Extension of Nuclear Island Seismic Analyses to Soil Sites

August 10, 2006

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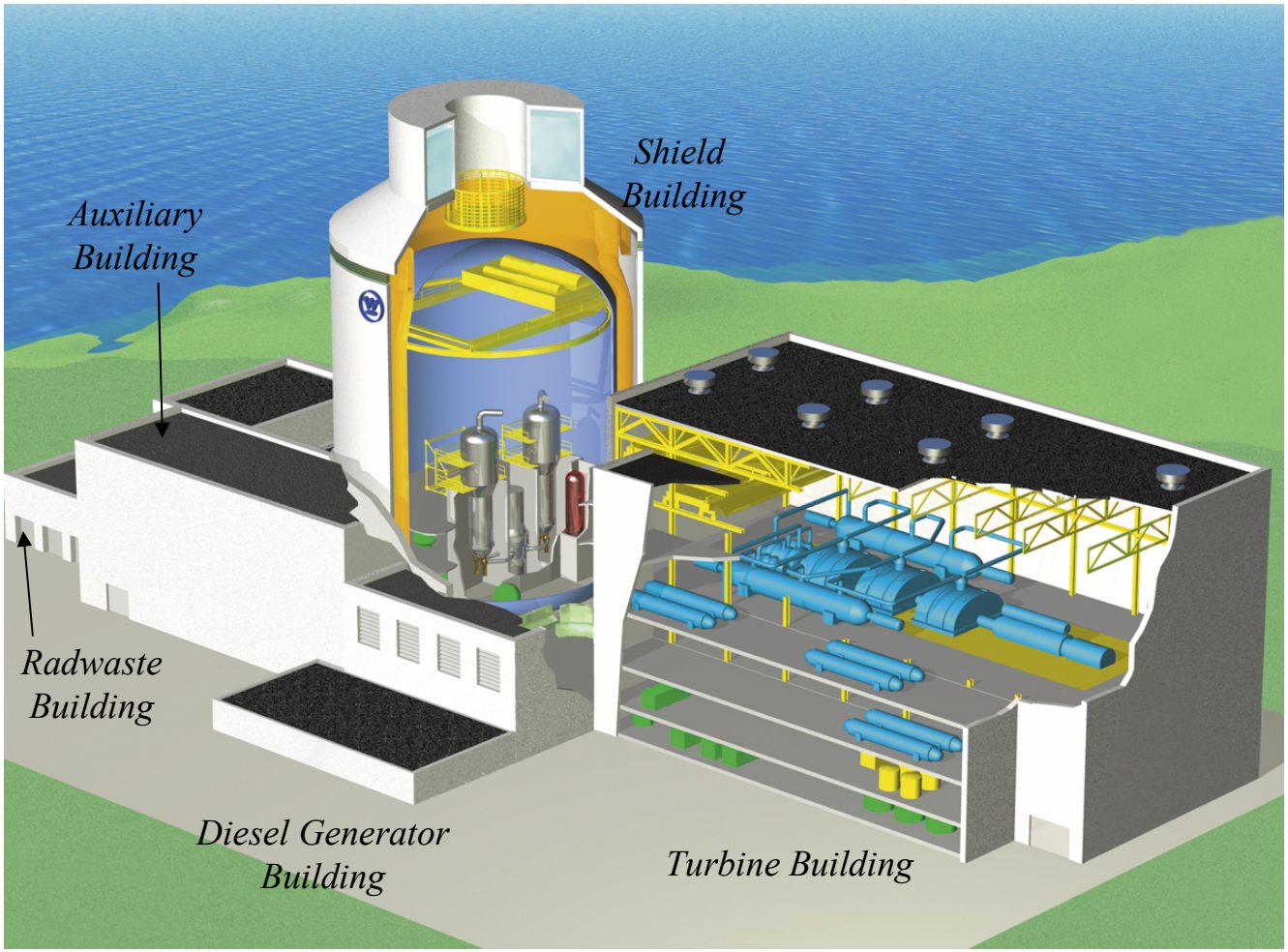
Agenda (Thursday August 10)

9:00	**Introductions**
9:15	**AP1000 Licensing Approach** *(Don Lindgren)*
9:30	**Extension of Nuclear Island Seismic Analyses to Soil Sites** *(Lee Tunon-Sanjur)*
11:30	**Other Issued and Planned Seismic/Structural Technical Reports** *(Richard Orr)*
12:00	**Lunch**
1:00	**Site Interface Requirements** *(Richard Orr)*
2:00	**Plan for Draft DCD revision** *(Don Lindgren)*
2:30	**Questions and Answers Opportunity for Public Comments**
3:00	**Adjourn**

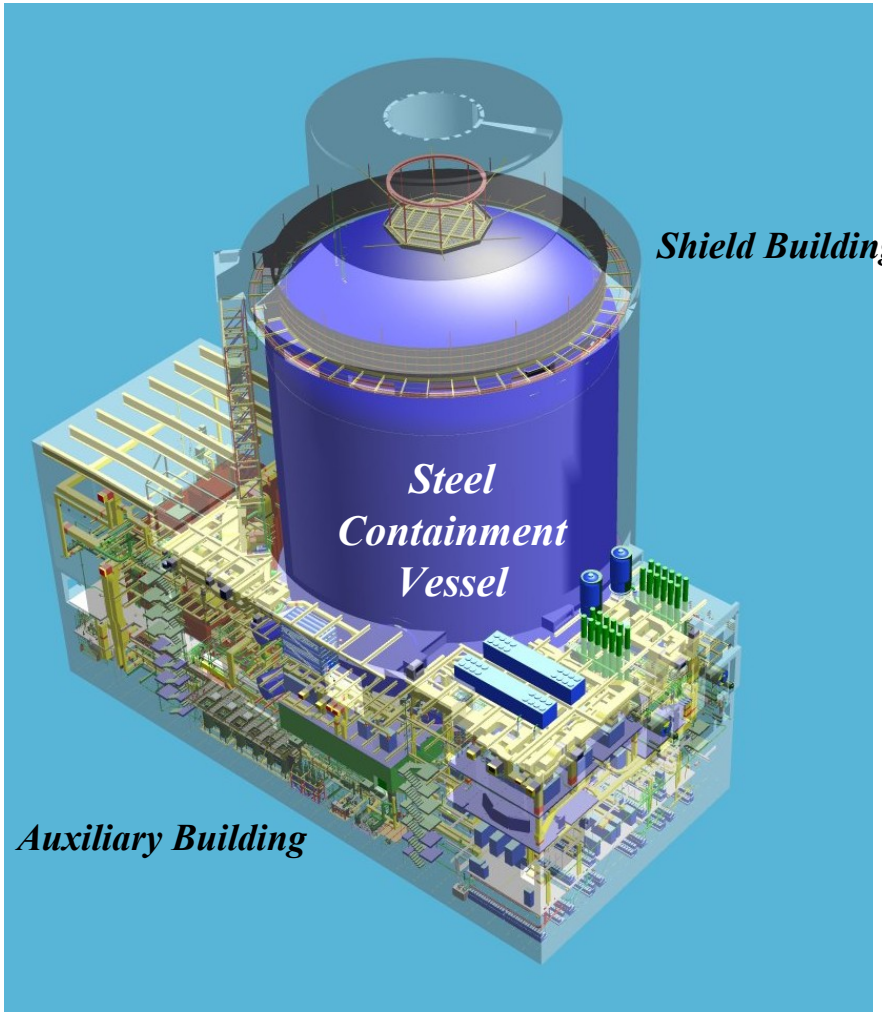
Overview

- **Westinghouse AP600 and AP1000 are advanced nuclear power plant designs utilizing passive safety features.**
- **AP600 design has been reviewed and approved by the US Nuclear Regulatory Commission for all sites.**
- **AP1000 design has been reviewed and approved by the US NRC for hard rock sites.**
  - **FE modelling of Nuclear Island structures**
  - **Seismic analyses performed to extend the applicability of the design to soil sites.**

AP1000 Principal Building Structures



AP1000 Nuclear Island Structures and Common Basemat

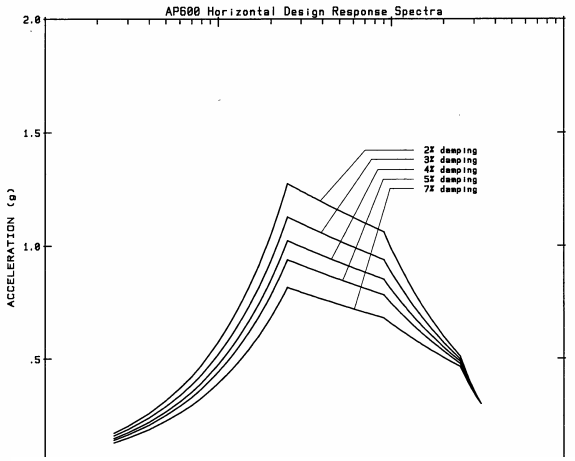


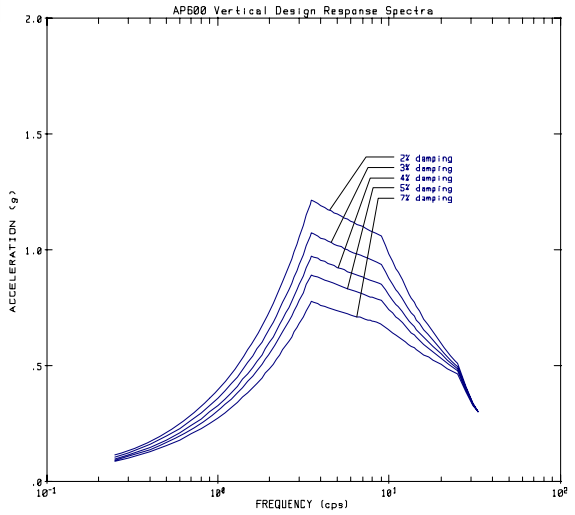
Seismic Input

- Design Response Spectra
- Design Time History
- Critical Damping Values
- Supporting Media for Seismic Category I Structures

Design Response Spectra

- AP1000 spectra has amplitudes equal to the Regulatory Guide 1.60 spectrum at control frequencies 0.25, 2.5, 9 and 33 hertz
- Spectra is augmented by 30 percent at 25 hertz





Design Time History

- A "single" set of three mutually orthogonal, statistically independent, synthetic acceleration time histories is used as the input in the dynamic analysis of seismic Category I structures.
- The design time histories are applied at the foundation level in the free field for hard rock sites and at surface for soil sites.
- The ground motion time histories (H1, H2, and V) are generated with time step size of 0.010 second for applications in soil structure interaction analyses.
- For applications in the fixed-base mode superposition time-history analyses, the time step size is reduced to 0.005 second by linear interpolation

Supporting Media for Seismic Category I Structures

- ~~Hard Rock Certification~~
- Technical Report No. 3 covers AP1000 design at Soil Sites
  - AP600 Parametric Soil Cases
  - AP1000 Parametric Soil Cases
  - AP1000 Generic Soil Profiles
- Additional Parametric Studies

Hard Rock and Soil Cases

- A survey of 22 sites, AP600 SSI analyses and numerous meetings with NRC led to an agreement on generic soil cases to be analyzed for AP600
- For the AP1000 2D and 3D time history analyses have been performed.
- ANSYS is used for hard rock
- SASSI is used for soil
- Three generic soil cases were used in the 3D SASSI analyses based on the AP600 and AP1000 2D SASSI parametric studies

AP600 Parametric Studies

Shear Wave Velocity Profile	Depth to Base Rock (ft)	Depth to Water Table (ft)	SSI Case (X-shaking)	SSI Case (Y-shaking)	SSI Case (Z-shaking)	Notes
Hard Rock	---	---	✓	✓	✓	Rigid Base
	---	---	---	✓	---	V_s = 20000 fps
	---	---	✓	✓	---	V_s = 8000 fps
Firm Rock	120	deep	---	✓	---	V_s = 3500 fps
Soft Rock	deep	deep	✓	✓	✓	
	120	deep	✓	✓	✓	
Soft-to-Medium Soil	deep	deep	✓	✓	✓	
	120	0	✓	---	✓	
		40	✓	---	✓	
		deep	✓	✓	✓	
	40	deep	✓	---	✓	
	120	0	*	*	---	
	120	deep	*	---	---	ν = 0.35
	120	deep	*	---	---	ν = 0.25
	120	0	---	*	---	Parabolic Soil Profile
	80	0	---	*	---	
	60	0	---	*	---	
	50	0	---	*	---	
	40	0	---	*	---	
	120	0	---	*	---	Parabolic, Lower Bound
Soft Soil	deep	deep	✓	✓	✓	
	120	deep	✓	✓	✓	
		40	✓	---	✓	
		0	✓	---	✓	
	120	0	*	*	---	
	50	0	---	*	---	
	120	0	*	---	---	Lower Bound
Step-Wise Layered Soil	deep	deep	✓	✓	✓	layered site study

Legend:

✓ Seed and Idris 1970 soil/rock degradation curves

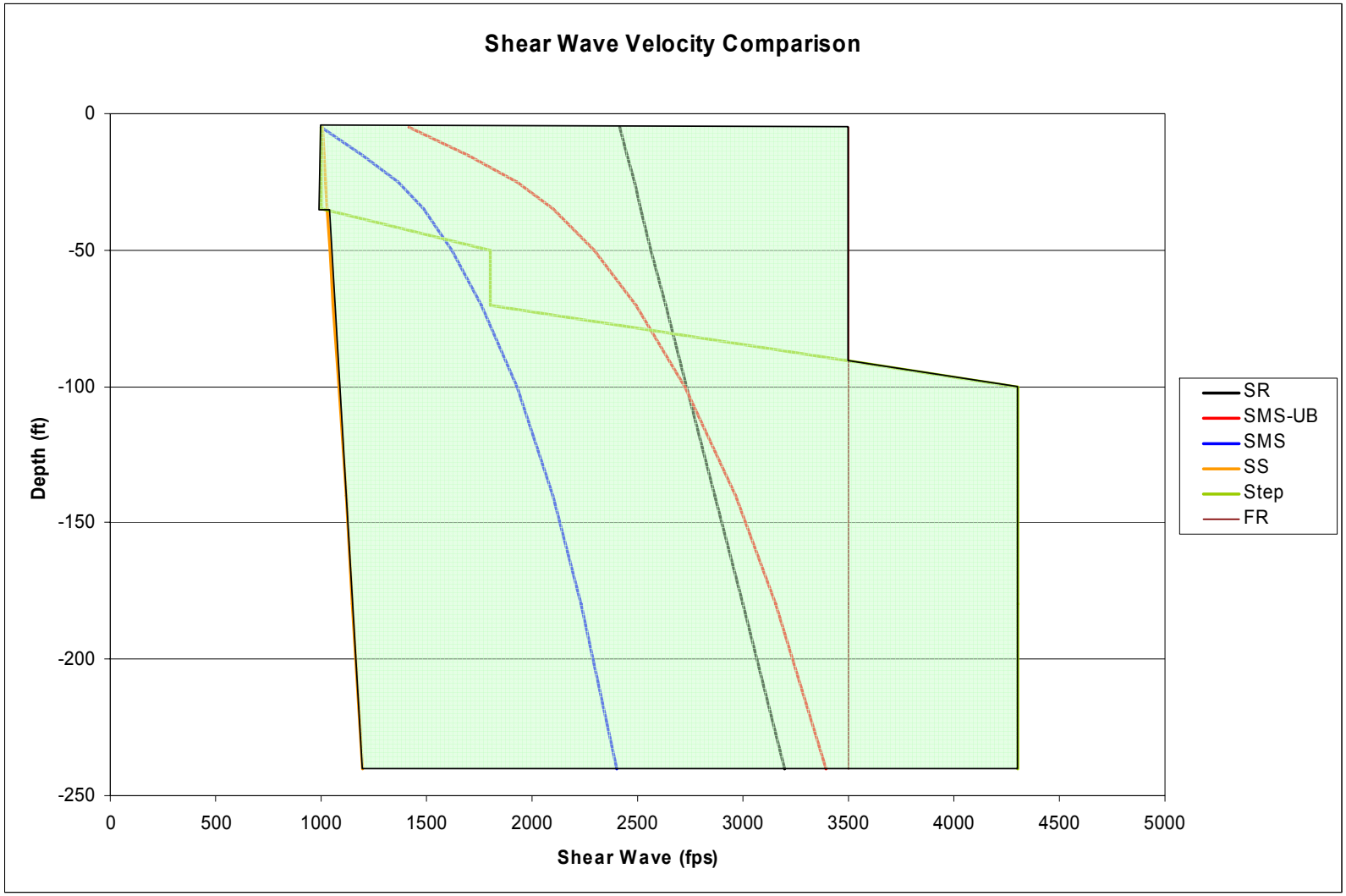
* Idris 1990 soil degradation curves

AP1000 2D SASSI Parametric Studies

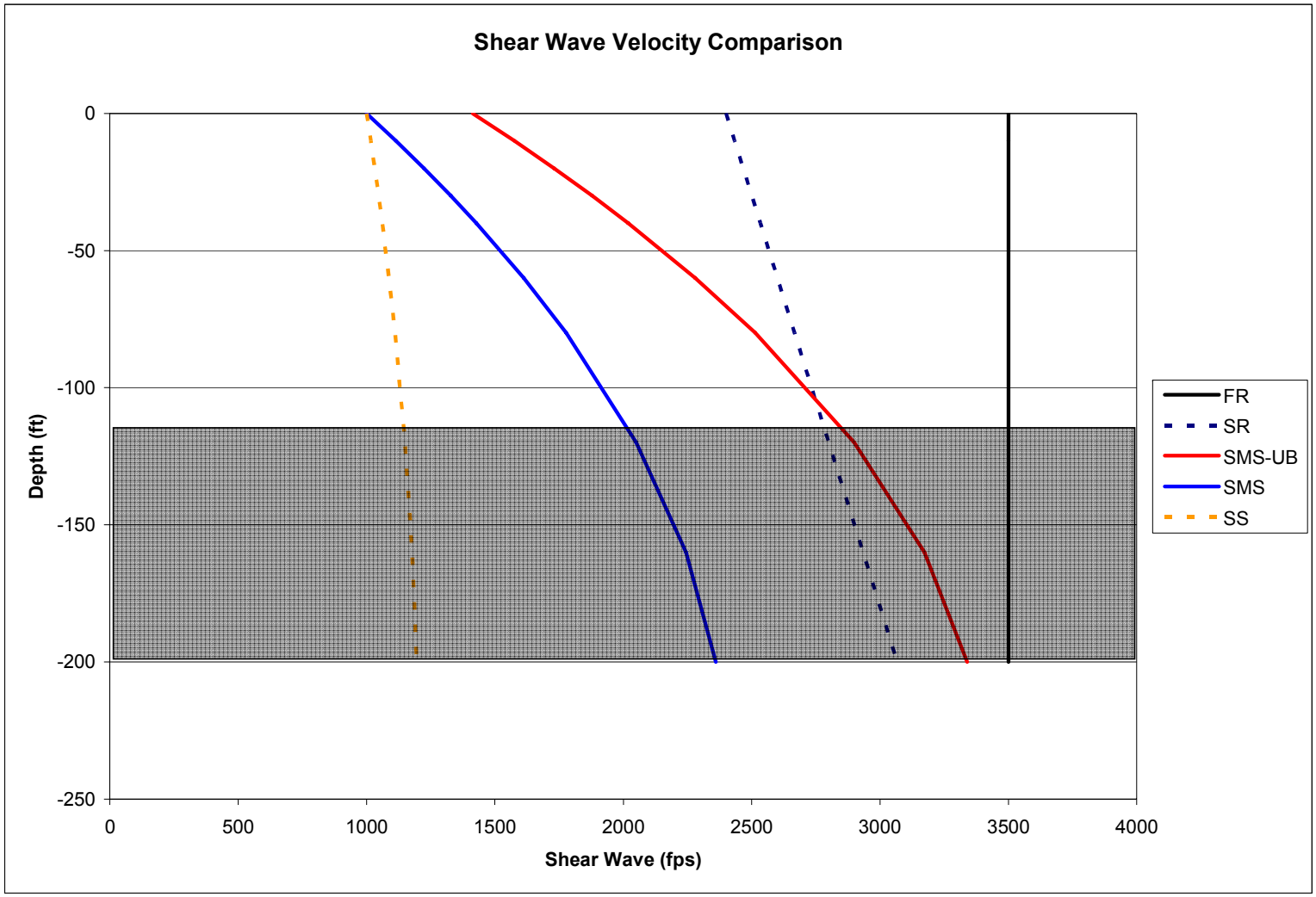
- Firm rock
- Soft Rock
- Upper bound soft to medium
- Soft to medium
- Soft Soil

- In addition, 2D SASSI analyses showed that the effect of adjacent structures was negligible

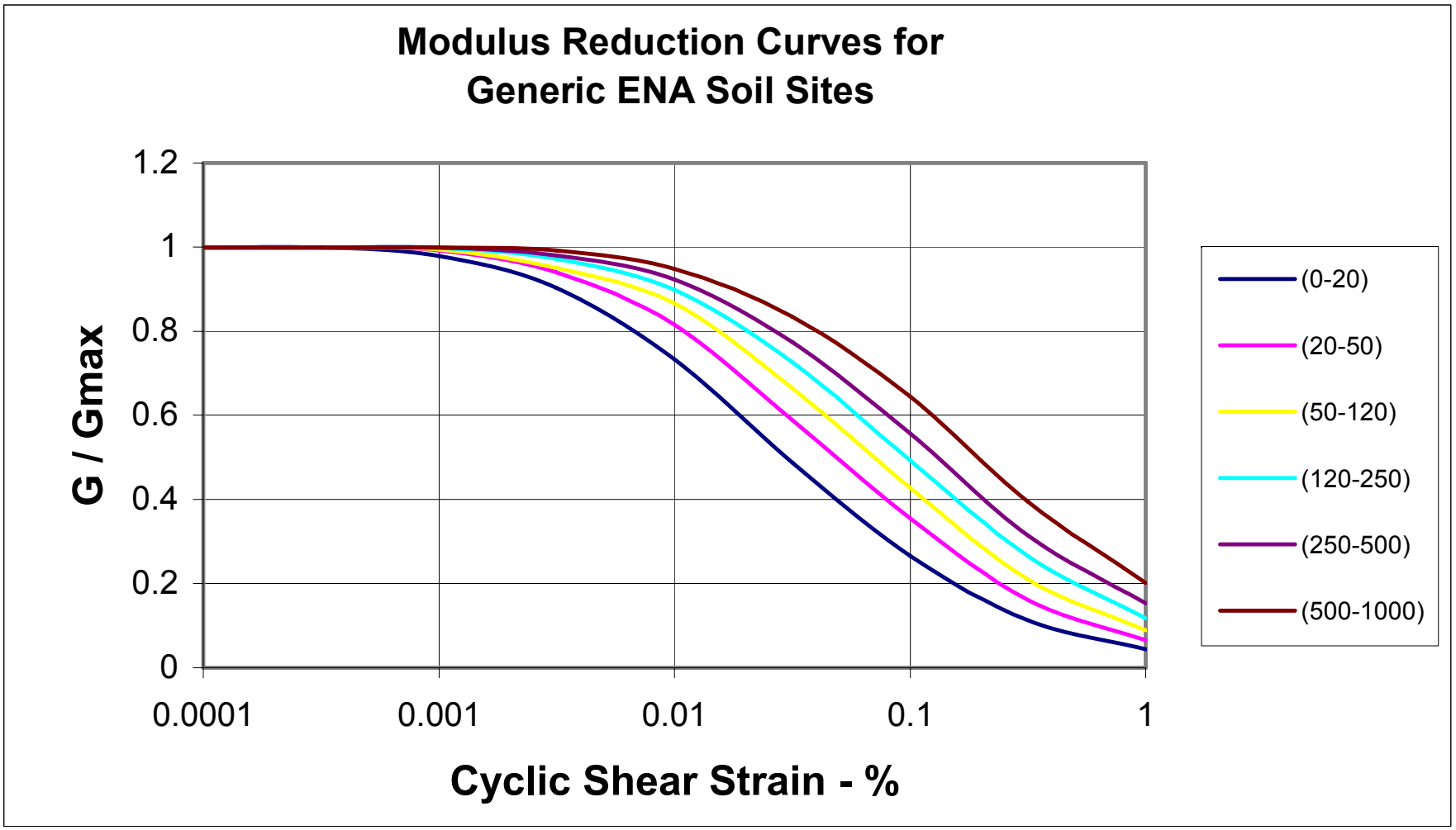
AP600 Parametric Soil Profiles



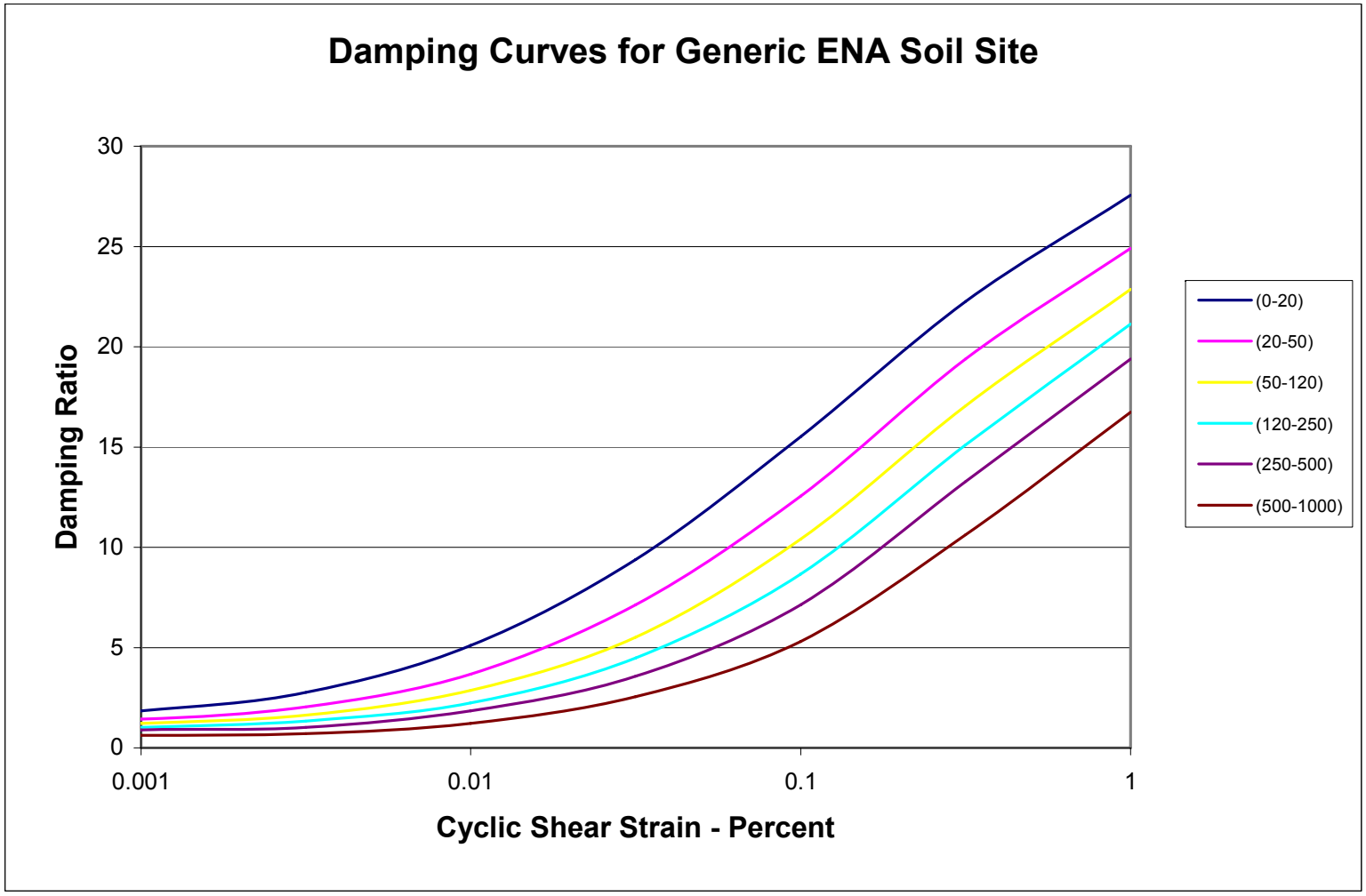
AP1000 Parametric Soil Profiles



EPRI 1993 Soil Degradation Curves

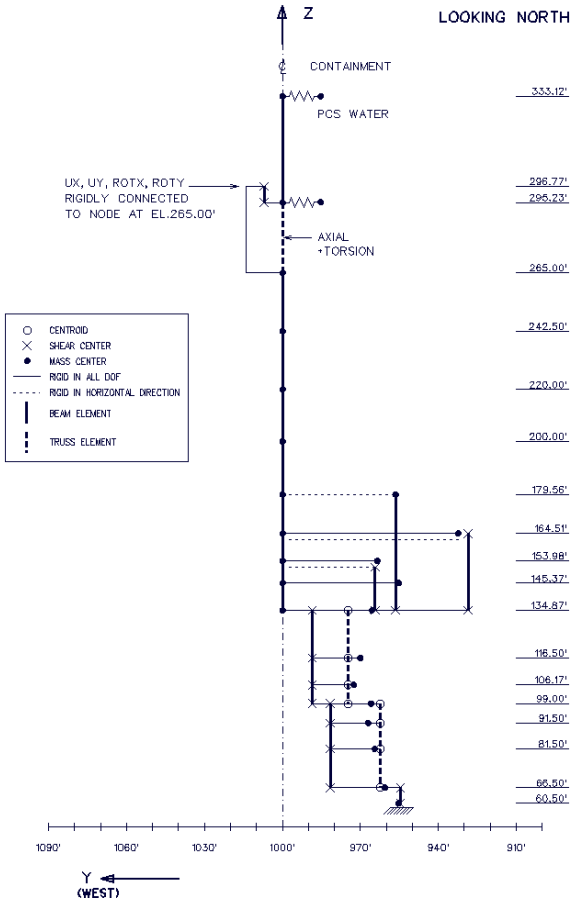


EPRI 1993 Soil Degradation Curves

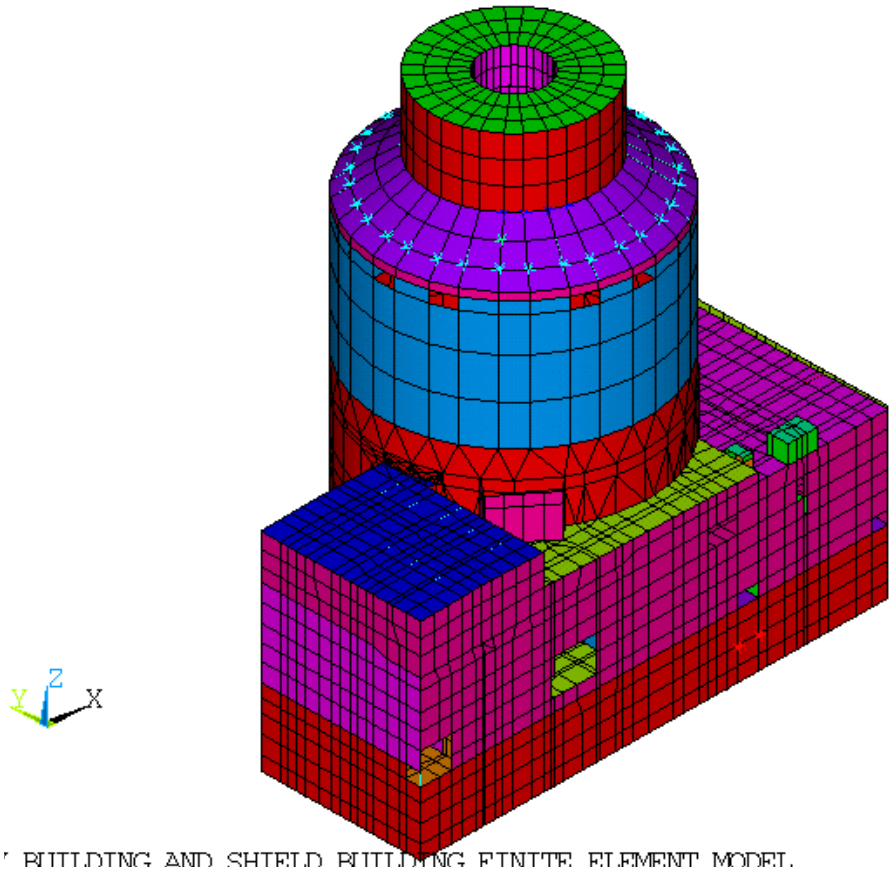


Results from two dynamic analysis models were reviewed by the NRC staff and its consultants during Hard Rock Certification

ASB Stick Model



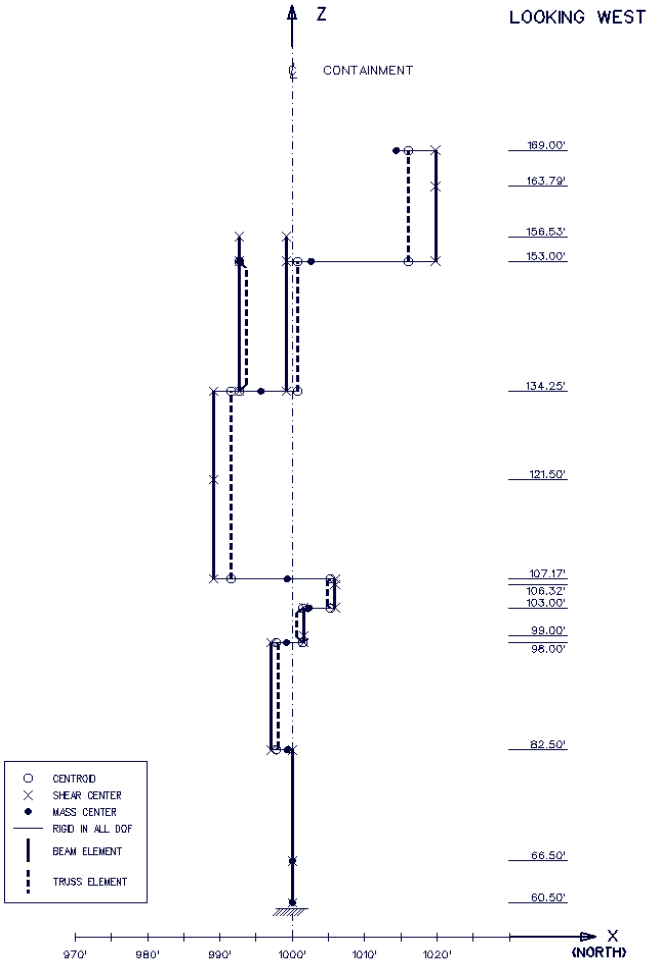
ASB FE Model (NI10)



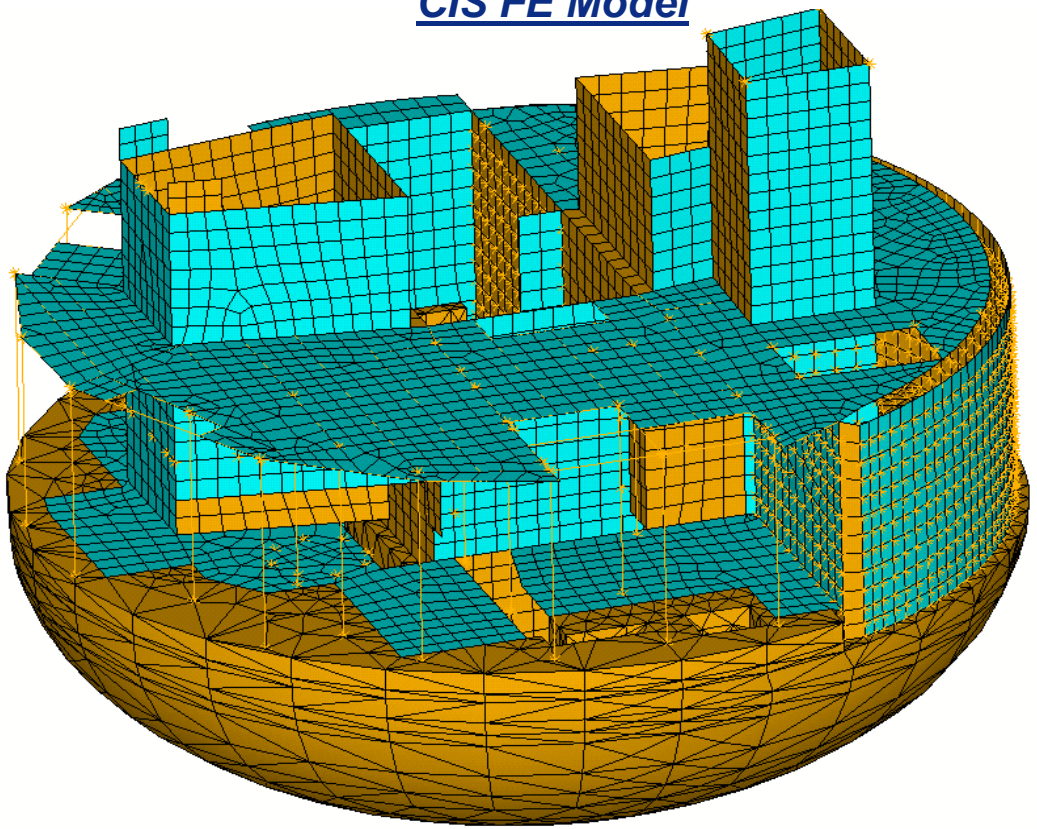
' BUILDING AND SHIELD BUILDING FINITE ELEMENT MODEL.

Only ASB results were compared. CIS was represented by superelement (stiffness and mass matrices).

CIS Stick Model



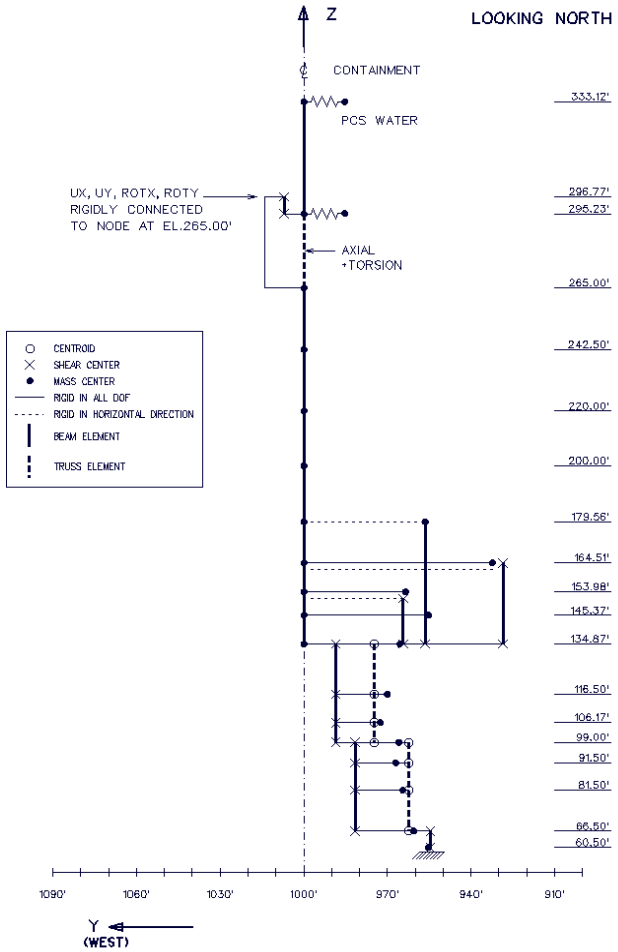
CIS FE Model



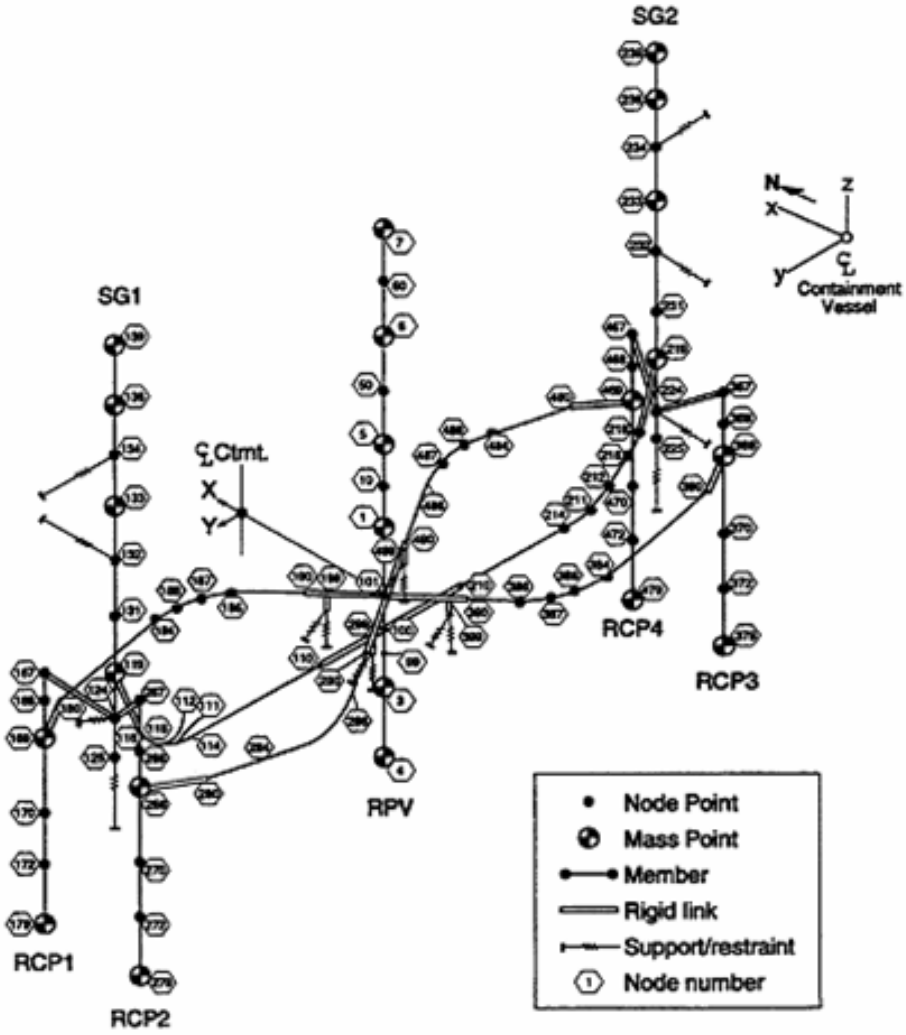
Lumped Mass Stick Model

- **Model properties of were determined using building sections extracted from the 3D building shell models.**
- **Masses are provided at major floor elevations and at locations of structural discontinuities.**
- **Centers of rigidity and of mass are considered.**
- **Building Models are interconnected with other stiff beam elements**
- **Seismic subsystems include the coupling of the reactor coolant loop model , polar crane model and the steel containment vessel.**
- **Other major subsystems and equipment is included as concentrated lumped-mass only.**

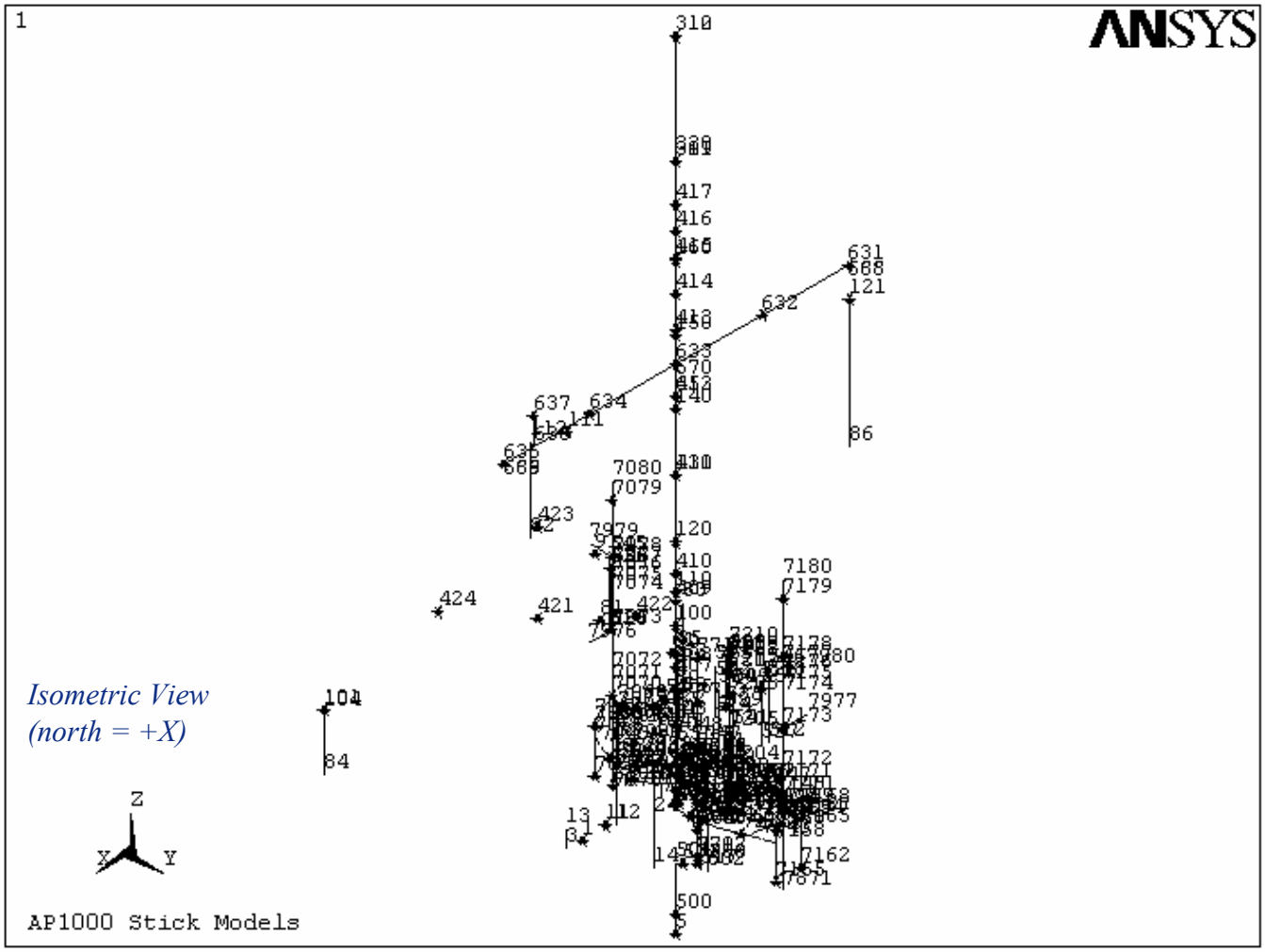
Nuclear Island Auxiliary and Shield Building Stick Model



Reactor Coolant Loop Model



Nuclear Island Auxiliary and Shield Building Stick Model



Building Modeling: Stick ⇨ Shell/Solid

AP1000

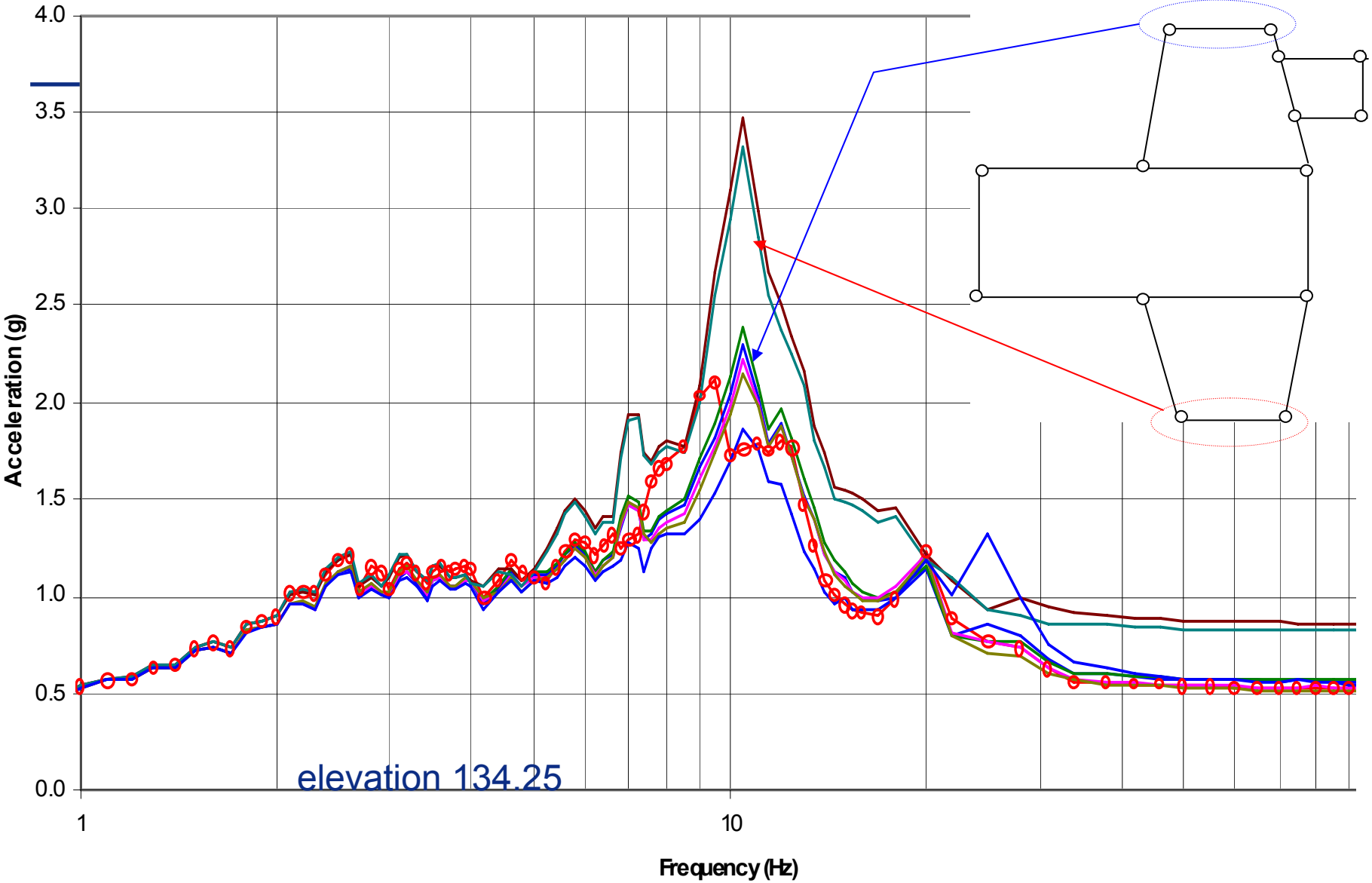
- **Comparisons of ASB stick vs shell during certification concluded that the shell model should be used to obtain the vertical response. CIS was not compared at that time.**
- **Informal discussions with NRC reviewers led to investigation of further use of the shell model as Westinghouse prepared to extend its analysis to soil sites**
- **The comparisons of stick vs shell showed that the CIS stick model did not represent such a complex structure well, especially when the major components were incorporated into the model**

Building Modeling: Stick ⇨ Shell/Solid

- Use of AP1000 FE shell model to generate spectra reveals that there are local responses in the CIS structure that are not predicted by the AP1000 stick models.
- The enveloping spectra generated from AP1000 FE shell results are higher and in some locations broader than the spectra generated from AP1000 stick model results.

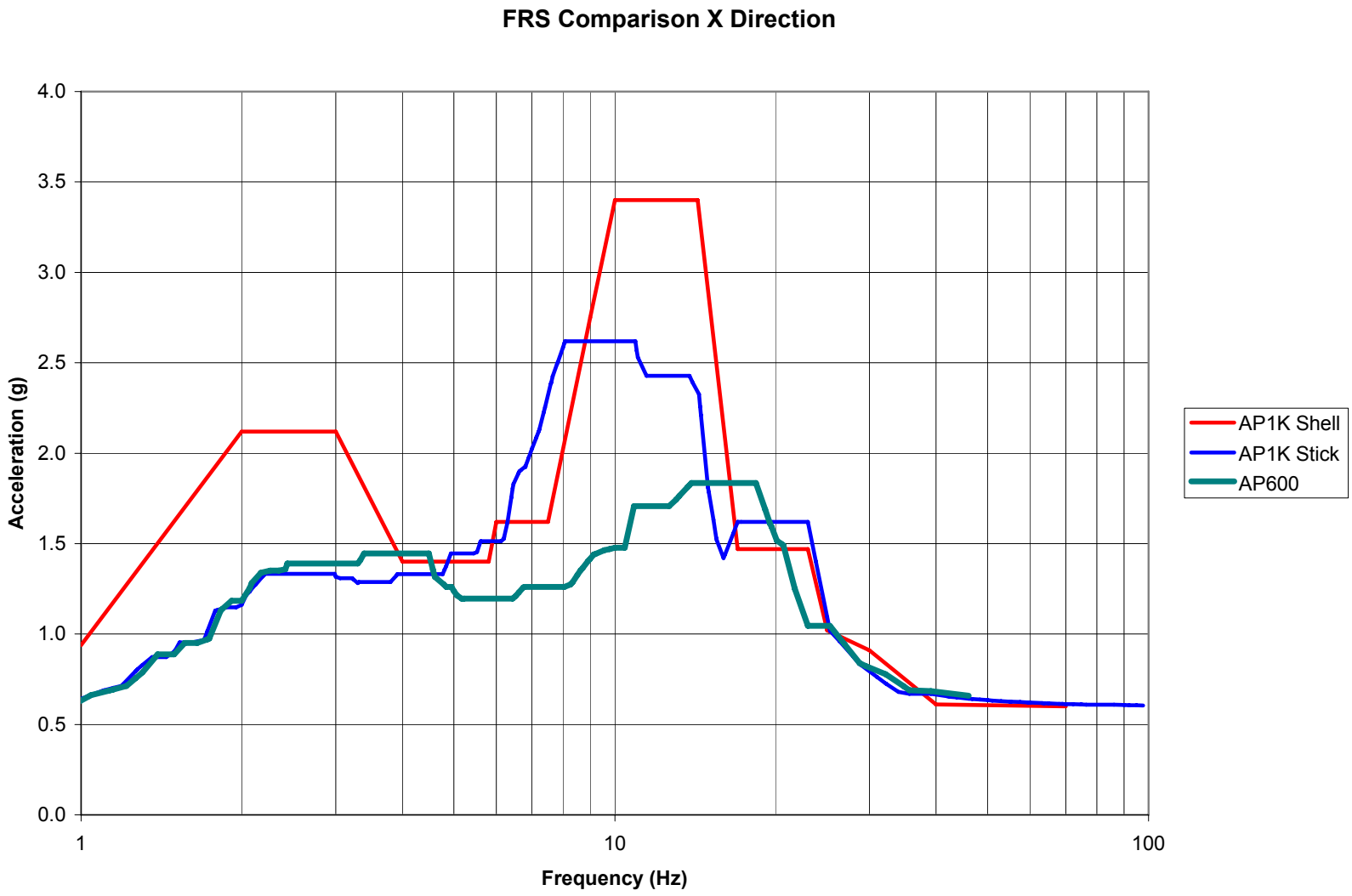
FRS Comparison X Direction

Example of more local response

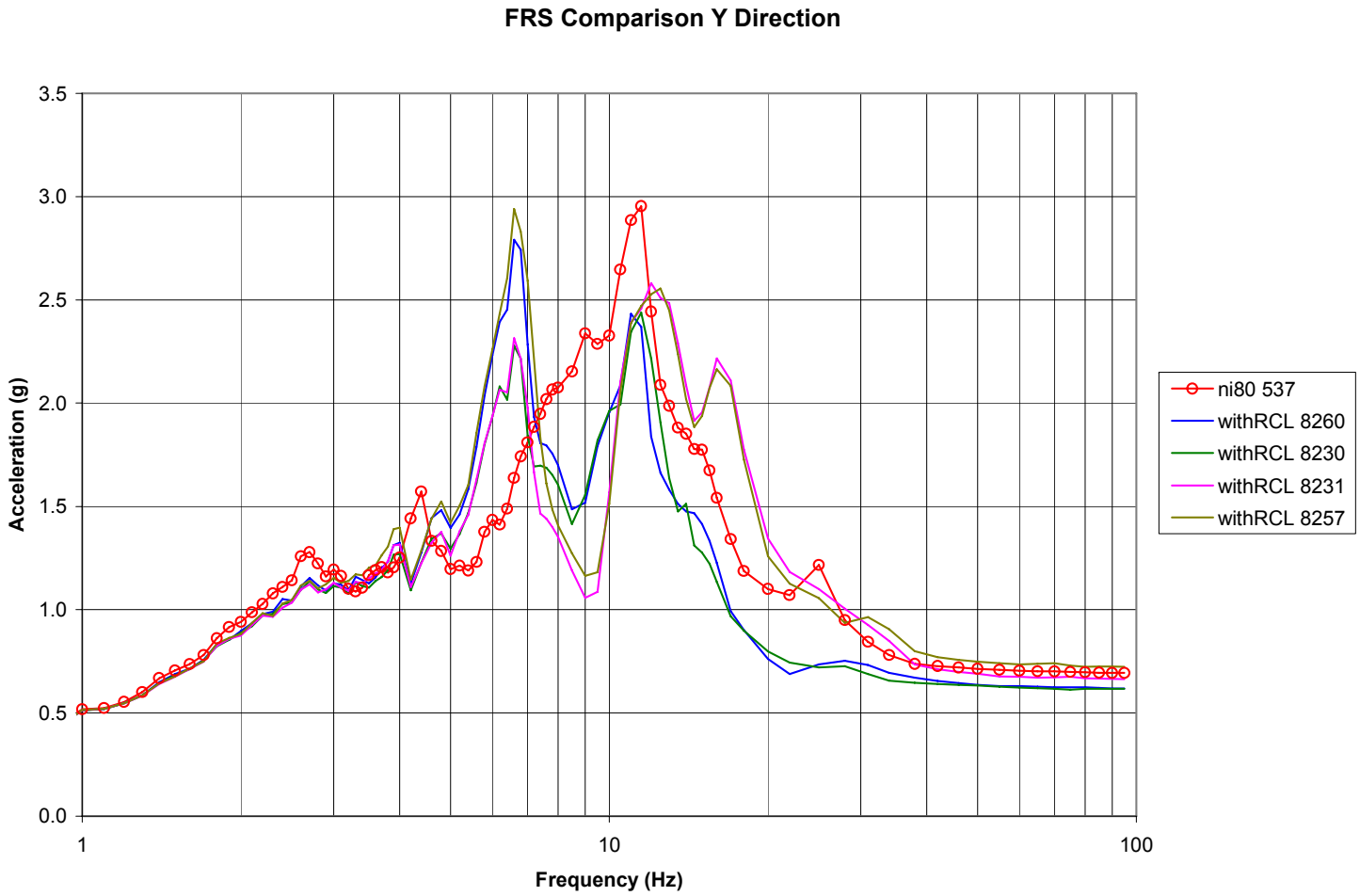


(From RSO original presentation cisc2 model)

SG West Compartment Spectra – 4% Damping



FRS Comparison Y Direction – SG West - El. 153



Seismic Analyses Finite Element Models

- **Detailed finite element shell model representation of the nuclear island and stick model representation of the SCV and major equipment for hard rock sites.**
- **The soil structure interaction model with coarse finite element shell model representation of the nuclear island and stick model representation of the major equipment for soft soil to firm rock sites.**

Summary

- The stick and shell seismic models have adequate level of detail to predict the responses in the frequency range of interest for seismic design.
- The AP1000 seismic analyses for sites from soft soil to hard rock have been efficiently performed using a combination of three models.
- The stick models were used to establish the important parameters that needed to be considered in soil structure interaction analyses and were also used to establish loads for overturning analysis.
- The coarse SSI model was used to develop the floor response spectra at soft to medium soil to firm rock sites.
- The Hard Rock Fine model was used to develop the floor response spectra at hard rock sites and to develop loads for flexible walls and floors.

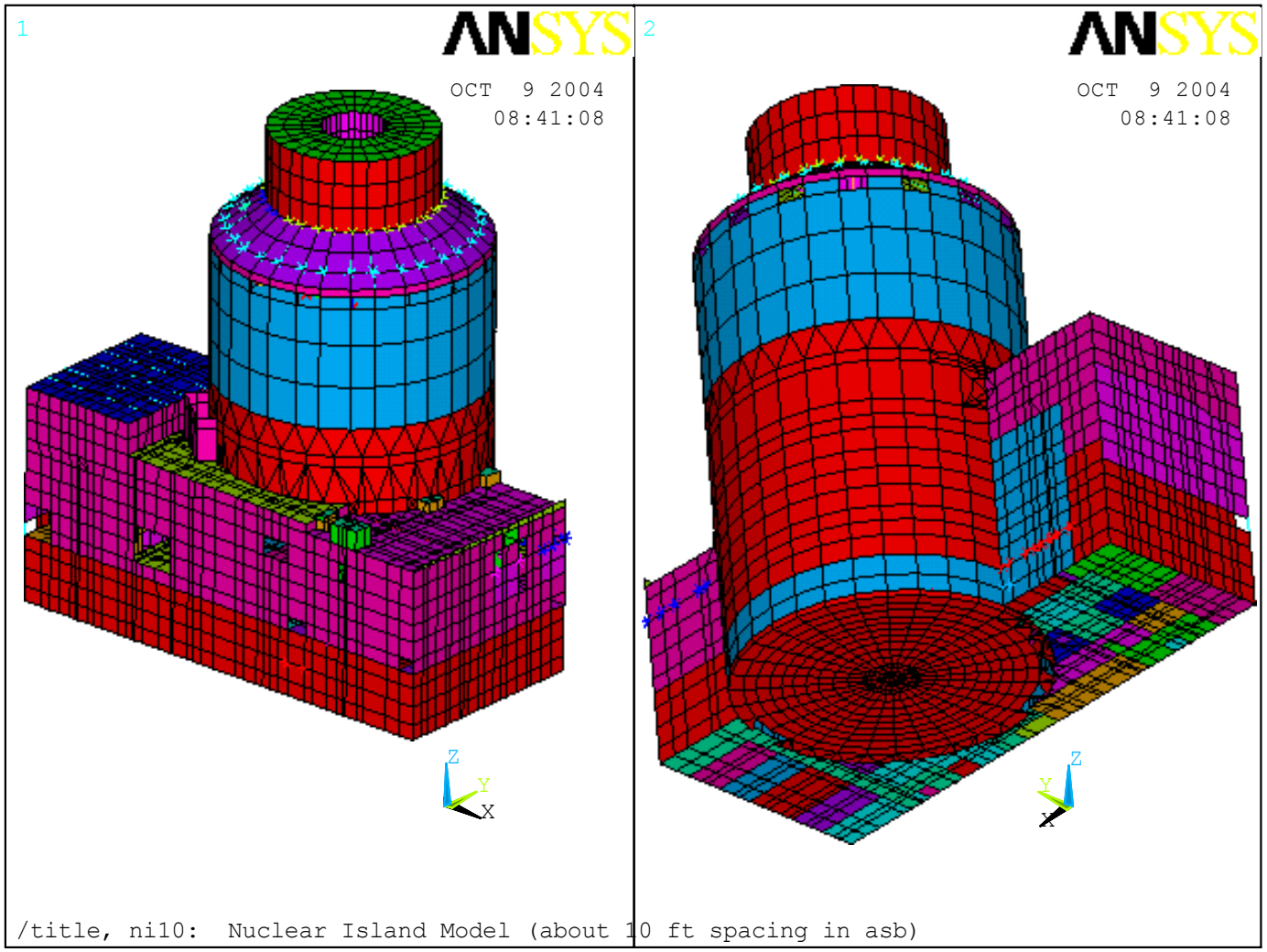
Finite Element Shell Model used for Hard Rock (NI10)

- **20,000 Nodes and 50,100 elements**
- **Auxiliary Shield Building (ASB) shell model**
- **Containment Internal Structures solid-shell model.**
- **Major equipment are connected to the CIS.**
  - **Steel Containment Vessel (SCV)**
  - **Polar crane**
  - **reactor coolant loop (RCL),**
  - **pressurizer (PZR) model.**
  - **Core Makeup Tank**

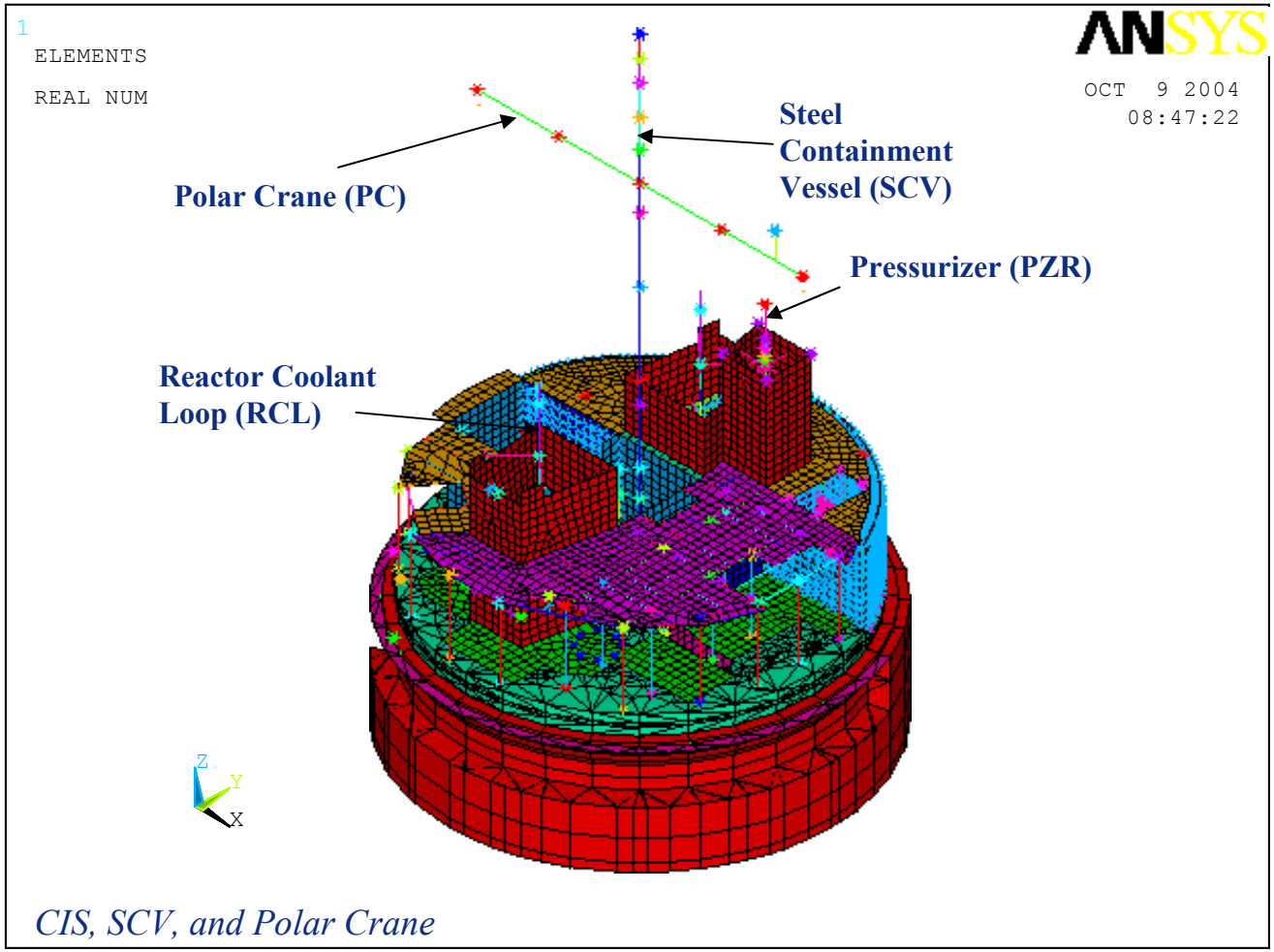
Finite Element Shell Model used for Hard Rock (NI10)

- **This model is designated NI10 since the nominal shell element dimension in the auxiliary building is about 10 feet.**
- **The time history analyses of the nuclear island shell model were performed in two analyses. One analysis used the finite element model of the ASB and a superelement of the CIS and major components, the other analysis used the finite element model of the CIS and major components and a superelement of the ASB.**
- **The Hard Rock model is also used as a benchmark for the lumped mass model and the soil structure interaction model.**
- **Modal analyses results of the lumped mass stick model and the soil structure interaction model were compared to those of the detailed Hard Rock model and found to be acceptable.**

Nuclear Island Fine Model – ni10

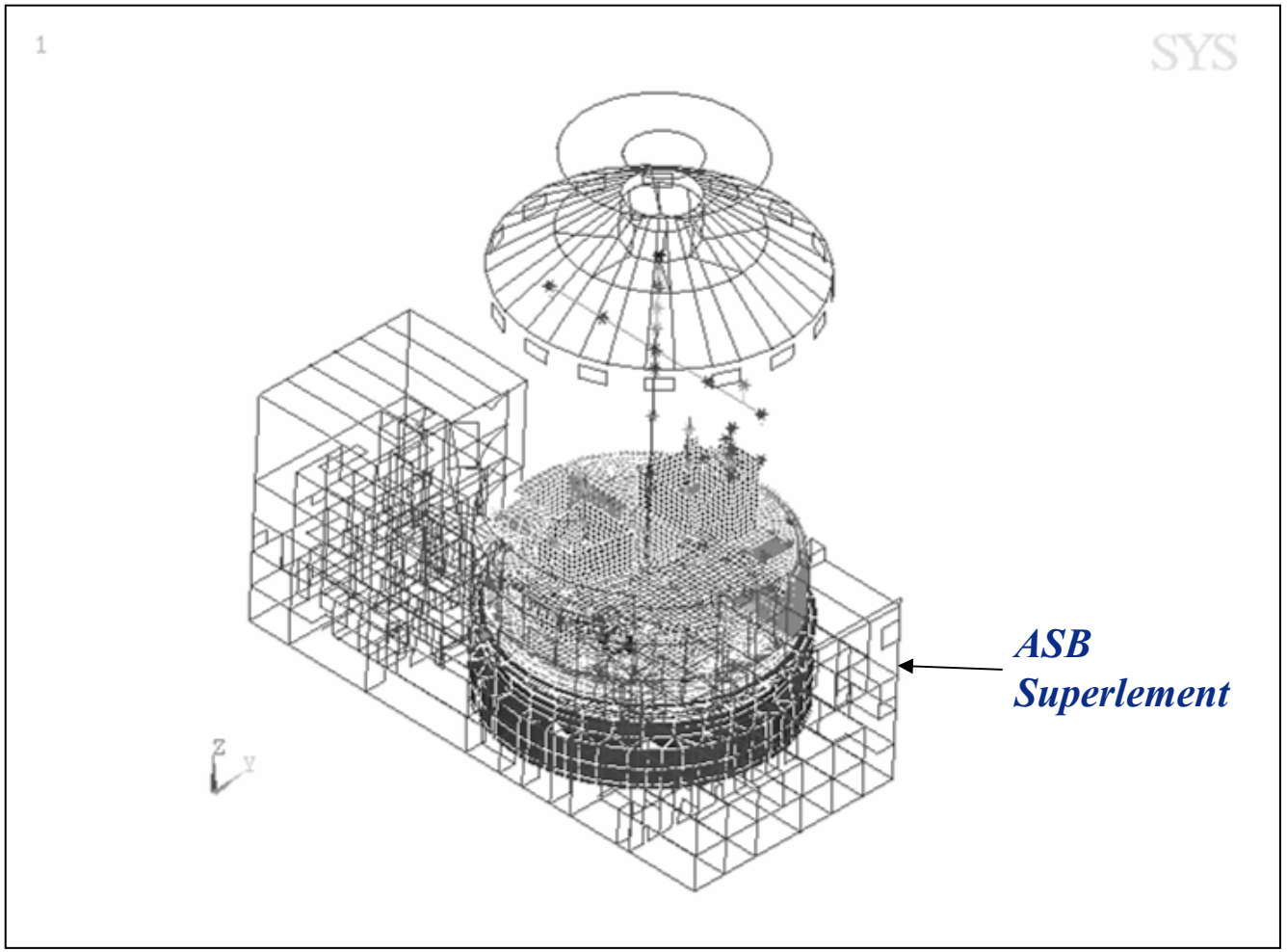


Inside Containment

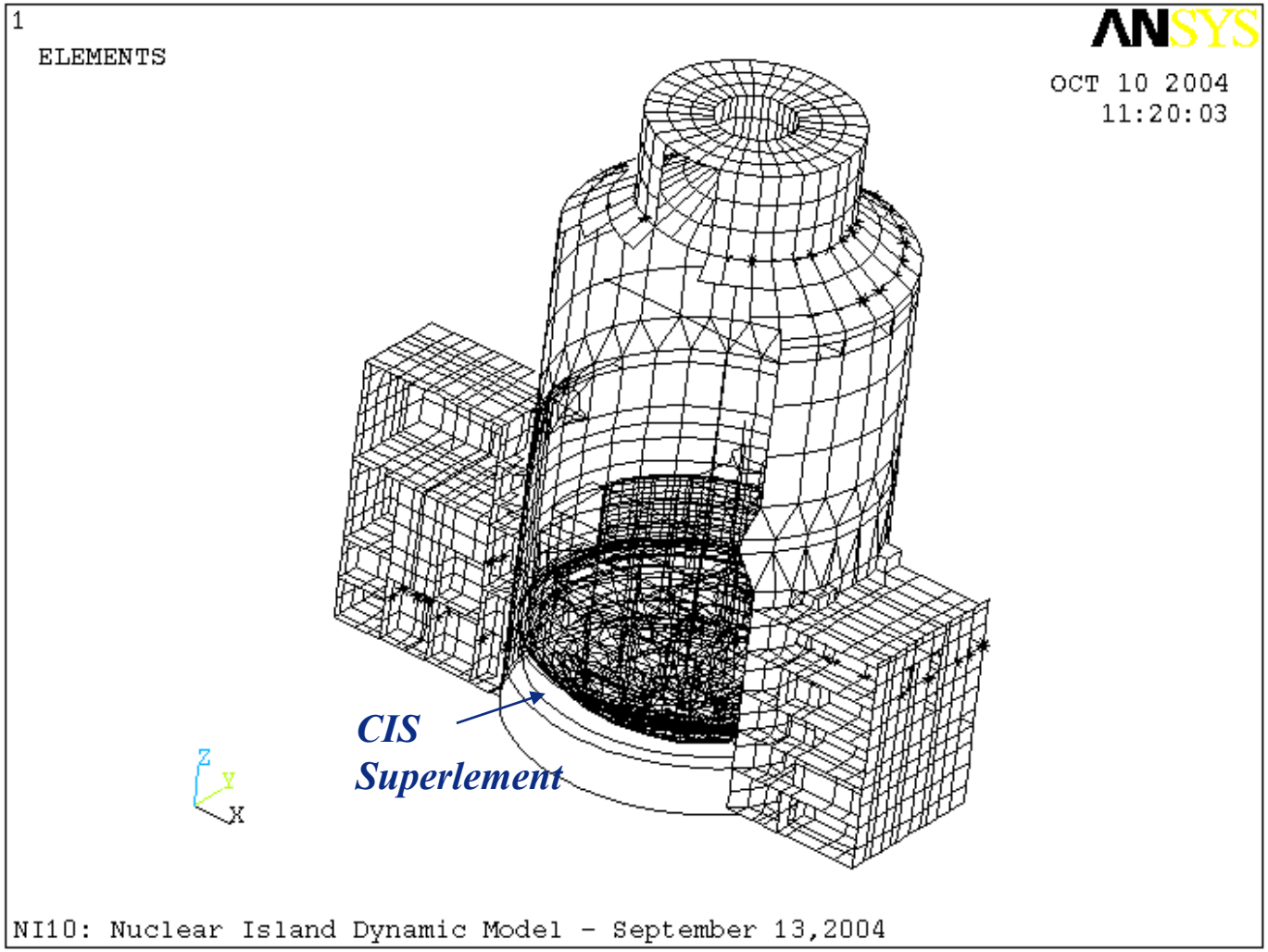


CIS, SCV, and Polar Crane

Nuclear Island Fine Model – ni10-asb



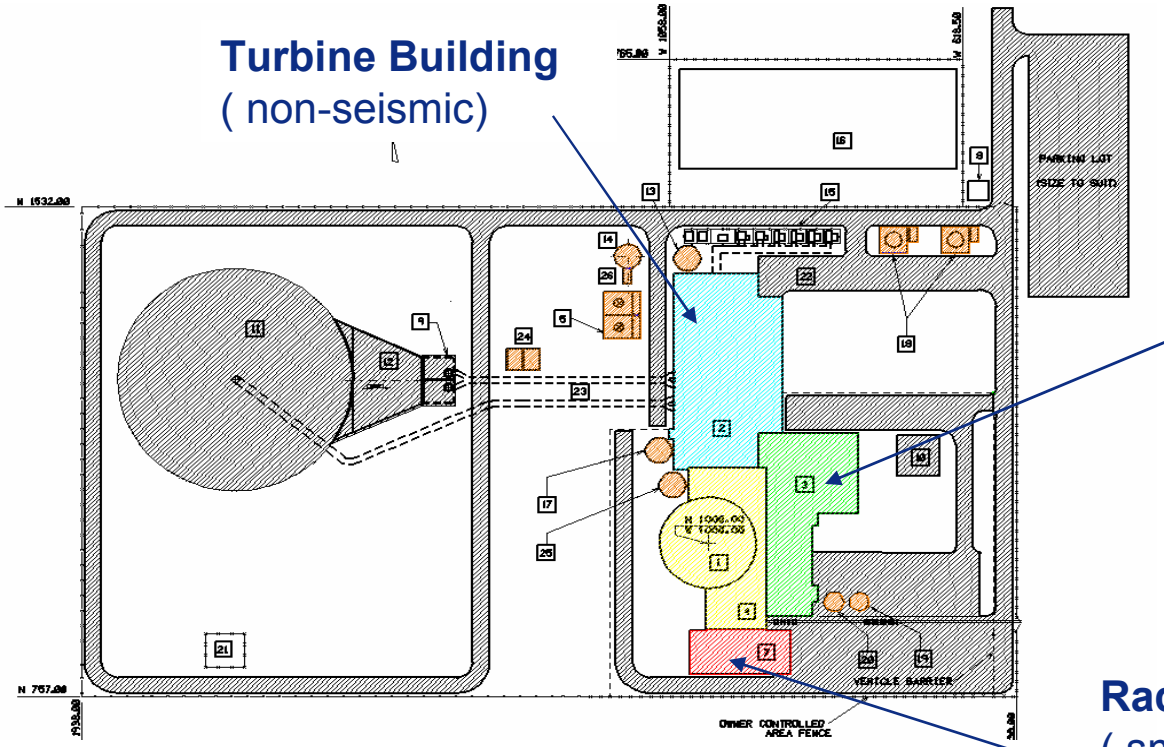
Nuclear Island Fine Model – ni10-cis



Soil Structure Interaction (SSI) Model (NI20)

- Fewer nodes and elements than the hard rock model
- Captures the essential features of the nuclear island configuration
- Nominal shell and solid element dimension is about 20 feet.
- The soil-structure interaction analyses of the nuclear island are performed using the program SASSI

Plan Layout

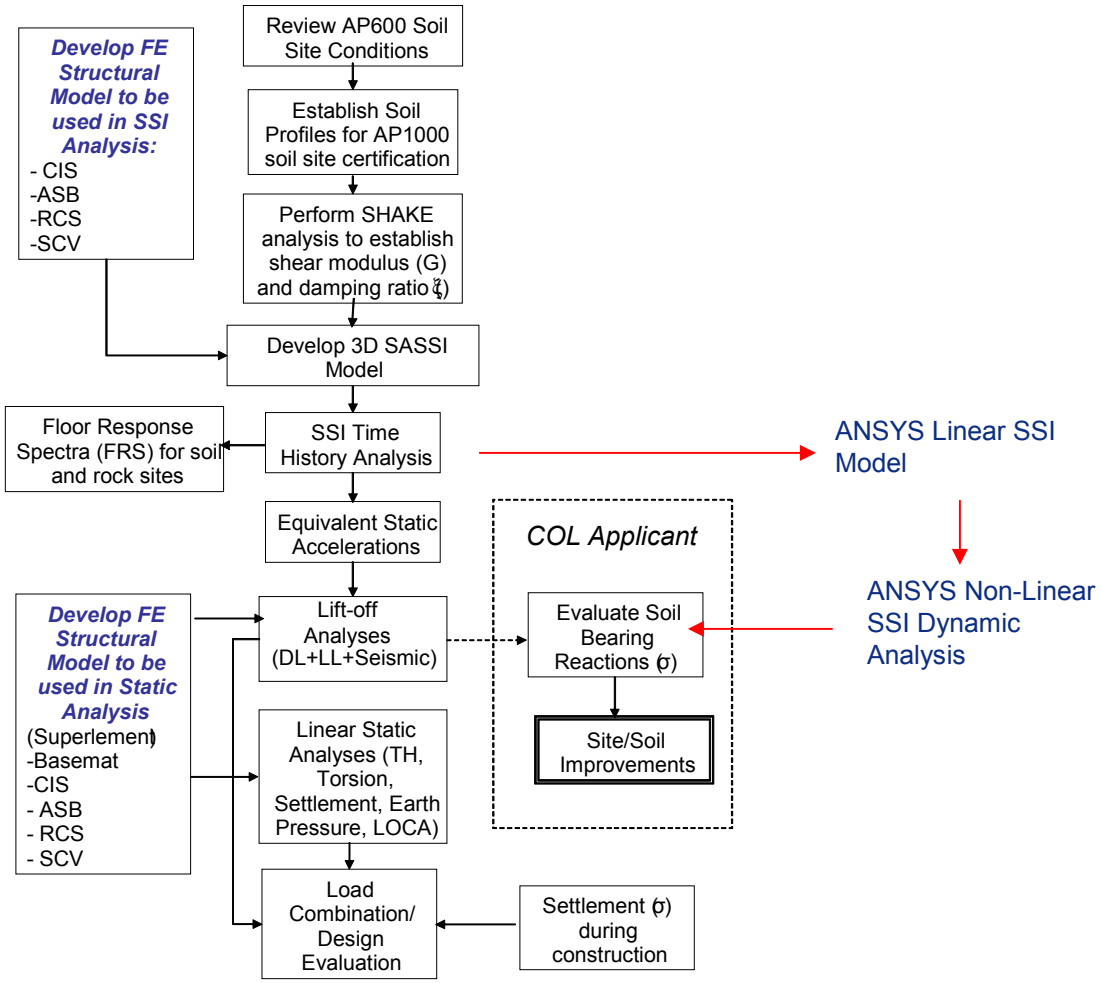


Turbine Building
(non-seismic)

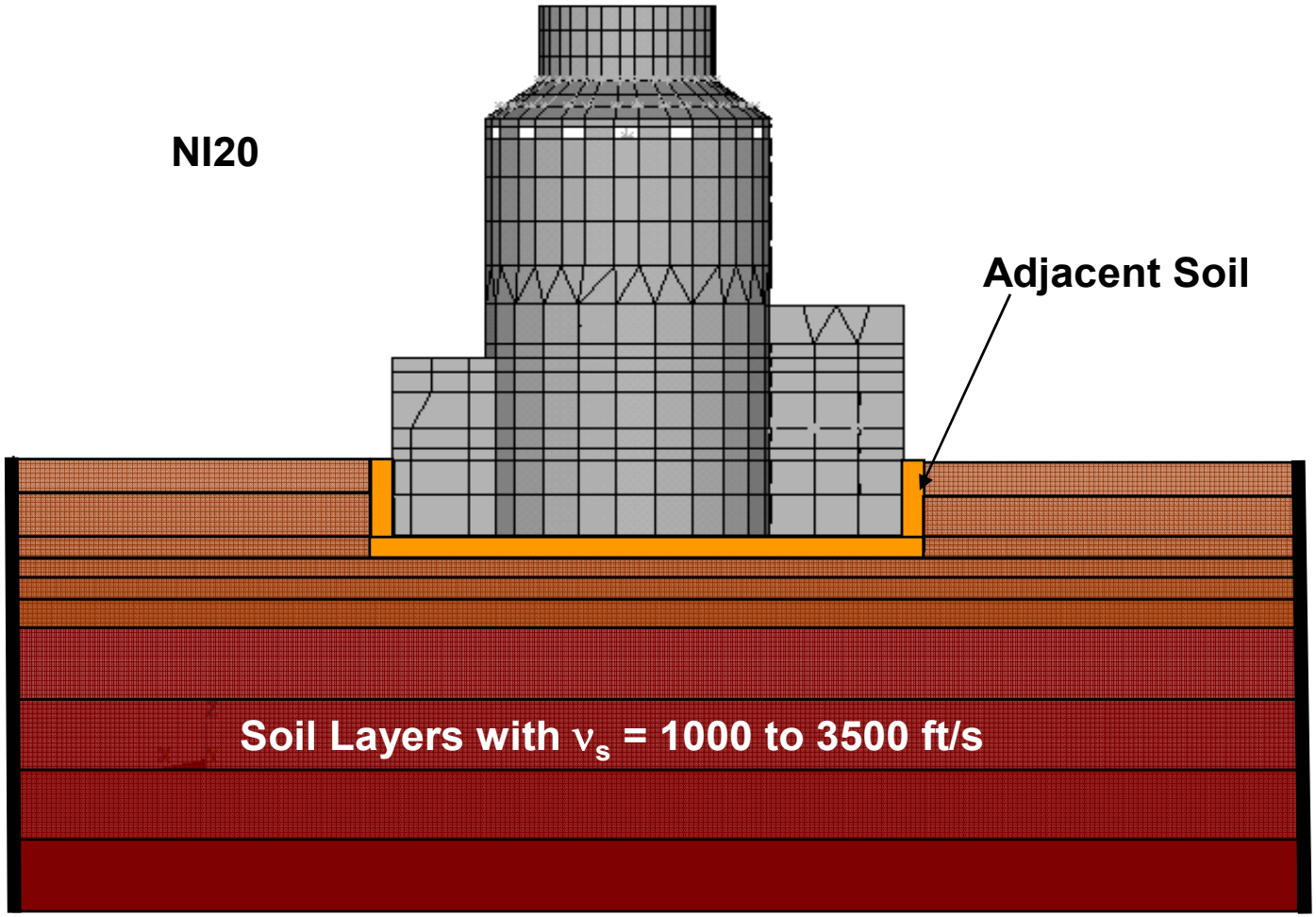
Annex Building
(Seismic Category II)

Radwaste Building
(small steel-frame building)
Collapse would not impair the integrity of the Nuclear Island

Soil-Structure Interaction



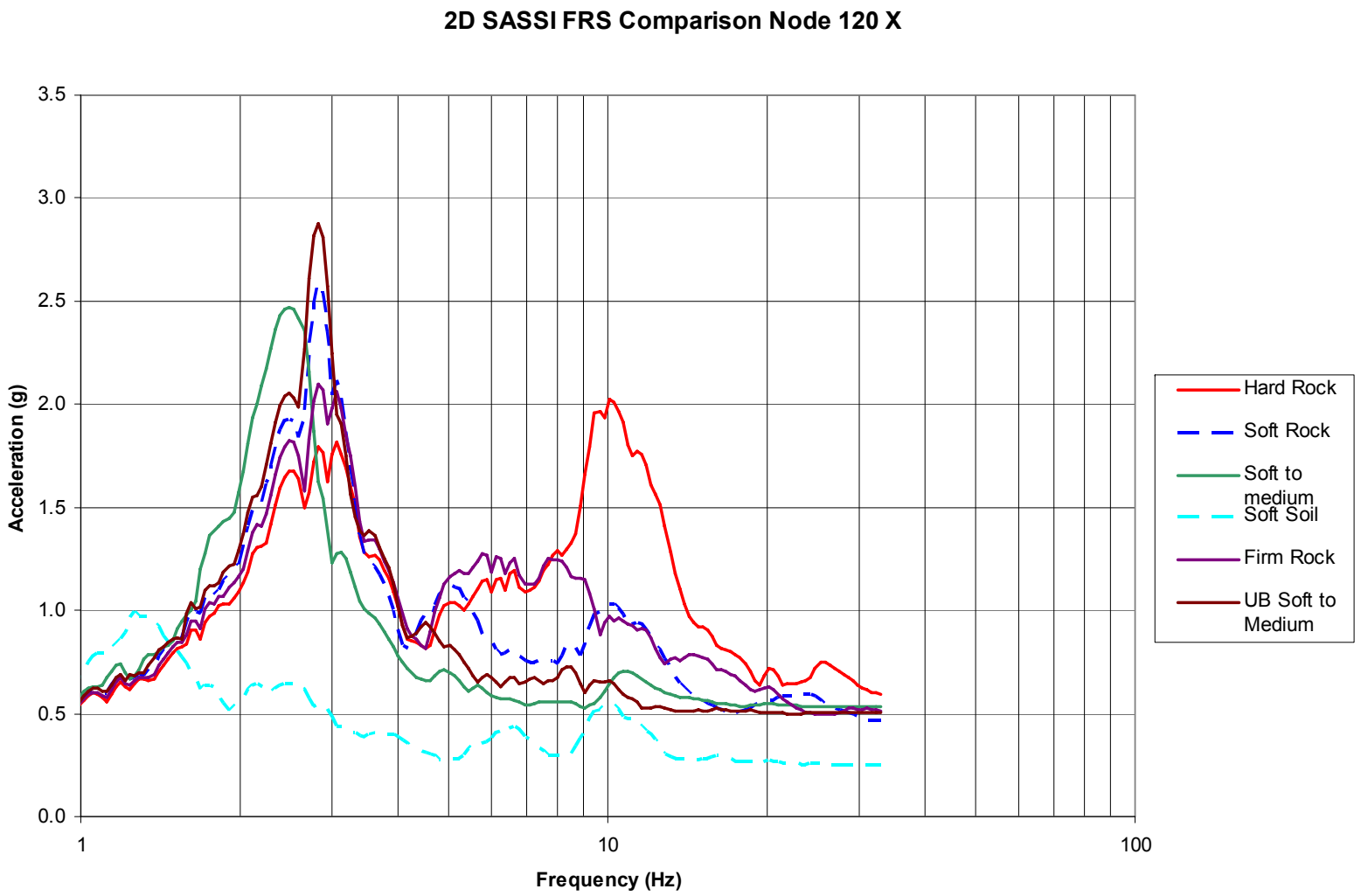
Soil Structure Interaction Model – ni20: Looking East



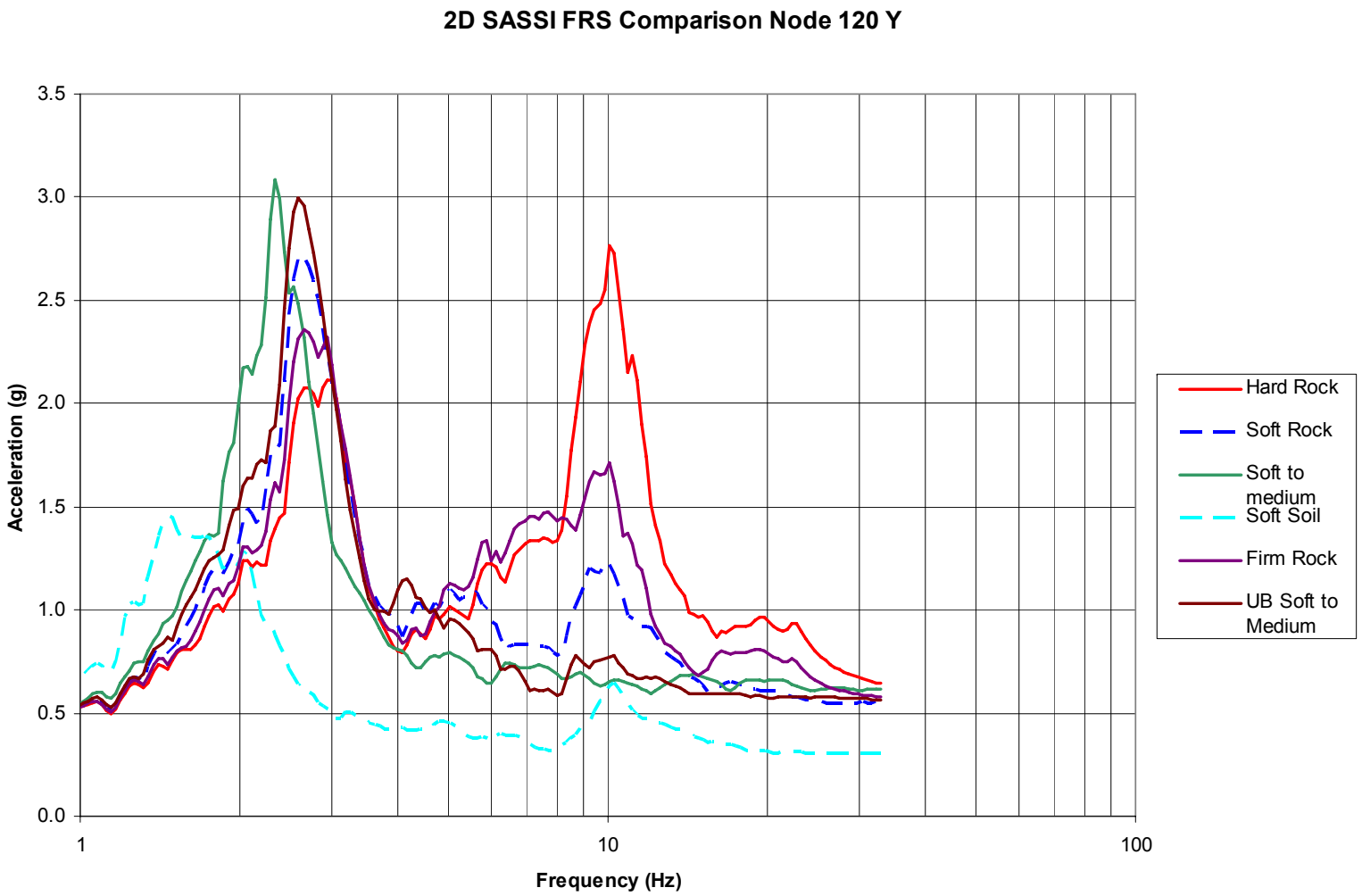
Development of Floor Response Spectra

- Hard Rock and Soil Cases
- Identification of Floor Response Spectra Nodes
- Enveloping of Base Conditions
- Grouping of FRS Nodes

2D SASSI FRS Comparison Node 120 X (ASB El. 179.6')

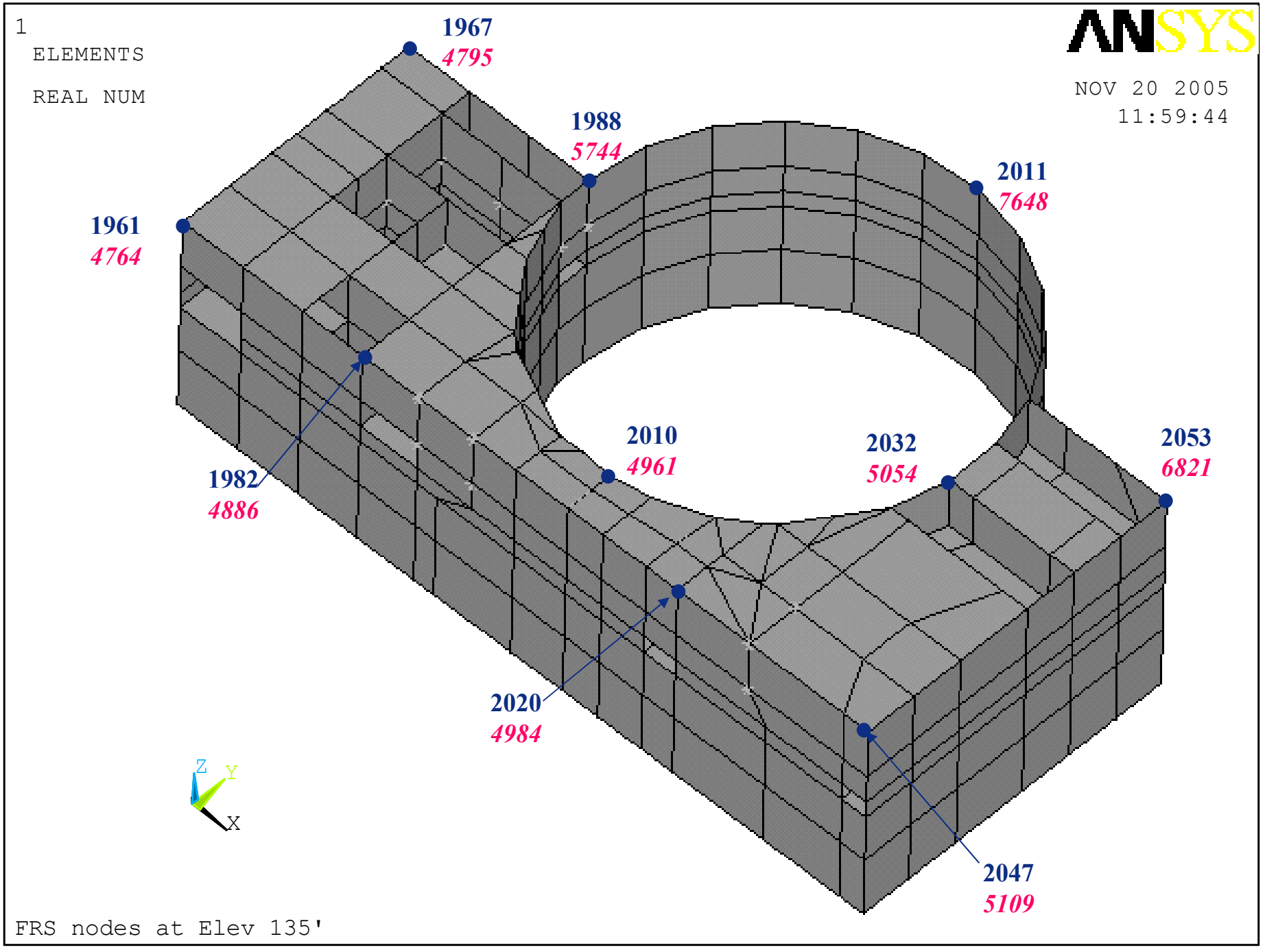


2D SASSI FRS Comparison Node 120 Y (ASB El. 179.6')



Hard Rock and 3D SASSI Soil Cases

- **Hard Rock (Fixed Base, ni10)**
- **Firm rock**
- **Upper bound soft to medium**
- **Soft to medium**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ELEMENTS
REAL NUM
ANSYS
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4795
1988
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2011
7648
1961
4764
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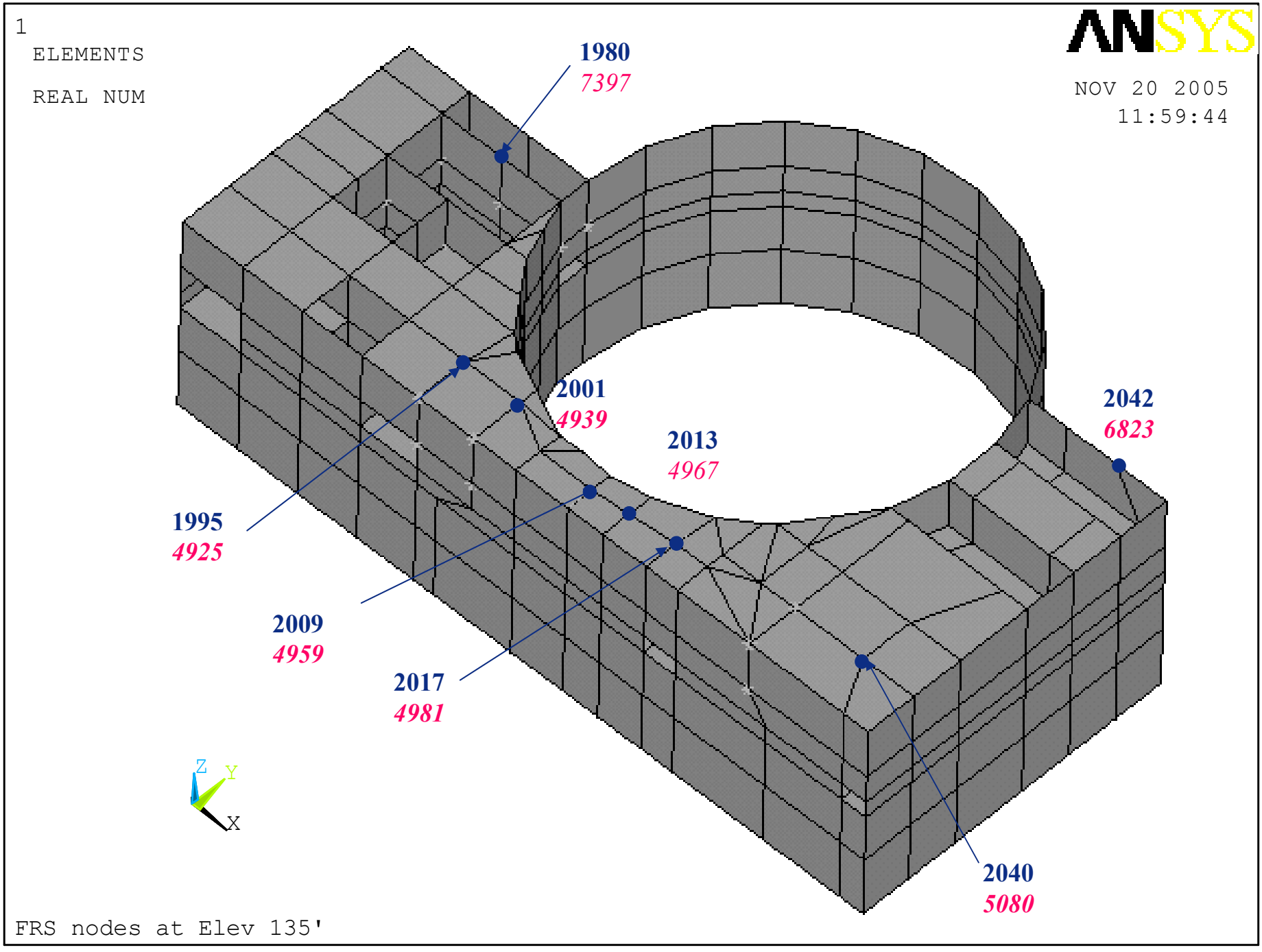
2047
5109
Z
Y
X
FRS nodes at Elev 135'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2009
4959
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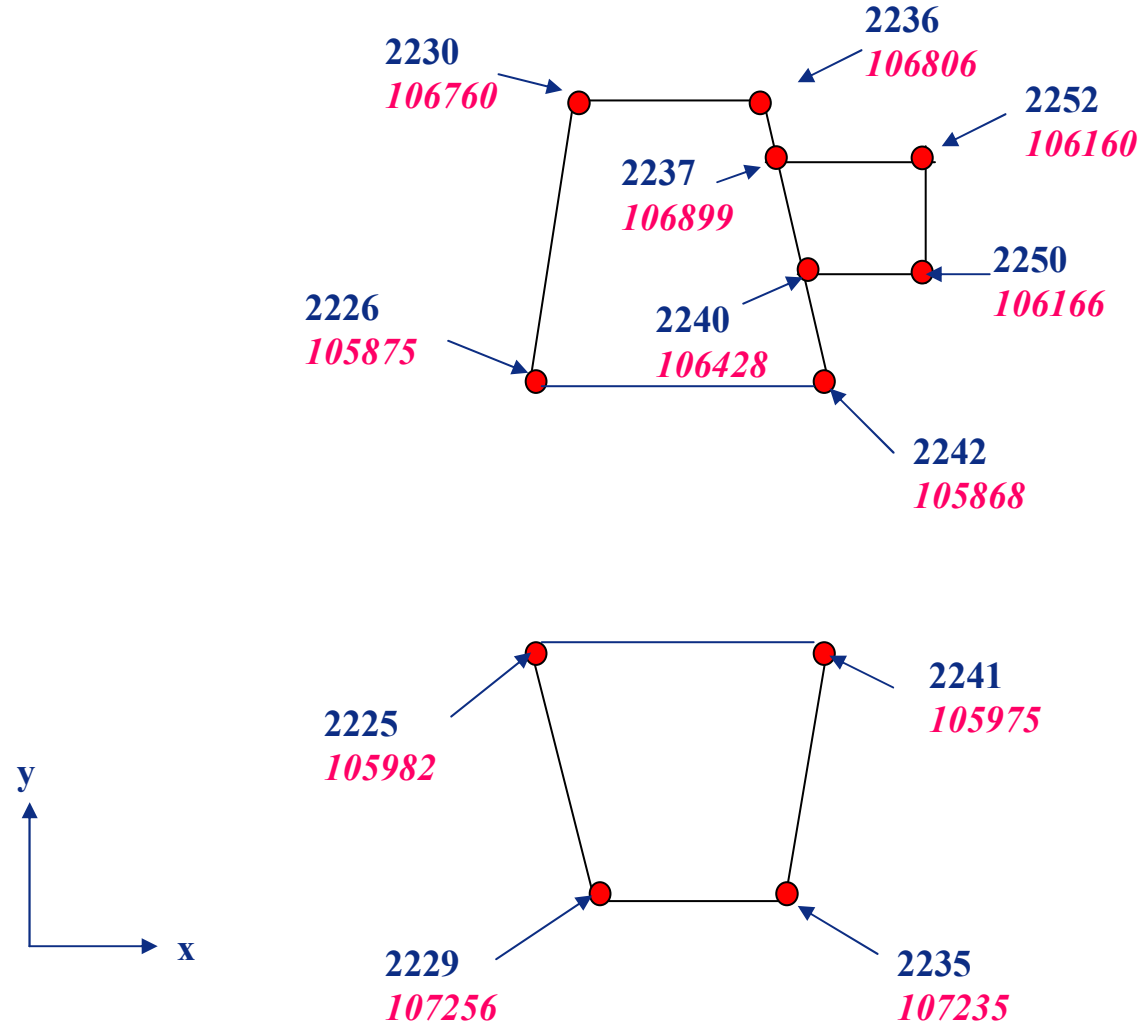
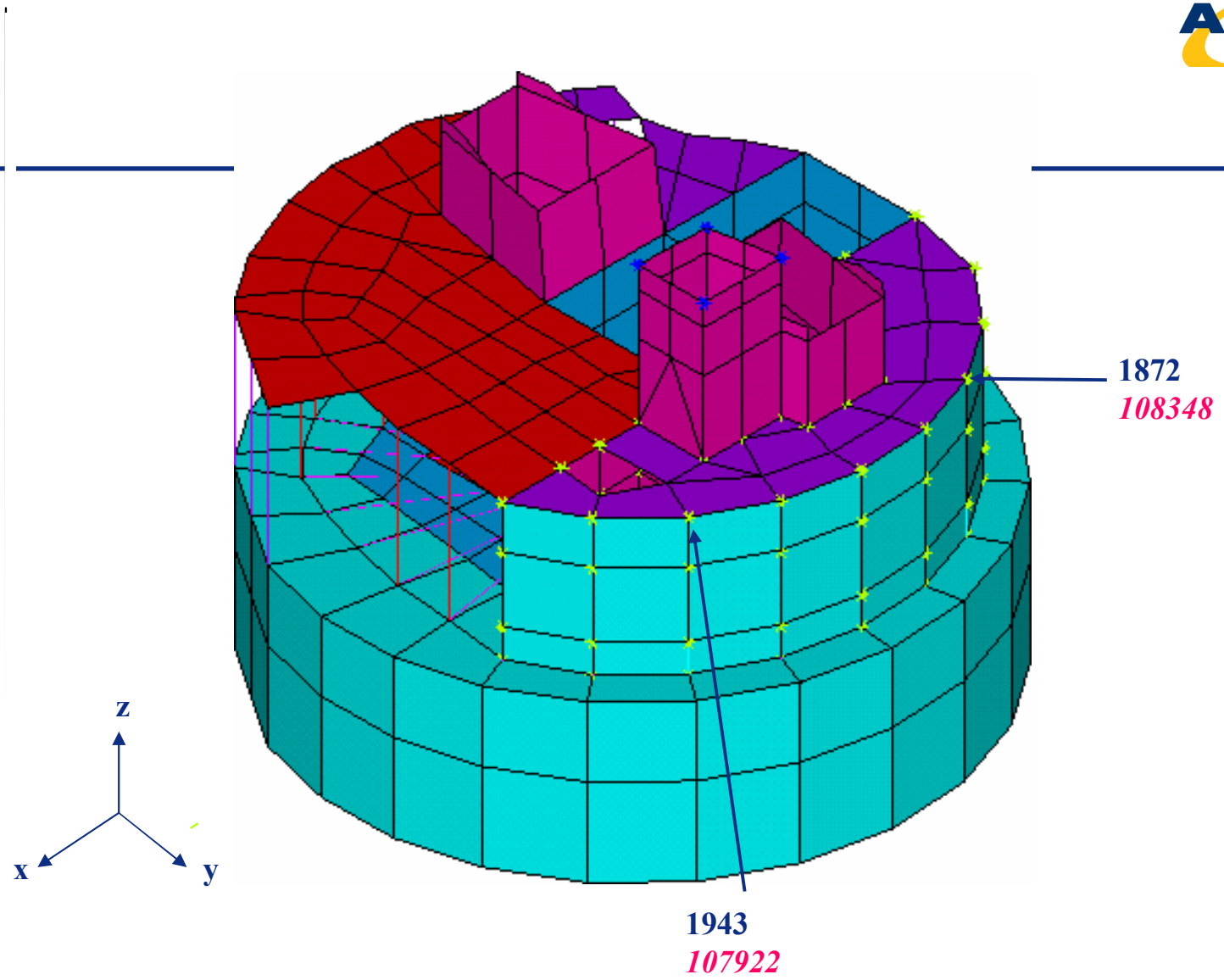
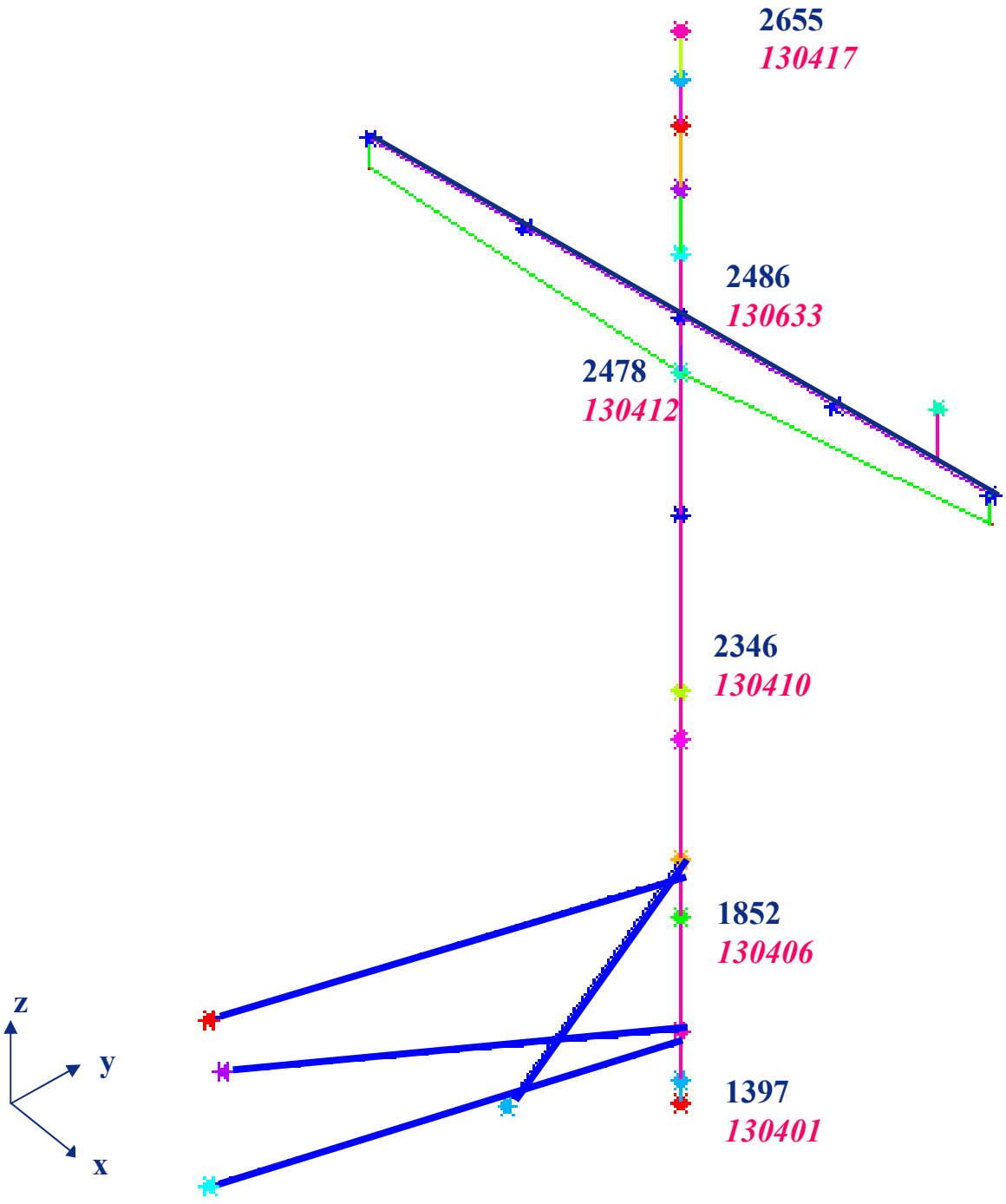
5080
Z
Y
X
FRS nodes at Elev 135'

Critical nodes for elevation 153





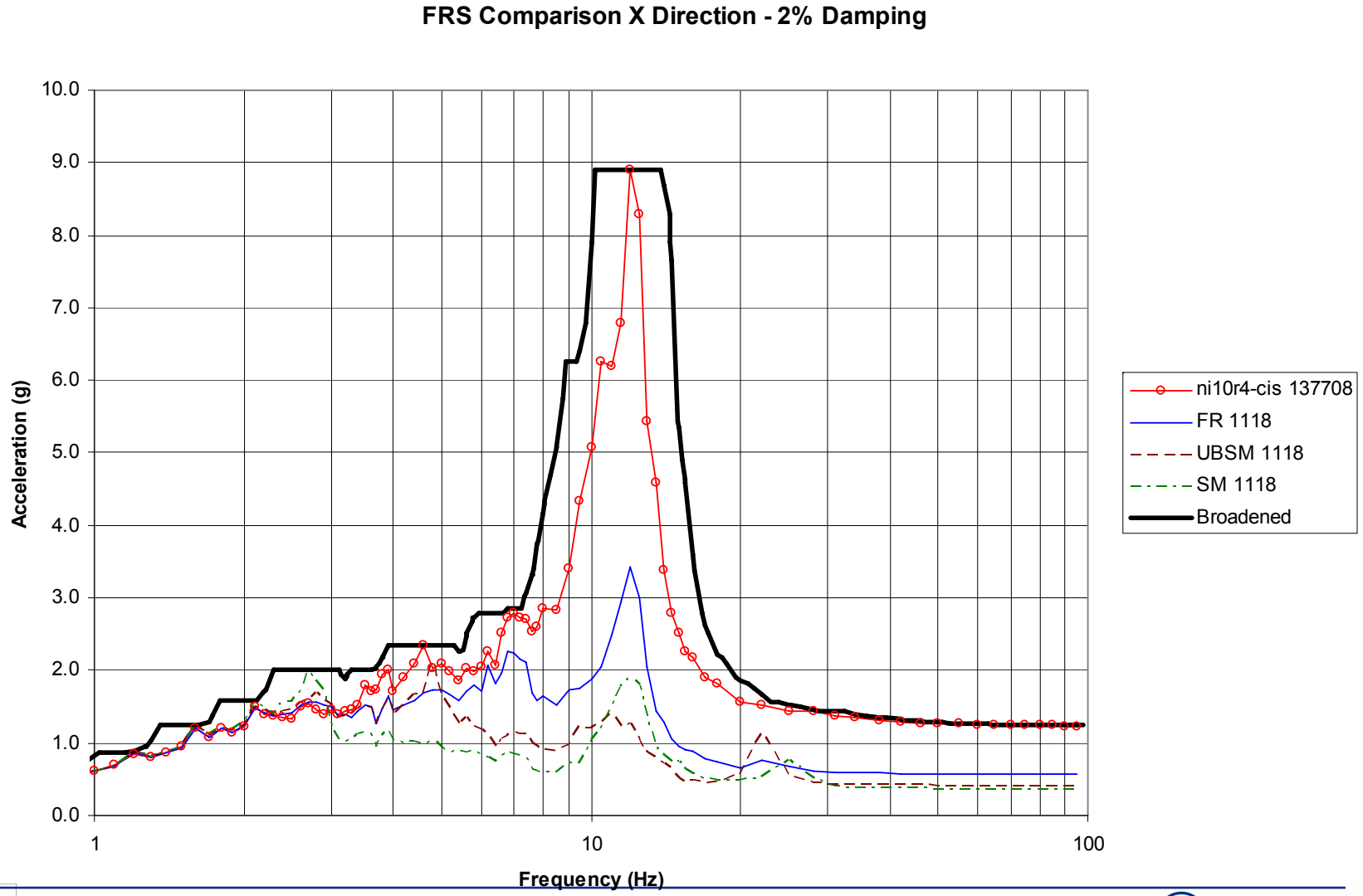
Critical nodes at isometric view


2655
130417
2486
130633
2478
130412
2346
130410
1852
130406
1397
130401
z
y
x

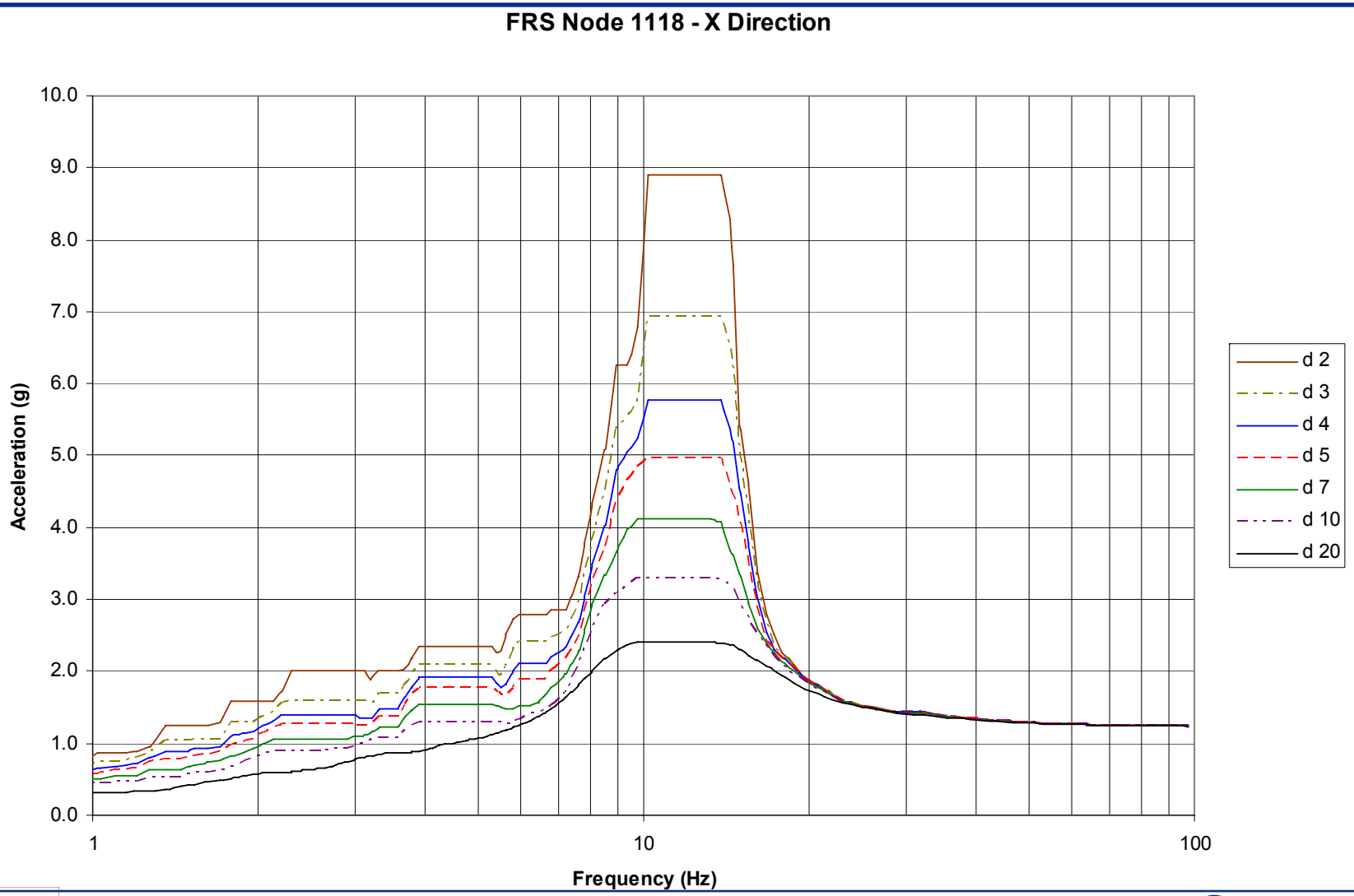
SEISMIC RESULTS

- Comparison of response spectra to hard rock stick spectra equivalent static accelerations
- Maximum seismic displacements
- Comparison of forces, moments, and stress for building design

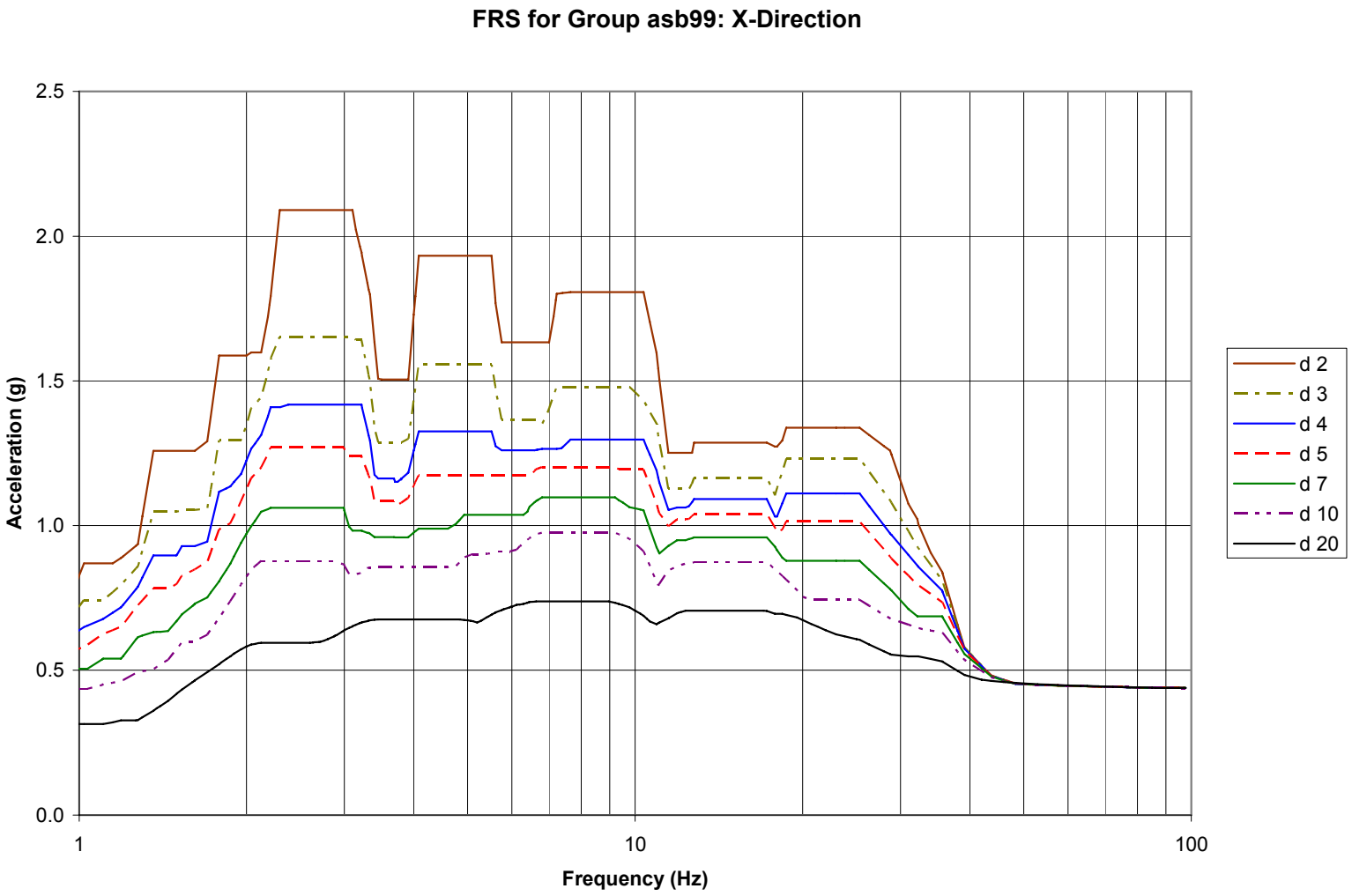
Single Node Enveloping of Soil Conditions



Broadening of Floor Response Spectra Nodes



Grouping of Floor Response Spectra Nodes

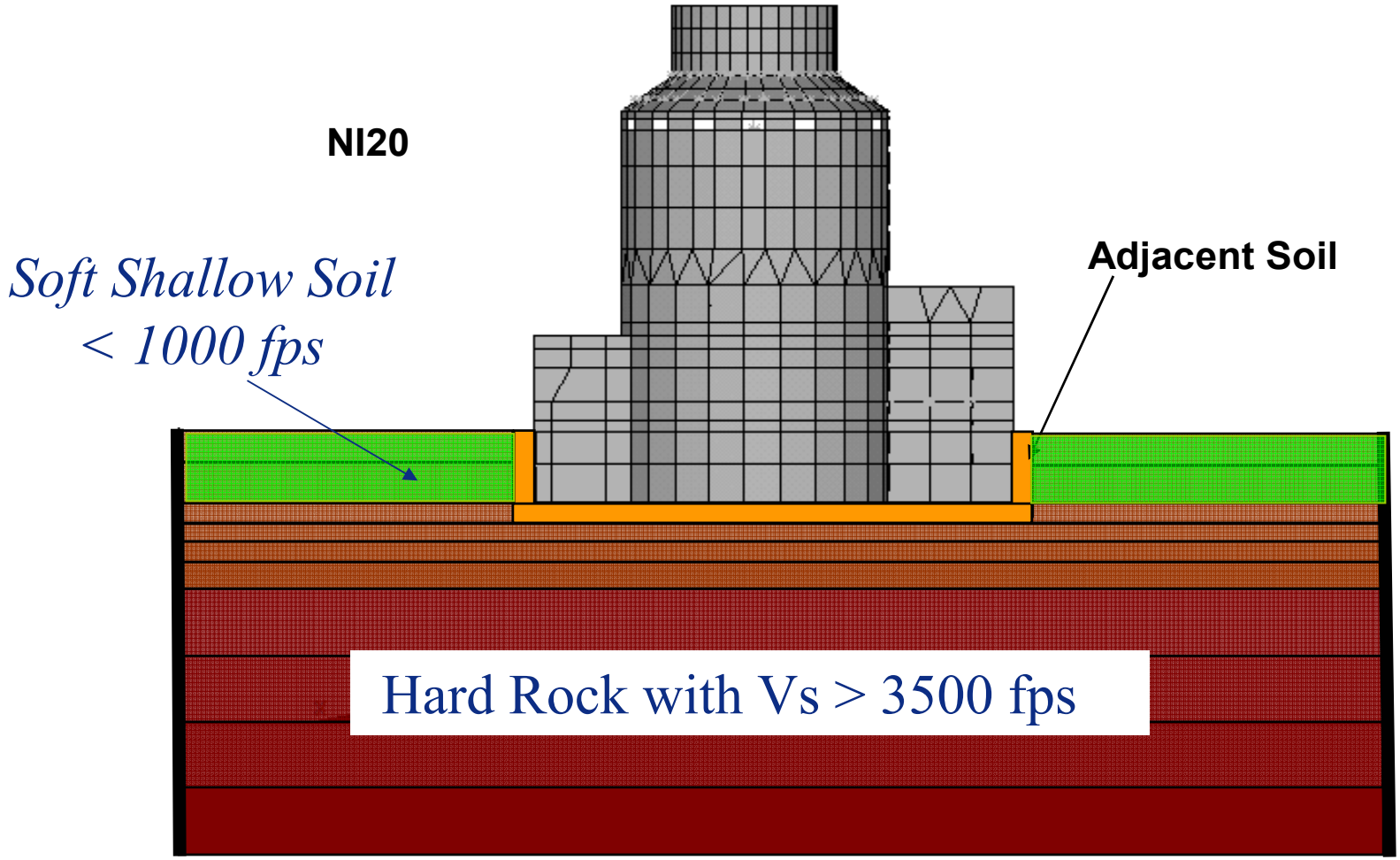


SEISMIC ANALYSES RESULTS

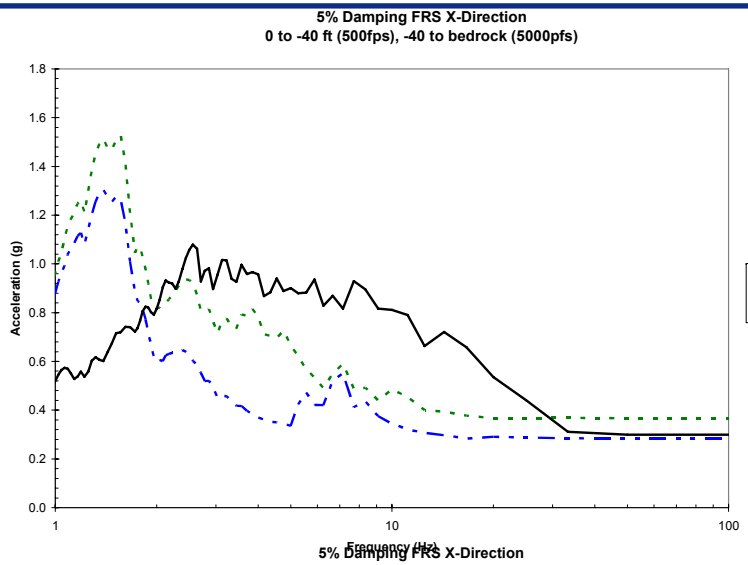
The site is acceptable for construction of the AP1000 if the floor response spectra from the site-specific evaluation do not exceed the AP1000 spectra given for the following six key locations:

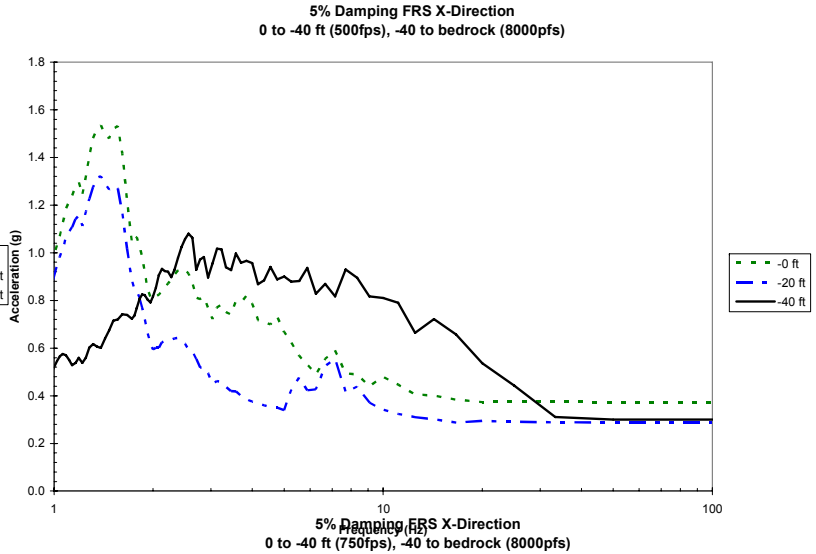
- **CIS at Reactor Vessel Support Location**
- **CIS at Operating Deck**
- **ASB North East Corner at Control Room Ceiling**
- **ASB Corner of Fuel Building Roof at Shield Building**
- **ASB Shield Building Roof Area**
- **SCV Near Polar Crane**

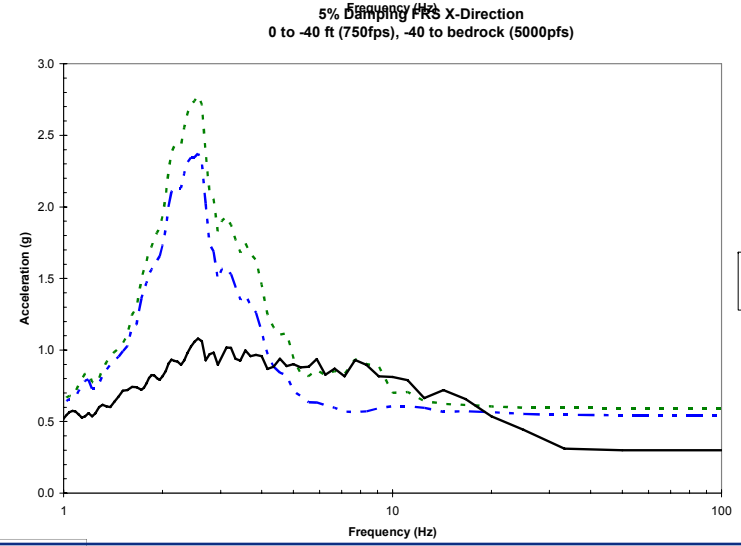
Shallow Soil Sites with Soft Soil on top of competent Rock

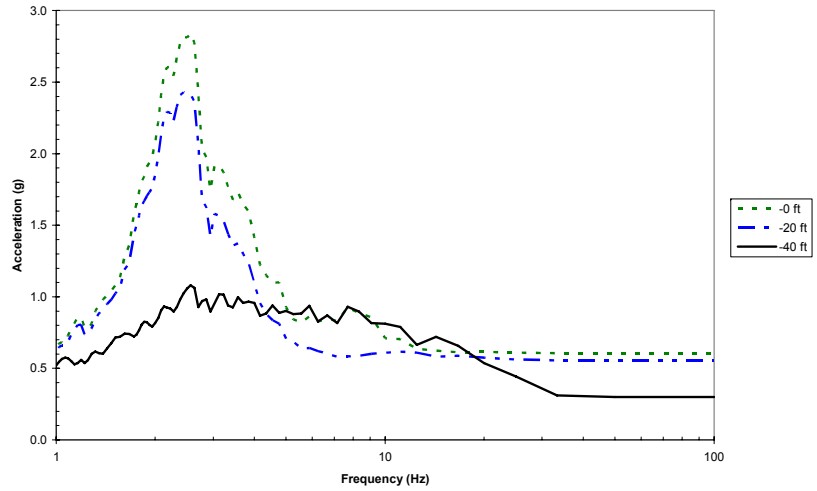


SHAKE Analyses

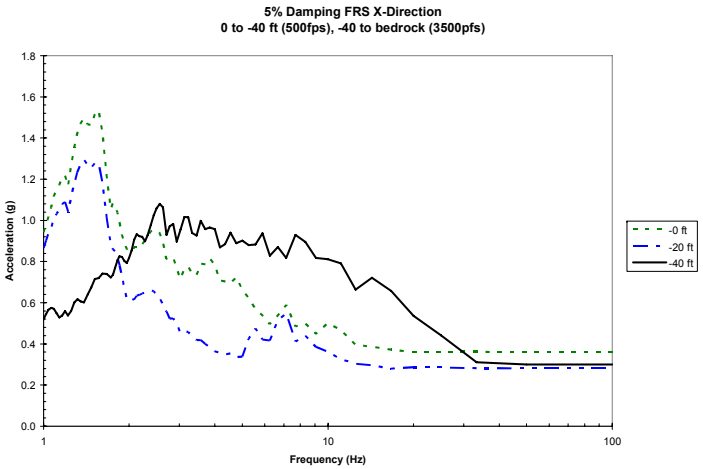


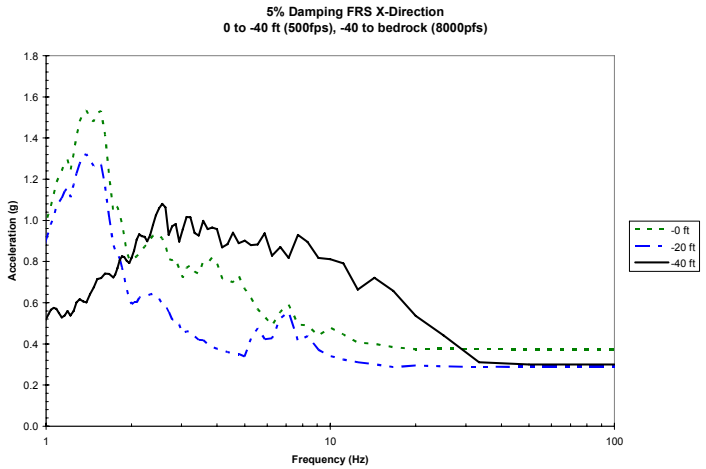


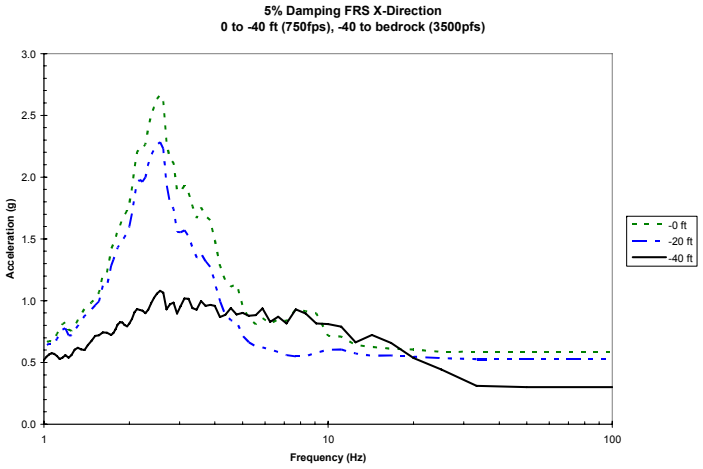


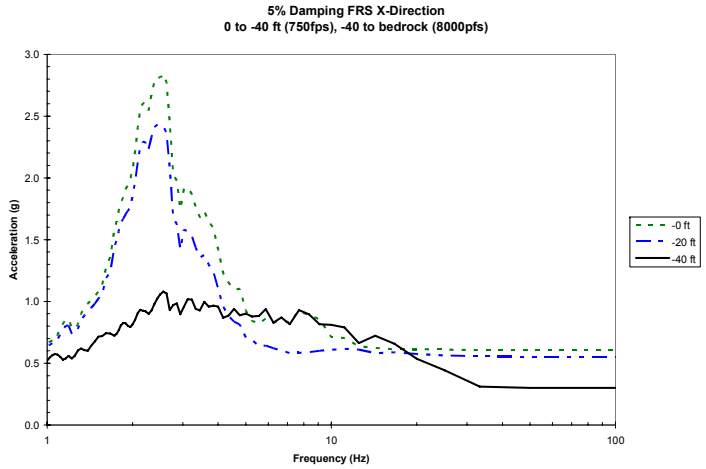


SHAKE Analyses

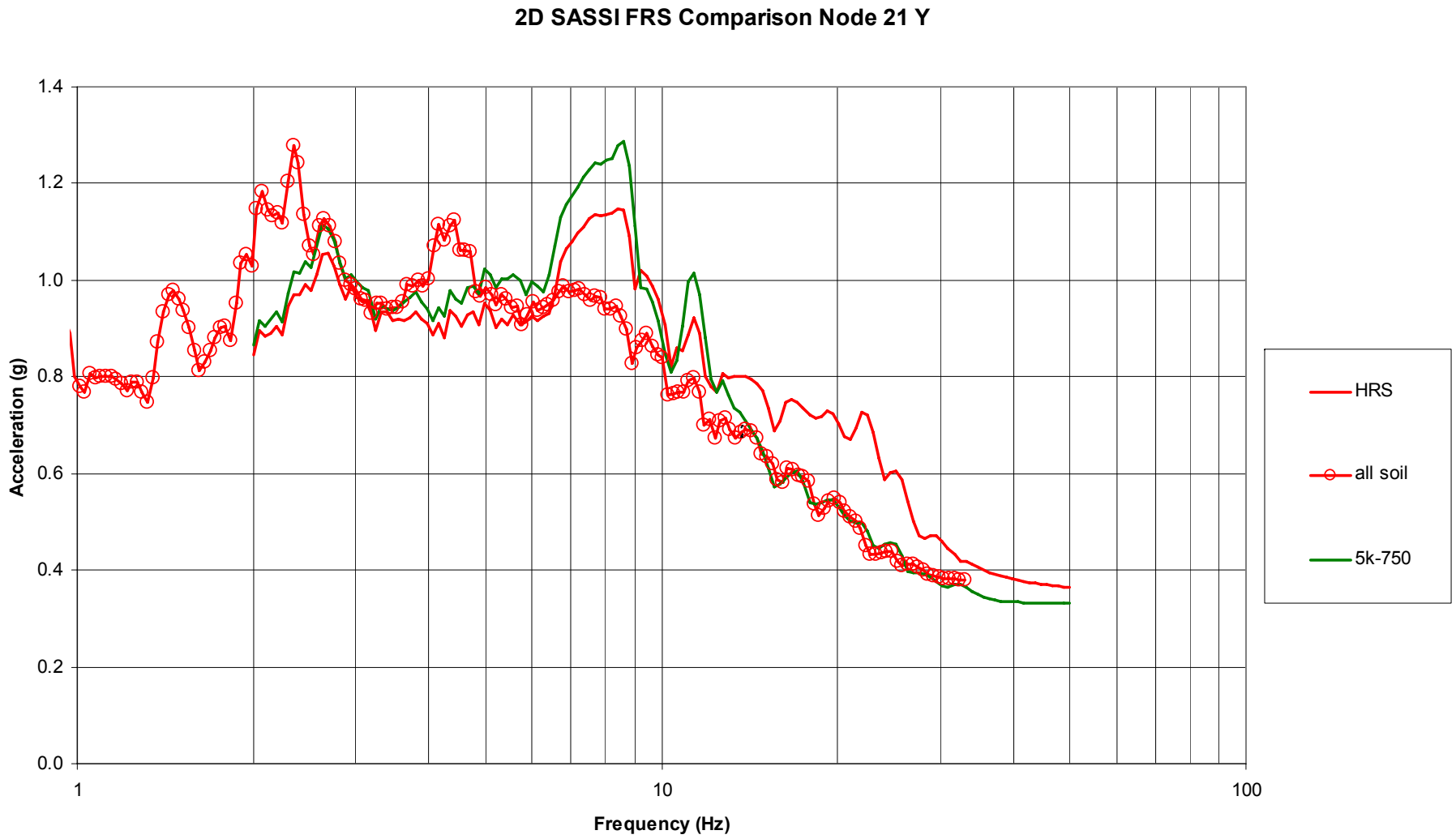




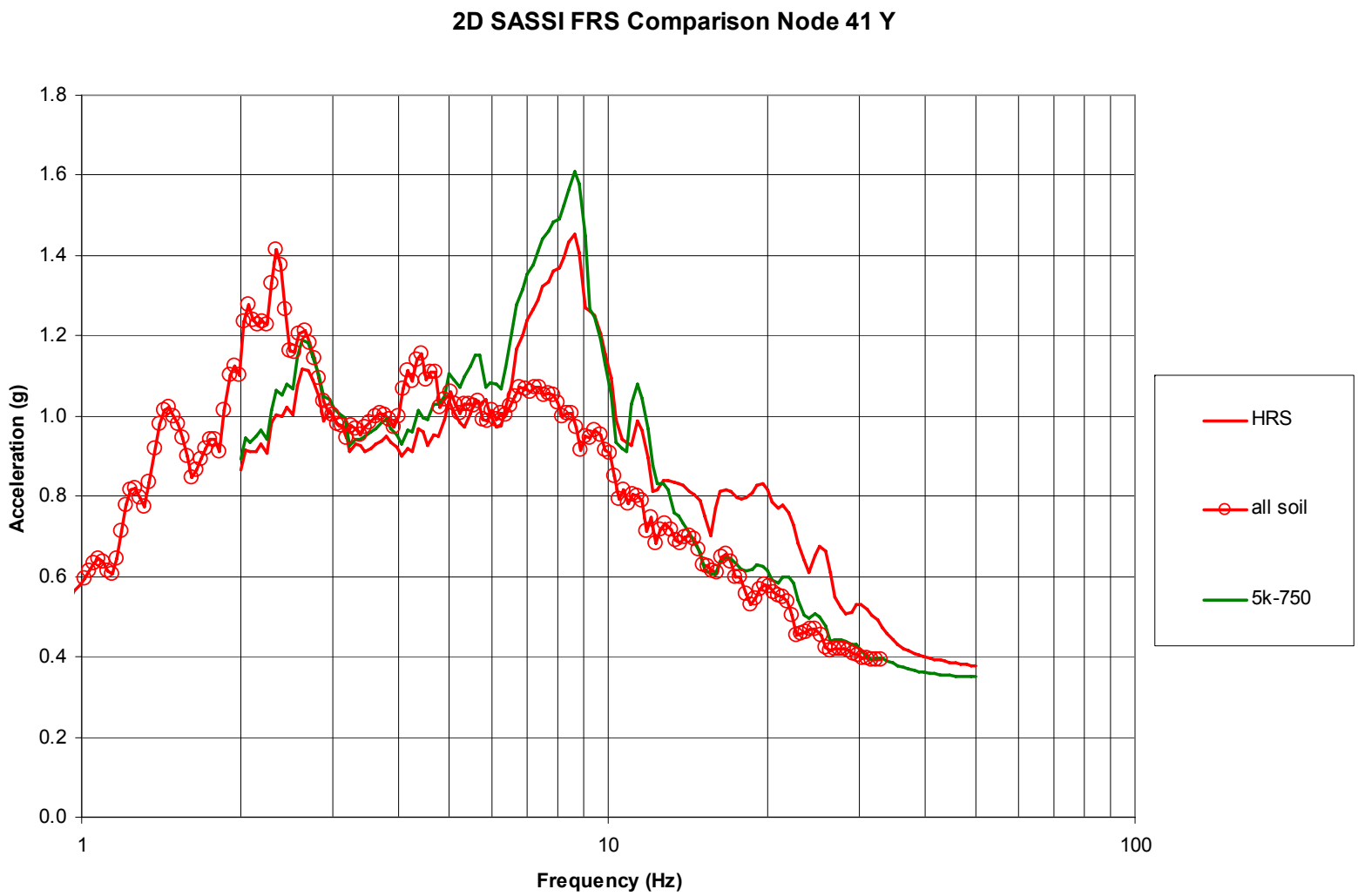




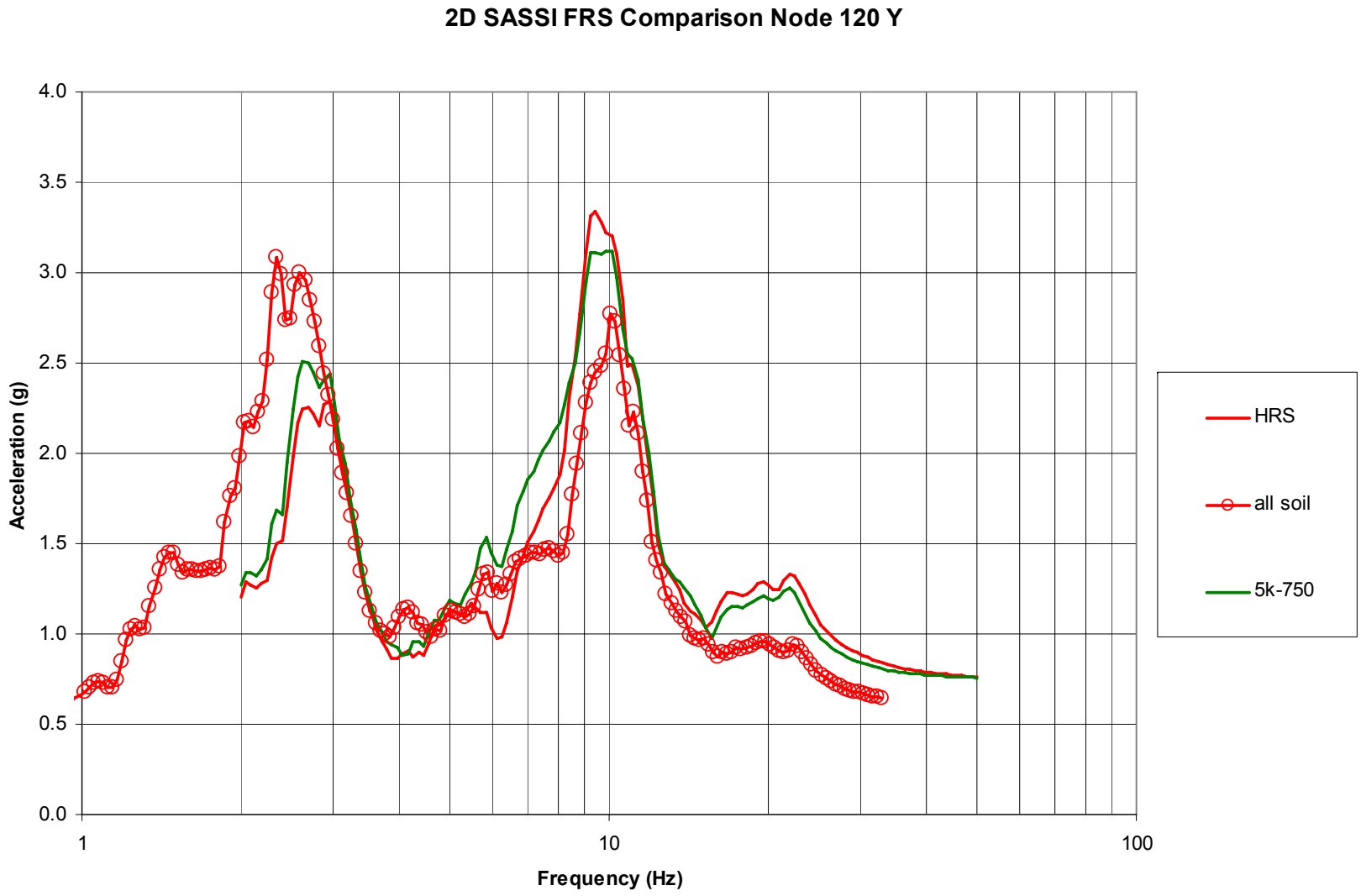
2D SASSI analyses – Thin Soft Soil Comparison ASB at EL 82.5'



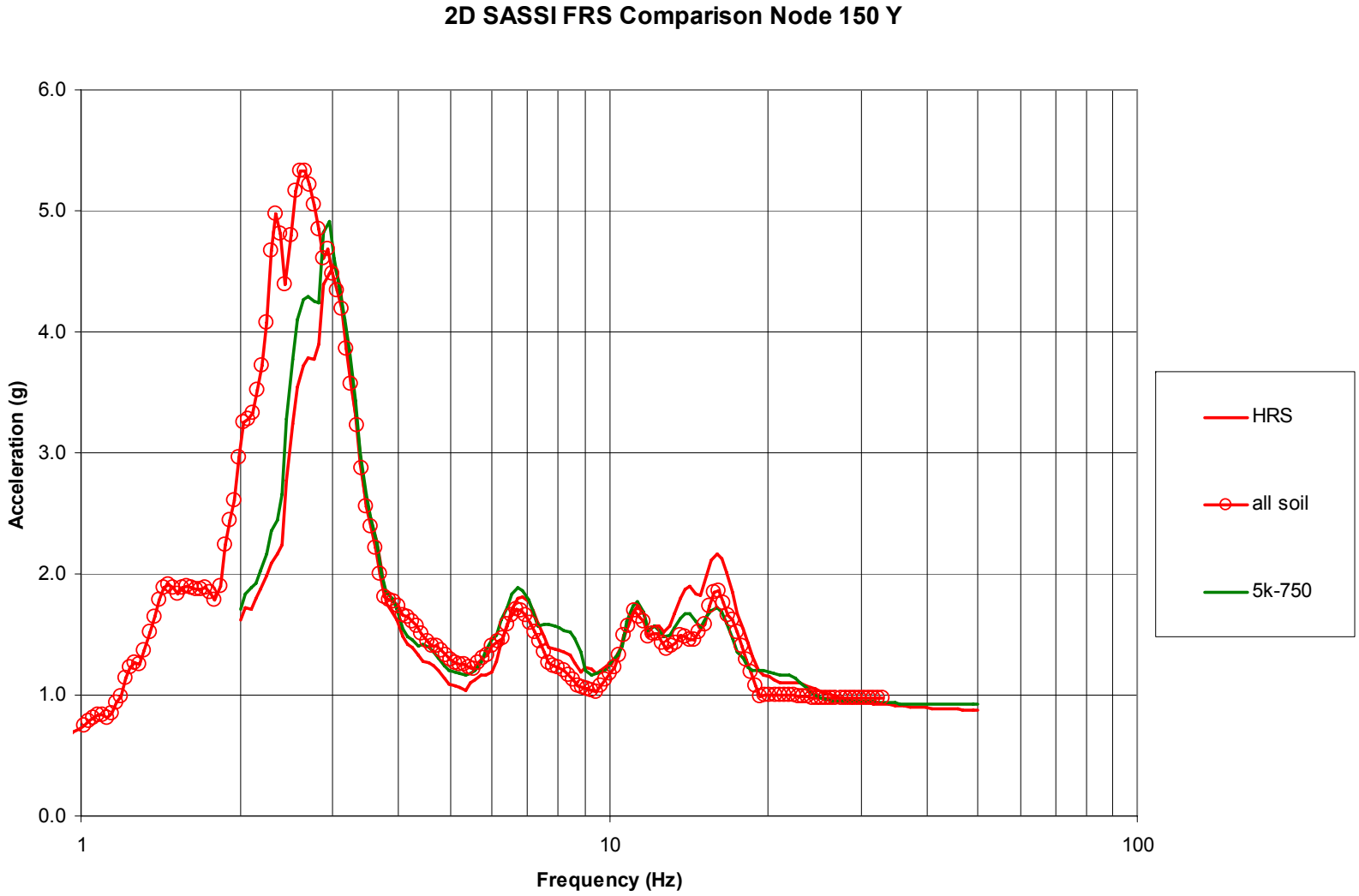
2D SASSI analyses – Thin Soft Soil Comparison
ASB at Grade



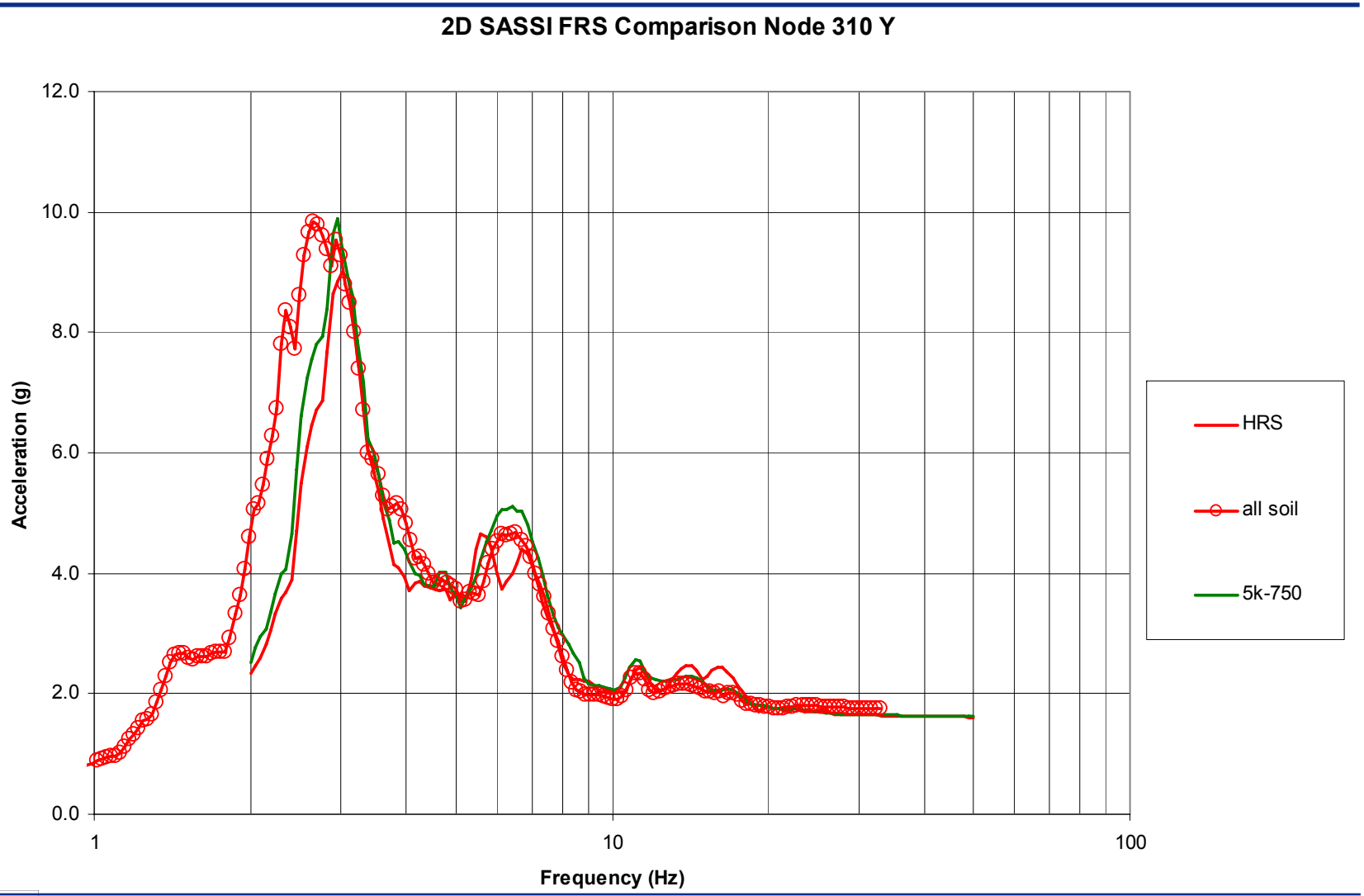
2D SASSI analyses – Thin Soft Soil Comparison
SCV at Polar Crane Elevation



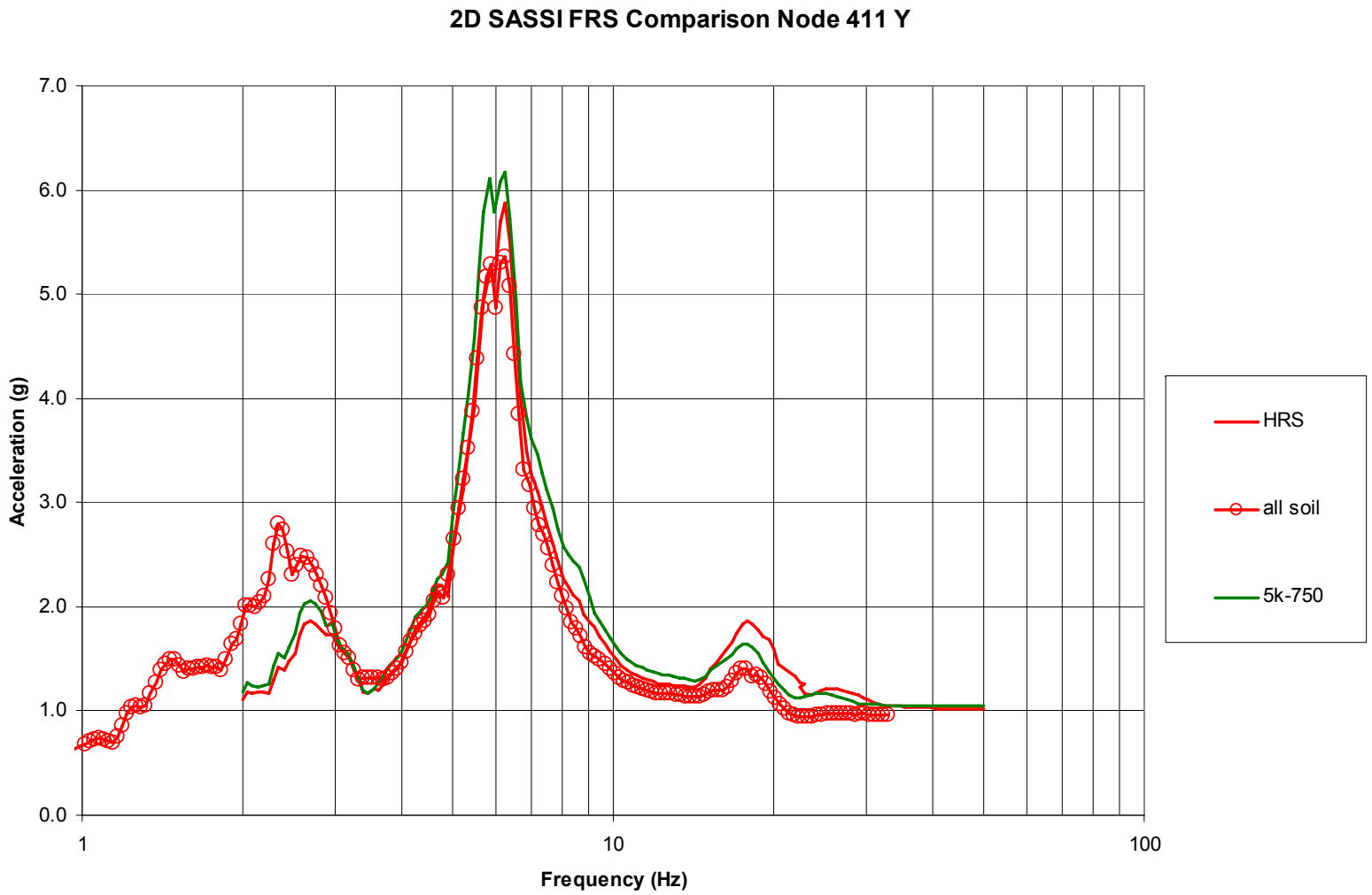
2D SASSI analyses – Thin Soft Soil Comparison ASB at EL 82.5'



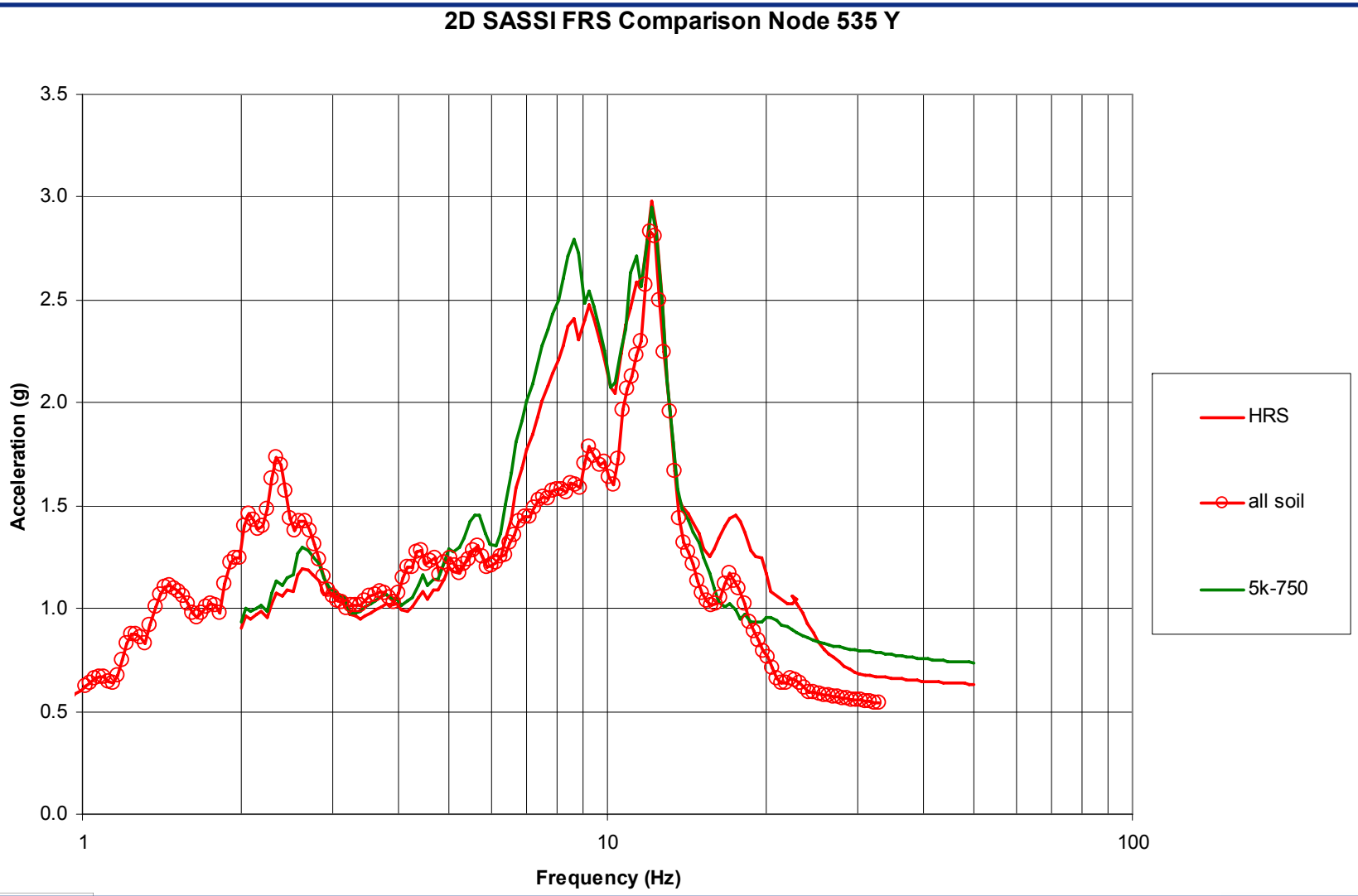
2D SASSI analyses – Thin Soft Soil Comparison ASB at 333’



2D SASSI analyses – Thin Soft Soil Comparison
SCV at Polar Crane Elevation



2D SASSI analyses – Thin Soft Soil Comparison
CIS at Elevation 135'



Resolution of Ground Motion Issues

- At ESP the seismic ground response spectrum is approved
- At COL compliance with design certification site parameters is demonstrated.
- At COL SSE determination analyses may be based on NRC approved alternative methodologies such as performance-based PSHA methodologies

Section 3.7 AP1000 Design Certification Strategy