Outcrop Motion Soil Output Depths (ft, e.g., d1, d2, ...): 0.0, 40.0, 120.0

Final Profile File (for Deterministic Analysis): FINALSOIL.PRFL

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Propagate >>> ☒ Copy previous if new <<< Prev Next >>> 1 of 12

	RV ID	Pt Value	Distribution	Mean	Std (COV)
Layer Thickness (ft):	H1	10.0	Lognormal	0.0	0.0
Weight Density (pcf):	PCF1	130.0	Lognormal	0.0	0.0
Shear Velocity (ft/s ²):	VS1	8000.0	Lognormal	0.0	0.0
Poisson's Ratio:	MU1	0.25	<-- for SSI only		

Soil Degradation Model Parameters

Model: SEED-IDRISS 1970

Soil Type: Sand Constant Model - Damping (%):

Degradation Curve Definition (MUST be a comma-separated list of 11 Points)

Strain Values:

Modulus Deg Ratio:

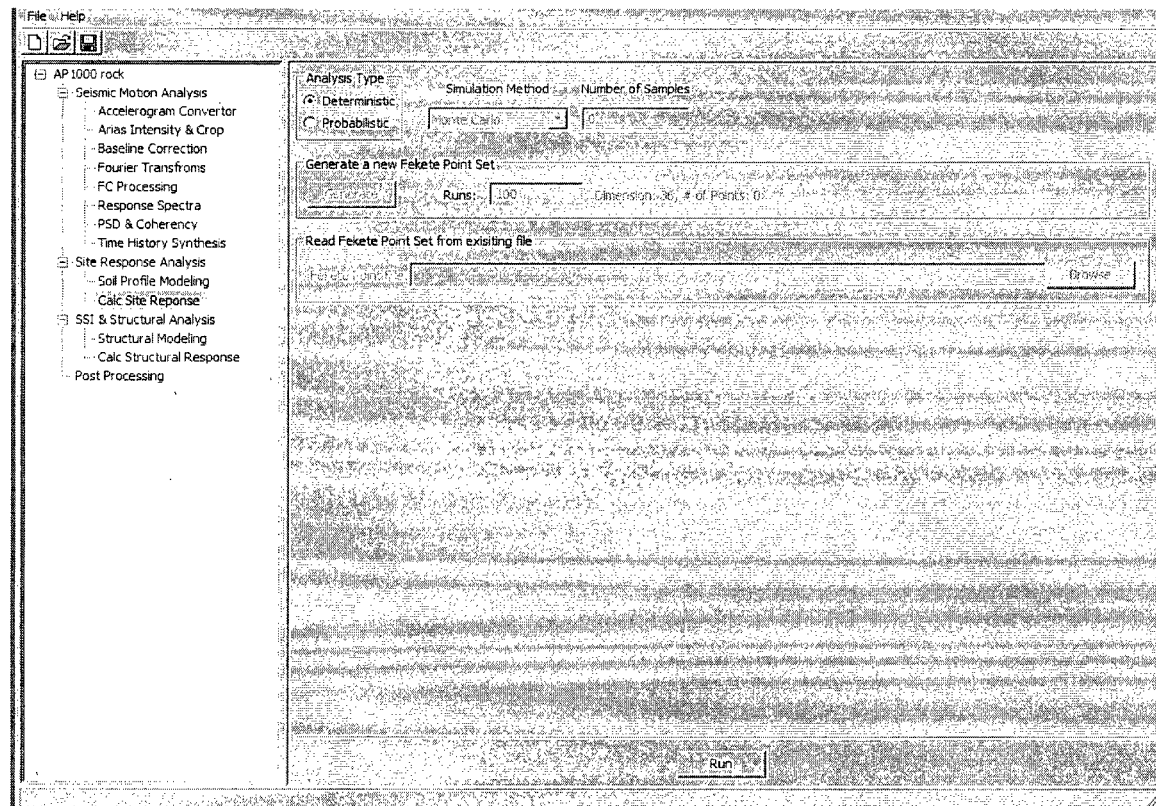
Damping Deg (%):

- AP 1000 rock
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General Info	Soil Layer Info	Correlation	Foundation
Characteristic Layer Thickness (ft):		0.000	Correlation: 0.1
		Initialize Correlation	
	RVID 1	RVID 2	Correlation Coefficient
1	G1	G2	0.1000
2	G1	G3	0.0135
3	G1	G4	0.0018
4	G1	G5	0.0002
5	G10	G11	0.1000
6	G10	G12	0.0135
7	G11	G12	0.1000
8	G2	G3	0.1000
9	G2	G4	0.0135
10	G2	G5	0.0018
11	G2	G6	0.0002
12	G3	G4	0.1000
13	G3	G5	0.0135
14	G3	G6	0.0018
15	G3	G7	0.0002
16	G4	G5	0.1000
17	G4	G6	0.0135
18	G4	G7	0.0018
19	G4	G8	0.0002
20	G5	G6	0.1000
21	G5	G7	0.0135
22	G5	G8	0.0018
23	G5	G9	0.0002
24	G6	G10	0.0002

General Info	Soil Layer Info	Correlation	Foundation
☒ Include kinematic interaction			
Foundation Depths			
Embedment (ft):		35.5	No Kinematic Interaction for Surface Foundation
Extended Depth (ft):		50.0	for Base Soil Calculation
Foundation Plan Dimension			
☐ Circular Foundation		☒ Rectangular Foundation	
Radius (ft):		X Length (ft):	254.0
		along motion direction	
		Y Length (ft):	158.0
Misc Information			
Side and Base Soil Damping (%):		5.0	

Site Response Analysis Calc Site Response



Click RUN.

Once Calc Site Response was completed, the staff went back to the “Seismic Motion Analysis/Fourier Transforms” and followed the steps below:

1. Click browse next to “Plot Accelerogram” and select the SYNTH.acc file for the node of interest.
2. Click “Plot Accelerogram”.
3. Click the yellow arrow next to “Plot Accelerogram”.
4. Click “Plot Fourier Spectrum”.

SSI & Structural Analysis

With the SSI & Structural Analysis, the staff compared the stick model with the six key locations identified in Table 3.G.4-1 of the AP1000 DCD. The nodes referred to the six key locations are indicated below:

Key Node Locations			
Location	General Area	Elevation (ft)	Referred Node
CIS at reactor vessel support	SCV Center	100.00	28
CIS at Operating Desk	SG West Compartment NE	134.25	31
ASB NE Corner at Control Room Floor	NE Corner	116.50	6
ASB Corner of Fuel Building Roof at Shield Building	NW Corner of Fuel Bldg	179.19	11
ASB Shield Building Roof Area	South Side of Shield Building	327.41	17
SCV Near Polar Crane	SCV Stick Model	224.00	23

SSI and Structural Analysis were conducted as shown in the following figures

Inertias and lumped masses were cited from the EPRI Report, but verified by staff by independent calculations. Based on the geometry and material density, masses were calculated to compute the mass moment of inertia I_x using the following formula (for the steel container):

$$I_x = M/2 \times r^2, \text{ where } M = \text{lumped mass, } r = \text{radius}$$

For the steel container, the staff computed the area moment of inertia (I_{xx}) using the following formula:

$$I_{xx} = \pi/4 \times (r_{out}^4 - r_{in}^4),$$

where r_{out} and r_{in} are the outer and inner radius, respectively

Shear area is the area under shear, so depending on the geometry of the given location the cross sectional area is calculated and used for analysis.

Material properties were taken from technical references. Dimensions and layout information was taken from the AP1000 DCD.

Data for Nodes

Node ID	X (ft)	y (ft)	z(ft)	Wt (kips)	Dx	Dy	Dz	Dxx	Dyy	Dzz	Ixx	Iyy	Izz
1	0.000	0.000	66.500	7612.000		*		*		*	1641500.000	1641500.000	0.000
2	0.000	0.000	81.500	15916.000		*		*		*	3612000.000	3612000.000	0.000
3	0.000	0.000	91.500	14145.000		*		*		*	1938300.000	1938300.000	0.000
4	0.000	0.000	99.000	10642.000		*		*		*	2619900.000	2619900.000	0.000
5	0.000	0.000	106.000	6765.000		*		*		*	1287500.000	1287500.000	0.000
6	0.000	0.000	116.500	14989.000		*		*		*	2526200.000	2526200.000	0.000
7	0.000	0.000	134.500	14226.000		*		*		*	3448492.000	3448492.000	0.000
8	0.000	0.000	145.400	5325.000		*		*		*	933560.000	933560.000	0.000
9	0.000	0.000	153.000	6118.000		*		*		*	1022510.000	1022510.000	0.000
10	0.000	0.000	164.000	5293.000		*		*		*	422680.000	422680.000	0.000
11	0.000	0.000	179.000	6452.000		*		*		*	323582.000	323582.000	0.000
12	0.000	0.000	200.000	4057.000		*		*		*	317710.000	317710.000	0.000
13	0.000	0.000	220.000	4250.000		*		*		*	333900.000	333900.000	0.000
14	0.000	0.000	242.500	4517.000		*		*		*	353540.000	353540.000	0.000
15	0.000	0.000	265.000	7438.000		*		*		*	529020.000	529020.000	0.000
16	0.000	0.000	295.000	13959.000	*	*	*	*	*	*	276470.000	276470.000	0.000
17	0.000	0.000	333.000	2940.000		*		*		*	63050.000	63050.000	0.000
18	100.000	0.000	66.500	0.000		*		*		*	0.000	0.000	0.000
19	30.000	0.000	100.000	461.250		*		*		*	110991.000	110991.000	0.000
20	30.000	0.000	130.000	936.932		*		*		*	125396.000	125396.900	0.000
21	30.000	0.000	160.000	874.544		*		*		*	125396.000	125396.900	0.000
22	30.000	0.000	190.000	874.544		*		*		*	125396.000	125396.900	0.000
23	30.000	0.000	220.000	730.924		*		*		*	116467.000	116467.500	0.000
24	30.000	0.000	244.200	541.425		*		*		*	116467.000	116467.500	0.000
25	30.000	0.000	256.000	620.622		*		*		*	96326.970	96326.970	0.000
26	30.000	0.000	268.000	419.702		*		*		*	54264.940	54264.940	0.000
27	30.000	0.000	280.830	30.976		*		*		*	205.000	205.069	0.000
28	50.000	0.000	100.000	19107.000		*		*		*	568000.000	568000.000	0.000
29	50.000	0.000	116.000	29869.000		*		*		*	1422000.000	1422000.000	0.000
30	50.000	0.000	131.500	15092.000		*		*		*	270800.000	270800.000	0.000
31	50.000	0.000	136.500	9216.000		*		*		*	185000.000	185000.000	0.000
32	50.000	0.000	140.500	7686.000		*		*		*	358900.000	358900.000	0.000
33	50.000	0.000	167.500	7683.000		*		*		*	282150.000	282150.000	0.000
34	50.000	0.000	186.500	470.000		*		*		*	6065.000	6065.000	0.000
35	50.000	0.000	202.500	303.000		*		*		*	748.000	748.000	0.000

Data for Beams

Beams	Area (ft^2)	Shear area Y	Shear area Z	I _y	I _z	J
1	15484.000	10322.000	10322.000	9717600.000	9717600.000	19435200.000
2	3462.000	1366.000	1366.000	6266240.000	6266240.000	12532480.000
3	3462.000	1366.000	1366.000	6266240.000	6266240.000	12532480.000
4	3462.000	1366.000	1366.000	6266240.000	6266240.000	12532480.000
5	3293.000	1214.000	1214.000	5744880.000	5744880.000	11489760.000
6	3293.000	1214.000	1214.000	5744880.000	5744880.000	11489760.000
7	3293.000	1214.000	1214.000	5744880.000	5744880.000	11489760.000
8	3197.000	1185.000	1185.000	4196560.000	4196560.000	8393120.000
9	3197.000	1185.000	1185.000	4196560.000	4196560.000	8393120.000
10	2501.000	874.000	874.000	3676560.000	3676560.000	7353120.000
11	1954.000	810.000	810.000	3083632.000	3083632.000	6167264.000
12	1338.000	535.000	535.000	2700000.000	2700000.000	5400000.000
13	1338.000	535.000	535.000	2700000.000	2700000.000	5400000.000
14	1338.000	535.000	535.000	2700000.000	2700000.000	5400000.000
15	1338.000	535.000	535.000	2700000.000	2700000.000	5400000.000
16	704.000	281.000	281.000	431720.000	431720.000	863440.000
17	24000.000	24000.000	24000.000	900000000.000	900000000.000	1800000000.000
18	59.490	28.000	28.000	125396.924	125396.000	250792.924
19	59.490	28.000	28.000	125396.924	125396.000	250792.924
20	59.490	28.000	28.000	125396.924	125396.000	250792.924
21	59.490	28.000	28.000	125396.924	125396.000	250792.924
22	55.240	21.000	21.000	116467.500	116467.000	232934.500
23	53.545	15.700	15.700	106033.500	106033.000	212066.500
24	39.700	13.000	13.000	59920.230	59920.000	119840.230
25	42.648	49.000	49.000	13182.940	13182.000	26364.940
26	24000.000	24000.000	24000.000	900000000.000	900000000.000	1800000000.000
27	15175.000	9228.000	9228.000	1240000.000	1240000.000	2480000.000
28	15175.000	9228.000	9228.000	1240000.000	1240000.000	2480000.000
29	6732.000	2977.000	2977.000	4600000.000	4600000.000	9200000.000
30	7944.000	4412.000	4412.000	6740000.000	6740000.000	13480000.000
31	5160.000	3027.000	3027.000	4600000.000	4600000.000	9200000.000
32	1705.000	614.000	614.000	783000.000	783000.000	1566000.000
33	484.000	93.980	93.980	38900.000	38900.000	77800.000
34	0.000	0.000	0.000	0.000	0.000	0.000

File Help

AP1000 rock

- Seismic Motion Analysis
 - Accelerogram Converter
 - Anas Intensity & Crop
 - Baseline Correction
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Nodes/Constraints | **Beam** | **Shear Wall** | **Damping** | **3D Model**

Node Definitions

Node ID must be 1, 2, 3.

	Node ID	X (ft)	Y (ft)	Z (ft)	Wt (kips)	Dx	Dy	Dz	Dxx	Dyy	Dzz	Ibx	Iyy	Izz
1	1	0.000	0.000	66.500	7612.000	☐	☒	☐	☒	☐	☒	1641500.000	1641500.000	0.000
2	2	0.000	0.000	81.500	15916.000	☐	☒	☐	☒	☐	☒	3612000.000	3612000.000	0.000
3	3	0.000	0.000	91.500	14145.000	☐	☒	☐	☒	☐	☒	1938300.000	1938300.000	0.000
4	4	0.000	0.000	99.000	10642.000	☐	☒	☐	☒	☐	☒	2619900.000	2619900.000	0.000
5	5	0.000	0.000	106.000	6765.000	☐	☒	☐	☒	☐	☒	1287500.000	1287500.000	0.000
6	6	0.030	0.000	116.500	14989.000	☐	☒	☐	☒	☐	☒	2526200.000	2526200.000	0.000
7	7	0.000	0.000	134.500	14226.000	☐	☒	☐	☒	☐	☒	3448492.000	3448492.000	0.000
8	8	0.000	0.000	145.400	5325.000	☐	☒	☐	☒	☐	☒	933560.000	933560.000	0.000
9	9	0.000	0.000	153.000	6118.000	☐	☒	☐	☒	☐	☒	1022510.000	1022510.000	0.000
10	10	0.000	0.000	164.000	5293.000	☐	☒	☐	☒	☐	☒	422680.000	422680.000	0.000

Coupled Degrees of Freedom

DOF (1=X, 2=Y, 3=Z, 4=R_x, 5=R_y, 6=R_z)

	Slave Node	Master node	DOF
1	0	0	0

Rigid Links

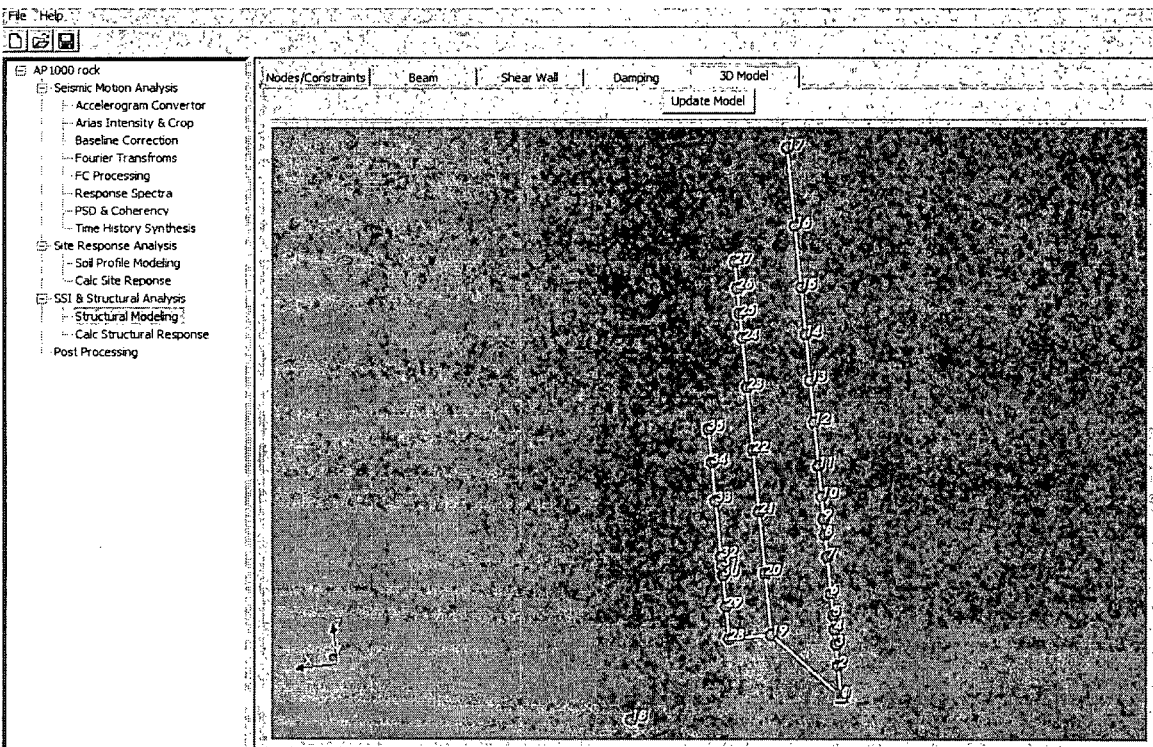
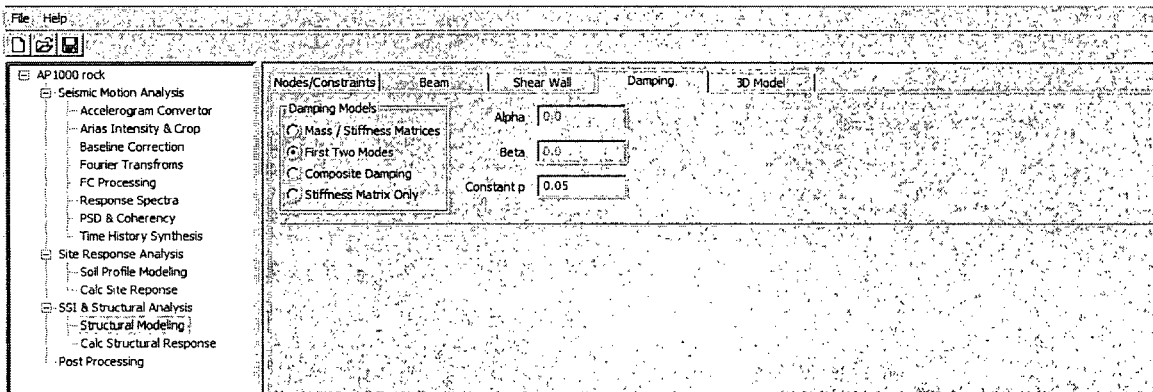
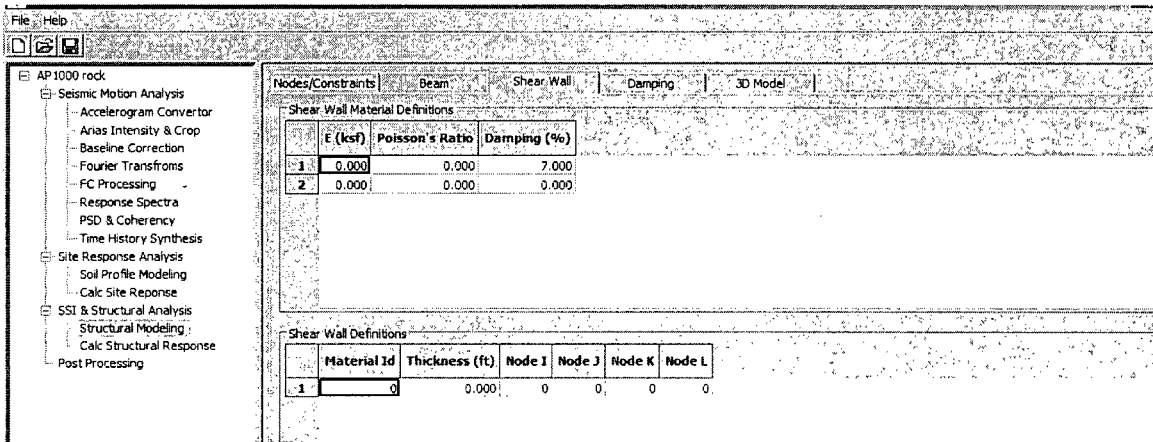
	Master Node	Slave node
1	0	0

Miscellaneous Info

SSI Node: Scale Factor:

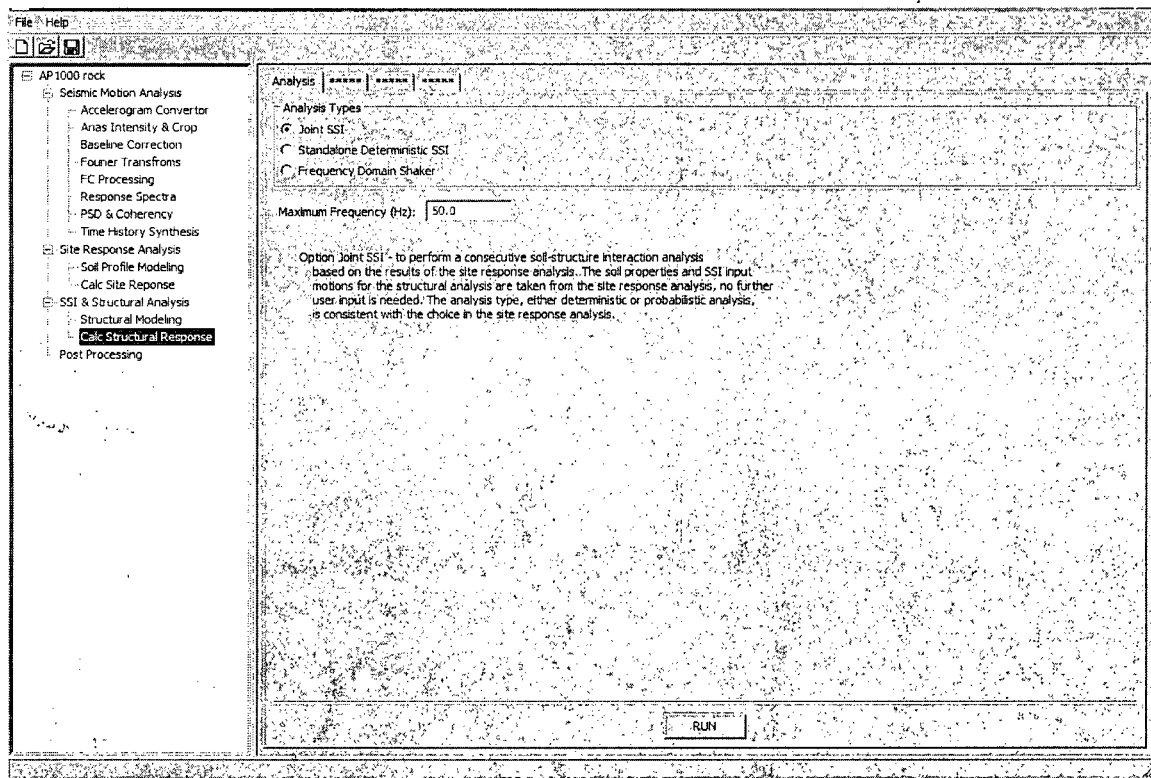
Output Nodes (e.g., 10, 15, ...):

☒ AP 1000 rock ☒ Seismic Motion Analysis -- Accelerogram Converter -- Arias Intensity & Crop -- Baseline Correction -- Fourier Transforms -- FC Processing -- Response Spectra, PSD & Coherency -- Time History Synthesis ☐ Site Response Analysis -- Soil Profile Modeling -- Calc Site Response ☒ SSI & Structural Analysis -- Structural Modeling -- Calc Structural Response -- Post Processing	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Nodes/Constraints</th> <th style="text-align: center;">Beam</th> <th style="text-align: center;">Shear Wall</th> <th style="text-align: center;">Damping</th> <th style="text-align: center;">3D Model</th> </tr> </thead> <tbody> <tr> <td colspan="5">Shear Beam Definitions</td> </tr> <tr> <td colspan="5">(1) Beam Material Definitions:</td> </tr> <tr> <td><table border="1" style="width: 100%; border-collapse: collapse;"><tr><th></th><th>E (ksf)</th><th>G (ksf)</th><th>Damping (%)</th></tr><tr><td>1</td><td>576000.000</td><td>280000.000</td><td>7.000</td></tr><tr><td>2</td><td>4176000.000</td><td>1612800.000</td><td>5.000</td></tr><tr><td>3</td><td>519120.000</td><td>280000.000</td><td>4.000</td></tr><tr><td>4</td><td>0.000</td><td>0.000</td><td>0.000</td></tr></table></td><td colspan="4"></td></tr> <tr> <td colspan="5">(2) Beam Section Definitions:</td> </tr> <tr> <td><table border="1" style="width: 100%; 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-Calc Structural Response

Select Joint SSI, and enter Maximum frequency (Hz): 50.0



Click RUN

Once Structural model RUN is completed, the staff went back to the “Seismic Motion Analysis/Fourier Transforms” and followed the steps below:

1. Go to “Seismic Motion Analysis/FC Processing” and click Browse
2. Select the file for the node, and direction (in this case X), of interest.
3. Click “ButterWorth Filter”, then “Safe FC”, and “To Time History”.
4. Then go to Seismic Motion Analysis/Response Spectra.
5. Click Browse and select the .fc.acc file for the node of interest and click “Spectrum” to get the Response Spectrum.
6. If want to safe the Response Spectrum Diagram, click the floppy icon and save as an EPS file.