3-Days Training for Practical Application of ACS SASSI NQA V4 to Seismic SSI Analysis of Nuclear Facility Structures

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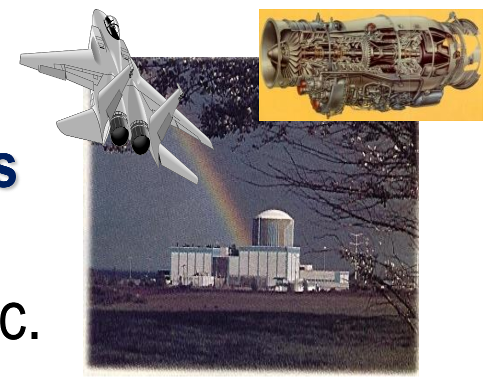

Part 2: Advanced Options A-AA, NON and PRO

USNRC Office, Rockville, MD

June 25-27, 2019

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Presentation Content

1. Option A-AA: Integrating with ANSYS
2. Option NON: Nonlinear Structure (Concrete walls, Isolators)
3. Option PRO: Probabilistic Site Response and SSI Analyses

Advanced options based on the ASCE 4-16 and ASCE 43-20 recommendations.

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1. Option A-AA: Integrating with ANSYS

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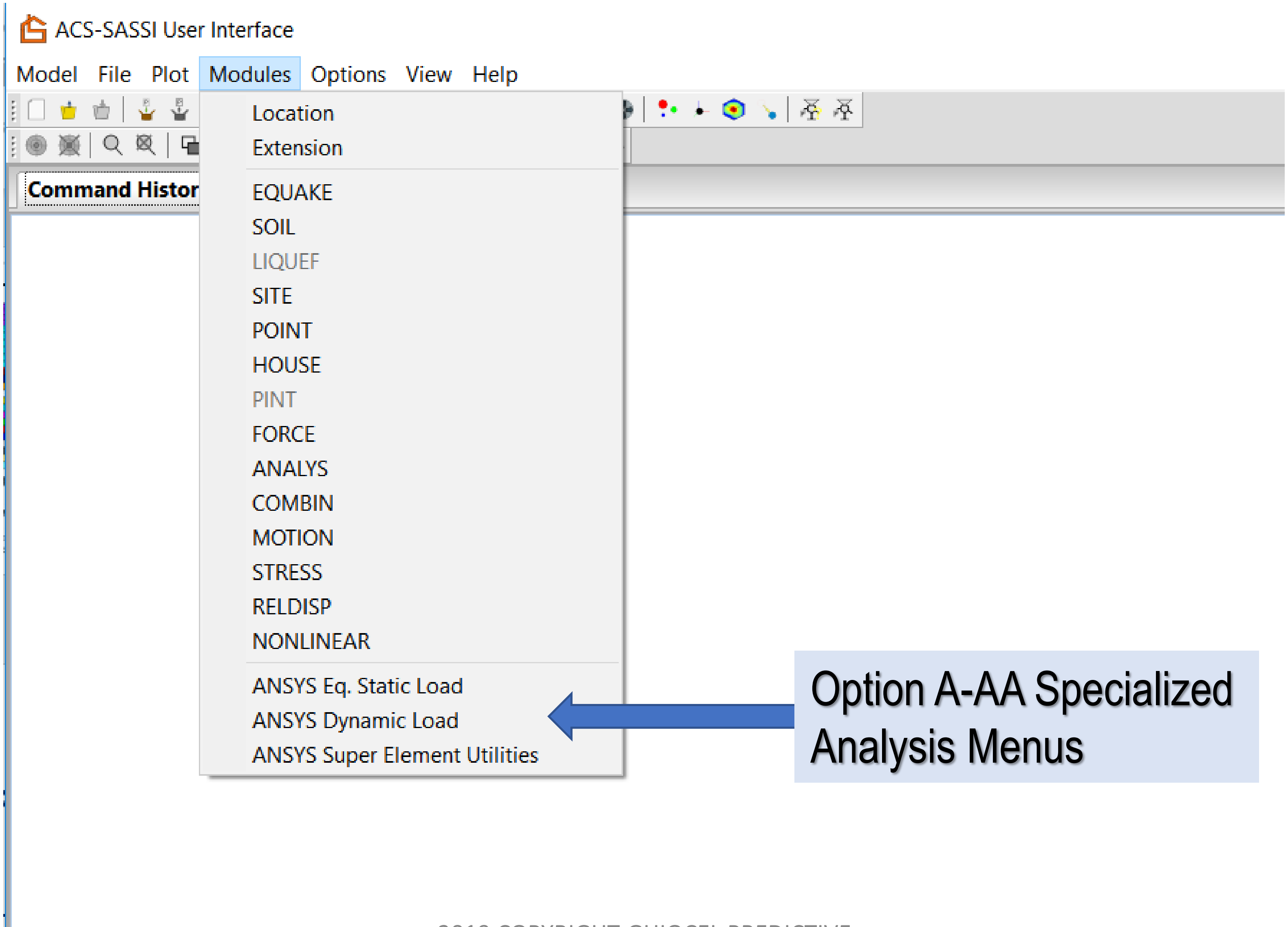
Option A-AA Menu Selections



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ACS SASSI-ANSYS Integration Capabilities (Options A and AA)

Two engineering analysis options in ACS SASSI:

i) ***One Step analysis*** *using ACS SASSI* for computing overall SSI responses of ACS SASSI or ANSYS FE model *(Option AA)*

ii) ***Two Step analysis*** *using ACS SASSI in 1st step and ANSYS in 2nd step.* The 2nd step uses SSI response as input BCs *(Option A)*

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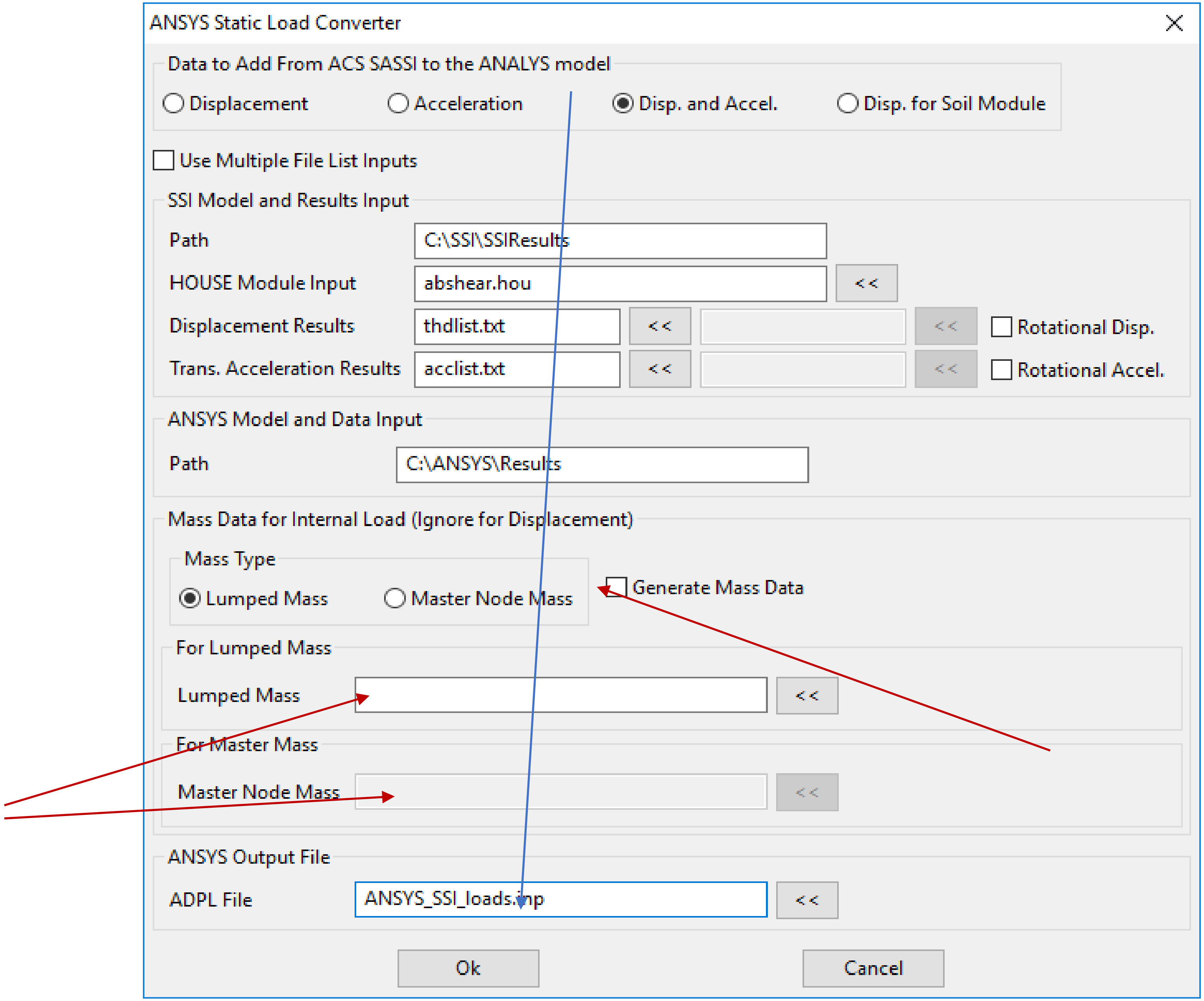
UI Input for *Option A Equivalent Static Option*



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OPTION A: ACS SASSI-ANSYS Interface for SSI Analysis Using ANSYS Models

ACS SASSI-ANSYS interfacing provides useful analysis capabilities:

For *structural stress analysis (Demo 5)*:

- *ANSYS Equivalent-Static Seismic SSI Analysis* Using Refined FE Models (including refined mesh, element types including local nonlinearities, nonlinear materials, contact elements, etc.)
- *ANSYS Dynamic Seismic SSI Analysis* Using More Refined FE Models (including refined mesh, element types including local nonlinearities, nonlinear materials, contact elements, etc.)

For *soil pressure computation (approximate) (Demo 6):*

- *ANSYS Equivalent-Static Seismic Soil Pressure Computation* including Soil-Foundation Separation Effects

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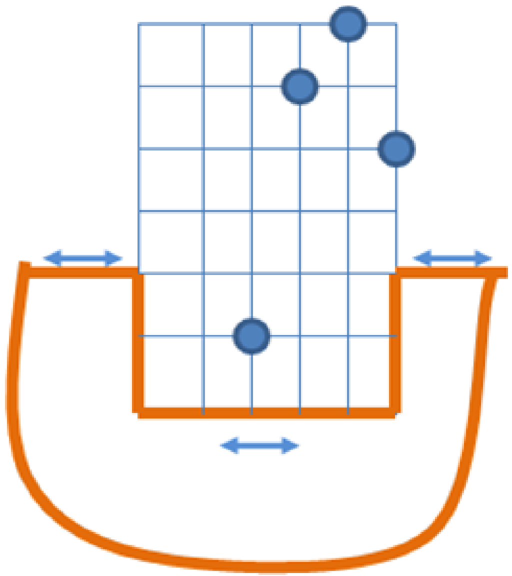
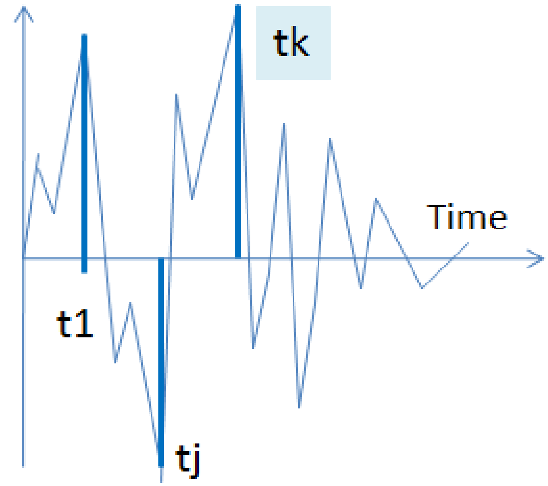
ACS SASSI Seismic SSI Analysis

Selected Critical Time Steps for Maximum Stresses
To be Used for Equivalent Static Structural Analysis

Computing Structural Stress/Forces

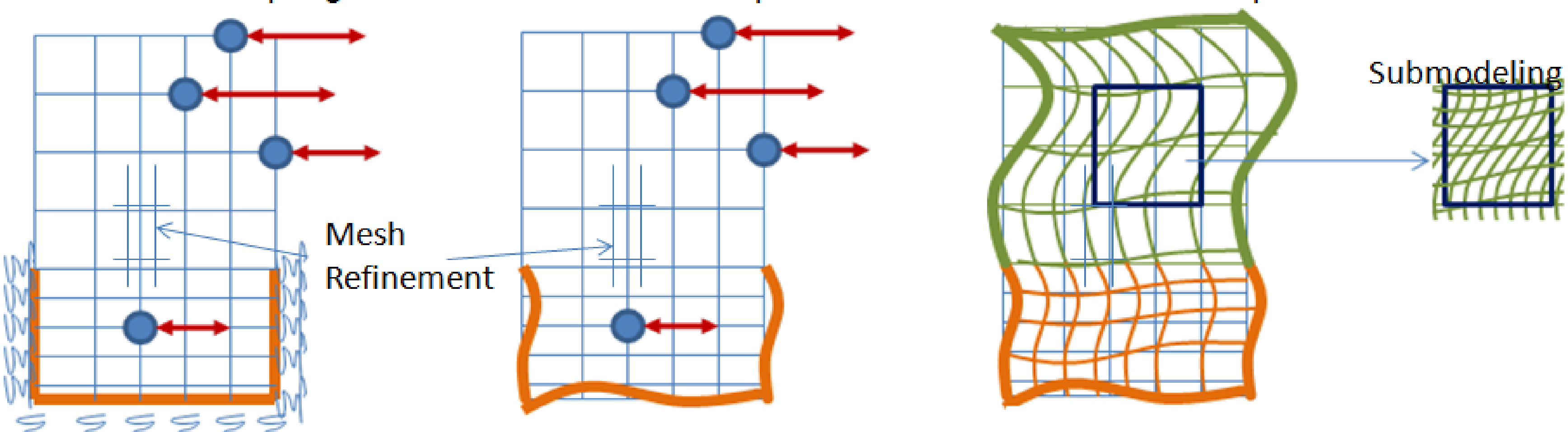


Structural Element Stress



SSI Solution Time Frames As Equivalent Static Structural Loading at Critical Time Steps

EQS Forces + BC Springs | EQS Forces + BC Displacements | EQS Relative Displacements



Variable Accuracy C-by-C | "Exact" | "Exact"

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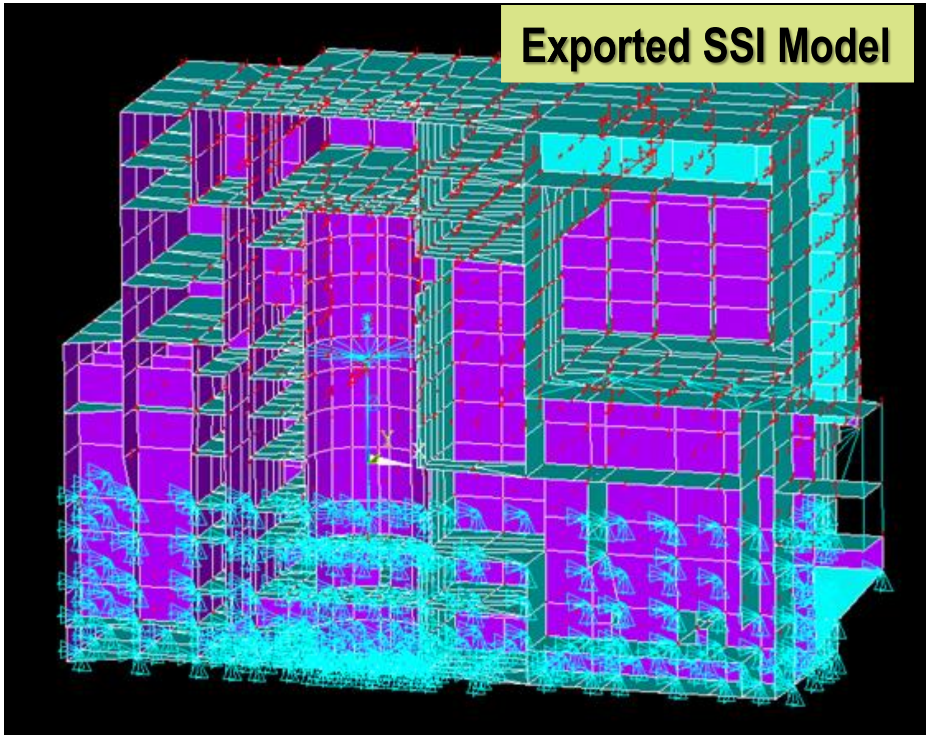
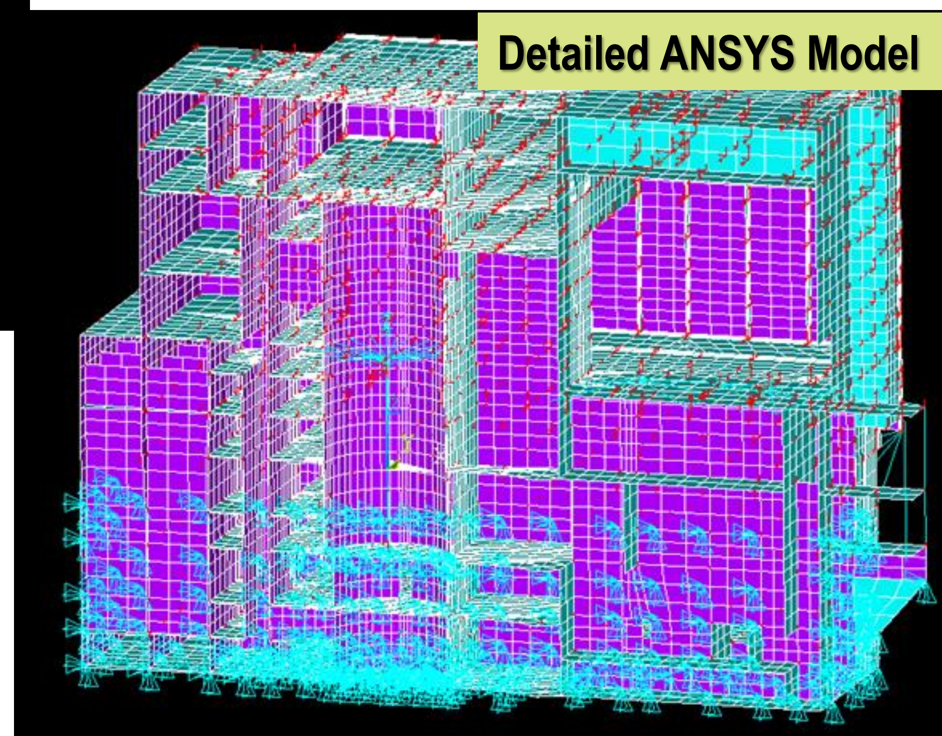
Option A for A Refined Seismic Stress Analysis (Demo 5)



ANSYS Structural Model Automatically Converted From ACS SASSI Using PREP Module



ANSYS Refined Structural Model Using EREFINE command or ANSYS GUI (rank 1-6)

Demo 5

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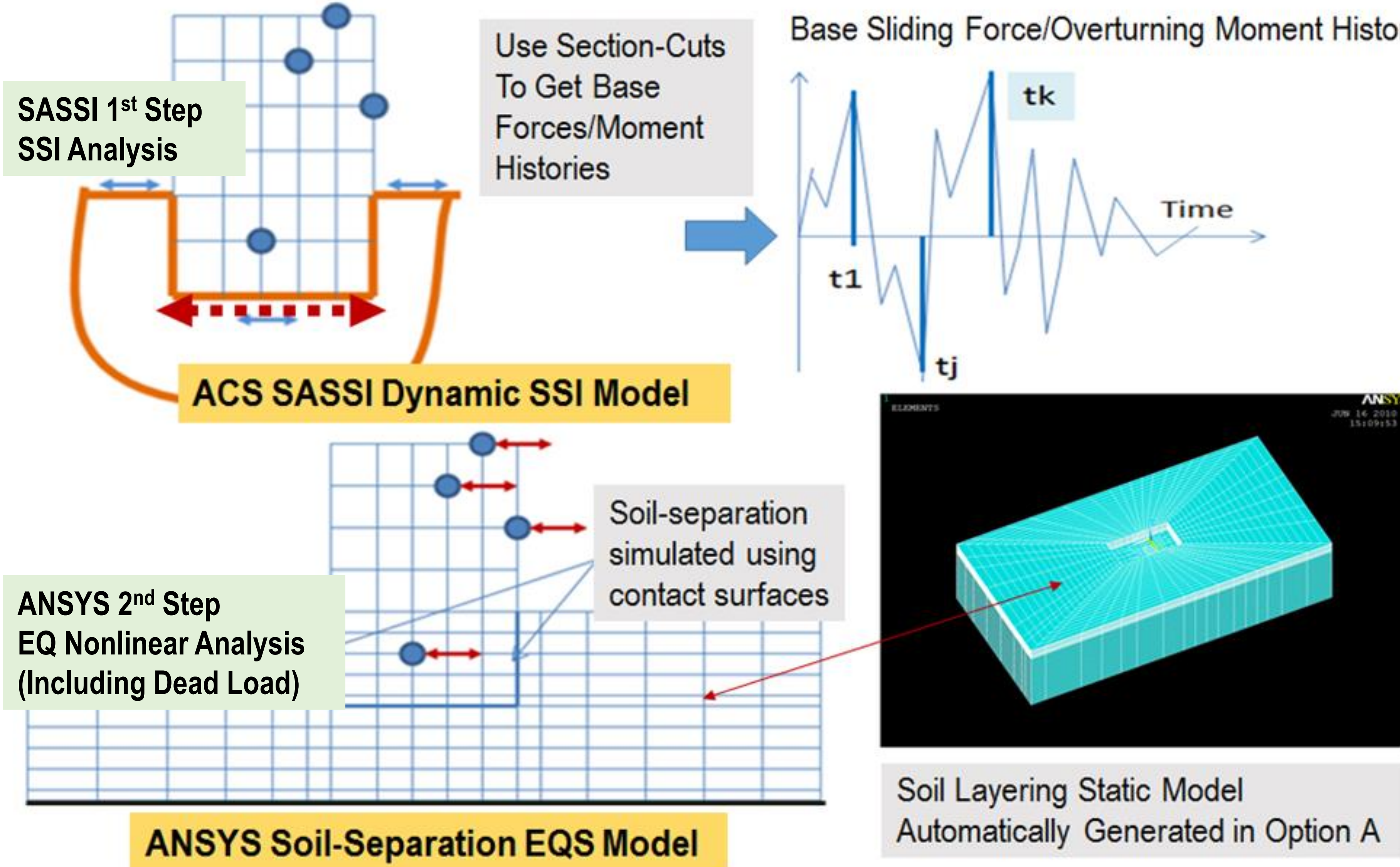
Option A-Based Nonlinear Analysis for Computing Soil Separation Effects (2nd Step is in ANSYS)



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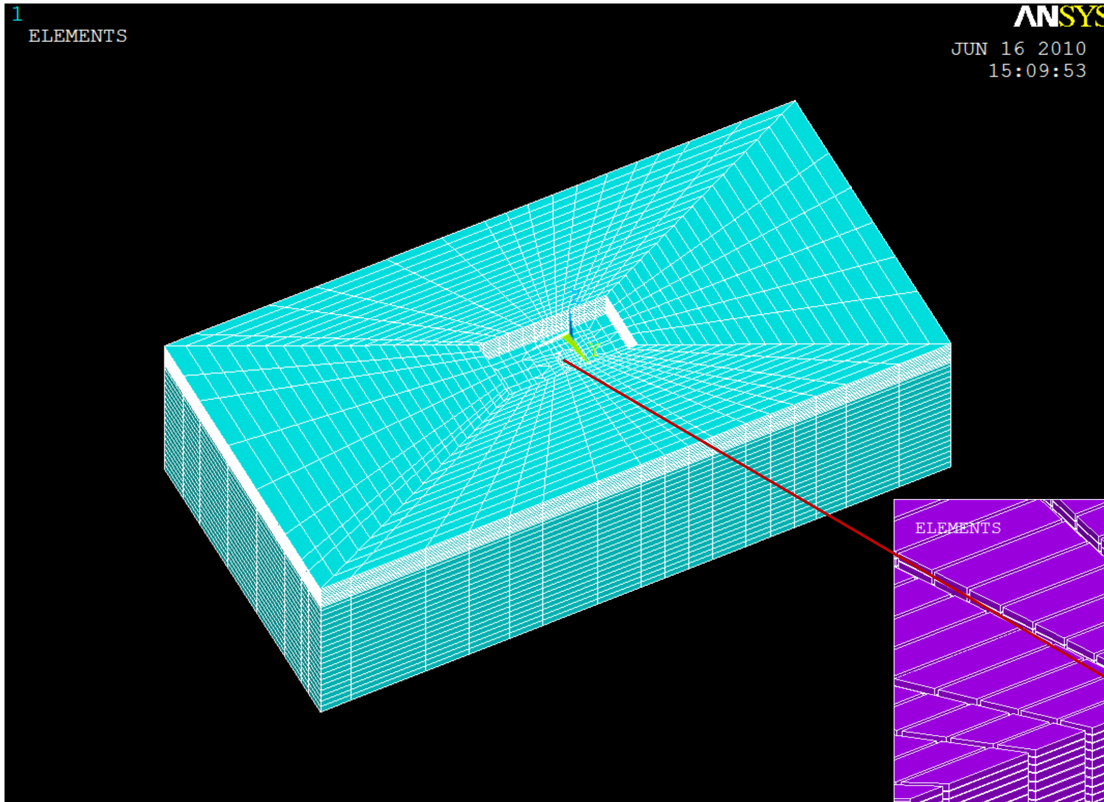
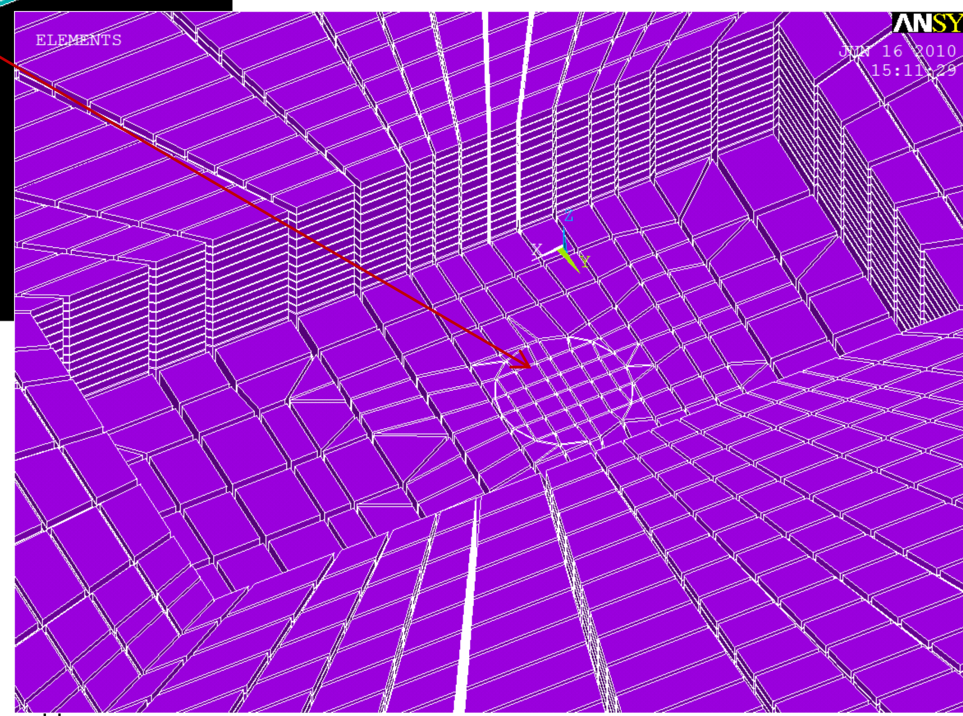
Option A for Seismic Soil Pressure Analysis (Demo 6)



ANSYS Soil FE Model
Is Automatically Generated
by SOILMESH Module

Demo 6



Embedment mesh is extended.
User controls extension size and
mesh density. Can use EREFINE.
Contact surfaces automatically added
By ACS SASSI SOILMESH module.

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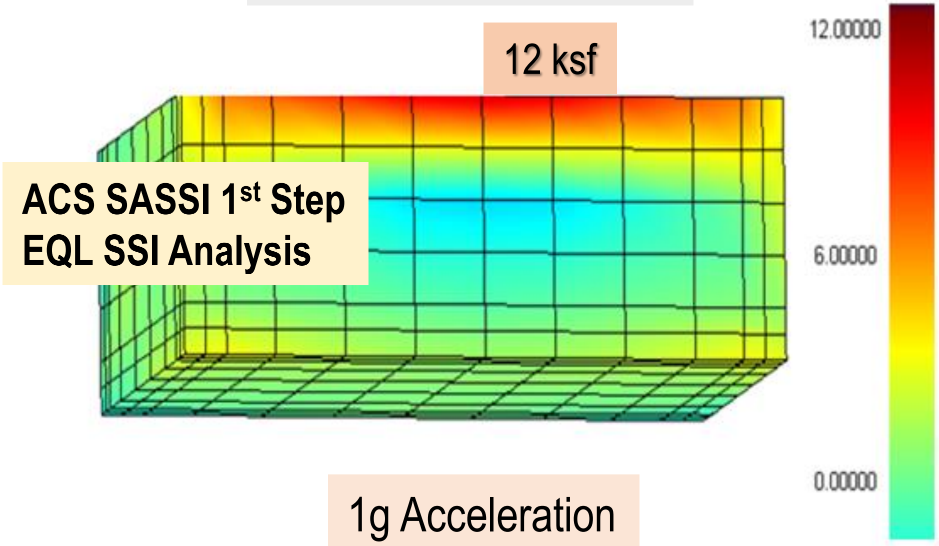
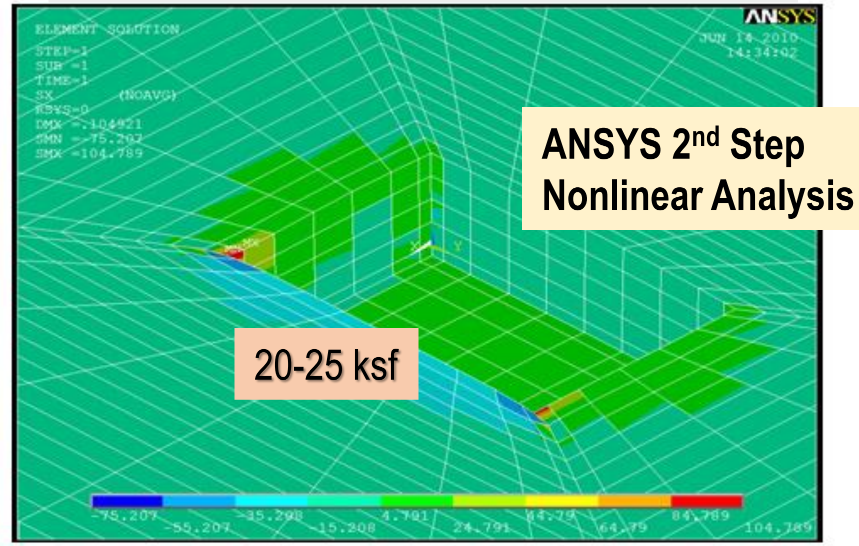
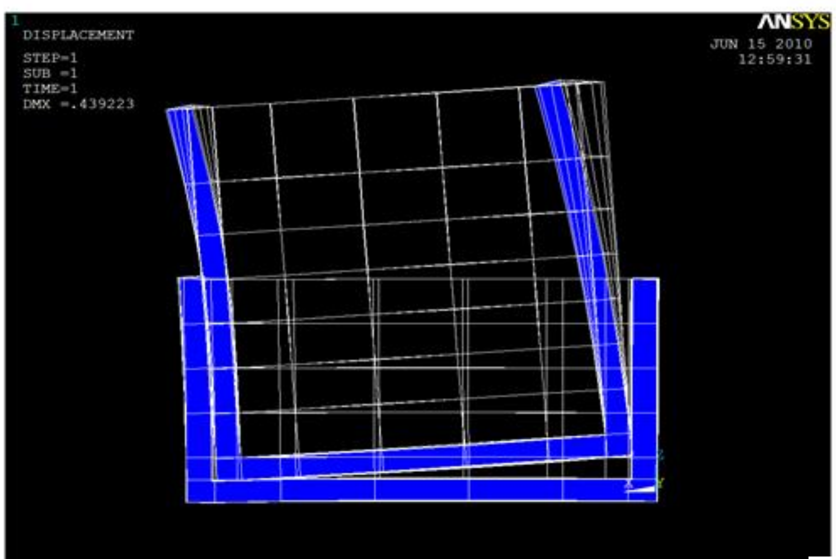
Soil Separation Example Using Two-Step SSI Approach

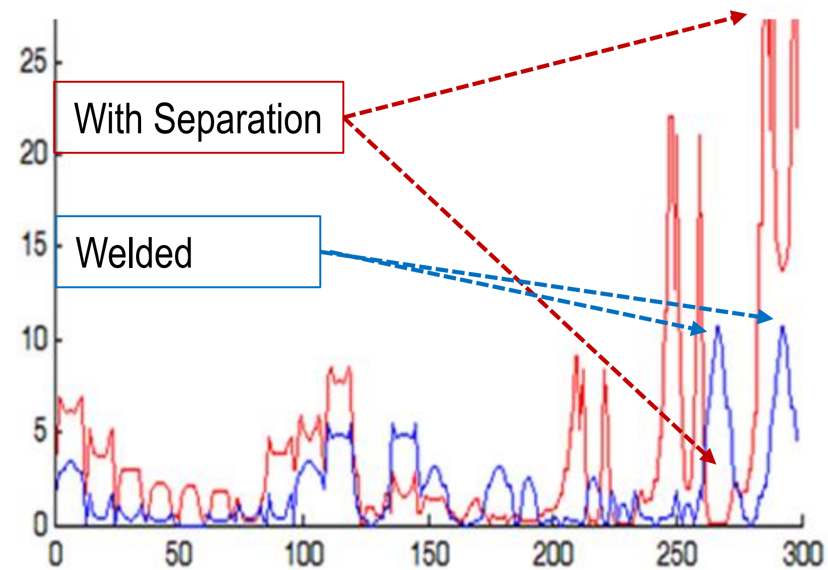
SASSI Soil Pressures



ACS SASSI Soil Pressures (Option A)







(Ghiocel and Saremi, SMiRT24 Paper 468, 2017)

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SURFACE SSI MODEL

Flexible Base (w/ Displ. BC)

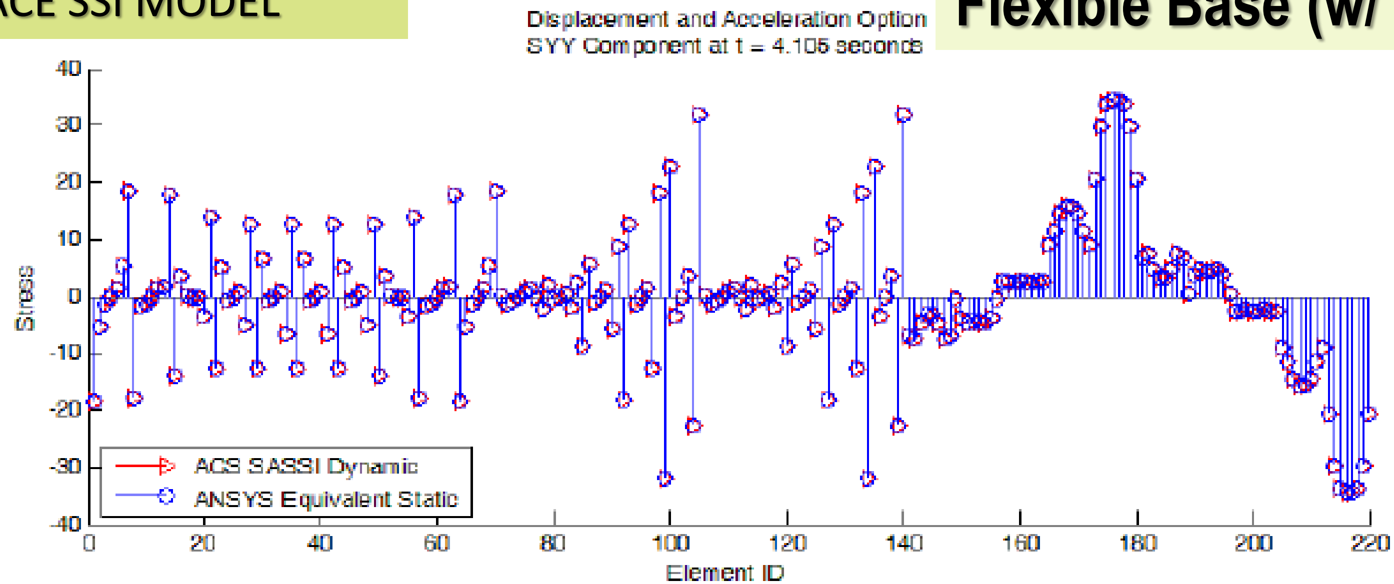

Figure 193: Case b) SYY Element Center Stresses for "Displacement and Acceleration" Option

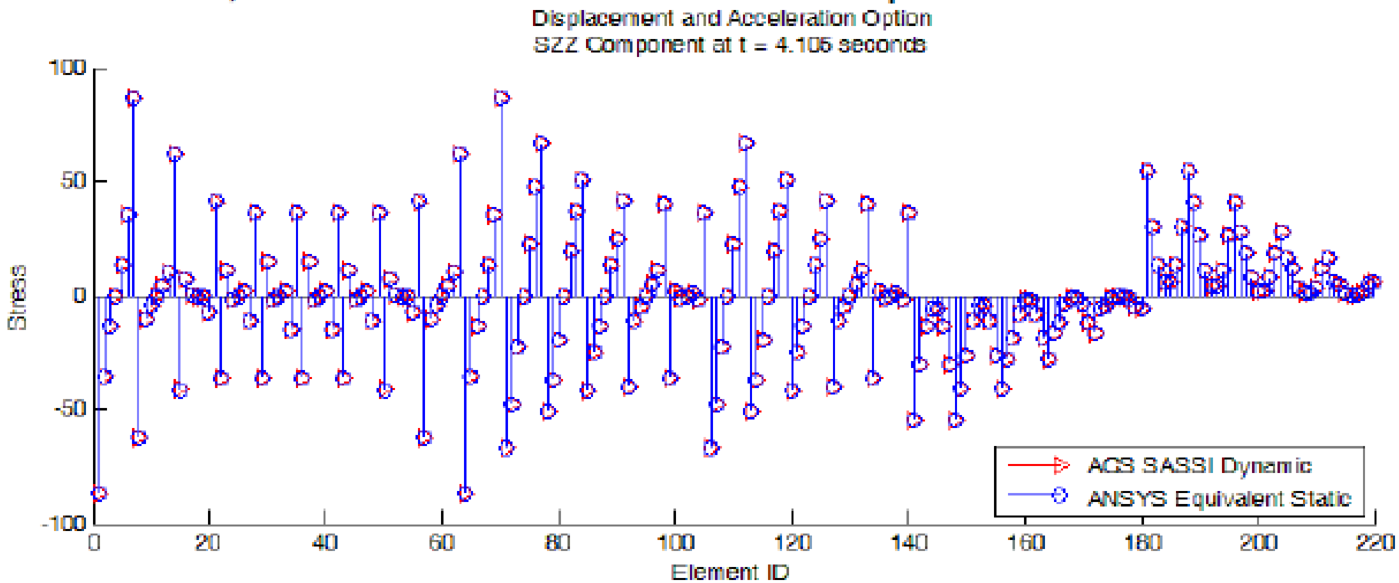

Figure 194: Case b): SZZ Element Center Stresses for "Displacement and Acceleration" Option

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SURFACE SSI MODEL

Rigid Base (w/o Displ. BC)

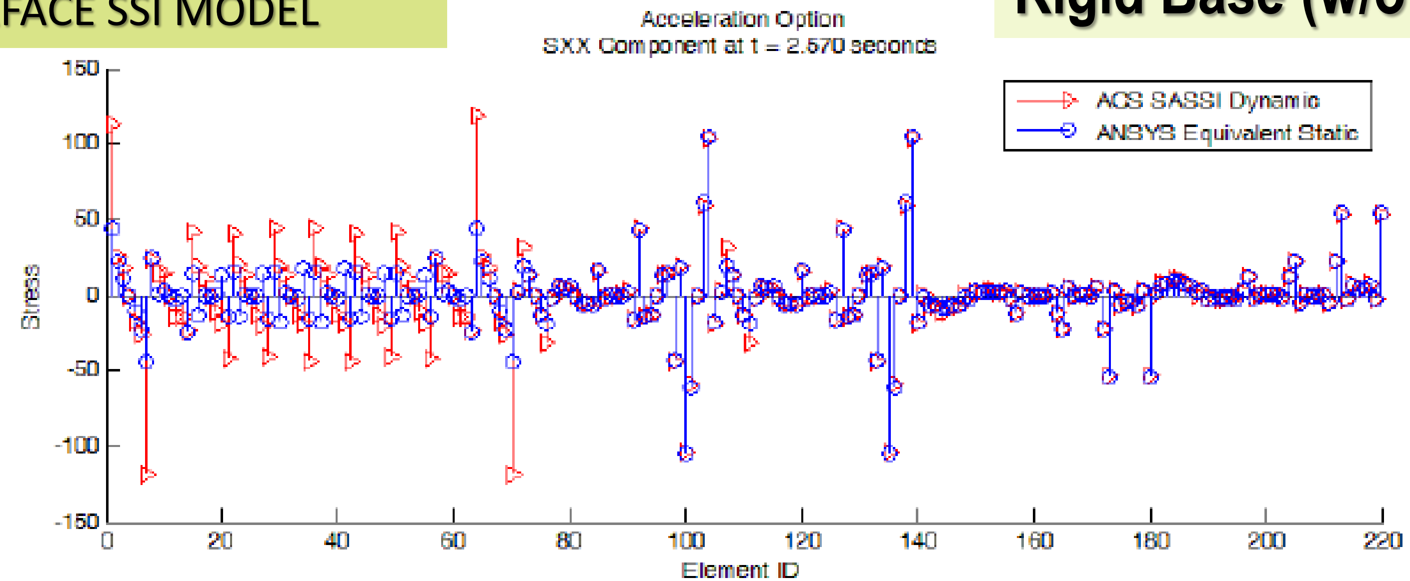

Figure 197: Case c): SXX Element Center Stresses for "Acceleration" Option

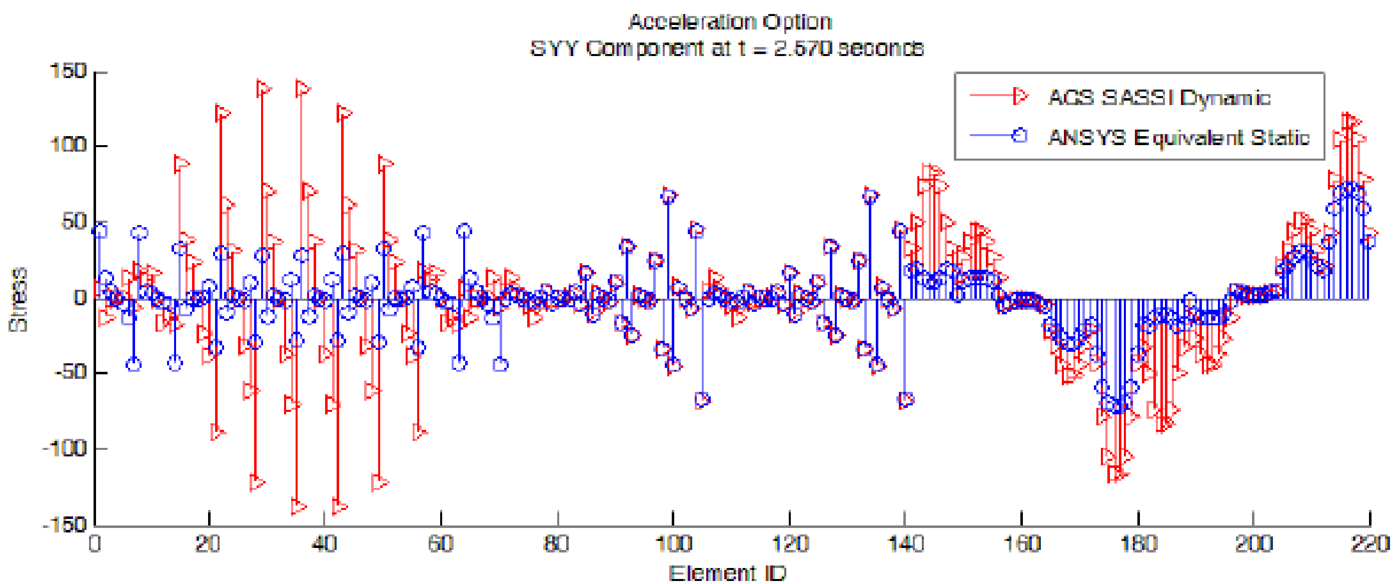

Figure 198: Case c): SYY Element Center Stresses for "Acceleration" Option

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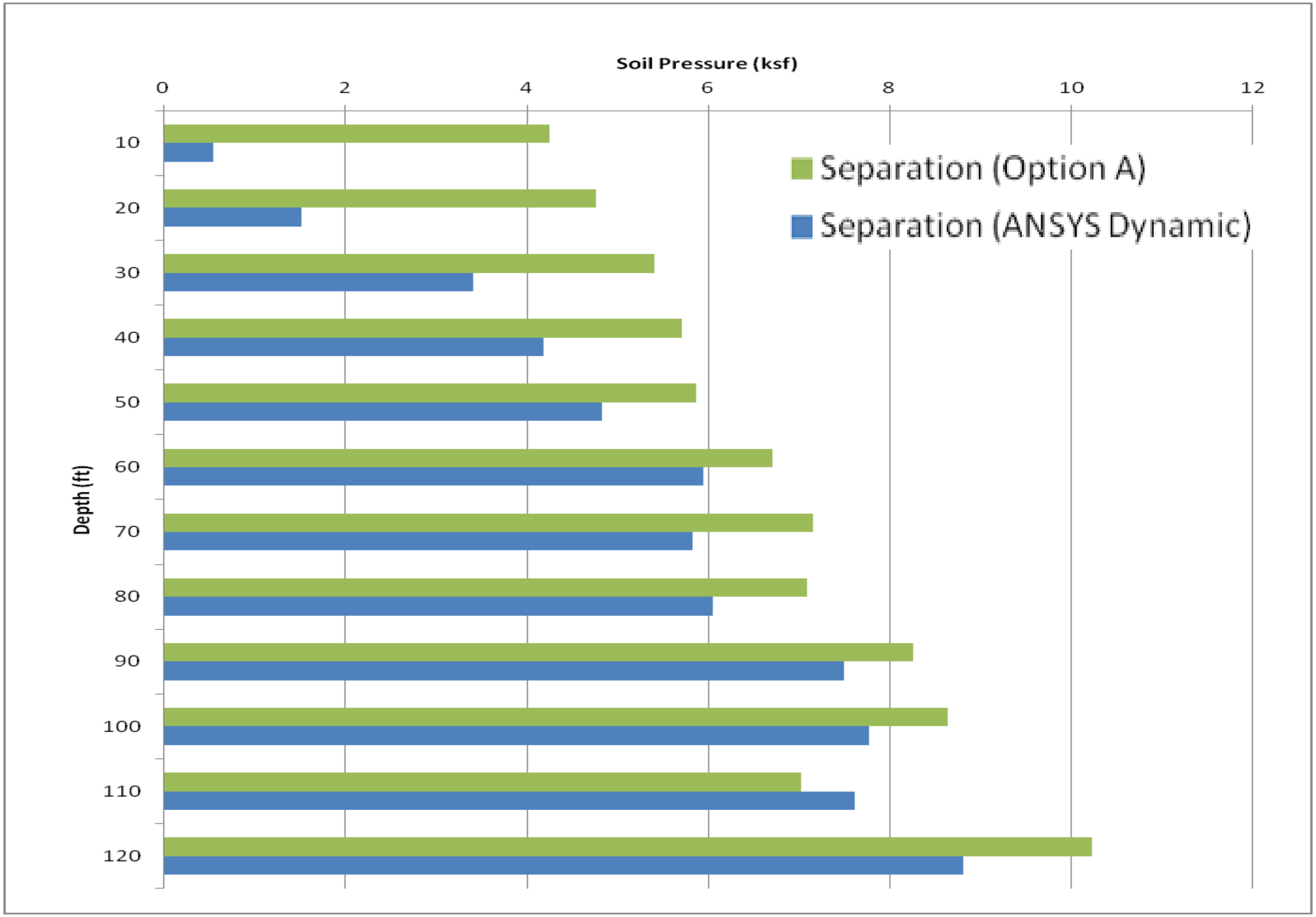
DES Soil Pressures for 0.6g Surface ZPA Input

ANSYS EQS Nonlinear (Option A) vs. ANSYS Dynamic Nonlinear



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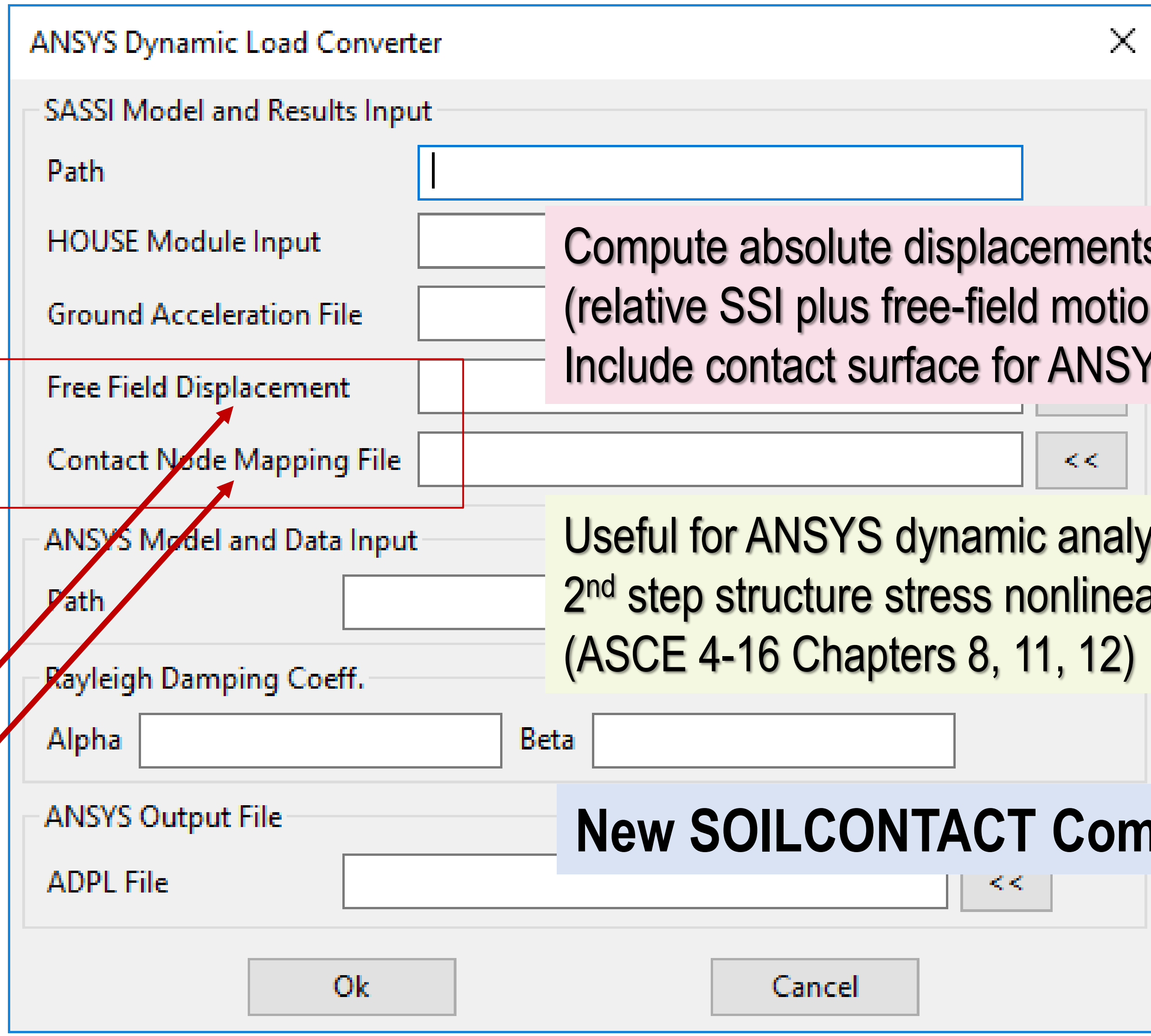
New UI Input for *Option A Dynamic Option*



Compute absolute displacements (relative SSI plus free-field motion). Include contact surface for ANSYS.

Useful for ANSYS dynamic analysis option for 2nd step structure stress nonlinear analysis (ASCE 4-16 Chapters 8, 11, 12)

New SOILCONTACT Command

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Seismic SSI Analysis per ASCE 4-16 Section 12 on Base-Isolation Using Two Steps Approach

SSI Step:
ACS SASSI
Option NON

Validation Step
Option A
for ANSYS
Dynamic
Nonlinear

- Seismic SSI Analysis for Nonlinear Hysteretic Base-Isolators:

1) SSI step: Nonlinear-isolator FD SSI using iterative equivalent linearization based on the shear forces computed in isolators to get the SSI responses (including the bottom base motion)

2) Validation step: Nonlinear-isolator TD SSI analysis for the basemat SSI motion computed at SSI Step assumed as input (for flexible base or rigid, if acceptable)

- *Simplified*: Assume rigid base and use its SSI acceleration motion (3 translations&3 rotations). *Neglect the base deformation.*

- *Accurate:* Consider the flexible base as is and use its SSI acceleration and relative displacement motions, or its absolute displacement motions at bottom as input. *Recommended.*

REMARK: Validation step should be used to *validate/calibrate SSI* step.
Use ACS SASSI for 1st SSI step and ANSYS for 2nd step (Option A)

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OPTION AA: ACS SASSI-ANSYS Interface for SSI Analysis Using ANSYS Models (Demo 7)

OPTION AA uses directly ANSYS structural model for SSI analysis

Sequence of Steps:

1) Develop ANSYS *structural* FEA model with no modeling restrictions (any FE type, CP, CE, rigid links)
2) If embedded, develop also the ANSYS *excavated soil* FEA model
3) Using an ANSYS ADPL macro generate matrices K, M, C
4) Using ACS SASSI UI read ANSYS model .cdb for structure and excavation to convert the ANSYS model geometry configuration to ACS SASSI for post-processing
5) Merge Structure and Excavation models using new UI. Add interaction nodes and AFWRITE the SSI model to produce HOUSE input.
6) Run SSI analysis using HOUSEFSA and ANALYSFSA

Demo 7

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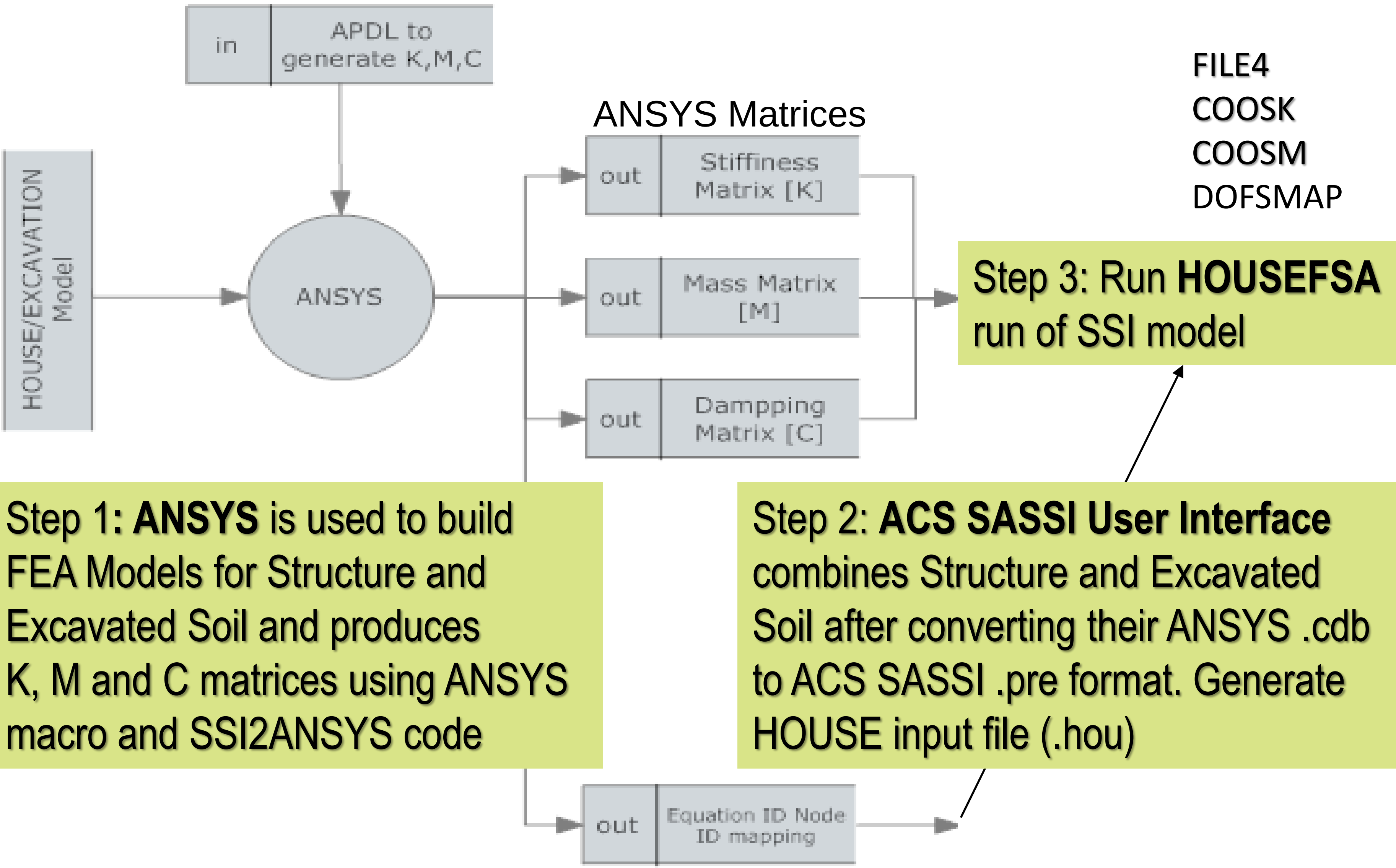
Steps for Running SSI analysis Using ANSYS Model



Step 3: Run **HOUSEFSA** run of SSI model

Step 1: **ANSYS** is used to build FEA Models for Structure and Excavated Soil and produces K, M and C matrices using ANSYS macro and SSI2ANSYS code

Step 2: **ACS SASSI User Interface** combines Structure and Excavated Soil after converting their ANSYS .cdb to ACS SASSI .pre format. Generate HOUSE input file (.hou)

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Using ANSYS with gen_kmc.mac APDL Macro

FOR STRUCTURE ANSYS Model:

At the ANSYS command line input
gen_kmc,'.',0,'.'

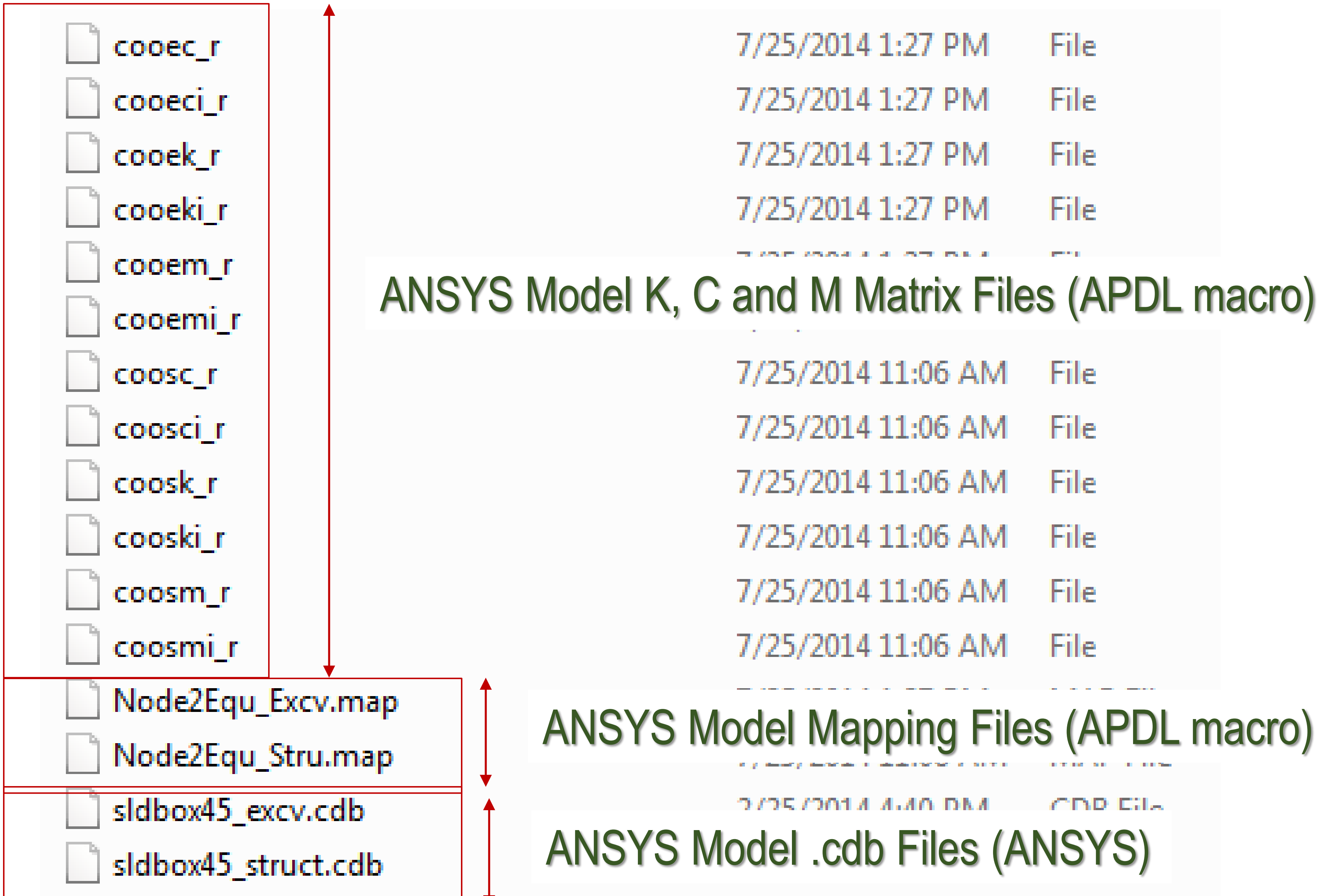
APDL Macro produces the following files:
coosk_r, cooski_r, coosm_r, coosmi_r, coosc_r, coosci_r, and Node2Equ_Stru.map

FOR EXCAVATION ANSYS Model:

At the ANSYS command line input
gen_kmc,'.',1,'.'

APDL Macro produces the following files:
cooek_r, cooeki_r, cooem_r, cooemi_r, cooec_r, cooeci_r, and Node2Equ_Excv.map

Using ANSYS with gen_kmc.mac APDL Macro



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User Interface Procedure to Merge ANSYS Structure and Excavation Models for Option AA

It is assumed that the ground surface is at Z=0. and the FV method will be used

```
*Convert  ANSYS Structure.cdb in Model 1
Actm,1
Convert,ansys,struct.cdb,32.2
Etypegen,1
Actm,2
Convert, ansys,Soil.cdb,32.2
* Define excavation elements of type 2
Etypegen,2
* Create SSI model by combining Models 1 and 2 in Model 3
Actm,3
MergeSoil,1,2,1,,,,mappingfile.txt
Groundelev, 0
Intgen, 1
```

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ANSYS FE Types Compatible with Option AA

- SOLID element types: SOLID45 and SOLID185;
- SHELL element types: SHELL63 and SHELL181;
- BEAM element types: BEAM44 and BEAM188;
- PIPE element types: PIPE288;
- COMBIN element types: COMBIN14;
- Couple nodes (CP command) and Constraint equations (CE command)
- Multipoint constraint element types: MPC184 Rigid Link and Rigid Beam
- Fluid element types: FLUID80 (legacy element*).*

FLUID30 to be included in a next upgrade via exporting the condensed soil stiffness matrix including excavation cavity to ANSYS.

- MATRIX50 Super Element
  - Included in Option AA using ANSYS model
  - Converted to General Matrix Element for the ACS SASSI Model

REMARK: Not all ANSYS keyopts or all input parameter values work!

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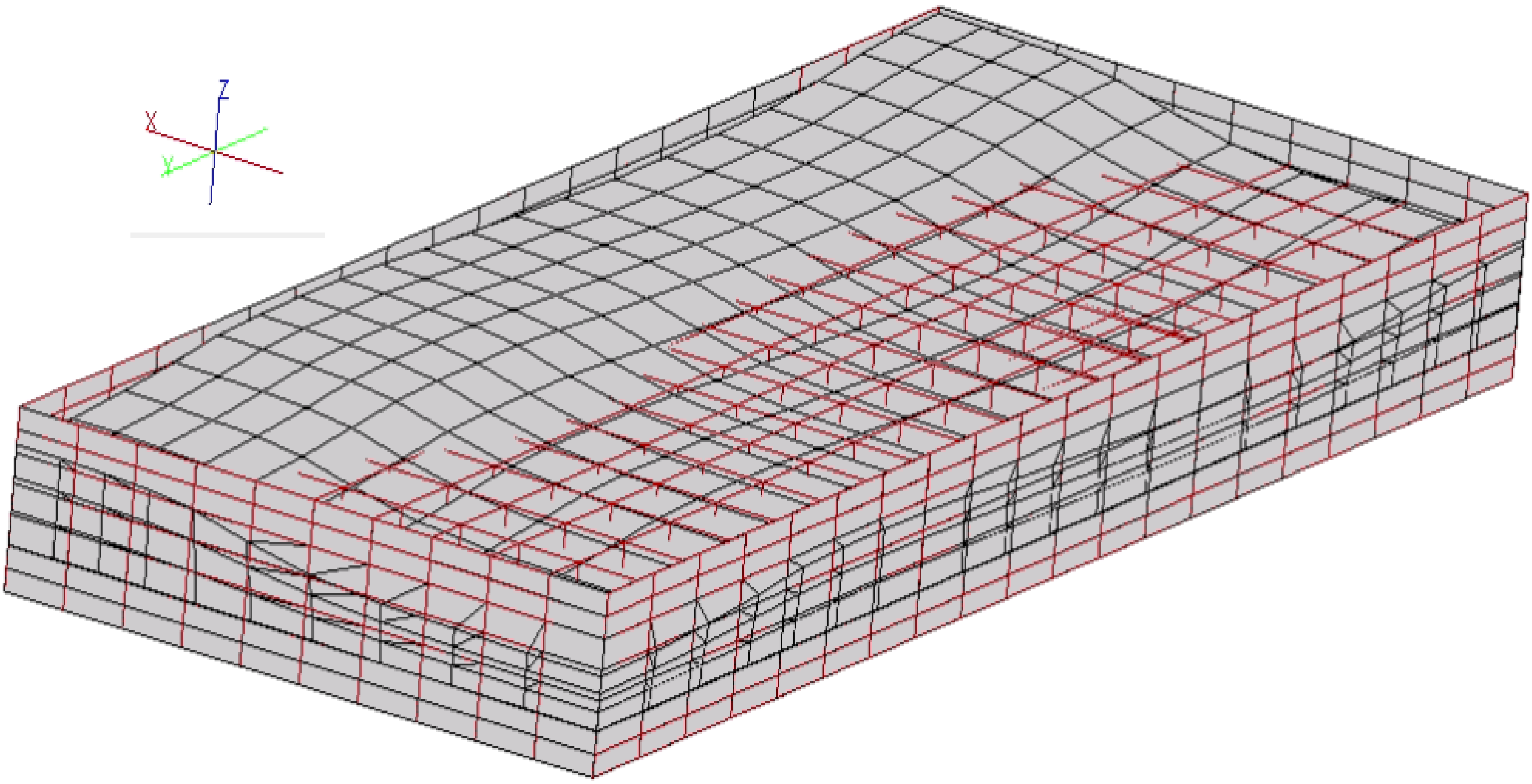
Pool Water Wave Displacement Response



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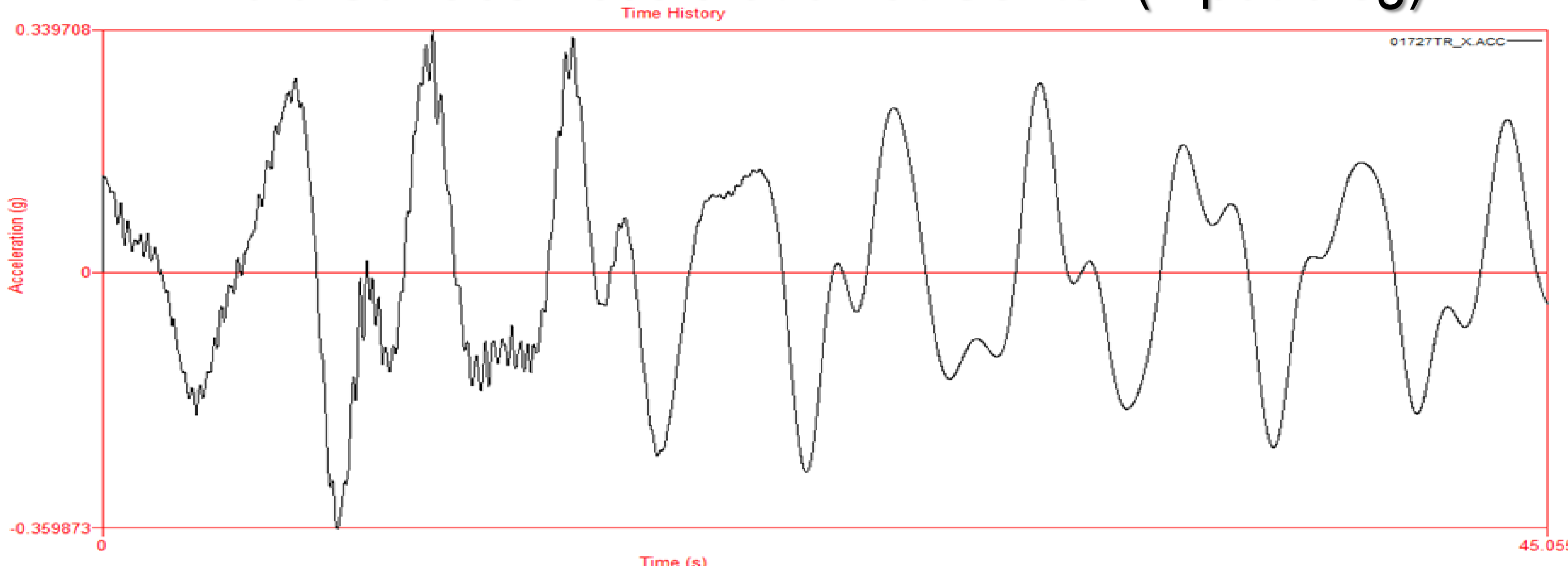
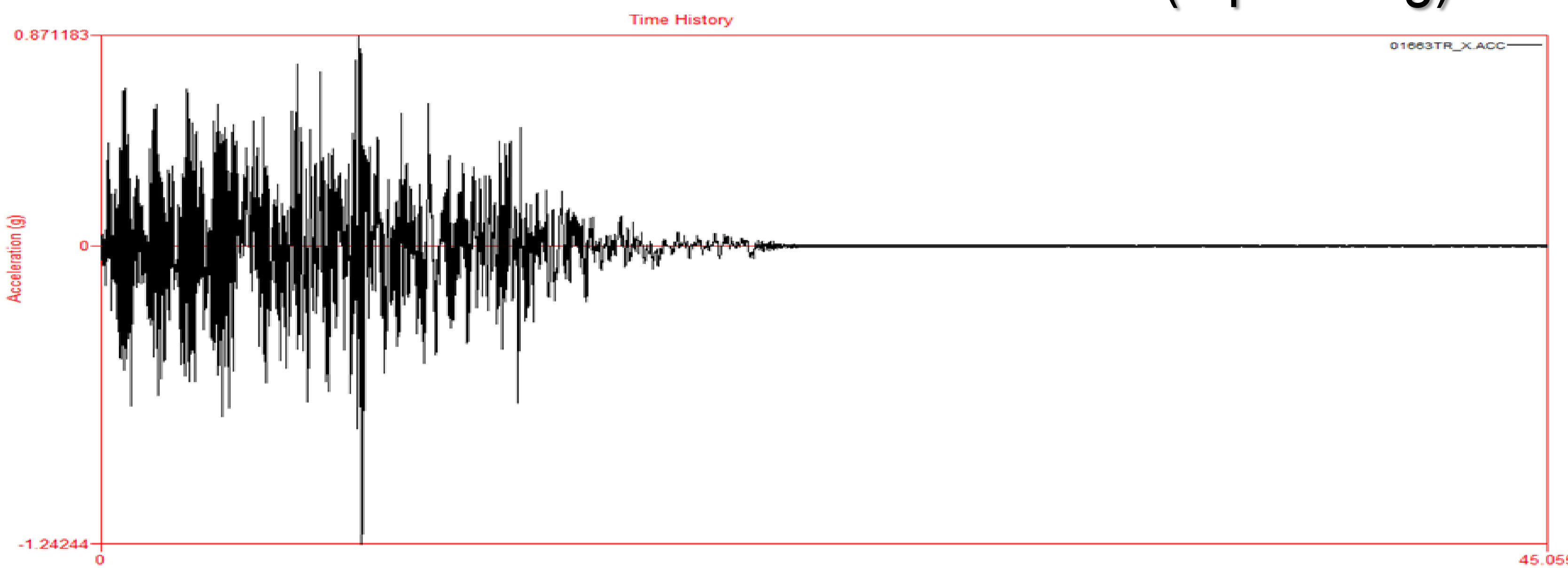
Fluid Surface Acceleration at Center (Input 0.3g)



Wall Transverse Acceleration at Center (Input 0.3g)



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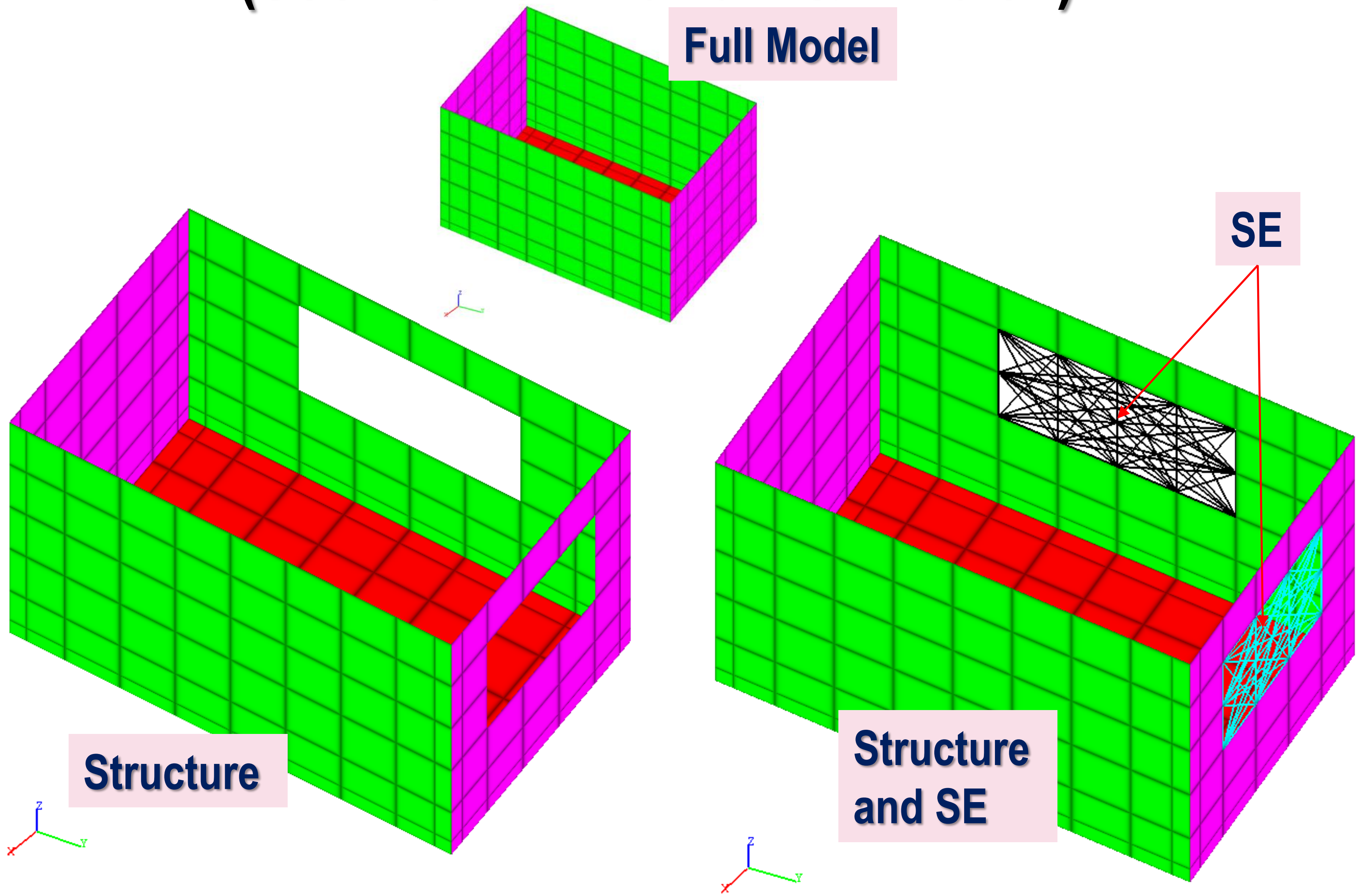
Using ANSYS MATRIX50 to Build Super Elements (see Demo 11 and V&V Pb 52)



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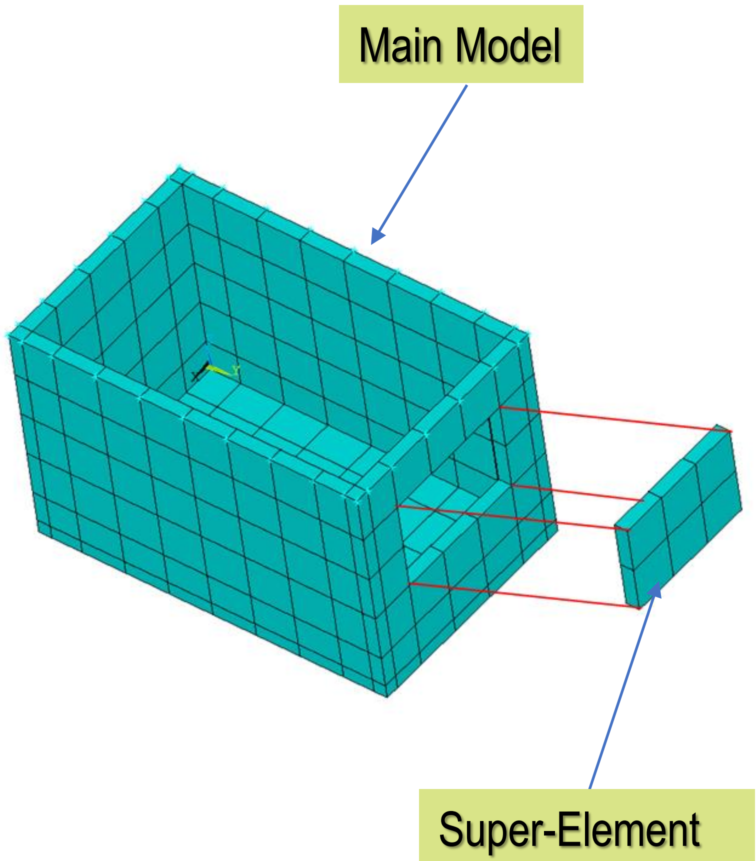
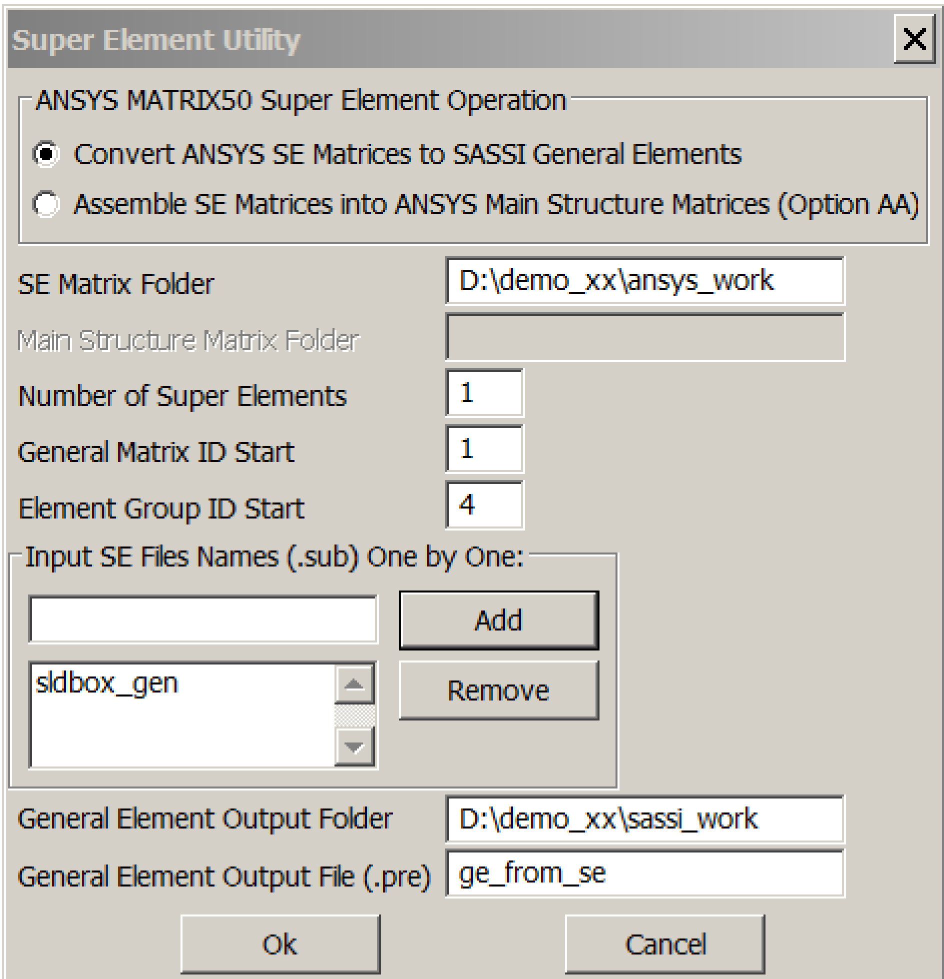
ANSYS Super Element (SE) Converted to ACS SASSI Using General Matrix Elements (GM)





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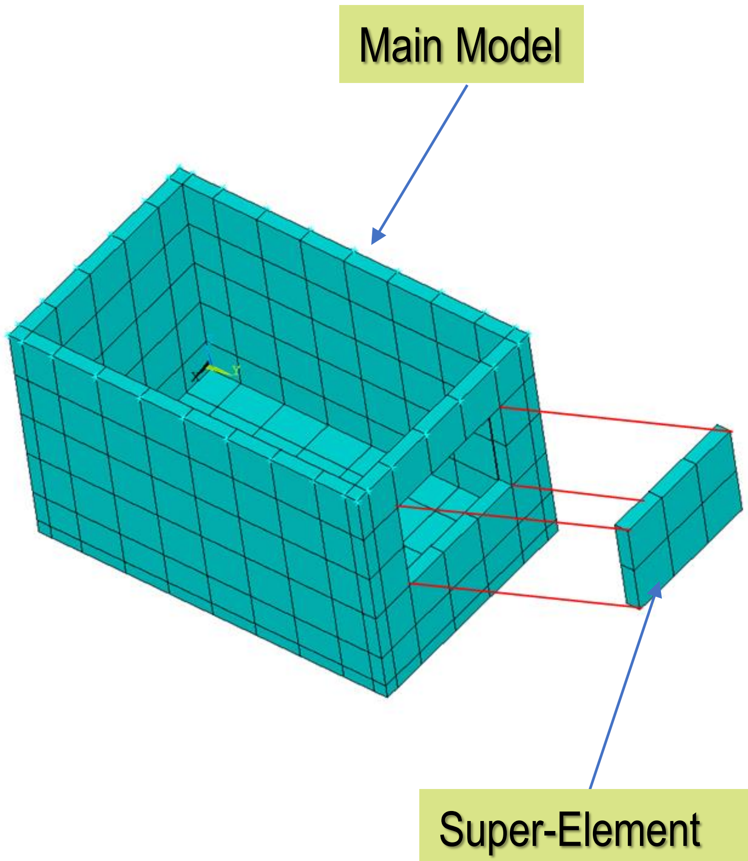
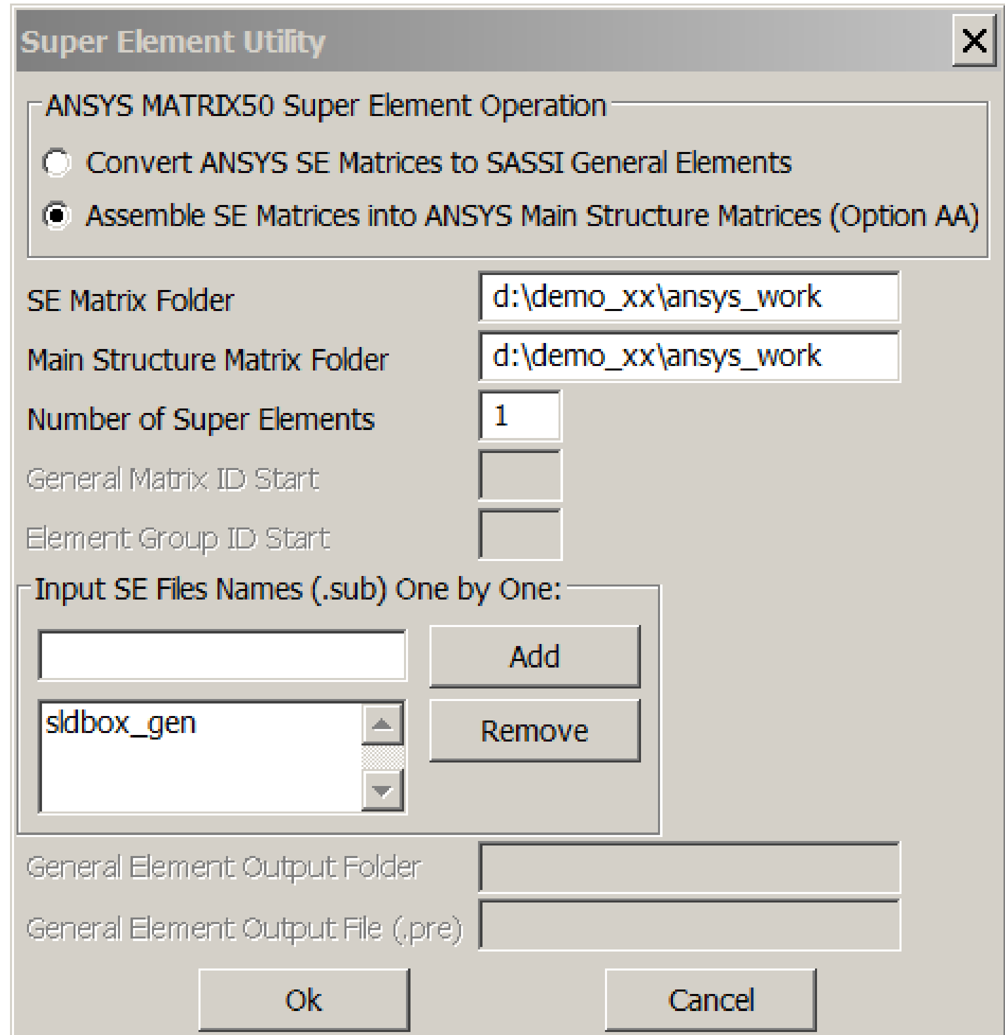
ANSYS Super Element (SE) Using Option AA By Adding Main Model and SE Model Matrices





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2. Option NON: Nonlinear Structure

(Concrete Walls and Base Isolators)

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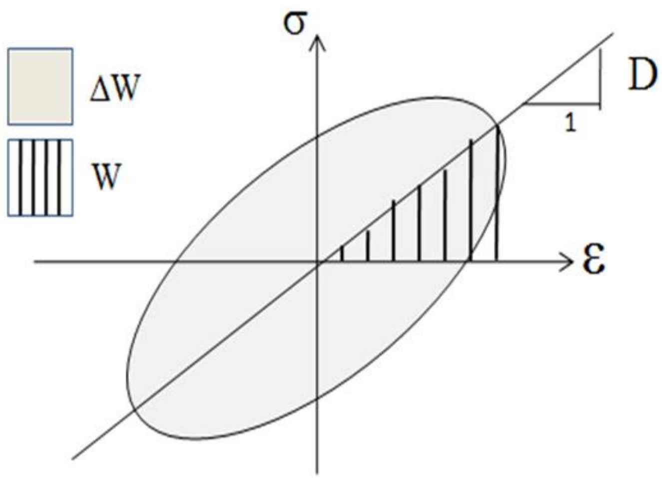
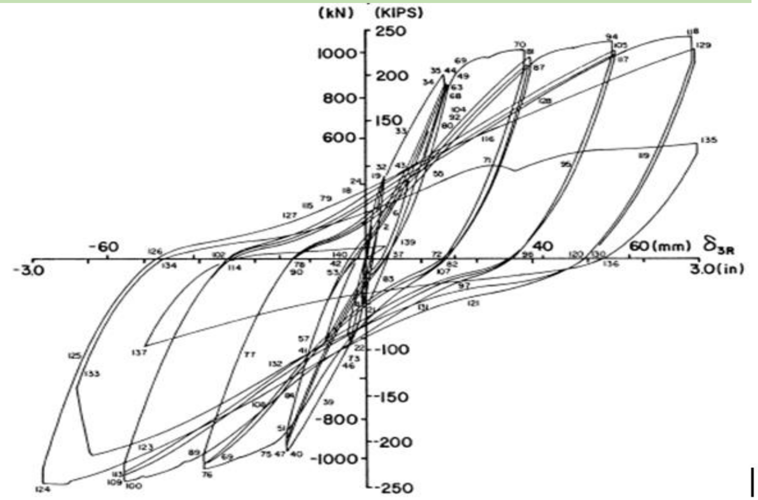
Option NON Modeling of Hysteretic Behavior

Linearized Hysteretic Model



Frequency Domain
Linearized Hysteretic Model

Experimental Hysteretic Model



Time Domain
Hysteretic Model

Comparative nonlinear SSI analysis results of the hybrid approach against the "*true*" nonlinear time-integration approach show a *good accuracy* (Ghiocel, SMIRT23, 2015). 30

Fast and accurate nonlinear SSI analyses at a small fraction of the runtime of a time domain nonlinear analysis, about 2-3 times linear SSI analysis runtime.

Much more robust than nonlinear time integration approaches - similar opinion has also Prof. Kausel (Kausel and Assimaki, 2002)

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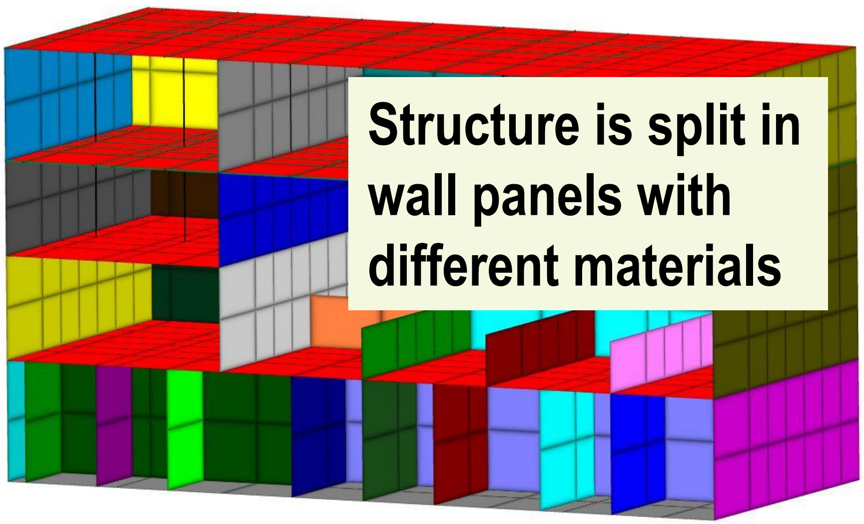
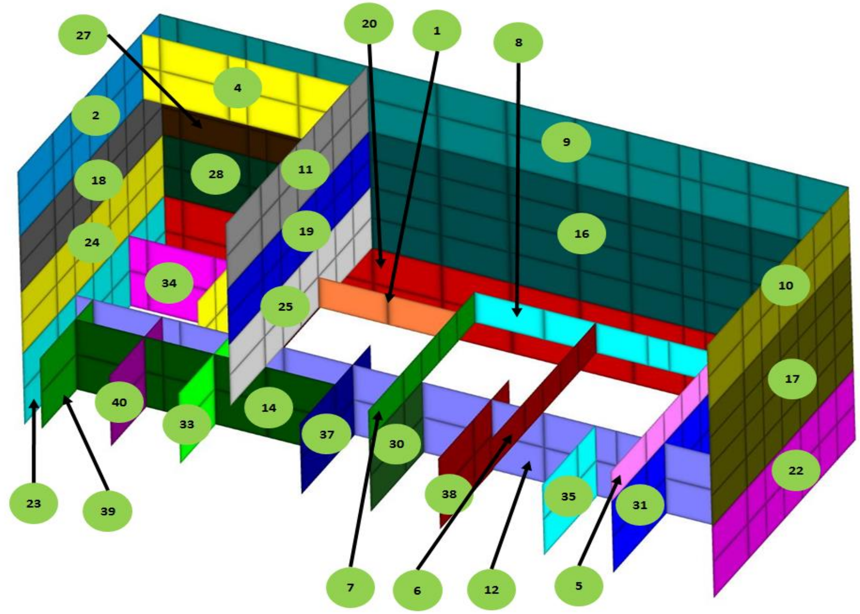
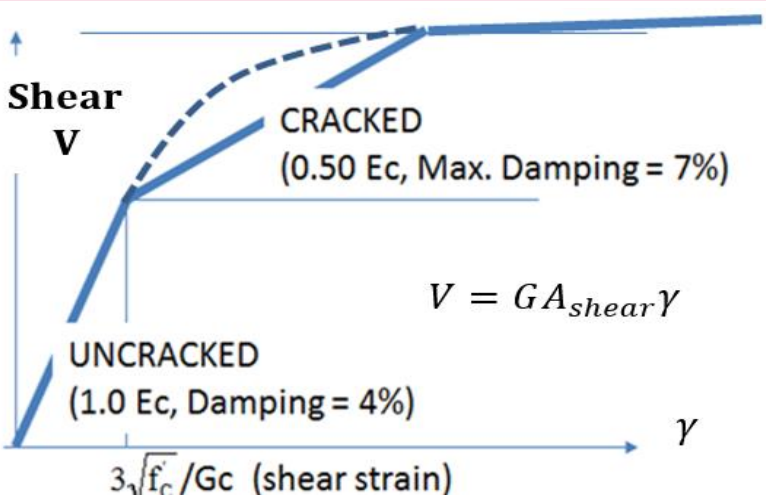
Reinforced Concrete Structural Behavior Consistent with Wall (Panel) Strains for Each Seismic Input

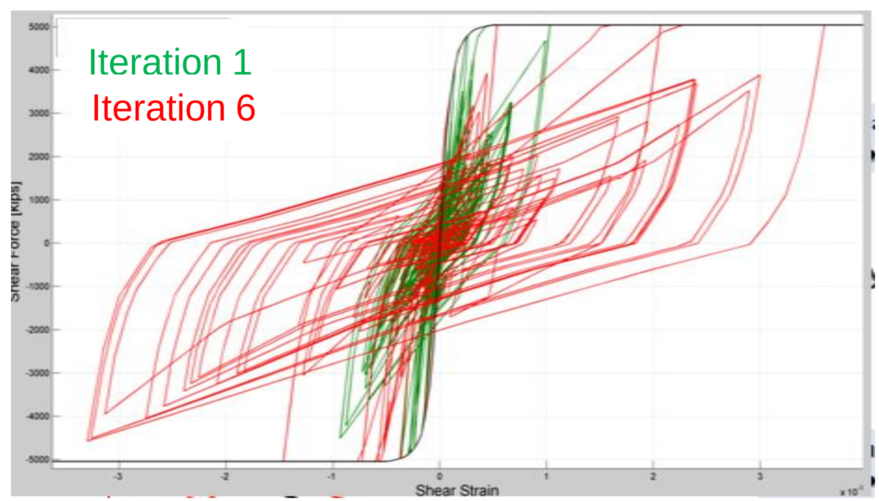




Backbone Curves Automatically Generated



Iterative SSI – For Large Nonlinear Behavior



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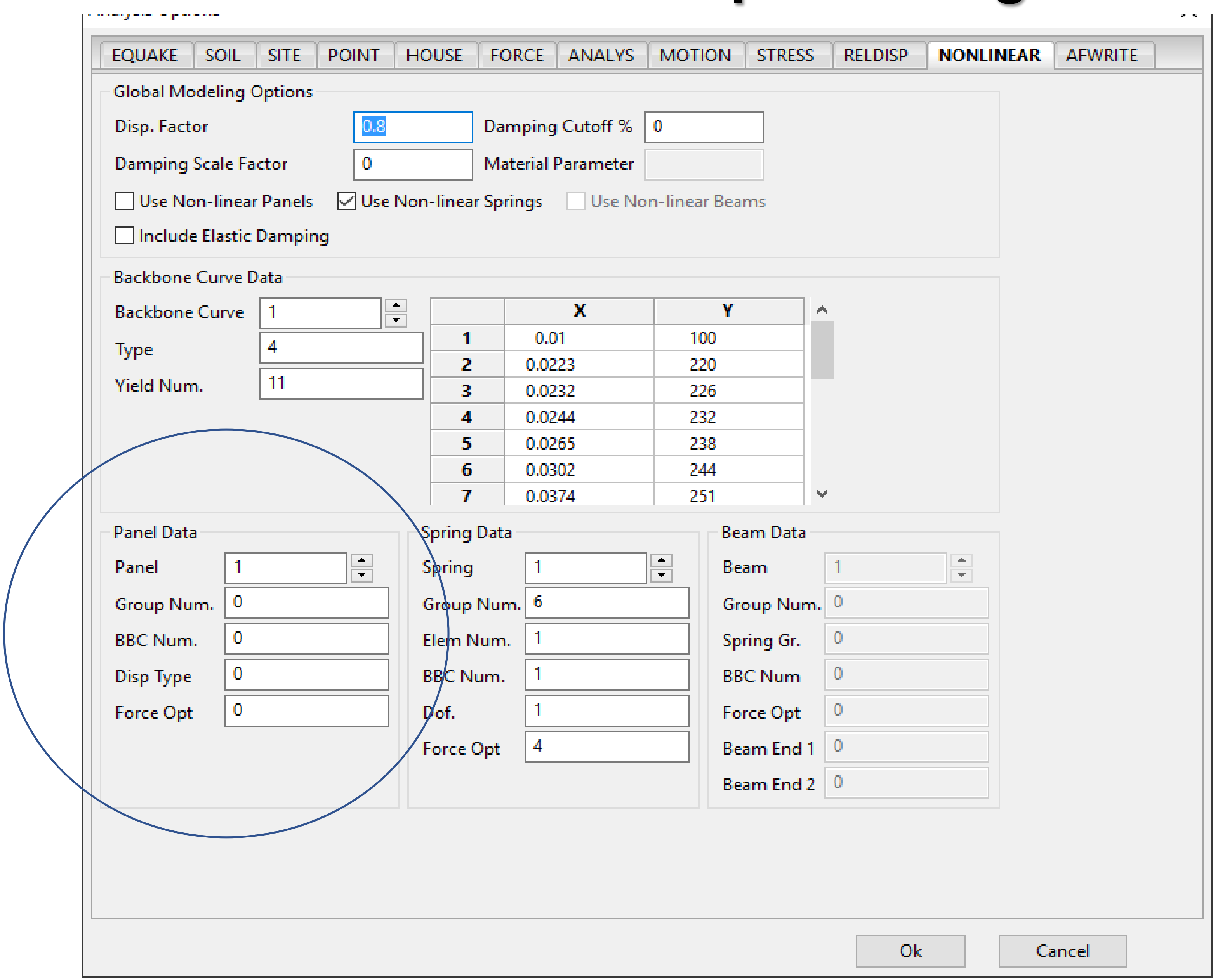
NONLINEAR Module UI Input Dialog Window



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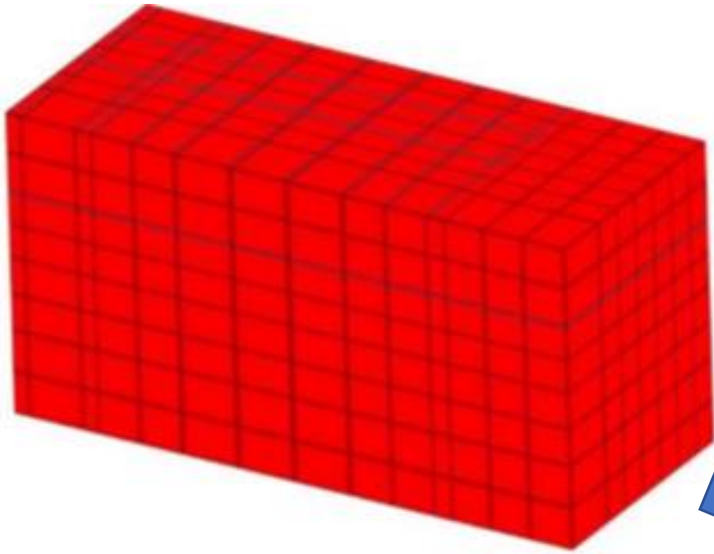
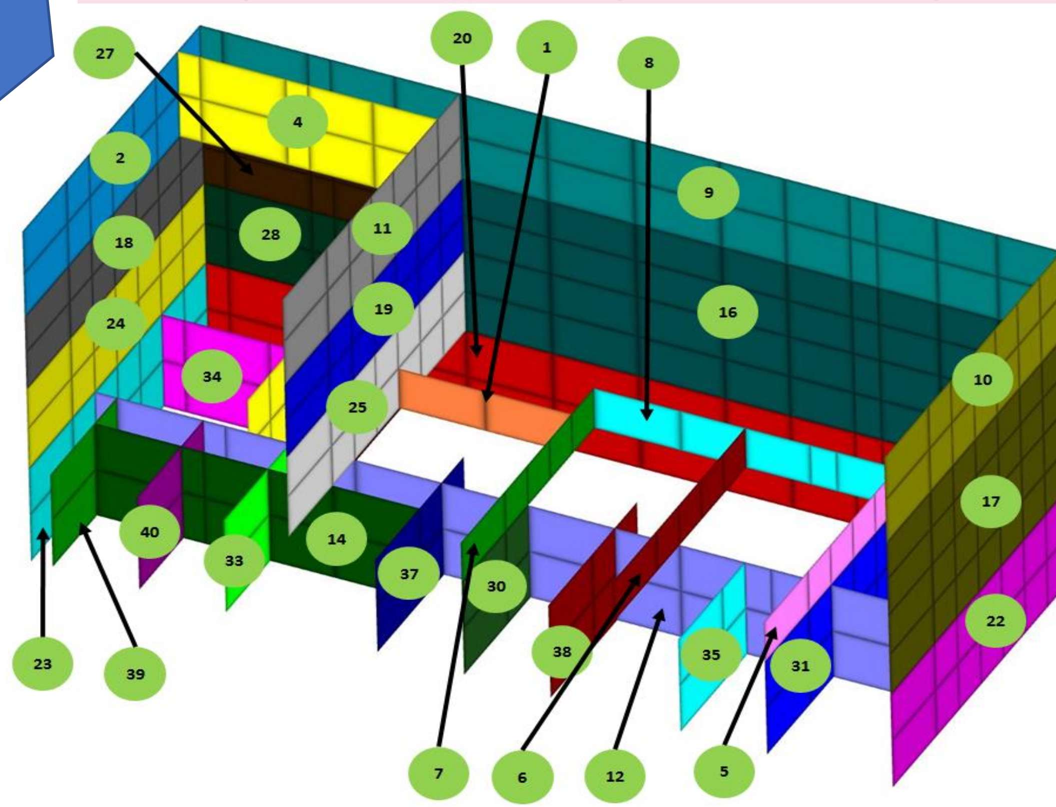
Nonlinear Concrete Building Split in Wall Panels



Nuclear building model split in nonlinear panels with different nonlinear properties. Many ACS SASSI User-Interface commands are available: WALLFLR, SPLITWALLS, SEGWALLS, MERGEPANEL, EDGE, UNIPL, MERGEGROUP, EDGEPANEL, etc.



Each panel should be described by its elastic properties, BBC and hysteretic model for in-plane shear or bending deformation (Cheng-Mertz for Shear and Bending, and Takeda)

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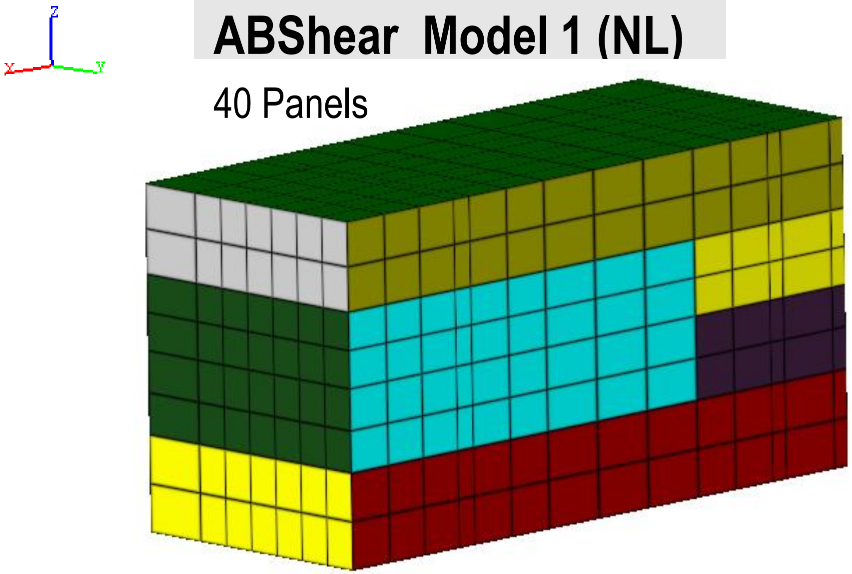
Different Panel Models Can Be Defined by Users

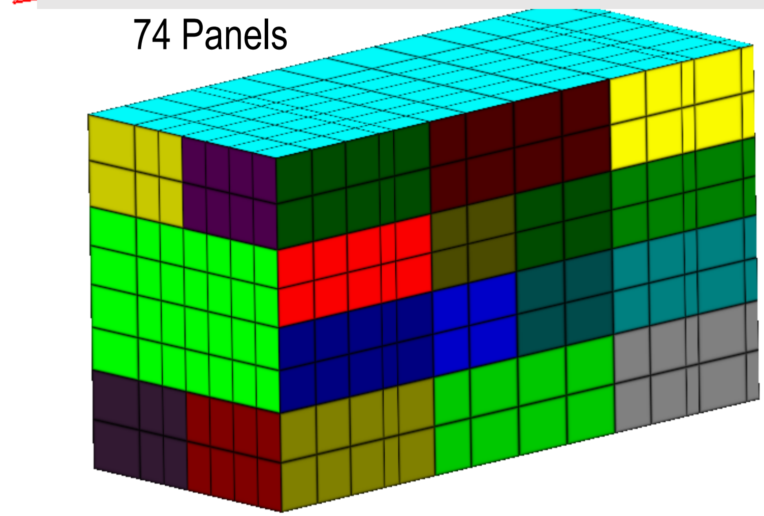
ABShear Model 1 (NL)

40 Panels



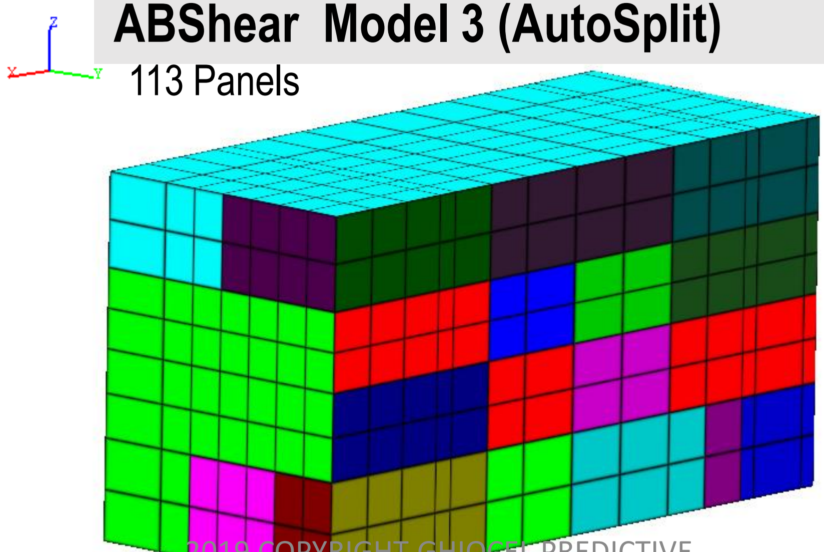
ABShear Model 2 (ManualSplit)

74 Panels



ABShear Model 3 (AutoSplit)

113 Panels



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Different Panel Models Provide Similar Results

PANEL 18 – Transverse Wall - Most Damaged Panel

Model	Panel #	Stiffness		Damping	
1 NL	18		223461		0.110
2 ManualSpilt	26	269297	249680	0.095	0.103
	43	186060		0.133	
	72	241902		0.100	
	31	254245		0.097	
	45	243142		0.099	
	74	303434		0.095	
3 AutoSpilt	26	334926	244339	0.095	0.115
	89	288742		0.095	
	111	294128		0.095	
	31	205217		0.121	
	90	182765		0.135	
	112	160254		0.149	

PANEL 29 – Longitudinal Wall –Lightly Damaged Panel

Model	Panel #	Stiffness		Damping	
1 NL	29		507341		0.05
2 ManualSpilt	29	519100	519100	0.040	0.04
	54	519100		0.040	
3 AutoSpilt	29	497500	508300	0.052	0.05
	96	519100		0.040	

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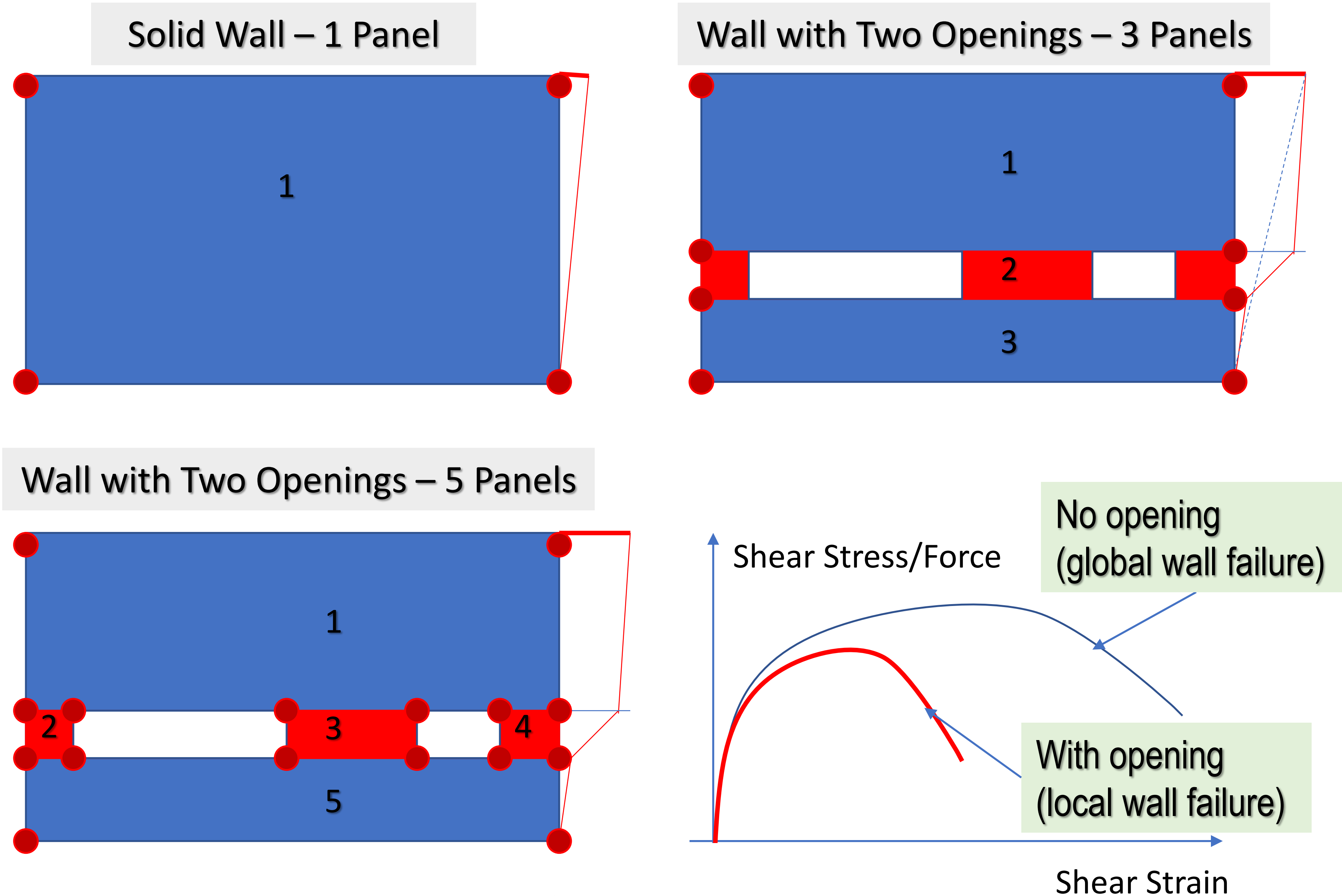
Including Wall Openings with EDGE Command



UI Commands: **EDGE, 1,0,0,1**, and then **EDGE,2**

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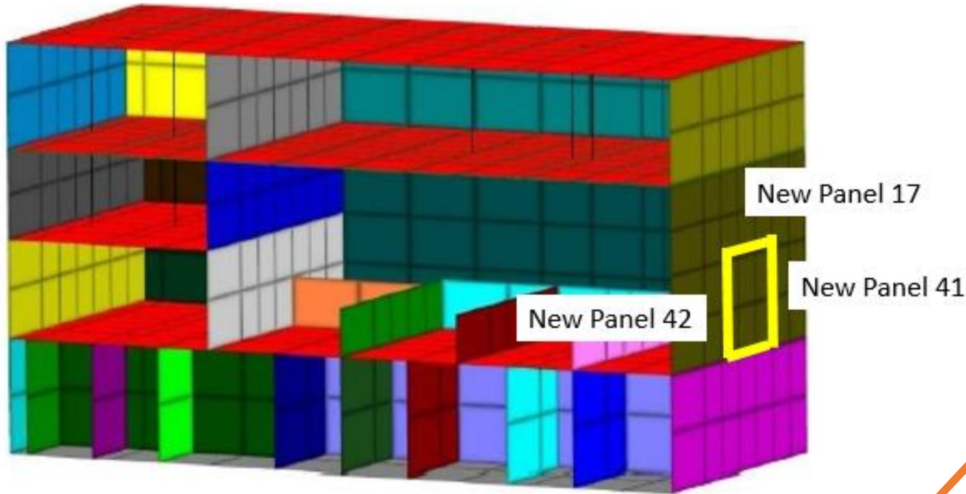
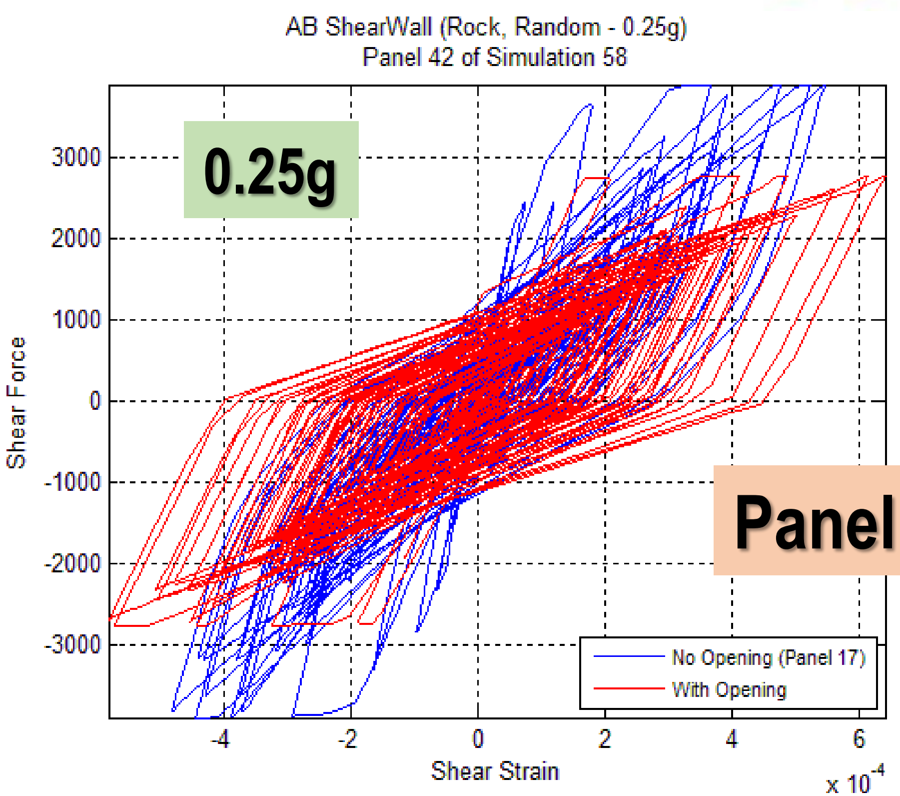
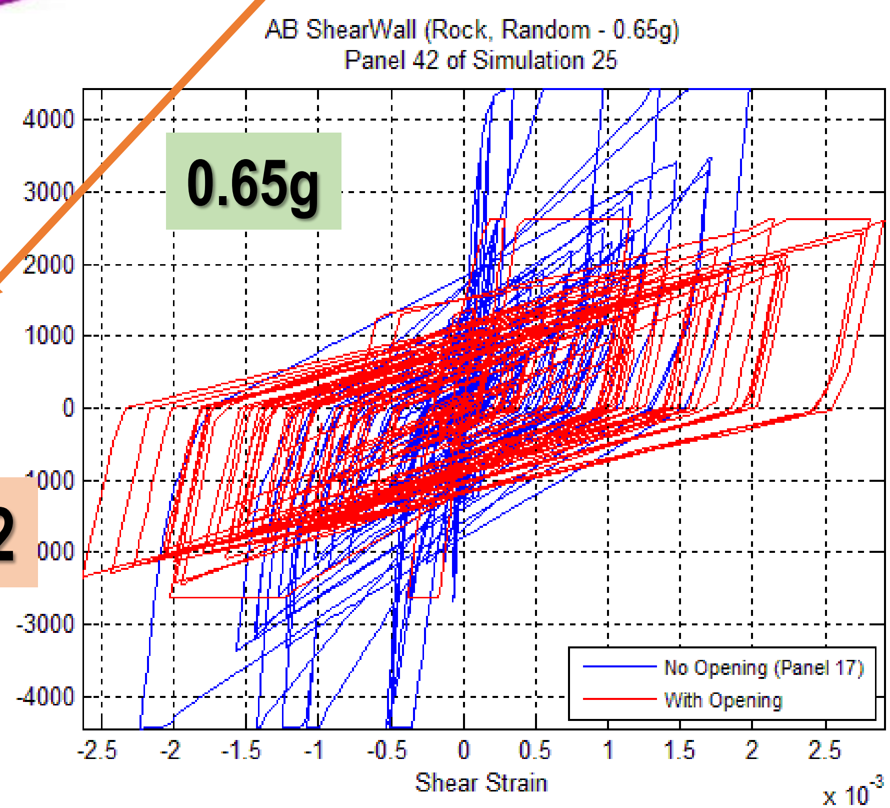
Nonlinear SSI Effects Due Openings in Walls



Wood1990 Eq.
CMS Hysteretic Model



Panel 42



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Nonlinear SSI Analysis Using An Iterative Equivalent-Linearization Approach

The implemented SSI hybrid approach uses an iterative equivalent-linearization (EQL) based on a *global* linearized SSI solution in the complex frequency combined a *local*, “true” nonlinear wall panel behavior in time domain based on the displacement BCs computed from each SSI restart iteration (about twice faster than initial run).

The runtime of an nonlinear SSI analysis based on iterative SSI analyses is only about 2-3 times (2-6 iterations) the runtime of a new linear SSI analysis.

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ACS SASSI Nonlinear SSI Analysis Procedure

Nonlinear concrete structure SSI Analysis computational steps:

- For the initial iteration, perform a linear SSI analysis using the elastic properties for the selected shearwall panels
- Compute concrete shearwall panel behavior in time domain that is used to calibrate the local panel hysteretic models associated to each nonlinear shearwall panel in complex frequency
- Perform a new SSI analysis iteration using a fast SSI reanalysis (restart analysis) in the complex frequency domain using the hysteretic models computed in Step 2 for all selected panels
- Check convergence of the nonlinear SSI response after new SSI iteration to stop; otherwise continue with a new iteration

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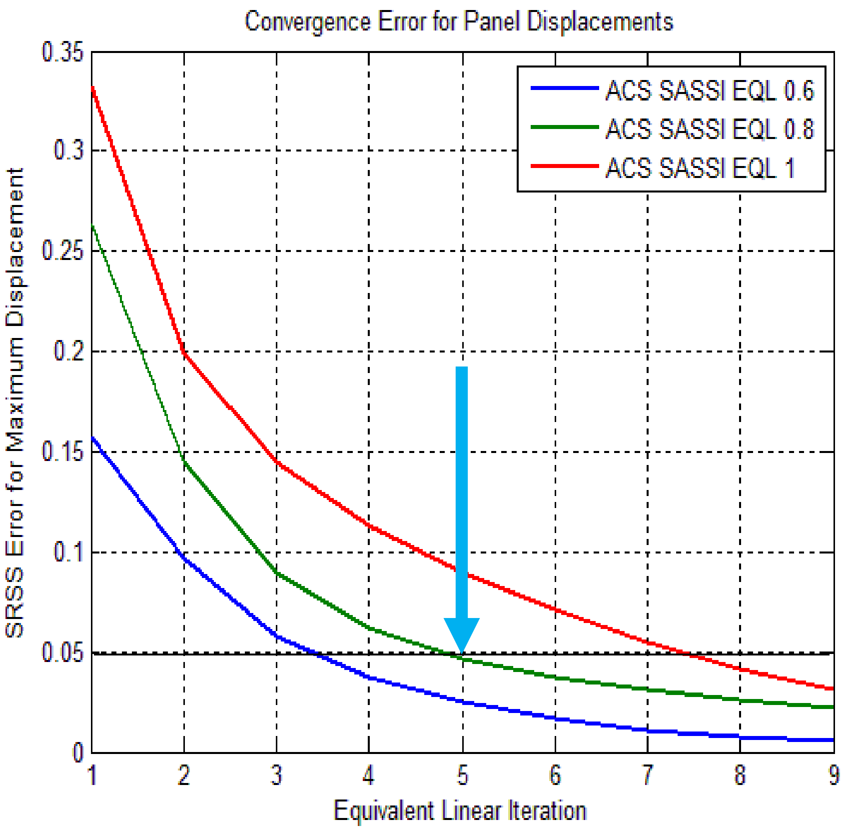
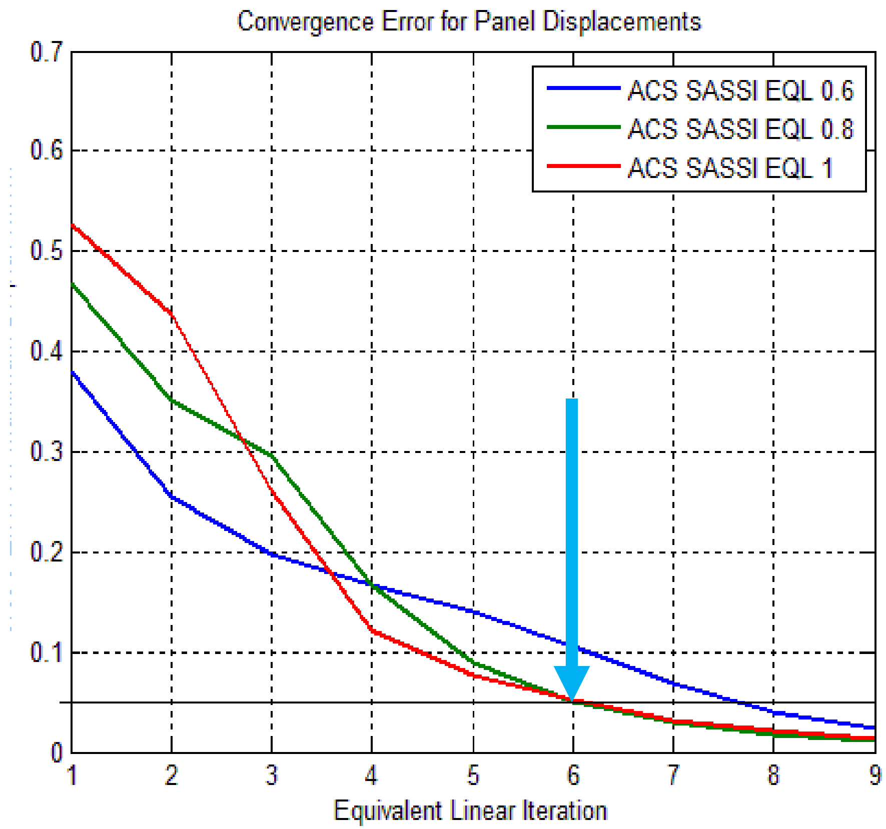
Typical Nonlinear SSI Solution Convergence for 5% SSI Reponse Accuracy Error

0.30g Input

0.60g Input





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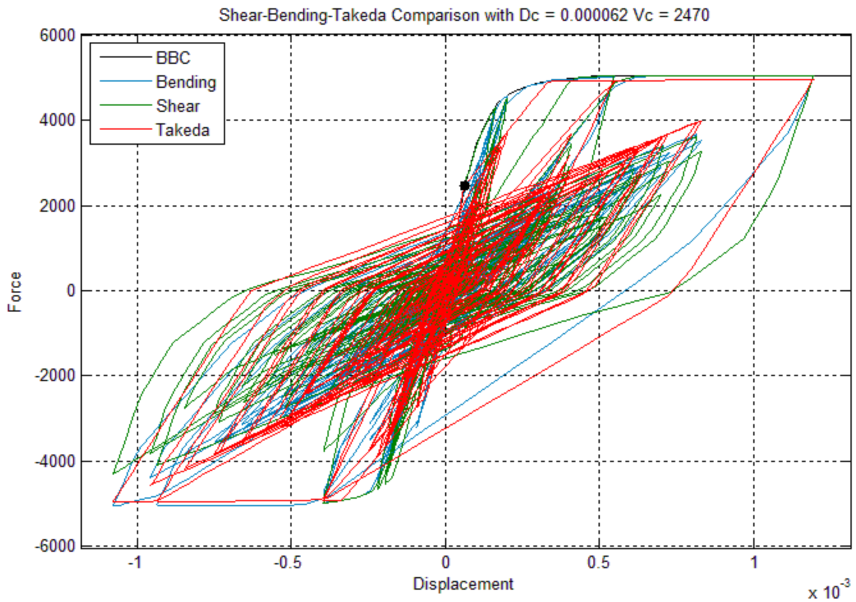
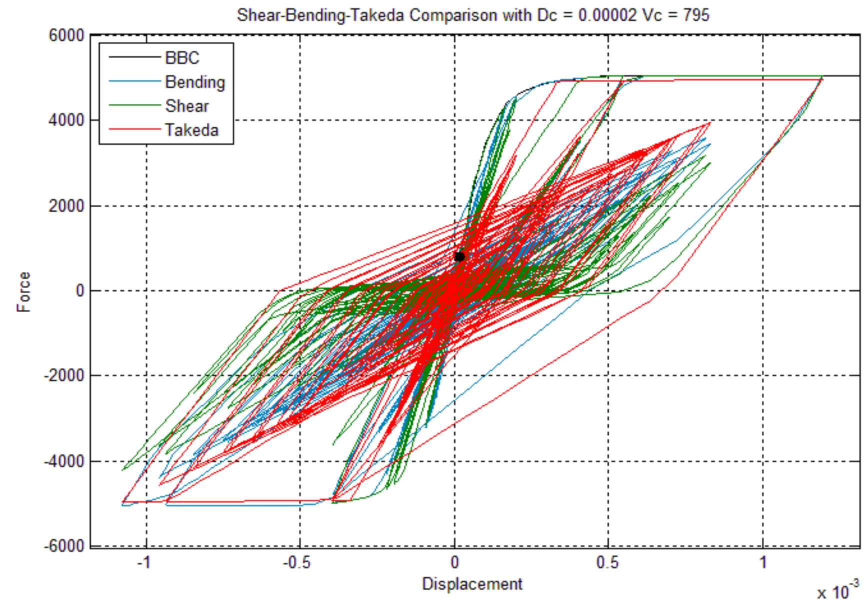
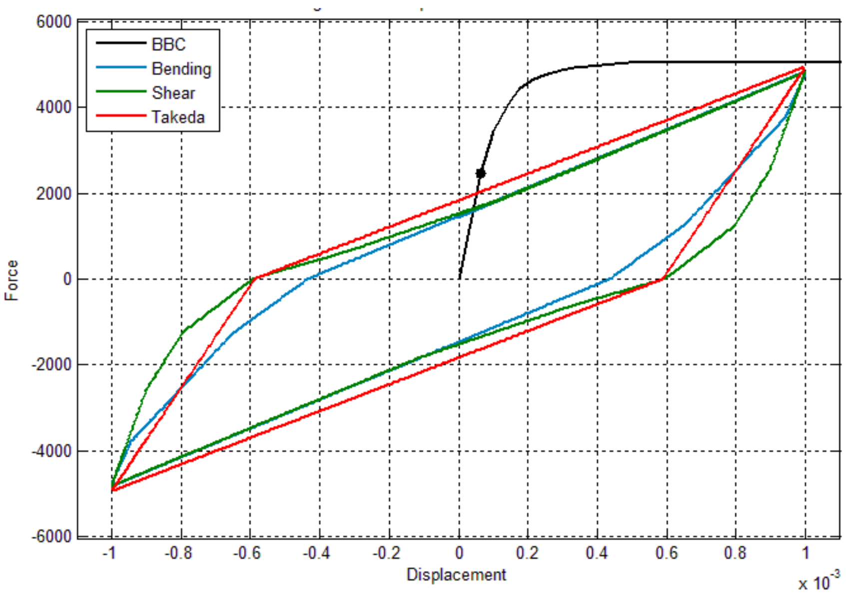
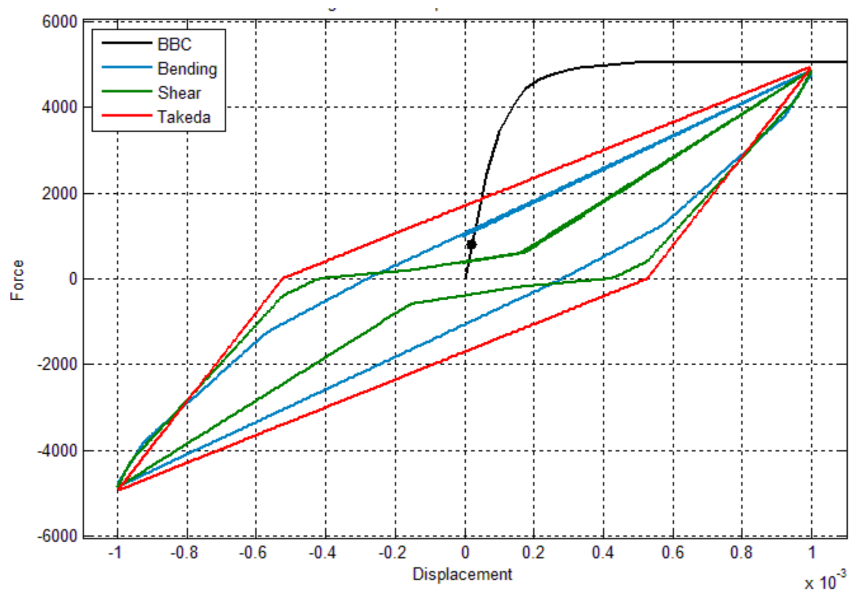
ACS SASSI Option NON Shearwall Hysteretic Models: Cheng-Mertz (CMS) and Takeda (TAK)

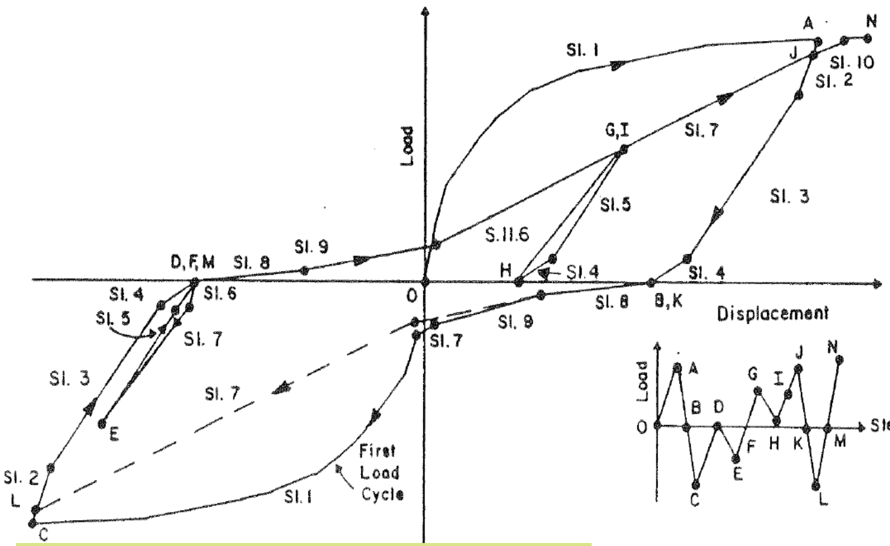




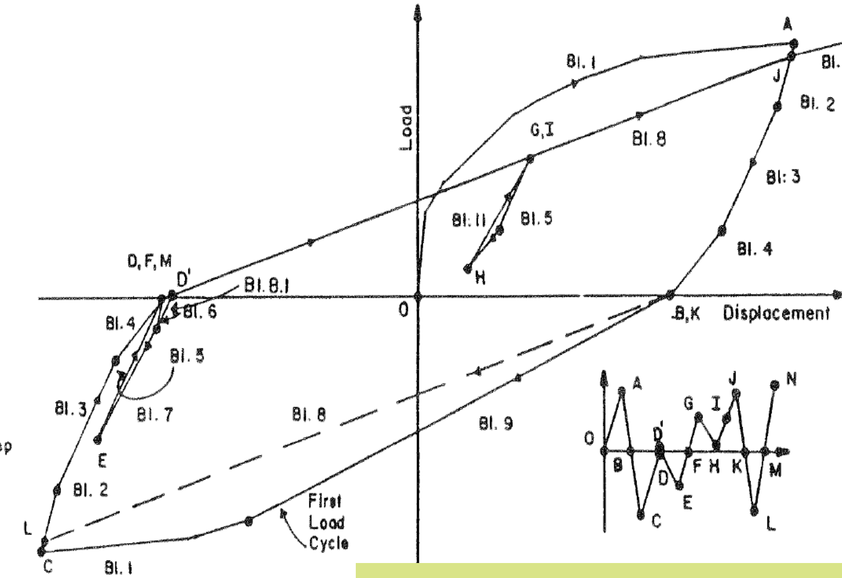




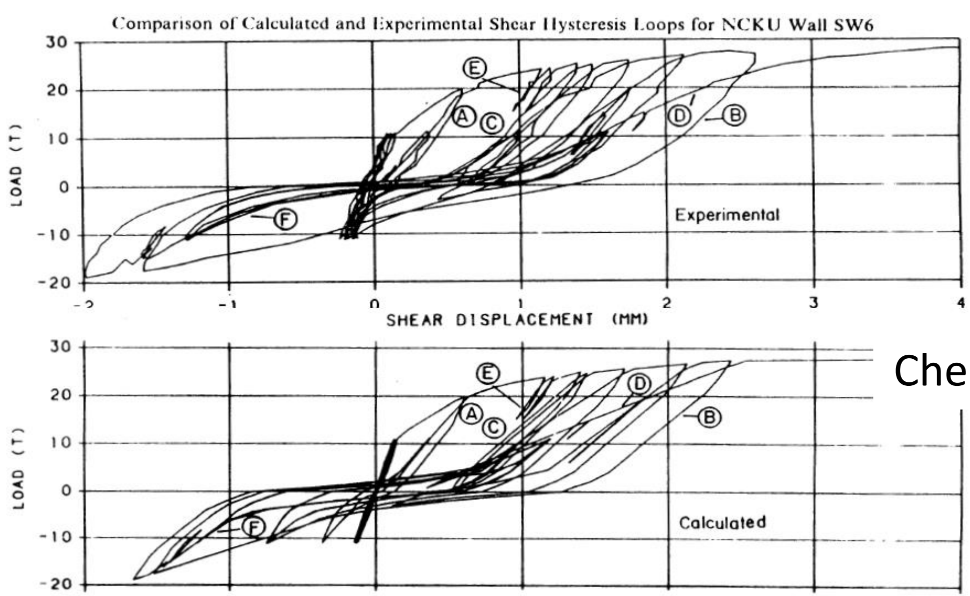
Chen-Mertz Hysteretic Model for Low-Rise Shearwalls



Wall In-Plane Shear



Wall In-Plane Bending



Cheng and Mertz, 1989

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Option NON Applicability to Concrete Structures

Option NON is applicable to the reinforced concrete structures for simulating the concrete cracking (for DBE) and post-cracking behavior (for BDBE) in the low-rise shearwalls.

Based on the time-domain hysteretic behavior, the elastic modulus and damping in each concrete wall are modified iteratively based on the local stress and deformation levels. No out-plane nonlinear behavior is considered.

The Option NON was validated for the low-rise reinforced concrete shearwall buildings that fail primarily due to the *in-plane shear deformation*. Option NON can also consider the nonlinear concrete behavior due to *the in-plane bending deformation* effects. In the same nonlinear structure FE model, the analyst can include wall panels that fail primarily either due to the shear deformation or the bending deformation, respectively. This is an useful practicality.

NOTE: Next upgrade by Fall 2019 will include the combined effects from the shear and bending deformation, plus additional hysteretic models based on Japanese JEAG standard.

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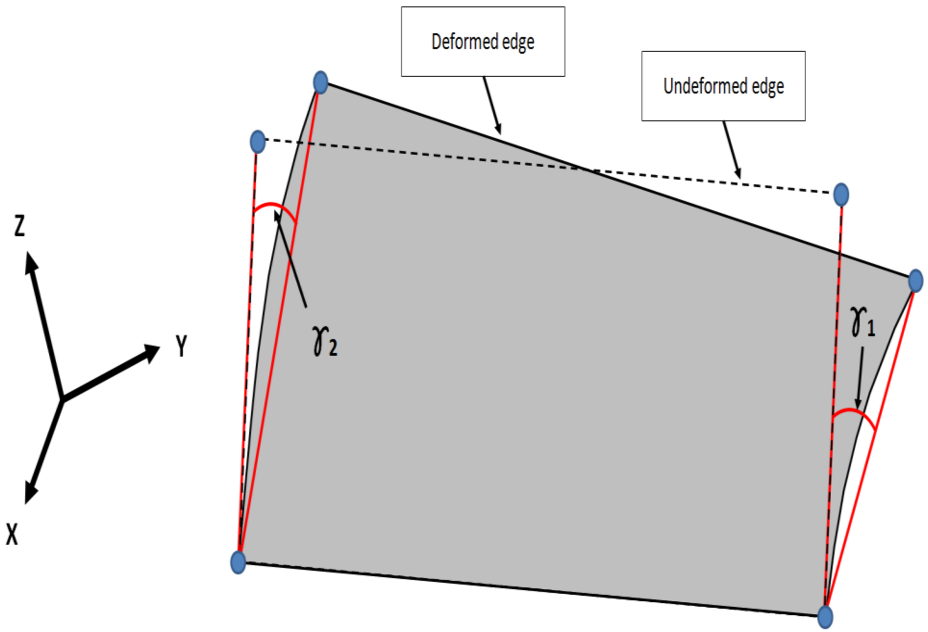
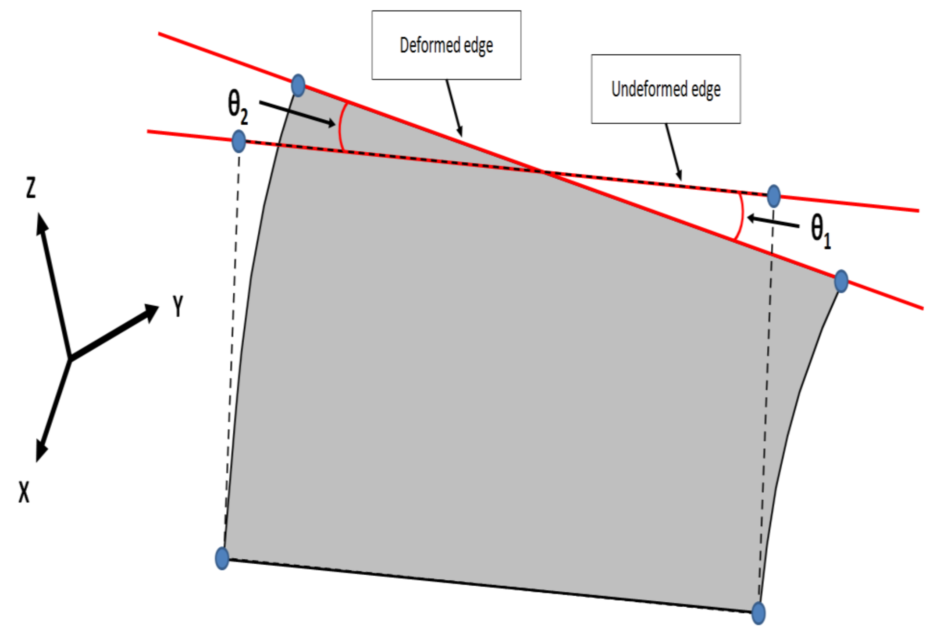
Wall Panel Shear and Bending Deformation Computed at Each SSI Iteration



Shear Strain



Bending Strain (Curvature)

Remark: Rigid body motion is removed. Very important.

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Applicable to Low-Rise Shearwall Structures

Based on the hysteretic behavior of each wall panel, the local equivalent-linear properties are computed after each SSI iteration. The stiffness reduction is applied directly to the elastic modulus for each panel. This implies, under the isotropy material assumption, that the shear, axial and bending stiffnesses suffer the same level of degradation. Poisson ratio is considered to remain constant.

The wall panel shear stiffness modification as a result on nonlinear behaviour is fully coupled with the bending stiffness. This is a *reasonable assumption only for the low-rise shearwalls* for which the nonlinear behaviour is governed by the shear deformation, while bending plays not the dominant role.

Based on various experimental tests done at Cornell University, Gergely points out in *NUREG/CR 4123, 1984* that in *the low-rise walls such as those that occur negliin the modern nuclear power plants, the flexural distortions and associated vertical yielding play a gible role.* This was also recognized by many other research studies, including the EPRI report on “Methodology for Developing Seismic Fragilities” (Reed and Kennedy, 1994).

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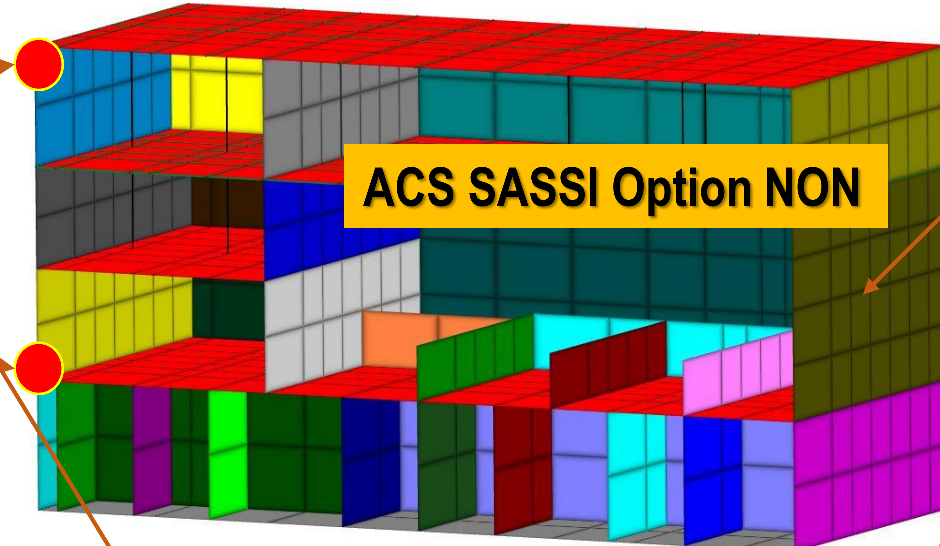
Fixed-Base Validation Study: ACS SASSI Option NON vs. PERFORM3D Nonlinear Time-History Analysis

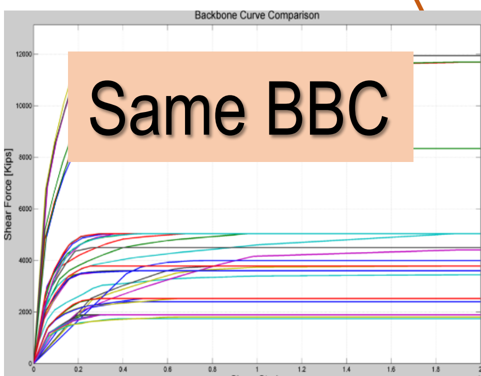
Node 33

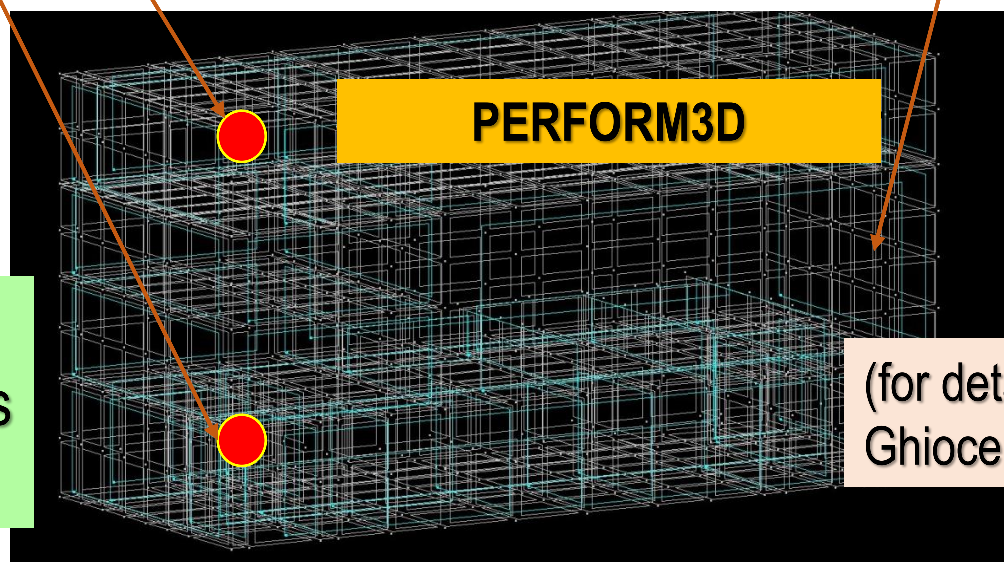
Node 243



Panel 17

CMS Model for Panels Same BBCs





Fiber Shear Model for Panels Same BBCs

(for details Ghiocel, 2015,SMiRT23)

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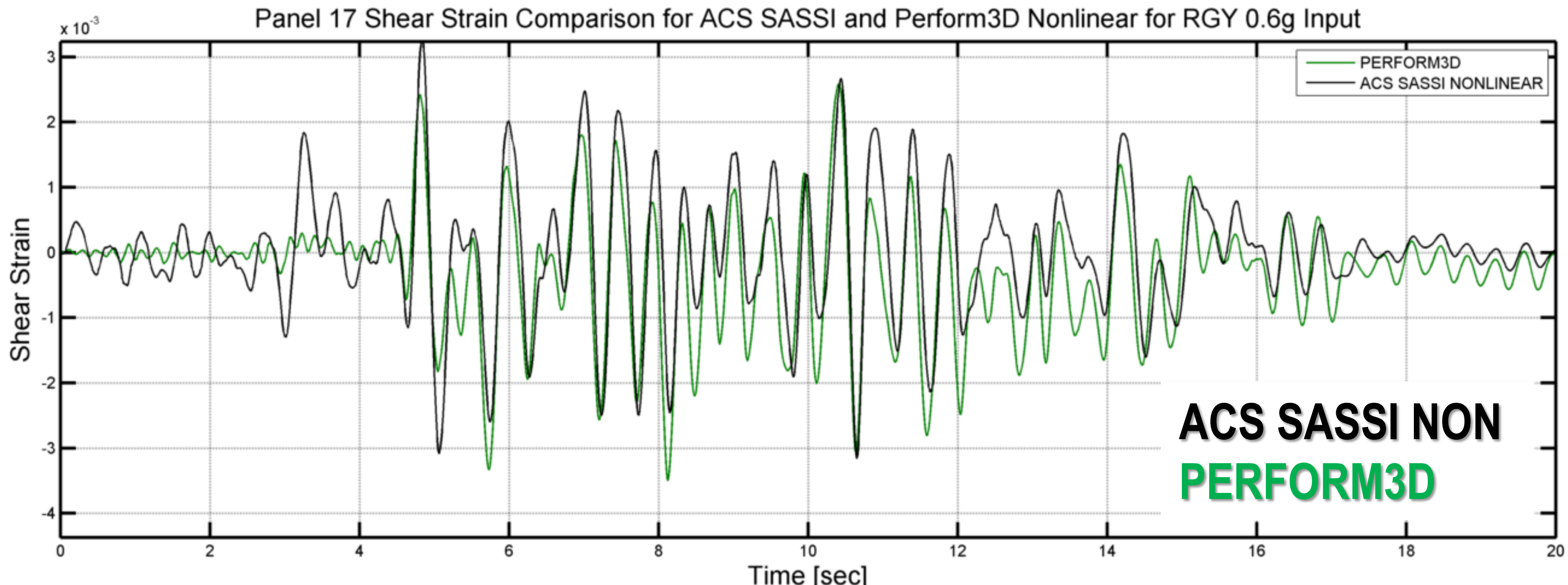
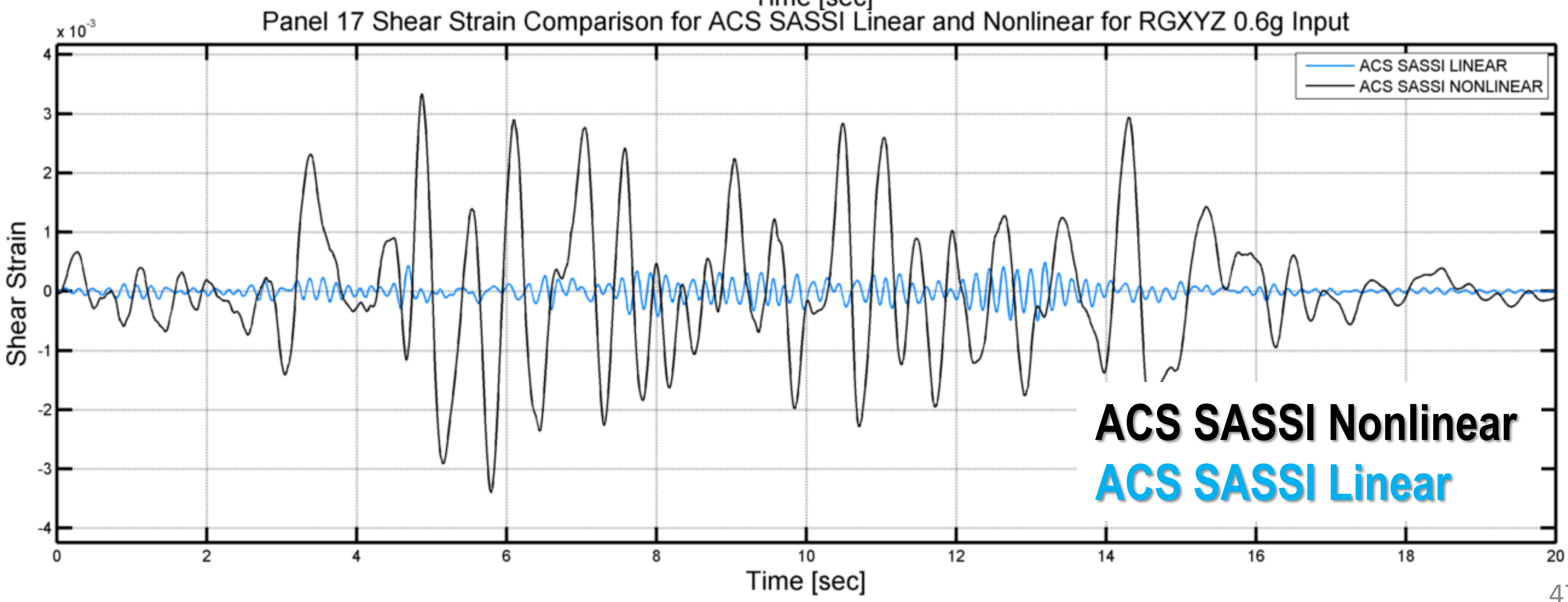
Panel 17 Shear Strains for 0.60g Input





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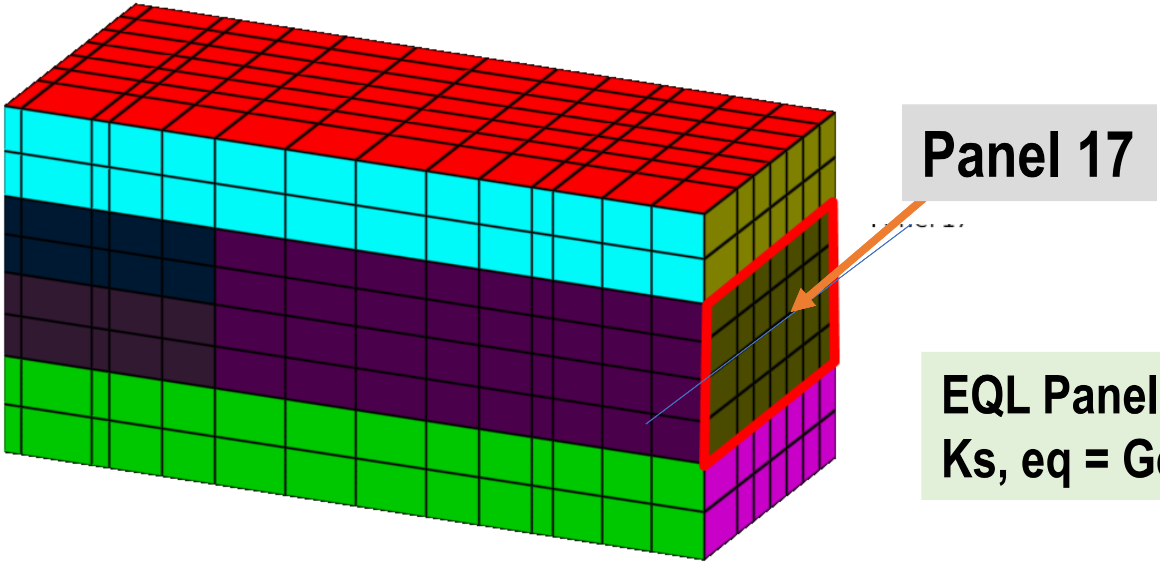
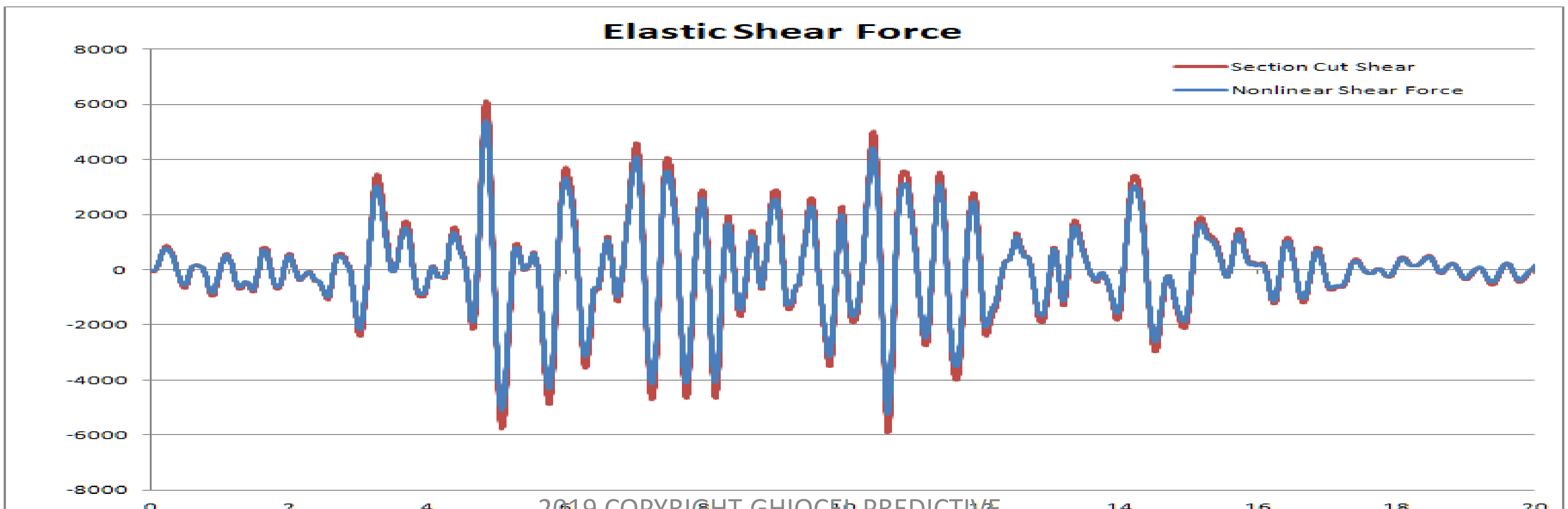
Validation of NONLINEAR Against UI Section-Cuts Using STRESS for Wall Panel In-plane Shear



EQL Panel Shear Stiffness:
Ks, eq = Geq x Area /1.2



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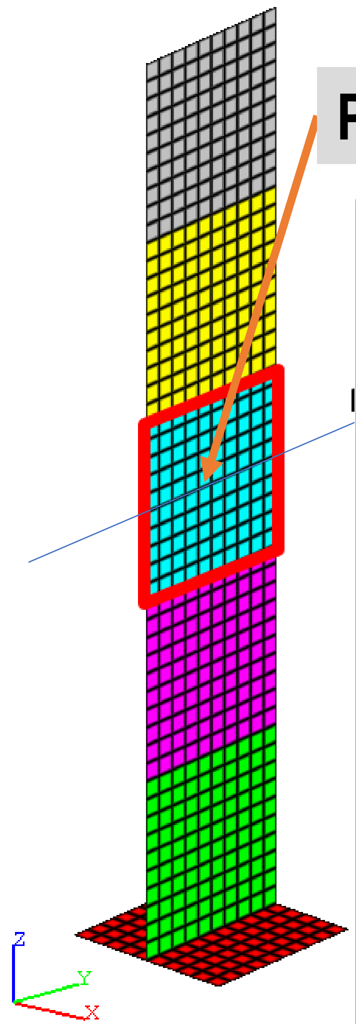
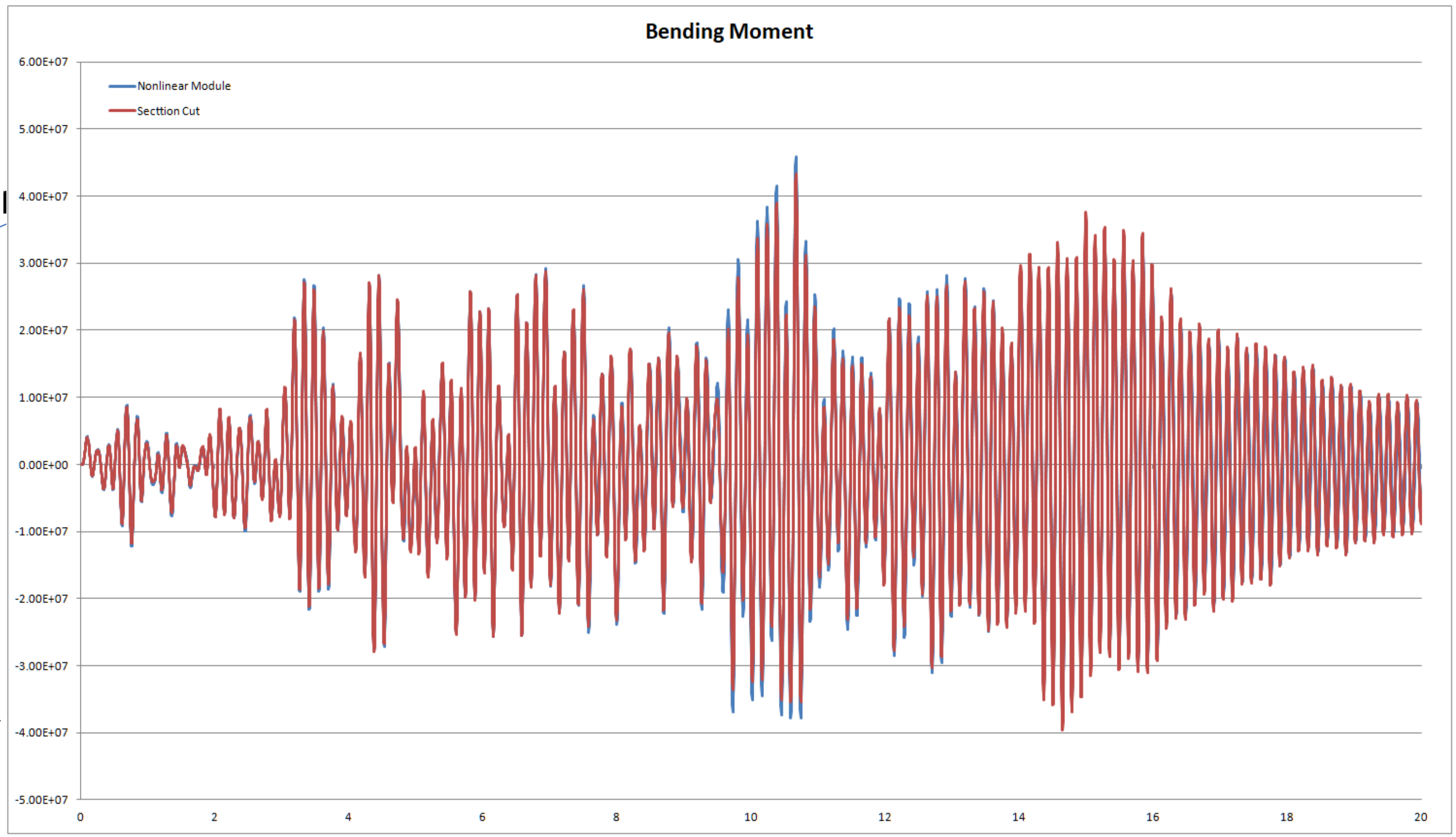
Validation of NONLINEAR Against UI Section-Cuts Using STRESS for Wall Panel In-plane Bending



EQL Panel Bending Stiffness:
Kb, eq = Eeq x Inertia Moment



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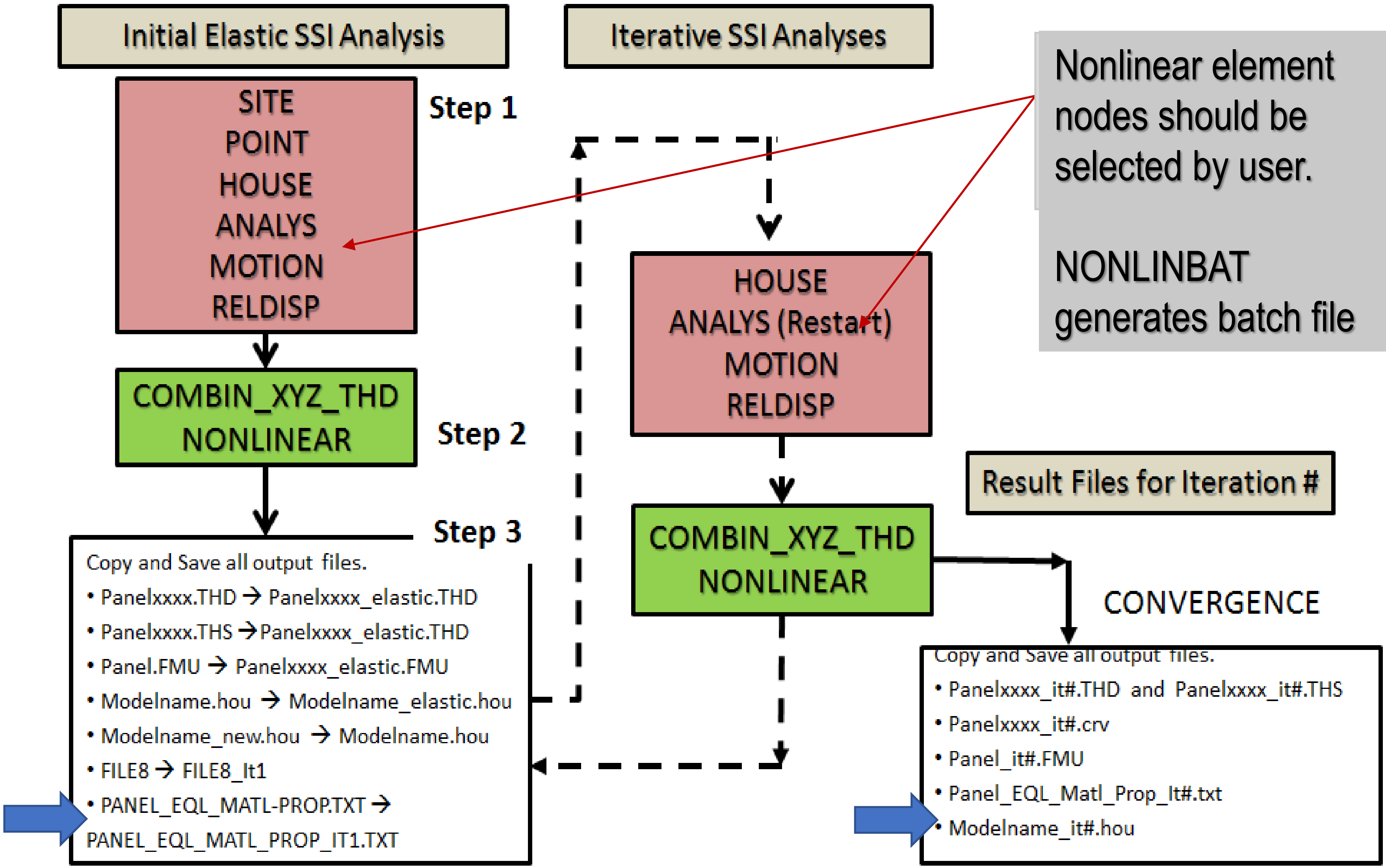
Option NON Application Details (See Demo 9/walls and 10/springs, 12/pushover and V&V Pbs 50, 51, 53 & 54)



Nonlinear XYZ Response at Each SSI Iteration

In the current Option NON there is no hysteretic model for handling axial deformation in wall panels under vertical uniform forces. It should be noted that new ASCE 4-16 recommends to reduce only the shear and bending wall stiffnesses due to the concrete cracking, while the axial stiffness remains unchanged. The structure behaves nonlinearly under the horizontal input components and linearly elastic under the vertical seismic component.

The horizontal and vertical displacements computed at the corners of each wall panel shall include for each SSI iteration, the combined effects of the three seismic input components. This is achieved by using the COMB_XYZ_THD auxiliary program that is automatically included in the batch run file generated by the NONLINBAT, 1. The COMB_XYZ_THD.inp text file that is the input of the COMB_XYZ_THD auxiliary should be defined by the user (see example file for the COMB_XYZ_THD auxiliary program included on the installation DVD).

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Option NON Batch Mode SSI Analysis

- Batch file for a typical nonlinear analysis can be created with the **NONLINBAT** command
  - Option 0 = Create batch file for single input direction, X
  - Option 1 = Create batch file for three-direction input, X, Y, Z
- This will only create the .bat file. The remaining input files need to be created using the AFWRITE function in the UI.
- Nonlinear spring nodes need to be requested as outputs for MOTION and RELDISP runs

NONLINMOTDISP Command

This Option NON command finds the corner nodes of all panels defined by the P command. The corner nodes are then added to the output request list of the MOTION and RELDISP modules.

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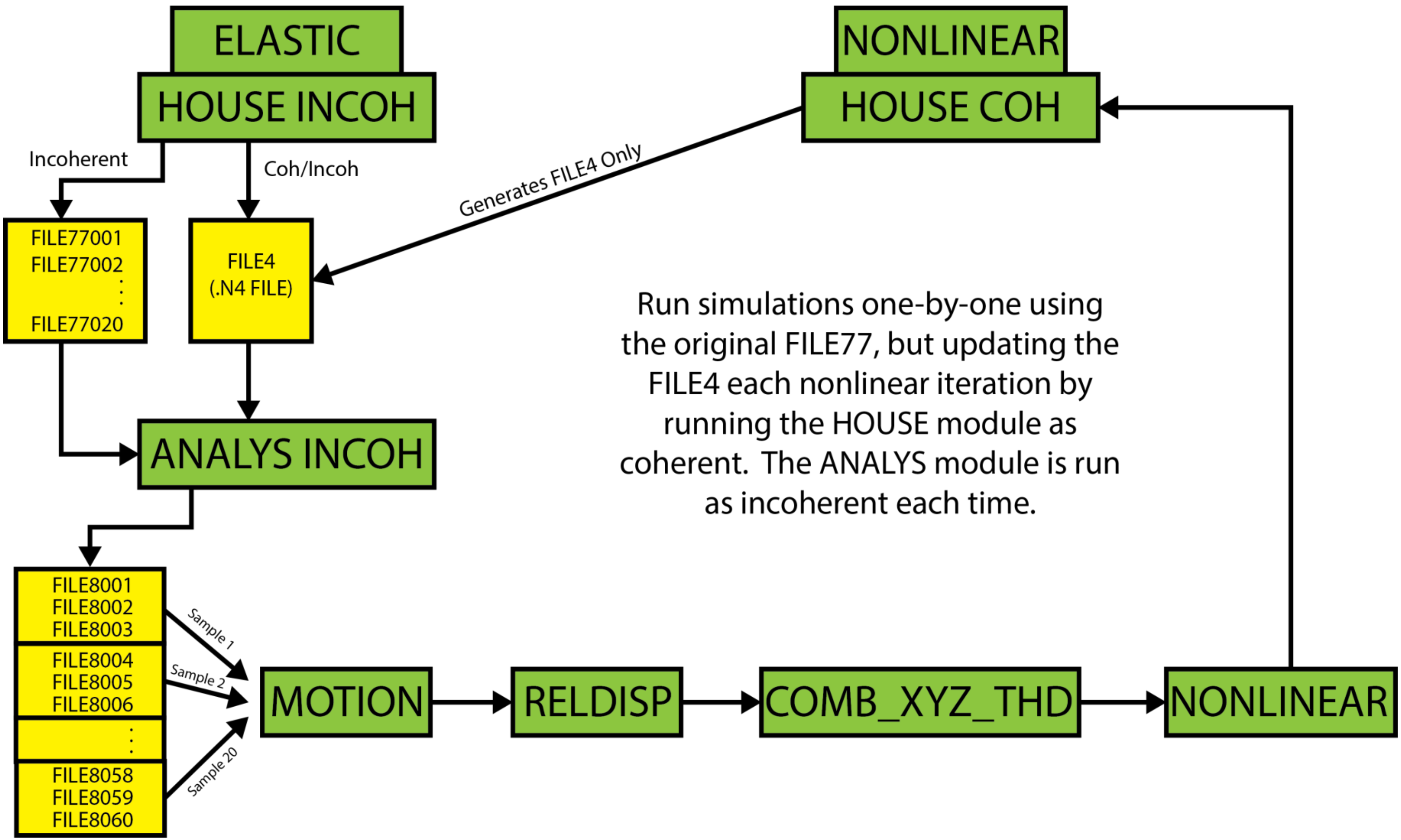
Incoherent Nonlinear SSI Analysis Using Option NON



Run simulations one-by-one using the original FILE77, but updating the FILE4 each nonlinear iteration by running the HOUSE module as coherent. The ANALYS module is run as incoherent each time.

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PANEL_EQL_MATL_PROP_IT# Text Files; Iteration 1,4,6

PANEL_EQL_MATL_PROP_IT1 - Notepa

File Edit Format View Help

00052	519100	0.040000
00053	444427	0.068024
00054	519100	0.040000
00055	428596	0.070299
00056	399598	0.075423
00057	357810	0.086960
00058	296877	0.099000
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00060	519100	0.040000
00061	519100	0.040000
00062	519100	0.040000
00063	519100	0.040000
00064	427612	0.070436
00065	430509	0.070032
00066	329360	0.099000
00067	497448	0.051490
00068	495021	0.052083
00069	486163	0.054532
00070	519100	0.040000
00071	492199	0.052772
00072	519100	0.040000
00073	332062	0.099000
00074	433258	0.069637
00075	428142	0.070362
00076	423965	0.070945
00077	323590	0.099000
00078	519100	0.040000
00079	493437	0.052469
00080	490450	0.053245
00081	305877	0.099000
00082	519100	0.040000
00083	432717	0.069715
00084	423693	0.070983

PANEL_EQL_MATL_PROP_IT4 - Note

File Edit Format View Help

00052	519100	0.040000
00053	434881	0.069402
00054	519100	0.040000
00055	379428	0.079385
00056	363115	0.084592
00057	202701	0.122536
00058	128331	0.172728
00059	519100	0.040000
00060	519100	0.040000
00061	519100	0.040000
00062	519100	0.040000
00063	504400	0.050117
00064	420231	0.071465
00065	408232	0.073671
00066	292851	0.099000
00067	484745	0.054958
00068	482626	0.055594
00069	470562	0.059843
00070	519100	0.040000
00071	477685	0.057287
00072	519100	0.040000
00073	175308	0.139764
00074	432823	0.069700
00075	436629	0.069150
00076	428687	0.070286
00077	276456	0.099000
00078	519100	0.040000
00079	475545	0.058055
00080	475535	0.058058
00081	161111	0.149287
00082	519100	0.040000
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PANEL_EQL_MATL_PROP_IT6 - N

File Edit Format View Help

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00061	519100	0.040000
00062	519100	0.040000
00063	519100	0.040000
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00065	421897	0.071233
00066	355619	0.087938
00067	497556	0.051464
00068	496152	0.051806
00069	489277	0.053597
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00071	492105	0.052795
00072	519100	0.040000
00073	149501	0.157120
00074	461457	0.064862
00075	462244	0.064421
00076	451532	0.067469
00077	331961	0.099000
00078	519100	0.040000
00079	490346	0.053276
00080	491813	0.052866
00081	135058	0.167238
00082	519100	0.040000
00083	450253	0.067567
00084	457948	0.066831

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Automatic BBCs for Shear Deformation

The wall panel BBC curves should have a smooth shape and variation that describes the nonlinear behavior of the wall panels under the lateral seismic loading.

The BBC could be built based on the existing pertinent technical recommendations, or computed using static nonlinear push-over FE analysis. For estimating the low-rise shearwall panel capacities there are a significant number of sources in the literature that provide empirical equations for computing the wall panel shear capacities (Gulec and Whittaker, 2009, Wood, 1990, ACI 349-08, Barda et al., 1977).

Using the SHEAR command the user can check the computed shear capacity values based on different shear capacity equations. Using the BBCGEN command smooth BBC curves can be automatically generated for many wall panels.

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Experiment-Based Shear Capacities for Squats

Walls have no openings!

Useful References for Peak Capacity Equations:

- Barda et al.,1977 in the 1994 EPRI Reports – could overly estimate
- ASCE 318-08, based on Barda
- Wood, 1990 – small bias, less 10% lower, for the median capacity
- Gulec and Whittaker, 2009, Eqs. 6.9-6.10, small bias for median capacity
- ASCE 43-05, 2005 Eqs. 4-3/4 based on Barda, *ASCE 43-19 took out it*

NOTE: ATC 72-1 Option 3, 2010 for reduce yielding and peak capacities to account cyclic degradation effects for many cycles.

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Shear Capacities for Squat Wall Panels

The wall panel BBC curves should have a *smooth shape* and variation that describes the nonlinear behavior of the wall panels under the lateral seismic loading. For estimating the low-rise shearwall panel capacities there are a significant number of sources in the literature that provide empirical equations for computing the wall panel shear capacities.

The SHEAR and BBCGEN commands include four capacity equations:

1 - ACI 318-08
2 - Wood 1990
3 - Barda 1977
4 - Gulec-Whittaker 2009

Please see details in Gulec and Whittaker, 2009, Wood, 1990, ACI 349-08, Barda et al., 1977.

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SHEAR Command

SHEAR, <panel>,[fc],[fy],[P],[Nu],[Fvw],[Fbe]

This command calculates the peak shear strength of a single panel or all wall panels. The SHEAR command uses four different peak shear equations, such as those provided by *ACI 318-08, Wood, 1990, Barda et al.,1977 and Gulec-Whitakker, 2009* (please see Gulec and Whittaker, 2009 for details).

The lower bound value for Wood, 1990, and the upper bound value for Wood, 1990 and ACI 318-08 equations are also included.

A total of six columns with computed peak shear strength are written for each panel. The columns of the result table are in order, the panel number, upper bound of ACI 318-08 and Wood, 1990, lower bound of Wood, 1990, Barda,1977 and Gulec-Whittaker, 2009.

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SHEAR Command for Computing Wall Shear Capacities

Barda et al., 1977:

The Barda equation (equation 2-7 or 4-7 in Gulec and Whittaker, 2009) is applicable to squat walls with heavily reinforced flanges (barbells). For typical shearwalls in nuclear facilities Barda equation could provide overly estimated shear strength values. Axial force effect is included.

$$V = \left(8\sqrt{f_c'} - 2.5\sqrt{f_c'}\,\frac{h_W}{l_W} + \frac{N_U}{4 l_W t_W} + \rho_V f_y \right) t_W (0.6 l_W)$$

Wood, 1990:

The Wood equation appears (equation 2-8 in Gulec and Whittaker, 2009) close to be quite close to the median estimates for ultimate shear strength for various squat wall tests. Axial force is not included.

$$6\sqrt{f_c'}A_W \le V = \frac{\rho_V A_W f_y}{4} \le 10\sqrt{f_c'}A_W$$

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ACI 318-08, 2008:

The ACI 318-08 Chapter 11 equation appears (equation 4-1 in Gulec and Whittaker, 2009) could provide overly estimated ultimate shear strengths. Axial force is not included.

$$V = \left(\alpha_c \sqrt{f'_c} + \rho_H f_y\right) A_W \leq 10\sqrt{f'_c}\, A_W$$

Gulec-Whittaker, 2009:

The Gulec-Whittaker equation appears (equation 6-9 in Gulec and Whittaker, 2009) to be also close close to the median estimates for the ultimate shear strength for various squat wall tests.

This Gulec-Whittaker equation is sensitive to the panel height/length aspect ratio. If this equation is applied to long panels the ultimate shear force goes up much closer to Barda, 1977 or ACI 318-08 shear force results, and even higher. Axial force is included.

$$V = \left(1.5\sqrt{f'_c}\, A_W + 0.25 F_{VW} + 0.20 F_{BE} + 0.40 N_U\right) / \sqrt{h_W / l_W}$$

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SHEAR Command Example for 20 Wall Panels

SHEAR,#,2,4.771,83.25,0.01

Panel #	Upper Bound ACI 318-08	ACI 318-08	Wood (1990)	Lower Bound (Wood, 1990)	Barda (1977)	Gulec-Whittaker (2009)
1	5968.3261	8983.4501	1798.2381	3580.9957	6904.5338	4850.7109
2	12533.4754	18865.2311	3776.2971	7520.0853	14484.2127	10054.6795
3	29692.4449	44692.6981	8946.2412	17815.4669	35128.3838	36663.1603
4	8952.4780	13475.1583	2697.3537	5371.4868	10175.8698	6069.8205
5	10966.7910	16507.0772	3304.2600	6580.0746	12918.2495	12082.1974
6	9400.1066	14148.9233	2832.2228	5640.0639	11033.3518	9587.9496
7	9400.1066	14148.9233	2832.2228	5640.0639	11033.3518	9587.9496
8	10444.6076	15721.0933	3146.9277	6266.7646	12290.0041	11229.6125
9	29692.4449	44692.6981	8946.2412	17815.4669	35128.3838	36663.1603
10	12533.4754	18865.2311	3776.2971	7520.0853	14484.2127	10054.6795
11	12533.4754	18865.2311	3776.2971	7520.0853	14484.2127	10054.6795
12	29692.4449	44692.6981	8946.2412	17815.4669	35083.6236	35357.2905
13	6266.7377	9432.6155	1888.1486	3760.0426	6899.8619	3428.2487
14	11190.6031	16843.9563	3371.6939	6714.3618	12823.8260	8180.6964
15	20739.9669	31217.5398	6248.8874	12443.9802	23898.7329	16082.1780
16	20739.9669	31217.5398	6248.8874	12443.9802	23898.7329	16082.1780
17	12533.4754	18865.2311	3776.2971	7520.0853	14025.4002	7555.0970
18	12533.4754	18865.2311	3776.2971	7520.0853	14577.4707	10949.3572
19	12533.4754	18865.2311	3776.2971	7520.0853	14577.4707	10949.3572
20	29692.4449	44692.6981	8946.2412	17815.4669	35083.6236	35357.2905

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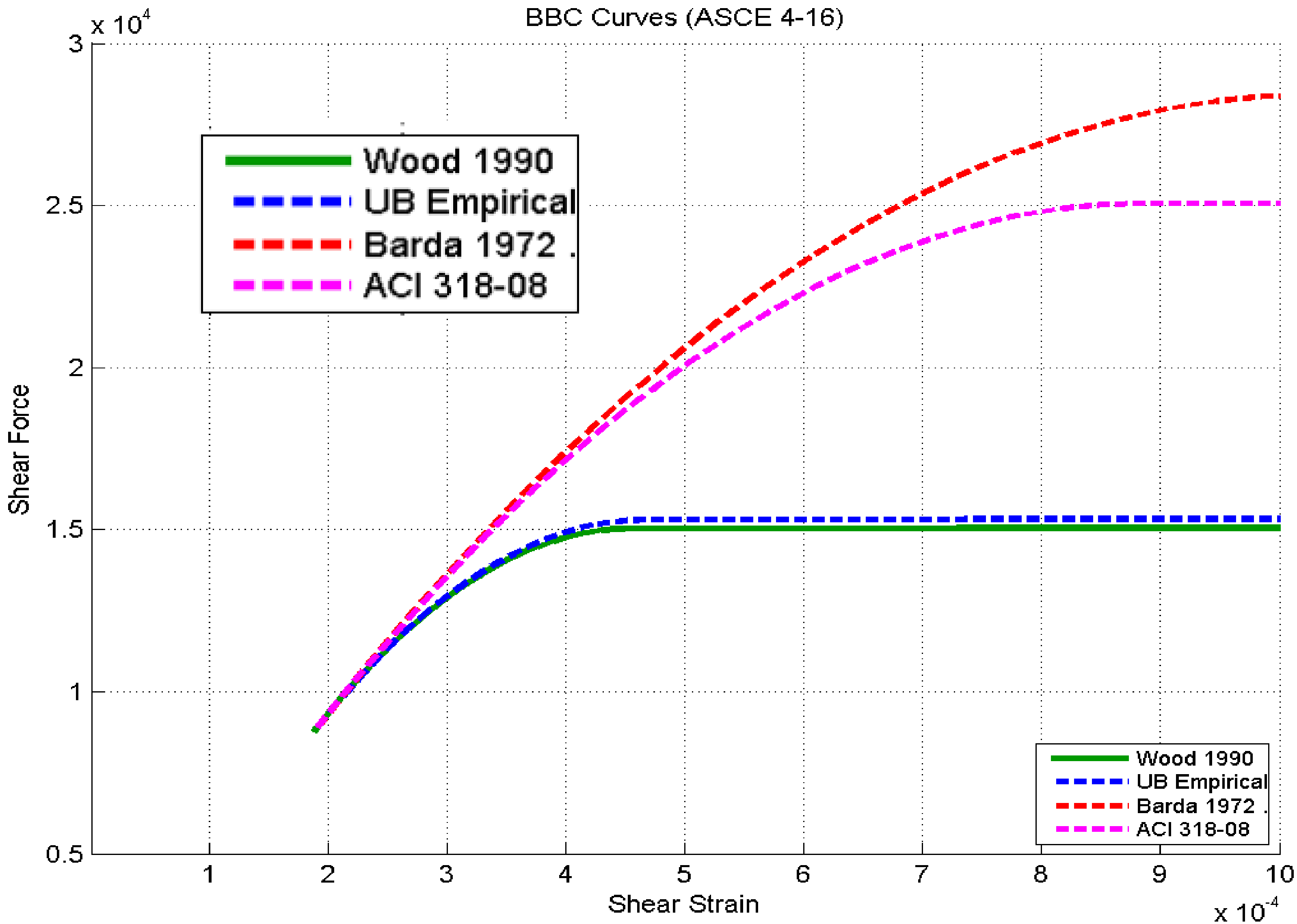
SHEAR Command Shear Capacities for Panel 17



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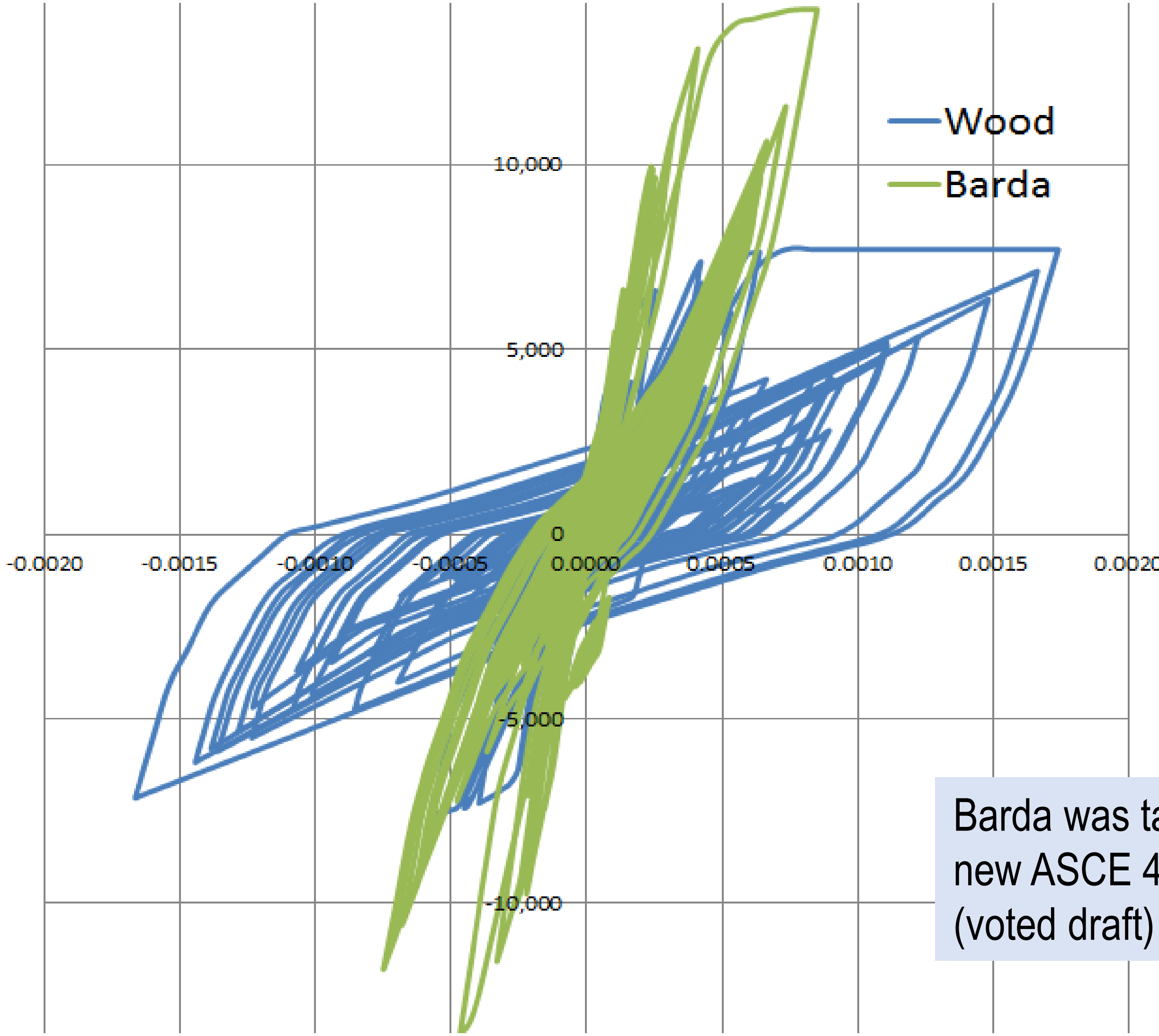
Shearwall Panel 17 Hysteretic Behavior Barda (1977) vs. Wood (1990) for 0.60g Input



Barda was taken out of the new ASCE 43-17 standard (voted draft)

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ASCE 4-16, Sect. C3.3.2 Recommendations

If the structure is being analyzed for site-specific demands (e.g., new nuclear facility at a specific site or an existing structure), complete the analysis by using the results from the cracked analysis runs to determine the structural seismic demands.

Accepted Practice:

- Iterative equivalent-linear hysteretic models are usually reasonable for the material nonlinear behavior. For the concrete cracking, the ASCE 4-16 Section C3.3.2 recommends at a minimum a two-step equivalent-linearization procedure to evaluate concrete cracking as a function of stresses in different structure parts.
- The equivalent-linear models are numerically efficient and reasonable accurate for practical engineering analysis purposes.

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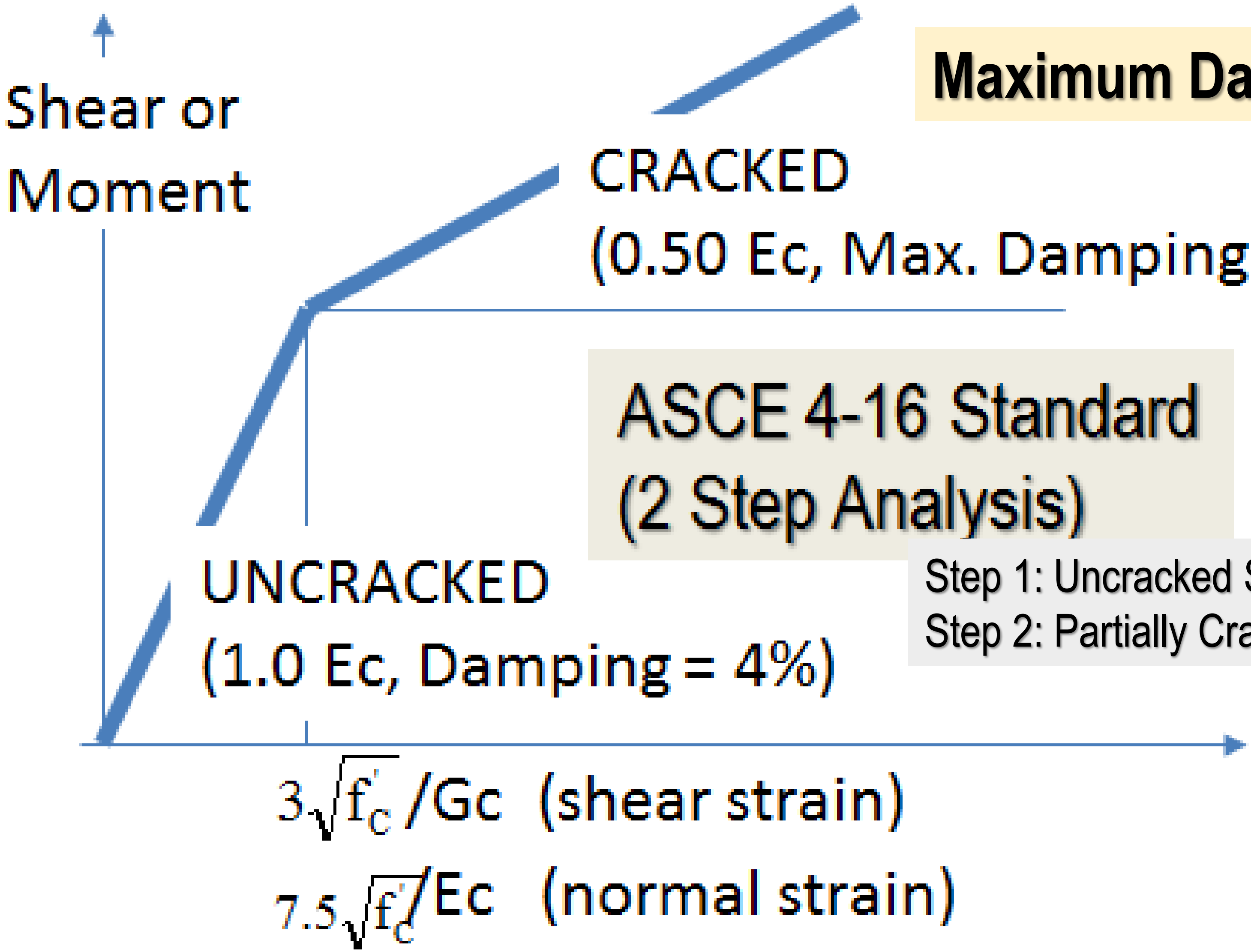
Design Level: Concrete Cracking Pattern for Site-Specific Applications Per ASCE 4-16 C3.3.2

Maximum Damping -RL2



ASCE 4-16 Standard
(2 Step Analysis)

Step 1: Uncracked SSI Model
Step 2: Partially Cracked SSI Model

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Automatic Building of Backbone Curves (BBC) Using Efficient Option NON UI Commands

Using *the PANELGEN command*, the entire structure can be panelized in seconds.

The wall panel BBC curves should have a smooth shape and variation that describes the nonlinear behavior of the wall panels under the lateral seismic loading. The BBC could be built based on the existing pertinent technical recommendations, or computed using static nonlinear pushover FE analysis. For estimating the low-rise shearwall panel capacities there are a significant number of sources in the literature that provide empirical equations for computing the wall panel shear capacities (Gulec and Whittaker, 2009, Wood, 1990, ACI 349-08, Barda et al., 1977).

Using the *SHEAR command* the user can check the computed shear capacity values based on different shear capacity equations.

The BBCGEN command smooth BBC curves can be automatically generated for many wall panels.

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Commands for Loading/Computing Wall BBCs

BBC	Add a backbone curve from a file
BBCGEN	Generate BBC curves for defined panels
BBCI	Sets BBC information
BBCP	Defines single point on BBC
BBCX	Backbone curve definition command
BBCY	Backbone curve definition command

BBCGEN Command

BBCGEN,<Panel>,<ShearModel>,[fc],[fy],[Pn],[Nu],[bre],[bys],[CrackingForceLevel]

The user can run first the SHEAR command and get the computed shear strength estimates based on ACI 318-08, Wood, Barda and Gulec-Whittaker empirical equations (see the SHEAR command for details).

The BBCGEN command always generates a 22 point BBC curves, the first point being the cracking point of the BBC curve. The next 20 points will be equidistantly spaced along the strain axis until the yield point is reached.

The final shear failure point for all BBC curves will be defined by default at (shear strain = 2% and shear force = 1.02 x ultimate shear force value).

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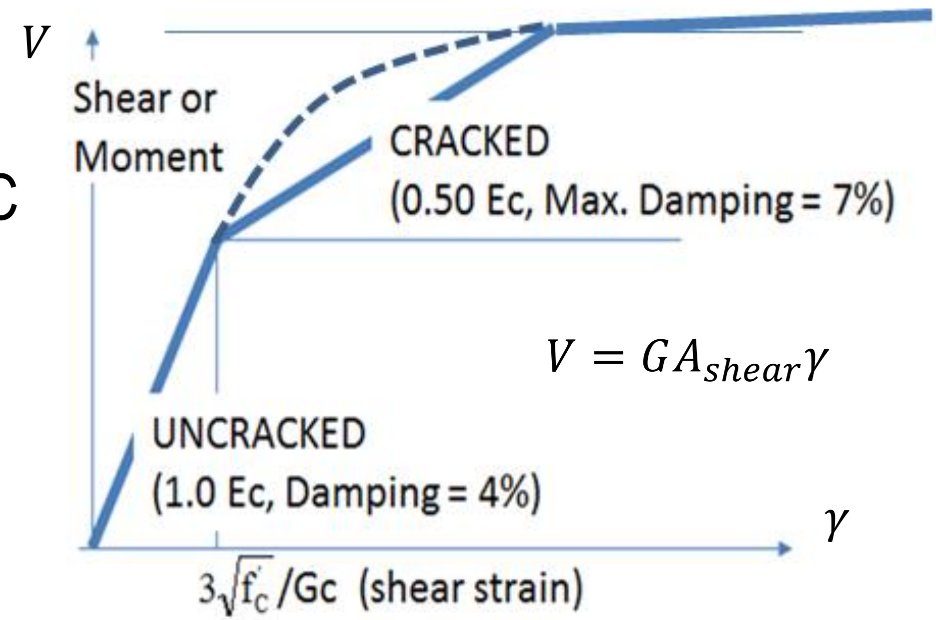
BBCGEN Command (continuation)

<Panel>
= 0, the BBC curves will be generated for all panels defined by the user assuming the same command parameters. The Panel = 0 option, it can be used in conjunction of submodels, to define properties of panel subsets.
= K, the BBC will be generated only for Panel K.

[CrackForceLevel]
= 0. Default option for building BBC curves uses new ASCE 4 standard recommendation in Section C.3.3.2 for defining the concrete cracking stress level by the value of $3\sqrt{f'_c}$



= Vcr/Vu alue in the [0.1 0.5] interval. Uses the cracking shear/ultimate shear force ratio to build the BBC curves.

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Elastic Behavior Segment in Wall BBCs

For nonlinear wall panels and springs, the slope of the first segment of the BCC curves should correspond to the elastic stiffness included in the initial HOUSE input file before any iteration.

For concrete wall panels, the BBC elastic shear stiffness values defined by the cracking point should be equal to GAshear for shear type BBCs, where G is the elastic shear modulus and Ashear is the cross-sectional shear area, and equal to EI for bending type BBCs, where E is the elastic longitudinal modulus and I is the moment of inertia of the cross-sectional area.

The effects of vertical axial forces, if significant, should be included in the BBCs since can affect the panel capacities.

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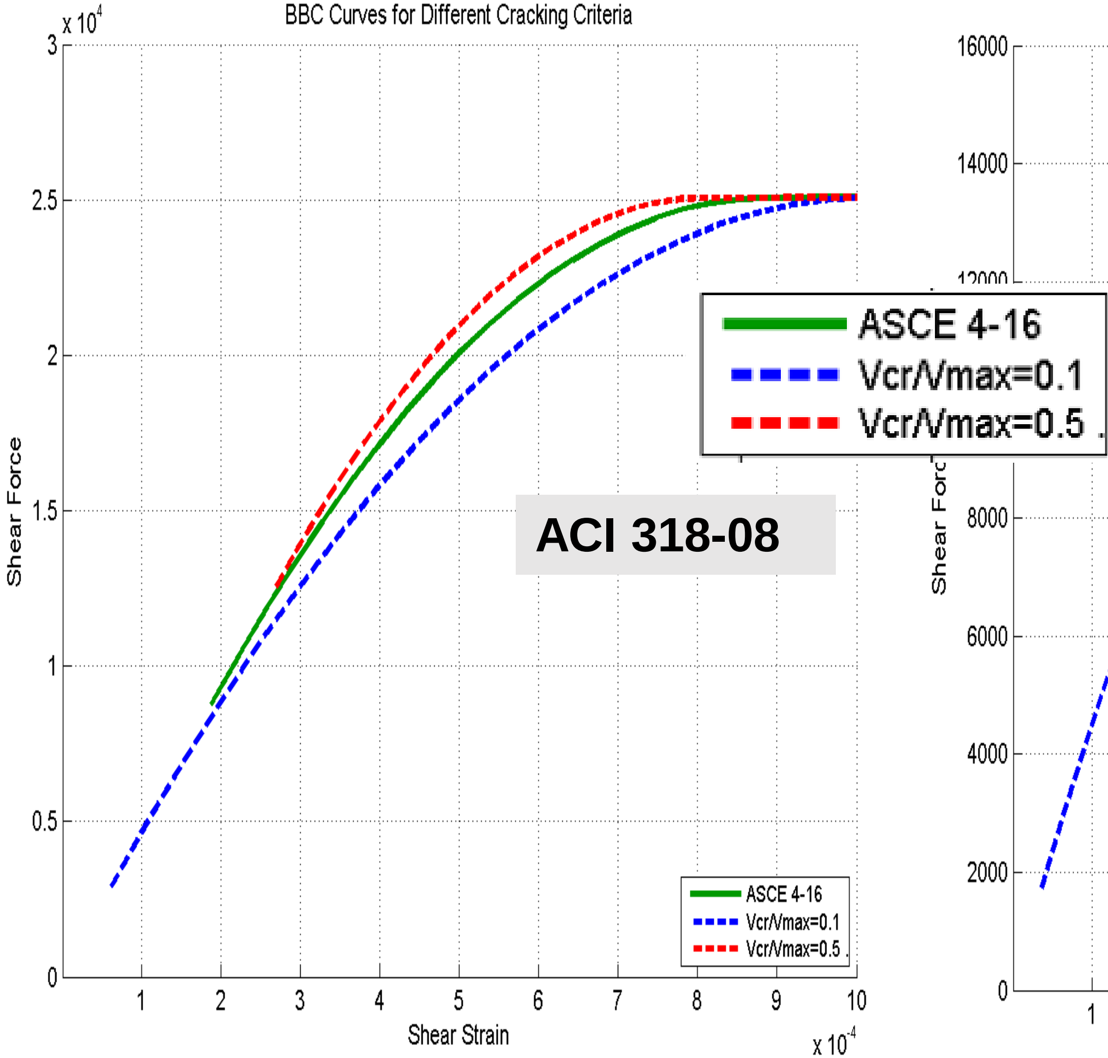
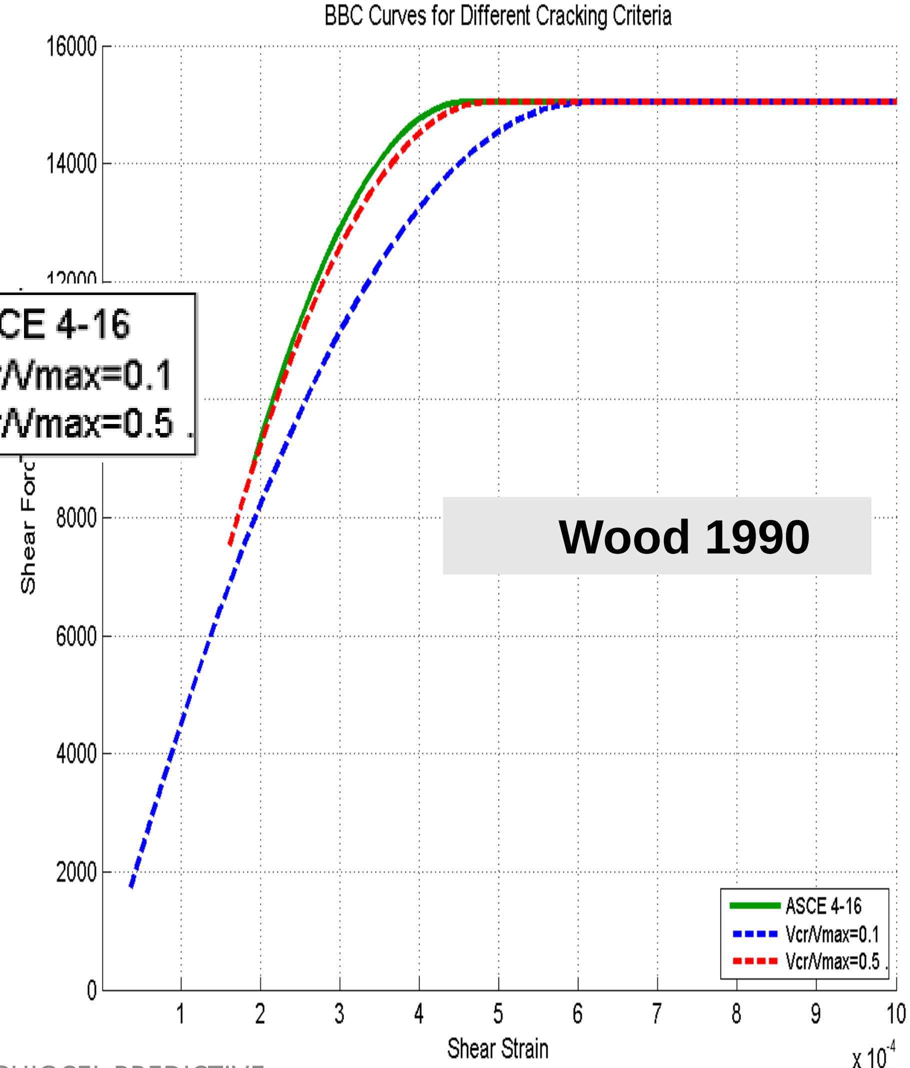
BBCGEN for Different Concrete Shear Cracking Criterion Parameter Options





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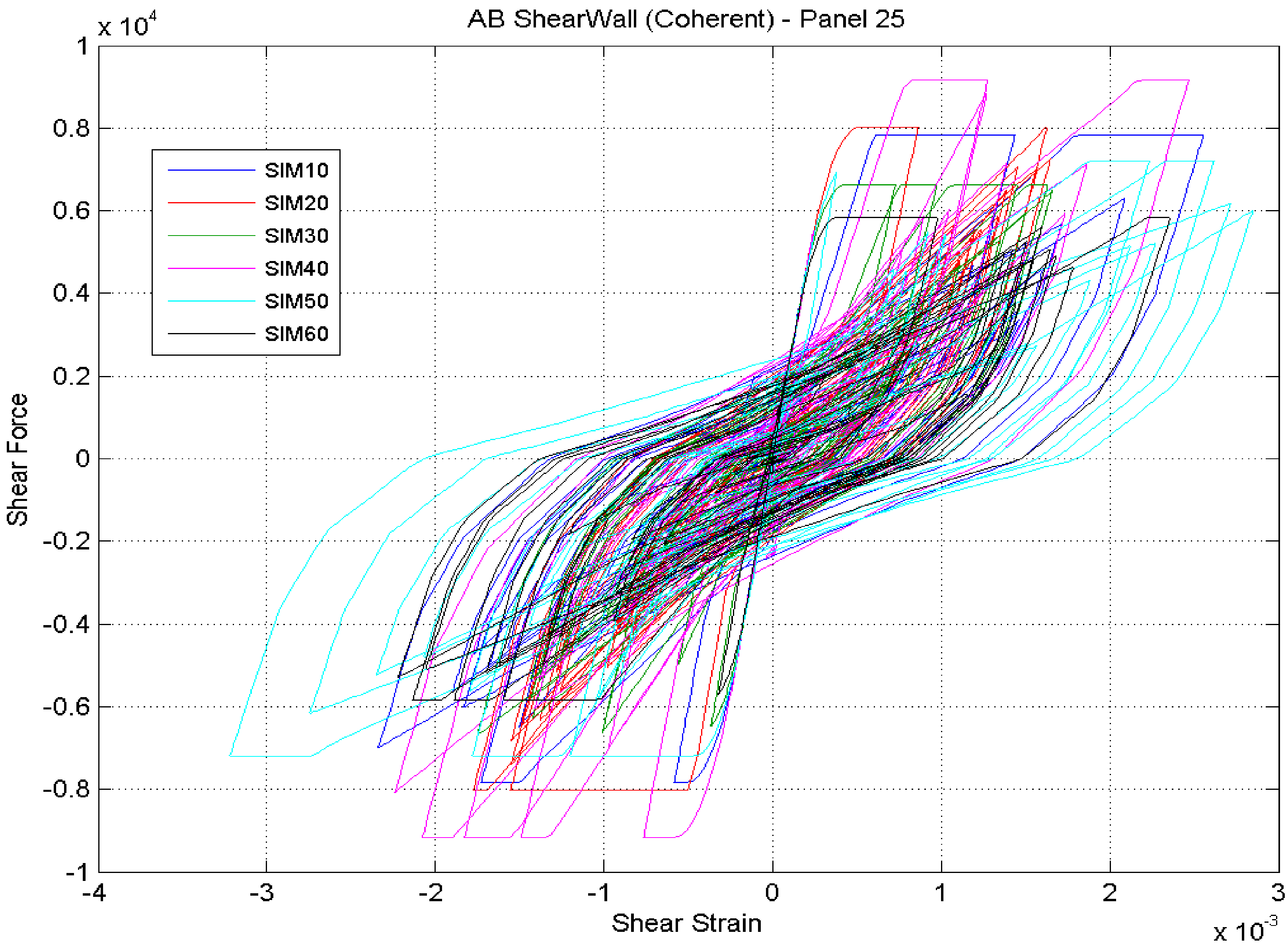
ProNON Simulations of Wall Hysteretic Loops



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Nonlinear Structure SSI Input .Pre File (EQL, P)

AB_SHEAR_NL.pre

```
L,11,5,0.15,200000,100000,0.01,0.01
L,12,5,0.15,200000,100000,0.01,0.01
L,13,5,0.15,200000,100000,0.01,0.01
L,14,5,0.15,200000,100000,0.01,0.01
L,15,5,0.15,200000,100000,0.01,0.01
L,16,5,0.15,200000,100000,0.01,0.01
* Real Property Table
R,1,11.111,0,0,17.387,10.288,10.288
R,2,13,0,0,22.316,9.75,20.343
R,3,2.849,0,0,28.958,0.333,28.292
* NonLinear
EQL,0.8,1,0,1,1
P,1,3,1,1,1
P,2,8,2,1,1
P,3,9,3,1,1
P,4,10,4,1,1
P,5,11,5,1,1
P,6,12,6,1,1
P,7,13,7,1,1
P,8,14,8,1,1
P,9,15,9,1,1
P,10,16,10,1,1
P,11,17,11,1,1
P,12,18,12,1,1
P,13,19,13,1,1
P,14,20,14,1,1
P,15,21,15,1,1
P,16,22,16,1,1
P,17,23,17,1,1
P,18,25,18,1,1
P,19,26,19,1,1
P,20,27,20,1,1
P,21,28,21,1,1
```

EQL command

EQL,<disp>,<NonLinOpts>,<dampCutoff>,<dampScale>,<ElasicD>

PANELGEN and P commands

P,<num>,<group>,<bbc>,<disp>,<force>

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EQL Command

EQL,<disp>,<NonLinOpts>,<dampCutoff>,<dampScale>,<ElasicD>

Set the options for the nonlinear structure simulation. This command is simlar to HOUSE,ANALYS or STRESS commands in that it sets header information for the nonlinear module input (*.eql) file. This information can also be set interactively using the NONLINEAR analysis options tab, found in the Options→Analysis menu selection.

- Disp – displacement/strain reduction factor (typically 0.80)
- NonLinOpts - non-linear options
- DampCutoff - damping cutoff value
- DampScale - damping scaling factor
- ElasicD - Include elastic damping flag
  - 0 - Don't include
  - 1 - Include

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P Command

P,<num>,<group>,<bbc>,<disp>,<force>

This Option NON command defines wall panels for nonlinear structure SSI analysis. This command associates the SSI model data with a finite shell element group to create the wall panel. This command does not define any new groups or elements and no linear SSI model information is changed by this command. All shells in a panel group should be coplanar. Coplanar shell groups can be created by using the WALLFLR command.

- num - panel number
- group - group number
- bbc - back bone curve number
- disp - displacement type
- force - force option

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PNLGEN Command

PNLGEN

This Option NON command generates panel data for each shell group that is found to be in the vertical plane. This command will associate a panel numbers in groups in an ascending order based on group number. Each panel will have BBC number equal to the panel number and the force option and displacement type equal to 1.

The user must fill in the backbone curve information for every panel using the BBCI and BBCP commands, or BBCGEN, or loading BBC information from an external file using the BBC command.

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Nonlinear Structure SSI Input .Pre File (BBCP)

BBCGEN

BBCGEN,<Panel>,<ShearModel>,[fc],[fy],[Pn],[Nu],[bre],[bys],[CrackingForceLevel]

```
P,106,113,106,1,1
P,107,114,107,1,1
P,108,115,
P,109,116,
P,110,117,
P,111,118,
P,112,119,
P,113,120,
BBCI,1,21,1
BBCP,1,1,0.00013825,2415.18
BBCP,1,2,0.000152075,2650.66
BBCP,1,3,0.0001659,2874.06
BBCP,1,4,0.000179724,3085.39
BBCP,1,5,0.000193549,3284.65
BBCP,1,6,0.000207374,3471.82
BBCP,1,7,0.000221199,3646.92
BBCP,1,8,0.000235024,3809.95
BBCP,1,9,0.000248849,3960.9
BBCP,1,10,0.000262674,4099.77
BBCP,1,11,0.000276499,4226.57
BBCP,1,12,0.000290324,4341.29
BBCP,1,13,0.000304149,4443.93
BBCP,1,14,0.000317974,4534.5
BBCP,1,15,0.000331799,4612.99
BBCP,1,16,0.000345624,4679.41
BBCP,1,17,0.000359449,4733.75
BBCP,1,18,0.000373274,4776.02
BBCP,1,19,0.000387099,4806.21
BBCP,1,20,0.000400924,4824.32
BBCP,1,21,0.000414749,4830.36
BBCP,1,22,0.02,4926.97
BBCI,2,21,1
BBCP,2,1,0.00013825,805.06
BBCP,2,2,0.000152075,883.554
BBCP,2,3,0.0001659,958.022
BBCP,2,4,0.000179724,1028.46
```

BBCI and BBCP Commands

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Automatic Section-Cuts for All Building Walls Using STRESS Binary Database

EXTRACTCUTS,<num>,<path>

Command that will automatically generate section cuts and cross sections for all defined rectangular wall panels. All cross sections will be perpendicular to one global coordinate system axis. The axis the cross sections is perpendicular to will be determined by the normal vector to the face of the wall panel.

The <num> argument will determine how many cross sections per panel will be generated. The extents of each panel will be calculated and cross sections will be placed along each panel based on the number of cross sections requested. If a cross section would be parallel to an element boundary the cross section will be moved slightly away from the boundary so that the cross section will be include a distinct row of elements

.

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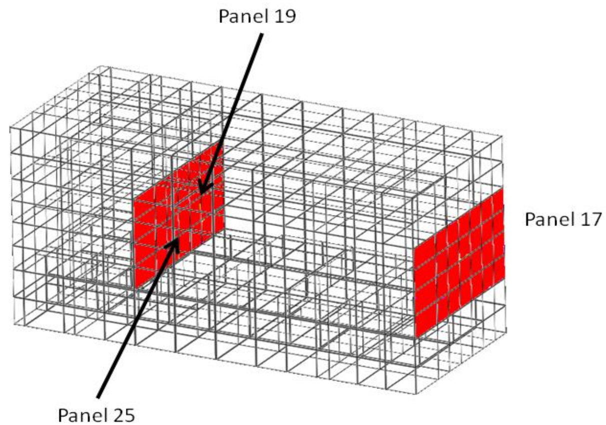
Automatic Section-Cuts for All Building Walls



Section-Cut Plot

EXTRACTCUTS,3,C:\ACSV300\DEMO_PROBLEMS\DEMO9\CutResults
INP,C:\ACSV300\DEMO_PROBLEMS\DEMO9\MODEL_PREP\autocuts.pre

```
CUTCLR,1
CUTADD,1,3,RANGE,1,4,1
CALCSECTHISTDB,1,0,0,-0.60833,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_1-Cut_1-Z.thcs
CALCSECTHISTDB,1,0,0,-12.0417,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_1-Cut_2-Z.thcs
CALCSECTHISTDB,1,0,0,-23.475,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_1-Cut_3-Z.thcs
CUTCLR,1
CUTADD,1,8,RANGE,1,1,1
CALCSECTHISTDB,1,0,0,74.5875,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_2-Cut_1-Z.thcs
CALCSECTHISTDB,1,0,0,69.2708,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_2-Cut_2-Z.thcs
CALCSECTHISTDB,1,0,0,63.9542,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_2-Cut_3-Z.thcs
CUTCLR,1
CUTADD,1,9,RANGE,1,10,1
CALCSECTHISTDB,1,0,0,73.2584,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_3-Cut_1-Z.thcs
CALCSECTHISTDB,1,0,0,62.7579,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_3-Cut_2-Z.thcs
CALCSECTHISTDB,1,0,0,51.9916,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_3-Cut_3-Z.thcs
CUTCLR,1
CUTADD,1,10,RANGE,1,10,1
CALCSECTHISTDB,1,0,0,73.2584,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_4-Cut_1-Z.thcs
CALCSECTHISTDB,1,0,0,62.7579,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_4-Cut_2-Z.thcs
CALCSECTHISTDB,1,0,0,51.9916,0,0,1,1,0,0,1,0.005,,,,C:\ACSV300\Demo_Problems\Demo9\CutResults\Panel_4-Cut_3-Z.thcs
```

Automatic Section-Cut Results for Each *Panel*

Panel_1-Cut_1-Z.thcs

```
0.005 0 -69.9309 37.6862 -106.972 11.1526 -4.09633
0.01 0 -67.8773 63.0343 -63.5459 11.4337 -4.3319
0.015 0 -69.4638 89.6154 -69.7269 13.0914 -4.5634
0.02 0 -74.1617 99.4689 -107.692 15.3697 -4.75573
0.025 0 -78.6502 91.6602 -152.279 18.2159 -4.97347
0.03 0 -78.2464 80.1548 -170.925 20.5321 -5.26611
0.035 0 -72.3995 76.2408 -138.615 22.3218 -5.59438
0.04 0 -67.5496 75.7959 -79.6207 25.7459 -5.89959
0.045 0 -67.3373 73.6568 -31.0075 32.0366 -6.30584
0.05 0 -66.3615 68.8503 -20.0202 40.7081 -7.046
0.055 0 -62.419 62.2072 -38.712 51.0918 -8.10038
0.06 0 -58.3239 58.1724 -64.3889 62.0341 -9.02595
0.065 0 -52.6974 64.6828 -97.1783 72.2112 -9.27489
0.07 0 -45.4708 82.3545 -129.664 80.5001 -8.80717
0.075 0 -40.7844 97.2829 -158.196 86.7036 -8.5307
0.08 0 -46.1877 97.0737 -196.334 91.5329 -10.3474
0.085 0 -58.4996 83.2897 -241.41 96.4255 -13.5889
0.09 0 -65.812 70.0311 -197.27 102.053 -16.8381
0.095 0 -65.1281 73.2022 -6.5975 108.447 -19.5814
0.1 0 -59.3704 114.679 92.9067 115.873 -21.5858
0.105 0 -59.3496 184.703 53.6404 124.925 -22.7502
0.11 0 -75.7758 247.515 -43.7629 135.286 -23.1046
0.115 0 -100.635 286.312 -146.877 145.889 -22.9445
0.12 0 -122.968 302.562 -214.511 154.831 -22.7468
0.125 0 -136.99 303.197 -232.66 160.209 -22.9484
```

....

```
53.105 0 -0.0214116 0.0375489 -0.0963075 0.0631199 -0.00778233
53.11 0 -0.018474 0.0377019 -0.0861549 0.0469432 -0.0058273
53.115 0 -0.0207454 0.0423199 -0.0860217 0.0630984 -0.00787859
53.12 0 -0.0117089 0.0491506 -0.0760295 0.0467119 -0.00601751
53.125 0 -0.0196888 0.0515773 -0.0637794 0.0631918 -0.00793249
53.13 0 -0.0145279 0.0365844 -0.0993899 0.0467873 -0.00585364
53.135 0 -0.0239281 0.0374023 -0.0848703 0.0632725 -0.00779552
53.14 0 -0.0150359 0.0398383 -0.0872971 0.0468199 -0.0059409
53.145 0 -0.0184727 0.0501768 -0.0724727 0.0630482 -0.00799586
53.15 0 -0.0129522 0.0501052 -0.0667431 0.0469106 -0.00603752
53.155 0 -0.0208128 0.0396215 -0.0870099 0.0631481 -0.00785401
53.16 0 -0.017962 0.0358831 -0.0880544 0.0469508 -0.00586535
53.165 0 -0.0215919 0.0404553 -0.0817124 0.0632063 -0.00790823
53.17 0 -0.0114243 0.0465765 -0.0797366 0.046706 -0.0060662
53.175 0 -0.0201326 0.0531173 -0.0613133 0.0632065 -0.00800924
53.18 0 -0.0143684 0.039221 -0.0897521 0.0468201 -0.0059232
53.185 0 -0.0236251 0.0360672 -0.0888324 0.0632722 -0.00781393
53.19 0 -0.0162419 0.0389148 -0.0835934 0.0469358 -0.00593302
53.195 0 -0.0188095 0.0476641 -0.0774831 0.0630613 -0.00798414
53.2 0 -0.0137601 0.051264 -0.0665003 0.0469145 -0.0060446
53.205 0 -0.0207728 0.0430494 -0.079199 0.0631862 -0.0078587
53.21 0 -0.0177523 0.0349275 -0.0962289 0.0469123 -0.00582196
53.215 0 -0.0226185 0.0398394 -0.0815674 0.0632713 -0.00783849
53.22 0 -0.0115192 0.044413 -0.0860175 0.0467145 -0.0059828
53.225 0 -0.0192341 0.0538855 -0.0632226 0.0632074 -0.00796208
53.23 0 -0.0136478 0.0427943 -0.0819503 0.0468822 -0.0058944
53.235 0 -0.0226164 0.0358968 -0.0964186 0.0632349 -0.00776433
53.24 0 -0.0168447 0.0388522 -0.0839933 0.046985 -0.005863
53.245 0 -0.0184628 0.0455753 -0.0839083 0.0630799 -0.00792329
MAX 0 -662.478 1554.4 -5878.59 1117.13 -189.035
```

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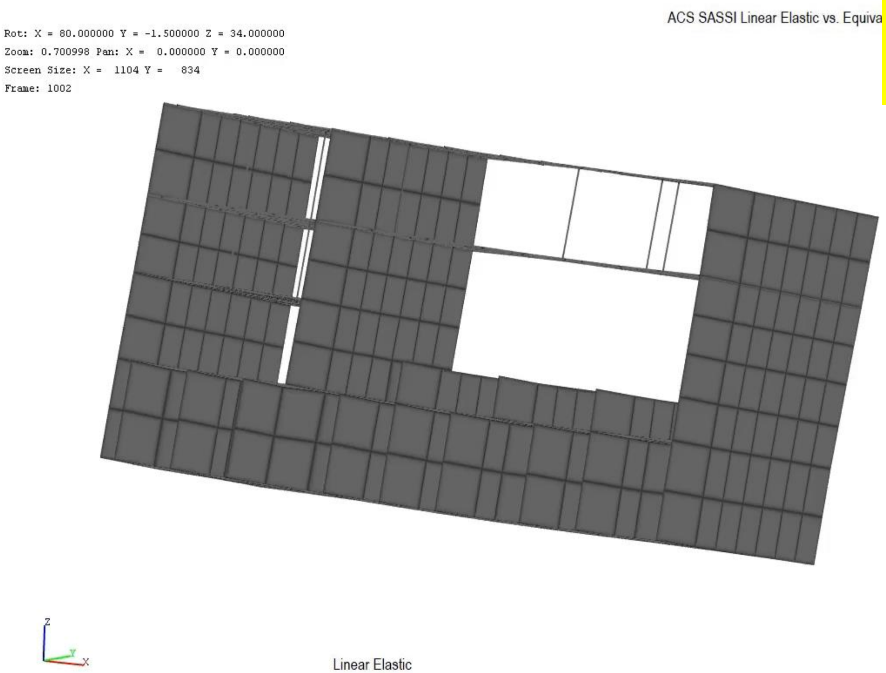
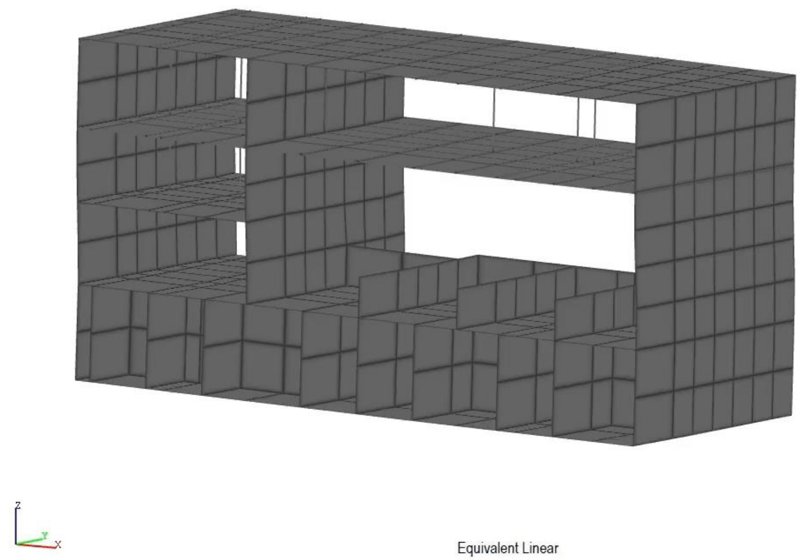
ACS SASSI Linear vs. Nonlinear Seismic SSI Results for Soil Site for 0.6g Input ZPGA

Structural Displacements

Foundation motion is sensitive to nonlinear structure behavior! SSI iterations are required!
Papers recommending a simple cascaded SSI nonlinear structure approach are published by influential authors!





ACS SASSI Linear SSI

ACS SASSI Nonlinear SSI

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Inelastic Factors for Fixed-Base and SSI (Soil)

	Rock Site				Soil Site			
	0.3g		0.6g		0.3g		0.6g	
Panel	μ*	Fμ	μ*	Fμ	μ*	Fμ	μ*	Fμ
2	1.25	1.40	3.70	1.66	1.01	0.94	2.13	1.34
3	1.27	1.31	2.24	2.07	1.27	0.95	2.16	1.50
9	1.28	1.21	2.24	1.92	1.30	0.93	2.31	1.44
10	1.97	1.63	5.58	2.35	2.40	1.07	10.80	1.50
11	6.20	2.03	15.91	3.43	6.29	1.47	16.27	2.47
13	3.14	1.81	6.91	3.27	2.85	1.60	8.18	2.75
17	12.71	2.51	61.80	5.03	10.97	1.66	65.76	3.33
18	2.66	1.38	37.62	2.43	1.89	1.01	24.83	1.50
19	7.40	1.95	50.01	3.88	6.22	1.38	41.31	2.68
22	3.22	2.17	6.61	4.07	3.00	1.36	10.46	2.52
23	4.27	1.88	9.34	3.39	2.86	1.43	7.65	2.32
24	9.85	1.92	64.26	3.84	3.71	1.24	52.54	2.40
25	9.55	1.92	56.04	3.84	5.64	1.42	50.37	2.79
30	1.92	1.27	4.90	2.02	0.97	1.02	2.84	1.31
31	2.25	1.39	5.63	2.26	2.37	1.33	8.74	2.22
33	2.73	1.69	6.02	3.09	1.61	1.41	3.52	2.19
35	1.60	1.14	4.35	1.70	0.99	1.00	3.80	1.24
36	2.94	1.57	6.72	2.67	2.28	1.35	7.14	2.09
37	2.49	1.54	5.69	2.67	1.95	1.41	4.64	2.20
38	1.82	1.13	4.93	1.67	1.67	1.28	4.77	1.83
39	2.36	1.45	5.28	2.53	0.95	0.96	2.23	1.37
40	2.44	1.45	5.61	2.45	1.11	1.13	2.68	1.65
Average	3.88	1.63	16.88	2.83	2.88	1.24	15.23	2.03
Max	12.71	2.51	64.26	5.03	10.97	1.66	65.76	3.33

Note * : The ductility ratio are computed with respect to cracking strain

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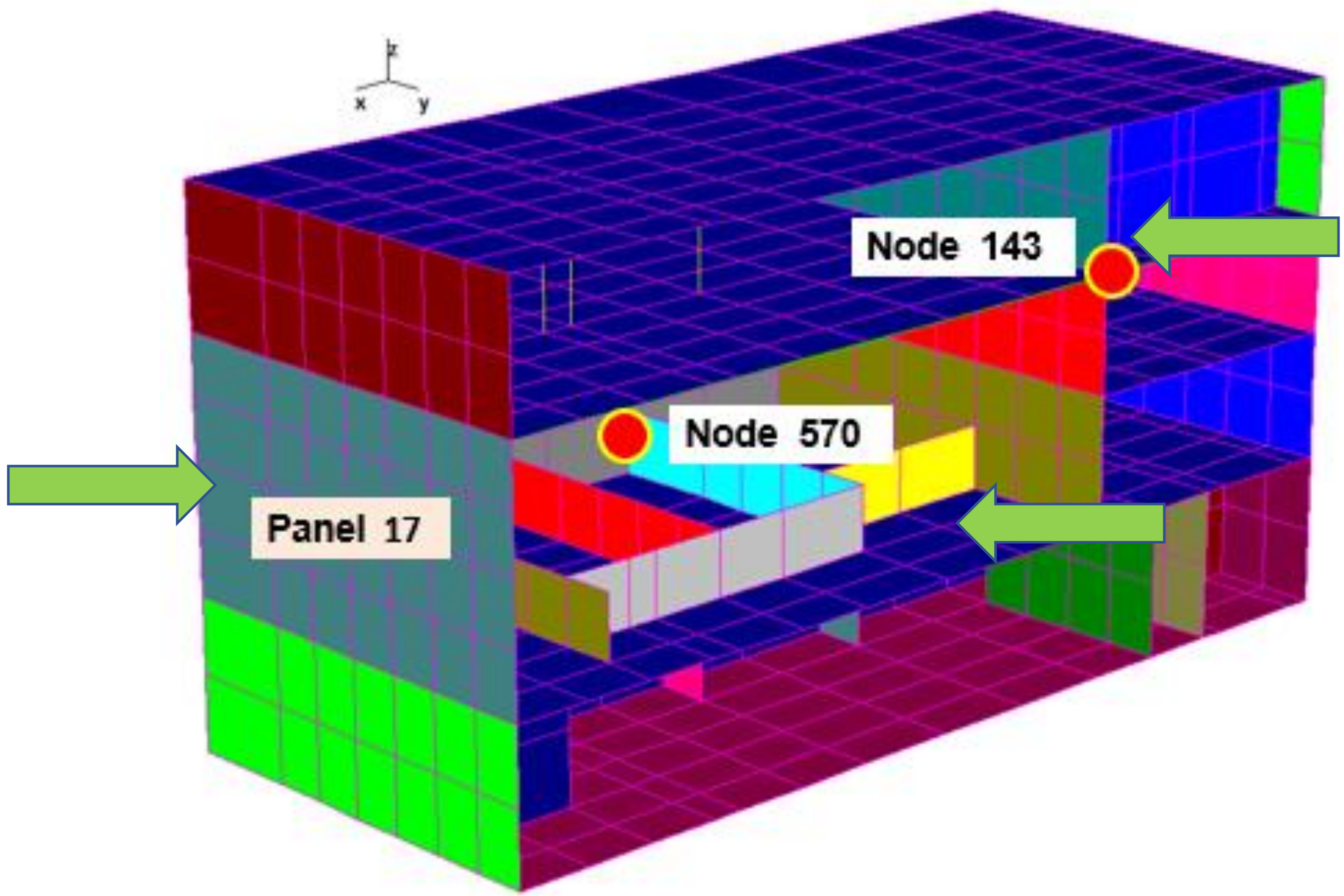
Selected Building Locations for Comparisons of Seismic SSI Responses



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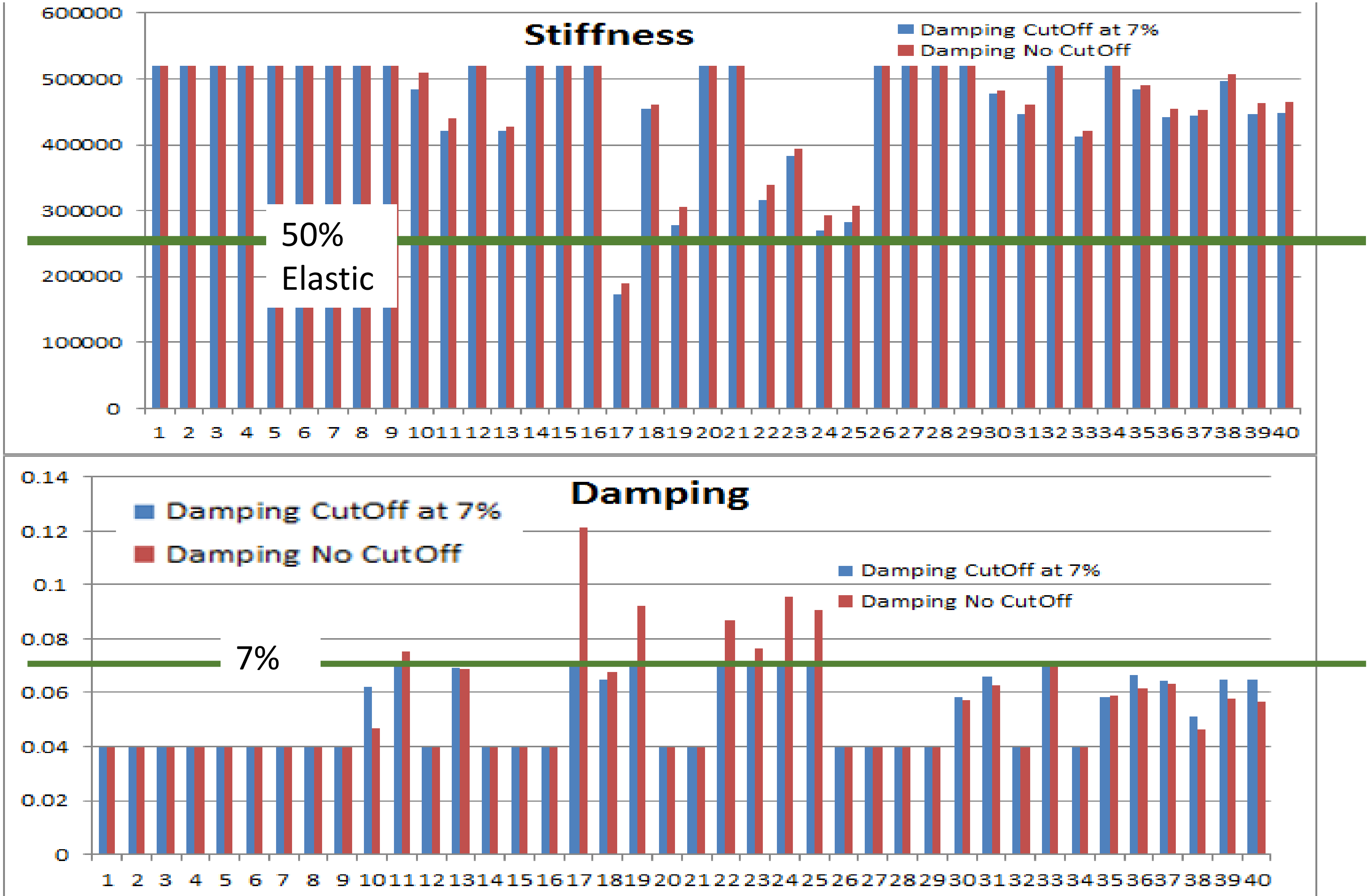
Effects of 7% Damping Cut-Off For *DBE Level* 0.30g Input on Effective Panel Stiffness



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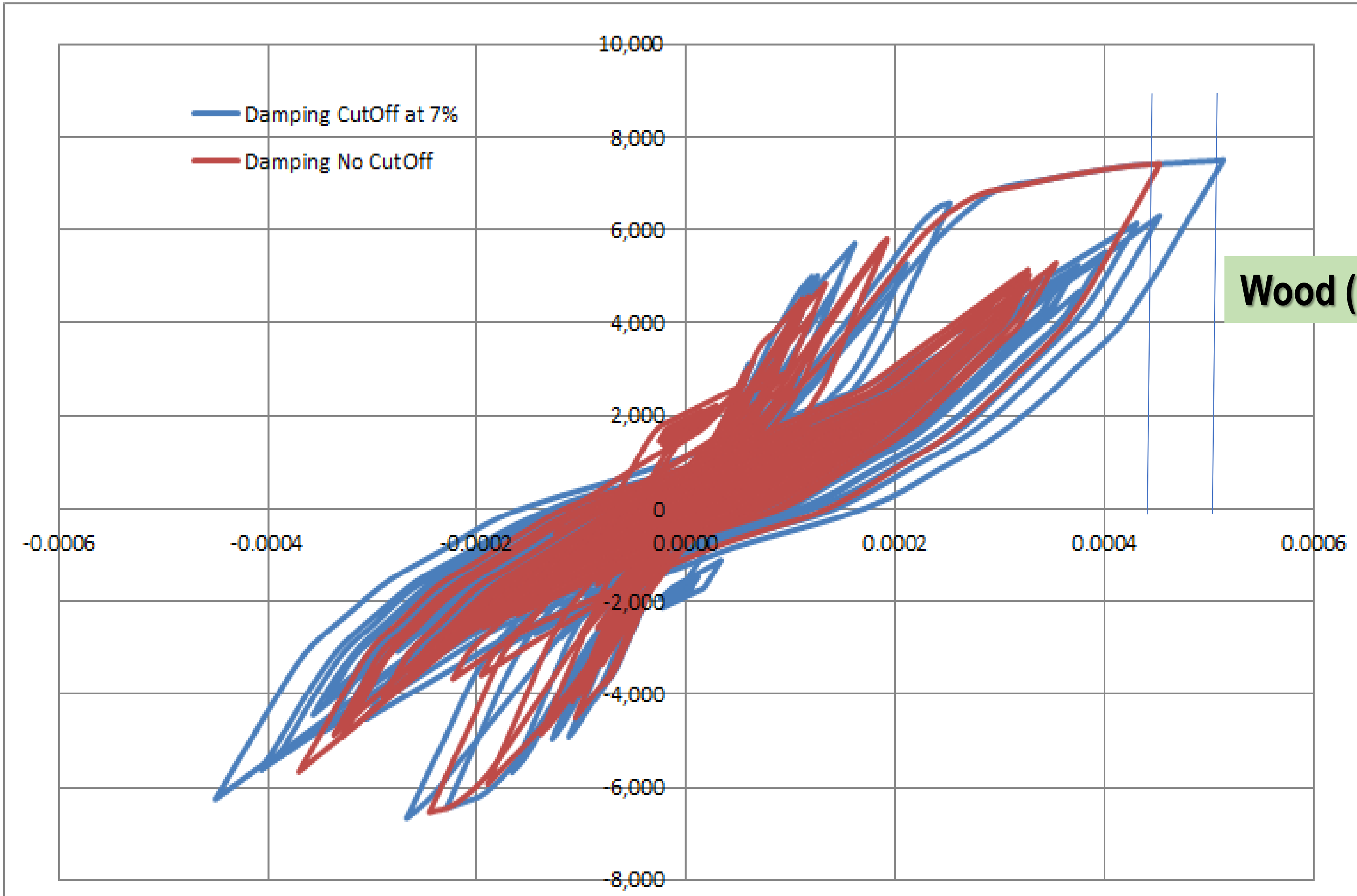
Panel 17 Hysteretic Behavior w/ and w/o 7% Damping Cut-Off for DBE 0.30g Input



Wood (1990)

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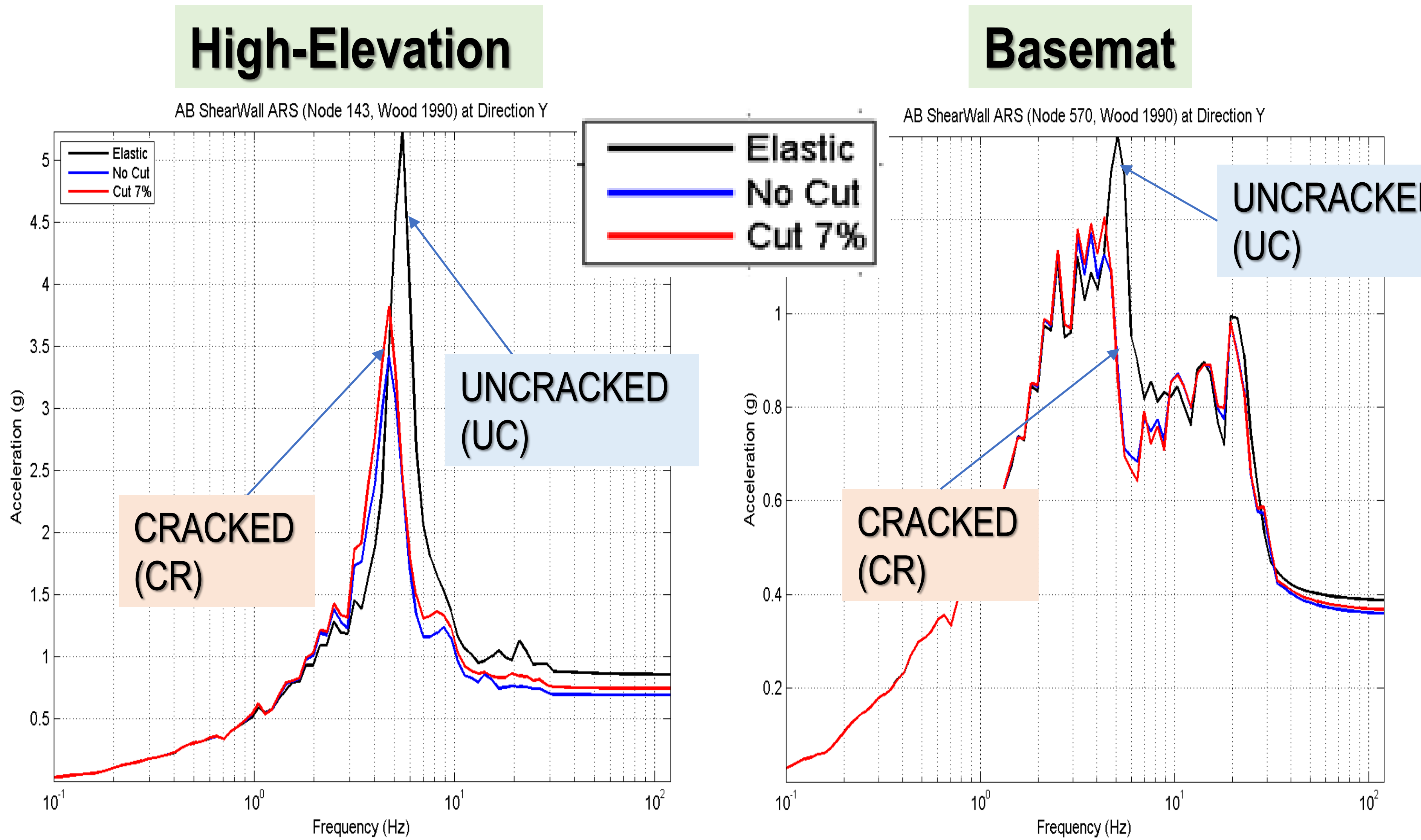
Computed ARS for *DBE* 0.30g Input.
UC 4% and CR 7% for No Damping Cut for 0.30g



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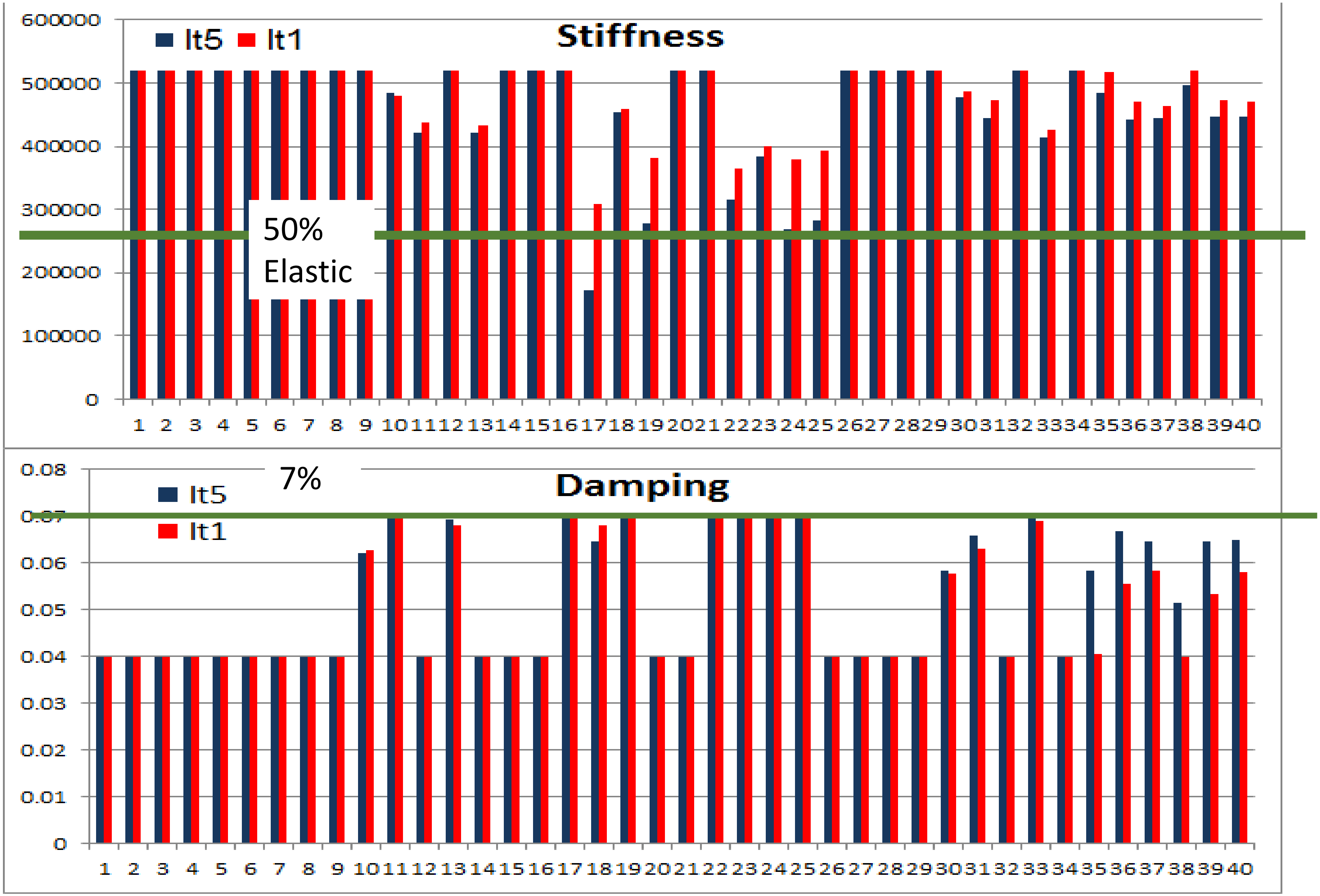
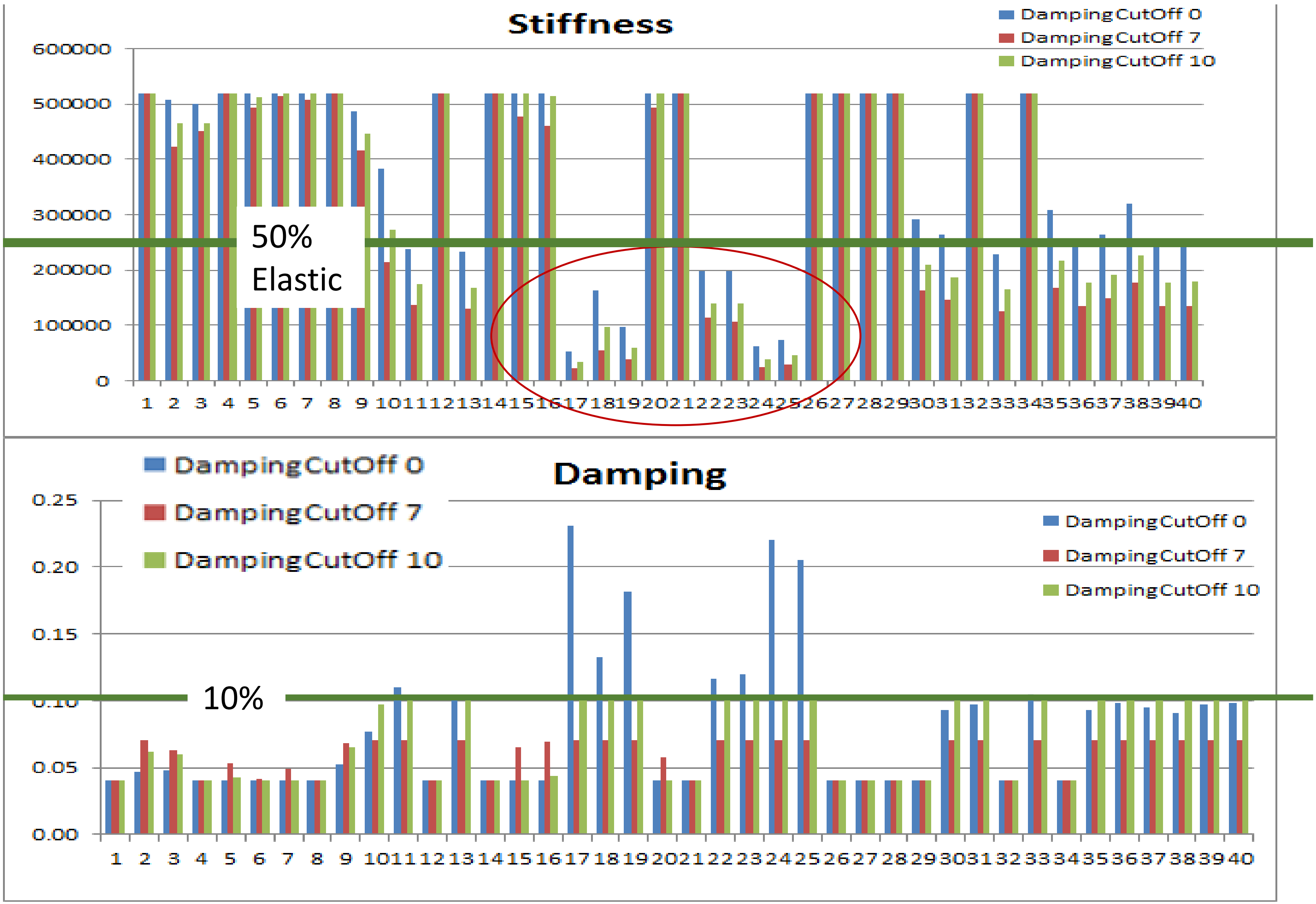
Effects of 7% Damping Cut-Off For *Design-Level* 0.30g Input on Effective Panel Stiffness - Iterations



Effects of 7% and 10% Damping Cut For *BDBE Level* 0.60g Input on Effective Stiffness



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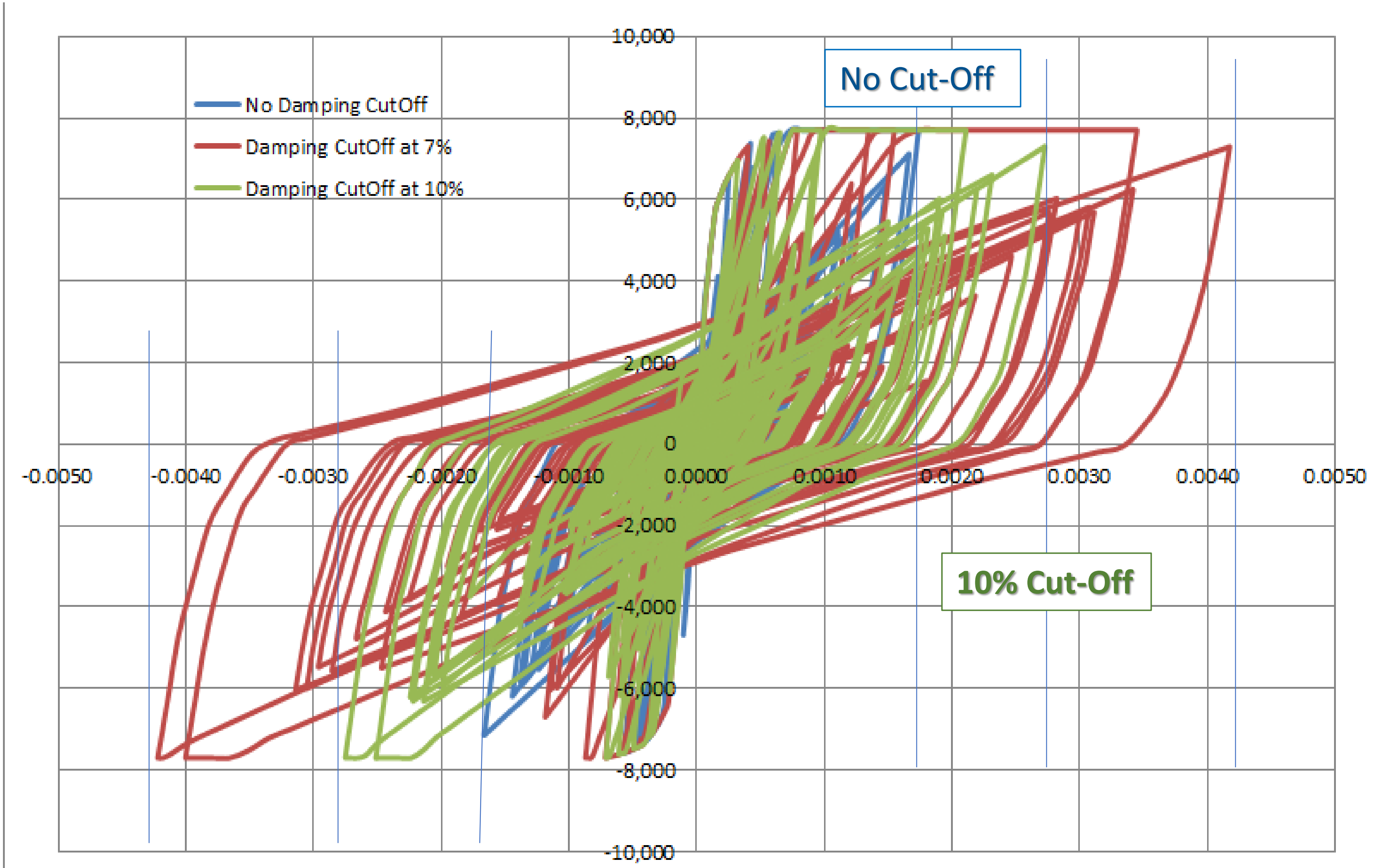
Effects of 10% Damping Cut For *BDBE Level* 0.60g Input on Panel 17 Hysteretic Behavior



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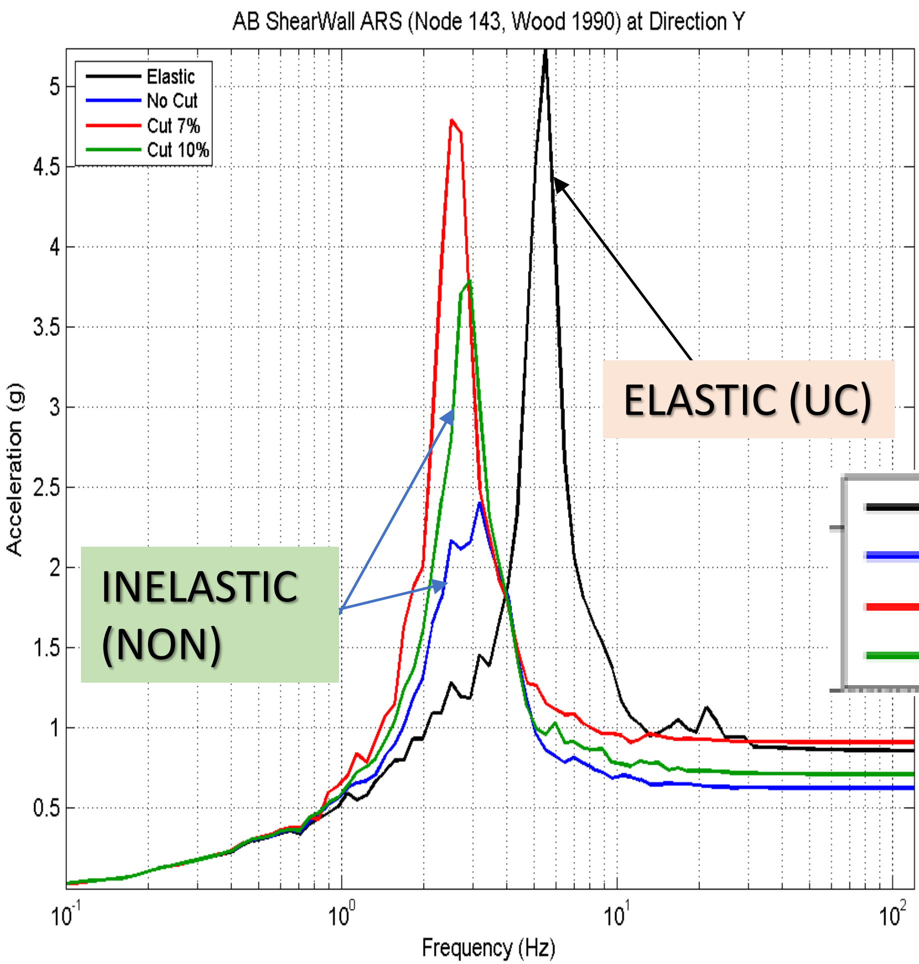
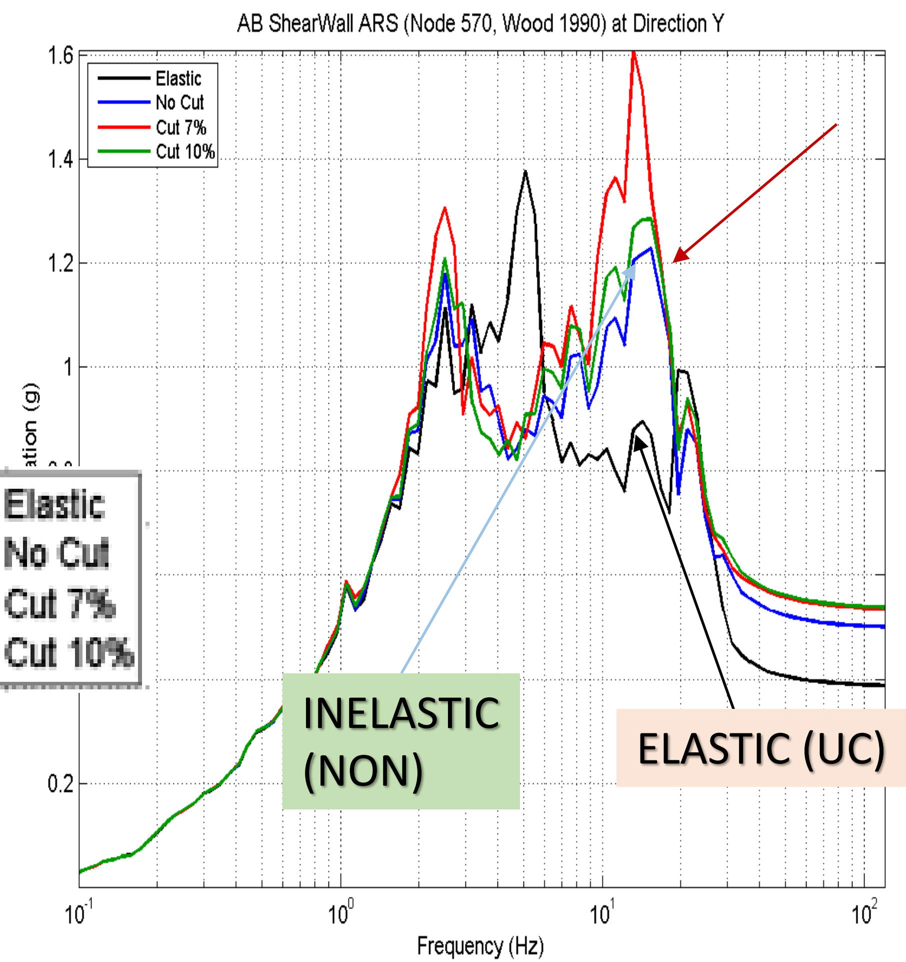
ARS at Different Elevations for Y-Dir for BDBE 0.60g Input for 4% and 7%, 10% or No Damping Cut





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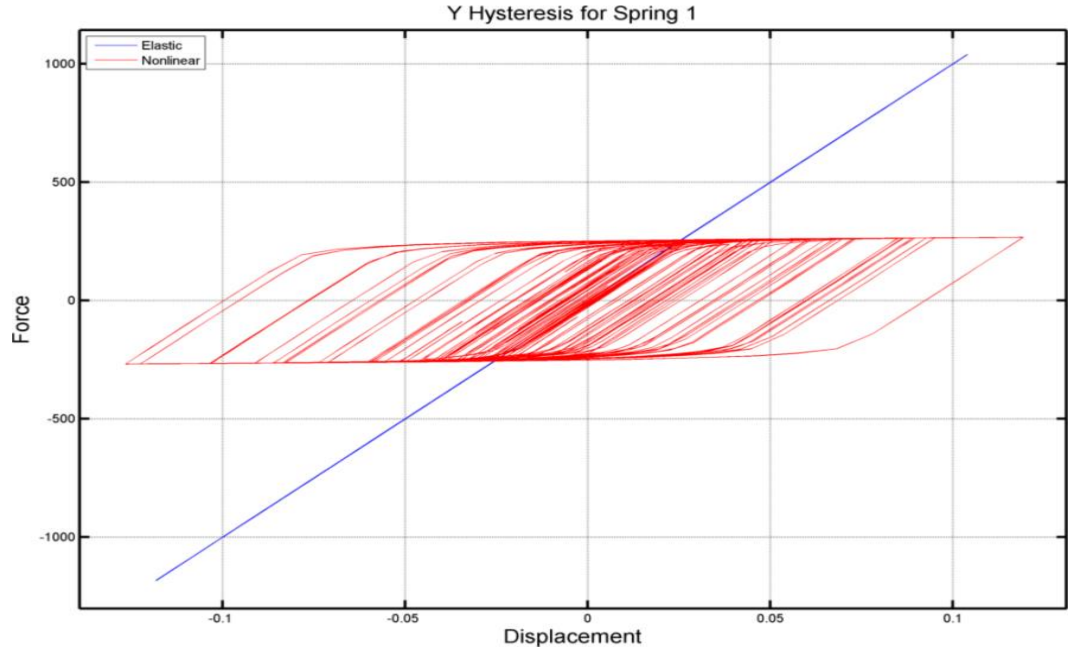
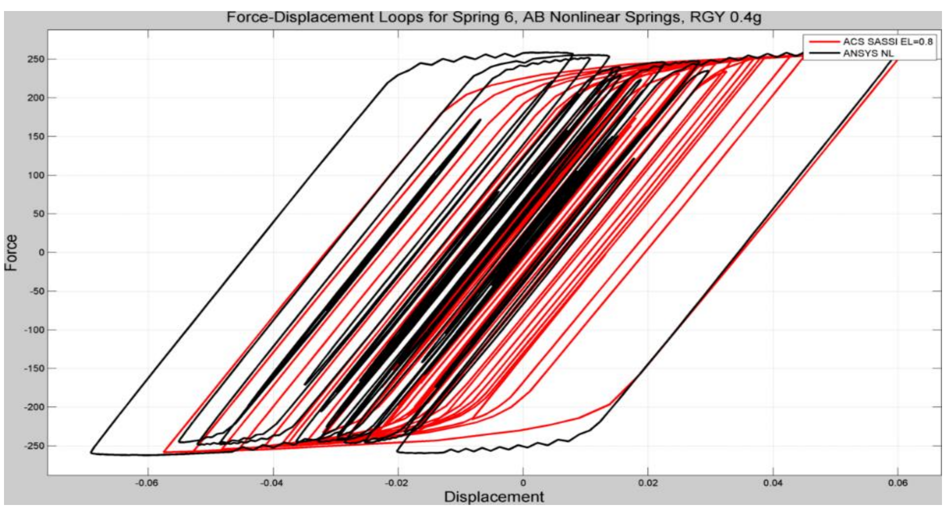
C

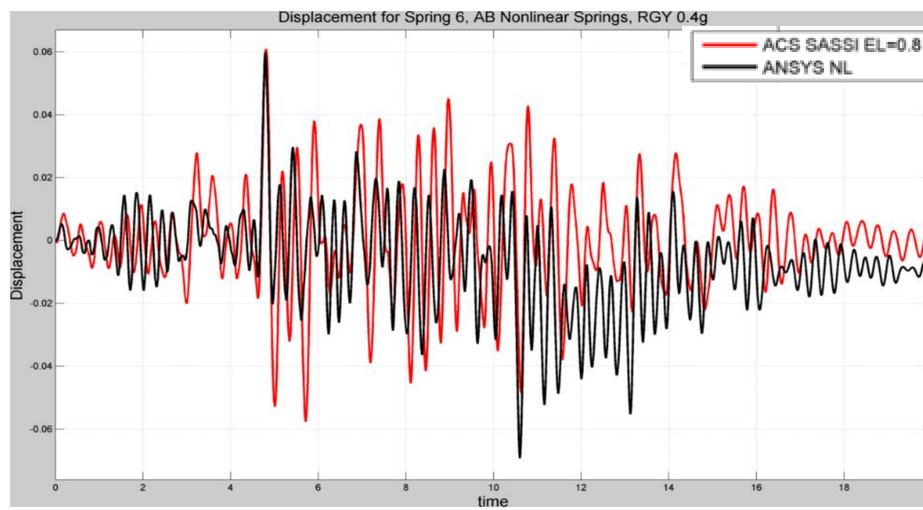
Nonlinear Springs Used for Modeling Base-Isolators or Checking Building Sliding

Base-Isolators

Small-Moderate Sliding







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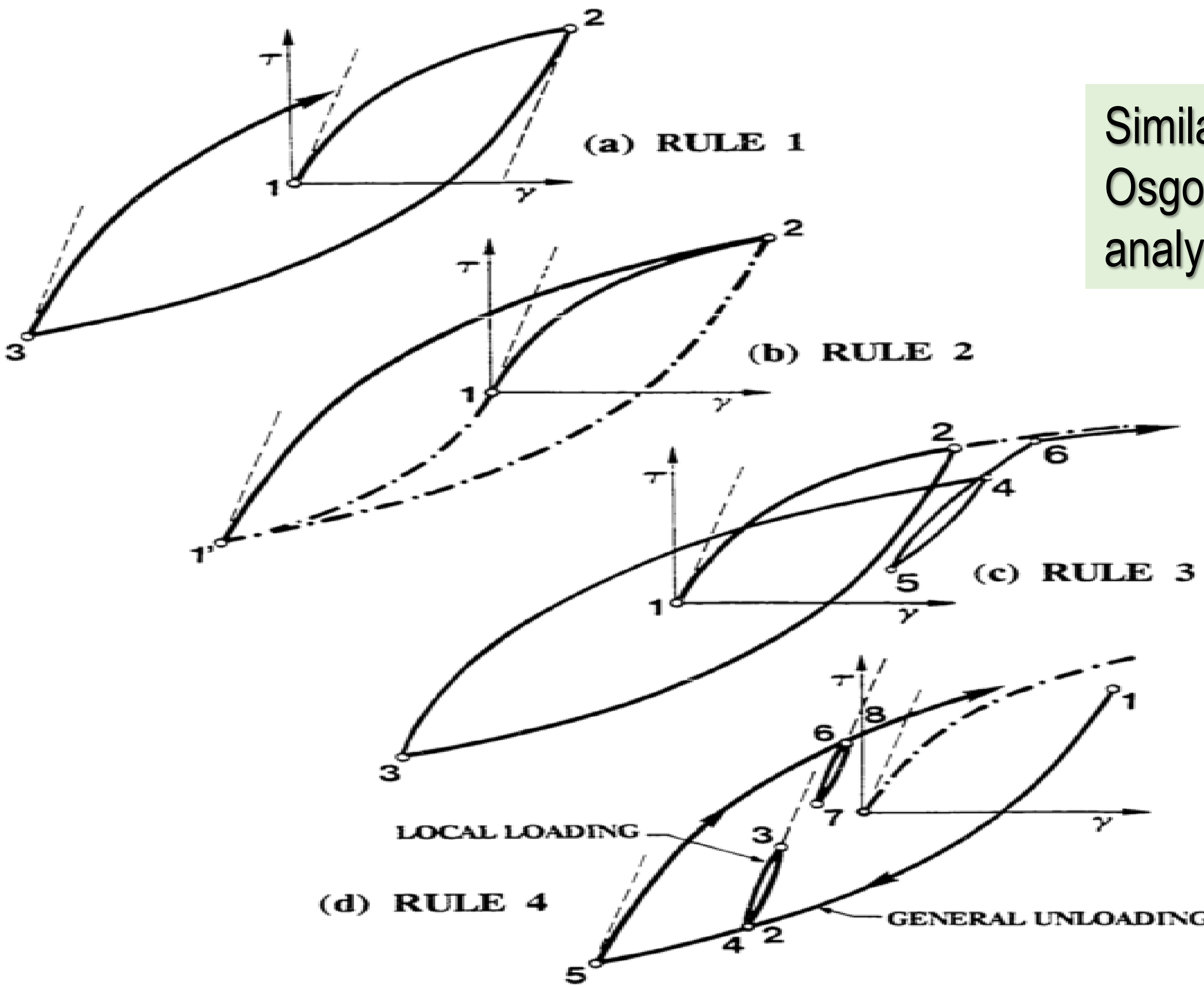
General Hysteretic Model (Model 4) for Nonlinear Springs Includes Four Massing Basic Rules



Similar shape with Ramberg Osgood and Hyperbolic analytical models

(Matasovic, 1993)

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General Hysteretic Model (4 Masing Rules)

The GENERAL HYSTERETIC element initial loading and the unloading and reloading curve follows the 4 general Massing Rules that are summarized below (Matasovic, 1993, others).

Rule 1, Initial Load

Initial loading for stress-strain follows the initial backbone curve $\boldsymbol{\tau} = \boldsymbol{f}(\boldsymbol{\gamma})$.

Rule 2, Unload/Reload Curve Shape

If a load reversal occurs at a point $(\boldsymbol{\tau_c}, \boldsymbol{\gamma_c})$, the unloading/reloading curve follows $\frac{\boldsymbol{\tau}-\boldsymbol{\tau_c}}{\mathbf{2}} = \boldsymbol{f}\left(\frac{(\gamma-\gamma_c)}{\mathbf{2}}\right)$. Where by solving for $\boldsymbol{\tau}$ yields $\boldsymbol{\tau} = \boldsymbol{\tau_c} + \mathbf{2}\boldsymbol{f}\left(\frac{(\gamma-\gamma_c)}{\mathbf{2}}\right)$. Which can determine the current stress value for a given strain.

Rule 3, Backbone Curve Intersection

If the unload/reloading curve passes the last maximum reversal strain, and proceeds to intersect the initial backbone curve, the reloading will follow the backbone curve until the next reversal.

Rule 4, Local Loading Loop

If the current unload/reload curve intersects the last past unload/reload cycle respectively, the following stress-strain unload/reload curve will follow the path from the previous cycle.

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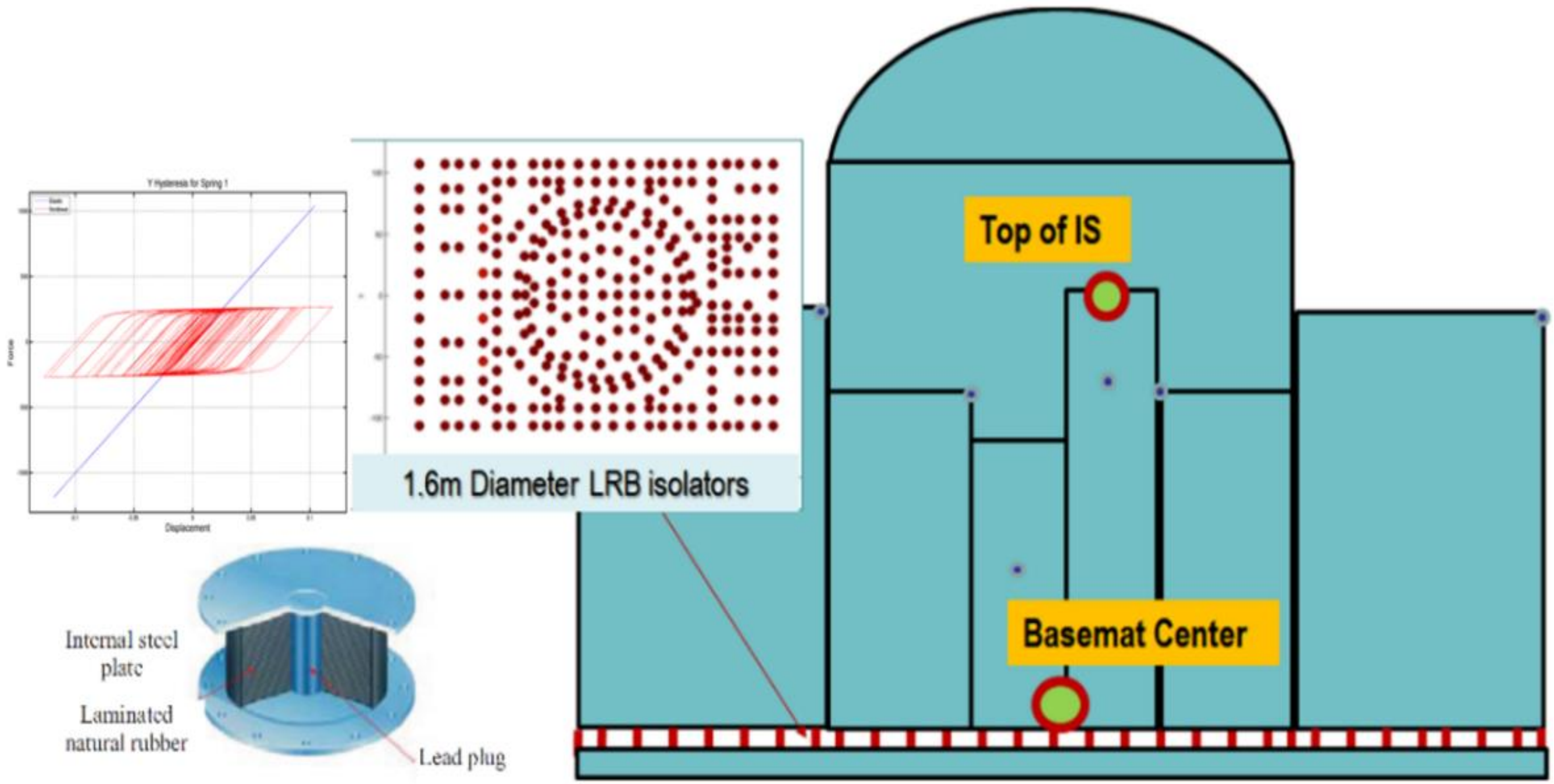
Typical Seismically Base-Isolated RB Complex (RBC) Model Using LRB Isolators



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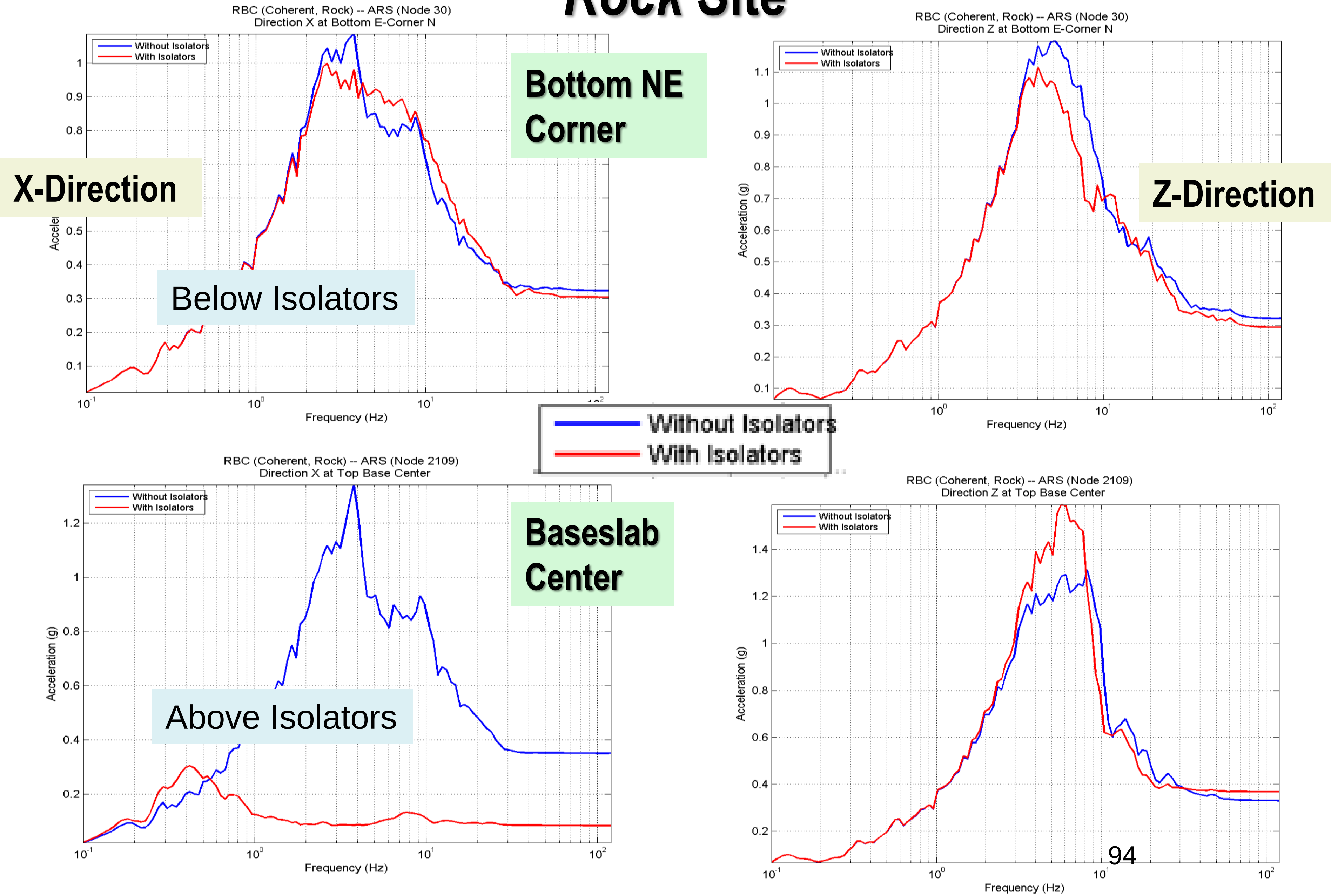
ARS in NI Complex With and Without Isolators, *Rock* Site



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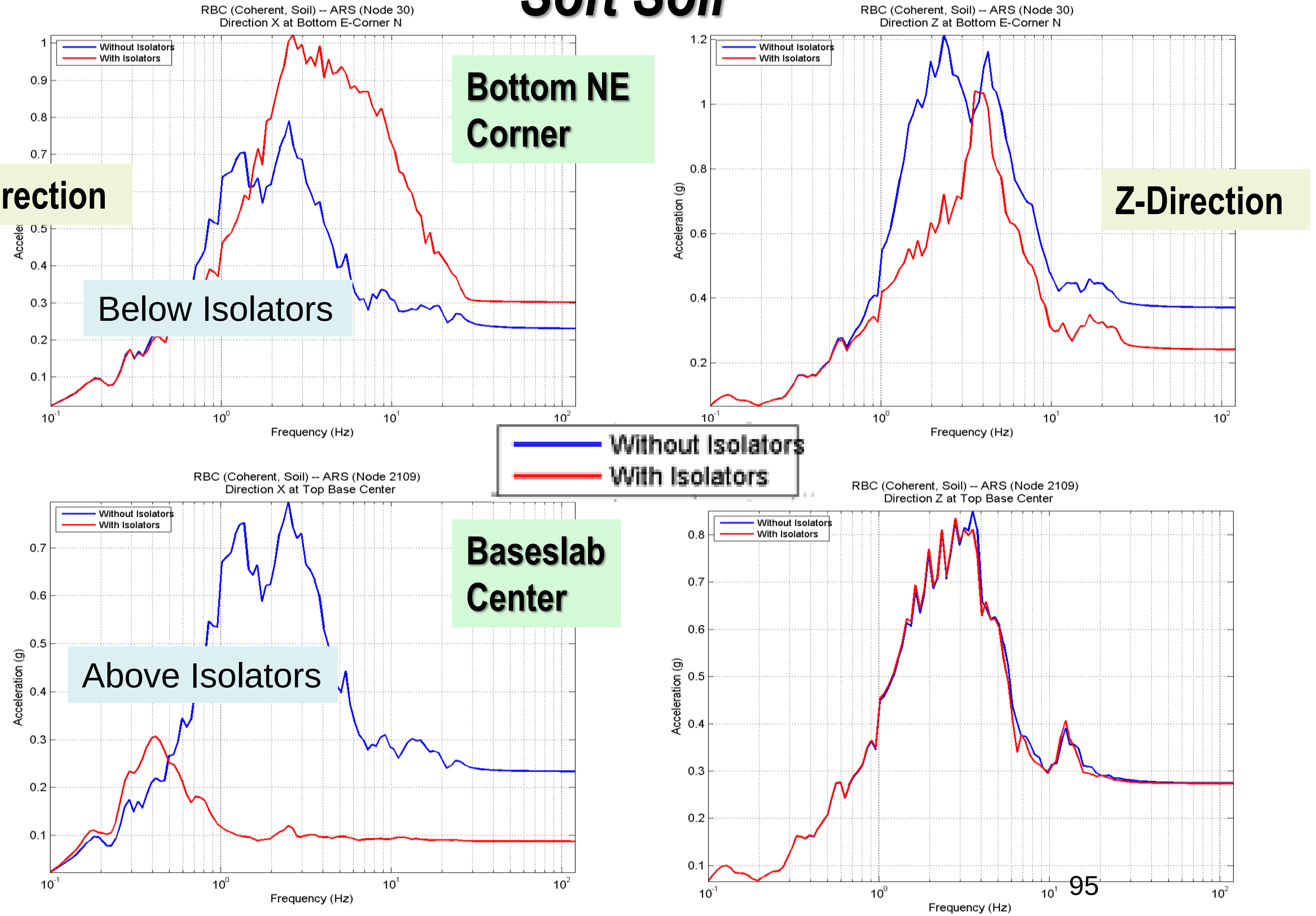
ARS in NI Complex With and Without Isolators, *Soft Soil*



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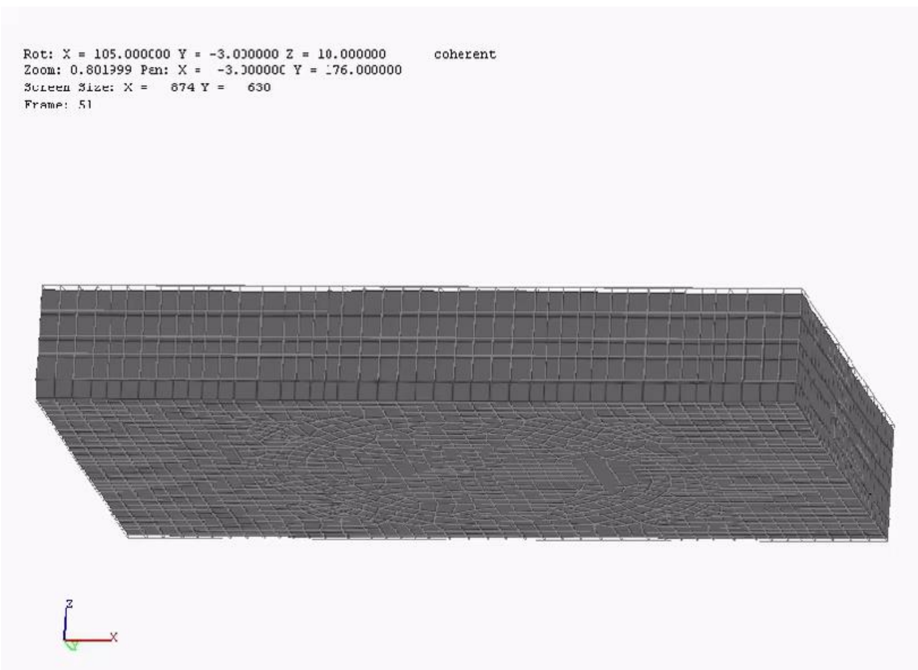
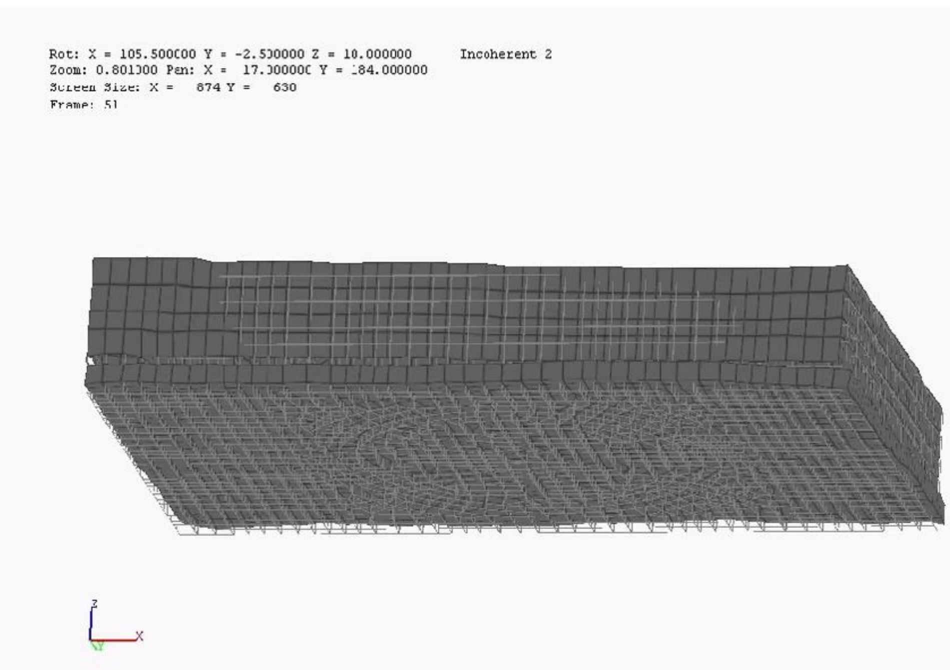
Seismically Isolated RBC Behavior for Coherent & Incoherent Motions for LRB Isolators

Accelerations

Coherent | Incoherent





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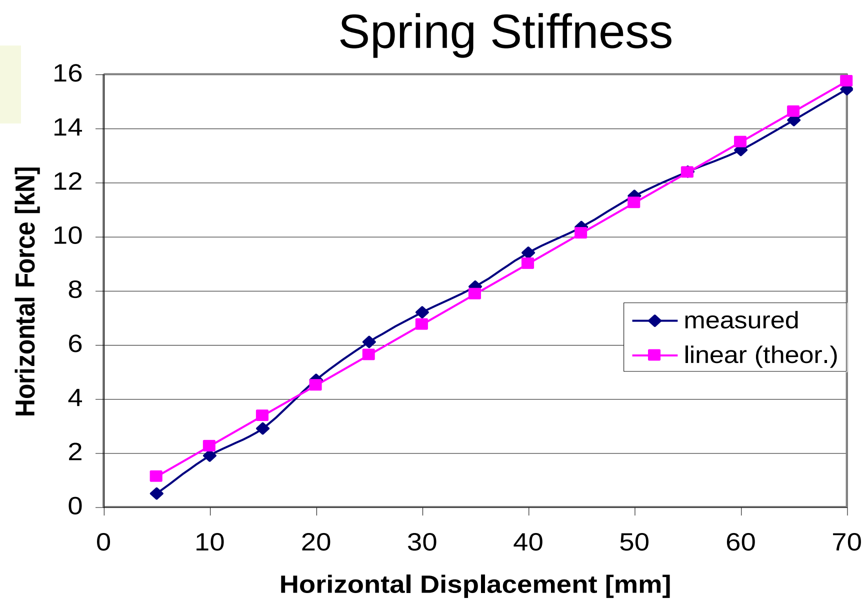
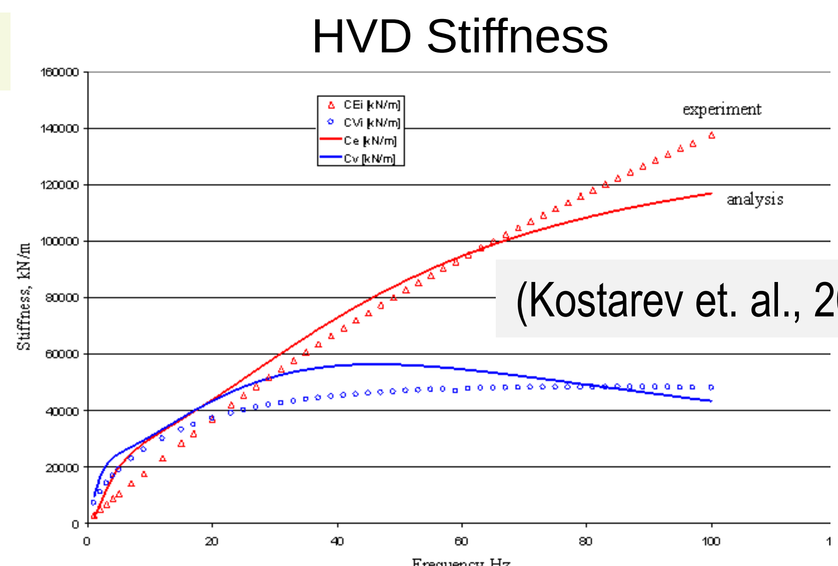
Using 3D HVD Elements for GERB BCS Isolators

3D Springs



3D HV Dampers



(Kostarev et. al., 2018)

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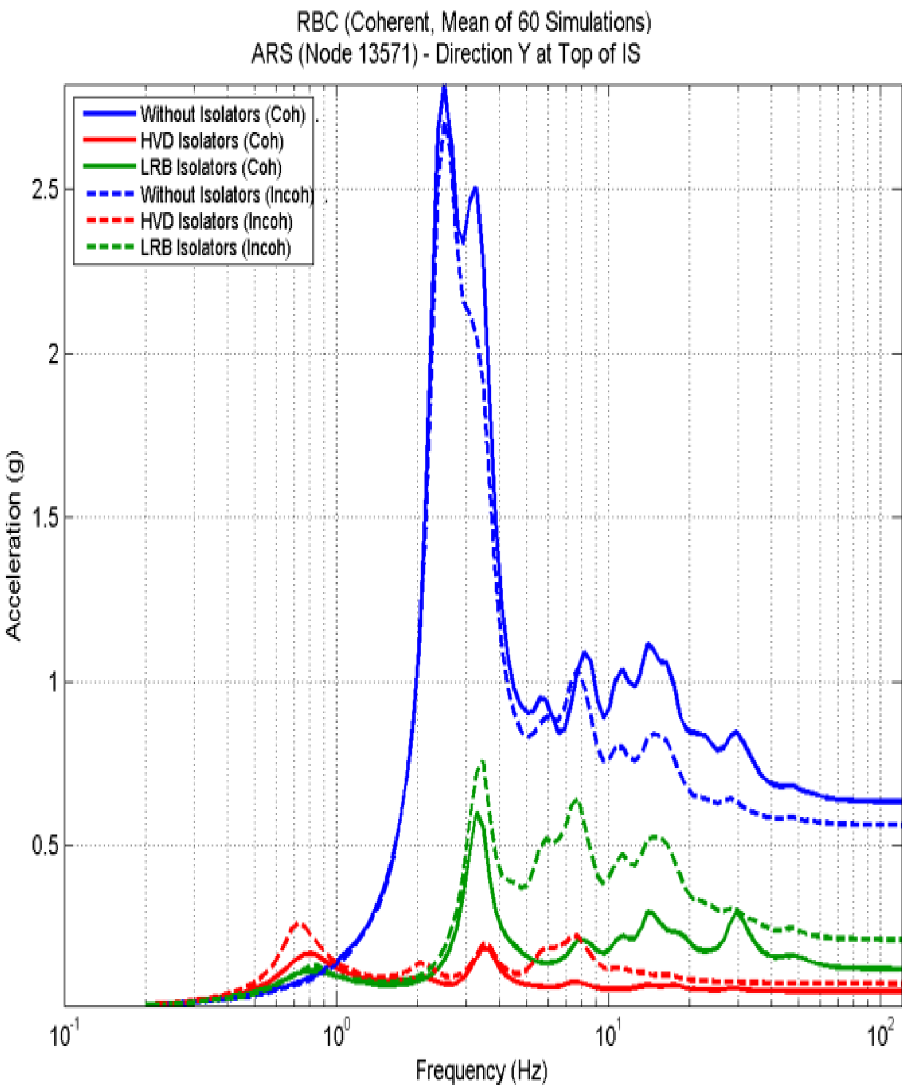
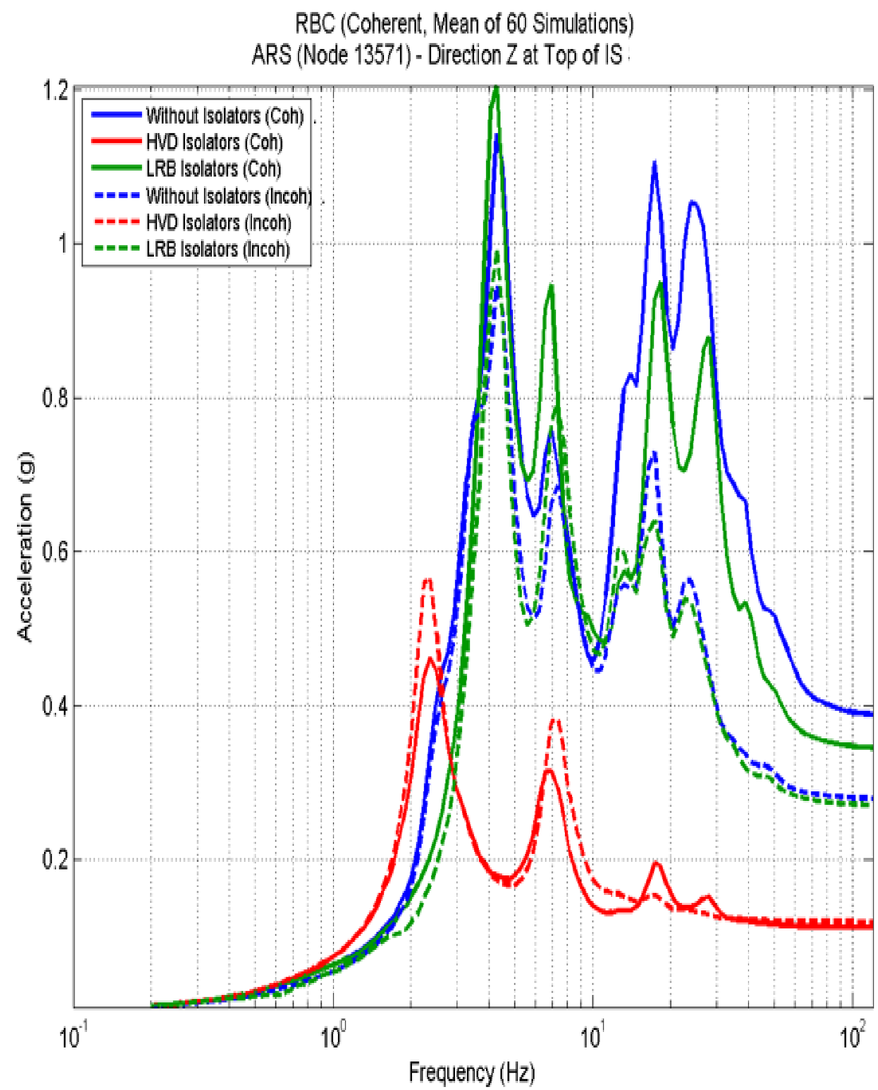
Coherent and Incoherent ISRS Within RBC





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Conclusions

- The nonlinear SSI analysis based on the hybrid approach is highly efficient when compared with time domain. Only 2-4 times slower than linear SSI analysis. It provides accurate results in comparison with nonlinear time history analysis (PERFORM3D)
- The current implementation of nonlinear SSI approach is applicable to low-rise concrete shearwall buildings per ASCE 4-16 recommendations. It considers the in-plane shear or bending wall deformation, separately, or both in the same model, based on experimental hysteretic models (Cheng-Mertz, Takeda). Option NON tested for large nonlinear wall behaviors with shear strains up to 2-3% or even more.
- It can be easily applied in compliance with the ASCE 4/43 standard recommendations for the *design-level or beyond design-level applications* to satisfy the maximum allowed damping values and stiffness reductions for Response Levels 2 and 3, respectively.
- Applicable also to containment structures based on the calibration of the panel BBC inputs against experimental/analysis pushover results. Iterative modifications of BBCs required to improve accuracy of the pushover results.

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1. Option PRO:
PSRA and PSSIA

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ASCE 4-16 Seismic Probabilistic SSI Analysis (PSSIA)

Based on the new ASCE 04-2016 recommendations:

- *Probabilistic SSI analyses should be performed using at least 30 LHS randomized simulations.*

- For the ***design-level applications***, *probabilistic SSI responses should defined for the 80% non-exceedance probability (NEP)*.

- Probabilistic modeling should minimally include:
  - SEISMIC INPUT: GMRS/UHRS amplitude assumed to randomly varying (Methods 1 and 2).
  - SOIL PROFILE: Vs and D soil profiles
  - STRUCTURE: Effective stiffness and damping, as functions of stress/strain level in different parts of structure.

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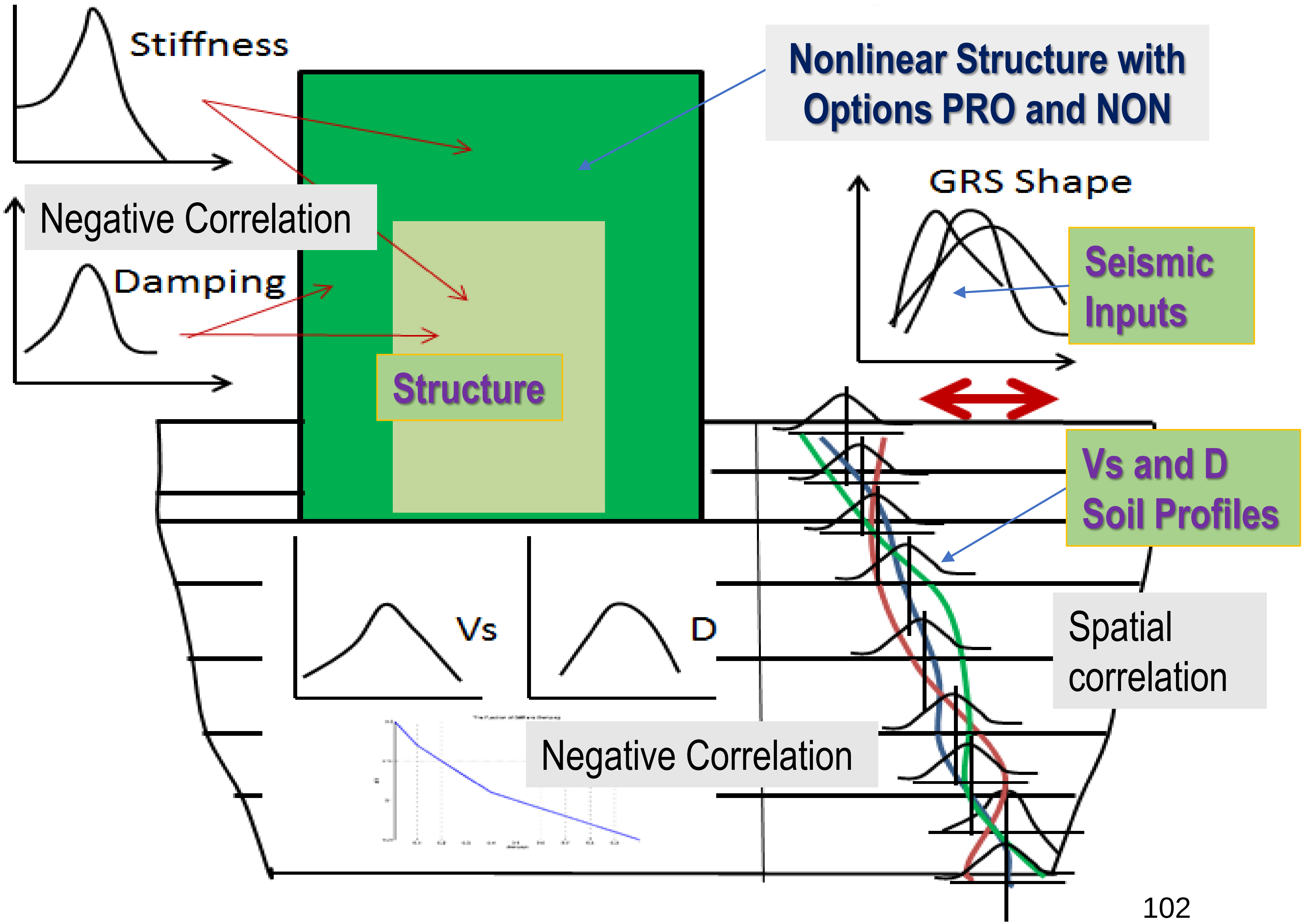
ASCE 4-16 /ACS SASSI Option PRO Probabilistic SSI Simulation Concept



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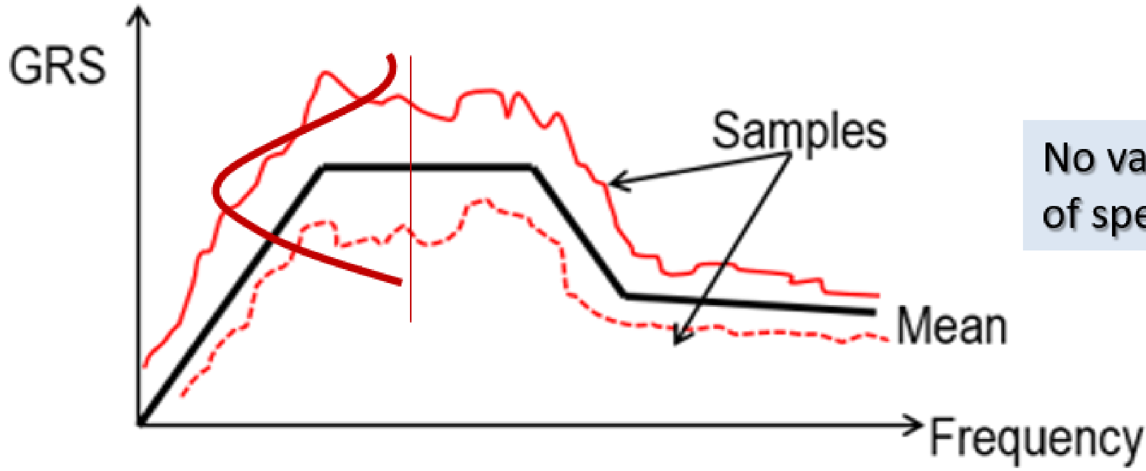
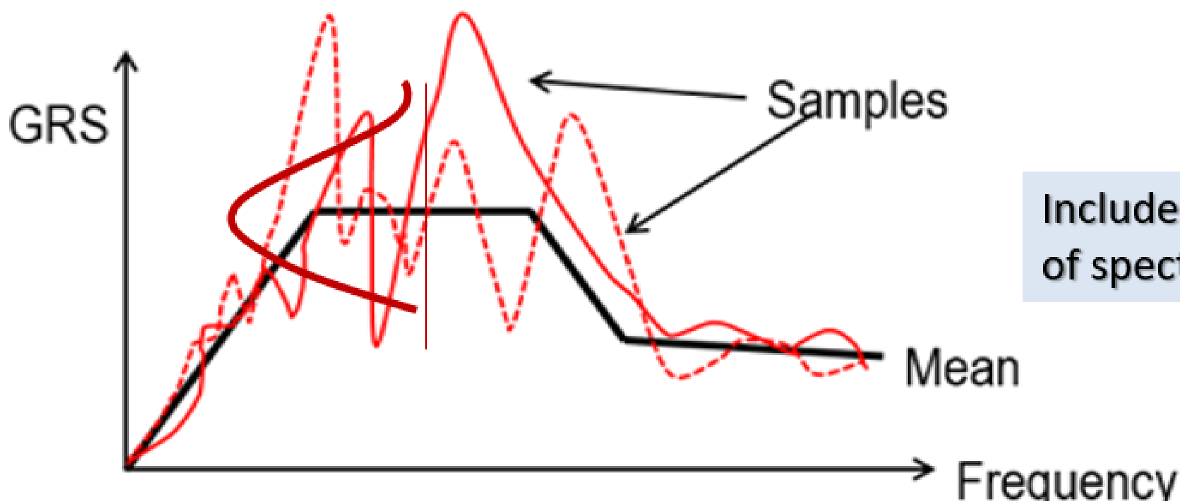
Probabilistic Seismic Input Models

ASCE 04 Method 1



No variation
of spectral shape

ASCE 04 Method 2



Include variation
of spectral shape

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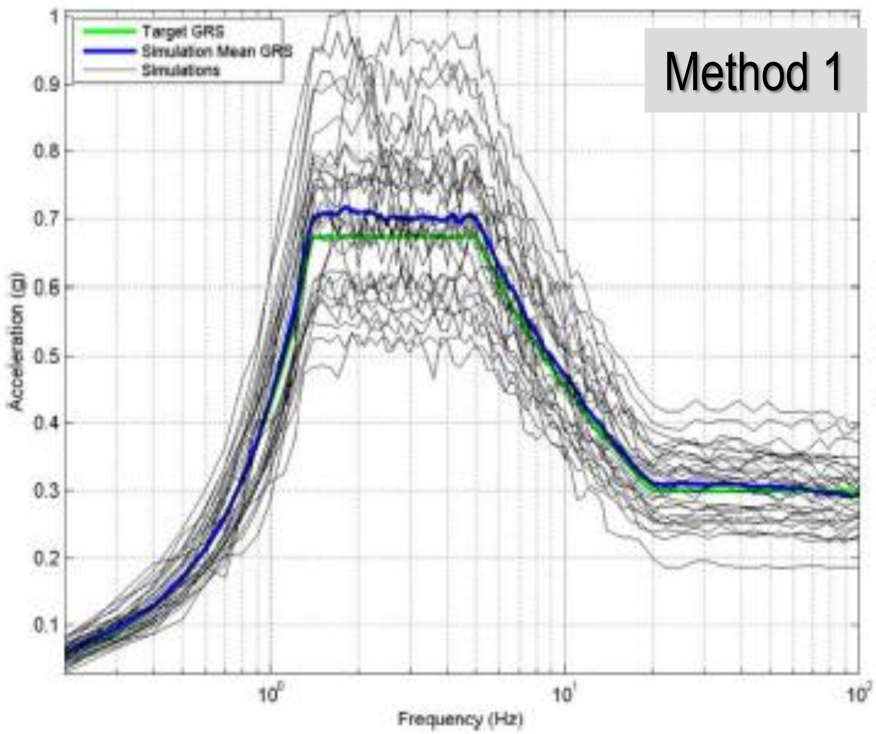
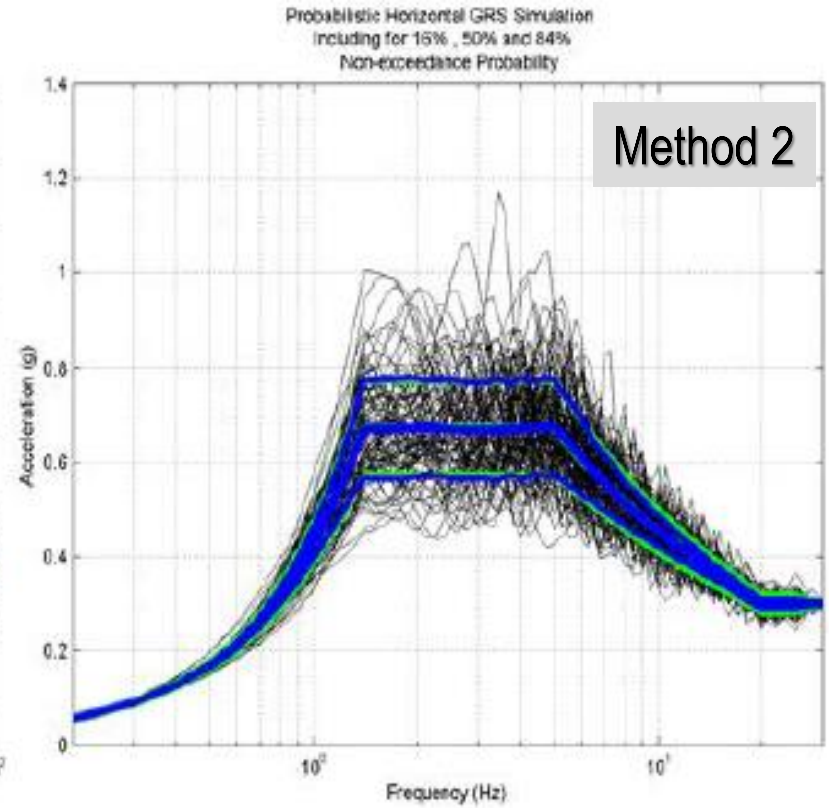
ProEQUAKE for Probabilistic Seismic Input





Probabilistic GRS and Its Simulated GRS Samples using
ASCE 4 Methods 1 (left) and Method 2 (right)

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GRS Amplitude Correlation for Different Frequencies

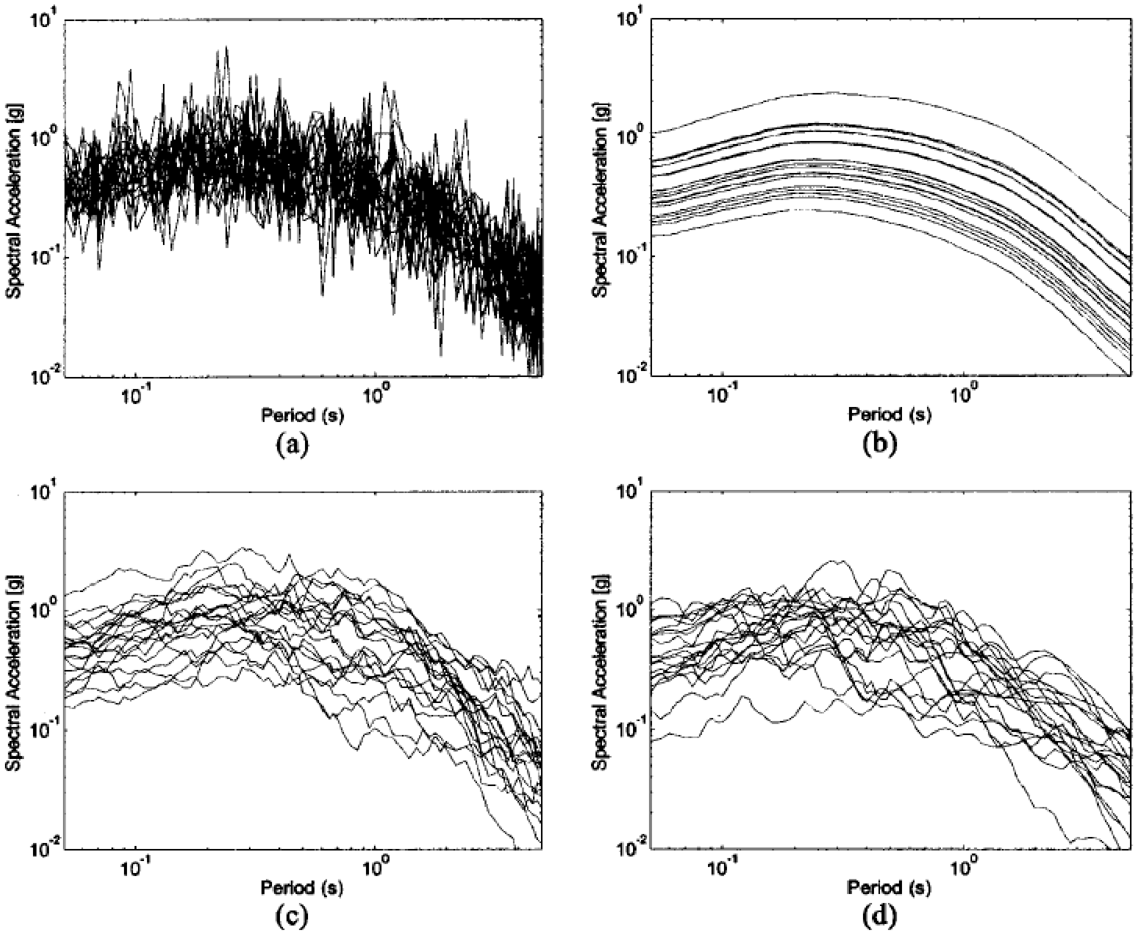

Figure 11. Samples of 20 response spectra from magnitude 6.5 earthquakes with a source-to-site distance of 8 km. The simulated spectra use means and variances from Abrahamson and Silva (1997). (a) Simulated spectra using correlation coefficients equal to zero between all periods. (b) Simulated spectra using correlation coefficients equal to one between all periods. (c) Simulated spectra using correlation coefficients from equation (9). (d) Real spectra from recorded ground motions with magnitude ≅6.5 and distance ≅ 8 km.

Cases with Differing Periods but the Same Orientation

When the two periods of interest differ, more complex functional forms are needed. The correlation between the ε values of a single horizontal ground motion component at two differing periods is estimated by the function:

$$\rho_{\varepsilon_x,\varepsilon_x} = 1 - \cos\left(\frac{\pi}{2} - \left(0.359 + 0.163 I_{(T_{\min}<0.189)} \ln \frac{T_{\min}}{0.189}\right) \ln \frac{T_{\max}}{T_{\min}}\right), \quad (9)$$

where $I_{(T_{\min}<0.189)}$ is an indicator function equal to 1 if $T_{\min} < 0.189$ second and equal to 0 otherwise, implying that the form of the equation is simply $1 - \cos(a - b \ln (T_{\max}/T_{\min}))$ for periods larger than 0.189 sec. The variables $T_{\min}$ and $T_{\max}$ are used to denote the smaller and larger of the two periods of interest, respectively.

(Baker and Cornell, 2006)

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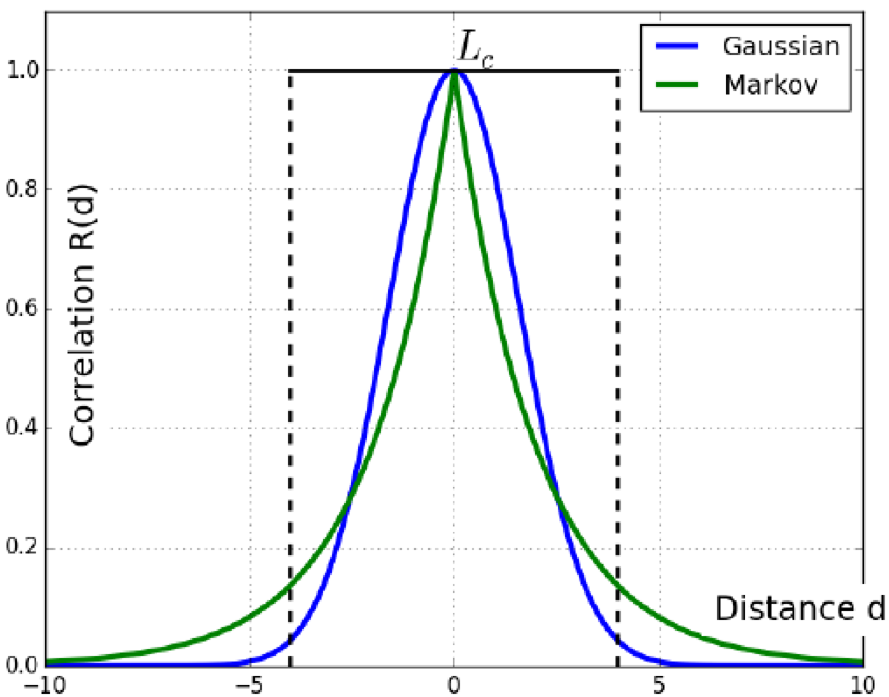
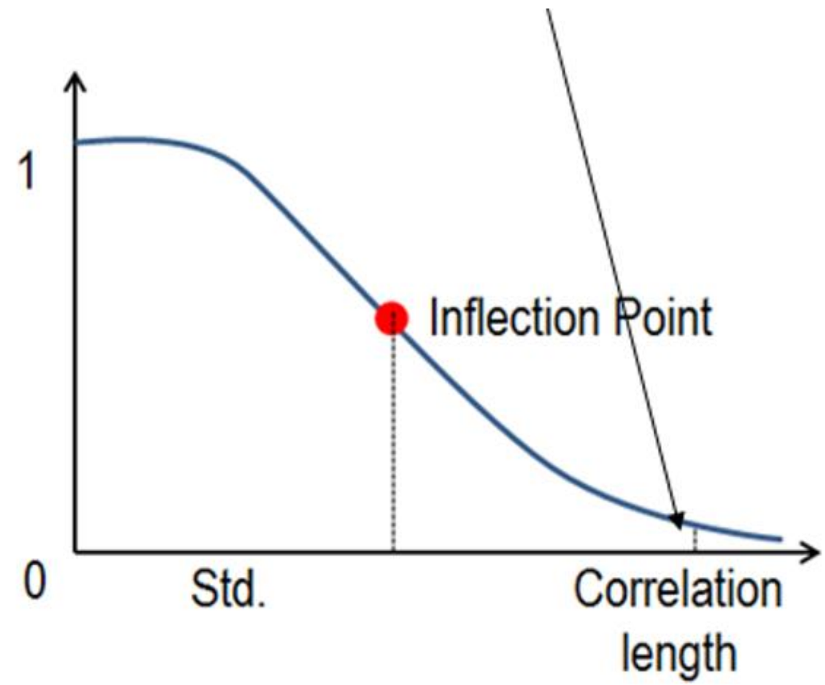
Correlation Length -"Strong Correlation Distance"

$$L_C = \int_{-\infty}^{\infty} R_U(d)\,dd$$

$$R_U(d) = \exp\left[-\sqrt{\pi}\left(\frac{d}{L_C}\right)^2\right]$$

$$\boxed{R_U(d) = \exp\left[-2\left(\frac{d}{L_C}\right)^2\right]}$$





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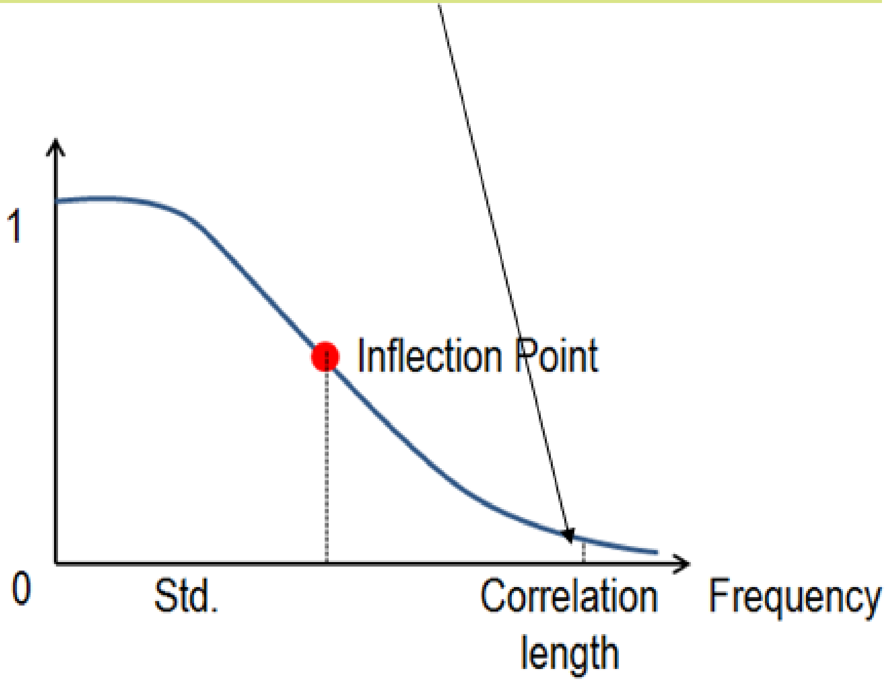
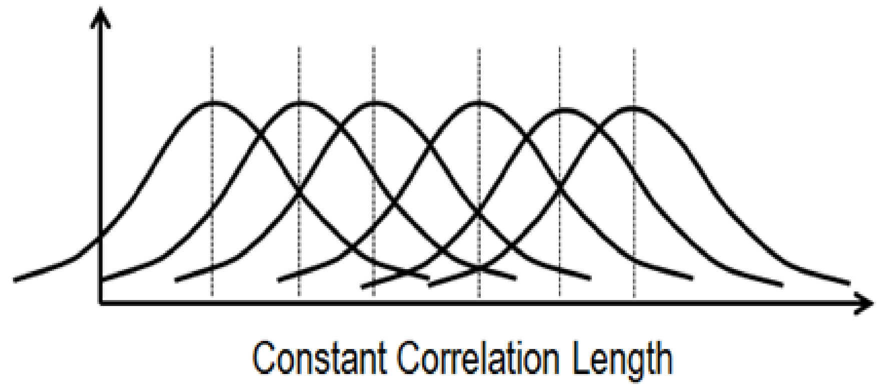
Constant vs. Variable Correlation Lengths

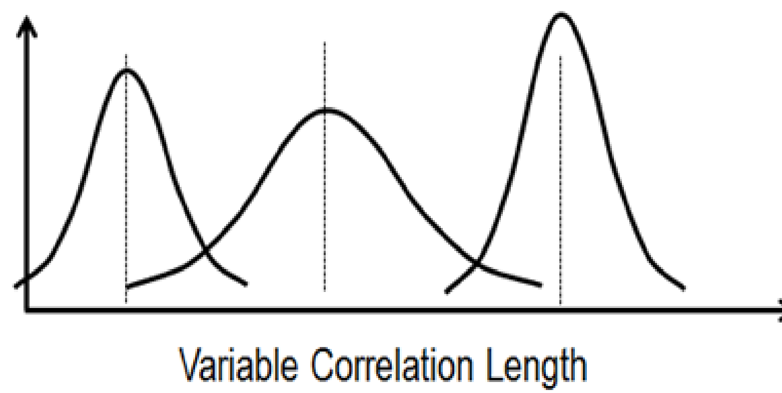
Correlation Length Definition



Variable correlation length or correlation matrix capture better the site response

Constant vs. Variable Correlation Length





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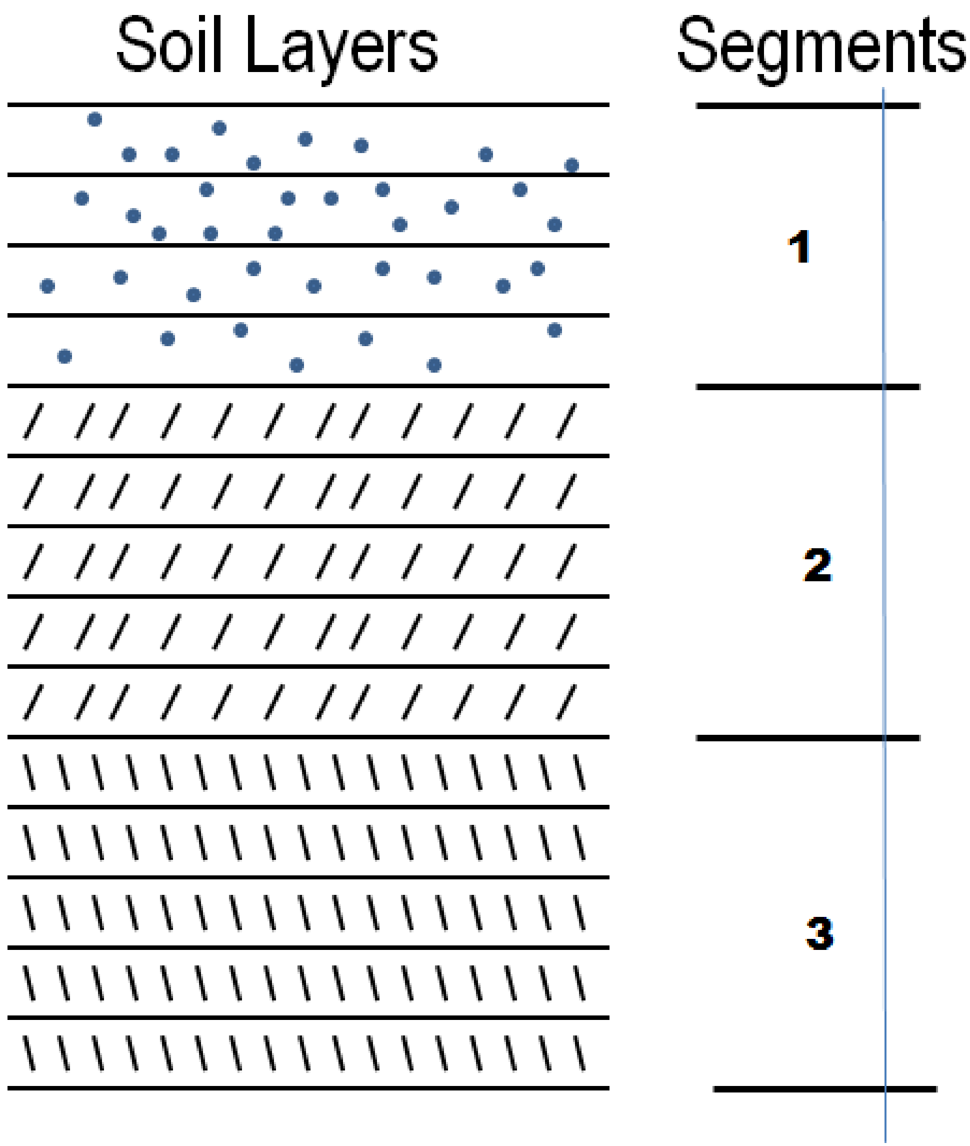
Probabilistic Vs and D Soil Profile 1D Models Using Multiple Homogeneous Segments



Different statistical properties for different soil profile segments in depth

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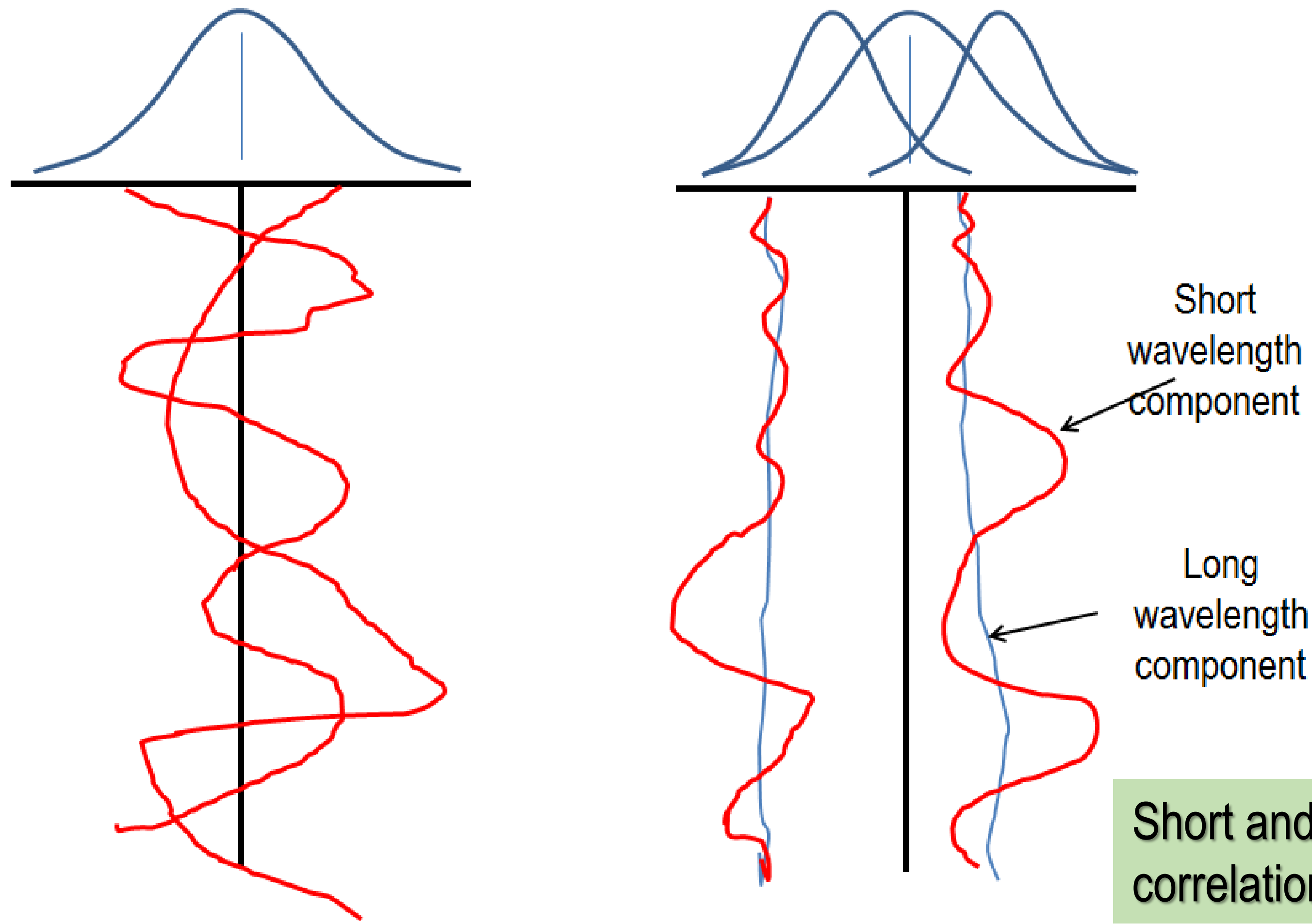
Vs & D Profiles Using Continuous Process 1D Models. Two Variation Models, M1 and M2



Short and large correlation lengths

Model 1 (Simple)

Model 2 (Composite)

(Popescu, 1996)

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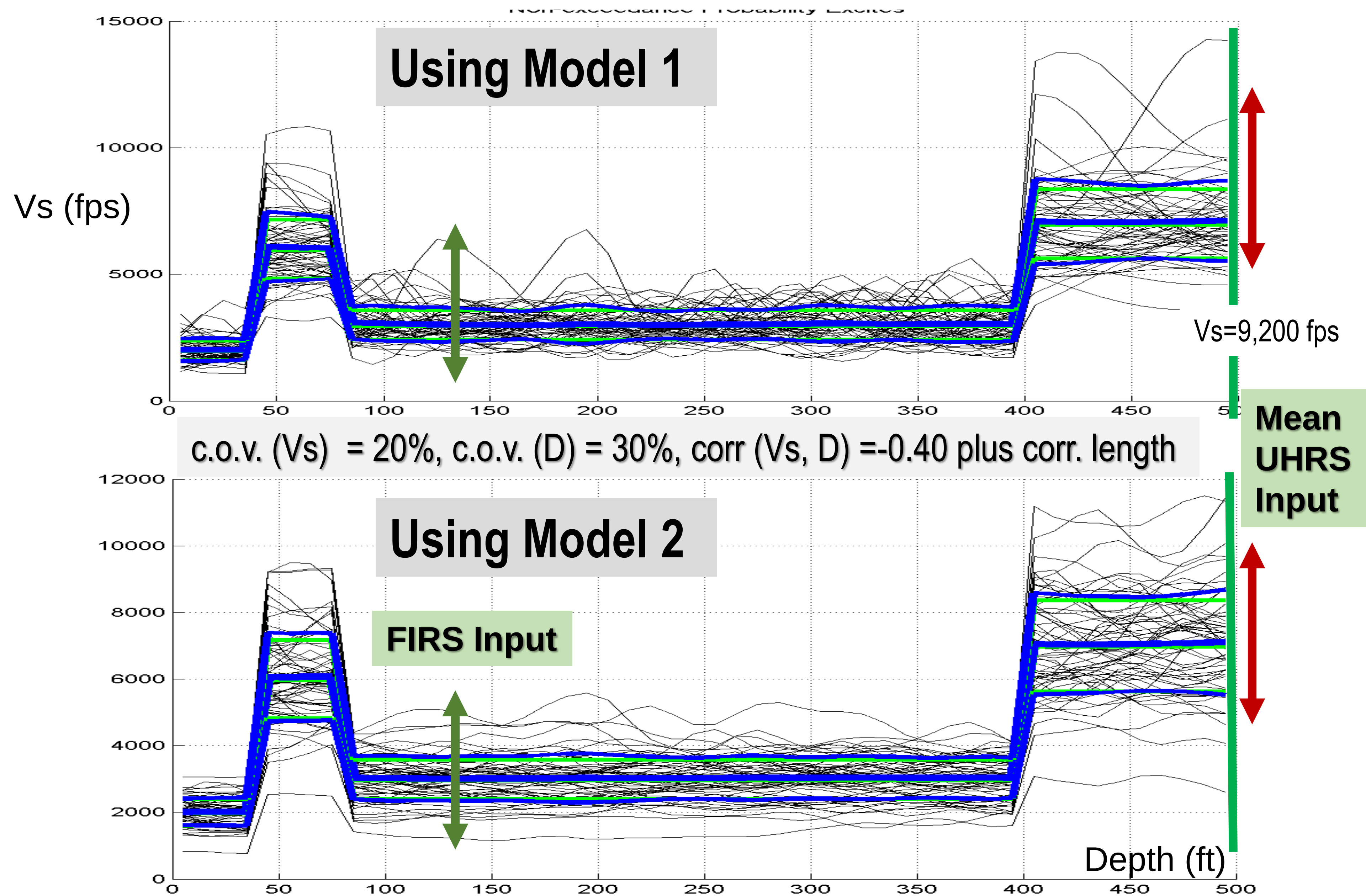
ProSITE for Probabilistic Vs and D Soil Profiles



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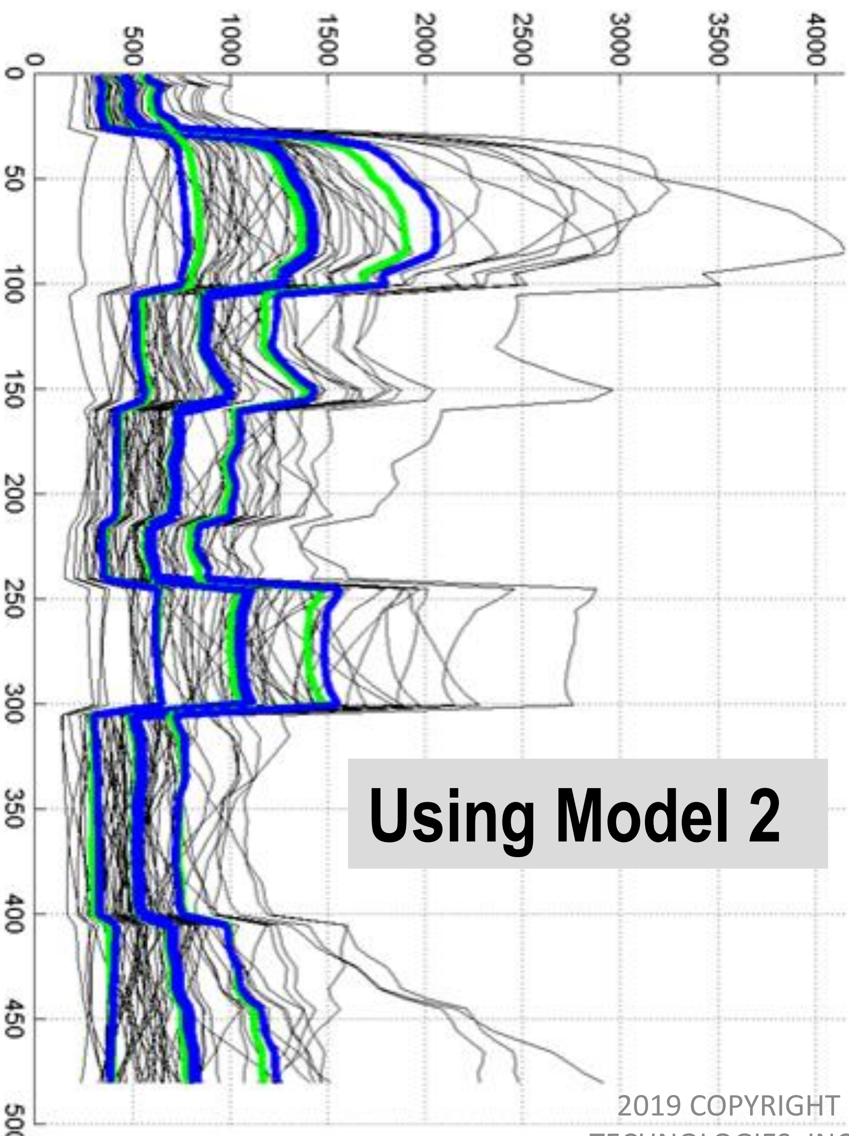
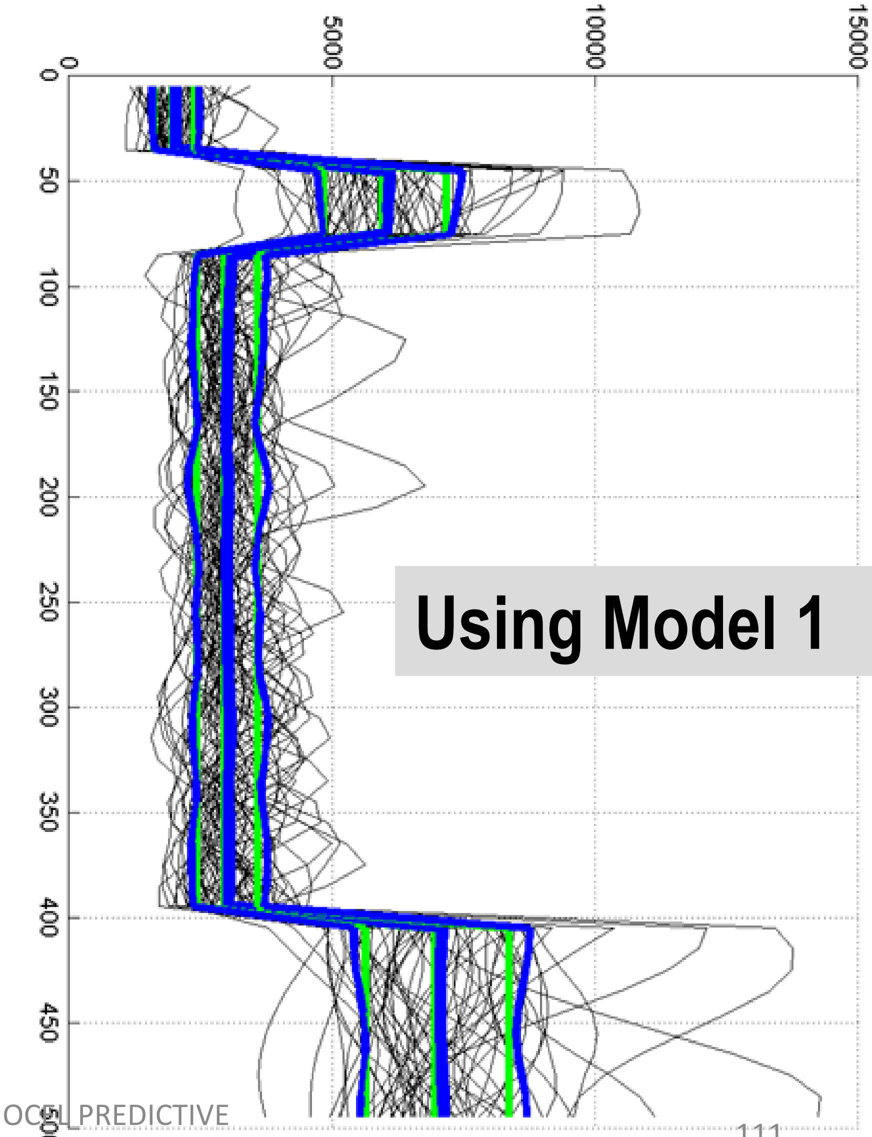
Simulated Vs Profiles for Nonuniform Soils Using Continuous Process Models





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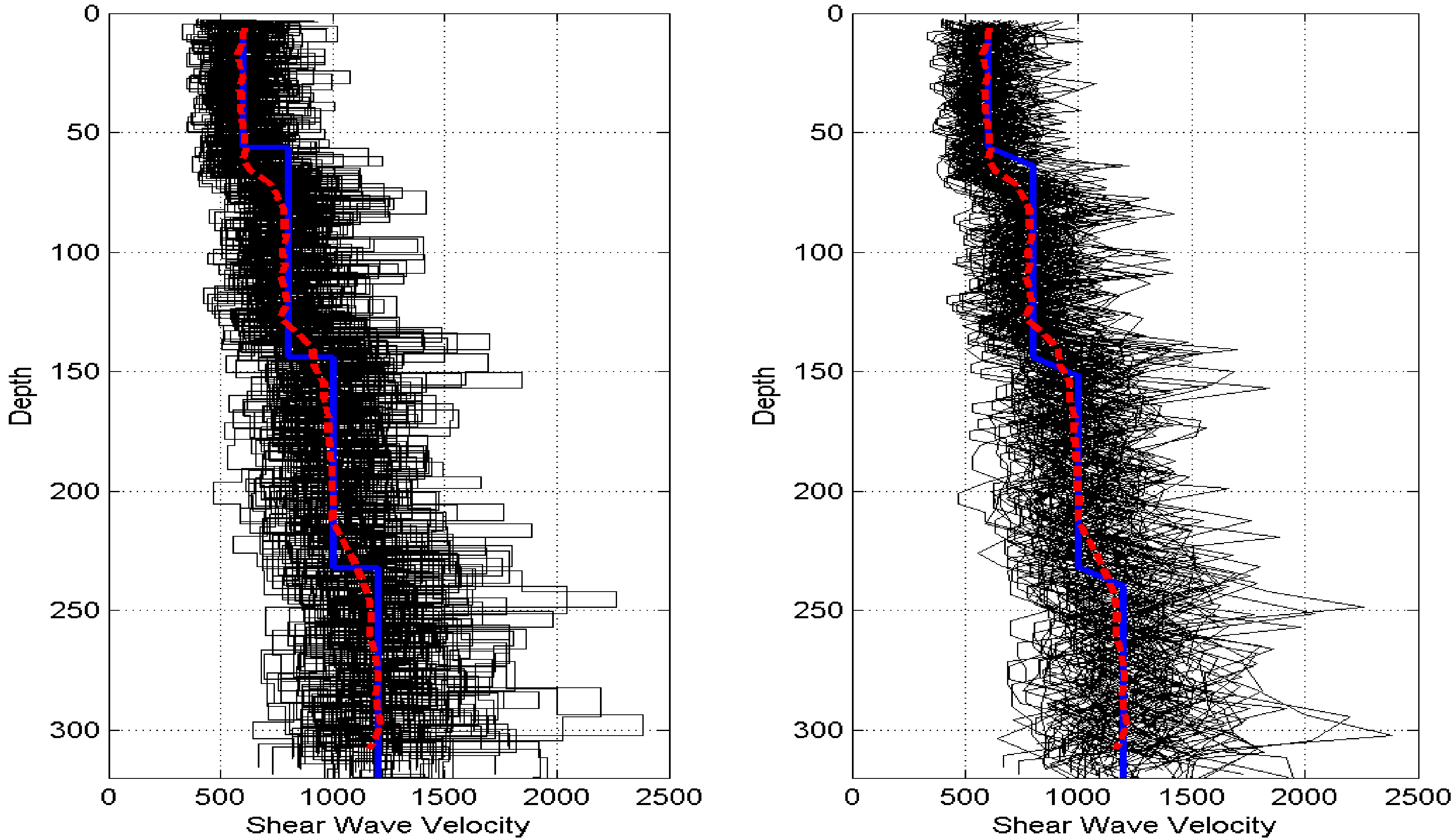
Probabilistic Simulations of Soil Profiles Using Discrete Process Model, Model 3 (Toro's Model)



Toro, G. R. (1995). "Probabilistic models of site velocity profiles for generic and site-specific ground-motion amplification studies", Brookhaven National Laboratory.

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Toro's Model (M3) If No Good Data Is Available

The Toro's model is a generic randomization of layer thicknesses (Toro, 1995) that results in a significant frequency shifts of peaks, and a decrease in in the amplitude of the motion site response spectral amplification. It was used in some past projects.

USNRC Vladimir Graizer, "Treasure Island Geotechnical Array Case Study for Site Response Analysis", 4th IASPEI/IAEE International Symposium: Effects of Surface Geology on Seismic Motion, UCSB, California, August 23–26,2011 states:

"This type of randomization of layer thicknesses is possibly useful in the situations when site characterization is generic, for example in cases when detailed characterization from neighboring sites is applied to nearby location. Based on my tests, I do not recommend applying generic (Toro, 1995) type of layer thicknesses and S-wave velocity randomization in cases when layer and velocity profile are well determined (typical for many recent critical facilities requiring detailed P- and S-wave site characterization). I recommend applying randomization of velocity and layer thickness based on actual geologic and geotechnical measurements providing actual limits of variability."

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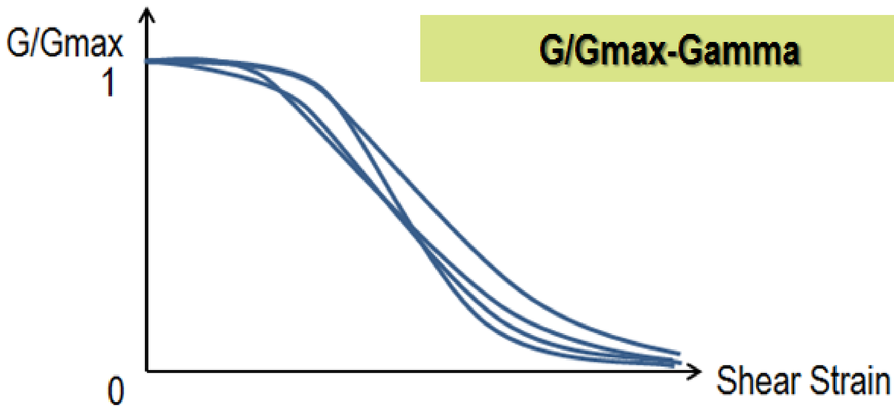
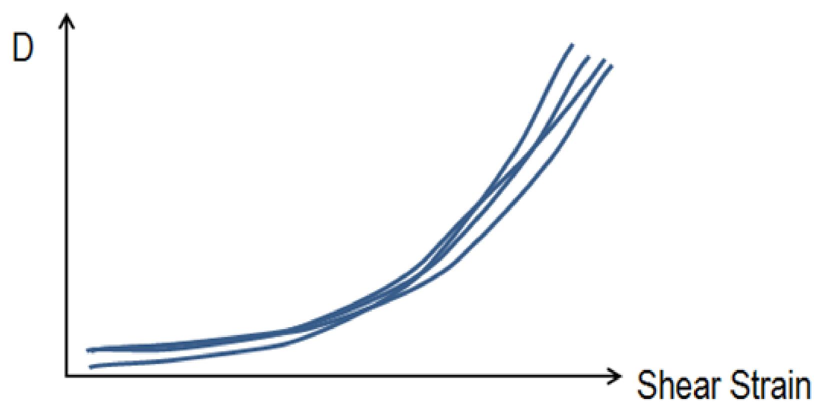
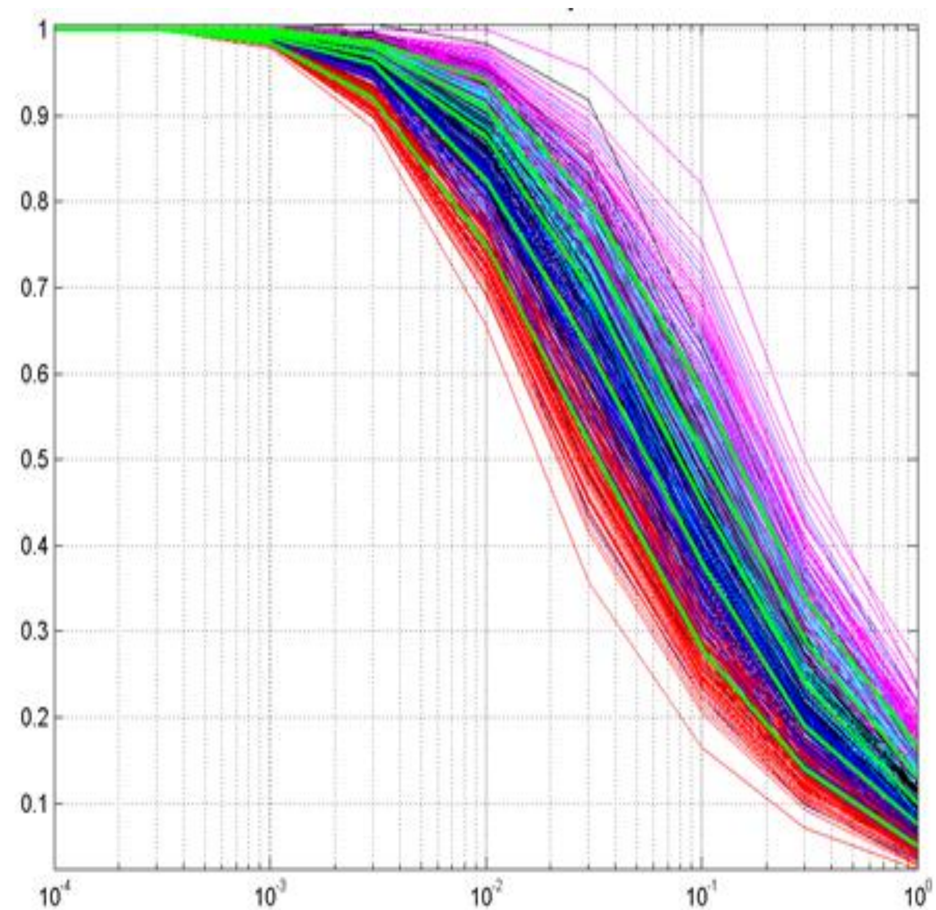
ProSOIL Simulation of Soil Material Behavior

G/Gmax-Gamma



D-Gamma





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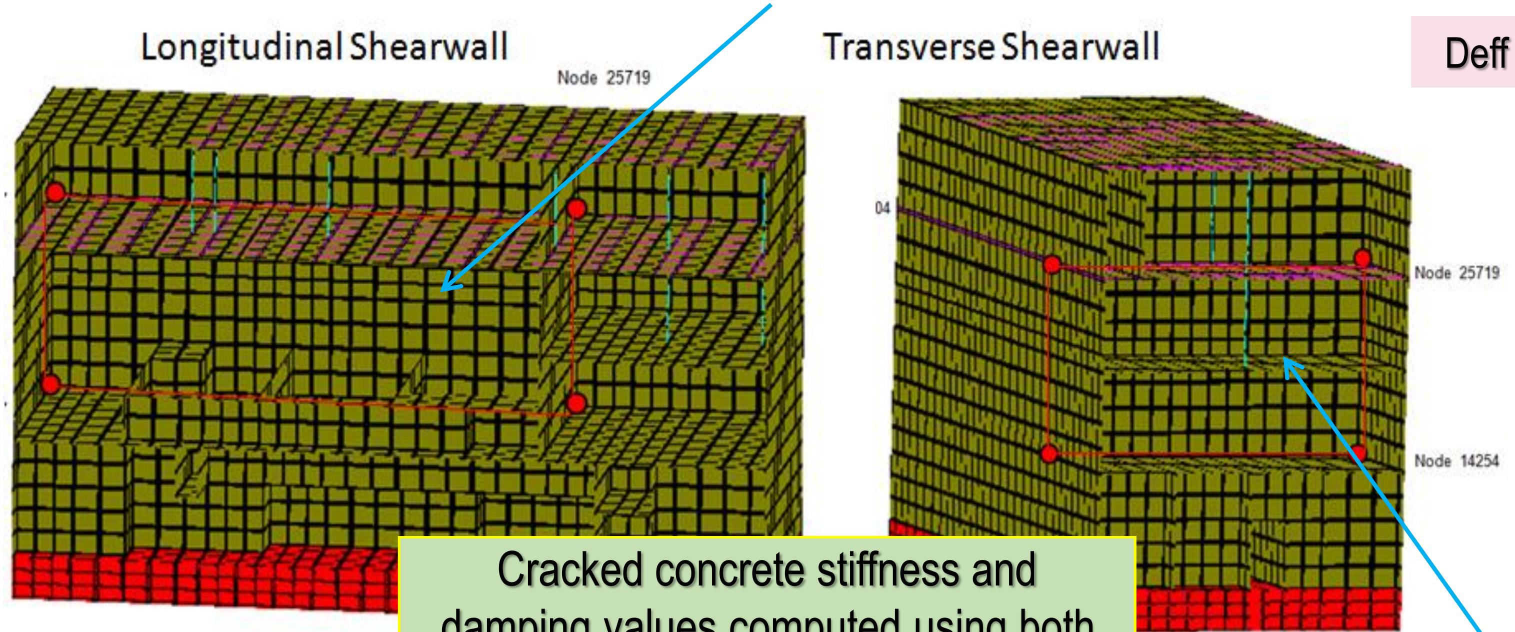
Probabilistic Structural Models; Effective Stiffness and Damping *Depend on Wall Strain Levels*

- Keff/Kel and Deff variables should defined by user *for each element group.*
- Effective stiffness ratio Keff/Kelastic and damping ratio, Deff, should be modeled as *statistically dependent* random variables. They can be considered *negatively correlated*, or Deff defined as a *response function* of Keff/Kelastic based on experimental tests.



Deff = f (Keff/Kelastic)

Stiff	Damp
0.01	0.20
0.10	0.17
0.20	0.15
0.30	0.13
0.40	0.11
0.50	0.10
0.60	0.09
0.70	0.08
0.80	0.07
0.90	0.06
1.00	0.05

Cracked concrete stiffness and damping values computed using both Option PRO and NON capabilities.

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Effective Wall Stiffness and Damping Can Be Computed with Option NON as Function of *Shear Strain*

An accurate approach for the low-rise concrete shearwall structures for estimating the effective stiffness and effective damping for each simulation due to the in-plane shear deformation is based on the Option NON that computes automatically these parameters based on the physical behavior of the concrete structure walls.

If Option NON is used, the initial values of the effective stiffness and effective damping for all concrete elements should be based on the uncracked concrete behavior that is 1.00 (uncracked elastic modulus) and 4% damping ratio.

ProNON should be used to simulate probabilistic BBCs for the concrete wall shear deformation.

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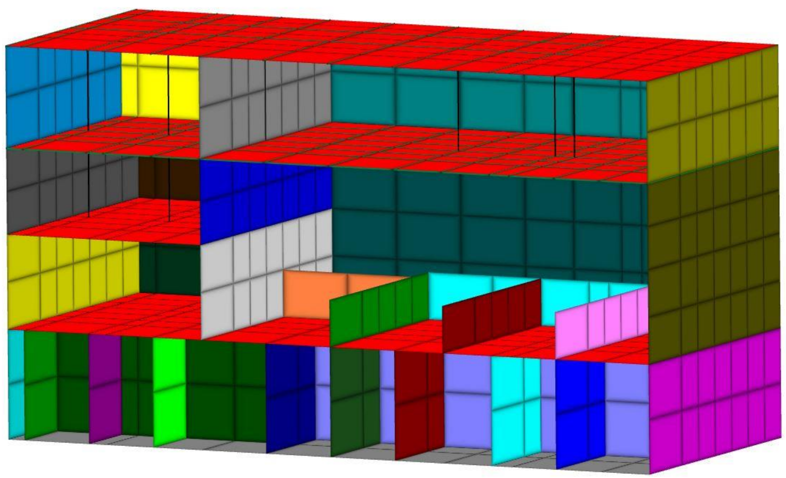
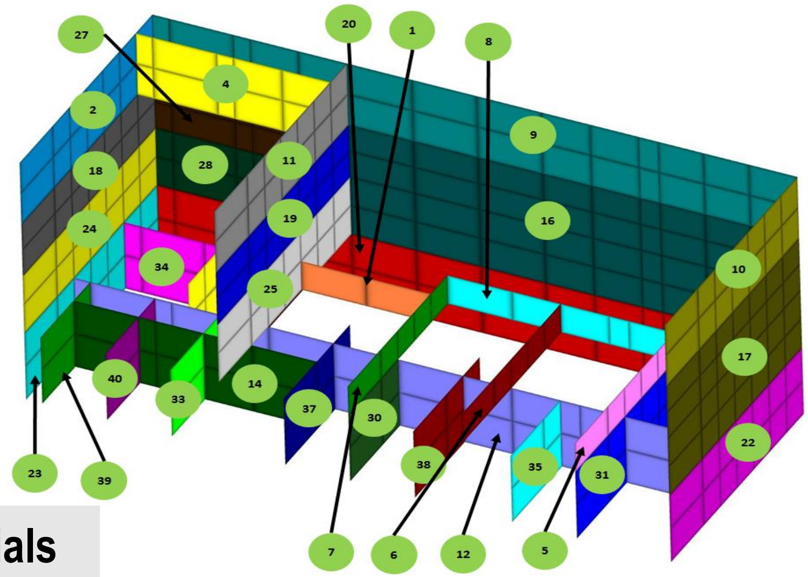
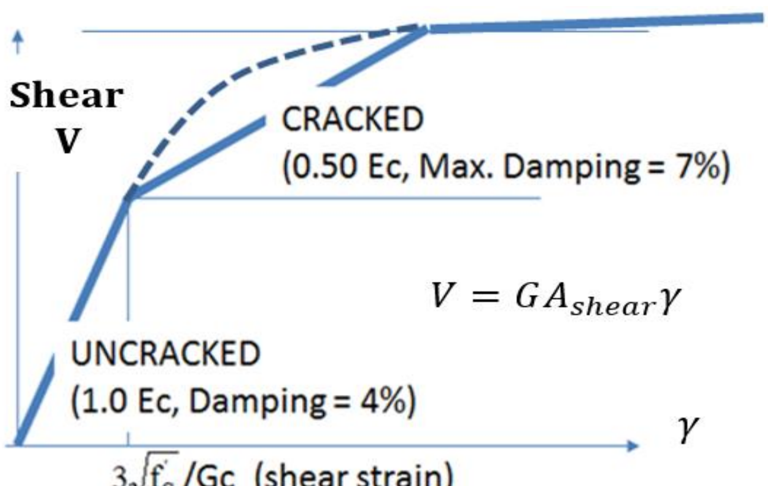
ProNON Simulates Randomized BBCs for Option NON

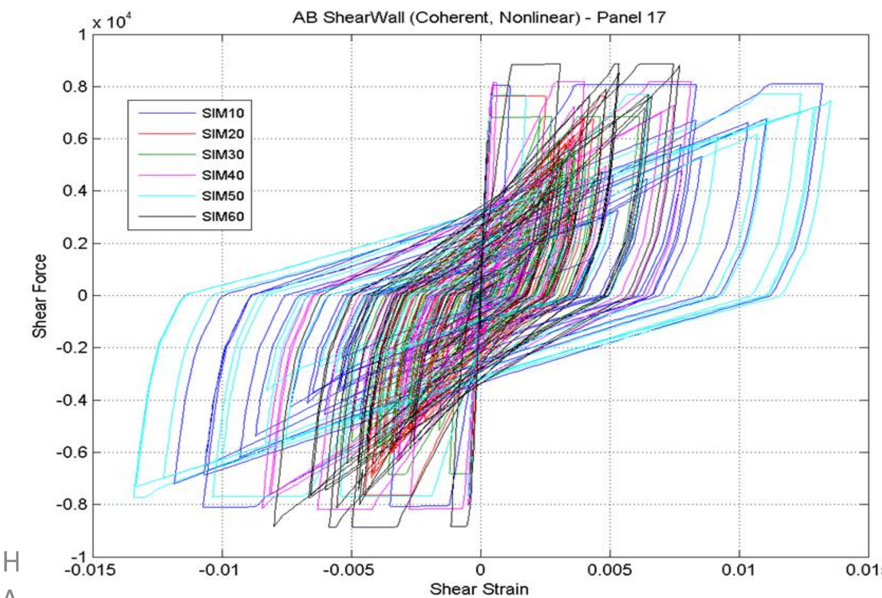




Structure is split in wall panels with different materials

ProNON Automatically Generates BBCs





HT GH
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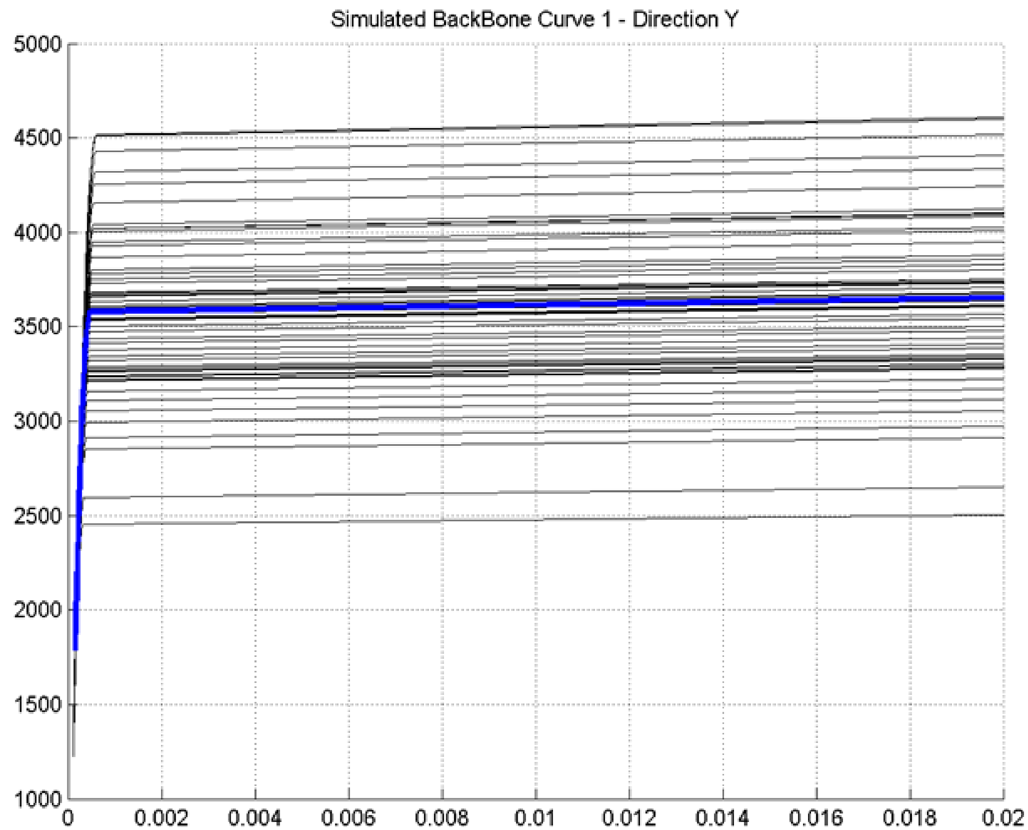
EXAMPLE 1. Simulation of Wall Panel BBCs

60 1 0.15 34522
BASELINE.EQL
GNONXXX.EQL
BASELINE.HOU
HOUSEXXX.HOU
1
0.02



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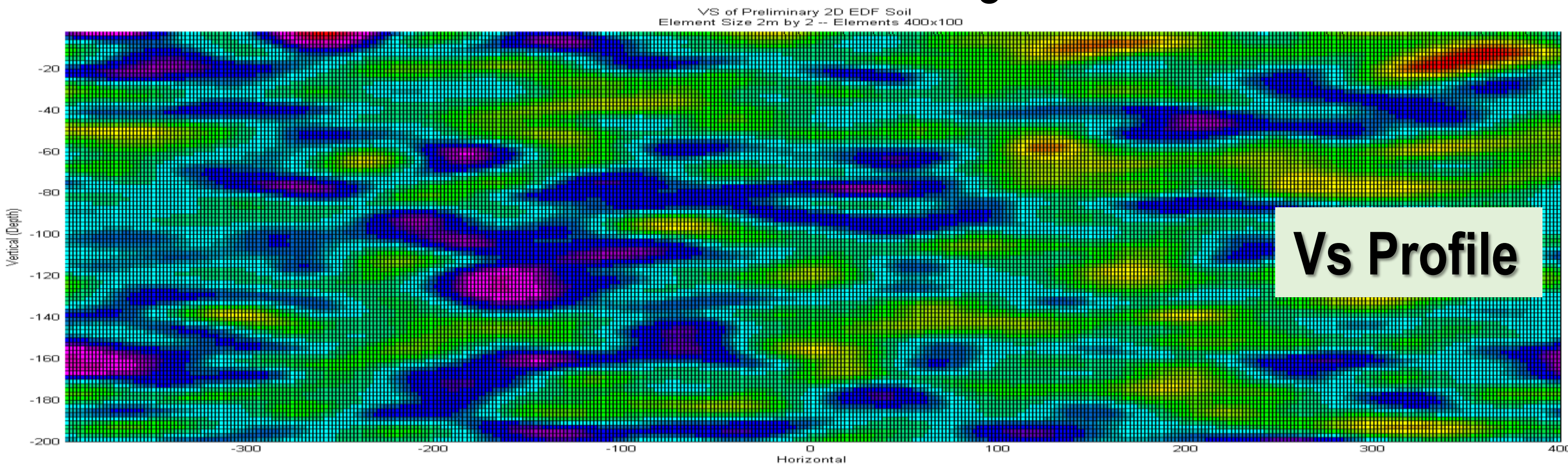
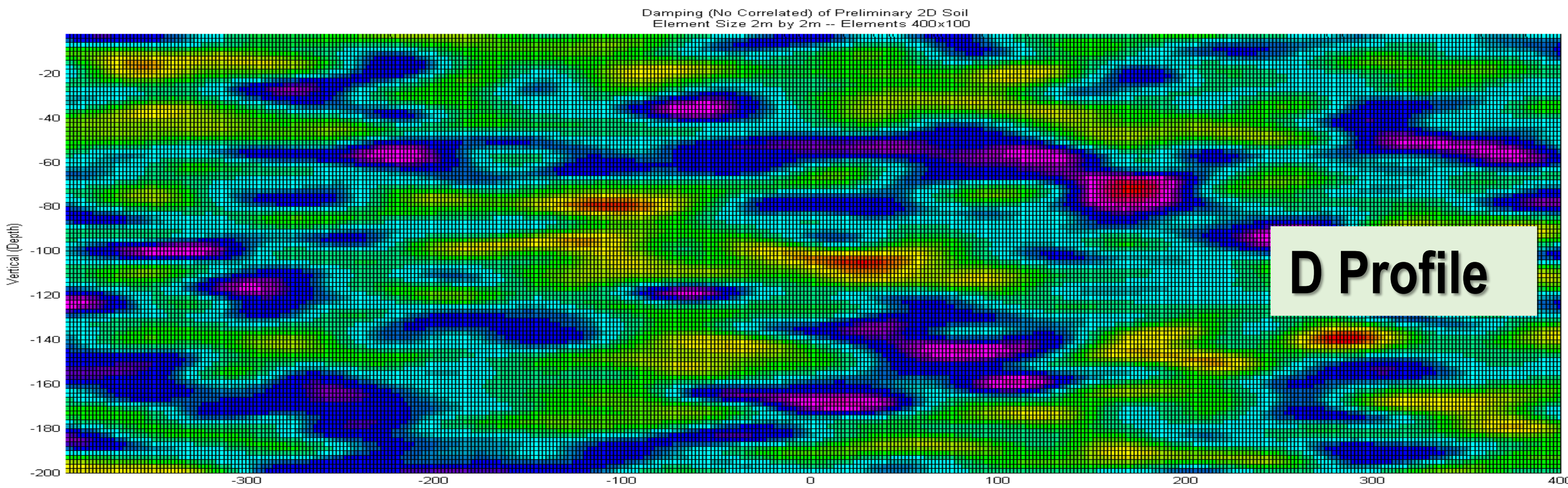
Simulated Vs and D Soil Profiles for An Uniform Deep Soil Deposit

Vs and D Simulation for Correlation Lengths of 60m x 10m





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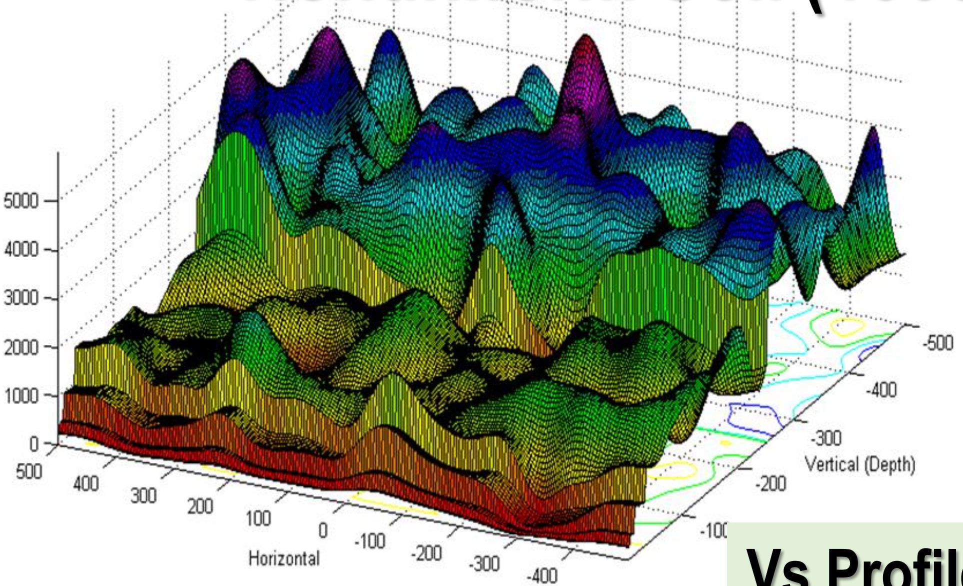
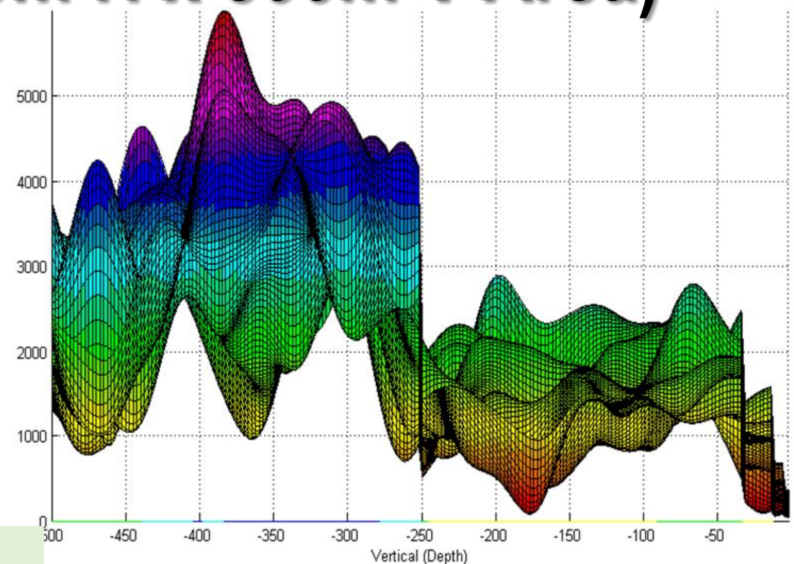
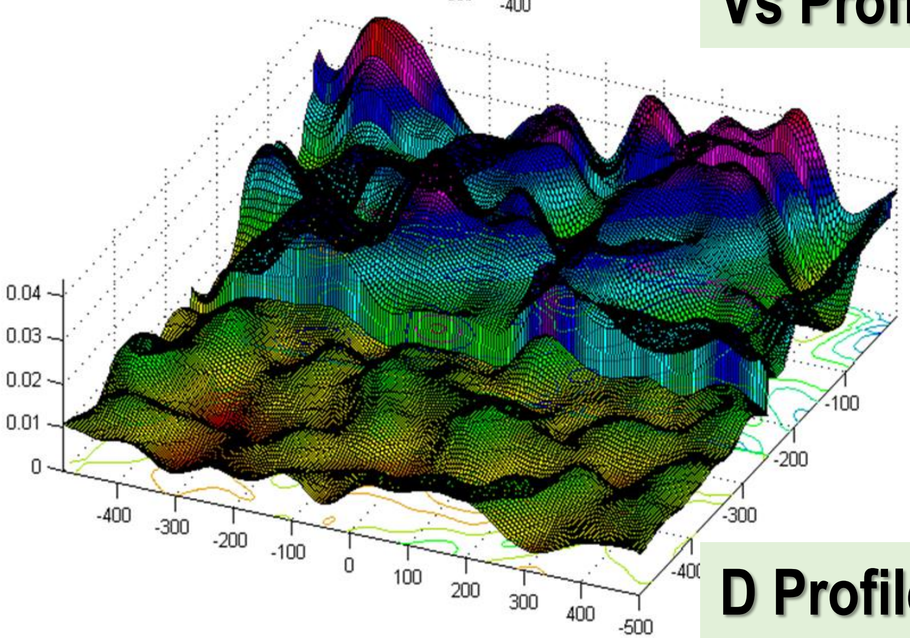
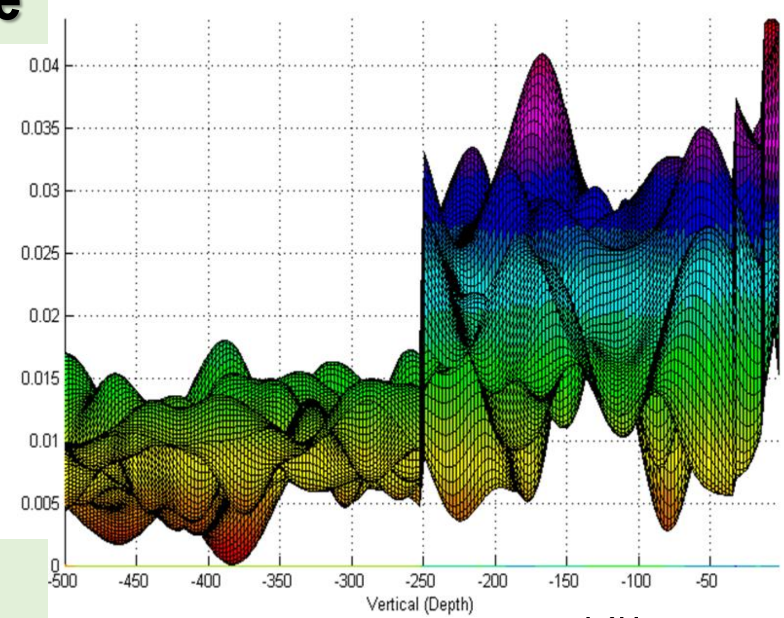
Probabilistic Simulations Vs and D Soil Profiles for Nonuniform Soil (1000m H x 500m V Area)





Vs Profile





D Profile

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PSRA and PSSIA Computational Steps

1) **PREPARE SSI INPUTS:** Using *ACS SASSI PRO modules*, generate the input simulations *(ProEQUAKE, ProSITE, ProSOIL and ProHOUSE, ProNON, ProMOTION, ProSTRESS)*

2) **PERFORM SSI ANALYSIS:** Using the *ACS SASSI modules,* run in batch the ensembles of the simulated input files to compute the SSI responses (SITE, SITE, SOIL, HOUSE, ANALYS, MOTION, RELDISP, NONLINEAR, STRESS).

3) **POST-PROCESS SSI RESPONSES:** Using the *ACS SASSI PRO* modules, post-process statistically the ensembles of the simulated SSI responses *(ProSRSS, ProRESPONSE)*

REMARK: The SSI input mean values which are deterministic quantities defined in the baseline files that are generated with the ACS SASSI UI commands, similar to deterministic SSI input values.

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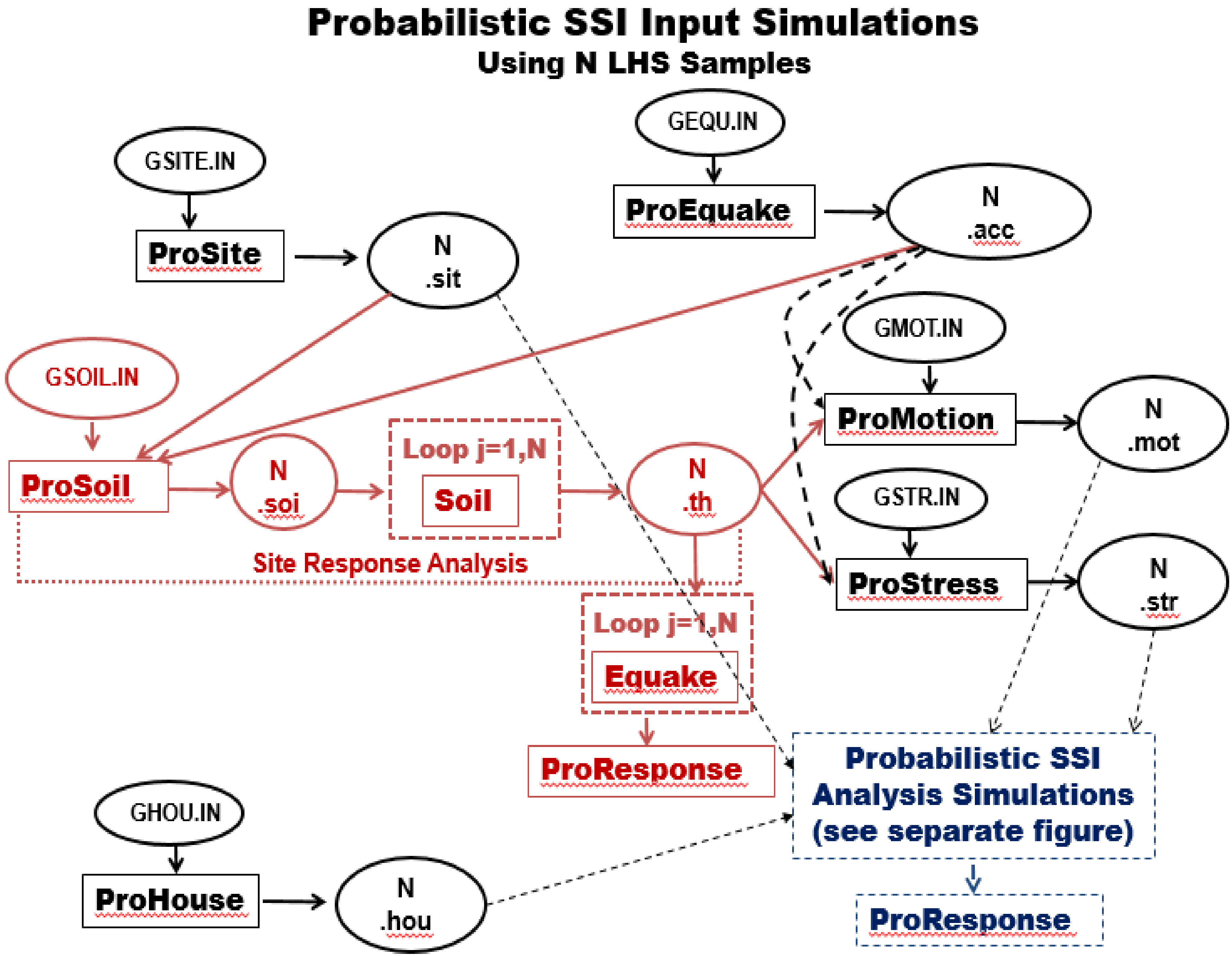

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Probabilistic Simulation Using PRO Modules

DET/ INPUT MEAN VALUES
Baseline Input Files
(BASELINE.ModuleExt)

Generated with ACS SASSI UI Command, similar to a deterministic SRA/SSI models.

Using ACS SASSI main software.

PRO/ INPUT STATISTICS
GProModule Input Files
(GModuleExt.In)

Generated with PRO Module Input Files.

Using ACS SASSI option PRO software.

PRO MODULE INPUT SIMULATIONS
Simulated Input Files
(GModuleNameXXX.ModuleExt)

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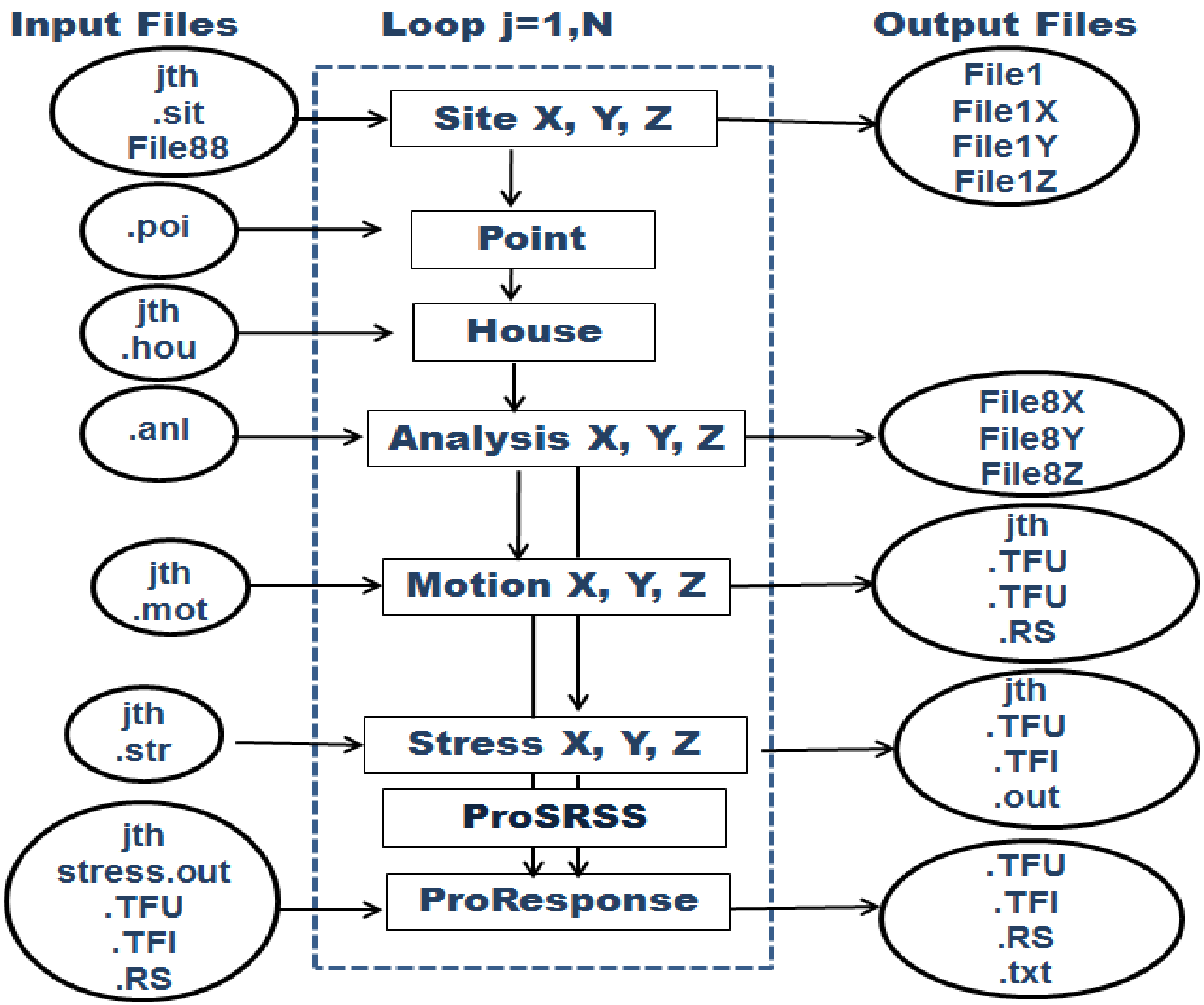
Probabilistic SSI Analysis Simulations

Using N LHS Samples



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Option PRO Modules for PSRA and PSSIA

Check_Site_Output.exe	Application	10,378 KB
ProEquake.exe	Application	1,970 KB
PROHOUSE.exe	Application	9,270 KB
ProMotion.exe	Application	695 KB
ProNon.exe	Application	80 KB
ProResponse.exe	Application	178 KB
ProSite.exe	Application	9,651 KB
ProSoil.exe	Application	9,079 KB
ProSRSS.exe	Application	722 KB
ProStress.exe	Application	37 KB
SITEPRO.exe	Application	640 KB
Write_Site_Input.exe	Application	25 KB

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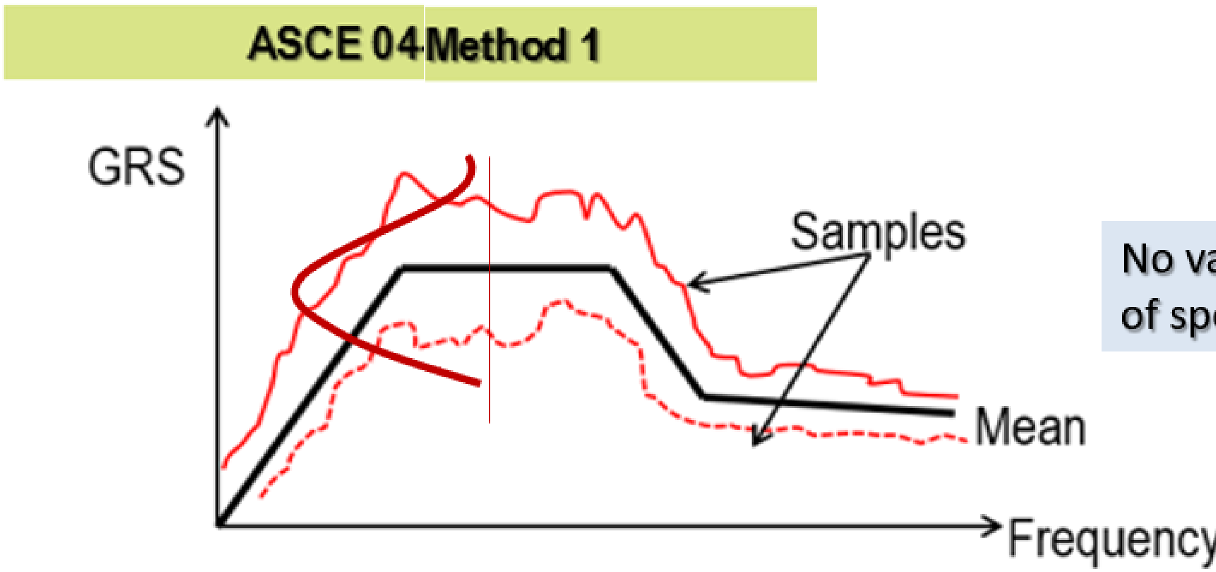
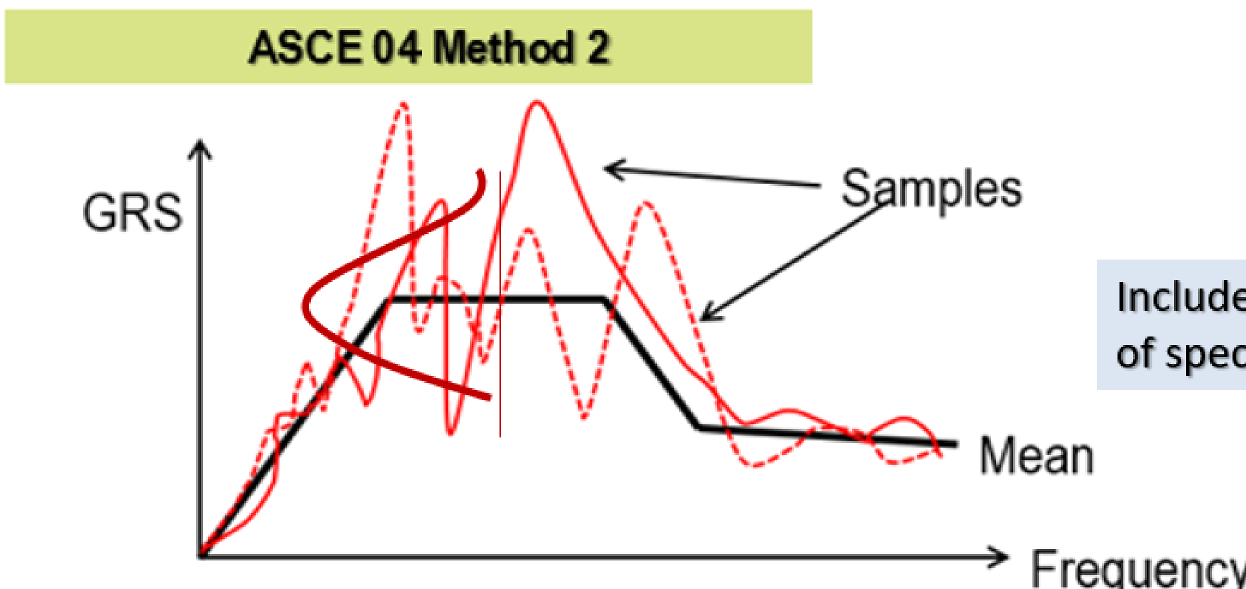
Probabilistic Seismic Input Models



No variation of spectral shape



Include variation of spectral shape

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ProEQUAKE Input Parameters

RSIXXX.RS
RSOXXX.RS
ACCXXX.acc
GEQUXXX.equ
GRSMEAN.RSI
0.05 32.2
15 0.005
100 12345 153414
0 1
26.0 135.0
0 0.3
10

Table 5.1 The ProEQUAKE Input File (GEQU.IN)

Input File Line Number	Variable Name (Input in free format)	Definition of Input Variables	Variable Type
1	FRSI	Filenames for the simulated GRS inputs (ex. RSIxxx.RS)	Output
2	FRSO	Filenames for the computed GRS samples (ex. RS0xxx.RS)	Output
3	FACC	Filenames for the computed acceleration histories (ex. ACCxxx.acc)	Output
4	FEQU	Filename for the simulated equ inputs (ex. GEQU001.equ)	Output/Input
5	FBASEL	Filename for the mean GRS amplitude (ex. BASELINE.RSI)	Input
6	DAMPING	Damping ratio for the GRS input (in percent)	Input
6	GRAVACC	Acceleration of gravity for ground velocity and displacement calculations	Input
7	DURATION	Duration of simulated acceleration histories (in seconds)	Input
7	TIMESTEP	Time step of simulated acceleration histories (in seconds)	Input
8	NSIMUL	Number of simulated seismic inputs for a single direction	Input
8	INITRSI	Initial SEED Random Number for RSIxxx.RS simulation	Input
8	INITACC	Initial SEED Random Number for ACCxxx.ACC simulation	Input
9	OPTMETH	Option for the Method used for GRS Simulation = 0 for Method 2 in ASCE 04-2016 (Line 11 not needed) = 1 for Method 1 in ASCE 04-2016 (Line 11 needed)	Input
9	DIR	Selected Input Direction: = 0 for X = 1 for Y = 2 for Z	Input
10	F1	1st Frequency for calculation of the c.o.v. factor (in Hz)	Input
10	F2	2nd Frequency for calculation of the c.o.v. factor (in Hz)	Input
11	OPTCOR	Option for GRS shape correlation structure: = 0 for frequency-independent correlation length (scalar) = 1 for frequency-dependent correlation length (vector) = 2 for full correlation matrix for GRS amplitudes (matrix)	Input
11	COV	Coefficient of variation of the GRS amplitudes	Input
12	SIGMA	For OPTCOR = 0 Correlation length value input	Input
12	SIGMAV	For OPTCOR = 1 Correlation length vector input	Input
12	CORRMAT	For OPTCOR =2 Correlation matrix file name input	Input

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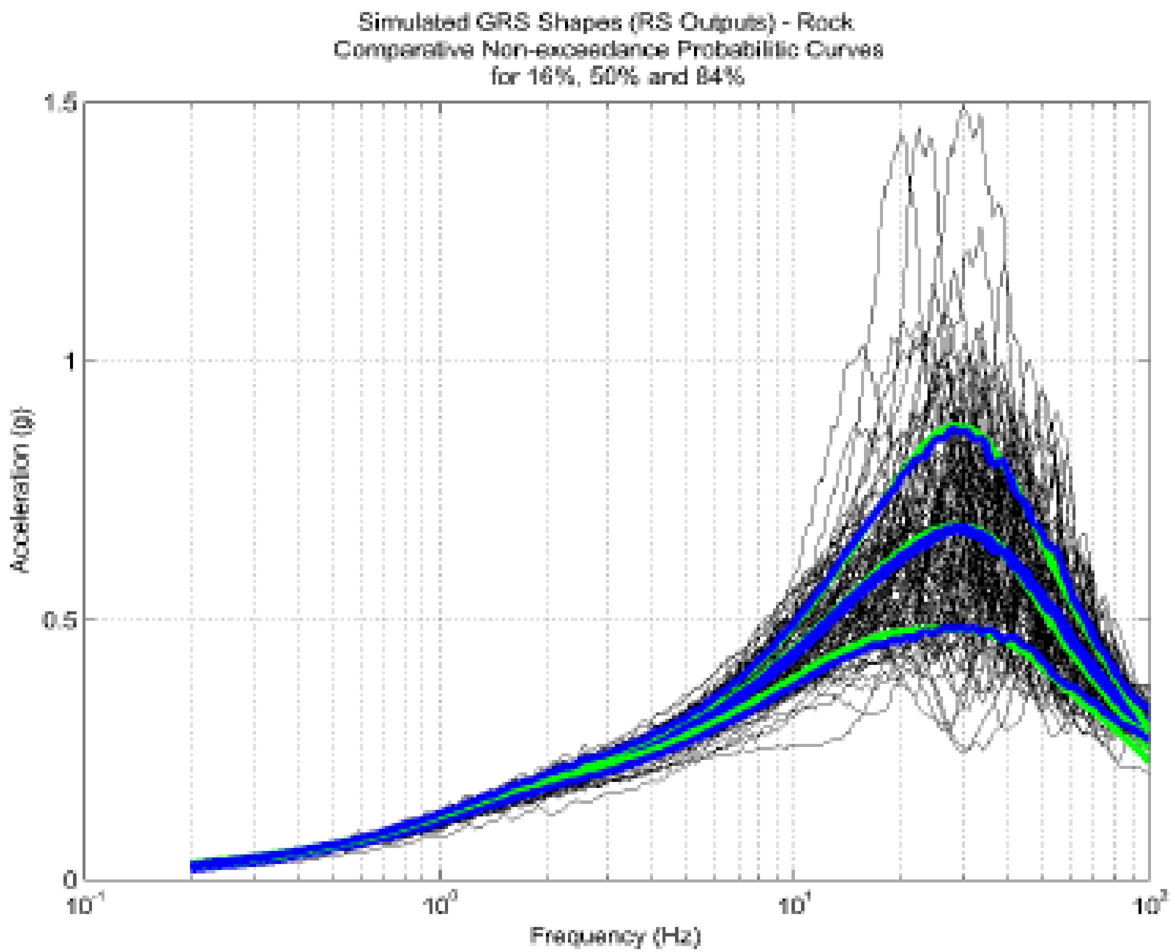
Example for ProEQUAKE Input Parameters

EXAMPLE 1: ROCK SITE - METHOD 2 WITH CONSTANT CORRELATION LENGTH

RSIXXX.RS
RSOXXX.RS
ACCXXX.acc

RSIXXX.RS
RSOXXX.RS
ACCXXX.acc
GEQUXXX.equ
GRSMEAN.RSI
0.05 32.2
15 0.005
100 12345 153414
0 1
26.0 135.0
0 0.3
10



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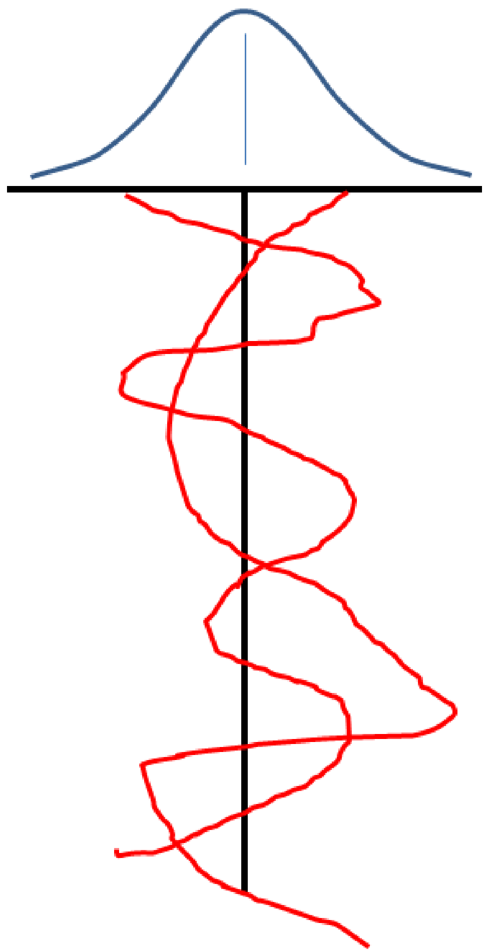
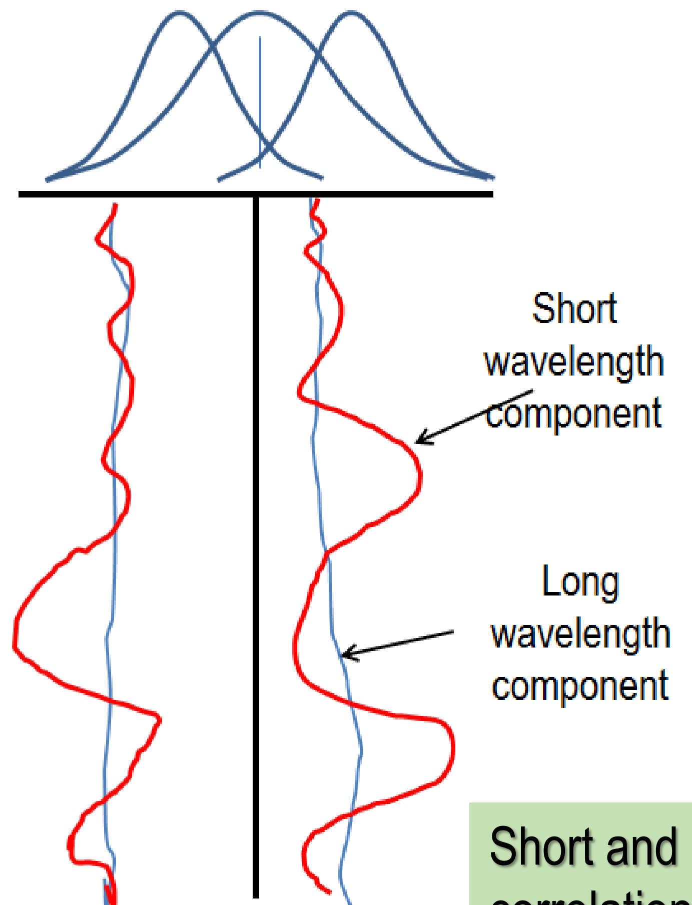
Vs & D Profiles Using Continuous Process 1D Models. Two Variation Models, M1 and M2





Short and large correlation lengths

Model 1 (Simple)

Model 2 (Composite)

(Popescu, 1996)

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ProSITE Soil Profile Modeling and Simulation

A. Gaussian Continuous Process Model, Models 1 (simplified) and 2 (accurate)
B. Poisson Discrete Process Model, Model 3 (simplified, limited to power correlation)

BLOCK A

OPTION INPUTS FOR METHOD SELECTION:
MODEL 1&2 (0) OR MODEL 3 (1)

BLOCK B.1

MODEL 1&2

BLOCK B.2

MODEL 3

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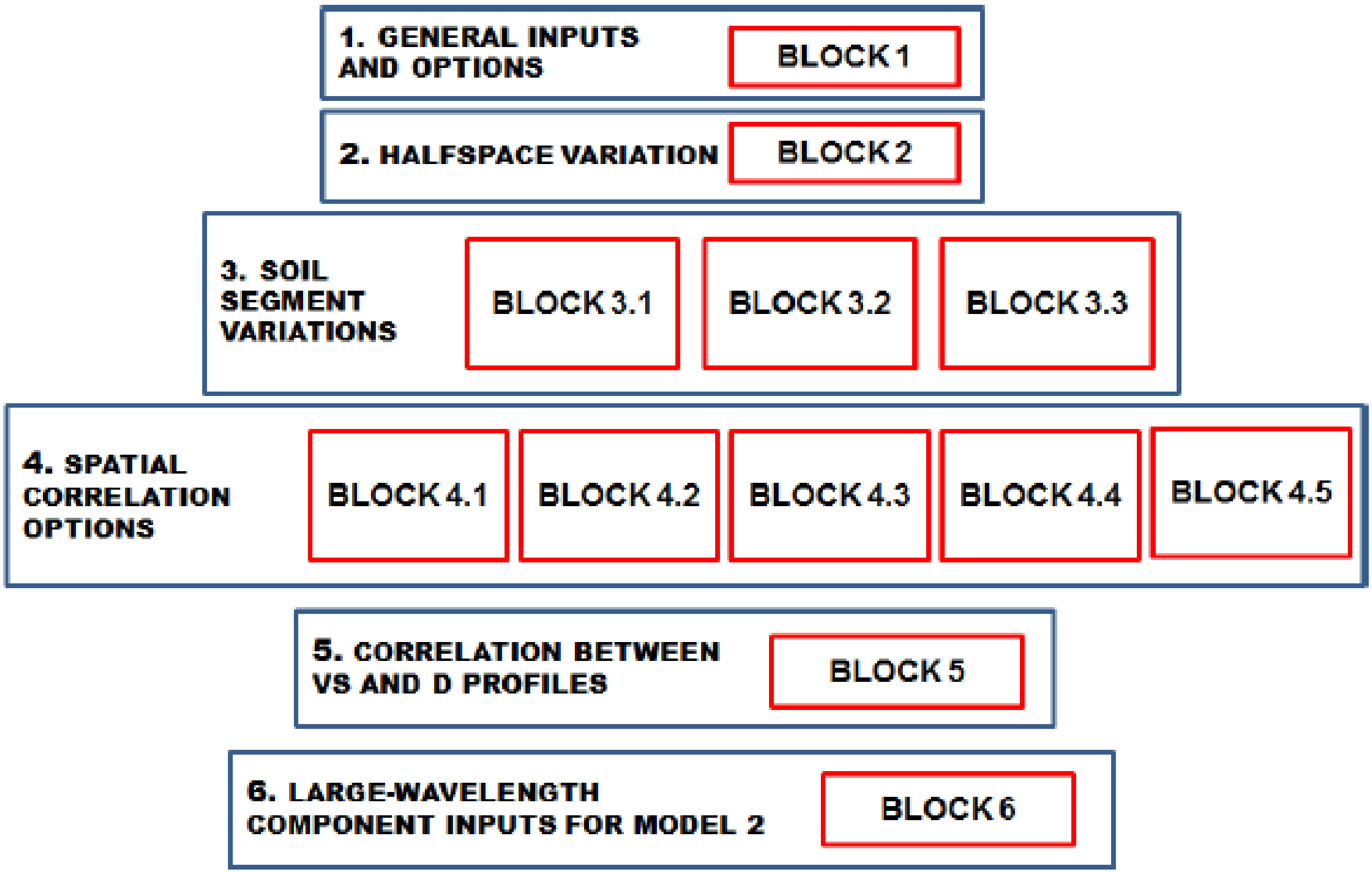
ProSITE Input Blocks for Block B.1 Models 1 & 2



GSITE.IN Input File Data Block Structure

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OPTVDCOR: Statistical Dependence for Vs and D

The OPTVDCOR variable controls the statistical dependence between the soil layer Vs and damping D values.
= 0 or 2. The options for values of 0 and 2 are straight forward.
= 1. For value of 1, the inverse statistical dependence is introduced based on the values that correspond to the same number of standard deviations from the mean values with changed sign.
= 3. For value of 3, the statistical dependence between Vs and D is included based a given, user-defined response function Vs = f(D).
=4. For value of 4, the statistical dependence is included by independently simulating the Vs and D sample values, and then pairing them, (Vs, D) in an inverse order (that corresponds to a rank correlation of -1.00).

WARNING: *The OPTVDCOR = 1 option should be used only when Vs and D have normal distributions. If Vs and D have lognormal distributions, this option may produce too low damping values, as shown in Appendix 2.*

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OPTSPCOR: Spatial Correlation for Vs and D

The OPTSPCOR variable controls the option for soil profile spatial correlation structure with depth.

For OPTSPCOR values o

= 0, 1 and 2, the correlation is defined either by a constant or a variable correlation length that is defined for a generic, analytical Gaussian spatial correlation function with an inflection point defined at the half of the correlation length value, as shown in (left plot).

= 3. For the OPTSPCOR value of 3, a more general model based directly on the spatial correlation matrix is considered. This soil profile correlation matrix should be determined based on the on-site Vs and D soil profile data or site response simulations.

The correlation length vector and correlation matrix should be input in a free format.

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OPTPROFIL: Soil Profiles By Models 1 and 2

The OPTPROFIL variable controls the selection of the random field models for Vs and D soil profiles idealized by Gaussian Continuous Process Model, with Normal or Lognormal PDF. For the OPTPROFIL values

= 0 for Model 1, the Vs and D profiles are modeled as 1D random fields

= 1 for Model 2, the Vs and D profiles are modeled as a superposition of two 1D random fields with significantly different spatial correlation wavelength content. The first random field should have a long wavelength variation with depth, while the second random field should have a short wavelength variation. For the OPTSPCOR value of 1, user has to input in addition to the statistical parameters of the short-wavelength component profile, the statistical parameters of the long-wavelength profile in terms of coefficient of variation and correlation length for each soil profile segment.

The superposition model is useful to simulate “slow-varying” type of random fields, rather than “rapid-oscillatory” type of random fields. The selection of the correlation structure depends on the statistical evidence obtained from the on-site Vs soil profile data.

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ProSITE Input Block Details for Block B.1

NSIMUL, OPTPDF, OPTVDCOR, OPTSPCOR, OPTPROFIL
FBASEL
FGSITE
NSEGM, OPTHS

Block 1

IF OPTHS=0 AND OPTVDCOR=0,1,2 THEN
COVHSVS, COVHSD

Block 2.1

IF OPTHS=0 AND OPTVDCOR=3,4 THEN
COVHSVS

Block 2.2

IF OPTVDCOR=3 THEN

LOOP J=1,NSEGM
NLAYSEG(J), COVVS(J),INSEEDVS(J)
NDATAFCT(J), INSEEDFCT(J)
LOOP I=1, NDATAFCT(J)
VSDAT(J,I),DDAT(J,I), VSNOISE(J,I)
END LOOP I
END LOOP J

Block 3.1

IF OPTVDCOR=4 THEN

LOOP J=1,NSEGM
NLAYSEG(J), COVVS(J), INSEEDVS(J)
RSMEANVS(J), RSCOVVS(J)
RSMEAND((J), RSCOVD(J)
END LOOP J

Block 3.2

IF OPTVDCOR=0,1,2 THEN

LOOP J=1,NSEGM
NLAYSEG(J), COVVS(J),INSEEDVS(J) ,
COVD(J), INSEEDD(J)
END LOOP J

Block 3.3

IF OPTSPCOR=1 AND OPTVDCOR=0,1,2 THEN

LOOP J=1, NTLAYER
CORLVS(J), CORLD(J)
END LOOP J

Block 4.1

IF OPTSPCOR=1 AND OPTVDCOR=3,4 THEN

LOOP J=1, NTLAYER
CORLVS(J)
END LOOP J

Block 4.2

IF OPTSPCOR=3 THEN

CORMAT *(CORRLELATION MATRIX FILE)*
- IF OPTVDCOR=0,1,2: THEN
INPUT CORRELATION MATRICES FOR VS AND DAMPING FOR ALL LAYERS
- IF OPTVDCOR=3,4: THEN
INPUT CORRELATION MATRIX FOR VS

Block 4.3

IF OPTSPCOR=0,2 AND OPTVDCOR=3,4 THEN

LOOP J=1, NSEGM
CORLVS(J)
END LOOP J

Block 4.4

IF OPTSPCOR=0,2 AND OPTVDCOR=0,1,2 THEN

LOOP J=1, NSEGM
CORLVS(J), CORLD(J)
END LOOP J

Block 4.5

IF OPTVDCOR =0 THEN
CORVSD

Block 5

IF OPTPROFIL = 1 THEN
LOOP J=1, NSEGM
COVMEANVS(J), CORLLWVS(J), COVMEAND(J), CORLLWD(J)
END LOOP J

Block 6

Figure 5.3 GSITE.IN File Input Data Description

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ProSITE Input Parameters for Block 1 (M1, M2)

Input BlockNumber	Input File Line Number Inside Each Block	Variable Name (Input file in free format)	Definition of Input Variables
BLOCK A			
	1	NOPTMETH	Option for selecting methods = 0 for Models 1 or 2 simulation = 1 for Model 3 simulation
BLOCK B.1:	**BLOCK 1 -- BLOCK 6**		
BLOCK 1			
1	1	NSIMUL	Number of simulated seismic input files
1	1	OPTPDF	Option for probability distribution for Vs and D = 0 for Normal distribution = 1 for Lognormal distribution
1	1	OPTVDCOR	Statistical dependence between soil layer Vs and D = 0 using a linear correlation coefficient = 1 assuming inverse variation based an equal number of standard variations from mean value = 2 assuming statistical independence = 3 using given response function Vs=f(D) provided by the user = 4 using inverse probability variation based on simulation of a statistical response function Vs=f(D), obtained for rank correlation is -1.0.

ProSITE Input Parameters for Blocks 1 and 2

1	1	OPTSPCOR	Spatial correlation structure with depth for Vs and D = 0 for constant correlation length with depth (scalar) = 1 for variable correlation length with depth (vector) = 2 for infinite correlation length (perfect correlation with depth) = 3 for using the spatial correlation matrix (matrix)
1	1	OPTPROFIL	Soil profile random field models for Vs and D = 0 Model 1, using a 1D random field = 1 Model 2, using a superposition of two random fields; a long-wavelength and a short-wavelength variation
1	2	FBASEL	Filename for the mean soil profile (ex. BASELINE.SIT)
1	3	FGSITE	Filenames of the simulated SITE inputs (ex. GSITExxx.sit)
1	4	NSEGM	Number of the soil profile segments
1	4	OPTHS	Option for the half-space layer random samples = 0 independent from soil above = 1 full correlated with the soil layer above
BLOCK 2	Only for OPTHS=0		
2.1, 2.2	1	COVHSVS	Coefficient of variation for bedrock Vs
2.1	1	COVHSD	Coefficient of variation for bedrock D

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ProSITE Input Parameters for Block 3

BLOCK 3	Start Loop J=1,NSEGM		Loop over the number of soil layer segments
3.1, 3.2, 3.3	1 Inside J Loop	NLAYSEG(J)	Number of layers in the segment (J)
3.1, 3.2, 3.3	1 Inside J Loop	COVVS(J)	Coefficient of variation of Vs(J)
3.1, 3.2, 3.3	1 Inside J Loop	INSEEDVS(J)	Initial SEED for Vs(J)
3.3	1 Inside J Loop	COVD(J)	Coefficient of variation of D(J)
3.3	1 Inside J Loop	INSEEDD(J)	Initial SEED for D(J)
3.1	2 Inside J Loop	NDATAFCT(J)	Number of response function data
3.1	2 Inside J Loop	ISEEDFCT(J)	Initial seed for response function noise
3.2	2 Inside J Loop	RSMEANVS(J)	Mean Vs for simulation (to compute Vs=f(D) response function based on assuming a rank correlation = -1)
3.2	2 Inside J Loop	RSCOVD(J)	Coefficient of variation of Vs for simulation (to compute Vs=f(D) function based on assuming a rank correlation = -1)
3.1	Start Loop I=1,NDATAFCT(J)		Loop over Vs=f(D)+noise response surface data
3.1	3 Inside J Loop/1 Inside I Loop	VSDAT(J,I)	Response function Vs data points
3.1	3 Inside J Loop/1 Inside I Loop	DDAT(J,I)	Response function D data points
3.1	3 Inside J Loop/1 Inside I Loop	VSNOISE(J,I)	Response function noise standard deviation
3.1	End Loop I=1,NDATAFCT(J)		
3.2	3 Inside J Loop	RSMEAND(J)	Mean D for simulation (to compute response function based on assuming a rank correlation = -1)
3.2	3 Inside J Loop	RSCOVD(J)	Coefficient of variation of D for simulation (to compute response function based on assuming a rank correlation = -1)
	End Loop J=1,NSEGM		

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ProSITE Input Parameters for Blocks 4, 5 and 6

BLOCK 4			
4.1, 4.2	Start Loop J=1,NTLAYER		Loop over the number of soil layers
4.1,4.2	1 Inside J Loop	CORLVS(J)	Correlation length of Vs(J)
4.1	1 Inside J Loop	CORLD(J)	Correlation length of D(J)
4.1, 4.2	End Loop J=1,NTLAYER		
4.3	1	CORMAT	Correlation matrix file name
4.4, 4.5	Start Loop J=1,NSEGM		
4.4,4.5	1 Inside Loop J	CORLVS(J)	Correlation length of Vs(J)
4.5	1 Inside Loop J	CORLD(J)	Correlation length of Damping D(J)
4.4,4.5	End of Loop J=1,NSEGM		
BLOCK 5			
5	1	CORVSD	Correlation coefficient between Vs and D profiles
BLOCK 6			
	Start Loop J=1,NSEGM		
6	1 Inside Loop J	COVMEANVS(J)	Coefficient of variation of long-wavelength component Vs profile
6	1 Inside Loop J	COVMEAND(J)	Coefficient of variation of long-wavelength component D profile
6	1 Inside Loop J	CORLLWVS(J)	Correlation length of the long-wavelength component Vs profile
6	1 Inside Loop J	CORLLWD(J)	Correlation length of the long-wavelength component D profile
6	End of Loop J=1,NSEGM		

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Example for ProSITE Input Parameters

EXAMPLE 1: SOIL SITE – MODEL 1 WITH 4 SEGMENTS, VS AND D PROFILES WITH CONSTANT CORRELATION LENGTH, LOGNORMAL DISTRIBUTIONS, INVERSE VARIATION STATISTICAL DEPENDENCE FOR VS AND D

```
100 1 1 0 0
BASESITE.SIT
GSITEXXX.SIT
4 1
 7  0.20  222222  0.3   334522
11  0.20  313473  0.3   368953
11  0.20  513473  0.3   168953
11  0.20  118542  0.3   214345
40  40
40  40
40  40
40  40
```

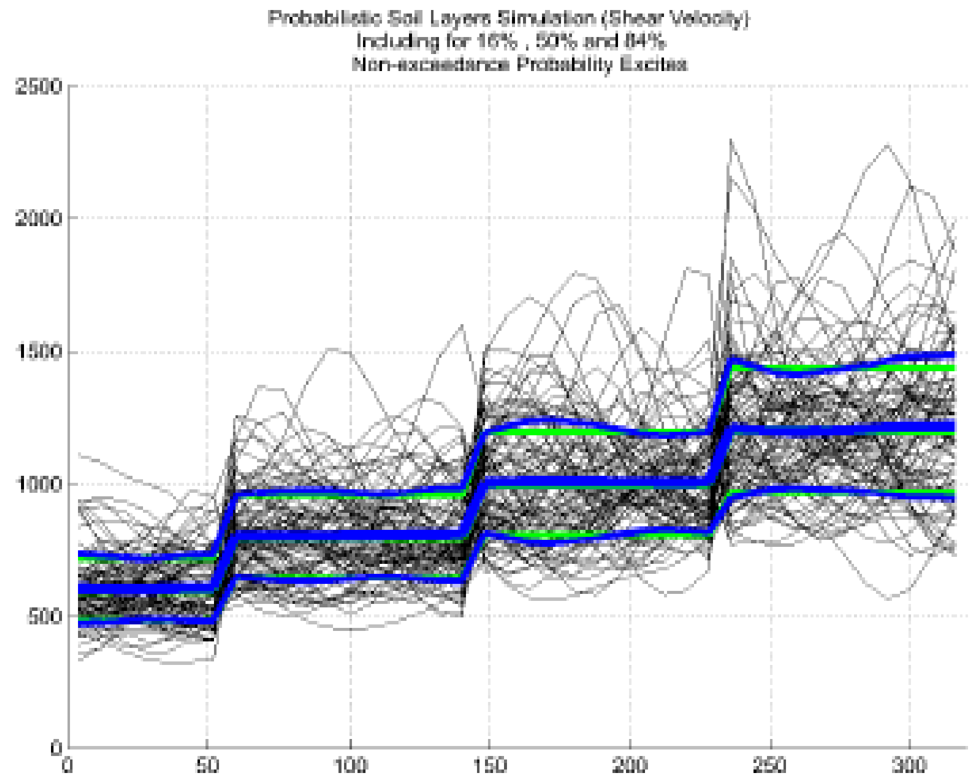

Figure A2.1 Shear Velocity Statistical Curves (Mean and Mean +/- Standard Deviation) and Simulated Samples (black); Computed Probability Curves based on Simulated Samples (blue line) are plotted Against Given Probability Curves (light green line)

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Example 1: Soil Site – Model 1 with 4 Segments, Vs and D Profiles with Constant Correlation Length, Lognormal Distributions, Inverse Variation Statistical Dependence for Vs and D

NSIMUL, OPTPDF, OPTVDCOR, OPTSPCOR, OPTPROFIL
FBASEL
FGSITE
NSEGM, OPTHS 1 1 0 0
Block 1

IF OPTHS=0 AND OPTVDCOR=0,1,2 THEN
COVHSVS, COVHSD
Block 2.1

IF OPTHS=0 AND OPTVDCOR=3,4 THEN
COVHSVS
Block 2.2

IF OPTVDCOR=3 THEN

LOOP J=1,NSEGM
NLAYSEG(J), COVVS(J),INSEEDVS(J)
NDATAFCT(J),INSEEDFCT(J)
LOOP I=1, NDATAFCT(J)
VSDAT(J,I),DDAT(J,I),VSNOISE(J,I)
END LOOP I
END LOOP J
Block 3.1

IF OPTVDCOR=4 THEN

LOOP J=1,NSEGM
NLAYSEG(J), COVVS(J), INSEEDVS(J)
RSMEANVS(J), RSCOVVS(J)
RSMEAND((J), RSCOVD(J)
END LOOP J
Block 3.2

IF OPTVDCOR=0,1,2 THEN

LOOP J=1,NSEGM
NLAYSEG(J), COVVS(J),INSEEDVS(J) ,
COVD(J), INSEEDD(J)
END LOOP J
Block 3.3

IF OPTSPCOR=1 AND OPTVDCOR=0,1,2 THEN

LOOP J=1, NTLAYER
CORLVS(J), CORLD(J)
END LOOP J
Block 4.1

IF OPTSPCOR=1 AND OPTVDCOR=3,4 THEN

LOOP J=1, NTLAYER
CORLVS(J)
END LOOP J
Block 4.2

IF OPTSPCOR=3 THEN

CORMAT *(CORRLELATION MATRIX FILE)*
- IF OPTVDCOR=0,1,2: THEN
INPUT CORRELATION MATRICES FOR VS AND DAMPING FOR ALL LAYERS
- IF OPTVDCOR=3,4: THEN
INPUT CORRELATION MATRIX FOR VS
Block 4.3

IF OPTSPCOR=0,2 AND OPTVDCOR=3,4 THEN

LOOP J=1, NSEGM
CORLVS(J)
END LOOP J
Block 4.4

IF OPTSPCOR=0,2 AND OPTVDCOR=0,1,2 THEN

LOOP J=1, NSEGM
CORLVS(J), CORLD(J)
END LOOP J
Block 4.5

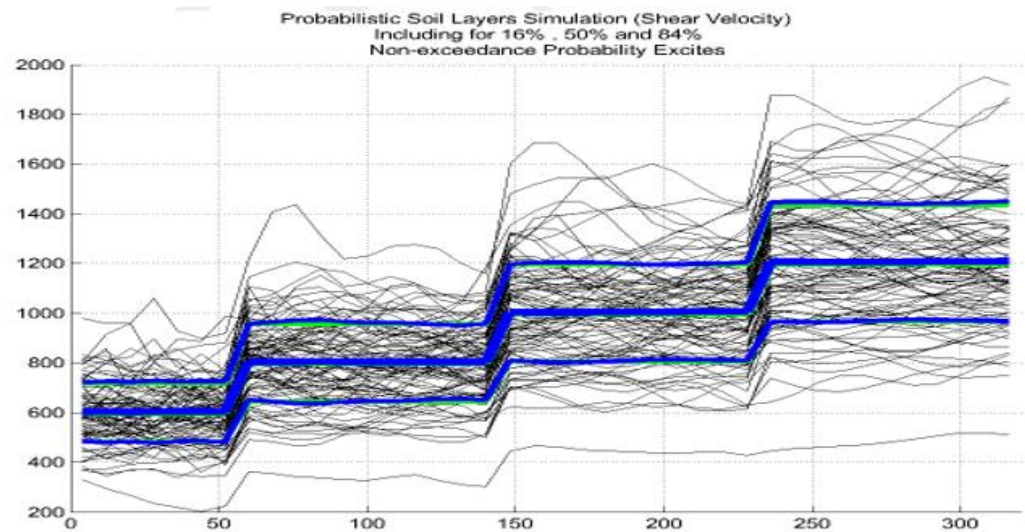
IF OPTVDCOR =0 THEN
CORVSD
Block 5

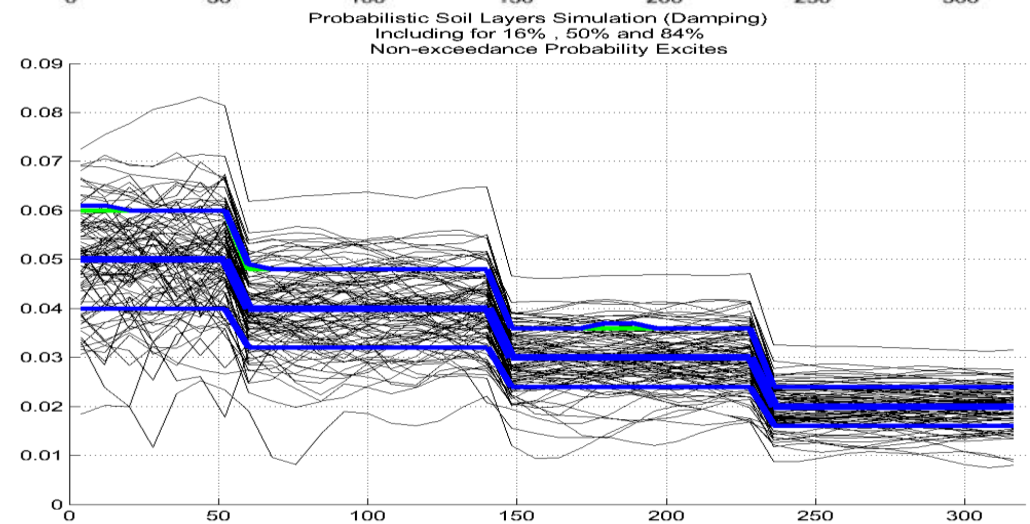
IF OPTPROFIL = 1 THEN
LOOP J=1, NSEGM
COVMEANVS(J), CORLLWVS(J), COVMEAND(J), CORLLWD(J)
END LOOP J
Block 6

Figure 5.3 GSITE.IN File Input Data Description

Example 9: Soil Site – Model 2 with 4 Segments, Vs and D Profiles with Constant Correlation Length, Lognormal Distributions, Inverse Variation Statistical Dependence for Vs and D

0
100 1 1 0 1
BASESITE.SIT
GSITEXXX.SIT
4 1
7 0.06 18542 0.06 32135
11 0.06 73322 0.06 52345
11 0.06 45621 0.06 67211
11 0.06 21854 0.06 14345
10. 10.0
20. 20.0
30. 30.0
40. 40.0
0.19 400.0 0.19 400.0
0.19 500.0 0.19 500.0
0.19 600.0 0.19 600.0
0.19 700.0 0.19 700.0





EXAMPLE 9: SOIL SITE – MODEL 2 WITH 4 SEGMENTS, VS AND D PROFILES WITH CONSTANT CORRELATION LENGTH, LOGNORMAL DISTRIBUTIONS, INVERSE VARIATION STATISTICAL DEPENDENCE FOR VS AND D

NSIMUL, OPTPDF, OPTVDCOR, OPTSPCOR, OPTPROFIL
FBASEL
FGSITE
NSEGM, OPTHS

1 1 0 1

Block 1

IF OPTHS=0 AND OPTVDCOR=0,1,2 THEN
COVHSVS, COVHSD

Block 2.1

IF OPTHS=0 AND OPTVDCOR=3,4 THEN
COVHSVS

Block 2.2

IF OPTVDCOR=3 THEN

LOOP J=1,NSEGM
NLAYSEG(J), COVVS(J),INSEEDVS(J)
NDATAFCT(J),INSEEDFCT(J)
LOOP I=1, NDATAFCT(J)
VSDAT(J,I),DDAT(J,I),VSNOISE(J,I)
END LOOP I
END LOOP J

Block 3.1

IF OPTVDCOR=4 THEN

LOOP J=1,NSEGM
NLAYSEG(J), COVVS(J), INSEEDVS(J)
RSMEANVS(J), RSCOVVS(J)
RSMEAND((J), RSCOVD(J)
END LOOP J

Block 3.2

IF OPTVDCOR=0,1,2 THEN

LOOP J=1,NSEGM
NLAYSEG(J), COVVS(J),INSEEDVS(J) ,
COVD(J), INSEEDD(J)
END LOOP J

Block 3.3

IF OPTSPCOR=1 AND OPTVDCOR=0,1,2 THEN

LOOP J=1, NTLAYER
CORLVS(J), CORLD(J)
END LOOP J

Block 4.1

IF OPTSPCOR=1 AND OPTVDCOR=3,4 THEN

LOOP J=1, NTLAYER
CORLVS(J)
END LOOP J

Block 4.2

IF OPTSPCOR=3 THEN

CORMAT *(CORRLELATION MATRIX FILE)*
- IF OPTVDCOR=0,1,2: THEN
INPUT CORRELATION MATRICES FOR VS AND DAMPING FOR ALL LAYERS
- IF OPTVDCOR=3,4: THEN
INPUT CORRELATION MATRIX FOR VS

Block 4.3

IF OPTSPCOR=0,2 AND OPTVDCOR=3,4 THEN

LOOP J=1, NSEGM
CORLVS(J)
END LOOP J

Block 4.4

IF OPTSPCOR=0,2 AND OPTVDCOR=0,1,2 THEN

LOOP J=1, NSEGM
CORLVS(J), CORLD(J)
END LOOP J

Block 4.5

IF OPTVDCOR =0 THEN
CORVSD

Block 5

IF OPTPROFIL = 1 THEN
LOOP J=1, NSEGM
COVMEANVS(J), CORLLWVS(J), COVMEAND(J), CORLLWD(J)
END LOOP J

Block 6

Figure 5.3 GSITE.IN File Input Data Description

EXAMPLE 9: SOIL SITE – MODEL 2 WITH 4 SEGMENTS, VS AND D PROFILES WITH CONSTANT CORRELATION LENGTH, LOGNORMAL DISTRIBUTIONS, INVERSE VARIATION STATISTICAL DEPENDENCE FOR VS AND D

```
0
100 1 1  0  1
BASESITE.SIT
GSITEXXX.SIT
4  1
7  0.06 18542 0.06  32135
11 0.06 73322 0.06  52345
11 0.06 45621 0.06  67211
11 0.06 21854 0.06  14345
10. 10.0
20. 20.0
30. 30.0
40. 40.0
0.19 400.0  0.19  400.0
0.19 500.0  0.19  500.0
0.19 600.0  0.19  600.0
0.19 700.0  0.19  700.0
```

Input BlockNumber	Input File Line Number Inside Each Block	Variable Name (Input file in free format)	Definition of Input Variables
BLOCK A			
	1	NOPTMETH	Option for selecting methods = 0 for Models 1 or 2 simulation = 1 for Model 3 simulation
BLOCK B.1:	**BLOCK 1 -- BLOCK 6**		
BLOCK 1			
1	1	NSIMUL	Number of simulated seismic input files
1	1	OPTPDF	Option for probability distribution for Vs and D = 0 for Normal distribution = 1 for Lognormal distribution
1	1	OPTVDCOR	Statistical dependence between soil layer Vs and D = 0 using a linear correlation coefficient = 1 assuming inverse variation based an equal number of standard variations from mean value = 2 assuming statistical independence = 3 using given response function Vs=f(D) provided by the user = 4 using inverse probability variation based on simulation of a statistical response function Vs=f(D), obtained for rank correlation is -1.0.

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Example 9: Soil Site – Model 2 with 4 Segments, Vs and D Profiles with Constant Correlation Length, Lognormal Distributions, Inverse Variation Statistical Dependence for Vs and D

```
0
100 1 1  0  1
BASESITE.SIT
GSITEXXX.SIT
4  1
7  0.06 18542 0.06  32135
11 0.06 73322 0.06  52345
11 0.06 45621 0.06  67211
11 0.06 21854 0.06  14345
10. 10.0
20. 20.0
30. 30.0
40. 40.0
0.19 400.0  0.19  400.0
0.19 500.0  0.19  500.0
0.19 600.0  0.19  600.0
0.19 700.0  0.19  700.0
```

1	1	OPTSPCOR	Spatial correlation structure with depth for Vs and D = 0 for constant correlation length with depth (scalar) = 1 for variable correlation length with depth (vector) = 2 for infinite correlation length (perfect correlation with depth) = 3 for using the spatial correlation matrix (matrix)
1	1	OPTPROFIL	Soil profile random field models for Vs and D = 0 Model 1, using a 1D random field = 1 Model 2, using a superposition of two random fields; a long-wavelength and a short-wavelength variation
1	2	FBASEL	Filename for the mean soil profile (ex. BASELINE.SIT)
1	3	FGSITE	Filenames of the simulated SITE inputs (ex. GSITExxx.sit)
1	4	NSEGM	Number of the soil profile segments
1	4	OPTHS	Option for the half-space layer random samples
			= 0 independent from soil above = 1 full correlated with the soil layer above
BLOCK 2	Only for OPTHS=0		
2.1, 2.2	1	COVHSVS	Coefficient of variation for bedrock Vs
2.1	1	COVHSD	Coefficient of variation for bedrock D

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EXAMPLE 9: SOIL SITE – MODEL 2 WITH 4 SEGMENTS, VS AND D PROFILES WITH CONSTANT CORRELATION LENGTH, LOGNORMAL DISTRIBUTIONS, INVERSE VARIATION STATISTICAL DEPENDENCE FOR VS AND D

```
0
100 1 1  0  1
BASESITE.SIT
GSITEXXX.SIT
4  1
7  0.06 18542 0.06  32135
11 0.06 73322 0.06  52345
11 0.06 45621 0.06  67211
11 0.06 21854 0.06  14345
10. 10.0
20. 20.0
30. 30.0
40. 40.0
0.19 400.0  0.19  400.0
0.19 500.0  0.19  500.0
0.19 600.0  0.19  600.0
0.19 700.0  0.19  700.0
```

BLOCK 3	Start Loop J=1,NSEGM		Loop over the number of soil layer segments
3.1, 3.2, 3.3	1 Inside J Loop	NLAYSEG(J)	Number of layers in the segment (J)
3.1, 3.2, 3.3	1 Inside J Loop	COVVS(J)	Coefficient of variation of Vs(J)
3.1, 3.2, 3.3	1 Inside J Loop	INSEEDVS(J)	Initial SEED for Vs(J)
3.3	1 Inside J Loop	COVD(J)	Coefficient of variation of D(J)
3.3	1 Inside J Loop	INSEEDD(J)	Initial SEED for D(J)
3.1	2 Inside J Loop	NDATAFCT(J)	Number of response function data
3.1	2 Inside J Loop	ISEEDFCT(J)	Initial seed for response function noise
3.2	2 Inside J Loop	RSMEANVS(J)	Mean Vs for simulation (to compute Vs=f(D) response function based on assuming a rank correlation = -1)
3.2	2 Inside J Loop	RSCOVD(J)	Coefficient of variation of Vs for simulation (to compute Vs=f(D) function based on assuming a rank correlation = -1)
3.1	Start Loop I=1,NDATAFCT(J)		Loop over Vs=f(D)+noise response surface data
3.1	3 Inside J Loop/1 Inside I Loop	VSDAT(J,I)	Response function Vs data points
3.1	3 Inside J Loop/1 Inside I Loop	DDAT(J,I)	Response function D data points
3.1	3 Inside J Loop/1 Inside I Loop	VSNOISE(J,I)	Response function noise standard deviation
3.1	End Loop I=1,NDATAFCT(J)		
3.2	3 Inside J Loop	RSMEAND(J)	Mean D for simulation (to compute response function based on assuming a rank correlation = -1)
3.2	3 Inside J Loop	RSCOVD(J)	Coefficient of variation of D for simulation (to compute response function based on assuming a rank correlation = -1)
	End Loop J=1,NSEGM		

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Example 9: Soil Site – Model 2 with 4 Segments, Vs and D Profiles with Constant Correlation Length, Lognormal Distributions, Inverse Variation Statistical Dependence for Vs and D

```
0
100 1 1  0  1
BASESITE.SIT
GSITEXXX.SIT
4  1
7  0.06 18542 0.06  32135
11 0.06 73322 0.06  52345
11 0.06 45621 0.06  67211
11 0.06 21854 0.06  14345
10. 10.0
20. 20.0
30. 30.0
40. 40.0
0.19 400.0  0.19  400.0
0.19 500.0  0.19  500.0
0.19 600.0  0.19  600.0
0.19 700.0  0.19  700.0
```

BLOCK 4			
4.1, 4.2	Start Loop J=1,NTLAYER		Loop over the number of soil layers
4.1,4.2	1 Inside J Loop	CORLVS(J)	Correlation length of Vs(J)
4.1	1 Inside J Loop	CORLD(J)	Correlation length of D(J)
4.1, 4.2	End Loop J=1,NTLAYER		
4.3	1	CORMAT	Correlation matrix file name
4.4, 4.5	Start Loop J=1,NSEGM		
4.4,4.5	1 Inside Loop J	CORLVS(J)	Correlation length of Vs(J)
4.5	1 Inside Loop J	CORLD(J)	Correlation length of Damping D(J)
4.4,4.5	End of Loop J=1,NSEGM		
BLOCK 5			
5	1	CORVSD	Correlation coefficient between Vs and D profiles
BLOCK 6			

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ProSITE Input Parameters for Block 2 (M3)

BLOCK B.2			
	1	NSIMUL	Number of simulated seismic input files
	1	MOPTDVS	The option for simulating thickness and vs = 0 only for simulating thickness = 1 simulating both thickness and vs
	1	NLAYTHK	The number of layering to start simulation
	1	XTHKSEED	The initial seed number
	2	FBASEL	Filename for the mean soil profile (ex. BASELINE.SIT)
	3	FGSITE	Filenames for the simulated SITE inputs(ex. GSITExxx.sit)
	4	AX	Coefficient parameter of the fitted model
	4	BX	Initial parameter of the fitted model
	4	CX	Exponent parameter of the fitted model
	4	FMAX	Maximum frequency number
	If MOPTDVS=1		
	5	DELTA	The parameter to change in correlation with depth
	5	P0	Correlation coefficient at surface level
	5	P200	Correlation coefficient at 200m depth level
	5	XCOV	c.o.v. for simulating VS
	5	XVSEED	Initial seed number for simulating VS

Layer thickness variation

Vs values variation

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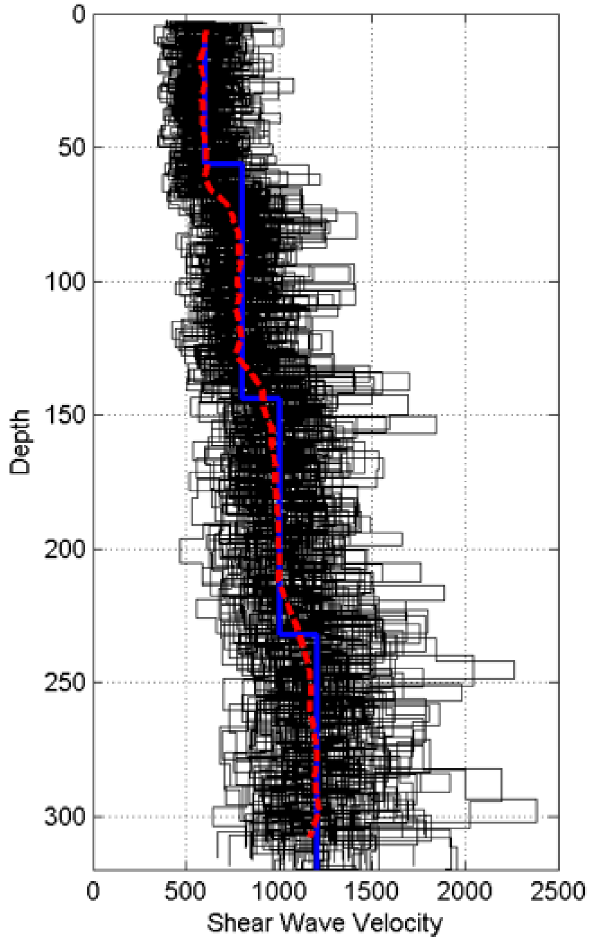
Example 10: Layer Thickness and VS Simulation by using Discrete Process Model

1
100 1 1 34521
BASESITE.SIT
GSITEXXX.SIT
1.98 10.86 -0.89 20
3.9 0.75 0.5 0.2 93152



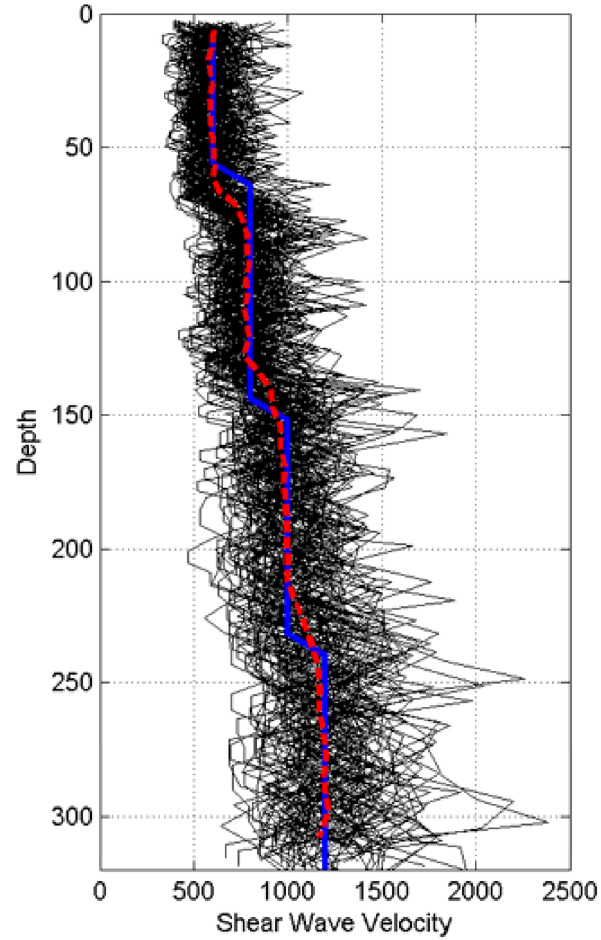


Figure A2.19 Thickness and Vs Mean Curves (red dotted) and Simulated Samples (black); Computed Probability Curves based on Input line (blue line) are plotted

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ProSOIL Simulation of Soil Material Behavior

```
NMAT2CUR, NSEGM, NSIMUL, NDIR, MOPT
FBASEL
FGSOIL
FGSITE
                                        Block 1
```

```
Loop J=1, NTCURVE
      SEEDMAT(J)
END LOOP J
                                        Block 2
```

```
Loop I=1, NTYPE
      NCURV(I), NDATA(I), CORL(I), GCOV(I), DCOV(I)
      Loop J=1, NDATA(I)
            SCALE(I,J))
      END LOOP J
END LOOP I
                                        Block 3
```

```
IF MOPT=1, THEN
      DMAX
ENDIF
                                        Block 4
```

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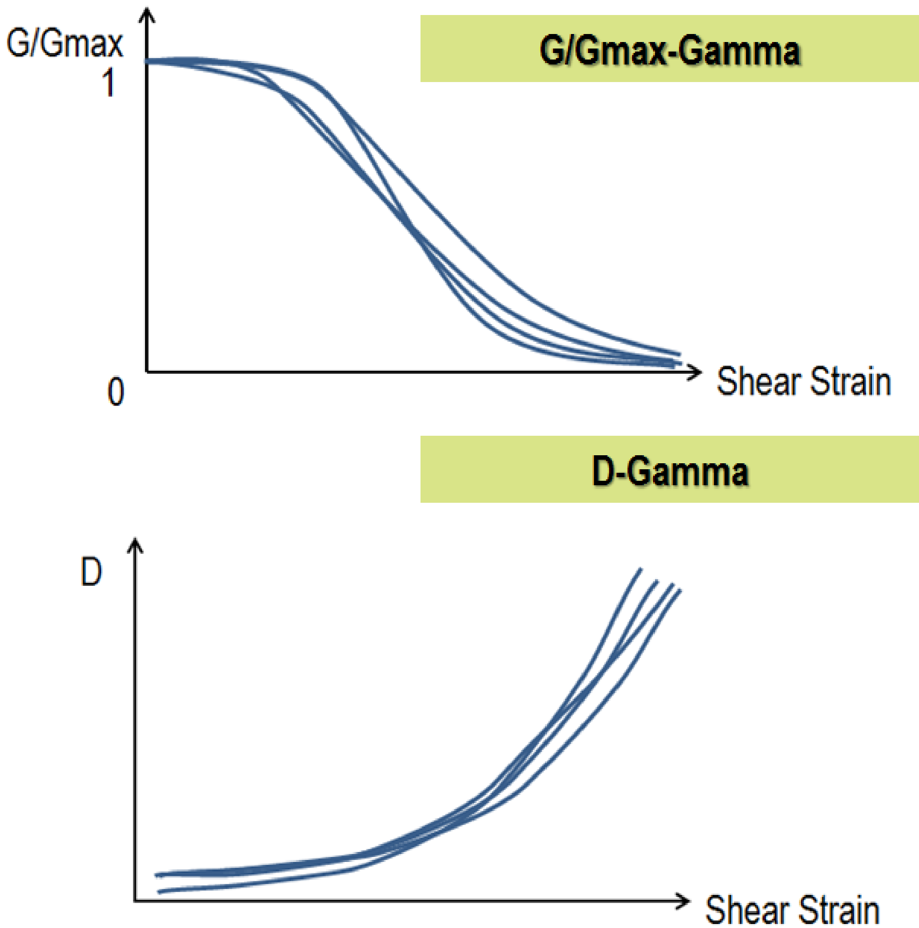
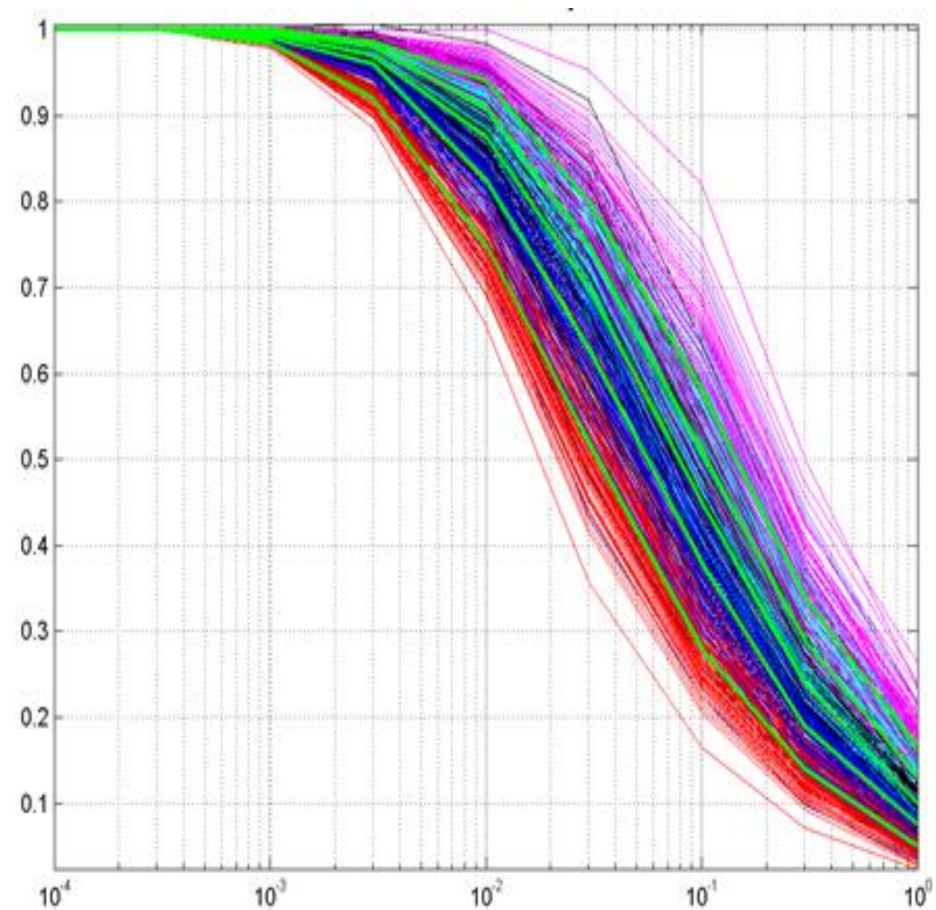
ProSOIL Simulation of Soil Material Behavior





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ProSOIL Input Parameters for Blocks 1 and 2

Input BlockNumber	Input File Line Number Inside Each Block	Variable Name (Input file in free format)	Definition of Input Variables
BLOCK 1			
1	1	NMAT2CUR	Number of soil material curves (this is twice than number of materials)
1	1	NSEGM	Number of the soil profile segments (or number of sets of multiple soil layers above half-space)
1	1	NSIMUL	Number of simulations
1	1	NDIR	Seismic input direction = 0 horizontal (uses Vs) = 1 vertical (uses Vp)
1	1	MOPT	Option to cut-off D-GAMMA curve = 0 No cut-off =1 Cut-off
1	2	FBASEL	Filename for the mean soil profile (ex. BASELINE.SOI)
1	3	FGSOIL	Filenames for the simulated SOIL inputs (ex. GSOILxxx.sit)
1	4	FGSITE	Filenames for the simulated SITE inputs (ex. GSITExxx.sit)
BLOCK 2	Start Loop J=1, NMAT2CUR		
	1 Inside of I Loop	SEEDMAT(J)	Seed number of material curve (J)
	End Loop J=1, NMAT2CUR		

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ProSOIL Input Parameters for Blocks 3 and 4

BLOCK 3	Start Loop I=1, NSEGM		
	1 Inside of I Loop	NCURV(I)	Number of material curves for soil segment (i)
	1 Inside of I Loop	NDATA(I)	Number of data points for material curvesin segment (i)
	1 Inside of I Loop	CORL(I)	Correlation length for segment (i)
	1 Inside of I Loop	GCOV(I)	Coefficient of variation for the low-strain shear modulus for segment (i)
	1 Inside of I Loop	DCOV(I)	Coefficient of variation for the low-strain damping for segment (i)
	Start Loop K=1, NDATA(I)		
	1 Inside of K Loop	SCALE(I,K)	Reduction factor for the coefficients of variations as a function of the soil shear strain
	End Loop K=1, NDATA(I)		
	End Loop I=1, NSEGM		
BLOCK 4	If MOPT = 1		
	DMAX		Max value to cut-off D-Gamma curve

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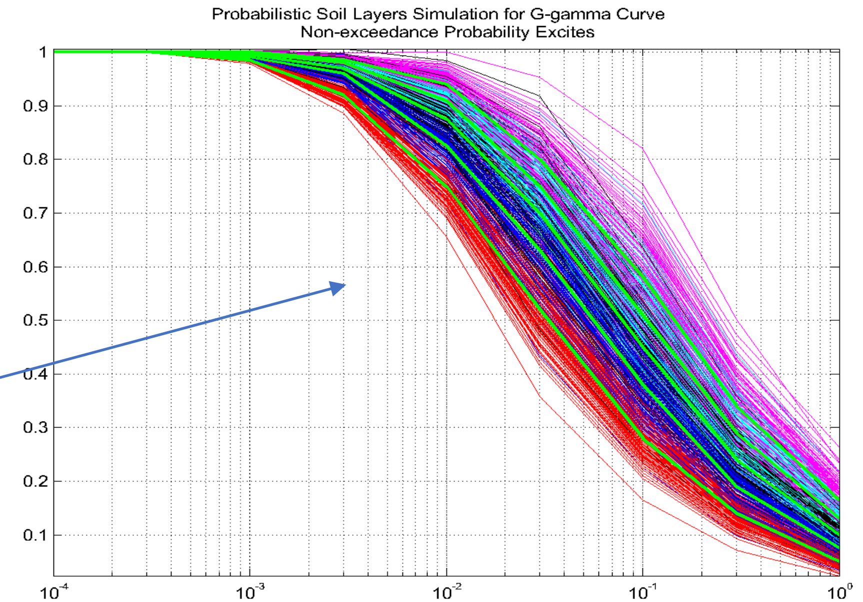
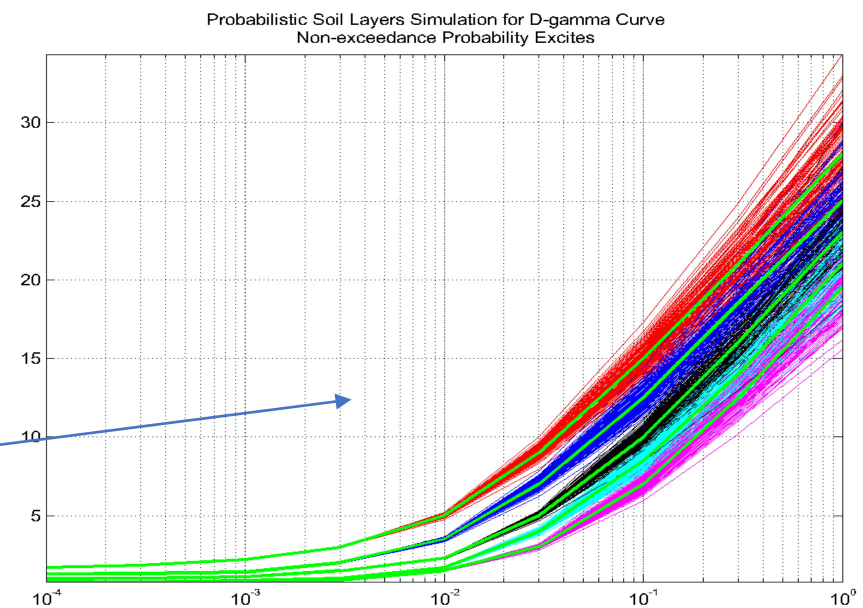
EXAMPLE 1: 3 SOIL LAYERING MATERIAL CURVES

10 3 100 0 0
BASESOIL.soi
GSOILXXX.soi
GSITEXXX.SIT
12345
12313
34212
34345
57322
34556
78434
45667
56734
89832
5 9 4.0 0.40 0.15
0
0
0.005
0.03
0.1
0.25
0.33
0.4
0.5
3 9 4.0 0.40 0.15
0
0
0.0025
0.01
0.05
0.15
0.33
0.4
0.5
2 9 4.0 0.40 0.15
0
0
0.0025
0.01
0.05
0.15
0.33
0.4
0.5





Example 1: 3 Soil Layering Material Curves

10 3 100 0 0
BASESOIL.soi
GSOILXXX.soi
GSITEXXX.SIT
12345
12313
34212
34345
57322
34556
78434
45667
56734
89832
5 9 4.0 0.40 0.15
0
0
0.005
0.03
0.1
0.25
0.33
0.4
0.5
3 9 4.0 0.40 0.15
0
0
0.0025
0.01
0.05
0.15
0.33
0.4
0.5
2 9 4.0 0.40 0.15
0
0
0.0025
0.01
0.05
0.15
0.33
0.4
0.5

1

2

3

BLOCK 3	Start Loop I=1, NSEGM		
	1 Inside of I Loop	NCURV(I)	Number of material curves for soil segment (i)
	1 Inside of I Loop	NDATA(I)	Number of data points for material curvesin segment (i)
	1 Inside of I Loop	CORL(I)	Correlation length for segment (i)
	1 Inside of I Loop	GCOV(I)	Coefficient of variation for the low-strain shear modulus for segment (i)
	1 Inside of I Loop	DCOV(I)	Coefficient of variation for the low-strain damping for segment (i)
	Start Loop K=1, NDATA(I)		
	1 Inside of K Loop	SCALE(I,K)	Reduction factor for the coefficients of variations as a function of the soil shear strain
	End Loop K=1, NDATA(I)		
	End Loop I=1, NSEGM		
BLOCK 4	If MOPT = 1		
	DMAX		Max value to cut-off D-Gamma curve

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ProHOUSE for Structure (or Soil) Properties

This ProHOUSE Module has two optional inputs:

- Option 1: For 2D or 3D structure FE models, input the structure effective stiffness and damping per element group, or
- Option 2: For 2D soil models, input Vs and D soil profiles with random variations in both vertical and horizontal directions.

The first line of the input file ‘GHOU.IN’ lists the option: 0 for 3D simulations and 1 for 2D simulations.

BLOCK A

OPTION INPUTS FOR SIMULATIONS:
OPTION 1: STRUCTURE PROPERTIES OR OPTION 2: 2D SOIL MODELS

BLOCK B.1

OPTION 1: STRUCTURE

BLOCK B.2

OPTION 2: 2D SOIL MODEL

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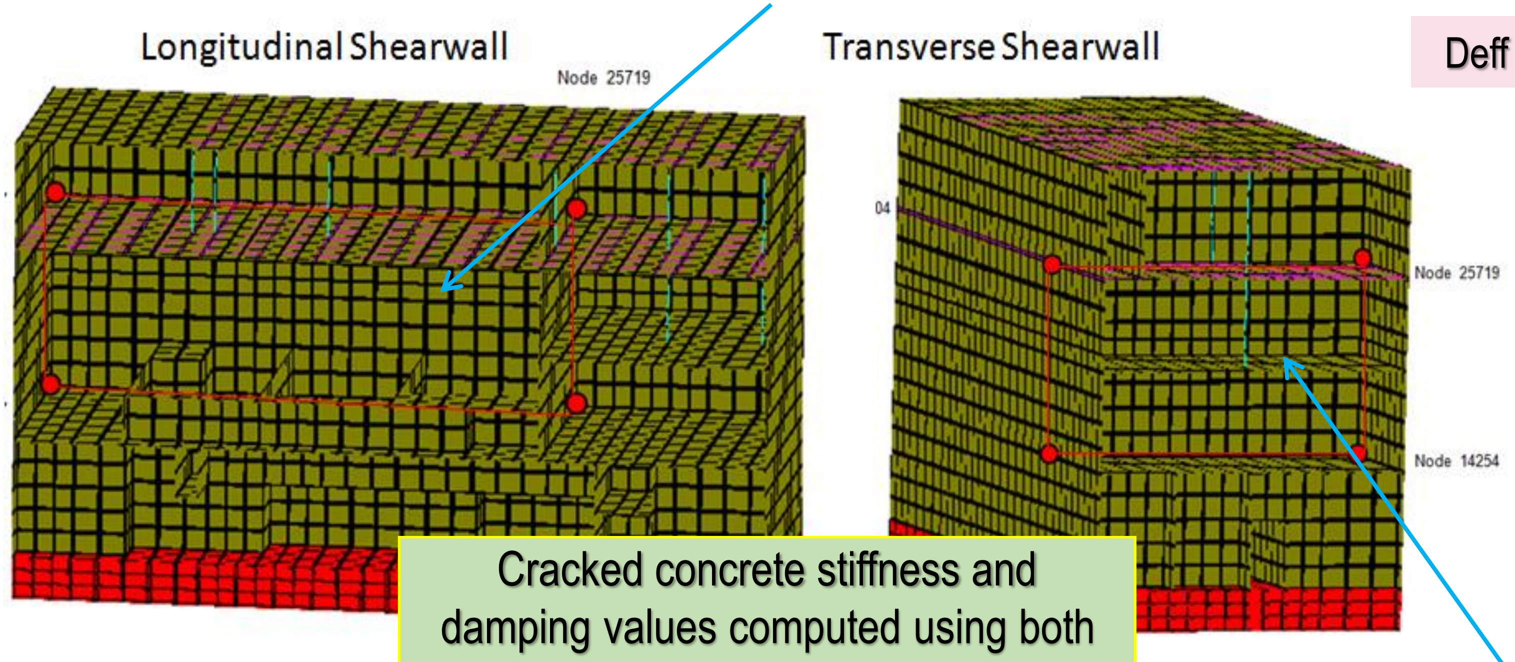
Option 1: Probabilistic Structural Models; Effective Stiffness and Damping *Depend on Wall Strain Levels*

- Keff/Kel and Deff variables should defined by user *for each element group.*
- Effective stiffness ratio Keff/Kelastic and damping ratio, Deff, should be modeled as *statistically dependent* random variables. They can be considered *negatively correlated*, or Deff defined as a *response function* of Keff/Kelastic based on experimental tests.



Cracked concrete stiffness and damping values computed using both Option PRO and NON capabilities.

Deff = f (Keff/Kelastic)

Stiff	Damp
0.01	0.20
0.10	0.17
0.20	0.15
0.30	0.13
0.40	0.11
0.50	0.10
0.60	0.09
0.70	0.08
0.80	0.07
0.90	0.06
1.00	0.05

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Effective Wall Stiffness and Damping Can Be Computed with Option NON as Function of *Shear Strain*

An accurate approach for the low-rise concrete shearwall structures for estimating the effective stiffness and effective damping for each simulation due to the in-plane shear deformation is based on the Option NON that computes automatically these parameters based on the physical behavior of the concrete structure walls.

If Option NON is used, the initial values of the effective stiffness and effective damping for all concrete elements should be based on the uncracked concrete behavior that is 1.00 (uncracked elastic modulus) and 4% damping ratio.

ProNON should be used to simulate probabilistic BBCs for the concrete wall shear deformation.

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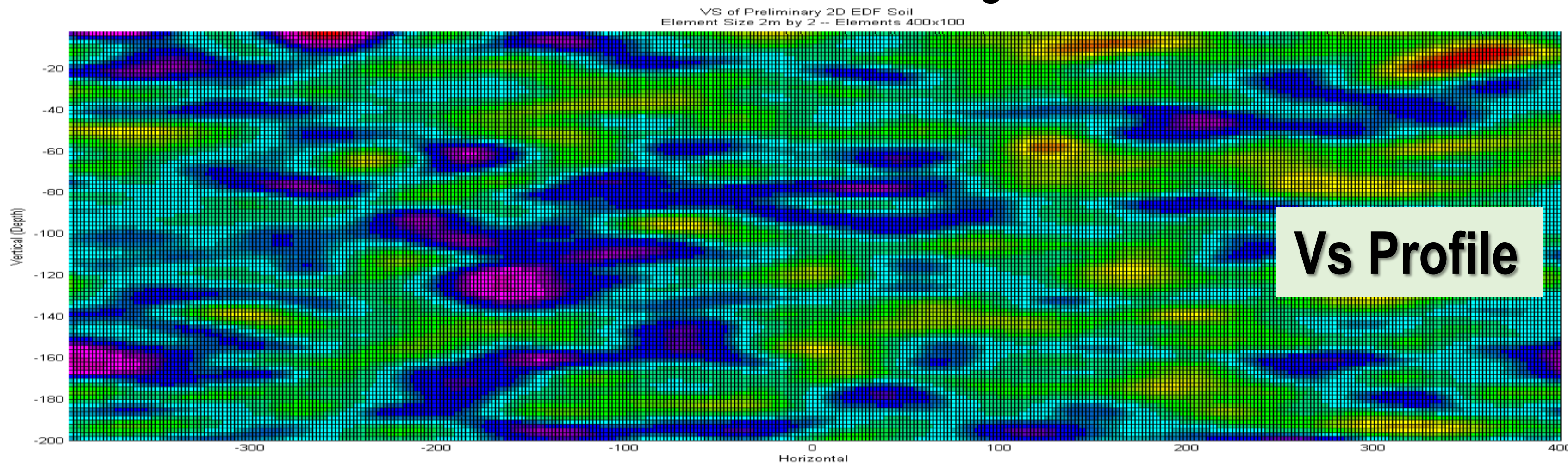
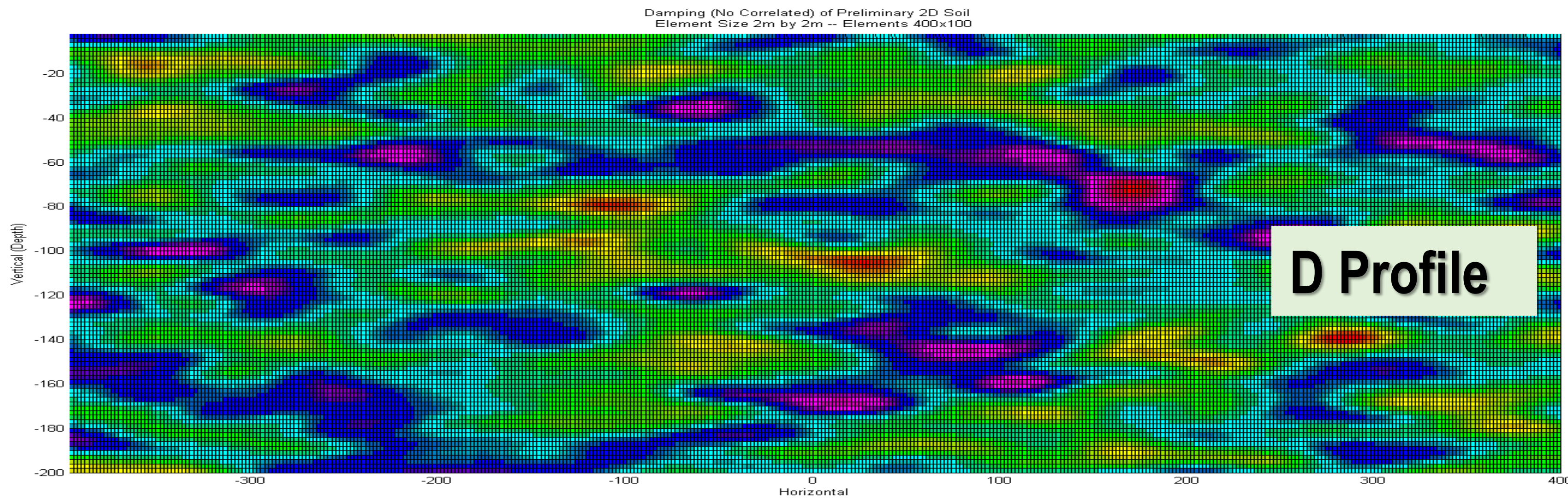
Option 2: Simulated Vs and D Soil Profiles for Uniform Deep Soil Deposit

Vs and D Simulation for Correlation Lengths of 60m x 10m





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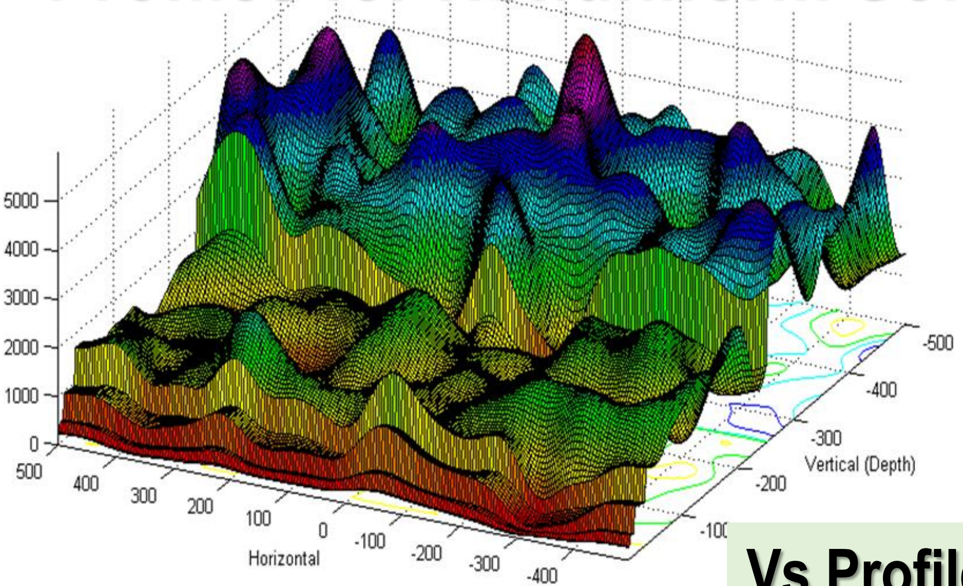
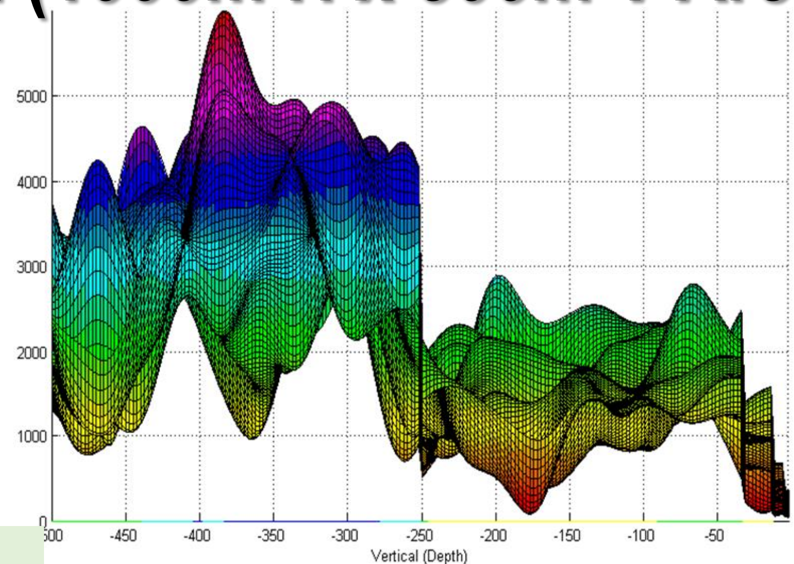
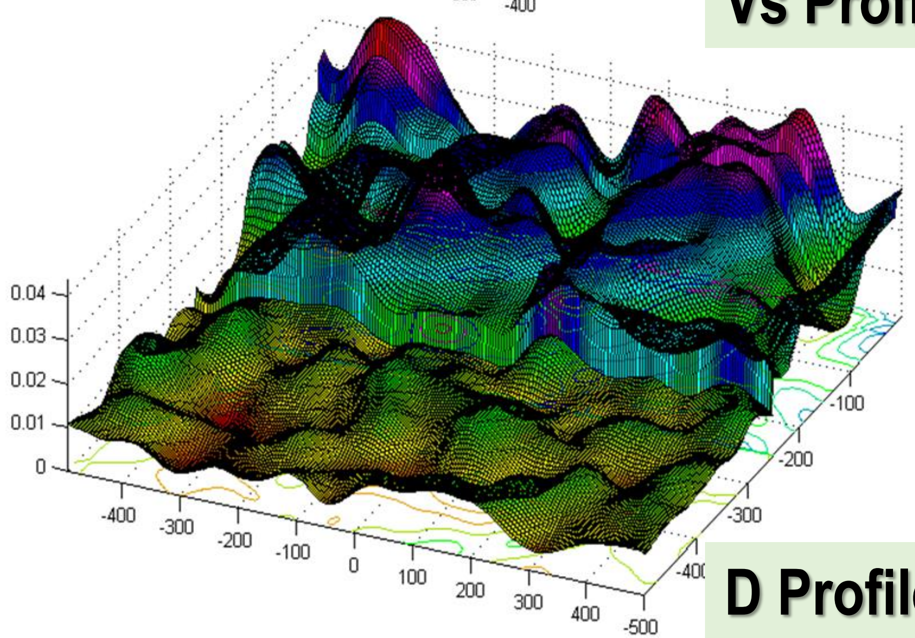
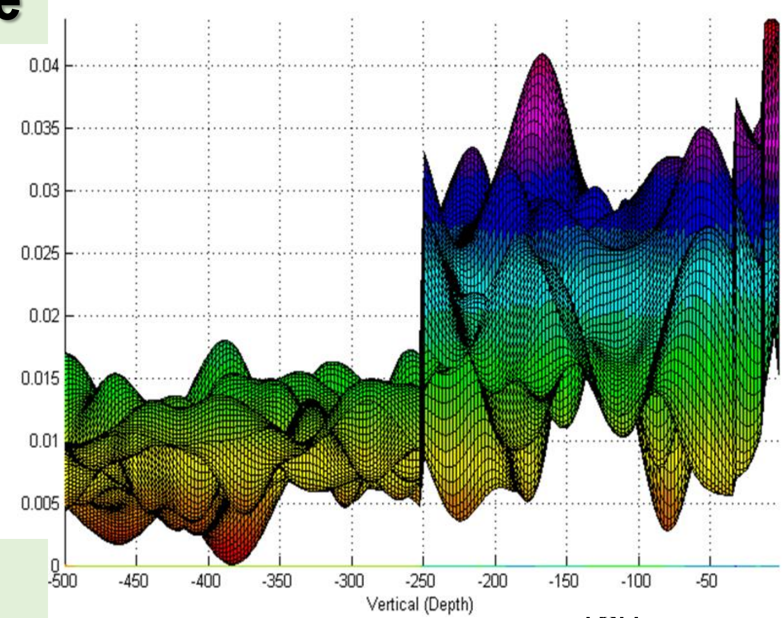
Option 2: Probabilistic Simulations Vs and D Soil Profiles for Nonuniform Soil (1000m H x 500m V Area)





Vs Profile





D Profile

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ProHOUSE Input for Option 1 (Block B.1)

```
NMODGRP, NSIMUL, OPTCOR, IEMB
IF IEMB = 1 THEN   FGSITE
FBASEL
FGHOU
                                        Block 1
```

```
LOOP J=1,NMODGRP
    JGROUP(J), NTYPE(J), NMAT(J), SEEDST(J)
    IF NTYPE(J) =1  THEN
       LOOP N=1, NMAT(J)
           JNVAR(J,N),  STFMEAN(J,N), STFCOV(J,N)
       END LOOP N
    IF NTYPE(J) =2  THEN
       LOOP N=1, NMAT(J)
           JNVAR(J,N),  VPMEAN(J,N), VPCOV(J,N) ),  VSMEAN(J,N), VSCOV(J,N)
       END LOOP N
    IF NTYPE(J) = 3  THEN
       LOOP N=1, NMAT(J)
           JNVAR(J,N),  XMEAN(J,N), XCOV(J,N) ),  YMEAN(J,N), YCOV(J,N) ,
           ZMEAN(J,N), ZCOV(J,N) ),  XXMEAN(J,N), XXCOV(J,N) ),
           YYMEAN(J,N), YYCOV(J,N),  ZZMEAN(J,N), ZZCOV(J,N)
       END LOOP N
                                                            Block 2
```

```
IF OPTCOR ≤ 1  THEN  SEEDD(J)
    LOOP N=1, NMAT(J)
        DGMEAN(J,N),  DCOV(J,N)
    END LOOP  N
 END LOOP J
                              Block 3.1
```

```
IF OPTCOR = 2  THEN  NDATA(J)
    LOOP K=1, NDATA(J)
        SRATIO(J,K),  DRATIO(J,K)
    END LOOP  K
 END LOOP J
                              Block 3.2
```

```
IF OPTCOR = 0
CORRSTD
                              Block 4
```

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NMODGRP Variable for Material Randomization

The NMODGRP variable is the number of material groups used by the analyst to define the statistical dependency status between different materials. It should be noted that different materials in the same or different element groups can be either statistically independent or perfectly correlated. The material groups includes a number of subsets of materials that are statistically independent.

For example, if an element group has five materials which are considered all statistically independent, then, all these five materials belong to the same single material group. If all five materials are considered perfectly correlated, then, each material has to be defined in a separate group with the same SEEDST number. Each material group includes a single material. If the SEEDST number is not the same between different material groups, then, the material groups are statistically independent. Thus, the SEEDST number is used to control the statistical dependency, independent or perfectly correlated, between material groups. It should be noted that the materials should not necessarily belong to the same element group.

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OPTCOR Variable for Statistical Dependence Between Stiffness and Damping Variations

The ProHOUSE module includes three options to handle the dependency between the effective stiffness reduction and the damping increase. These options are controlled by the OPTCOR input variable.

The four dependency options between the stiffness reduction and the damping correspond to:

1) correlated variables (Blocks 3.1 and 4),
2) independent variables (Block 3.1), and
3) damping is a function of stiffness reduction (Block 3.2).

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ProHOUSE Input Parameters for Option 1, Block 1

Input BlockNumber	Input File Line Number Inside Each Block	Variable Name (Input file in free format)	Definition of Input Variables
BLOCK A			
1	1	OPTDIM	Dimension selection: =0 Structure Material Properies =1 2D Soil Model Vs and D Properties
BLOCK B.1:			
BLOCK 1			
1	1	NMODGRP	Number of element groups that are modified (groups can be repeated for different independent materials)
1	1	NSIMUL	Number of simulations
1	1	OPTCOR	Option for statistical dependency between stiffness reduction and damping = 0 Correlated random variables = 1 Independent random variables = 2 Deterministic functional dependence; damping is a function of stiffness reduction
1	1	IEMB	Model option: 0 = surface model 1 = embedded model
1	2 (for IEMB=1)	FGSITE	SITE simulated files (GSITExxx.sit)
1	2 (for IEMB=0) or 3 (for IEMB=1)	FBASEL	Baseline input file (BASELINE.HOU)
1	3 (for IEMB=0) or 4 (for IEMB=1)	FGHOU	HOUSE simulated files (GHOUxxx.hou)

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ProHOUSE Input Parameters for Option 1, Block 2

BLOCK 2	Start Loop J=1,NMODGRP		
2	1 Inside of J Loop	JGROUP(J)	Number of the element group
2	1 Inside of J Loop	NTYPE(J)	Element property type: 1 = Concrete type property, E materials 2 = Soil type property, Vp and Vs 3 = Spring properties
2	1 Inside of J Loop	NMAT(J)	Number of materials in JGROUP(J) that use the same SEEDST(J); fully correlated
2	1 Inside of J Loop	SEEDST(J)	Seed number for stiffness simulation
2	Start Loop N=1,NMAT(J)		
2	1 Inside of N Loop If NTYPE(J) = 1	JNVAR(J,N)	"E" Material number for JGROUP(J)
2		STFMEAN(J,N)	Stiffness reduction factor mean for JNVAR(J)
2		STFCOV(J,N)	Stiffness reduction factor coefficient of variation for JNVAR(J)
	1 Inside of N Loop If NTYPE(J) = 2	JNVAR(J,N)	"Soil Property" number for JGROUP(J)
		VPMEAN(J,N)	VP reduction factor mean for JNVAR(J)
		VPCOV(J,N)	VP reduction factor coefficient of variation for JNVAR(J)

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ProHOUSE Input Parameters for Option 1, Block 2

		VSMEAN(J,N)	VS reduction factor mean for JNVAR(J)
		VSCOV(J,N)	VS reduction factor coefficient of variation for JNVAR(J)
	1 Inside of N Loop If NTYPE(J) = 3	JNVAR(J,N)	"Spring Property" number for JGROUP(J)
		XMEAN(J,N)	X Stiffness reduction factor mean for JNVAR(J)
		XCOV(J,N)	X Stiffness reduction factor coefficient of variation for JNVAR(J)
		YMEAN(J,N)	Y Stiffness reduction factor mean for JNVAR(J)
		YCOV(J,N)	Y Stiffness reduction factor coefficient of variation for JNVAR(J)
		ZMEAN(J,N)	Z Stiffness reduction factor mean for JNVAR(J)
		ZCOV(J,N)	Z Stiffness reduction factor coefficient of variation for JNVAR(J)
		XXMEAN(J,N)	XX Stiffness reduction factor mean for JNVAR(J)
		XXCOV(J,N)	XX Stiffness reduction factor coefficient of variation for JNVAR(J)
		YYMEAN(J,N)	YY Stiffness reduction factor mean for JNVAR(J)
		YYCOV(J,N)	YY Stiffness reduction factor coefficient of variation for JNVAR(J)
		ZZMEAN(J,N)	ZZ Stiffness reduction factor mean for JNVAR(J)
		ZZCOV(J,N)	ZZ Stiffness reduction factor coefficient of variation for JNVAR(J)
	End Loop N=1,NMAT(J)		

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ProHOUSE Input Parameters for Option 1, Block 3

BLOCK 3			
3.1	1	SEEDD(J)	Seed number for the damping simulation
3.1	Start Loop N=1,NMAT(J)		
3.1	1 Inside N Loop	DMEAN(J,N)	Damping mean for JNVAR(J)
3.1	1 Inside N Loop	DCOV(J,N)	Damping coefficient of variation for JNVAR(J)
3.1	End Loop N=1,NMAT(J)		
3.2	1	NDATA(J)	Number of data points for damping as a function of stiffness reduction factor (<100)
3.2	Start Loop K=1,NDATA(J)		
3.2	1 Inside K Loop	STRESF(J,K)	Stiffness value at data points
3.2	1 Inside K Loop	DRESF(J,K)	Damping value at data points
3.2	End Loop K=1,NDATA(J)		
3.1,.3.2	End Loop J=1, NMODGRP		
BLOCK 4			
	1	CORRSTD	Correlation between stiffness reduction factor and damping

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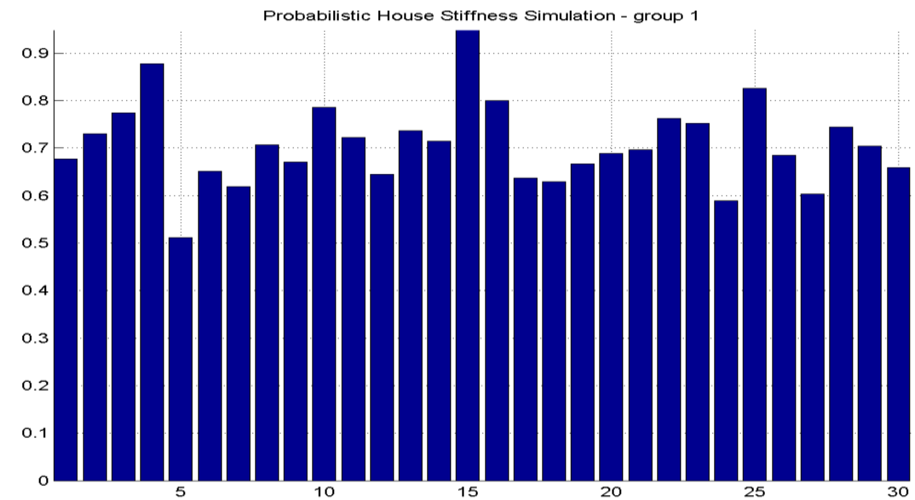
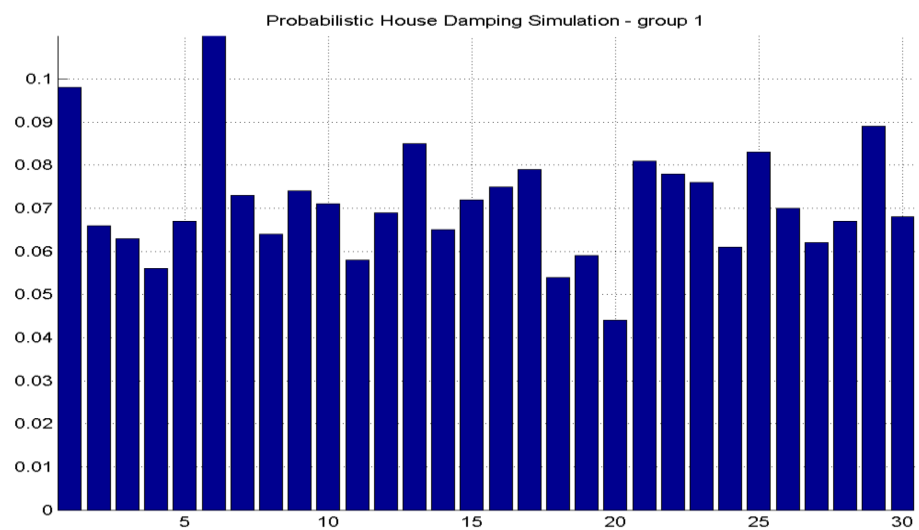
Example 3: Embedded SSI Model with Soil Properties, Single Element Group, Stiffness Reduction Factor (SRF) and Damping D are Statistically Correlated with C.C. = - 0.80

```
0
3 30  0  1
GSITEXXX.SIT
BASELINE.hou
HOUSEXXX.hou
2 1 1 34511
1  0.7  0.1
56789
0.07  0.15
3 1 1 13451
1  0.9  0.1
15289
0.04  0.15
5 1 1 10951
1  0.9  0.1
64578
0.03  0.15
-0.8
```





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EXAMPLE 3: EMBEDDED SSI MODEL WITH SOIL PROPERTIES, SINGLE ELEMENT GROUP, STIFFNESS REDUCTION FACTOR (SRF) AND DAMPING D ARE STATISTICALLY CORRELATED WITH C.C. = - 0.80

```
0
3 30  0  1
GSITEXXX.SIT
BASELINE.hou
HOUSEXXX.hou
2 1 1 34511
1  0.7  0.1
56789
0.07  0.15
3 1 1 13451
1  0.9  0.1
15289
0.04  0.15
5 1 1 10951
1  0.9  0.1
64578
0.03  0.15
-0.8
```

Block 1

```
NMODGRP, NSIMUL, OPTCOR, IEMB
IF IEMB = 1 THEN   FGSITE
FBASEL
FGHOU
```

3 30 0 1

Block 2

```
LOOP J=1,NMODGRP
    JGROUP(J), NTYPE(J), NMAT(J), SEEDST(J)
    IF NTYPE(J) =1  THEN
        LOOP N=1, NMAT(J)
            JNVAR(J,N),  STFMEAN(J,N), STFCOV(J,N)
        END LOOP N
    IF NTYPE(J) =2  THEN
        LOOP N=1, NMAT(J)
            JNVAR(J,N),  VPMEAN(J,N), VPCOV(J,N) ),  VSMEAN(J,N), VSCOV(J,N)
        END LOOP N
    IF NTYPE(J) = 3  THEN
        LOOP N=1, NMAT(J)
            JNVAR(J,N),  XMEAN(J,N), XCOV(J,N) ),  YMEAN(J,N), YCOV(J,N) ,
            ZMEAN(J,N), ZCOV(J,N) ),  XXMEAN(J,N), XXCOV(J,N) ),
            YYMEAN(J,N), YYCOV(J,N),  ZZMEAN(J,N), ZZCOV(J,N)
        END LOOP N
```

Block 3.1

```
IF OPTCOR ≤ 1  THEN   SEEDD(J)
    LOOP N=1, NMAT(J)
        DGMEAN(J,N),  DCOV(J,N)
    END LOOP  N
END LOOP J
```

Block 3.2

```
IF OPTCOR = 2  THEN   NDATA(J)
    LOOP K=1, NDATA(J)
        SRATIO(J,K),  DRATIO(J,K)
    END LOOP  K
END LOOP J
```

Block 4

```
IF OPTCOR = 0
    CORRSTD
```

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Example 3: Embedded SSI Model with Soil Properties, Single Element Group, Stiffness Reduction Factor (SRF) and Damping D are Statistically Correlated with C.C. = - 0.80

0
3 30 0 1
GSITEXXX.SIT
BASELINE.hou
HOUSEXXX.hou

---

2 1 1 34511
1 0.7 0.1
56789
0.07 0.15
3 1 1 13451
1 0.9 0.1
15289
0.04 0.15
5 1 1 10951
1 0.9 0.1
64578
0.03 0.15
-0.8

BLOCK 2	Start Loop J=1,NMODGRP		
2	1 Inside of J Loop	JGROUP(J)	Number of the element group
2	1 Inside of J Loop	NTYPE(J)	Element property type: 1 = Concrete type property, E materials 2 = Soil type property, Vp and Vs 3 = Spring properties
2	1 Inside of J Loop	NMAT(J)	Number of materials in JGROUP(J) that use the same SEEDST(J); fully correlated
2	1 Inside of J Loop	SEEDST(J)	Seed number for stiffness simulation
2	Start Loop N=1,NMAT(J)		
2	1 Inside of N Loop	JNVAR(J,N)	"E" Material number for JGROUP(J)
2	If NTYPE(J) = 1	STFMEAN(J,N)	Stiffness reduction factor mean for JNVAR(J)
2		STFCOV(J,N)	Stiffness reduction factor coefficient of variation for JNVAR(J)
BLOCK 3			
3.1	1	SEEDD(J)	Seed number for the damping simulation
3.1	Start Loop N=1,NMAT(J)		
3.1	1 Inside N Loop	DMEAN(J,N)	Damping mean for JNVAR(J)
3.1	1 Inside N Loop	DCOV(J,N)	Damping coefficient of variation for JNVAR(J)
3.1	End Loop N=1,NMAT(J)		
3.2	1	NDATA(J)	Number of data points for damping as a function of stiffness reduction factor (<100)
3.2	Start Loop K=1,NDATA(J)		
3.2	1 Inside K Loop	STRESF(J,K)	Stiffness value at data points
3.2	1 Inside K Loop	DRESF(J,K)	Damping value at data points
3.2	End Loop K=1,NDATA(J)		
3.1,.3.2	End Loop J=1, NMODGRP		
BLOCK 4			
	1	CORRSTD	Correlation between stiffness reduction factor and damping

ProHOUSE Input for Option 2, Block B.2

NSIMUL, OPTCOR , OPTDIST
FBASEL
FGHOU

Block 1

VSHCOLL, VSVCOLL, VSCOV, VS_SEED
DPHCOLL, DPVCOLL, DPCOV, DP_SEED

Block 2

IF OPTCOR = 1
CORRSTD

Block 3

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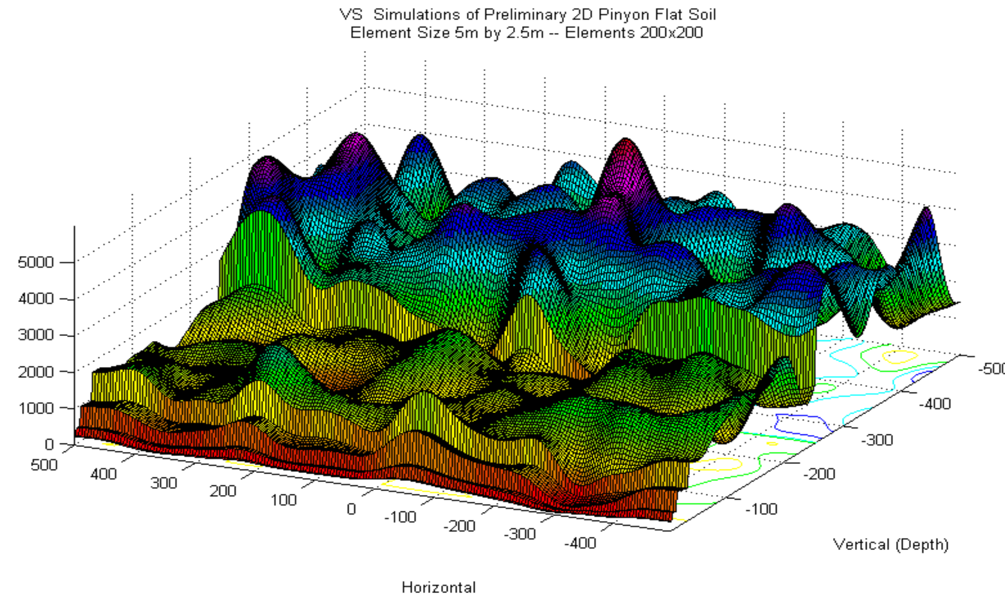
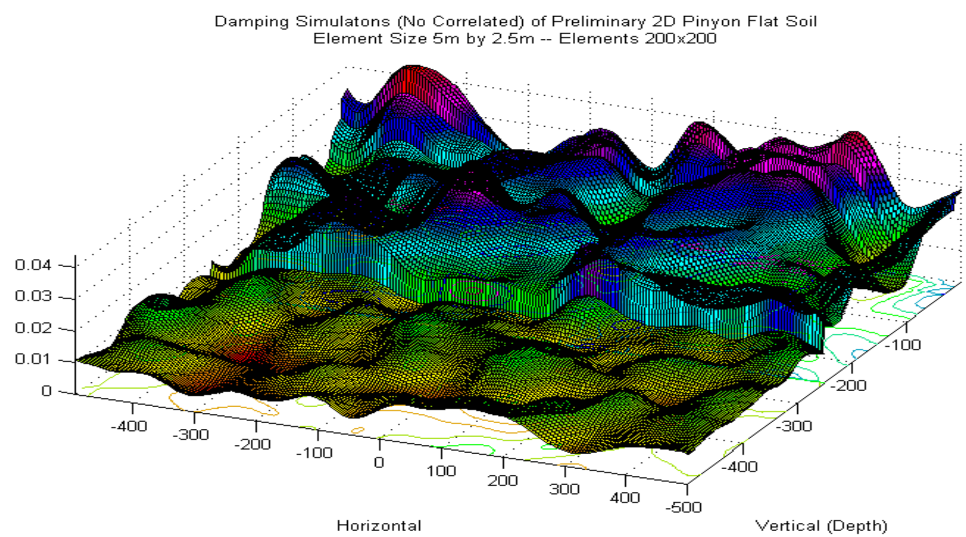
ProHOUSE Input for Option 2, Block B.2

Input Block Number	Input File Line Number Inside Each Block	Variable Name (Input file in free format)	Definition of Input Variables
BLOCK A			
1	1	OPTDIM	Dimension selection: =0 Structure Material Properties =1 2D Soil Model Vs and D Properties
BLOCK B.2			
BLOCK 1			
1	1	NSIMUL	Number of simulations
	1	OPTCOR	Option for correlation between shear velocity and damping = 0 Correlated = 1 No Correlated
1	1	OPTDIST	Option for Distribution which simulated outputs must follow = 0 Normal Distribution = 1Lognormal Distribution
1	2	FBASEL	Baseline input file (BASELINE.HOU)
1	3	FGHOU	HOUSE simulated files (GHOUxxx.hou)
BLOCK 2			
2	1	VSHCOLL	Correlation Length of Horizontal for Vs
2	1	VSVCOLL	Correlation Length of Vertical for Vs
2	1	VSCOV	coefficient of variation for Vs
2	1	VS_SEED	InitialSeed number for Vs simulation
2	2	DPHCOLL	Correlation Length of Horizontal for Damping
2	2	DPVCOLL	Correlation Length of Vertical for Damping
2	2	DPCOV	coefficient of variation for Damping
2	2	DP_SEED	InitialSeed number for Damping simulation
BLOCK 3			
3	1	CORRSTD	Correlation between shear velocity reduction factor and damping

EXAMPLE 4: FOR 2D LAYERED SOIL MODEL: SIMULATED SOIL SHEAR VELOCITY VS AND DAMPING D AS GAUSSIAN STOCHASTIC FIELDS WITH SEPARATED SPATIAL CORRELATION STRUCTURE FOR HORIZONTAL AND VERTICAL DIRECTIONS, AND NEGATIVELY INTER-CORRELATED

1
60 0 0
BASELINE.HOU
Soil2DXXX.HOU
50 25 0.3 18556
50 25 0.3 85256
-0.6





Example 4: For 2D Layered Soil Model: Simulated Soil Shear Velocity Vs and Damping D As Gaussian Stochastic Fields With Separated Spatial Correlation Structure for Horizontal and Vertical Directions, and Negatively Inter-Correlated

```
1
60 0 0
BASELINE.HOU
Soil2DXXX.HOU
50 25 0.3 18556
50 25 0.3 85256
-0.6
```

Input Block Number	Input File Line Number Inside Each Block	Variable Name (Input file in free format)	Definition of Input Variables
BLOCK A			
1	1	OPTDIM	Dimension selection: =0 Structure Material Properties =1 2D Soil Model Vs and D Properties
BLOCK B.2			
BLOCK 1			
1	1	NSIMUL	Number of simulations
	1	OPTCOR	Option for correlation between shear velocity and damping = 0 Correlated = 1 No Correlated
1	1	OPTDIST	Option for Distribution which simulated outputs must follow = 0 Normal Distribution = 1Lognormal Distribution
1	2	FBASEL	Baseline input file (BASELINE.HOU)
1	3	FGHOU	HOUSE simulated files (GHOUxxx.hou)
BLOCK 2			
2	1	VSHCOLL	Correlation Length of Horizontal for Vs
2	1	VSVCOLL	Correlation Length of Vertical for Vs
2	1	VSCOV	coefficient of variation for Vs
2	1	VS_SEED	InitialSeed number for Vs simulation
2	2	DPHCOLL	Correlation Length of Horizontal for Damping
2	2	DPVCOLL	Correlation Length of Vertical for Damping
2	2	DPCOV	coefficient of variation for Damping
2	2	DP_SEED	InitialSeed number for Damping simulation
BLOCK 3			
3	1	CORRSTD	Correlation between shear velocity reduction factor and damping

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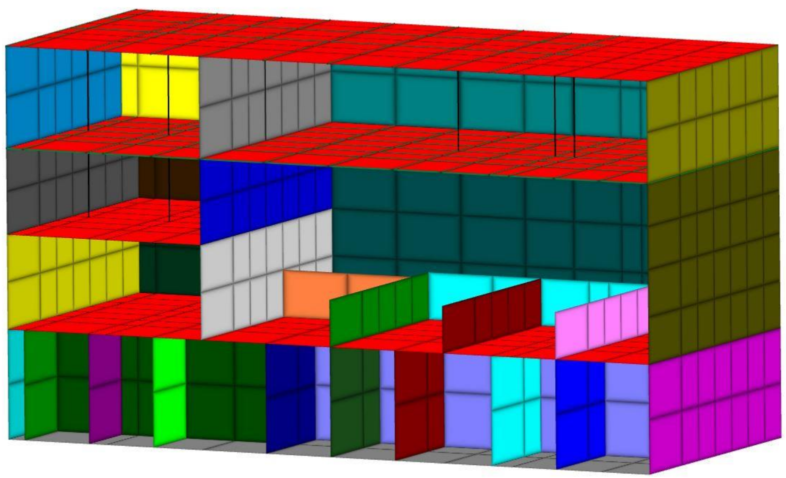
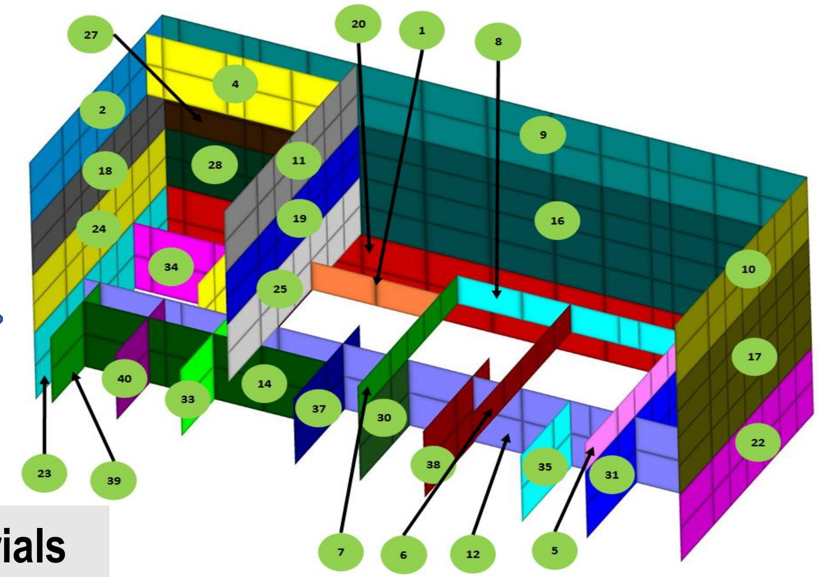
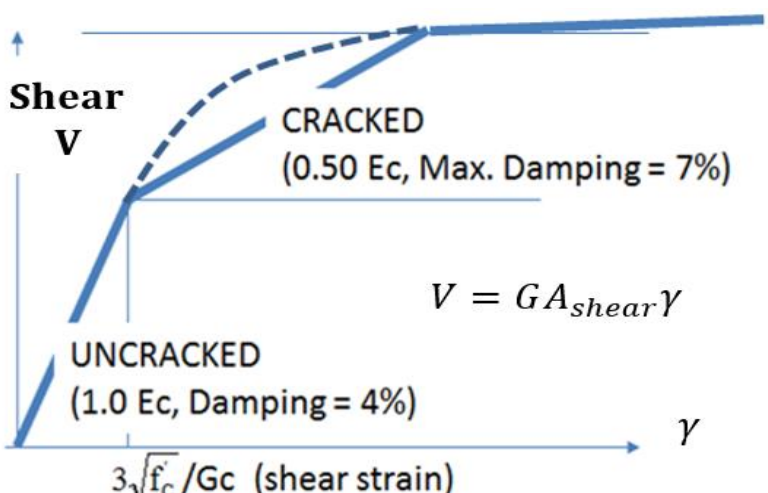
ProNON Simulates Randomized BBCs for Option NON

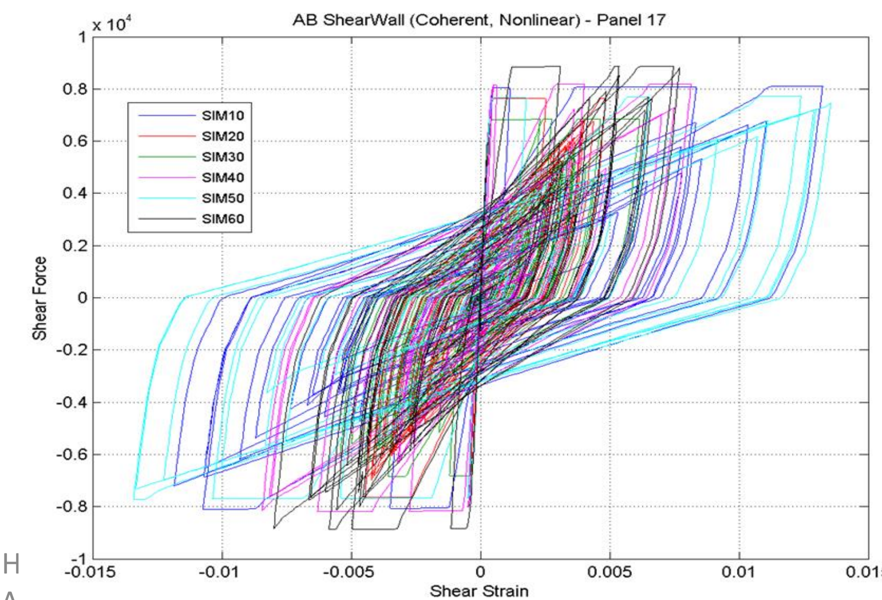




Structure is split in wall panels with different materials

ProNON Automatically Generates BBCs





HT GH
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ProNON for BBC Simulations for Option NON

Input File Line Number	Variable Name (Input in free format)	Definition of Input Variables	Variable Type
1	NSIMUL	Number of simulations	Input
1	XM	Mean of Uncertainty Scale Factor	Input
1	XCOV	C.O.V of Uncertainty Scale Factor (	Input
1	ISEED	Initial Seed Number of Uncertainty Scale Factor	Input
2	FBASEL	Baseline input file (BASELINE.EQL)	Input
3	FGEQL	Simulated input samples for the nonlinear runs (.eql extension)	Output
4	FBASEH	Baseline hou input file (BASELINE.HOU)	Input
5	FGHOU	Simulated input *.HOU files (.hou extension)	Input
6	NOPT	Option to set the maximum of strain (0=use maximum of simulations, 1=users define)	Input
7	XSTRAIN	Maximum of strain (if NOPT = 1)	Input

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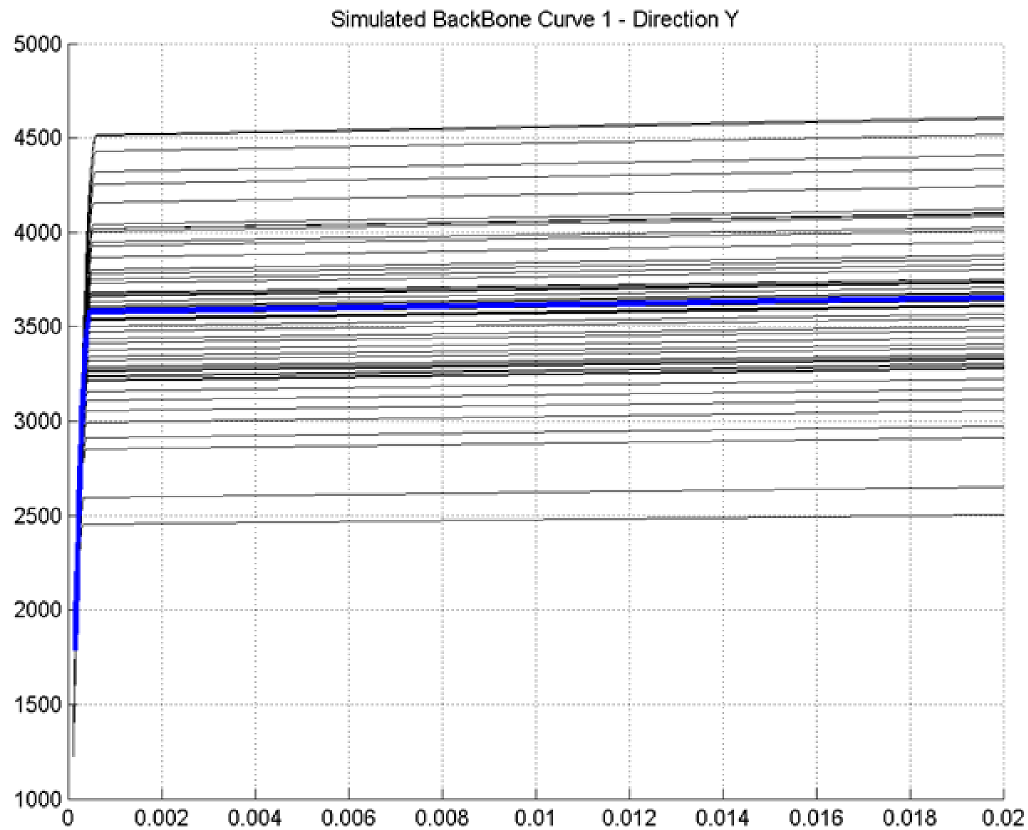
EXAMPLE 1. Simulation of Wall Panel BBCs

60 1 0.15 34522
BASELINE.EQL
GNONXXX.EQL
BASELINE.HOU
HOUSEXXX.HOU
1
0.02



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ProMOTION Input Parameters

Table 5.6ProMOTION Input File (GMOT.IN)

Input File Line Number	Variable Name (Input in free format)	Definition of Input Variables	Variable Type
1	NSIMUL	Number of simulations	Input
1	NOPT	Option to Scale Time History (0=No, 1=Yes)	Input
2	FINACC	Input acceleration file names (.acc extension)	Input
3	FBASEL	Baseline input file (BASELINE.MOT)	Input
4	FGMOT	Simulated input samples for the MOTION runs (.mot extension)	Output
5	XM	Meanof Uncertainty Scale Factor (if NOPT=1)	Input
5	XCOV	C.O.V of Uncertainty Scale Factor (if NOPT=1)	Input
5	ISEED	Initial SeedNumberof Uncertainty Scale Factor (if NOPT=1)	Input

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ProSTRESS Input Parameters

Table 5.7ProSTRESS Input File (GSTR.IN)

Input File Line Number	Variable Name (Input in free format)	Definition of Input Variables	Variable Type
1	NSIMUL	Number of simulations	Input
1	NOPT	Option to Scale Time History (0=No, 1=Yes)	Input
2	FINACC	Input acceleration file names (.acc extension)	Input
3	FBASEL	Baseline input file (BASELINE.STR)	Input
4	FGSTR	Simulated input samples for the STRESS runs (.str extension)	Output
5	XM	Meanof Uncertainty Scale Factor (if NOPT=1)	Input
5	XCOV	C.O.V of Uncertainty Scale Factor (if NOPT=1)	Input
5	ISEED	Initial SeedNumberof Uncertainty Scale Factor (if NOPT=1)	Input

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ProSRSS Input Parameters

```
NSIM, NRESP, OPTOUT
                                   Block 1
```

```
IF OPTOUT = 0 THEN
Loop J=1:NRESP
    FIN(J)
  END LOOP J
                         Block 2.1
```

```
IF OPTOUT = 1, 2 THEN
 FSTR
Loop J=1:NRESP
    FIN(J)
  END LOOP J
                         Block 2.2
```

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Input Block Number	Input File Line Number Inside Each Block	Variable Name (Input file in free format)	Definition of Input Variables
BLOCK 1			
1	1	NSIM	Number of simulations
1	1	NRESP	Number of generic response files
1	1	OPTOUT	Option for response type to be computed = 0 Acceleration response spectra (extension..rxxx) = 1 Stress/forces in structural elements (extension .oxxx)
BLOCK 2			
2.1	Start Loop J=1,NRESP		
2.1	1 Inside Loop J	FIN(J)	Acceleration response spectra
2.1	End Loop J=1,NRESP		
2.2	1	FSTR	Stress input (*.str), RDISP input (*.rdi)
2.2	Start Loop J=1,NRESP		
2.2	1 Inside Loop J	FIN(J)	Stress outputs, relative displacement outputs
2.2	End Loop J=1,NRESP		

Example of ProSRSS Input Parameters

EXAMPLE 1:

The example input files are in the folder called .\Examples\ProSRSS\Ex1. The input filename is SRSS-RS.IN. This case is used to combine nodal SRSS for 3 directories X, Y, Z.

The text content of the GSOIL.IN is

```
30 9 0
00001TR_X01.rXXX
00001TR_Y01.rXXX
00001TR_Z01.rXXX
00151TR_X01.rXXX
00151TR_Y01.rXXX
00151TR_Z01.rXXX
00158TR_X01.rXXX
00158TR_Y01.rXXX
00158TR_Z01.rXXX
```

EXAMPLE 2:

The example input files are in the folder called .\Examples\ProSRSS\Ex2. The input filename is SRSS-STRESS.IN. This case is used to combine stress SRSS for 3 directories X, Y, Z.

The text content of the GSOIL.IN is

```
60 1 1
STRESS.STR
STRESS.OXXX
```

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ProRESPONSE Input Parameter Loops

NOPTINP, NOPTOUT

Block 1

IF NOPTOPT =0 THEN
NSIM, NFINP
LOOP J=1,NFINP
FINP(J)
END LOOP J

Block 2.1

IF NOPT=1 THEN
NSIM, NFINP, IDTYPE, NPROB
LOOP K=1,NPROB
PROBVAL(J)
END OF LOOP K
LOOP J=1,NFINP
FINP(J)
END OF LOOP J

Block 2.2

Figure 5.7 GRESP.IN Data Description

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ProRESPONSE Input Parameters

Table 5.8 ProRESPONSE Input File (GRESP.IN)

Input BlockNum ber	Input File Line Number Inside Each Block	Variable Name (Input file in free format)	Definition of Input Variables
BLOCK 1			
1	1	NOPTINP	Options for inputs: = 0 Acceleration response spectra (extension .rxxx files) = 1 Uninterpolated transfer functions (extension .uxxx files) = 2 Interpolated transfer functions(extension .ixxx files) = 3 Maximum stress output (extension .oxxx files)
1	1	NOPTOUT	Options for outputs: = 0 Mean response will be computed = 1 Probability level response to be computed
BLOCK 2			
2.1, 2.2	1	NSIM	Number of simulations
2.1,2.2	1	NFINP	Number of generic simulated response files to be used as inputs for ProRESPONSE
2.2	1	IDTYPE	Probability distribution type

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ProRESPONSE Input Parameters (Continuation)

			0 = Sample distribution (using sample CDF) 1 = Lognormal distribution 2 = Gumbel distribution
2.2	1	NPROB	Number of probability levels
2.2	Start Loop K=1,NPROB		
2.2	1 Inside Loop K	PROBVAL(J)	Non-exceedance probability (NEP)for computing probabilistic SSI responses (for P1, P2, P3….)
2.2	End Loop K=1,NPROB		
2.1,2.2	Start Loop J=1,NFINP		
2.1,2.2	1 Inside Loop J	FINP(J)	Generic input file name for simulated response files to be used as inputs by ProRESPONSE
2.1,2.2	End of Loop J=1,NFINP		

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Example of ProRESPONSE Input Parameters

The text content of the RS-MEAN.IN is

```
0 0
30 3
00001TR_X01.rXXX
00151TR_X01.rXXX
00158TR_X01.rXXX
```

The text content of the GumbelD.IN is

```
0 1
30 3 2 2
0.8 0.95
00001TR_X01.rXXX
00151TR_X01.rXXX
00158TR_X01.rXXX
```

The text content of the LognormalD.IN is

```
0 1
30 3  1 2
0.8 0.95
00001TR_X01.rXXX
00151TR_X01.rXXX
00158TR_X01.rXXX
```

The text content of the SampleD.IN is

```
0 1
30 3 0 2
0.8 0.95
00001TR_X01.rXXX
00151TR_X01.rXXX
00158TR_X01.rXXX
```

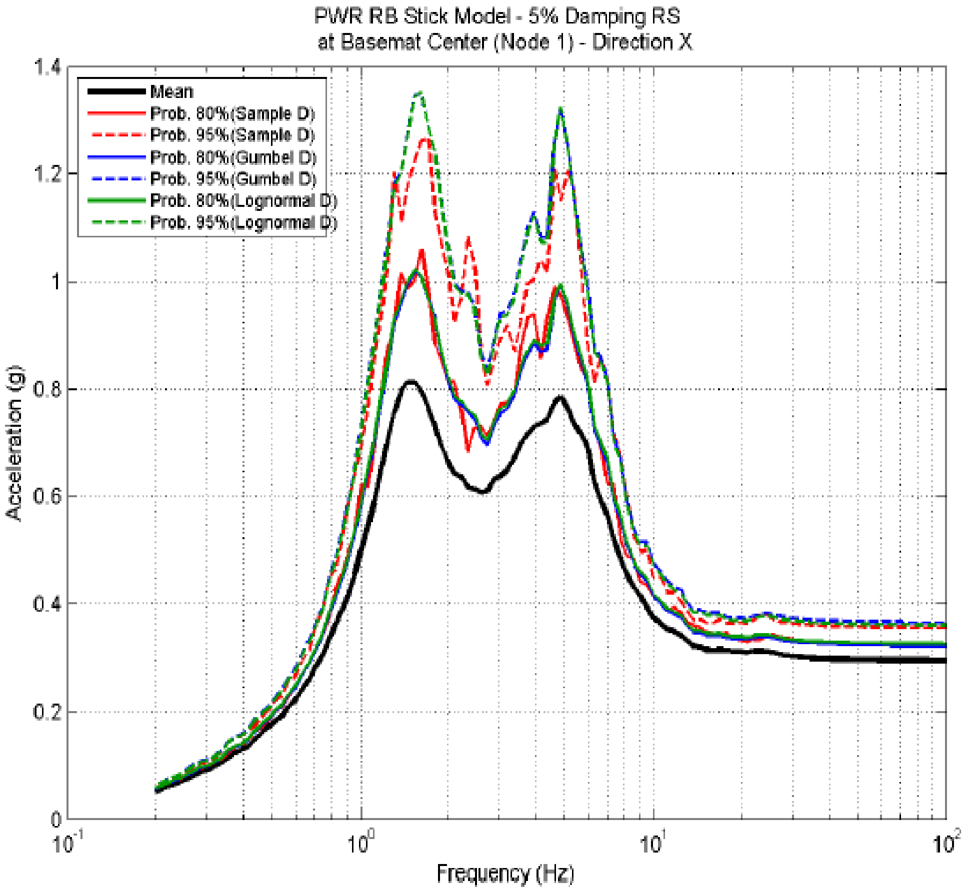

Figure A8.1Node 1 RS Probability Level Curves for Mean, and 80% and 95% NE

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Example of ProRESPONSE Input Parameters

The text content of the RS-MEAN.IN is

3 0
60 1
stress.oXXX

The text content of the GumbelD.IN is

3 1
60 1 2 2
0.8 0.95
stress.oXXX

The text content of the LognormalD.IN is

3 1
60 1 1 2
0.8 0.95
stress.oXXX

The text content of the SampleD.IN is

3 1
60 1 0 2
0.8 0.95
stress.oXXX

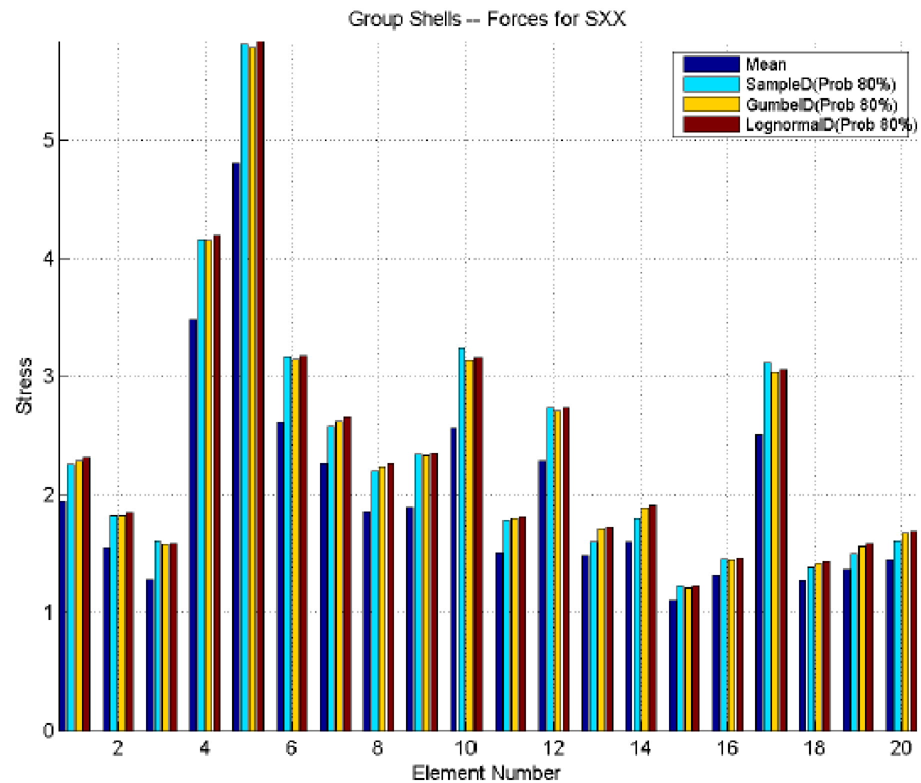

Figure A8.6 Probabilistic Maximum SXX Stress with 80% and 95% NEP

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