ACS SASSI Capabilities and Options Including Demo Sample Problems

Session 3: 1:00pm 3:00pm

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Purpose:

Present a top-level overview of the ACS SASSI software application to the seismic SSI analysis, including simple demonstrative examples.

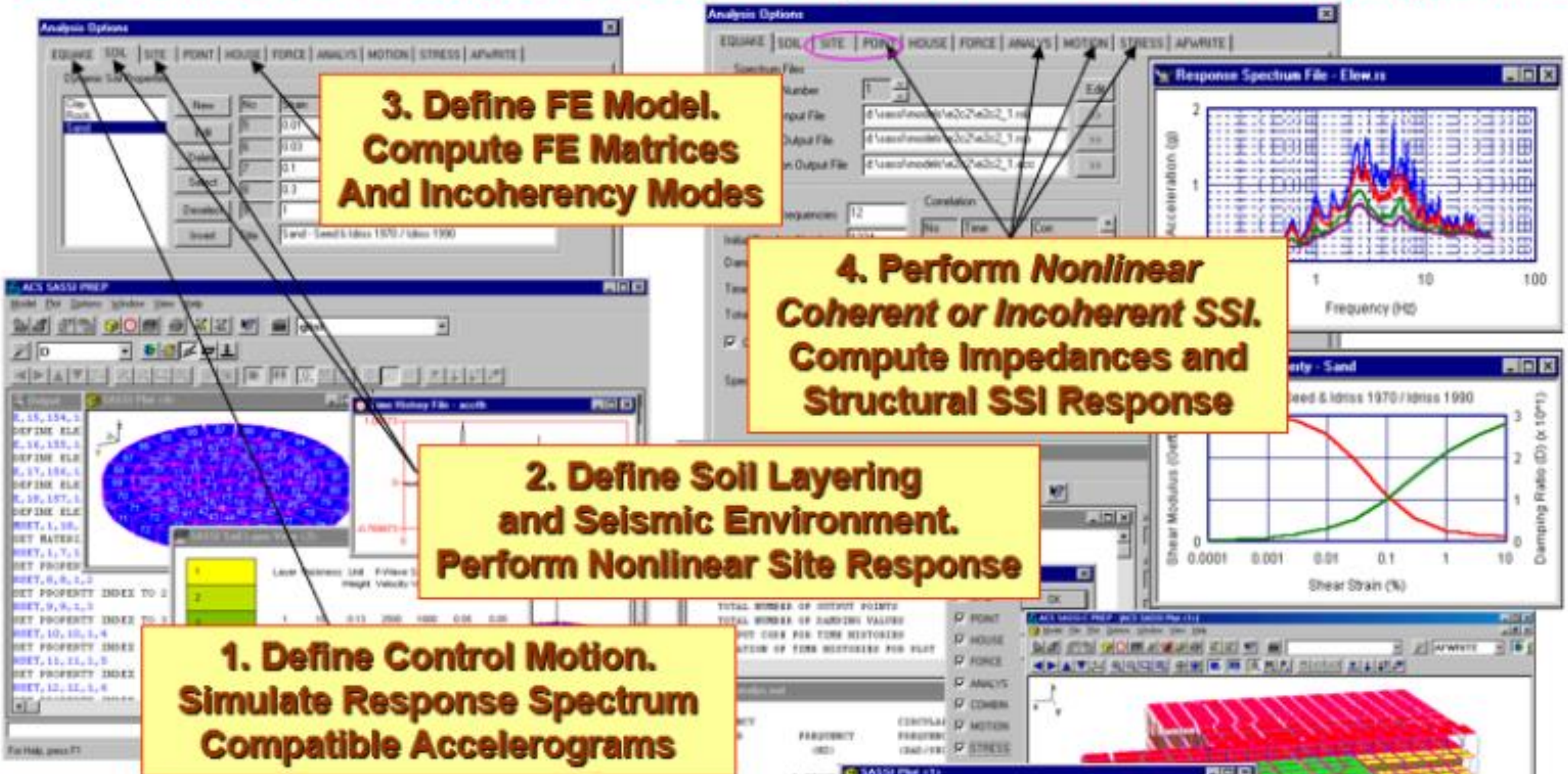
The overview includes brief descriptions of the special SSI modeling capabilities of Options A-AA, NON and PRO implemented in the support of the recent ASCE 4-16 standard recommendations and the most recent USNRC requirements, including SMRs.

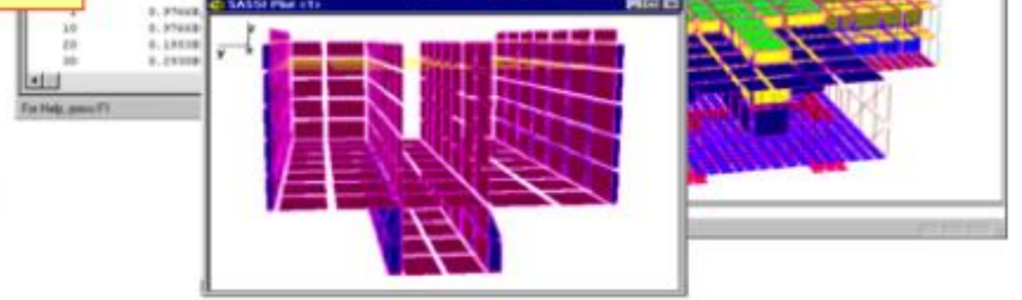
Content:

1. ACS SASSI SSI Analysis Options
2. Modular Configuration and SSI Module Input Descriptions
3. UI Commands and Macros for SSI Model Checking and Result Post-Processing Using Text Files
4. UI Commands for Fast Post-Processing of SSI Response Time Histories Using Full FE Model Binary Database
5. Option A-AA, ACS SASSI-ANSYS Interfacing, applicable to Multistep Nonlinear Analyses
6. Option NON, Nonlinear Structure Behavior for Concrete Structures
7. Option PRO, Probabilistic SRA and SSIA
8. Show Demos 1, 7, 13

1. ACS SASSI SSI Analysis Options

An Advanced Computational Software for Dynamic Soil-Structure Interaction Analysis on Personal Computers





ACS SASSI

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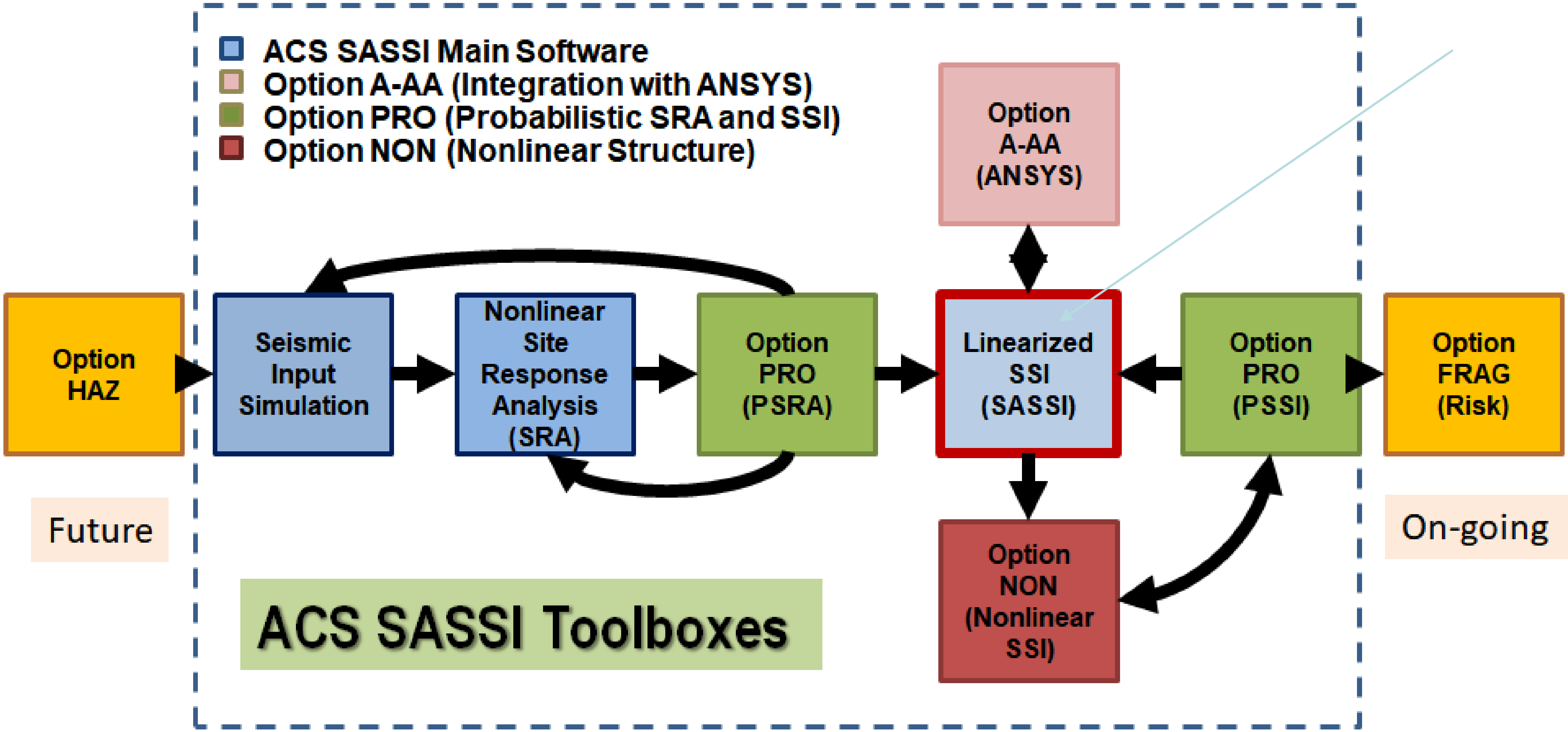
ACS SASSI Framework Development

Present/Options A-AA, NON and PRO, Future/Options HAZ and FRAG

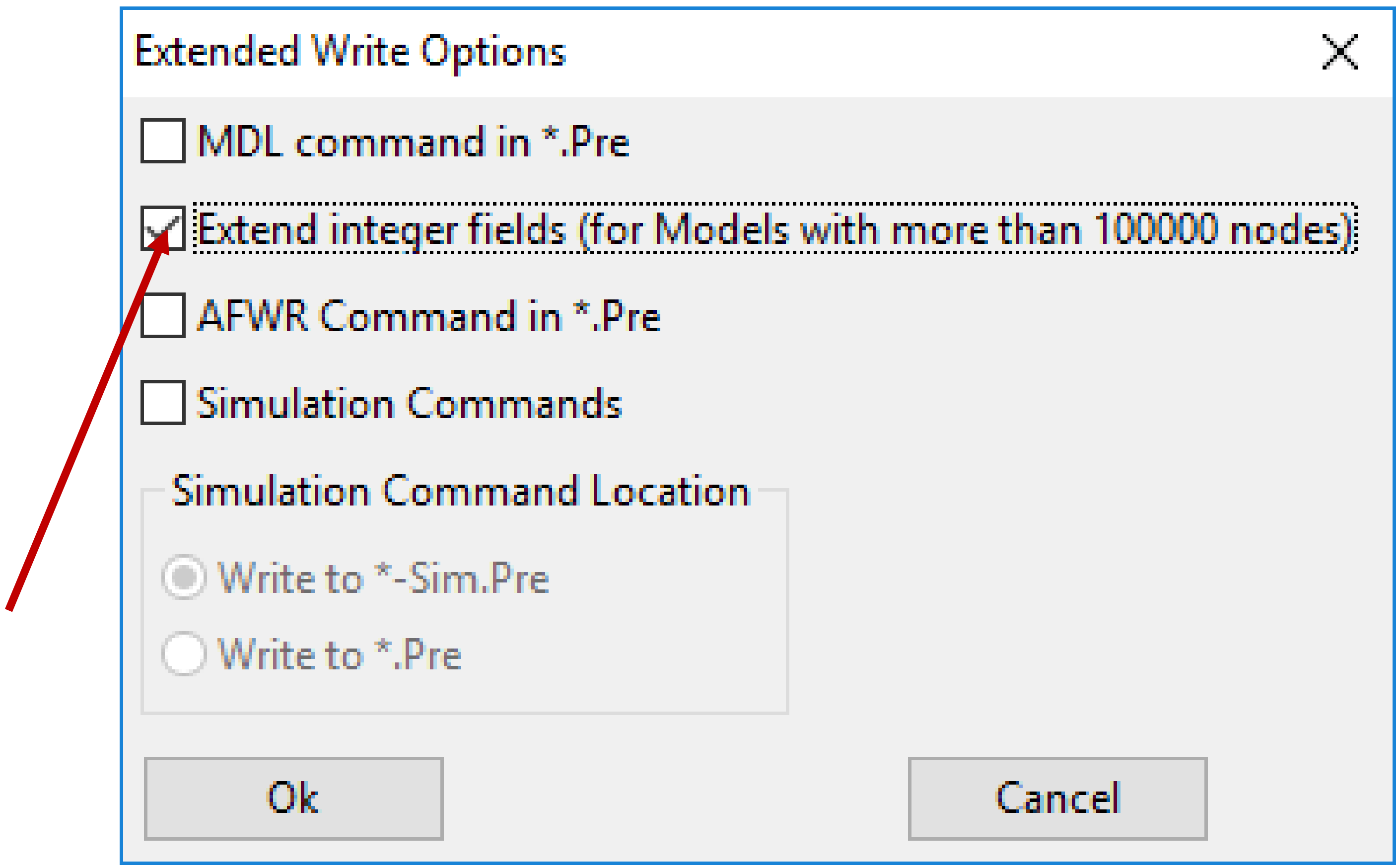


2018 ACS SASSI V3 Software IKTR10_650K

The ACS SASSI Version 3 IKTR10_650k was tested for 3D SSI models with up to 640,000 nodes and 33,500 interaction nodes on typical 512 GB RAM workstations running under MS Windows 10.

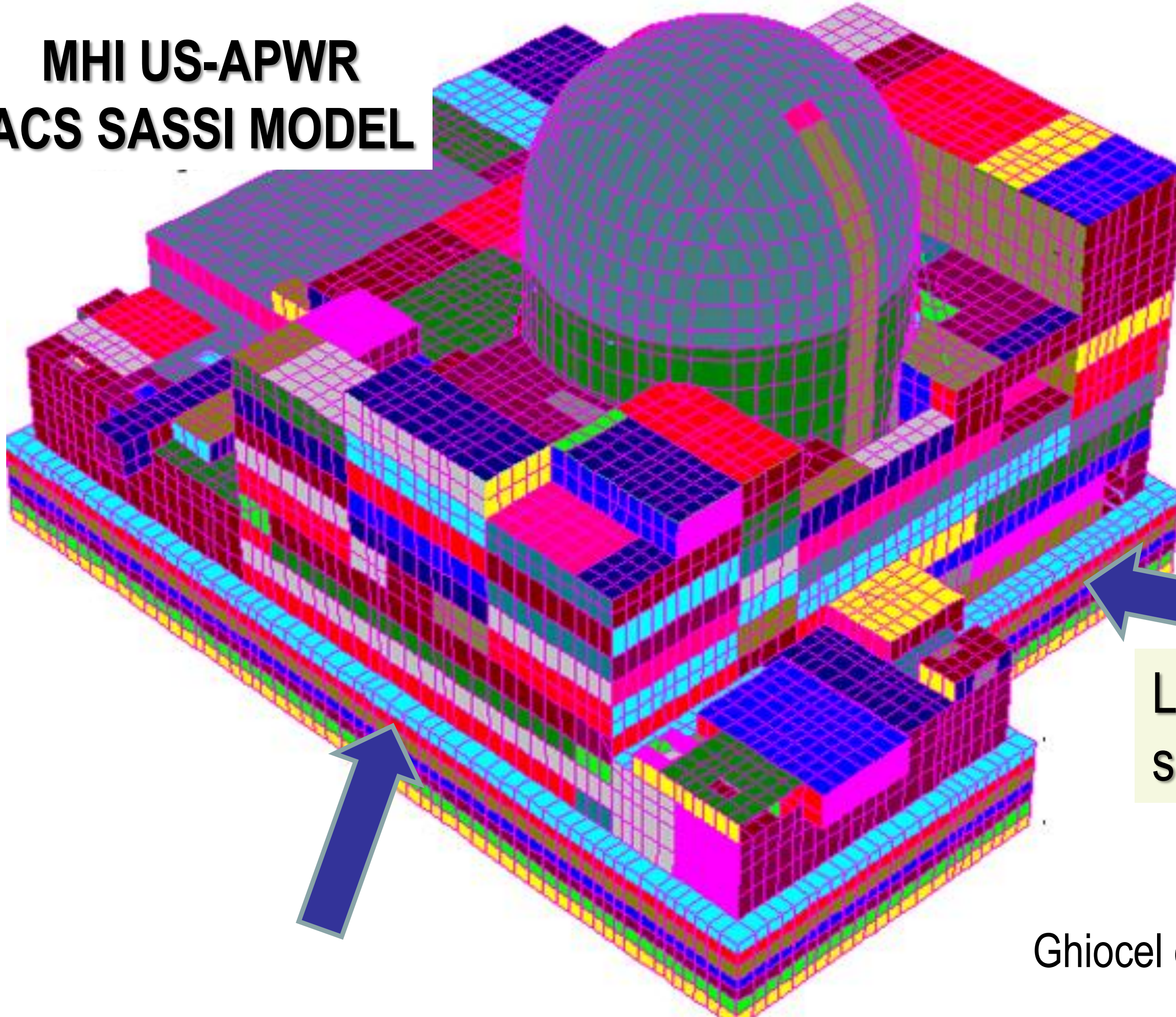
It is intentioned that the SSI model size limitation to 650,000 nodes to be relaxed from time to time in future as the MS Windows workstation RAM and HDD resources continue increase.

New WRITE Option "Extend Integer Fields" for SSI Models with 100,000 to 650,000 Nodes

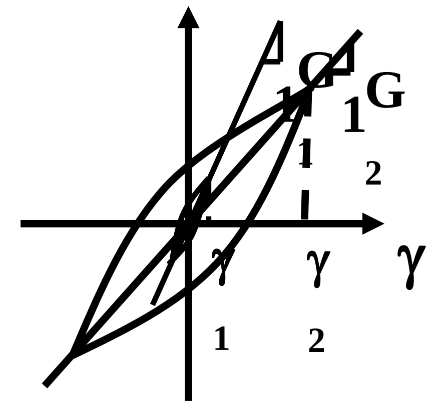


Typical ACS SASSI SSI Model

MHI US-APWR
ACS SASSI MODEL



Iterative EQL



Linear of Nonlinear soil solid elements

Ghiocel et. al., 2013, SMIRT22)

2018 ACS SASSI V3 SSI Analysis Options

1) Main or Baseline Software. Include advance pre-post processing, nonlinear soil modeling, motion incoherency, others. Plus, includes seismic motion simulation and site response capabilities.

2) Option A-AA. Integration with ANSYS. The ANSYS structure FE models can be used directly for the 1st step of the overall SSI analysis (Option AA), and/or in the 2nd step for the detailed stress analysis using the SSI responses as input BCs (Option A)

3) Option NON. Nonlinear structure, applicable to concrete structures and base-isolation (per ASCE 4-16 Sections 3, 11,12)

4) Option PRO. Probabilistic SRA and SSI analyses (per ASCE 4-16 Sections 2 and 5)

2. Modular Configuration and SSI Module Input Descriptions

ACS SASSI SSI Modules (Main Software)

1. **EQUAKE** – Generates Control Motion
2. **SOIL** – Compute Equivalent Soil Properties and Free-Field Motions
3. **SITE** – Compute Site Layering Behavior Under Different Wave Types
4. **POINT** – Compute Soil Layering Flexibilities Under Point Loads
5. **HOUSE** – Defines the Structure and Near-Field Soil and Incoherence
6. **ANALYS** – Compute Impedances & Solves SSI Problem (ATF solution)
7. **MOTION** – Computes Accelerations, RS in Structure/Near-Soil
8. **RELDISP** - Computes Relative Displacements
9. **STRESS** – Computes Stresses/Strains in Structure and Near-Soil
10. **COMBIN** – Combine ANALYS Solutions with Different Frequencies

Auxiliary Programs:

COMB_XYZ_STRAIN applicable to 3D nonlinear soil site response or SSI analysis using iterative equivalent linear procedure. Combines three directional shear-strains for X, Y and Z inputs in the nonlinear soil solid elements at each SSI iteration.

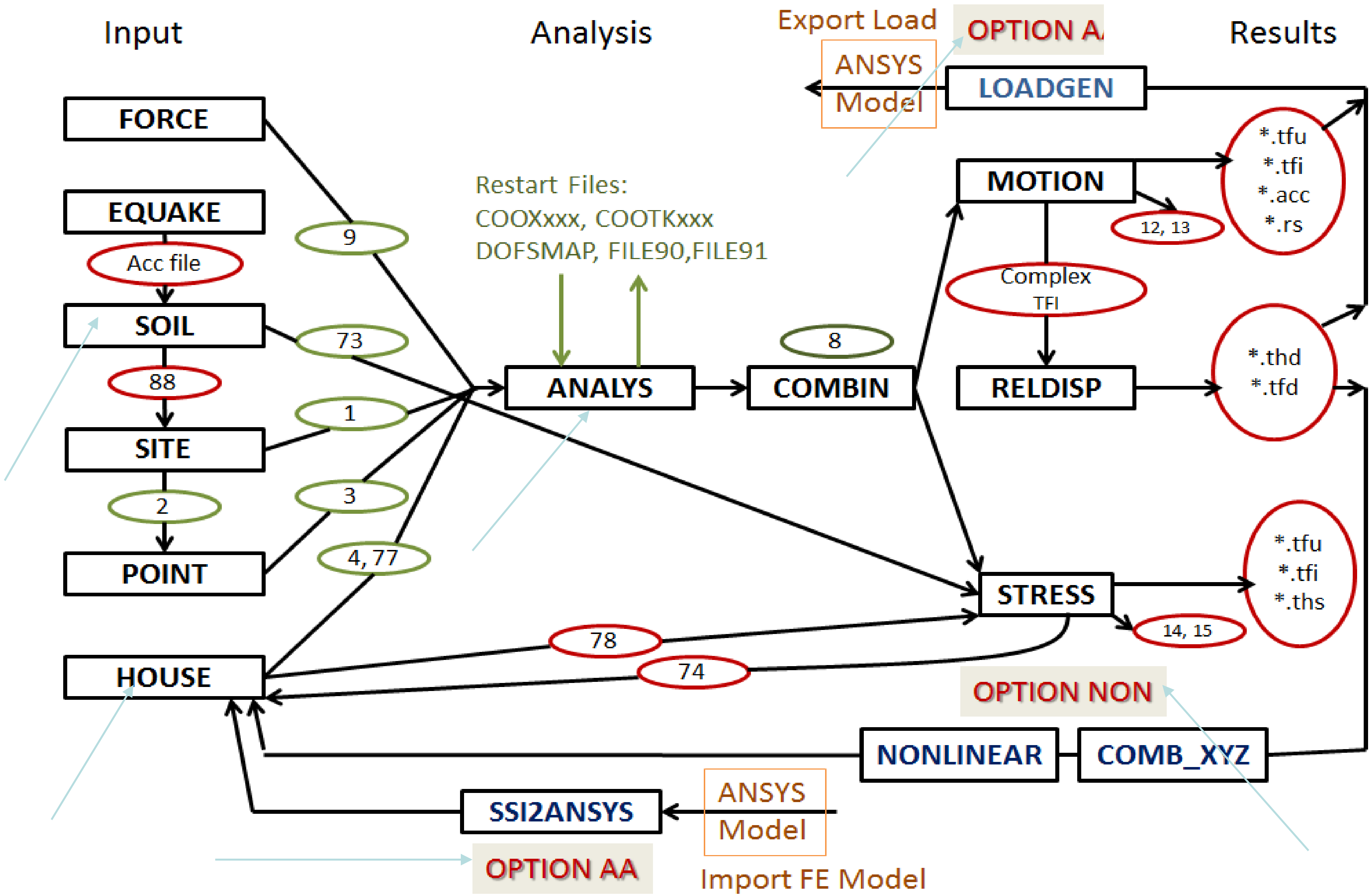
COMB_XYZ_THD applicable to nonlinear structure SSI analysis using iterative equivalent linear procedure (*for Option NON*). Combines directional node displacements for nonlinear shell walls and spring elements at each SSI iteration.

File8-CP-Resp-Recovering

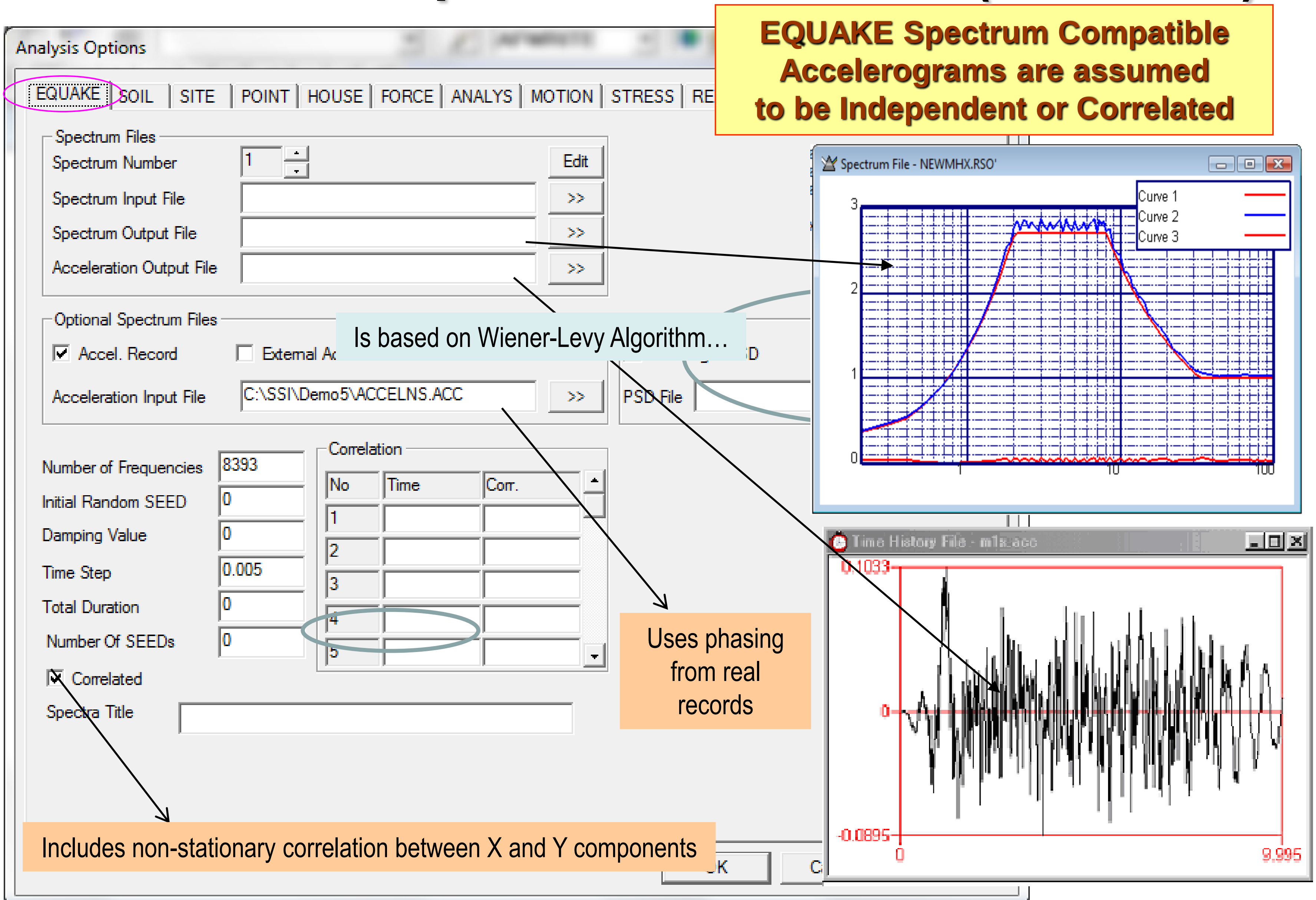
This auxiliary code recovers the slave nodes response of the ANSYS CP constraints for Option AA. It finds the master nodes response, copies them to the corresponding slave nodes, then creates new file8 for further processing, based on the input information.

BuildFile77 applicable to incoherent SSI analysis of deeply embedded structures, such as SMRs. *Very complex, needs support!*

ACS SASSI Modular Configuration

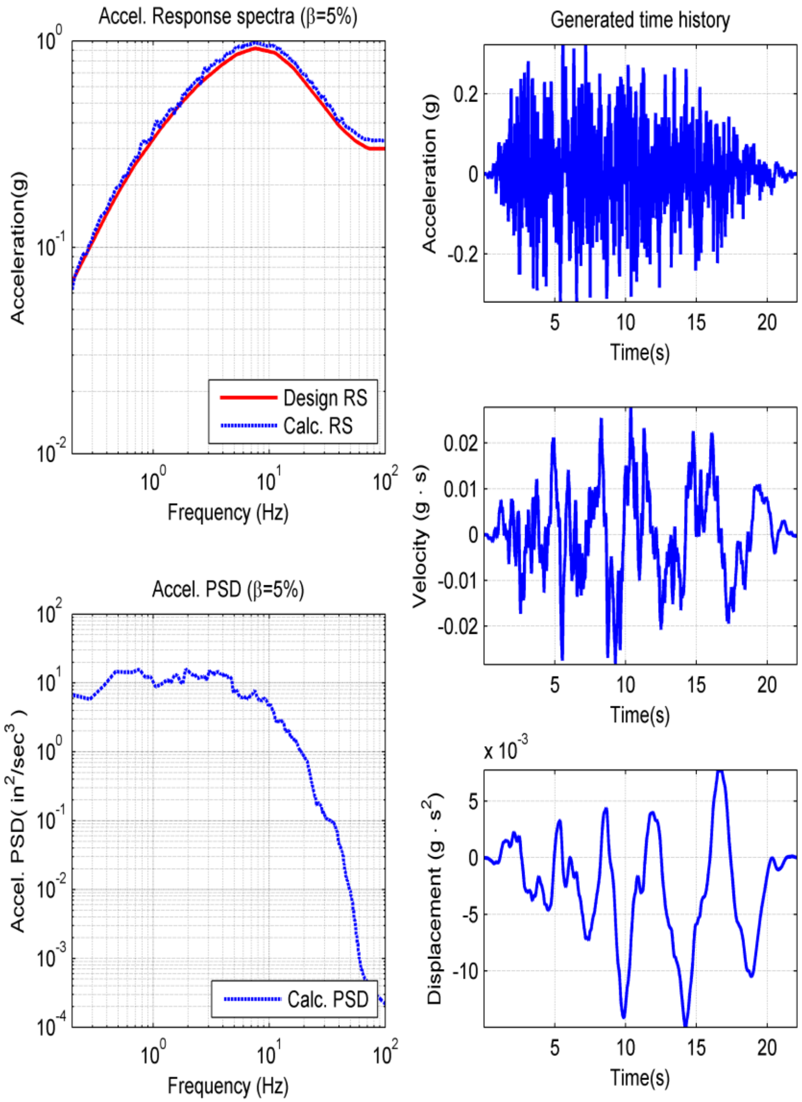


Simulation of Input Control Motion (EQUAKE)

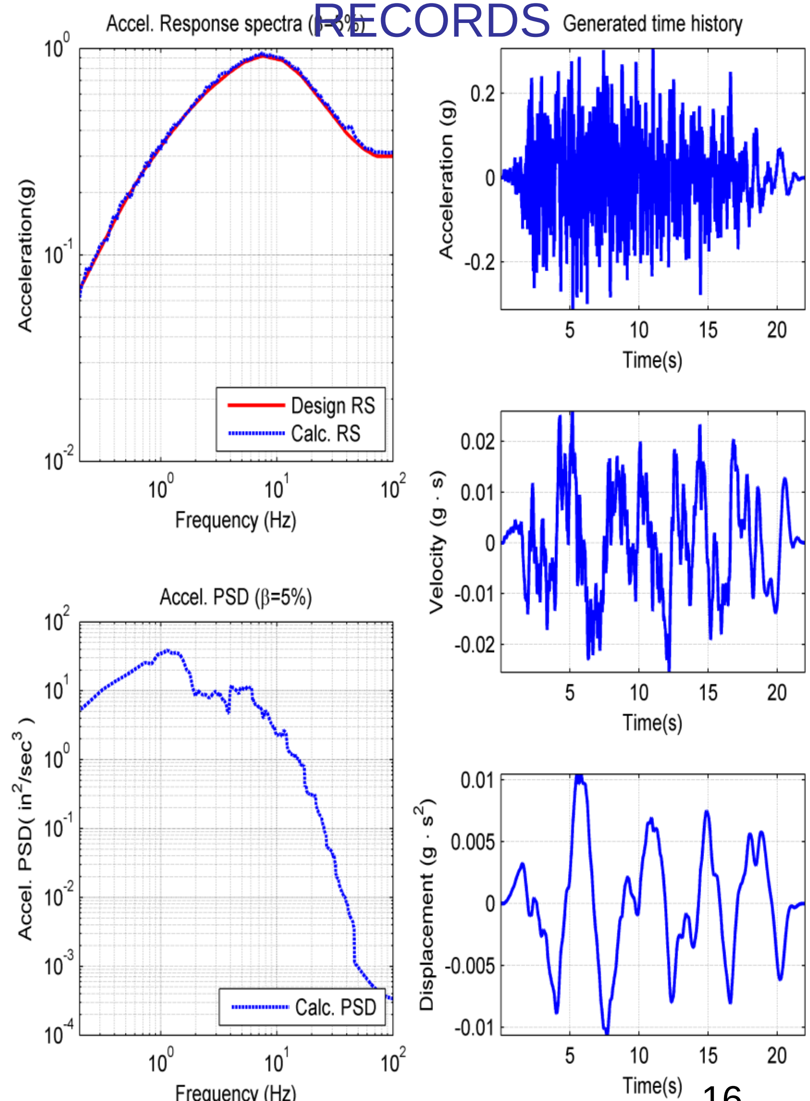


EQUAKE Module Capabilities – Firm Soil Site

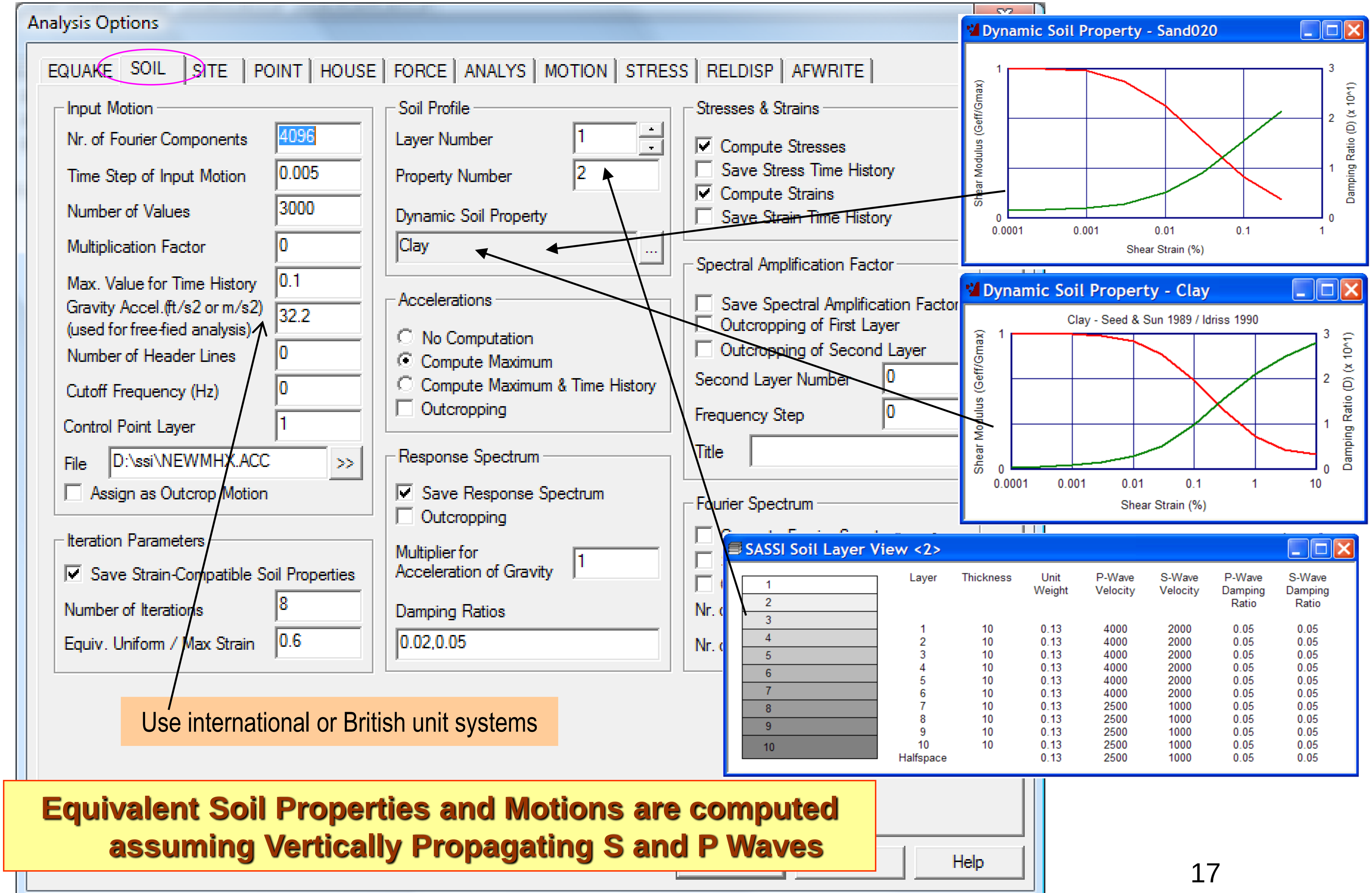
WITHOUT SEED RECORDS



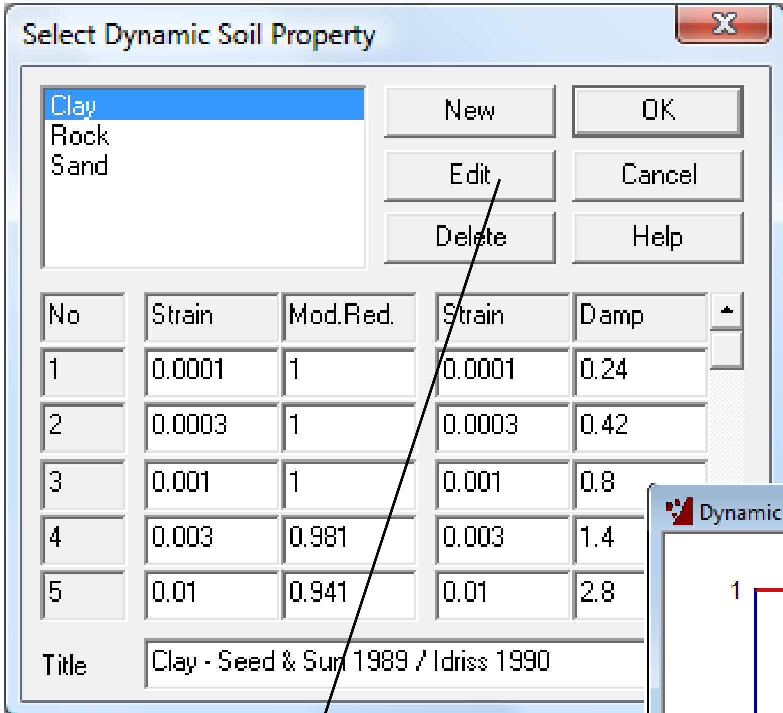
WITH SEED RECORDS



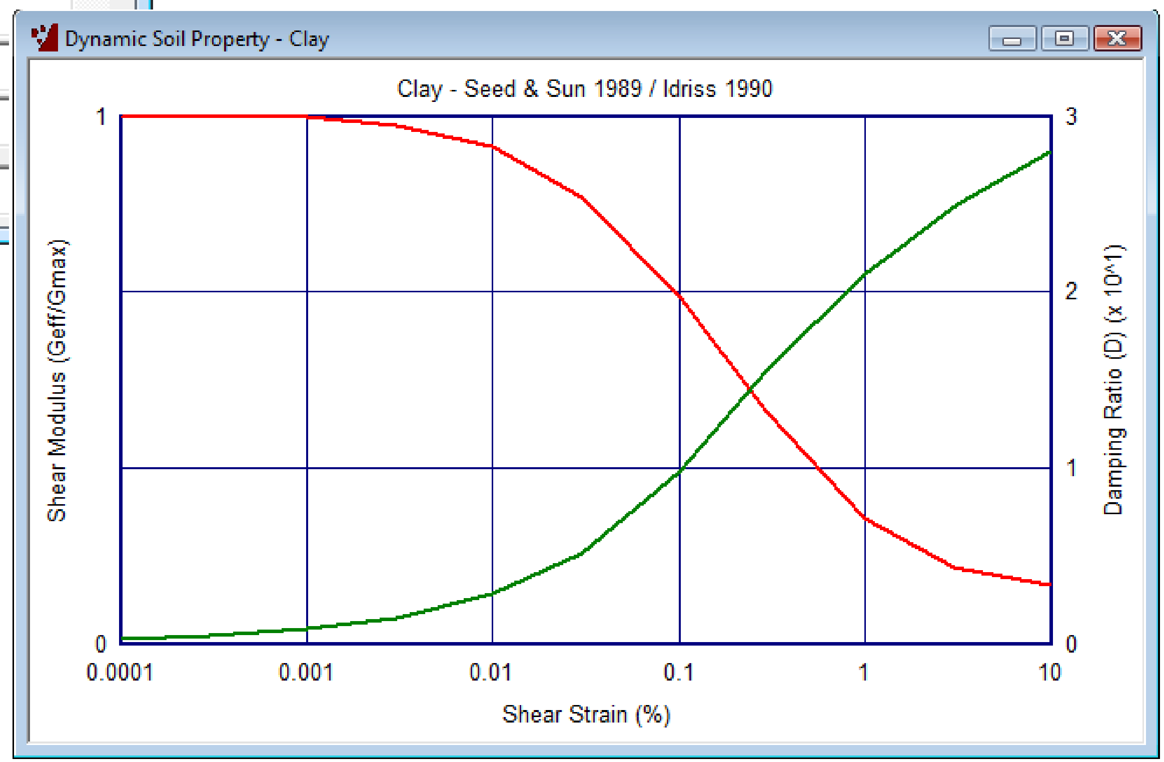
Site Response Via SHAKE Methodology (SOIL)



Equivalent Soil Properties and Motions are computed assuming Vertically Propagating S and P Waves



Nonlinear soil material curve database; Shear modulus and damping ration as functions of soil shear strain



User can add edit, delete, and included new curves

Computation of Equivalent Soil Properties

SOIL Module (based on SHAKE approach) Computes Equivalent Soil Properties Using Seed-Idriss Equivalent Linear Model

Input Acceleration Time History

```
MAXIMUM ACCELERATION =    .85600
AT TIME              =   4.37 SEC
THE VALUES WILL BE MULTIPLIED BY A FACTOR =    .350
TO GIVE NEW MAXIMUM ACCELERATION          =    .30000
MEAN SQUARE FREQUENCY =        6.87 C/SEC.
***  CONTROL MOTION LAYER ***
 **  MOTION OF LAYER NUMBER     1  OUTCROPPING

***  STRAIN COMPATIBLE SOIL PROPERTIES ***
 MAXIMUM NUMBER OF ITERATIONS     =     8
 STRAIN FACTOR IN TIME DOMAIN     =    .60

    EARTHQUAKE    -            C:\ACS_C\NEWMHX.ACC
```

Initial Soil Layering Properties

```
*** SOIL PROFILE DESCRIPTION ***
NEW SOIL PROFILE NO.    1       IDENTIFICATION
NUMBER OF LAYERS                    5          DEPTH TO BEDROCK         40.00
```

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	Tot. PRESS. (ksf)	MODULUS (ksf)	DAMPING	UNIT WT. (kcf)	SHEAR VEL (fps)
1	1	10.00	5.00	.65	4037.	.050	.130	1000.0
2	1	10.00	15.00	1.64	4037.	.050	.130	1000.0
3	1	10.00	25.00	2.31	4037.	.050	.130	1000.0
4	1	10.00	35.00	2.99	4037.	.050	.130	1000.0
5	BASE				4037.	.050	.130	1000.0

```
PERIOD =   .16 FOR AVERAGE SHEAR VELOCITY =   1000.
```

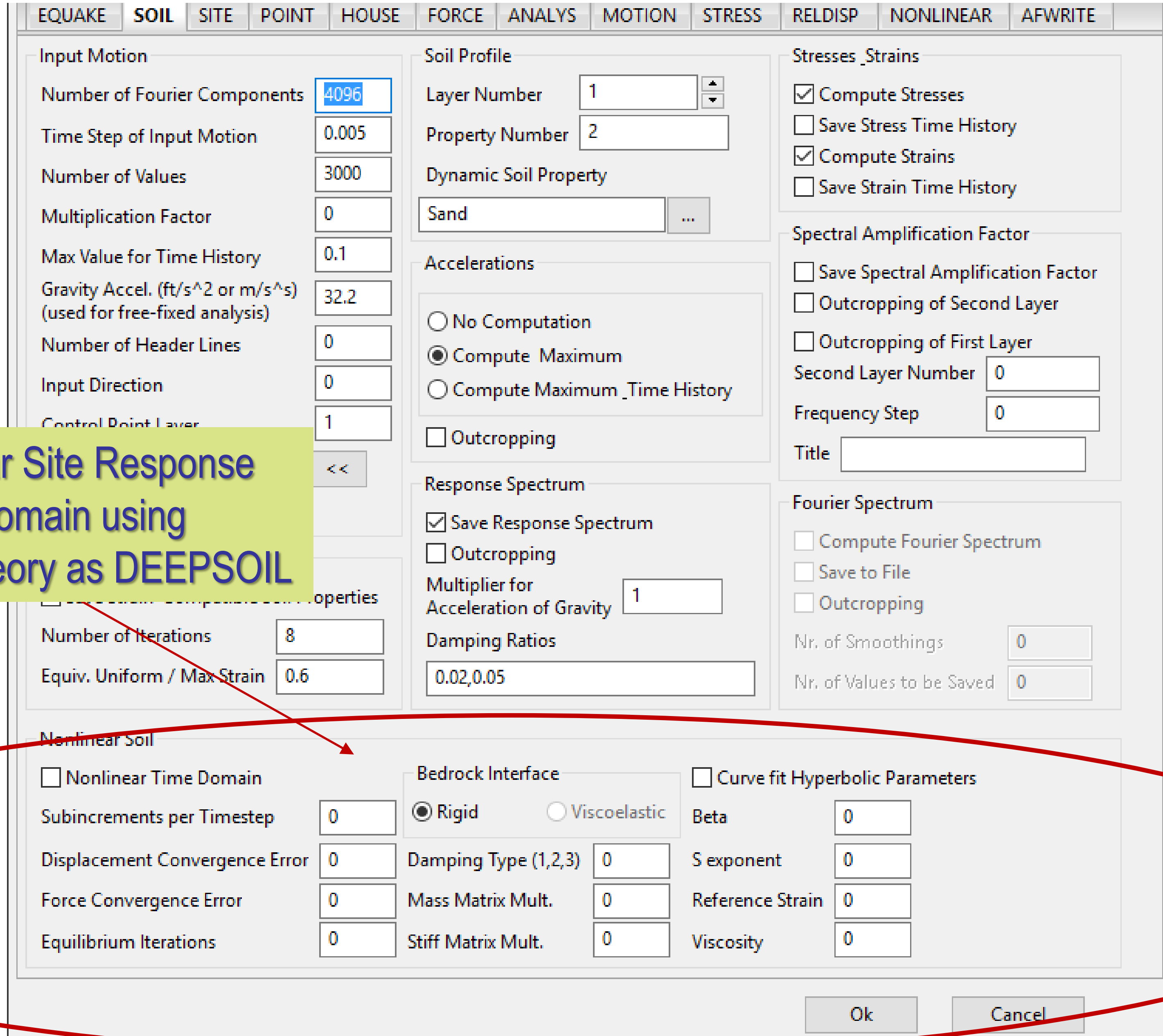
Final Soil Layering Properties

```
ITERATION NUMBER   8

VALUES IN TIME DOMAIN
```

NO	TYPE	DEPTH (FT)	UNIFRM. STRAIN	<---- NEW	DAMPING USED	----> ERROR	<---- SHEAR NEW	MODULUS USED	-----> ERROR	G/Go RATIO
1	1	5.0	.00296	.014	.014	.0	3877.2	3877.2	.0	.960
2	1	15.0	.00909	.027	.027	0.0	3466.9	3466.9	.0	.859
3	1	25.0	.01629	.038	.038	0.0	3055.3	3055.3	0.0	.757
4	1	35.0	.02485	.047	.047	0.0	2729.1	2729.2	0.0	.676

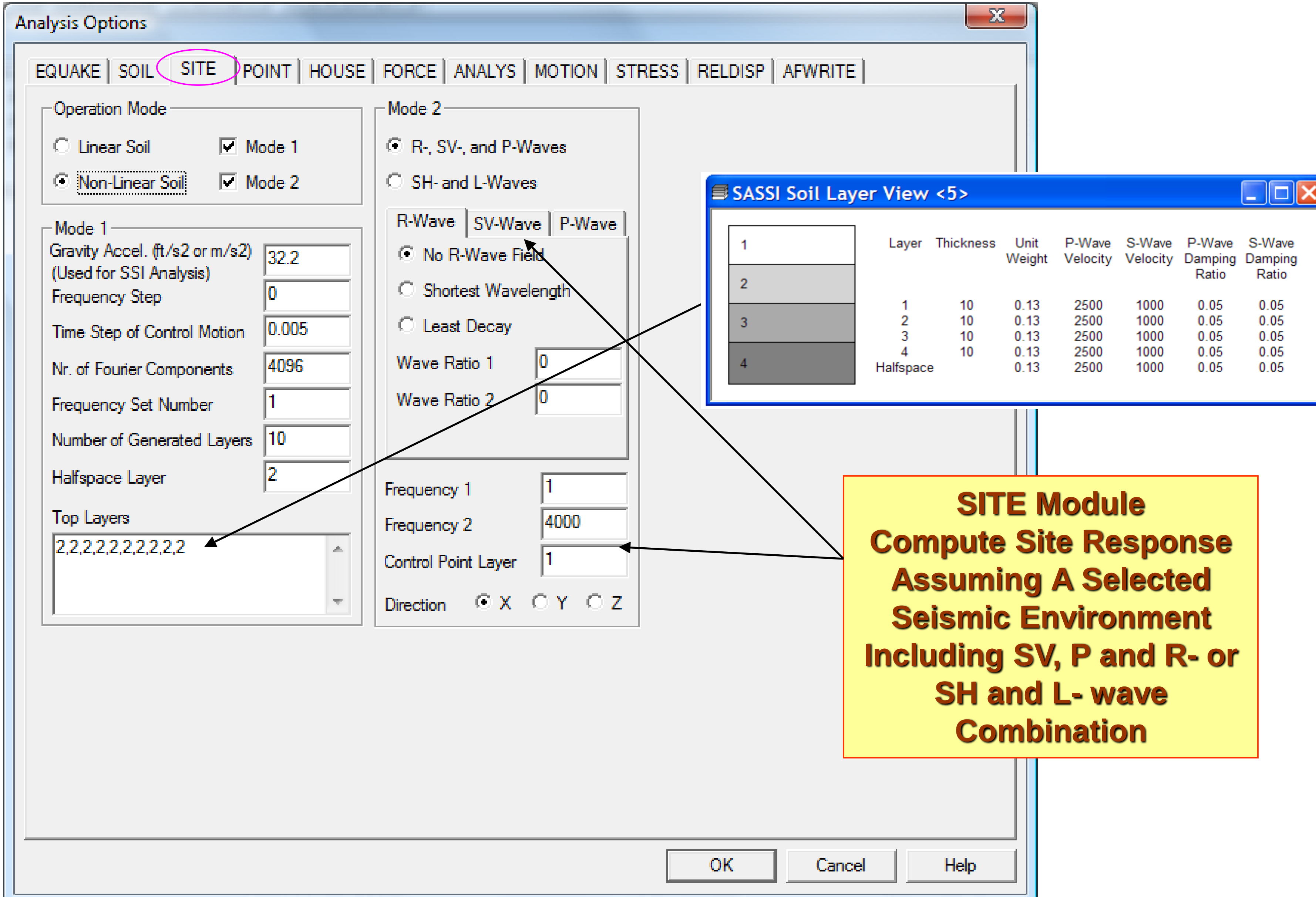
```
PERIOD =   .18 FOR AVERAGE SHEAR VELOCITY =    900.
```

SOIL Includes SHAKE or DEEPSOIL Option



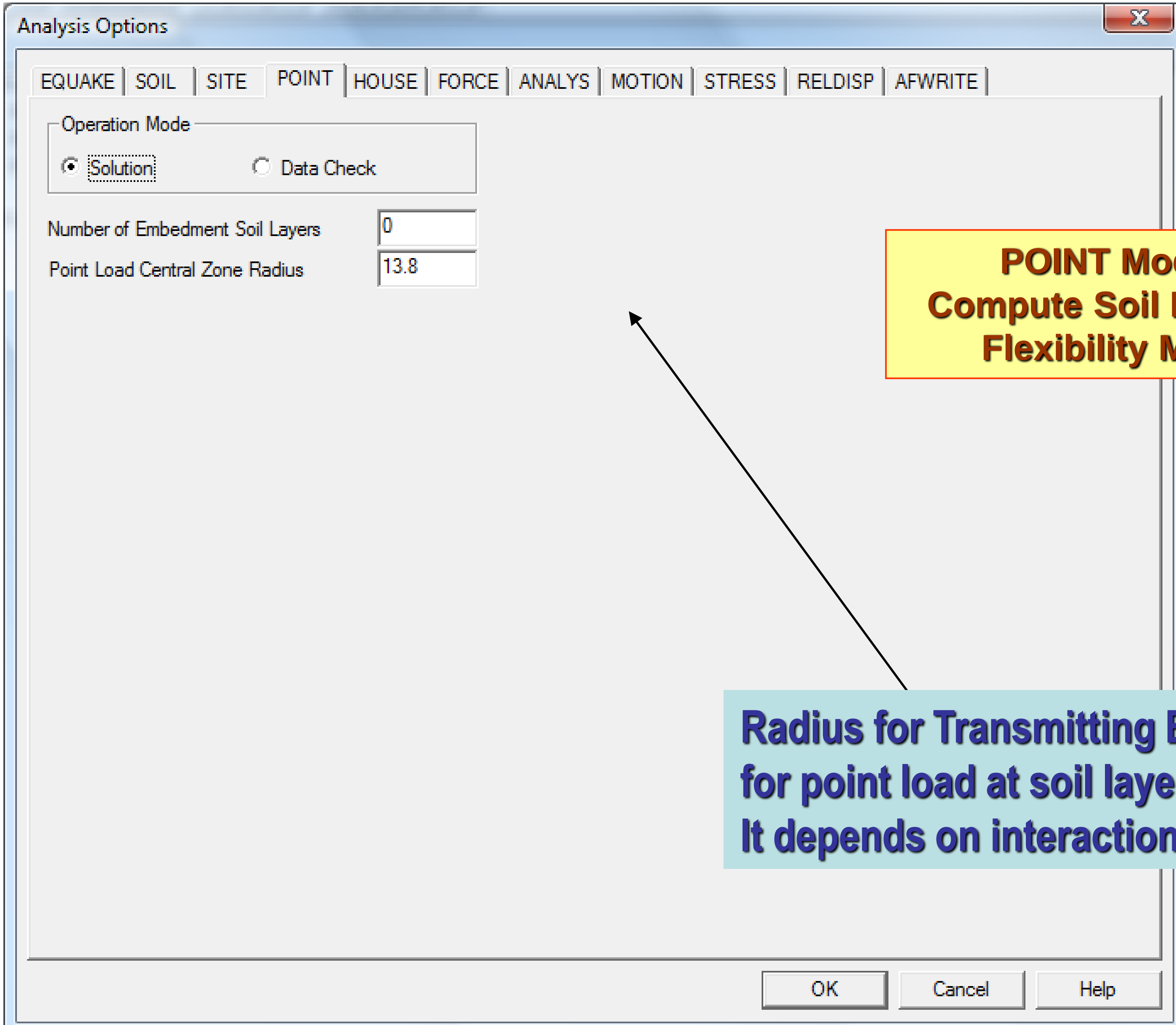
Nonlinear Site Response in time domain using same theory as DEEPSOIL

Selection of Seismic Wave Environment (SITE)



SITE Module
Compute Site Response Assuming A Selected Seismic Environment Including SV, P and R- or SH and L- wave Combination

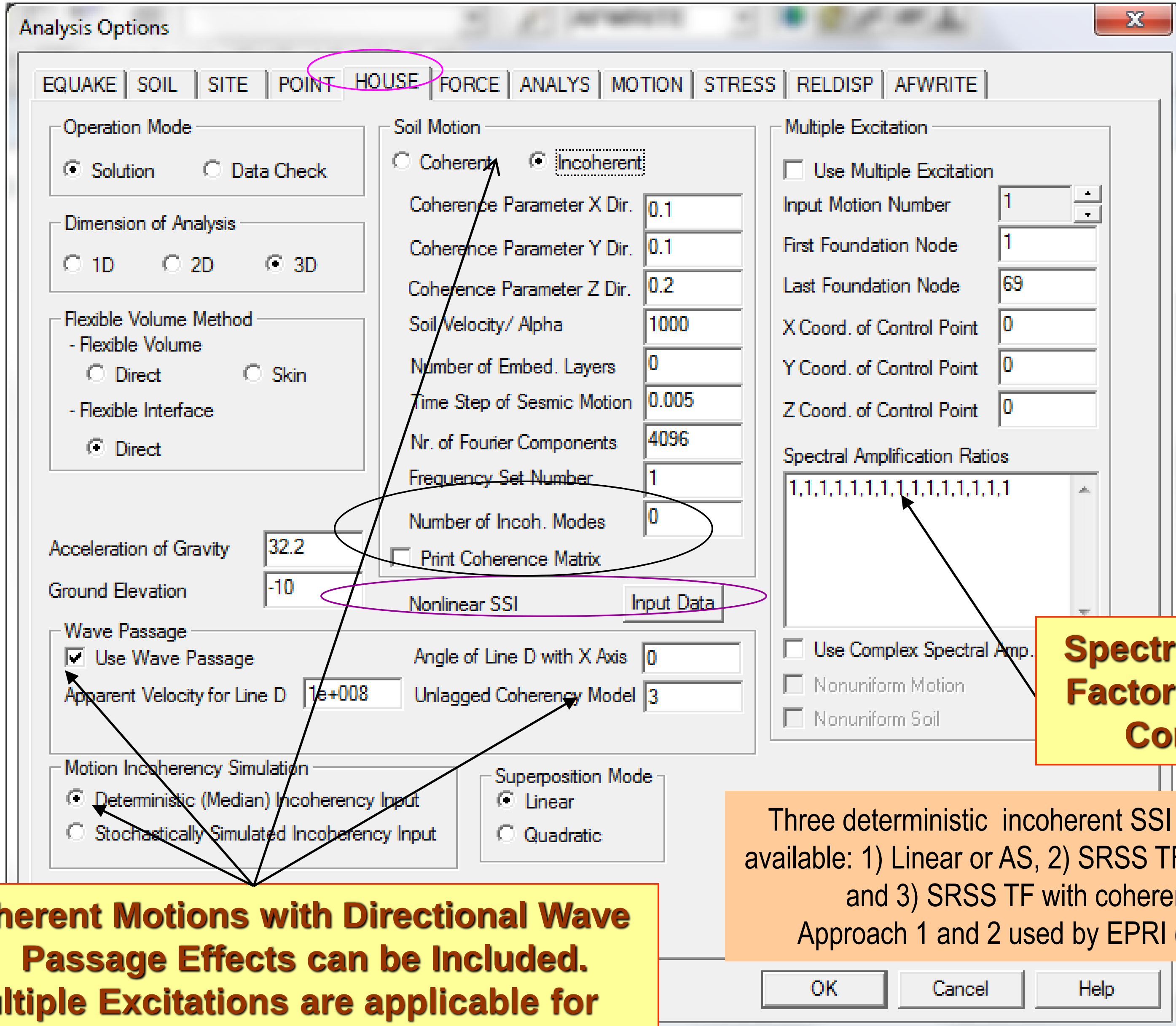
Input for Computing Soil Flexibility Matrix (POINT)



POINT Module
Compute Soil Layering Flexibility Matrix

Radius for Transmitting Boundary for point load at soil layer interface. It depends on interaction node mesh.

Inputs for Coherent and Incoherent SSI (HOUSE)



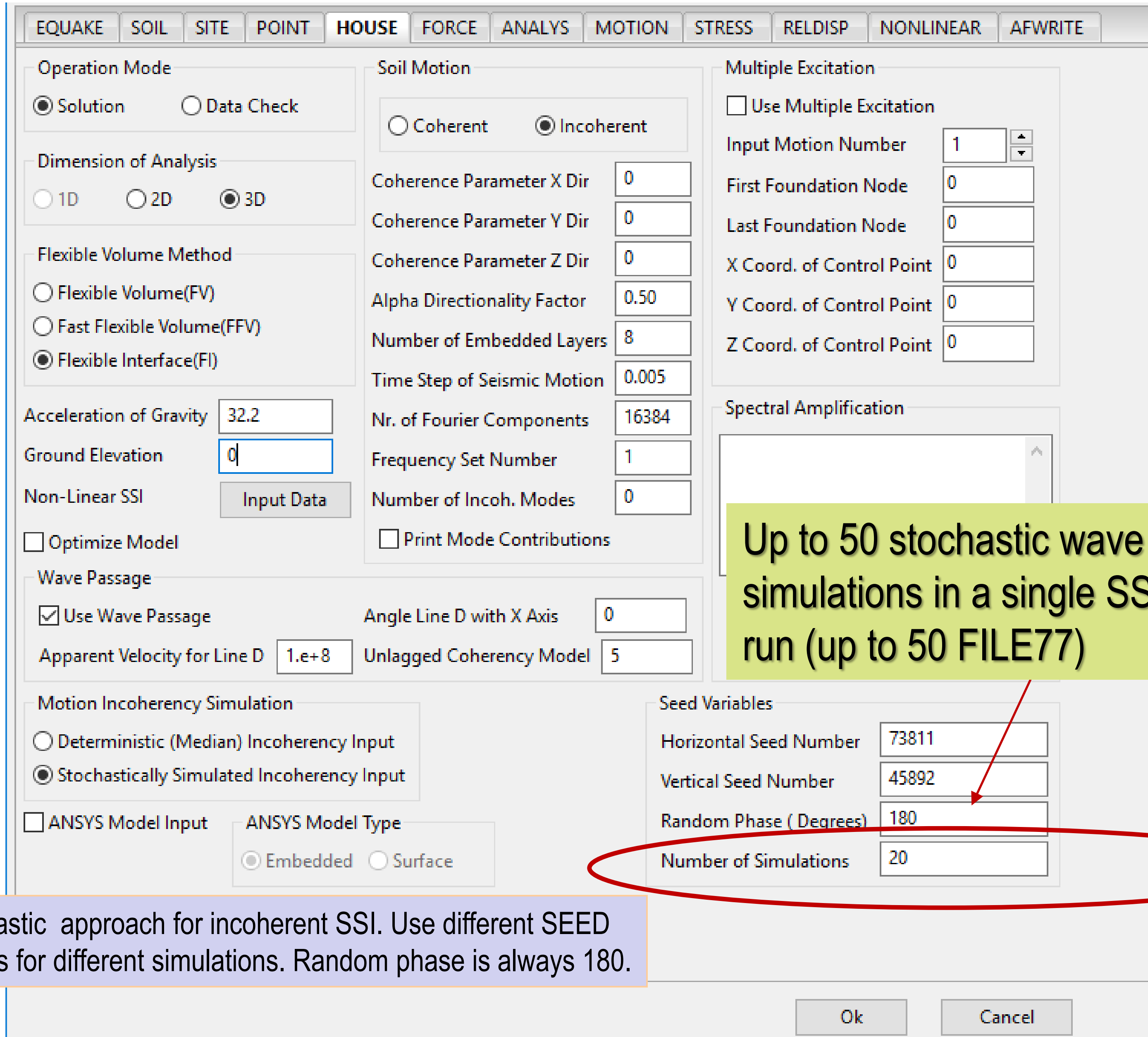
HOUSE include also a (hidden) node numbering optimization algorithm (1 in col 1 line of .hou)

Spectral Amplification Factors are applied to Control Motion

Three deterministic incoherent SSI approaches are available: 1) Linear or AS, 2) SRSS TF with zero phase, and 3) SRSS TF with coherent phase.
Approach 1 and 2 used by EPRI (TR 1015111)

Incoherent Motions with Directional Wave Passage Effects can be Included.
Multiple Excitations are applicable for Separate Isolated Foundations.

HOUSE Module for Incoherent SSI



Up to 50 stochastic wave field simulations in a single SSI analysis run (up to 50 FILE77)

Stochastic approach for incoherent SSI. Use different SEED numbers for different simulations. Random phase is always 180.

HOUSE Incoherent SSI Capabilities

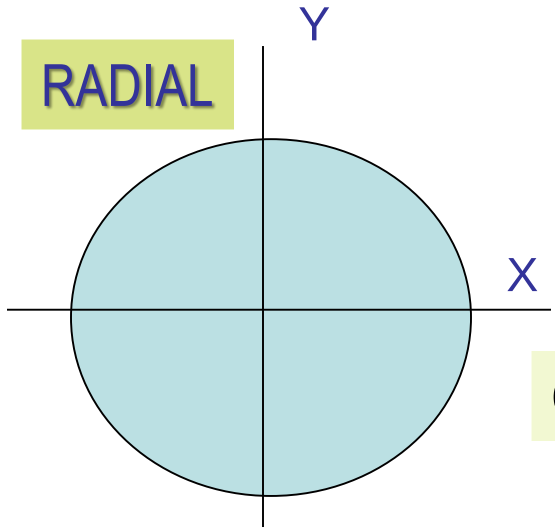
There are several plane-wave incoherency models (with wave passage effects):

1) 1986 Luco-Wong model (theoretical, unvalidated, geom anisotropic)
2) 1993 Abrahamson model for all sites and surface foundations
3) 2005 Abrahamson model for all sites and surface foundations
4) 2006 Abrahamson model for all sites and embedded foundations
5) 2007 Abrahamson model for hard-rock sites and all foundations (NRC)
6) 2007 Abrahamson model for soil sites and surface foundations
7) *User-Defined, Site-Specific Plane-Wave Coherency Functions for X, Y and Z.*

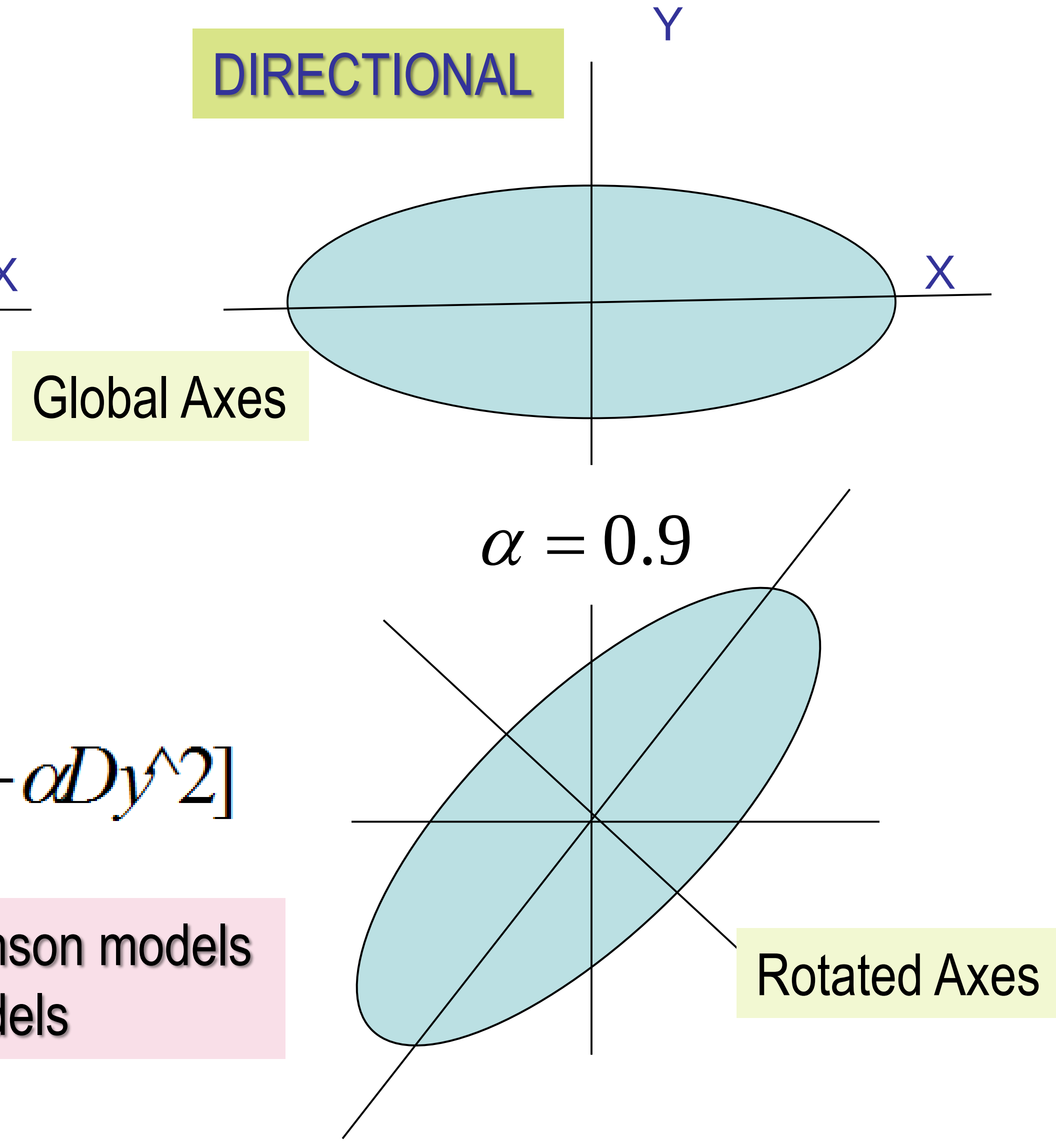
REMARKS:

1) Also includes *directional* Abrahamson or user-defined coherency models.
2) For general, more complex situations, can include *nonuniform motion in horizontal plane* by both amplitude and phase changes at different interaction nodes;

Radial vs. Directional Motion Coherency Models



$$\alpha = 0.5$$

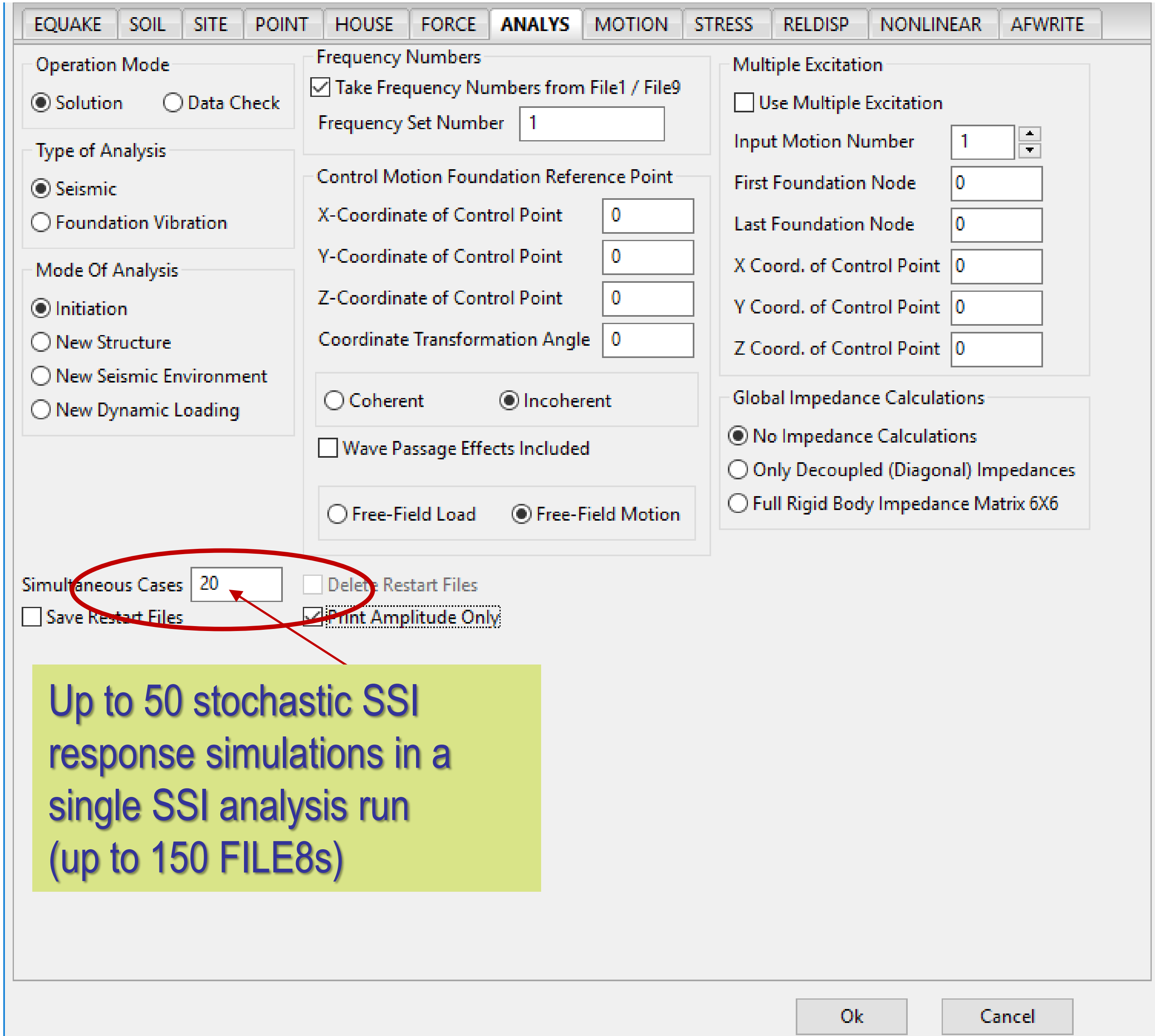


$$\alpha = 0.9$$

$$D^2 = 2[(1-\alpha)Dx^2 + \alpha Dy^2]$$

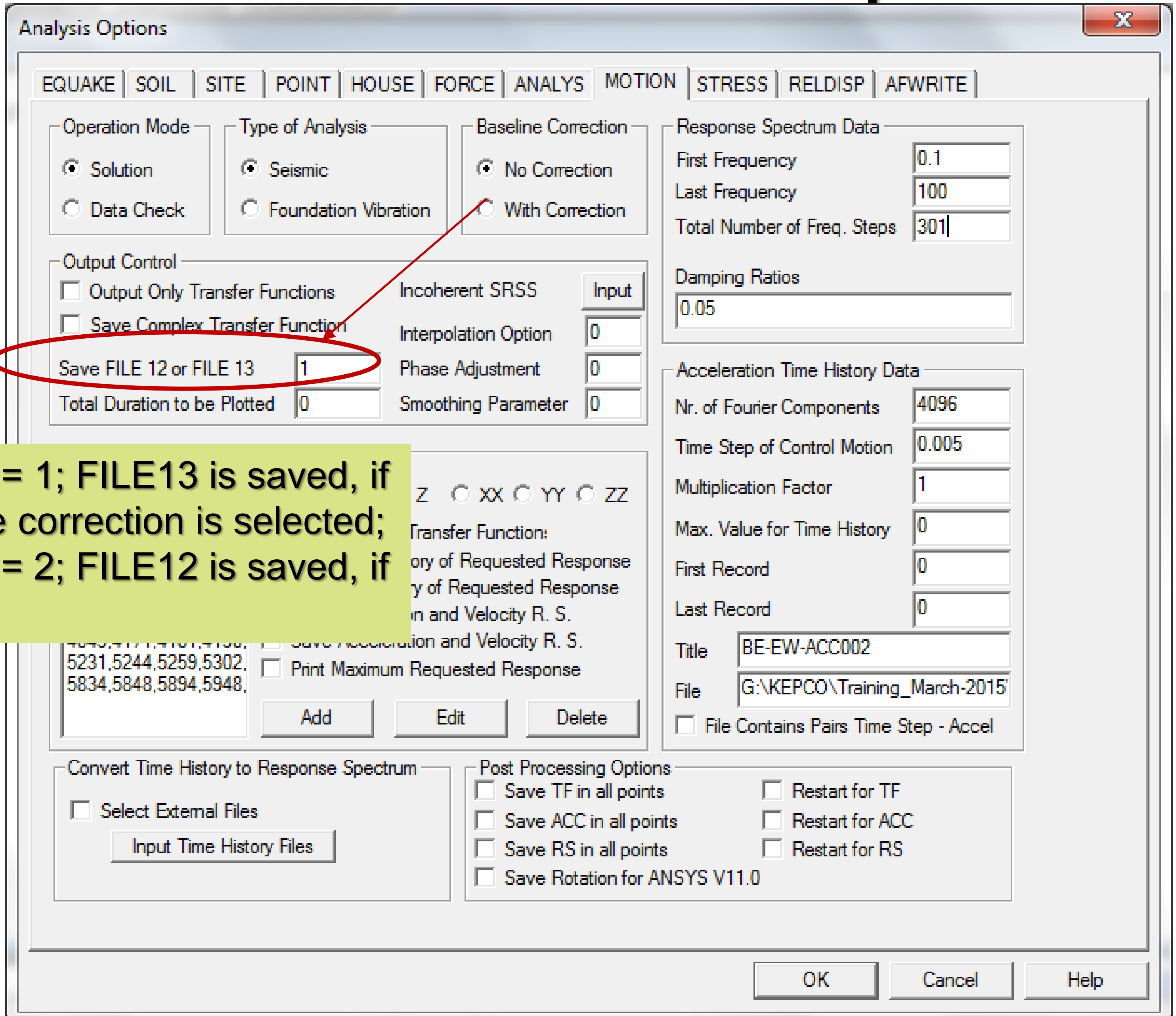
Applicable to the generic, Abrahamson models and user-defined, site-specific models

ANALYS Module Coherent & Incoherent SSI



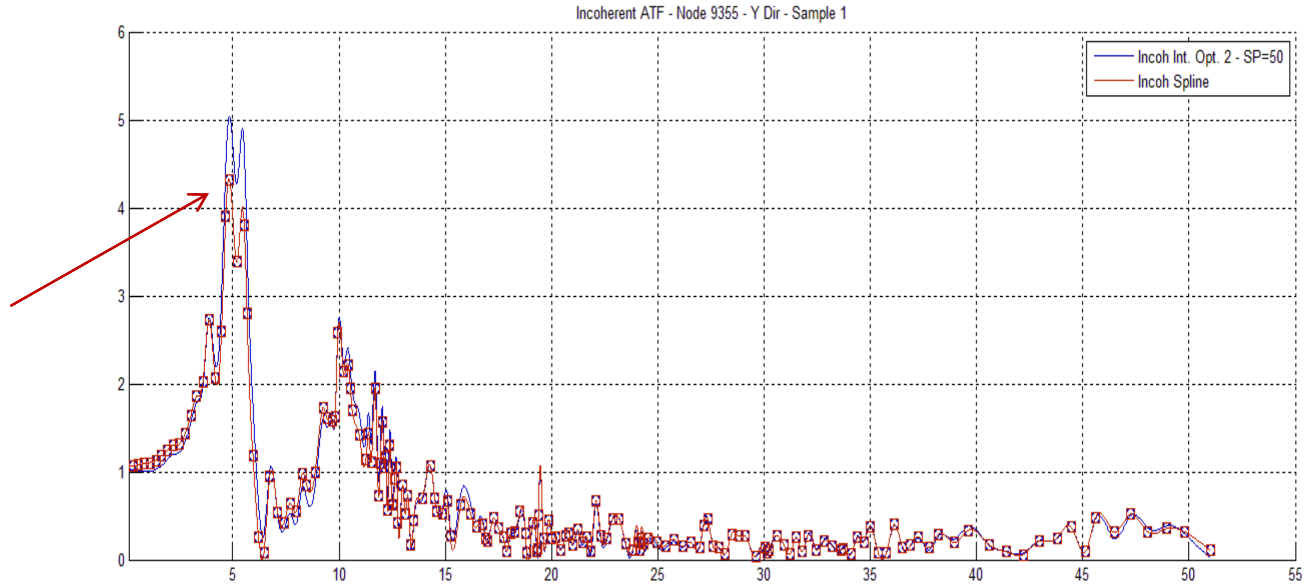
Up to 50 stochastic SSI response simulations in a single SSI analysis run (up to 150 FILE8s)

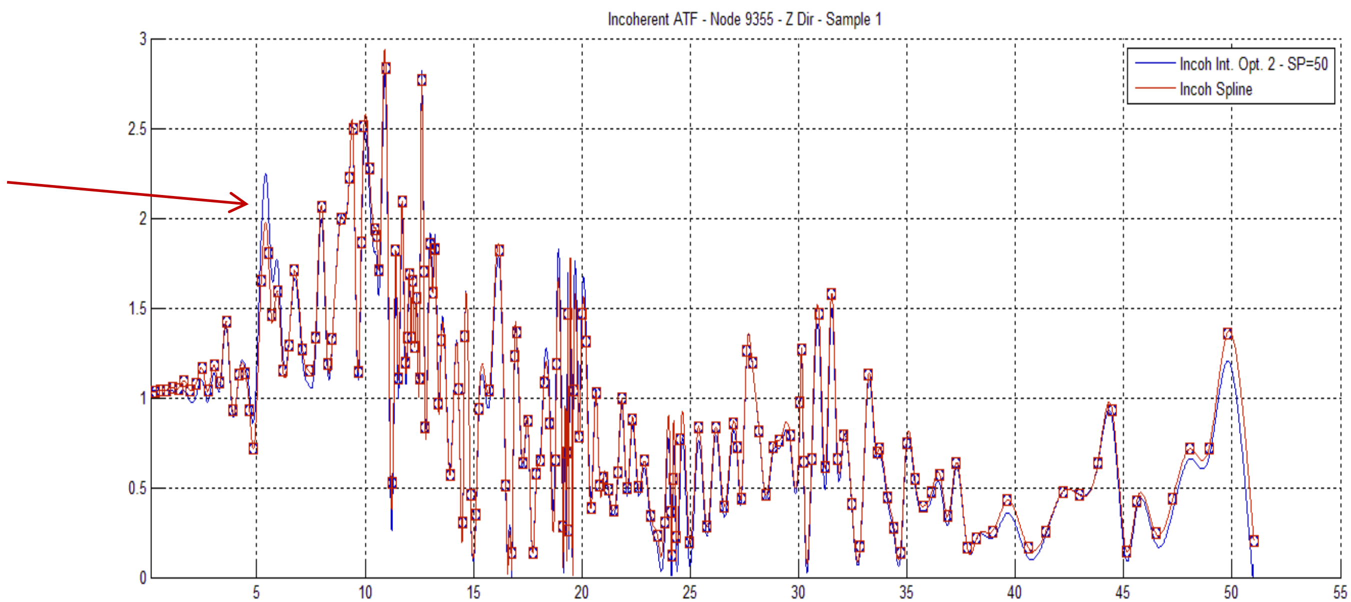
MOTION New GUI Input



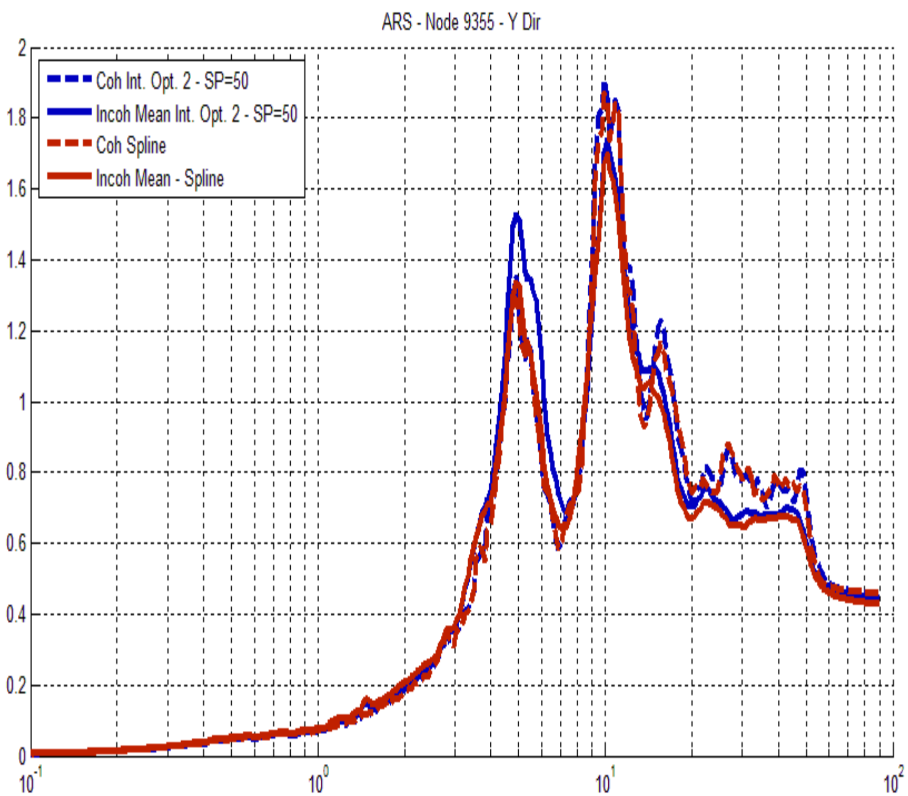
Save… = 1; FILE13 is saved, if baseline correction is selected; Save… = 2; FILE12 is saved, if needed

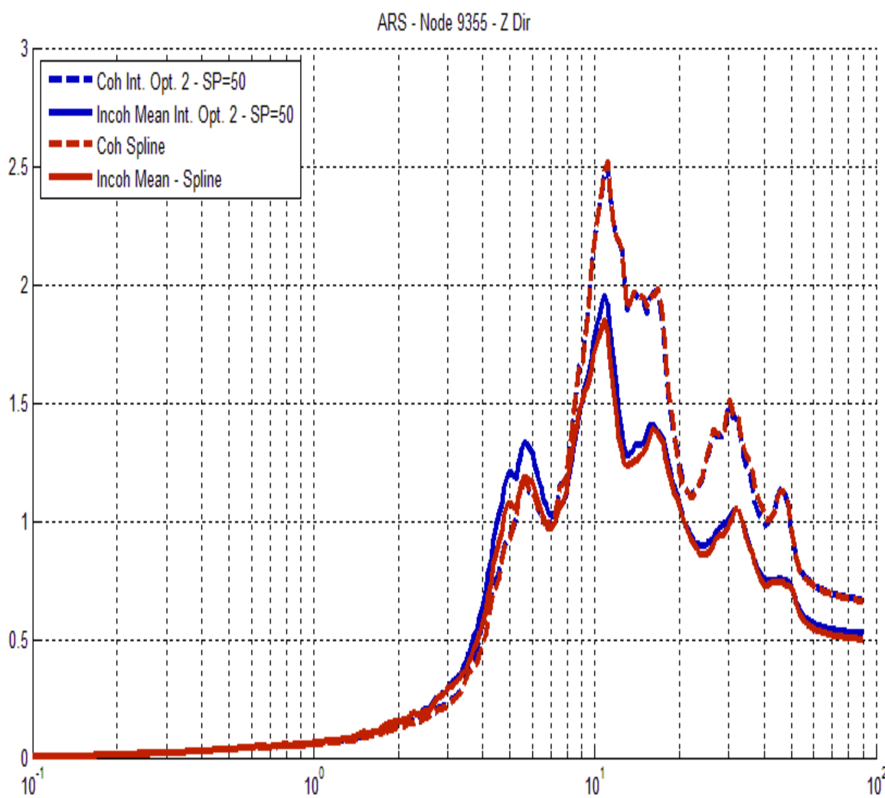
Spline Interpolation Applied to SSI Simulations



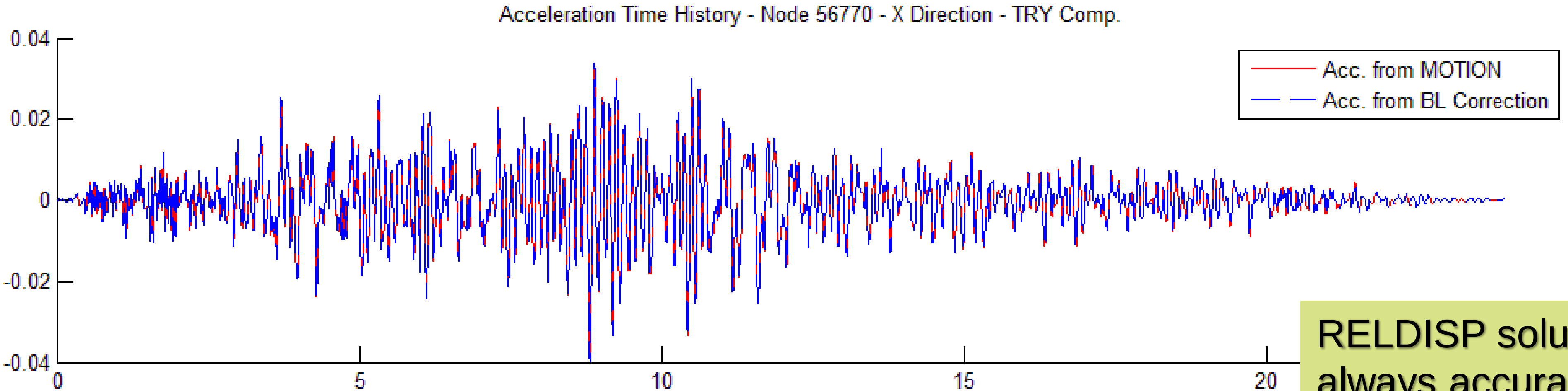


Spline Interpolation Applied to Incoherent SSI Simulation Approach

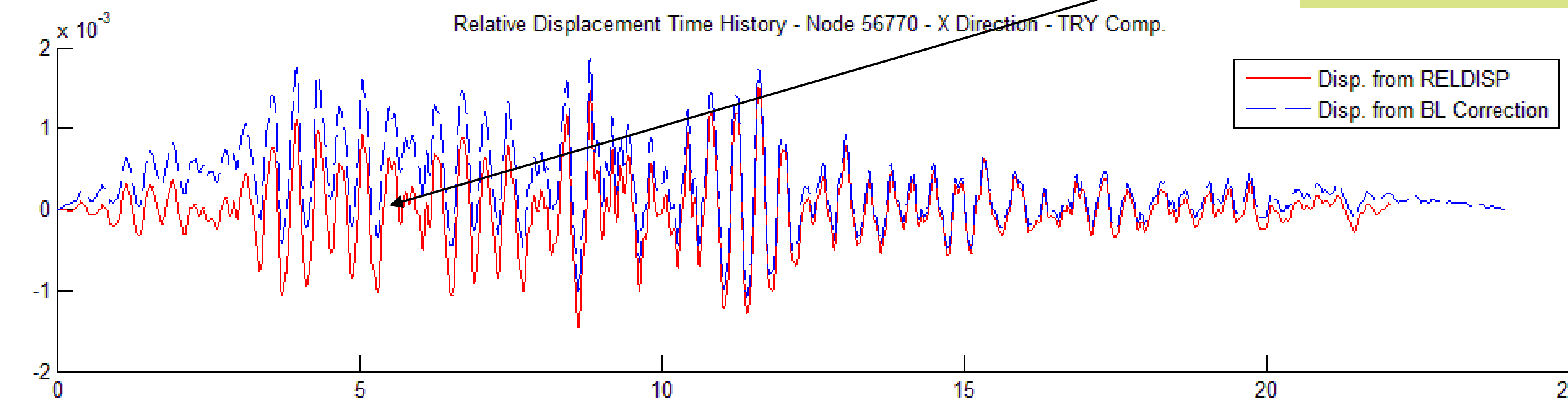




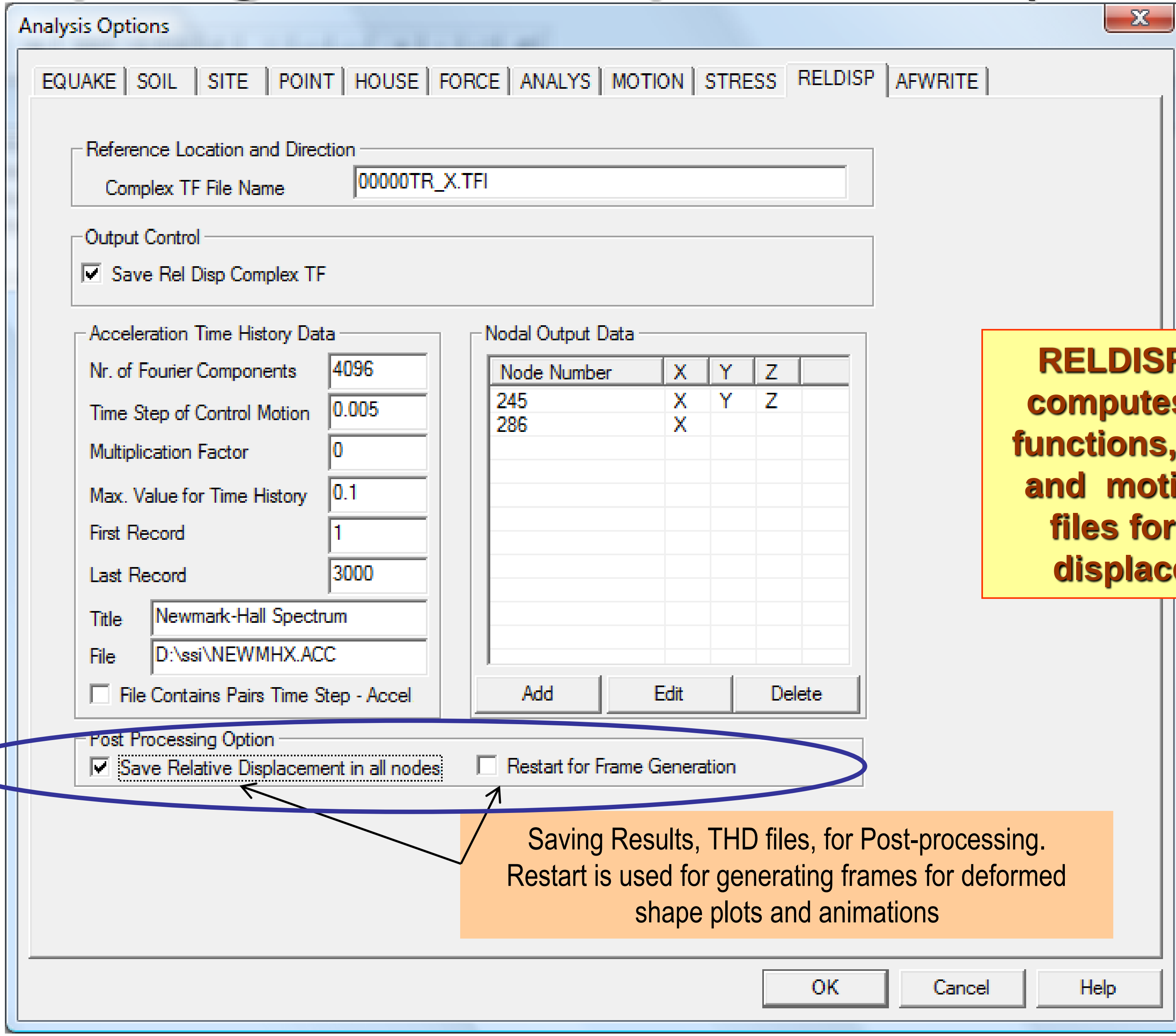
Relative Displacements Computed Using Baseline Correction ("Approximate") and RELDISP ("Exact")



RELDISP solu
always accura
Use RELDISP



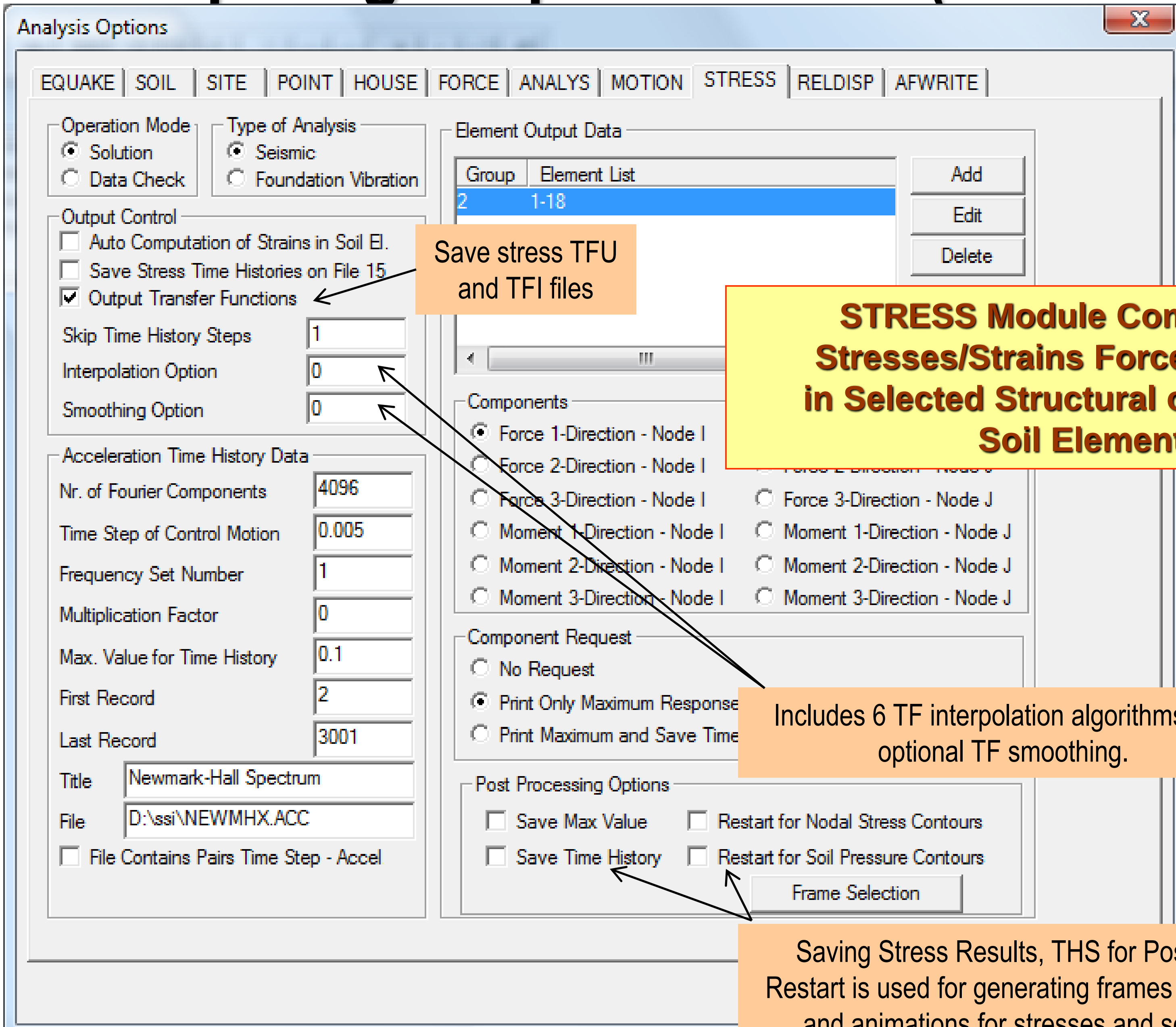
Computing Relative Displacements (RELDISP)



RELDISP Module computes transfer functions, TFD files, and motions, THD files for relative displacements.

Saving Results, THD files, for Post-processing. Restart is used for generating frames for deformed shape plots and animations

Computing Output Stresses (STRESS)



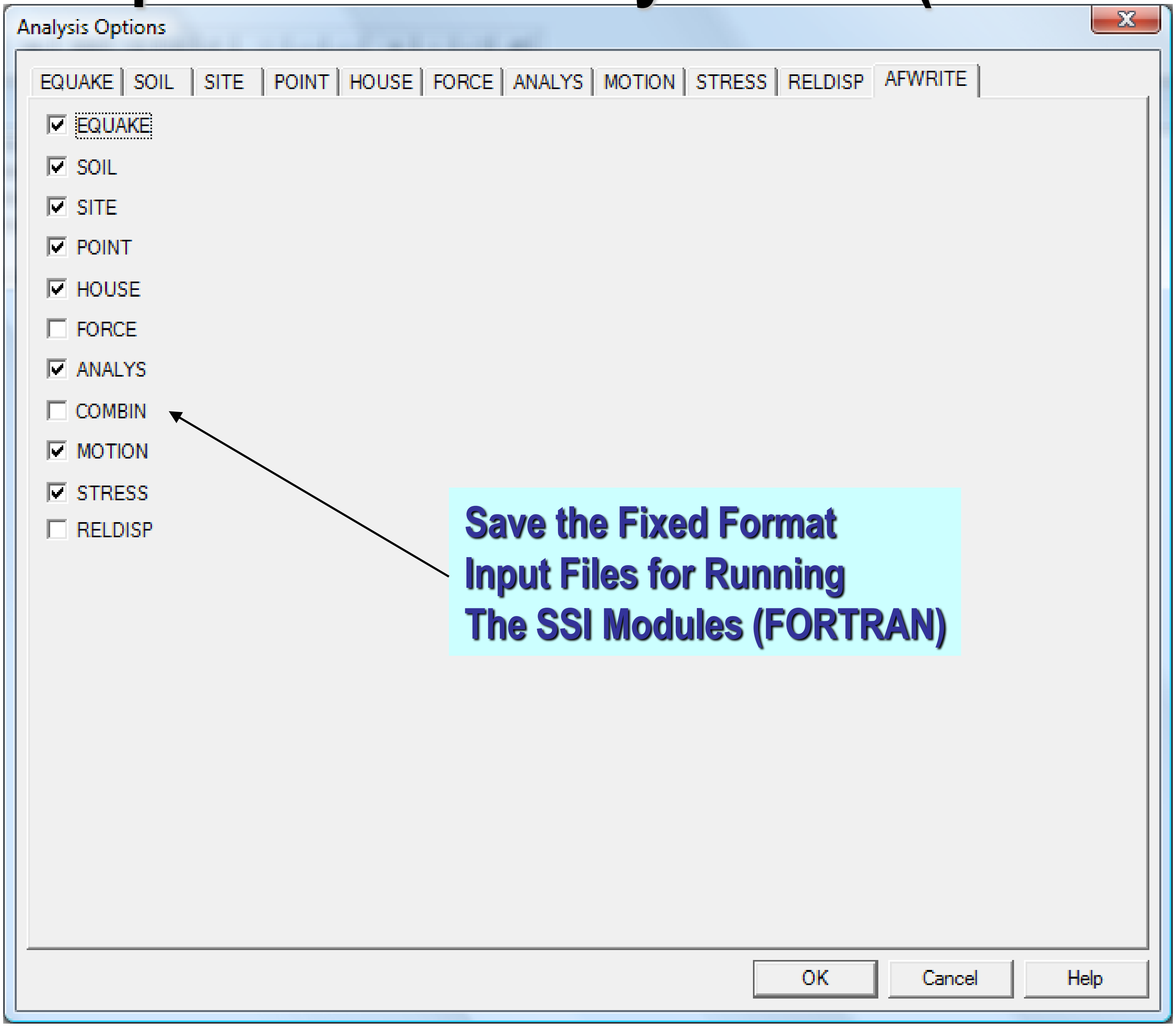
Save stress TFU and TFI files

STRESS Module Computes Stresses/Strains Forces/Moments in Selected Structural or Near-Field Soil Elements

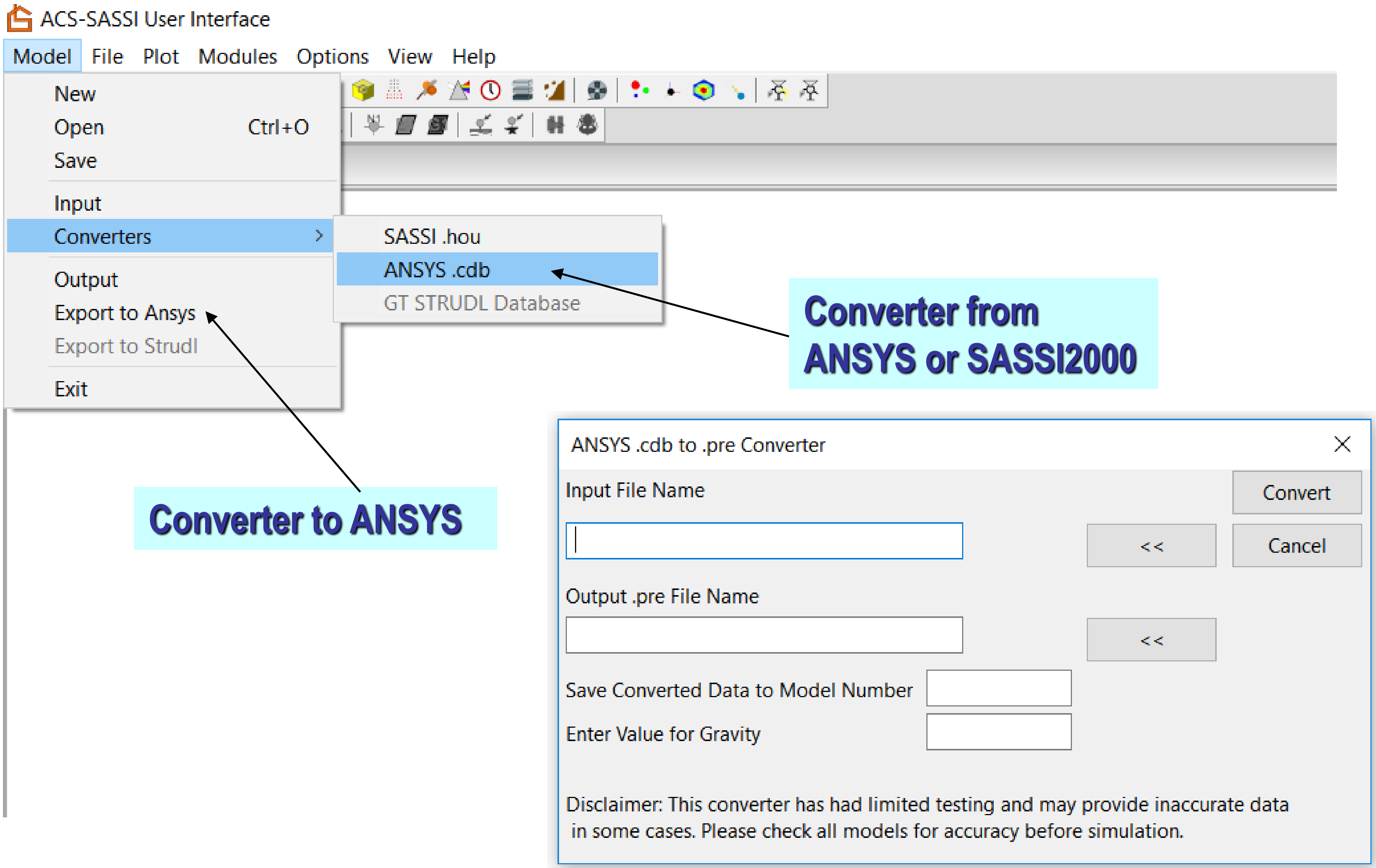
Includes 6 TF interpolation algorithms and optional TF smoothing.

Saving Stress Results, THS for Post-processing. Restart is used for generating frames for contour plots and animations for stresses and soil pressures.

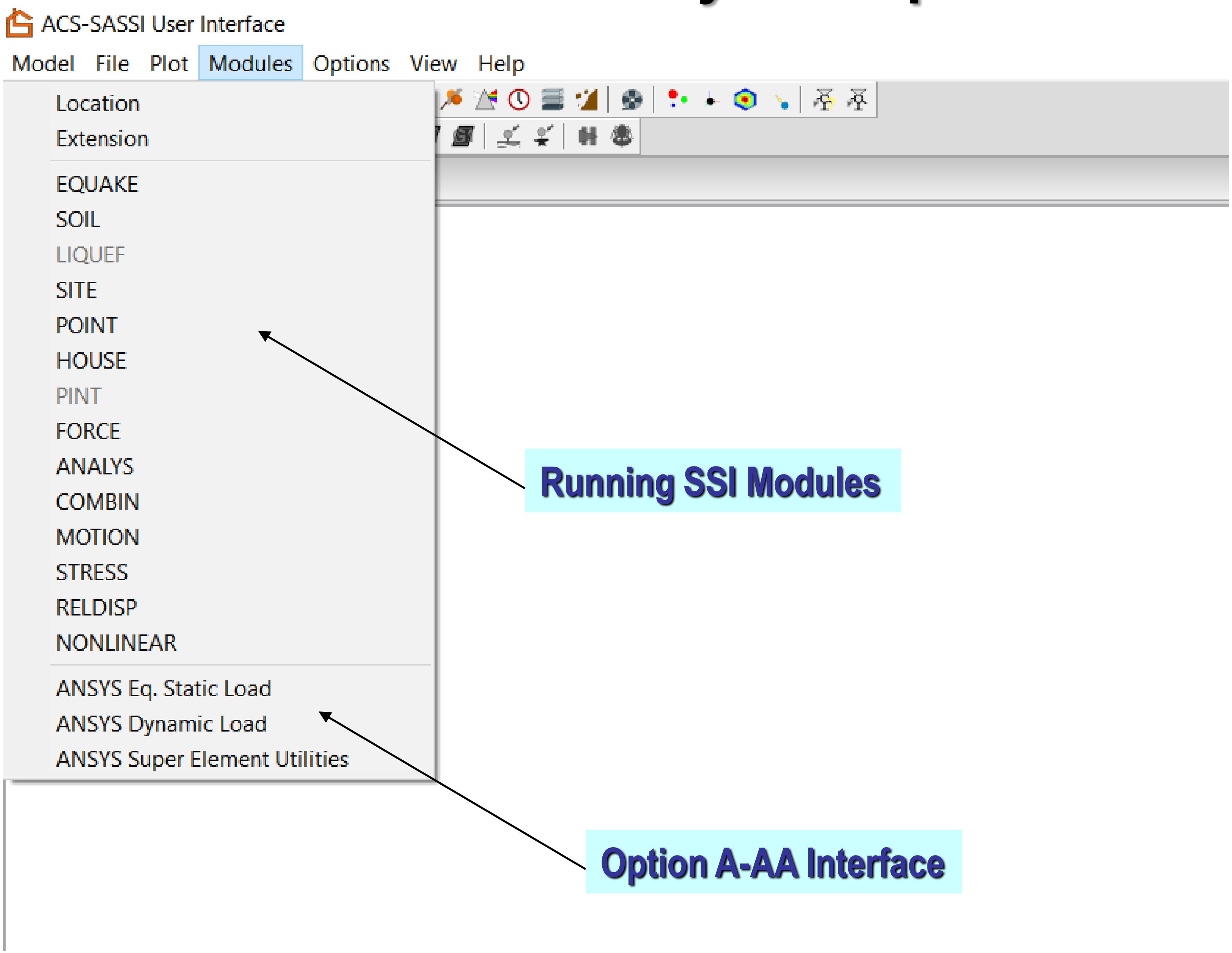
Save Inputs for SSI Analysis Run (AFWRITE)



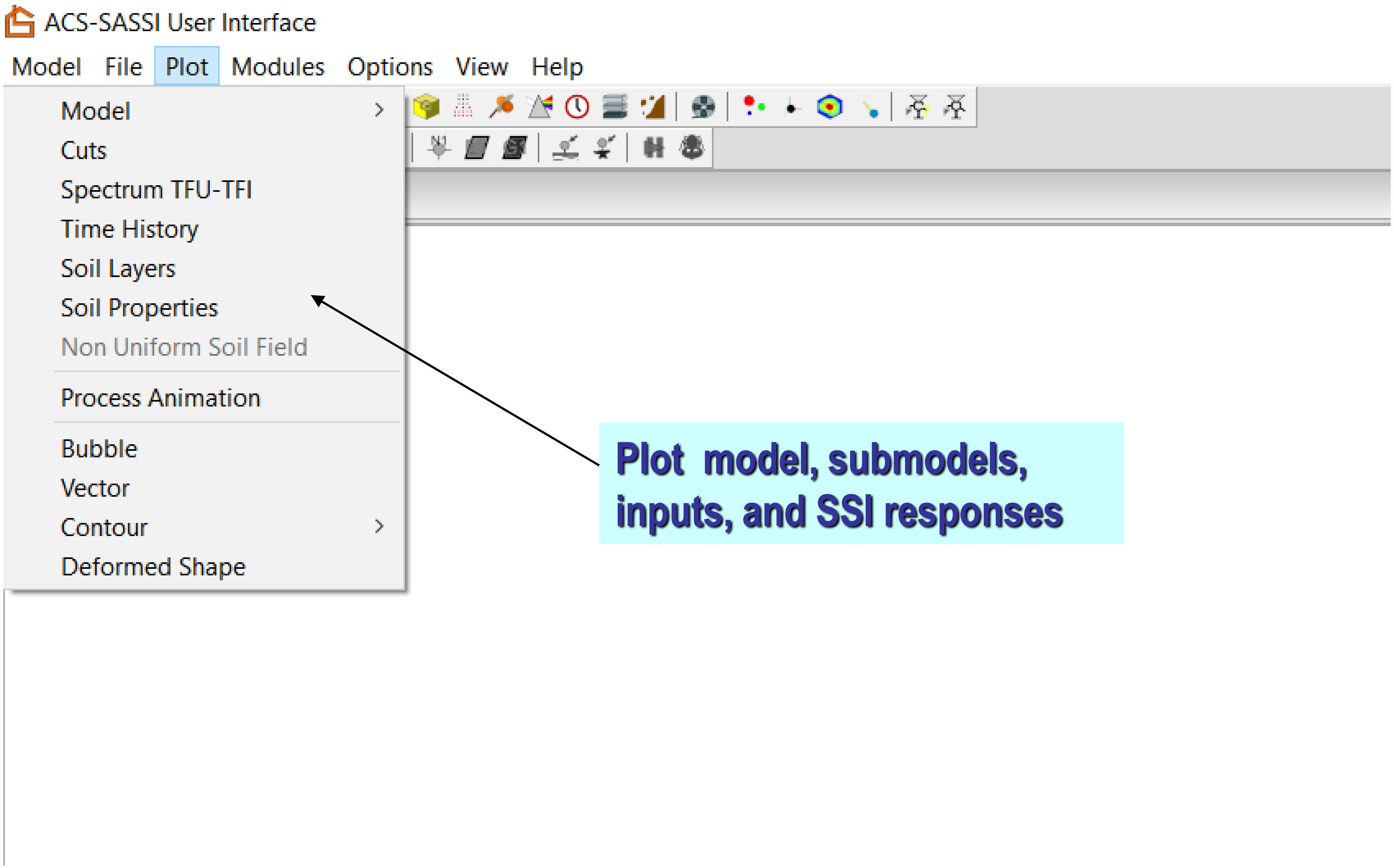
ACS SASSI Model Input File Capabilities



ACS SASSI SSI Analysis Capabilities



ACS SASSI Post Processing Capabilities



Transfer Function (TF), Response Spectra (RS) and Time History (TH) Text Files for Post-Processing

RS	Response spectra data files generated by the motion module		
	Naming Scheme for TFU, TFI, TFD, ACC Files		
	Characters 1-5	Node Number	
	Characters 6-9	Translation (TR) or Rotational (R) degree of freedom	
	Characters 10-11	Damping ratio number	
TFU	Uninterpolated acceleration transfer functions written by the motion module and stress transfer functions		
TFI	Interpolated acceleration transfer functions written by the motion module and stress transfer functions written by the stress module		
TFD	Displacement transfer functions generated by the reldisp module		
THD	Displacement time history written by reldisp module		
ACC	Acceleration time history written by motion module		
	Naming Scheme for Acceleration TFU, Acceleration TFI, TFD, THD, and ACC Files		
	Characters 1-5	Node Number	
	Characters 6-9	Translation (TR) or Rotational (R) degree of freedom	
TH	Soil time history for layers		
	Naming Scheme		
	ACC***	Acceleration time history for soil layer ***	i.e. ACC001.TH is the acceleration time history for soil layer 1
	SN***	Strain time history for soil layer ***	i.e. SN001.TH is the strain time history for soil layer 2
	SS***	Stress time history for soil layer ***	i.e. SS001.TH is the stress time history for soil layer 3
THS	Stress time history written by stress module		
	Naming Scheme for THS, stress TFU, and Stress TFI		
	etype_gnum_enum_comp		e.g. BEAMS_012_00001_FXI.THS
	etype =	element type	
	gnum =	group number	
	enum =	element number	
	comp =	stress component	
Frames.txt	Post processing frames for stress and motion		
ELEMENT_CENTER_ABS_MAX_STRESSES.TXT	List of maximum stresses for each element		
STATIC_SOIL_PRESSURES.TXT	Defines additional soil pressure (geological pressure) to be included in soil pressure frames		
SRSSTF.txt	SRSS option in motion		

3. UI Commands and Macros for Model Checking and Post-Processing

Useful UI Commands for Checking FE Models and Improving Numerical Condition, Section-Cuts

Commands for building SSI and SSSI models:
MERGESOIL, EXCAV, EXTRACTEXCAV, INTGEN, FIXEDINT, HINGED, EXCSTRCHK

Improving the FEA model numerical condition and speed/storage:
FIXROT, FIXSHELL, FIXSOLID, FIXSPRING

Section-Cut Commands:
CUTVOL, SLICE, CSECT, CALCPAR, CALCSECTHIST, etc. (see Demo 8)

Create Nonlinear Models, PANELIZE, PANELGEN, SHEAR, BBCGEN,…

SSI Model Checking UI Commands

Command	Action
EXCSTRCHK	Checks excavation nodes for potential errors
FIXEDINT	Find Fixed Interaction Nodes
FREESPRING	Find Free Spring Nodes
HINGED	Check model for possible hinged connections
KINT	Find K node that are interaction nodes
USED	Check and fix Unused nodes

EXCSTRCHK Commands

EXCSTRCHK

This command checks if the Excavation interior nodes are common with the Structure basement nodes. This will be incorrect from a SASSI modeling point of view. A list detailing the shared nodes will be printed to the command history. The number of entries in the list is controlled by the Check Options break message number.

This command does not change the active model in any way.

Useful UI Commands for SSI and SSSI Model Building and Combination

Command	Action
EXCAV	Create an Excavation volume for a model
MERGE	Merge 2 models
MERGEGROUP	Merge 2 groups together
MERGEPANEL	Merge a Panel Model to the Solids and beams of the original model
MERGESOIL	Merge a Structural Model With a Matching Soil
ROTATE	Rotate the model around a point
SOILMESH	Create a soil mesh for the active model
TRANSLATE	Translate all nodes a specified distance
WELD	Combine nodes that share the same location

Using ACS SASSI User Interface (UI) Macros. Few Examples…See also Demo 3

- Perform fast repeated UI operations easily
- Post-Process SSI results (SRSS, averaging, time superposition by algebraic summation, etc.)
- Identify missing frequencies based on ATF or STF results, and build list of new frequencies to be added
- Generate Backbone Curves for Nonlinear SSI Analysis (Option NON)
- Automate the running of SSI Analysis

Macro Basic Functions

- Macros are loaded into the UI with the LOADMACRO command
- Macros are called with the MACRO command
- Input arguments for a macro are written in the form n, where n is the number of the argument, i.e. 1 is the first input argument, 2 is the second, etc.
  - In the example below, the macro call would look like **macro,srss,.\XDIR\00001TR_X01.rs,.\YDIR\00001TR_X01.rs,.\ZDIR\00001TR_X01.rs,.\SRSS\00001TR_X01_SRSS.rs**
  - From this example, the first argument is the X-Direction .rs file, the second is the Y-Direction .rs file, the third is the Z-Direction .rs file, and the last argument is the file to save the computed SRSS to.

```
* Compute SRSS
READSPEC,$1$,1,1
READSPEC,$2$,1,2
READSPEC,$3$,1,3
SRSS,4,1,2,3
WRITESPEC,$4$,4
```

Nested Macros for Efficient Post-Processing

Macros can be nested to easily perform repeated operations. This example calls the nesting macro to pass file name information to the macro performing the SRSS operation. The nesting macro is passed file name information from the top level .pre file, looping through nodes to build file names to pass to the nesting macro with the FOREACH command.

Top Level .pre File Calling Nesting Macro

```
* Define Variables
mdl,temp,<work folder>\Coherent\Post-Processing
var,path,.
loadvar,nodes,@Path[1]\Nodes.txt

* Load Macros
loadmacro,srss,SRSS-macro.pre
loadmacro,nestSRSS,Nested-SRSS.pre

* Combine Results
foreach,nodes,macro,nestSRSS,@nodes[#],01,X,@path[1]
```

Macro Calling SRSS Macro (Nested-SRSS.pre)

```
* NEST SRSS
macro,srss,$4$\XDIR\$1$TR_$3$$2$.rs,$4$\YDIR\$1$TR_$3$$2$.rs,
$4$\ZDIR\$1$TR_$3$$2$.rs,$4$\Combined\ISRS\$1$TR_$3$$2$.RS
```

Macro to Perform SRSS Calculation (SRSS-macro.pre)

```
* SRSS MACRO
READSPEC,$1$,1,1
READSPEC,$2$,1,2
READSPEC,$3$,1,3
SRSS,4,1,2,3
WRITESPEC,$4$,4
```

Section-Cuts Capability Using ESTRESS Frames

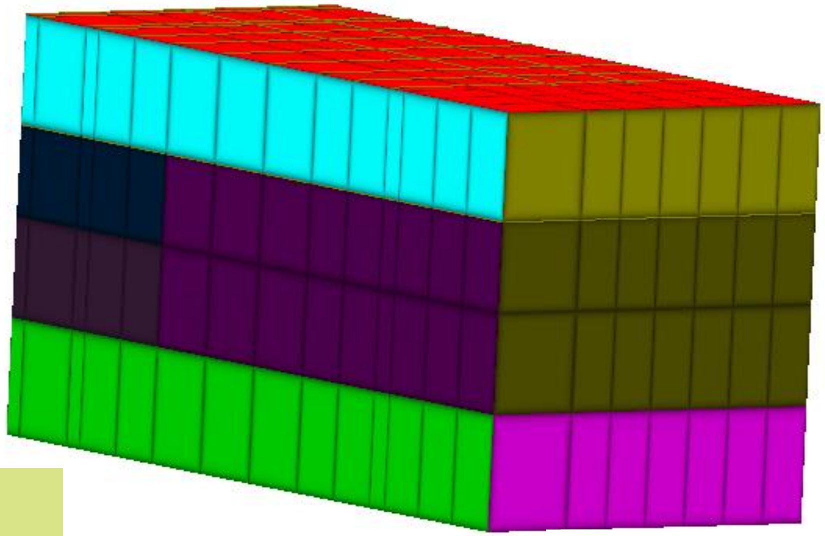
The UI Section-Cut capability has two options:

1) Uses *a single frame of stress data* (single .ess frame file) to compute the section-cut forces and moments on a cross-section at a specific time step.

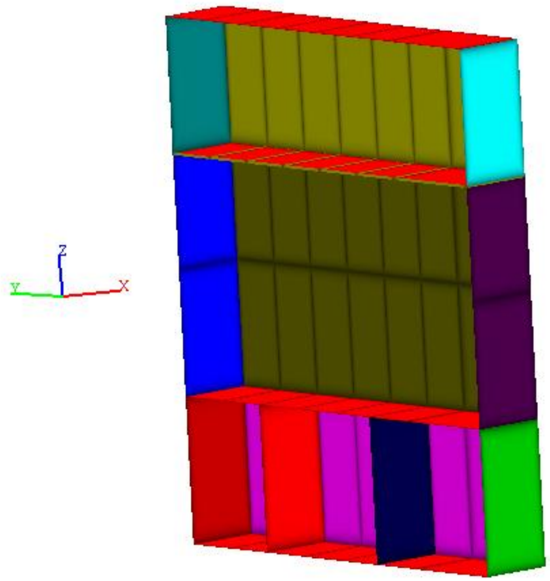
2) Uses a *multiple frames of stress data* (all .ess frame files) to compute the full time-history of the section-cut forces and moments.

Demo 8

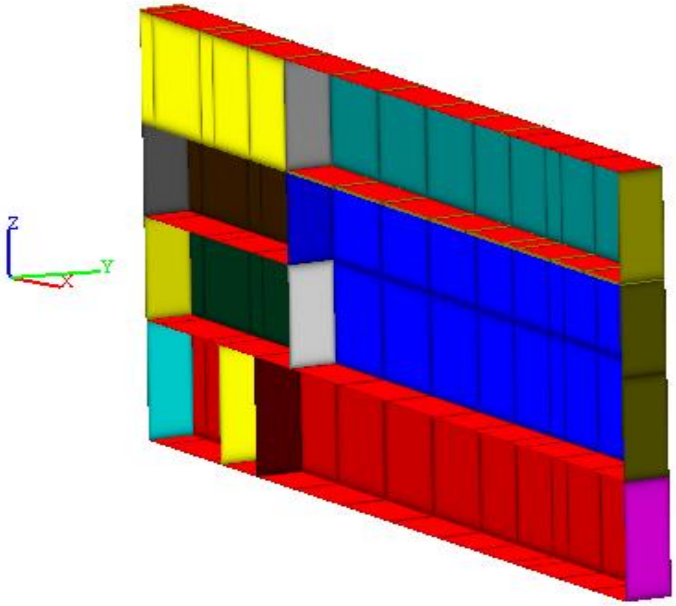
Section-Cut Submodel Models



Transverse Wall



Longitudinal Wall



Section-Cut for Single ESTRESS Stress Frame

* Read element center stress frame

READSTR, estress_02617.ess, C:\DEMOS\DEMO8\ESS_STRESS

*For the 1st section-cut in the SUBMODELER command line, type

CUTVOL,1,132.4

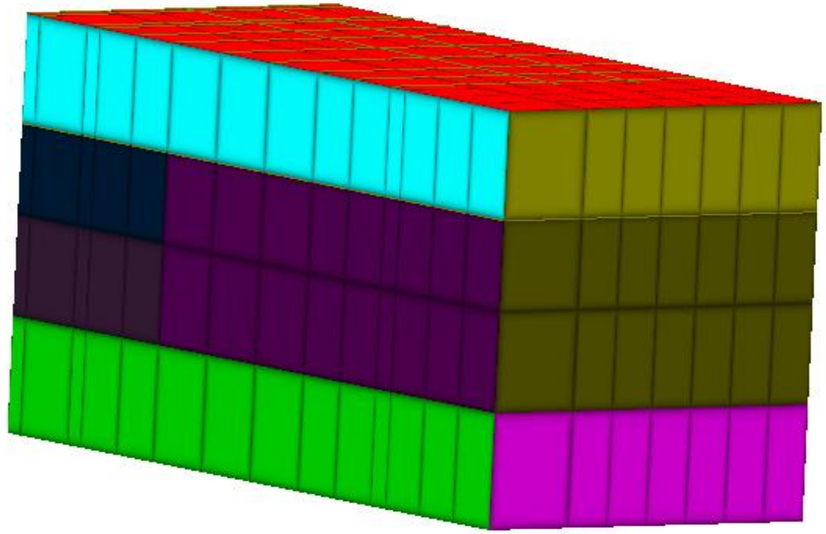
*The blank arguments to this command are interpreted as the respective
*minimum or maximum extent of the building model geometry. This cut volume
*is saved to cut #1.

CSECT,1,1,0,0,15.3,0,0,1

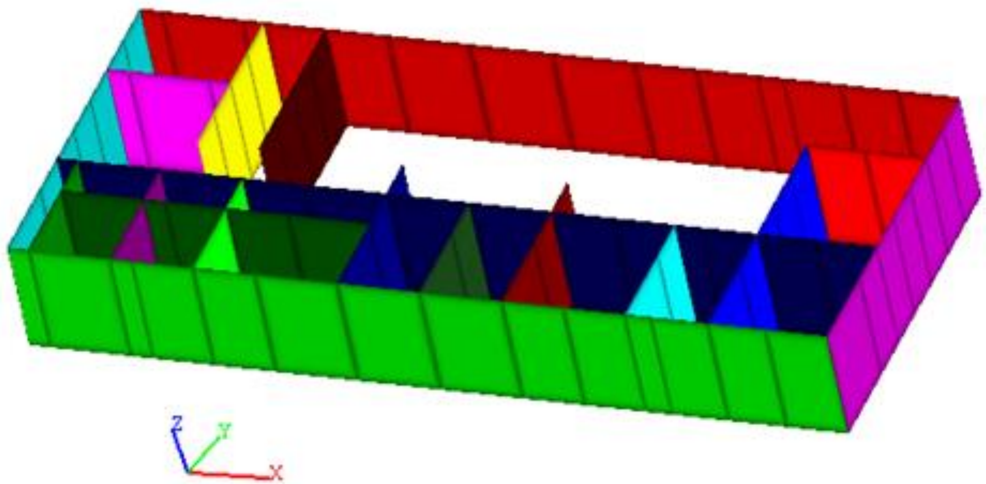
*This creates a cross-section model from cut #1 through point (0.0, 0.0, 15.3),
*with a cross-section plane normal unit vector of (0.0, 0.0, 1.0). The cut cross-
*section is saved to model #1

CALCPAR, 0.0, 0.0, 1.0, 1.0, 0.0, 0.0" in the command SUBMODELER window to calculate the cross-section parameters, seismic forces and moments

Section-Cut for Time History ESTRESS Frames



Section-Cut Model



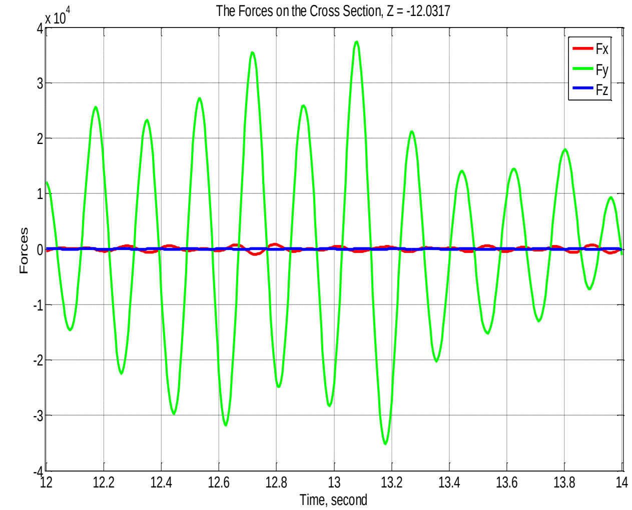
CALCSECTHIST Command Example

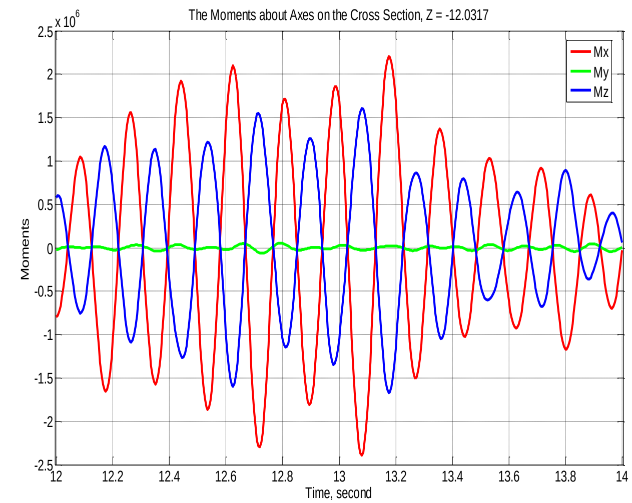
```
*
*Batch .pre input file of section cut for multiple frame data
*
actm,0
*Replace Directory Path
inp,demo8.pre,C:\DEMO_PROBLEMS\DEMO8\
*
* Define structure component to be cut
slice,1,0.0,0.0,-12.0317,0.0,0.0,1.0
*
* Cut the selected structure component using cutting plane
* Calculate the parameters on it, and output to given file
Calcsecthist,C:\DEMO_PROBLEMS\DEMO8\estr_frame_files.lst,1,0.0,0.0,-
12.0317,0.0,0.0,1.0,1.0,0.0,0.0,1,.005,C:\DEMO_PROBLEMS\DEMO8\frc_mmt
_on_cut02.txt

* output cross sections for visualization with PREP (optional)
cut2sub,1,1
actm,1
write,Slice.pre,C:\DEMO_PROBLEMS\DEMO8\
```

CALCSECTHIST Results

C:\DEMO_PROBLEMS\DEMO8\frc_mmt_on_cut02.txt file:

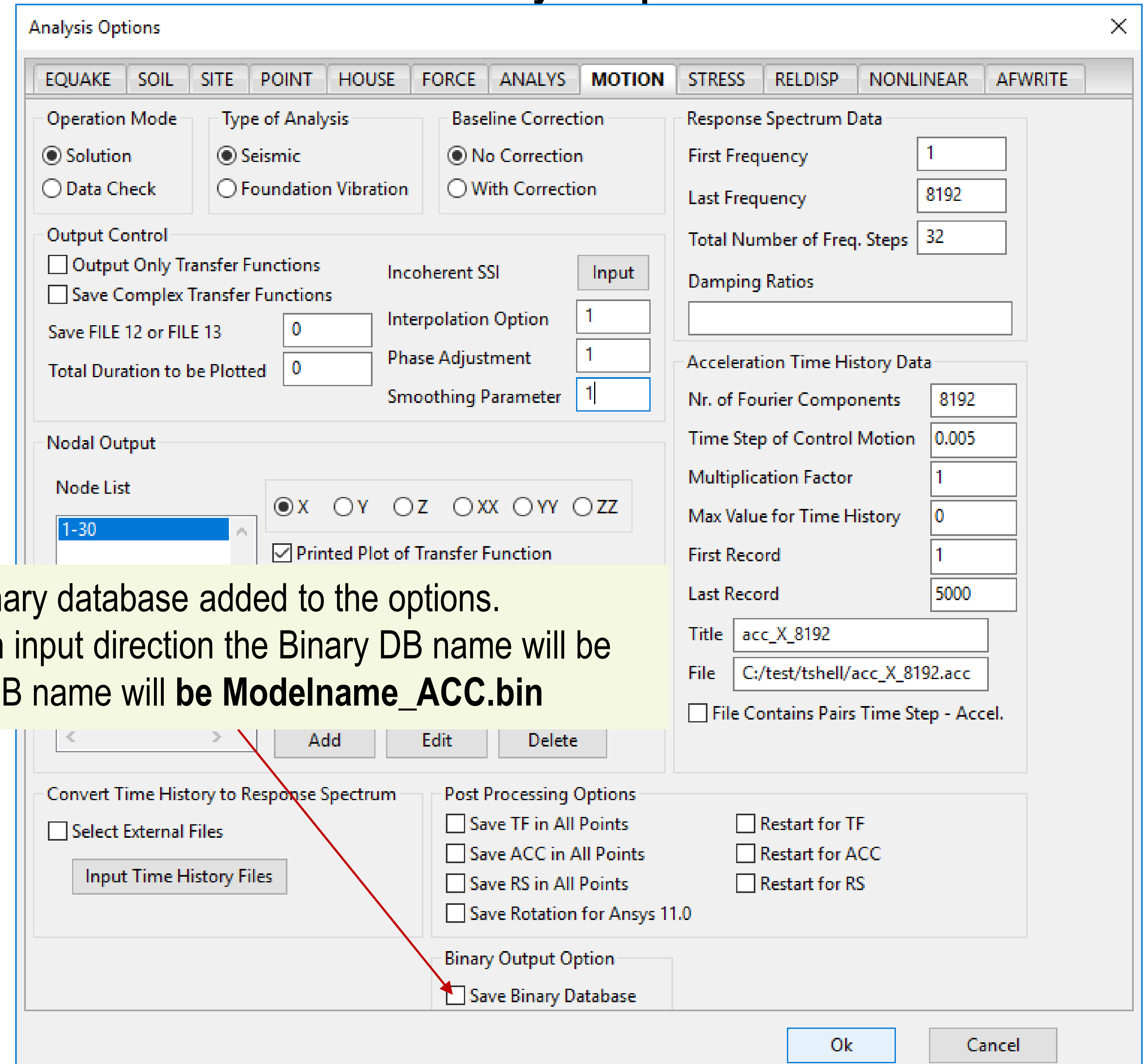
0.005 -343.777 12065.2 0.229168 -800746 -21965.1 581499
0.01 -268.056 11539.5 0.300395 -779248 -16700.6 600032
0.015 -189.851 10623.5 0.294853 -733816 -10990.5 593052
0.02 -114.229 9320.15 0.227868 -665089 -5282.46 558887
0.025 -44.3936 7645.78 0.144148 -573880 2.20757 497620
0.03 18.0423 5647.78 0.0908182 -461901 4514.26 411756
0.035 72.3351 3391.01 0.0894927 -331126 8011.35 305474
0.04 117.752 967.345 0.124164 -184604 10378.6 184558
... ...
1.97 -676.309 9226 0.149393 -698463 -42784.3 401711
1.975 -631.161 8753.78 0.143451 -677218 -40340.6 396997
1.98 -553.34 7862.11 0.158777 -627501 -35783.4 376102
1.985 -450.432 6584.62 0.16545 -550419 -29410.2 339107
1.99 -330.715 4981.56 0.133199 -448530 -21628.8 287164
1.995 -202.2 3116.14 0.0512961 -325035 -12940.6 221694
2 -72.0058 1058.89 -0.0630017 -184306 -3907.81 144578
2.005 53.7767 -1132.73 -0.172686 -30951.4 4886.85 57394.5





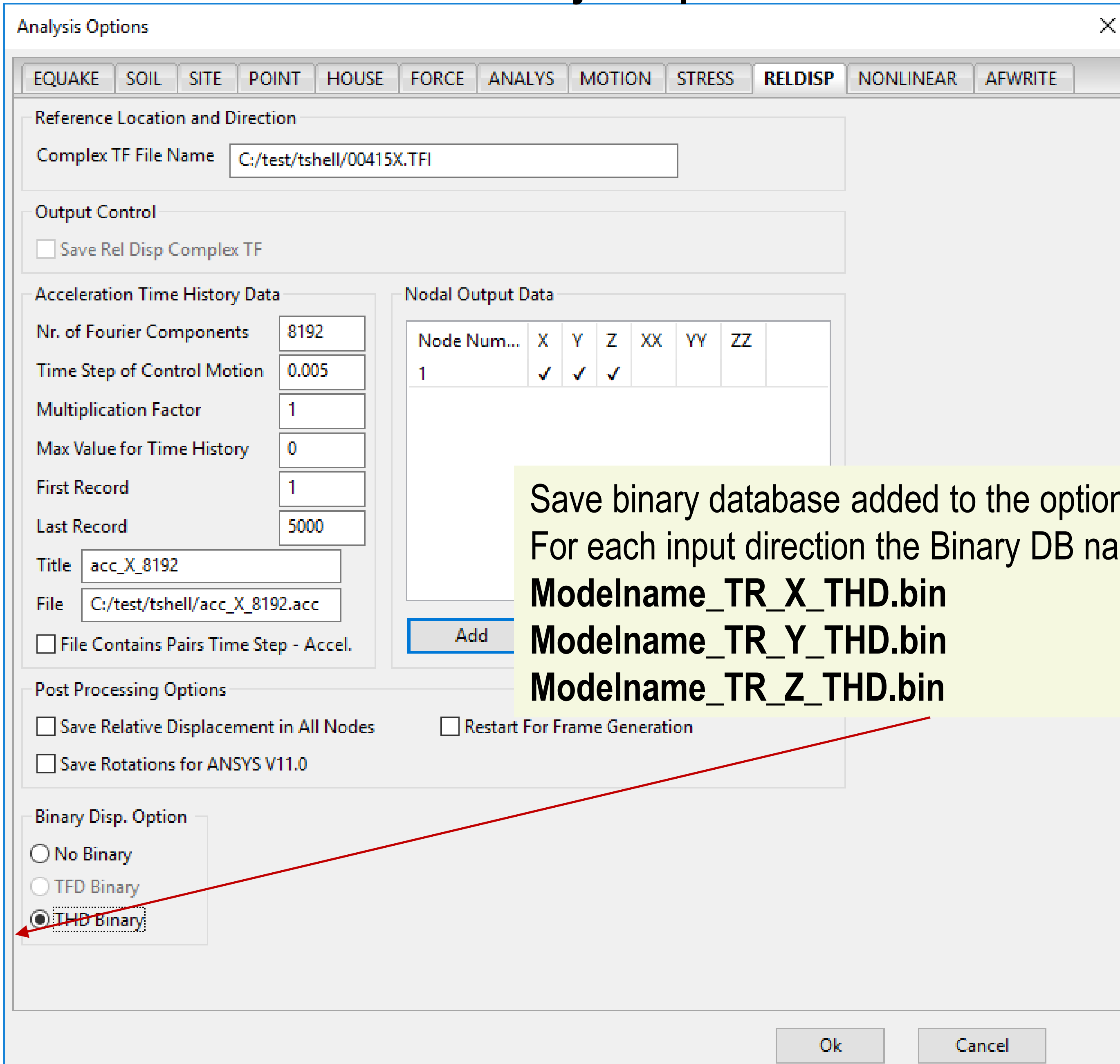
4. UI Commands for Fast Post-Processing of SSI Response Time Histories Using Compressed Binary Databases

MOTION Analysis Options



Save binary database added to the options.
For each input direction the Binary DB name will be
Binary DB name will **be Modelname_ACC.bin**

RELDISP Analysis Options



Save binary database added to the options

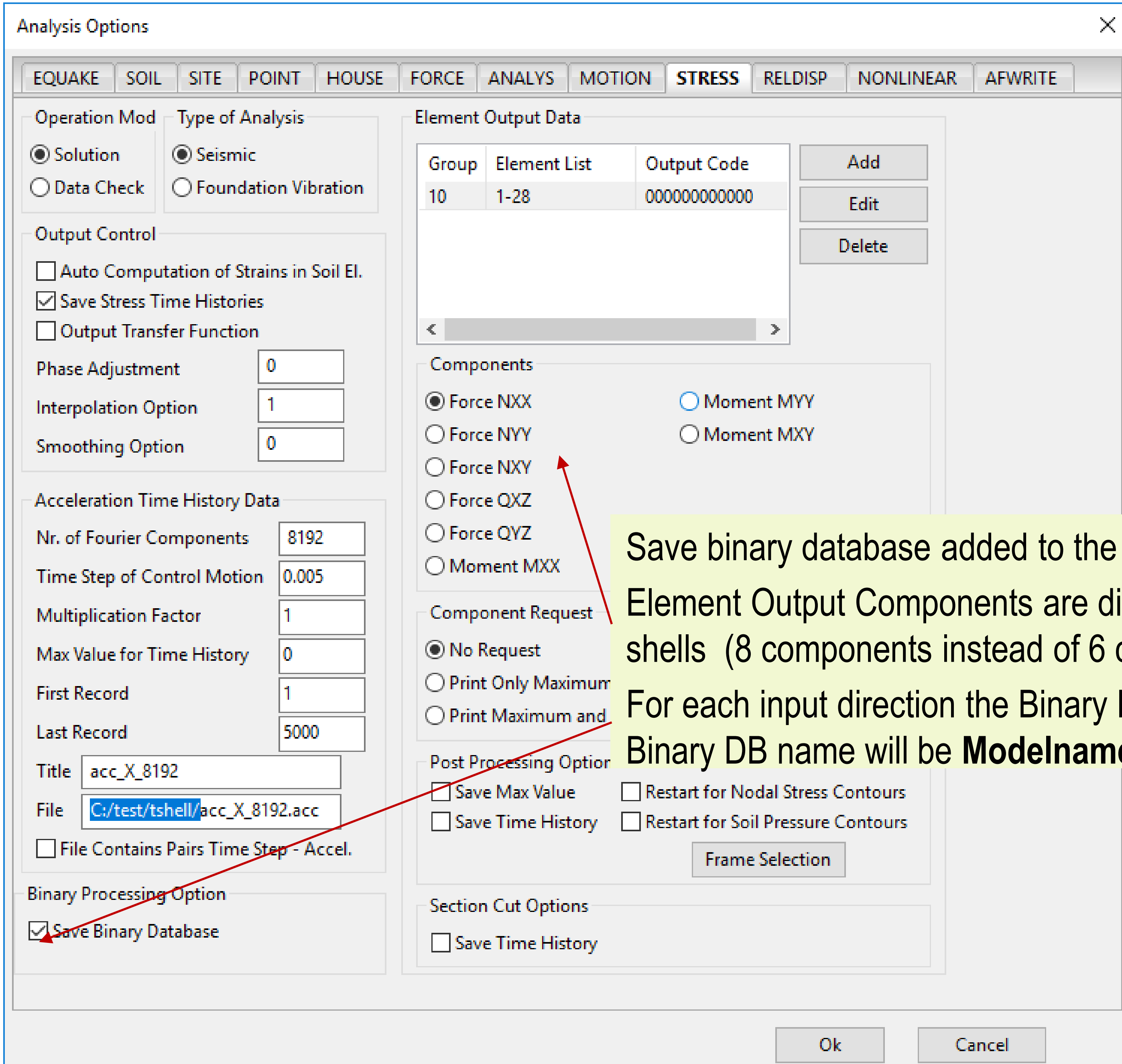
For each input direction the Binary DB name will be

Modelname_TR_X_THD.bin

Modelname_TR_Y_THD.bin

Modelname_TR_Z_THD.bin

STRESS Analysis Options



Save binary database added to the options

Element Output Components are different for thick shells (8 components instead of 6 components)

For each input direction the Binary DB name will be Binary DB name will be **Modelname_STRESS.bin**

SSI Response History Post-Processing Options

User Interface:

Binary Databases:

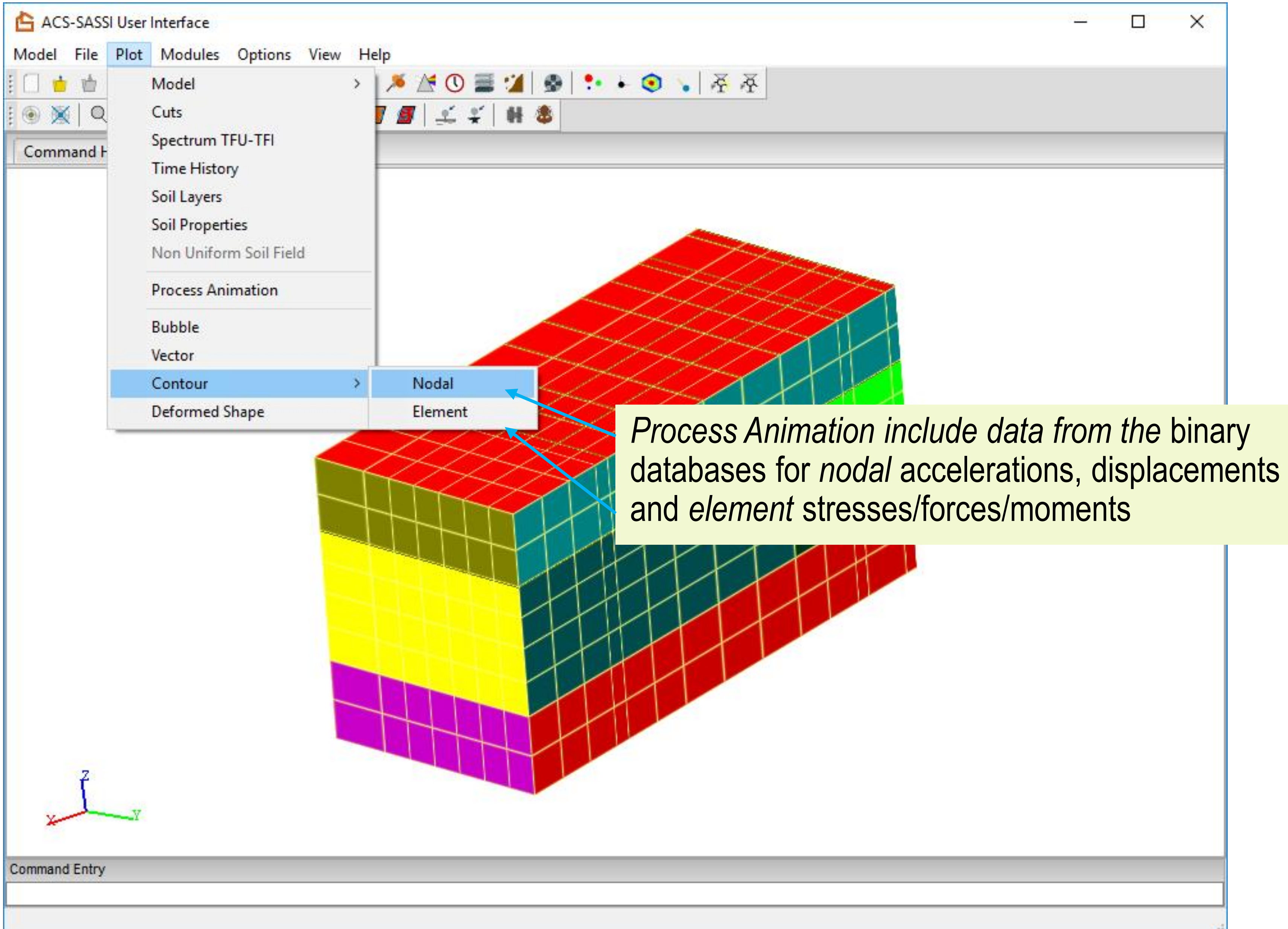
- Generate BDBs for each input direction; select flag for BDB
- Combine BDBs for three inputs XYZ using UI commands
- Use the XYZ combined BDB to extract frames at selected time steps or maximum values (text frame tables)
- UI commands are designed for extracting selected time histories from BDB and tables at given times or with maximum values

UI Extracting STRESS Maximum Element Outputs

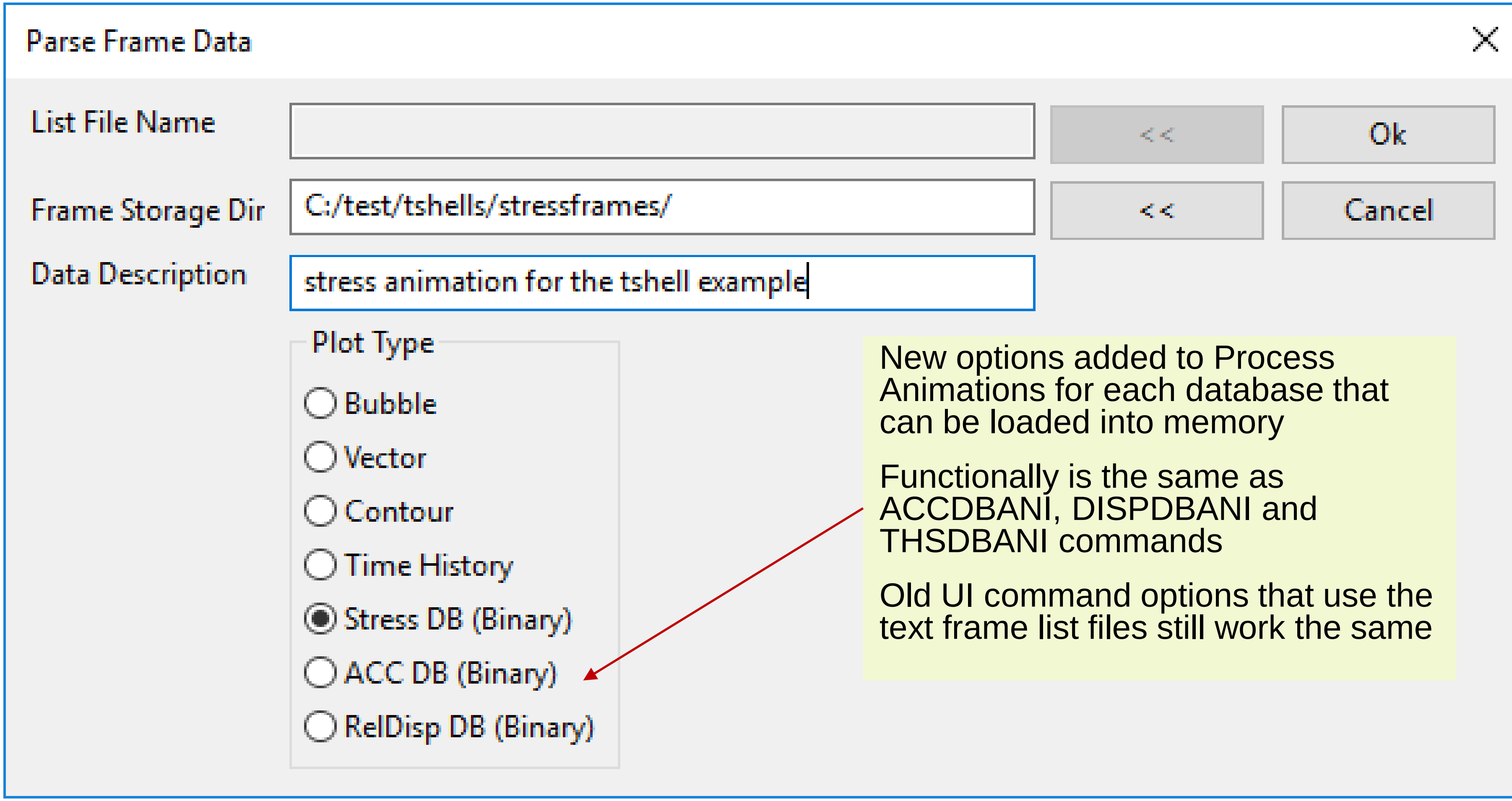
```
LOADTHSDB,C:\ACSV300\DEMO_PROBLEMS\DEMO9\XYZ_Analysis\STRESS\Combined\THS\AB_SHEAR_NL_STRESS.BIN
Database read took 3.906000 Seconds
LOADVAR,elist,C:\ACSV300\Demo_Problems\Demo9\XYZ_Analysis\element_output_list.txt
Variable Loaded Sucessfully from file
BINSTRTBL,34,elist,1,C:\ACSV300\Demo_Problems\Demo9\XYZ_Analysis\STRESS_MAX.txt
Table File : C:\ACSV300\Demo_Problems\Demo9\XYZ_Analysis\STRESS_MAX.txt  written
```

Gr.	Elem.	SXX	SYY	TXY	MXX	MYY	MXY
34	1	0.0619	1.3769	1.7051	0.2896	0.2343	0.3228
34	2	0.0092	1.6048	2.6930	0.2101	0.8928	0.1681
34	3	0.1953	1.0696	2.6461	0.5233	0.8652	0.1771
34	4	0.1861	0.7625	2.1855	0.2927	1.1031	0.1119
34	5	0.0589	0.8005	4.2785	0.5619	1.8940	0.0472
34	6	0.0849	0.7012	4.9323	0.8285	1.8190	0.1373
34	7	0.0262	0.6604	3.4275	0.6116	0.2215	0.4655
34	8	0.0329	0.4823	1.7195	0.2640	1.7506	0.5377
34	9	0.0498	0.7906	1.7139	0.7083	1.3001	0.2326
34	10	0.0864	0.5886	2.4700	0.5667	0.5384	0.1734

UI Plot Nodal Contours Using Binary Databases



UI Processing for Node or Element Animation Frame Lists for ACC, THD and THS Histories



New options added to Process Animations for each database that can be loaded into memory

Functionally is the same as ACCDBANI, DISPDBANI and THSDBANI commands

Old UI command options that use the text frame list files still work the same

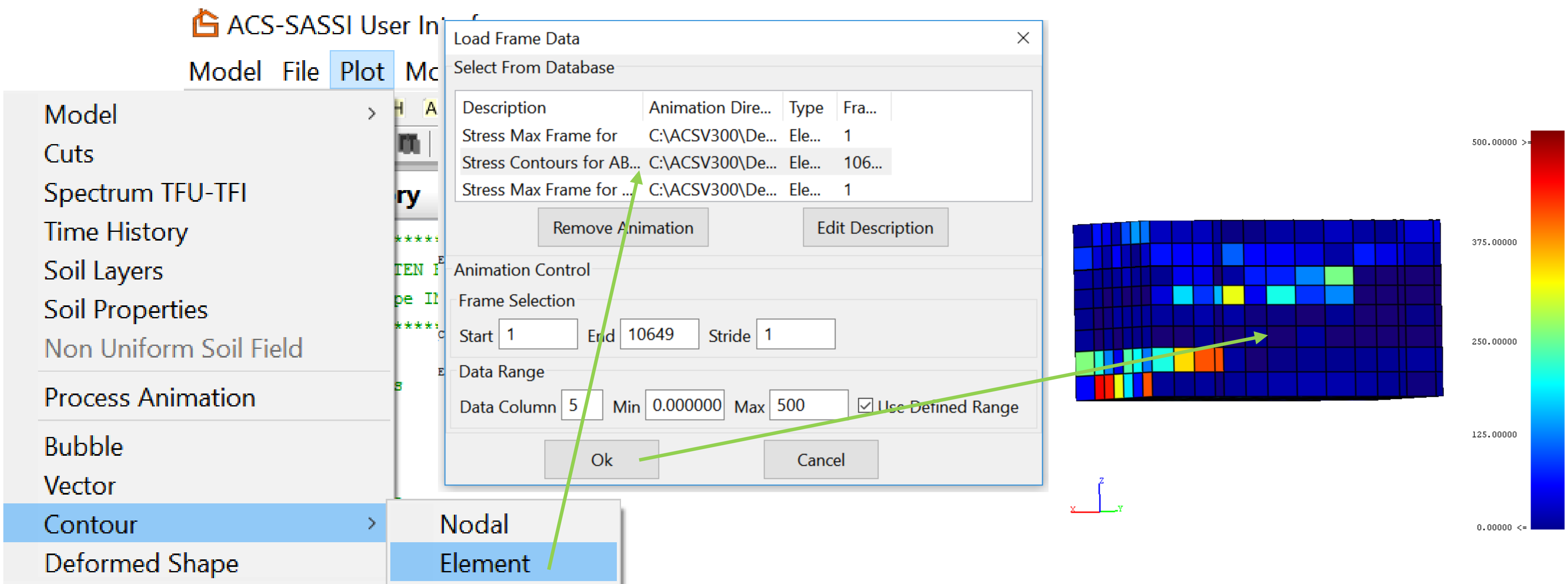
Plotting STRESS History of Max Element Outputs

```
INPUT FILE REACHED EOF, INPUT SWITCHED TO KEYBOARD
LOADTHSDB,C:\ACSV300\DEMO_PROBLEMS\DEMO9\XYZ_Analysis\STRESS\Combined\THS\AB_SHEAR_NL_STRESS.BIN
Database read took 7.110000 Seconds
LOADVAR,elist,C:\ACSV300\Demo_Problems\Demo9\XYZ_Analysis\element_output_list.txt
Variable Loaded Sucessfully from file
MAXDBFRAME,THS,C:\ACSV300\Demo_Problems\Demo9\XYZ_Analysis\STRESS\Combined\THS\Max_Frame_Contour
Max Frame added user interface animation database
```

1

1-10649

THSDBANI,C:\ACSV300\Demo_Problems\Demo9\XYZ_Analysis\STRESS\Combined\THS\All_Frame_Contour



Post-Processing SSI Responses Using Binary Databases Described in Detail in Demo 13

*** Define Variable for Working Directory**
VAR,PATH,C:\ACSV300\Demo_Problems\Demo13

*** Combining Three-Direction Response RELDISP Displacement Binary Databases for Each Seismic Input**
COMBDISPDIR,@PATH[1]\XDIR\ABShear_TR_X_thd.bin,@PATH[1]\XDIR\ABShear_TR_Y_thd.bin,@PATH[1]\XDIR\ABShear_TR_Z_thd.bin,@PATH[1]\XDIR\ABShear_thd.bin
COMBDISPDIR,@PATH[1]\YDIR\ABShear_TR_X_thd.bin,@PATH[1]\YDIR\ABShear_TR_Y_thd.bin,@PATH[1]\YDIR\ABShear_TR_Z_thd.bin,@PATH[1]\YDIR\ABShear_thd.bin
COMBDISPDIR,@PATH[1]\ZDIR\ABShear_TR_X_thd.bin,@PATH[1]\ZDIR\ABShear_TR_Y_thd.bin,@PATH[1]\ZDIR\ABShear_TR_Z_thd.bin,@PATH[1]\ZDIR\ABShear_thd.bin

*** Combining SSI Responses Computed for X, Y and Z Inputs Using Binary Databases for MOTION, RELDISP and STRESS**
COMBACCDB,@PATH[1]\XDIR\ABShear_ACC.bin,@PATH[1]\YDIR\ABShear_ACC.bin,@PATH[1]\ZDIR\ABShear_ACC.bin,@PATH[1]\Combined\ABShear_ACC.bin,0
COMBDISPDB,@PATH[1]\XDIR\ABShear_thd.bin,@PATH[1]\YDIR\ABShear_thd.bin,@PATH[1]\ZDIR\ABShear_thd.bin,@PATH[1]\Combined\ABShear_thd.bin,0
COMBTHSDB,@PATH[1]\XDIR\ABShear_STRESS.bin,@PATH[1]\YDIR\ABShear_STRESS.bin,@PATH[1]\ZDIR\ABShear_STRESS.bin,@PATH[1]\Combined\ABShear_STRESS.bin,0

*** Loading Binary Databases into the ACS SASSI UI for Fast SSI Response History Post-Processing**
LOADACCDB,@PATH[1]\Combined\ABShear_ACC.bin
LOADDISPDB,@PATH[1]\Combined\ABShear_THD.bin
LOADTHSDB,@PATH[1]\Combined\ABShear_STRESS.bin

Post-Processing SSI Responses Using Binary Databases Described in Detail in Demo 13

*** Plotting and Saving Results as Text Files from Binary Databases**
* Nodal Accelerations (MOTION Module)
ACCDBANI,@PATH[1]\Combined\ACC,Demo 13 Acceleration Time History
MAXDBFRAME,ACC,@PATH[1]\Combined\ACC_Max

* Nodal Relative Displacements (RELDISP Module)
DISPDBANI,@PATH[1]\Combined\THD,Demo 13 Relative Displacement
MAXDBFRAME,DISP,@PATH[1]\Combined\THD_Max

* Element Stresses/Forces (STRESS Module)
THSDBANI,@PATH[1]\Combined\STRESS,Demo 13 Stress Contour
MAXDBFRAME,THS,@PATH[1]\Combined\Stress_Max

* Saving Binary Database Results to Text Files
VAR,OUTNODES,63,137,205,219,253,271
VAR,OUTELEM,1,2,3,4,5,6,7,8,9,10,11,12,13,14

* Accelerations (MOTION Module)
ACCDBTHFILE,OUTNODES,1,@PATH[1]\COMBINED
BINFRAMEOUT,ACC,-1,0,0,@PATH[1]\Combined
BINFRAMEOUT,ACC,1000,0,0,@PATH[1]\Combined
BINFRAMEOUT,ACC,5.5,0.005,0,@PATH[1]\Combined

* Displacement (RELDISP Module)
DISPDBTHFILE,OUTNODES,1,@PATH[1]\COMBINED

* Stress (STRESS Module)
THSDBTHFILE,19,OUTELEM,1,@PATH[1]\Combined
BINSTRTBL,19,OUTELEM,-1,@PATH[1]\Combined\Group19_Max_Stress.txt
BINSTRTBL,19,OUTELEM,1000,@PATH[1]\Combined\Group19_tstep_1000_Stress.txt

A list of nodes or elements must be assigned to an ACS SASSI UI variable when saving specific nodes or elements to text files. These are not required when saving a frame containing all nodes or elements

The output direction is controlled by this argument, so 1 = X, 2 = Y, and 3 = Z

Use **ACC**, **DISP**, or **THS** for this argument in the BINFRAMEOUT command to save frames for acceleration, displacement, or stress, respectively

The output group number and stress component is controlled by this arguments, respectively

Coordinate Transformation for Forces and Moments in Shell Elements – Details in Demo 14

To apply coordinate transformations to element forces and moments, the requested elements must first be added to a (section cut) submodel in the ACS SASSI UI.

This submodeling operation conveniently allows for multiple walls or floors to be stored independently without having to redefine any grouping currently present in the model, as well as plotted separately to visualize the elements selected to apply coordinate transformation to.

Coordinate Transformation Commands

For Planar Geometry - CTRVEC,1,0,1,0,@PATH[1],MAX
For Cylindrical Geometry - CTRCCV,2,@PATH[1],MAX

Defines a vector for the X-axis of the coordinate system to transform to. CTRCCV does not require this argument, as it is calculated internally for the cylindrical surface

Some Useful Commands for Selecting Elements t

CutAdd,<cut num>,<group num>,<elem 1>, … <elem N>
CutAdd,<cut num>,<group num>,RANGE,<elem start>,[elem end], [stride]
CutVol,<cutnum>,[Xmin],[Xmax],[Ymin],[Ymax],[Zmin],[Zmax]
SLICE,<cutnum>,<pointx>,<pointy>,<pointz>,<normalx>,<normaly>,<normalz>

5. Option A-AA

ACS SASSI-ANSYS Interfacing

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)*

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)*:

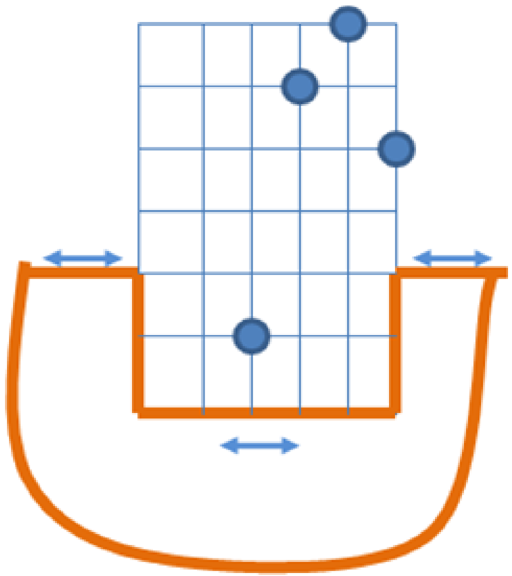
- *ANSYS Equivalent-Static Seismic SSI Analysis* Using Refined FE Models (including refined mesh, element types including local nonlinearities, nonlinear materials, contact elements, etc.)
- *ANSYS Dynamic Seismic SSI Analysis* Using More Refined FE Models (including refined mesh, element types including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

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

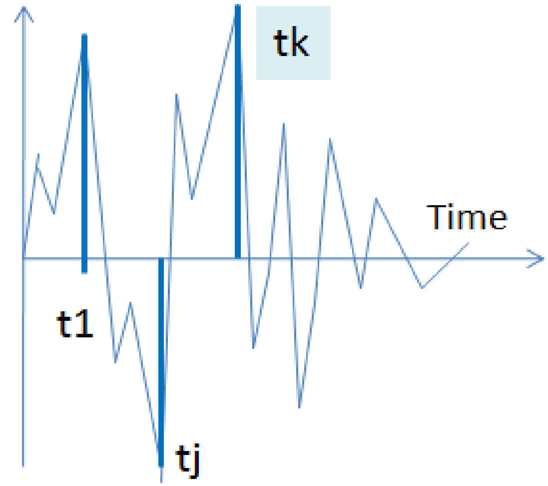
- *ANSYS Equivalent-Static Seismic Soil Pressure Computation* including Soil-Foundation Separation Effects

ACS SASSI Seismic SSI Analysis

Computing Structural Stress/Forces

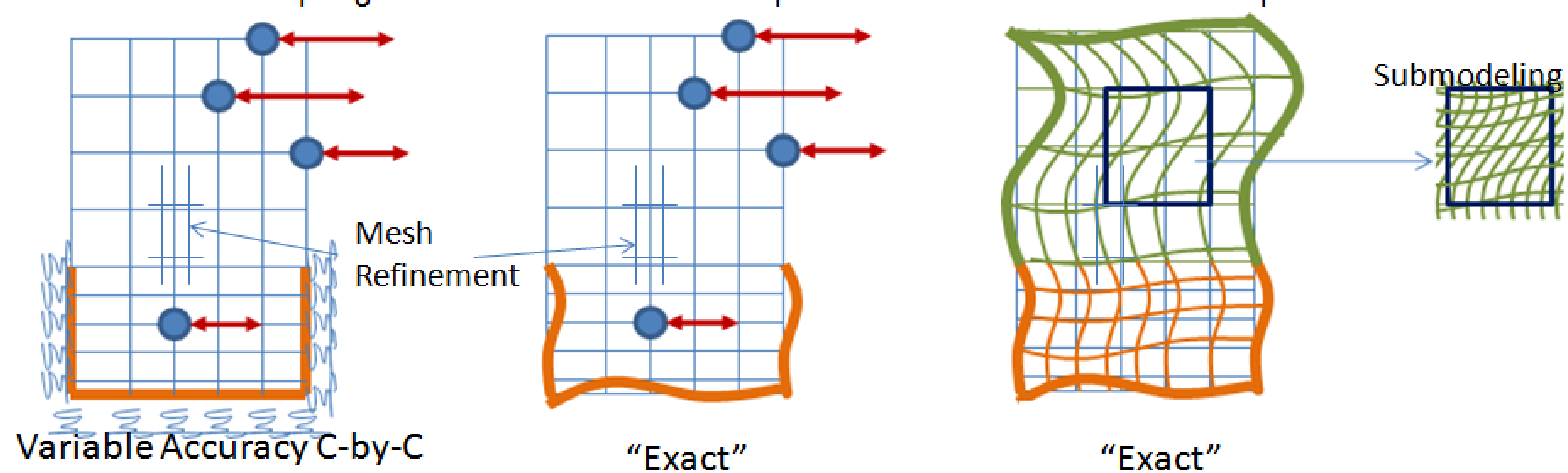


Selected Critical Time Steps for Maximum Stresses
To be Used for Equivalent Static Structural Analysis

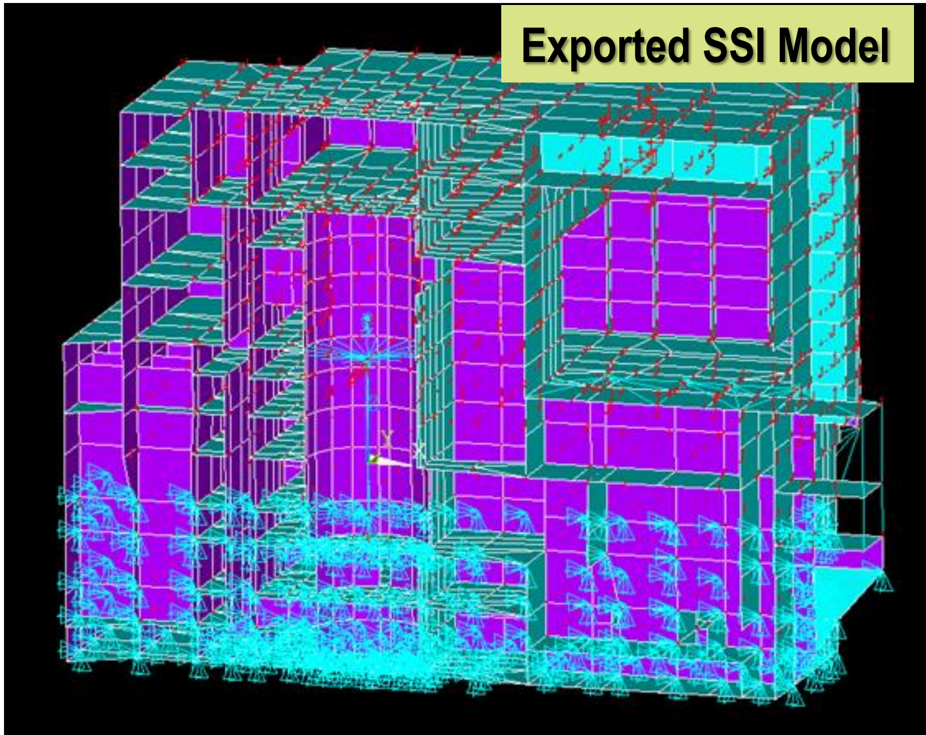


SSI Solution Time Frames As Equivalent Static Structural Loading at Critical Time Steps

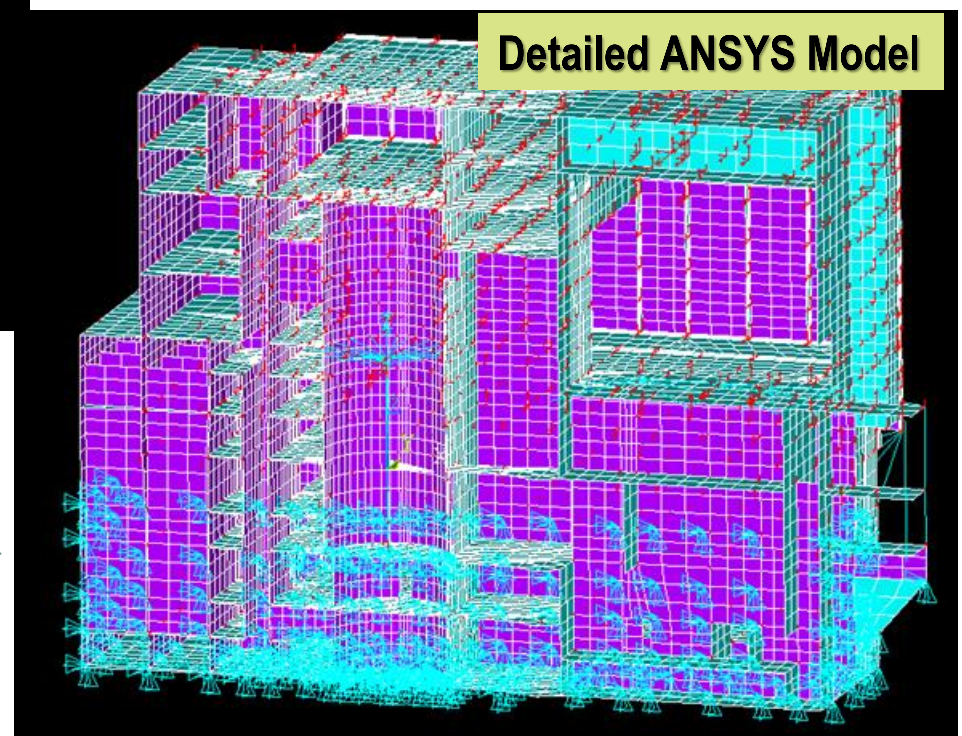
EQS Forces + BC Springs | EQS Forces + BC Displacements | EQS Relative Displacements



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



ANSYS Structural Model Automatically Converted From ACS SASSI Using PREP Module

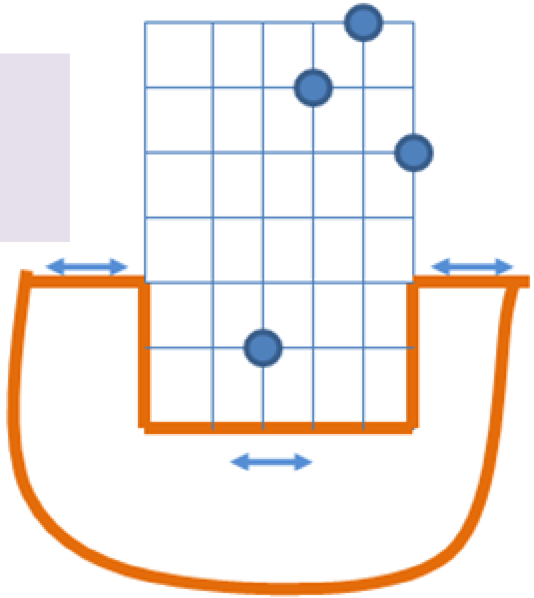


ANSYS Refined Structural Model Using EREFINE command or ANSYS GUI (rank 1-6)

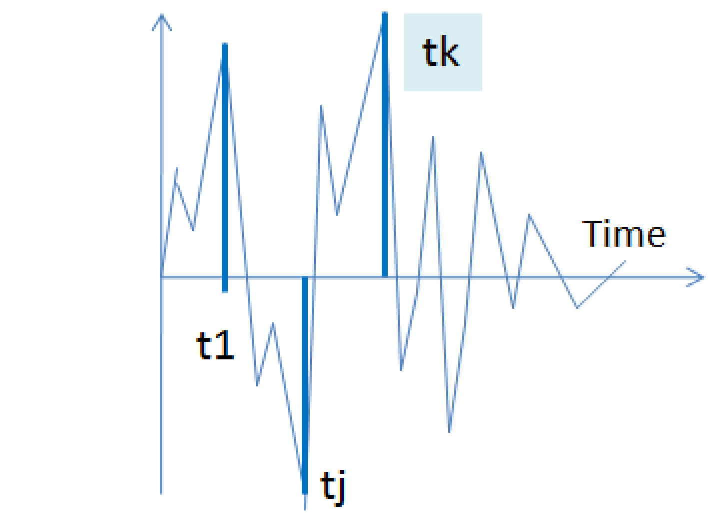
Demo 5

ACS SASSI Seismic SSI Analysis

Computing Seismic Soil Pressures



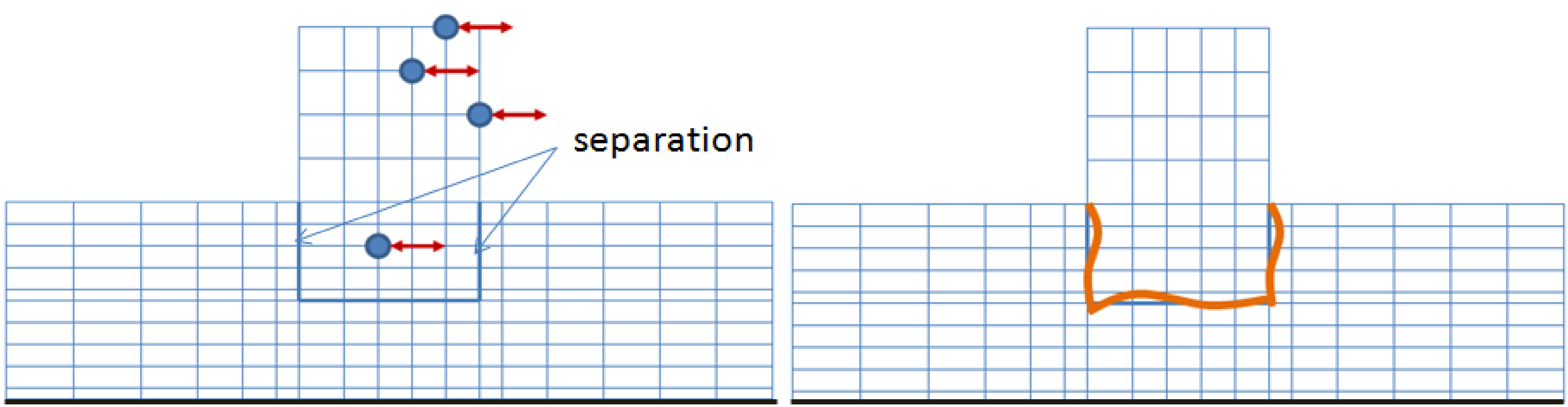
Selected Critical Time Steps for Maximum Stresses
To be Used for Equivalent Static Structural Analysis



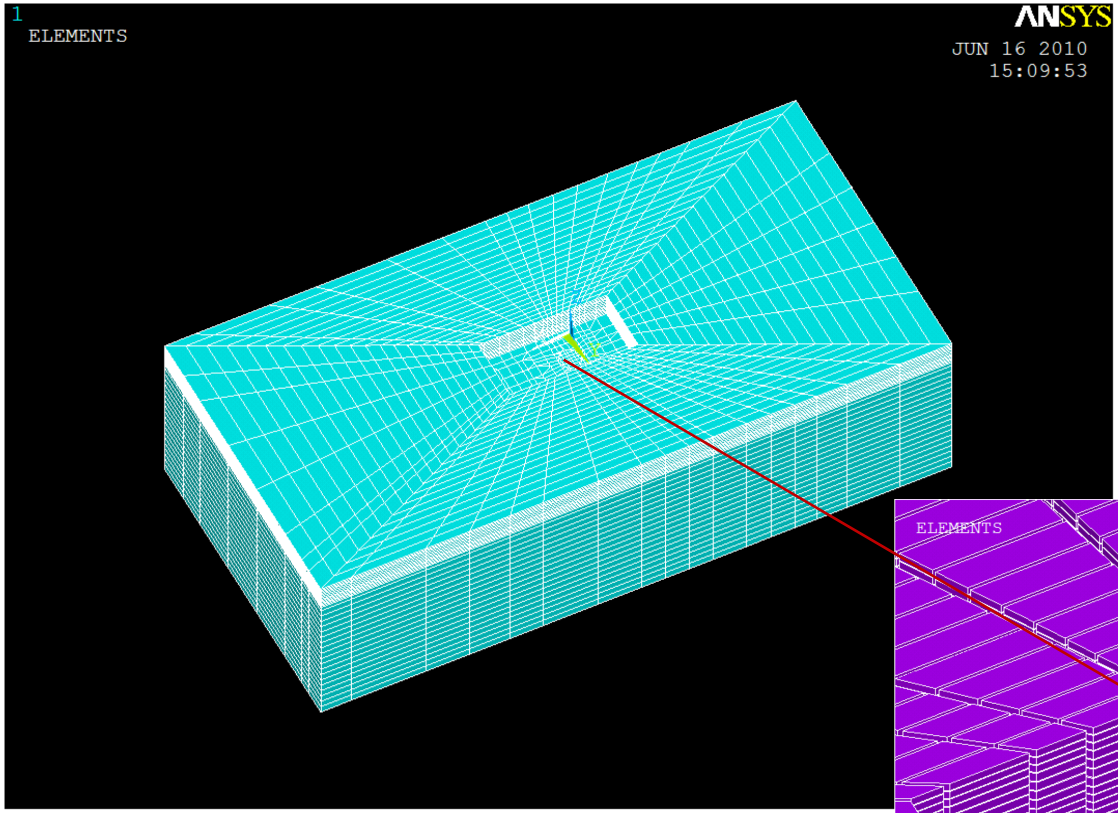
SSI Solution Time Frames As Equivalent Static Loading at Critical Time Steps

EQS Forces – Linear & Nonlinear

EQS Relative Displacements – Linear (Welded)

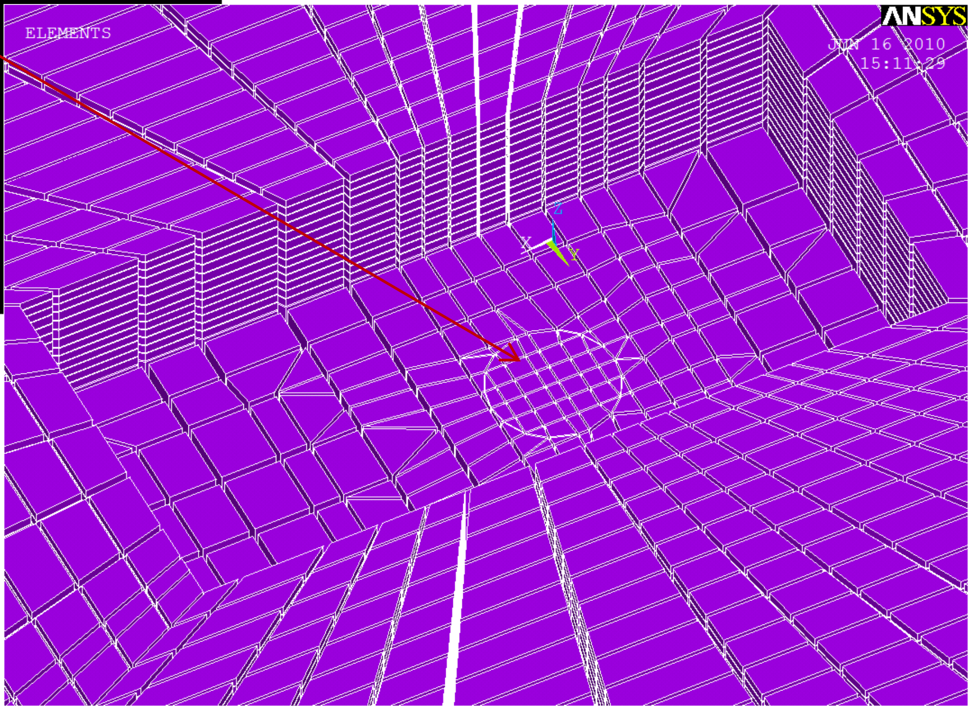


Option A for Seismic Soil Pressure Analysis (Demo 6)



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.

SURFACE SSI MODEL

Flexible Base (w/ Displ. BC)

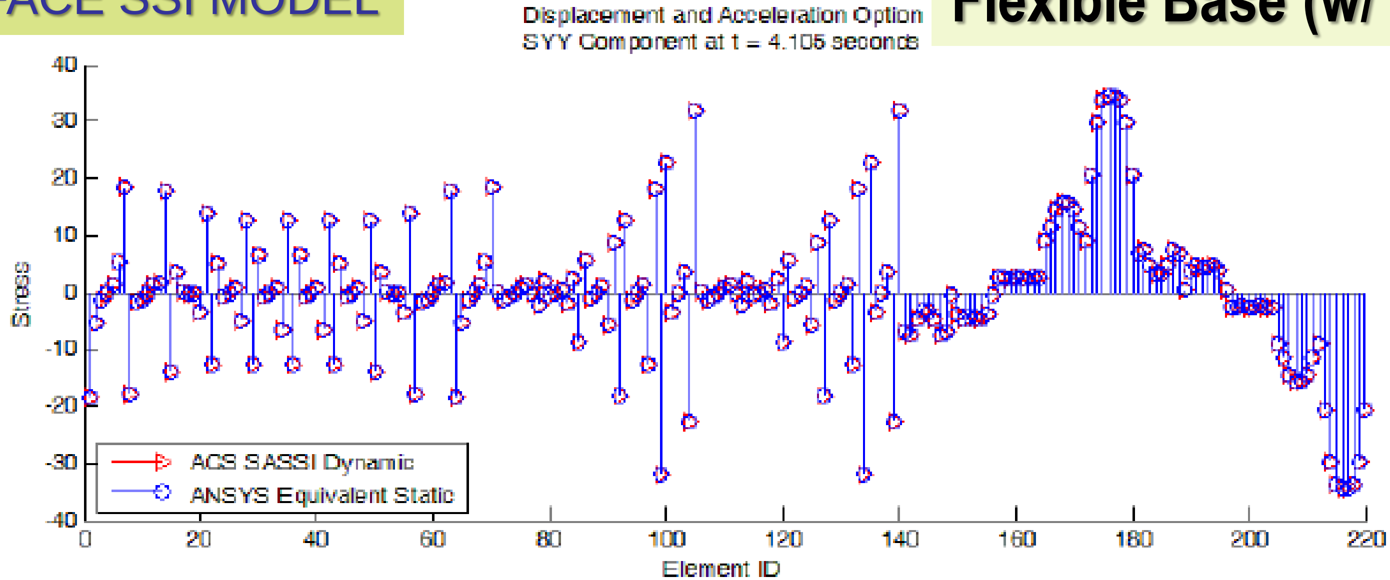


Figure 193: Case b) SYY Element Center Stresses for "Displacement and Acceleration" Option

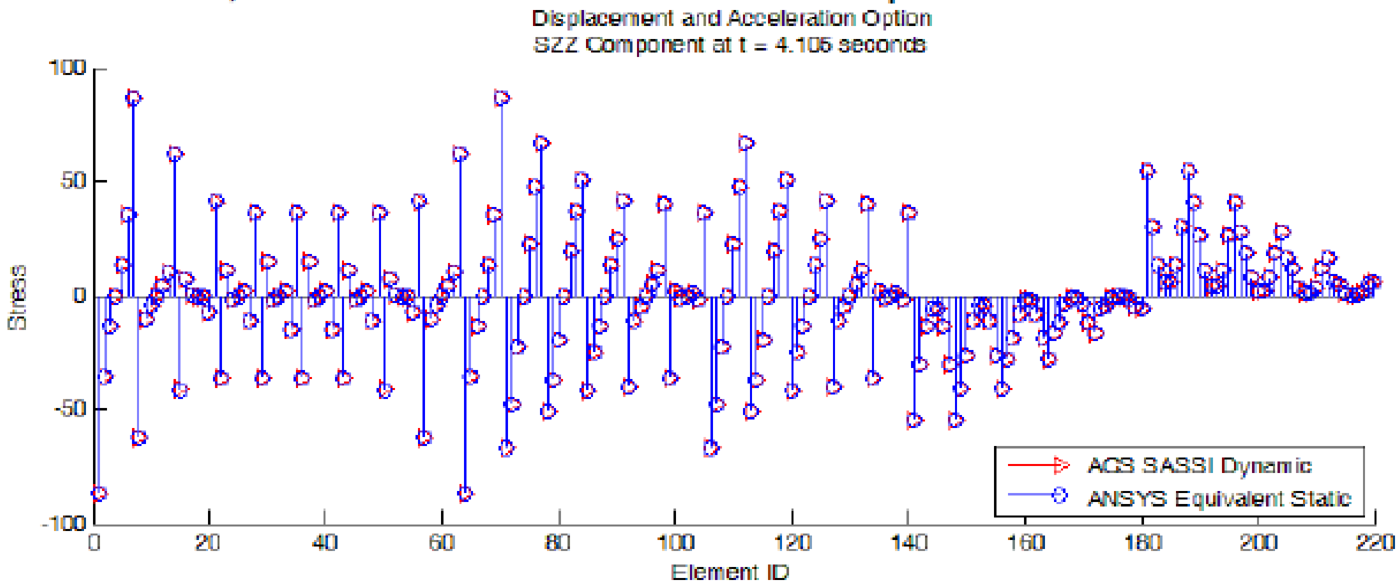


Figure 194: Case b): SZZ Element Center Stresses for "Displacement and Acceleration" Option

SURFACE SSI MODEL

Rigid Base (w/o Displ. BC)

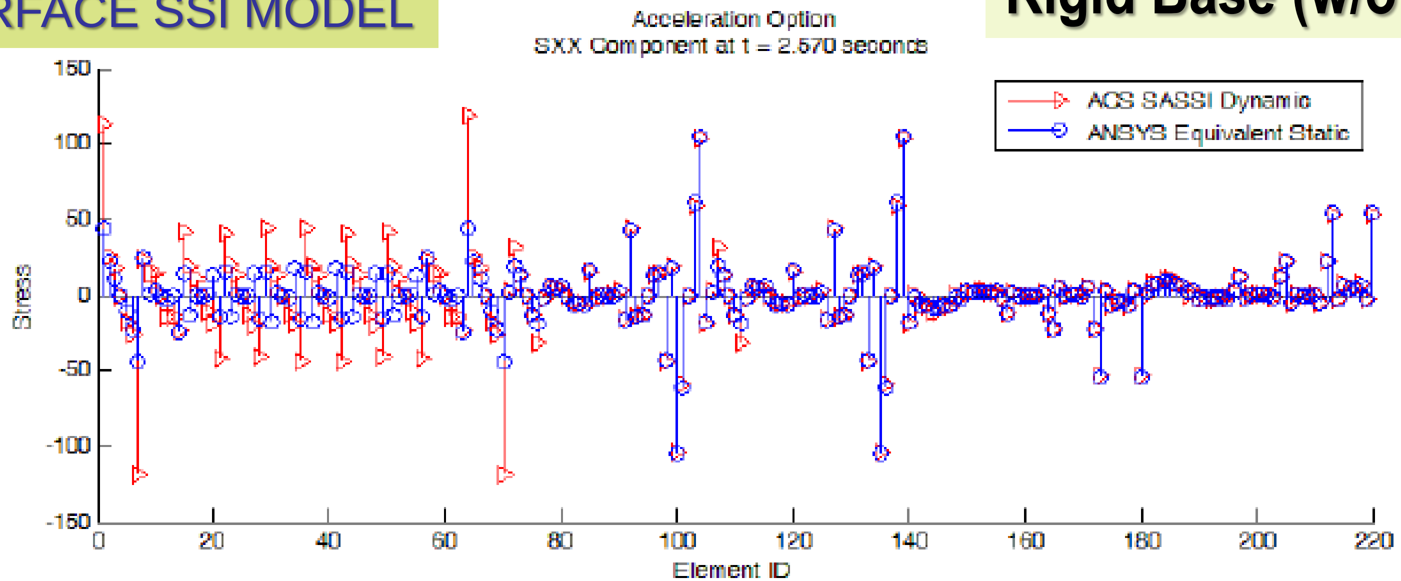


Figure 197: Case c): SXX Element Center Stresses for "Acceleration" Option

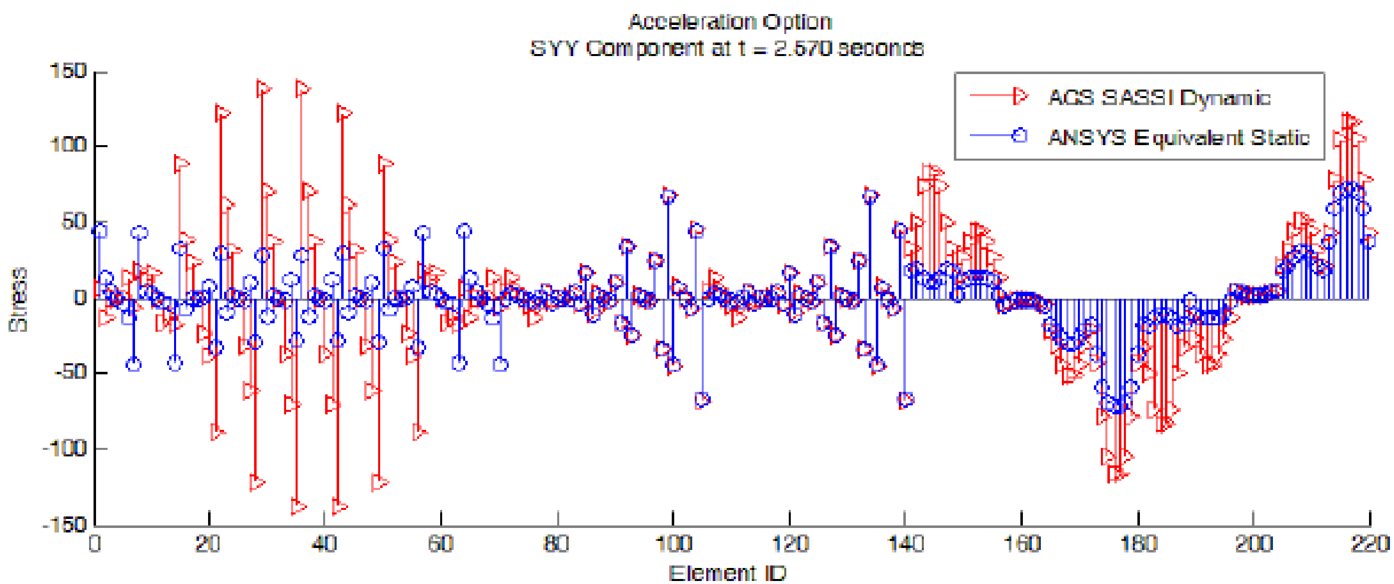
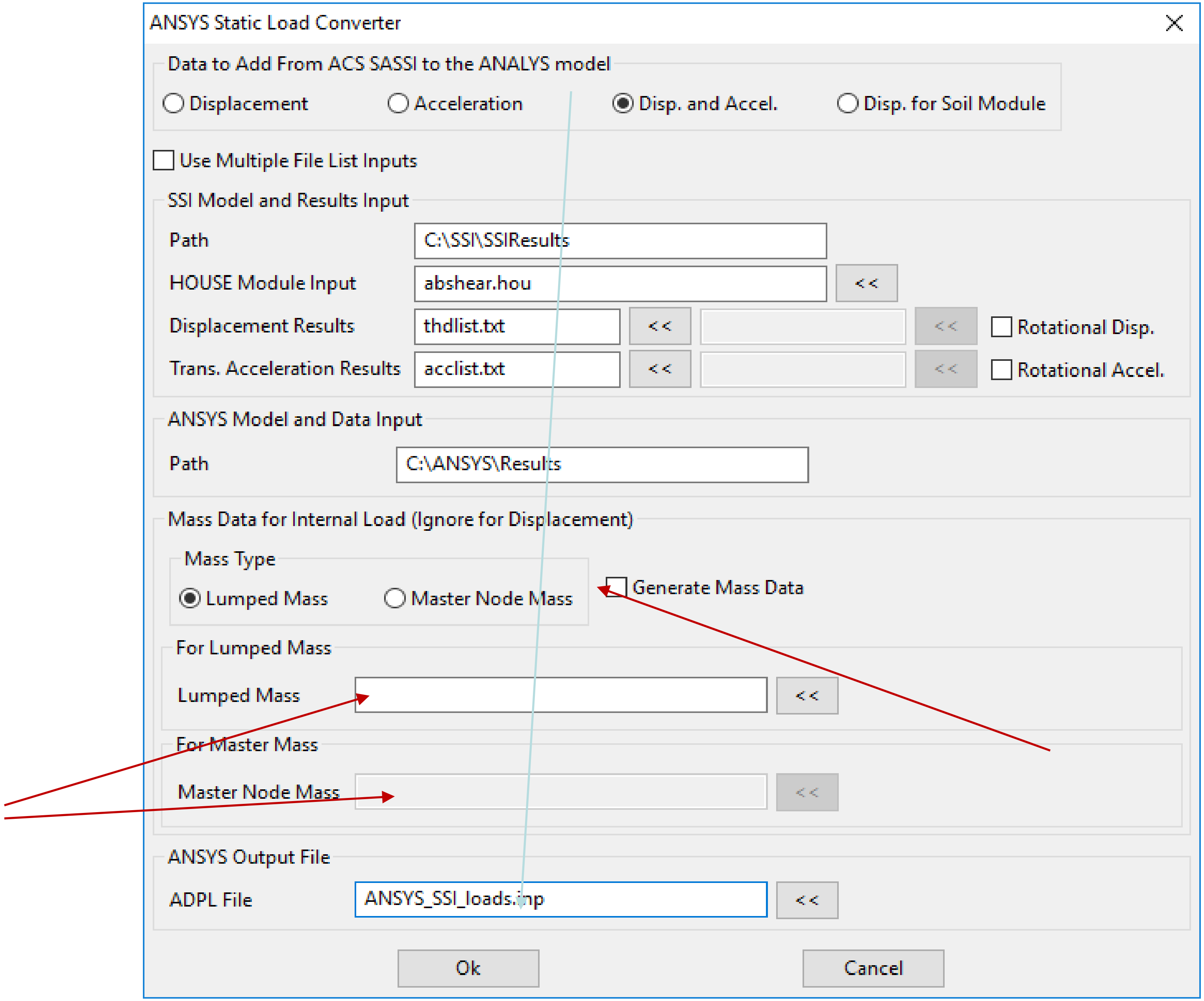


Figure 198: Case c): SYY Element Center Stresses for "Acceleration" Option

UI Input Window for Option A



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

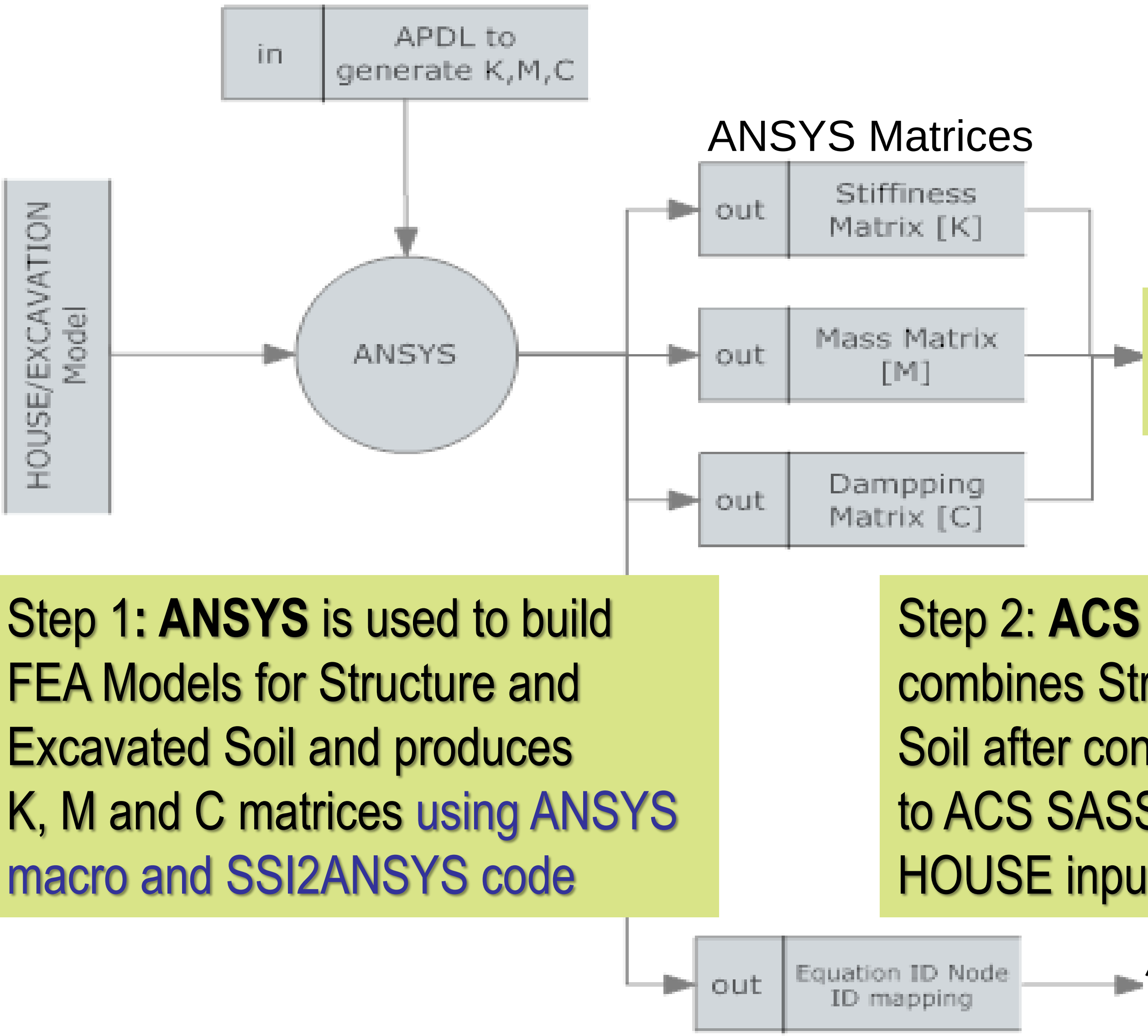
OPTION AA uses directly ANSYS structural model for SSI analysis

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

Steps for Running SSI analysis Using ANSYS Model



FILE4
COOSK
COOSM
DOFSMAP

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)

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

cooec_r	7/25/2014 1:27 PM	File
cooeci_r	7/25/2014 1:27 PM	File
cooek_r	7/25/2014 1:27 PM	File
cooeki_r	7/25/2014 1:27 PM	File
cooem_r		
cooemi_r		
coosc_r	7/25/2014 11:06 AM	File
coosci_r	7/25/2014 11:06 AM	File
coosk_r	7/25/2014 11:06 AM	File
cooski_r	7/25/2014 11:06 AM	File
coosm_r	7/25/2014 11:06 AM	File
coosmi_r	7/25/2014 11:06 AM	File
Node2Equ_Excv.map		
Node2Equ_Stru.map		
sldbox45_excv.cdb		
sldbox45_struct.cdb		

ANSYS Model K, C and M Matrix Files (APDL macro)

ANSYS Model Mapping Files (APDL macro)

ANSYS Model .cdb Files (ANSYS)

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

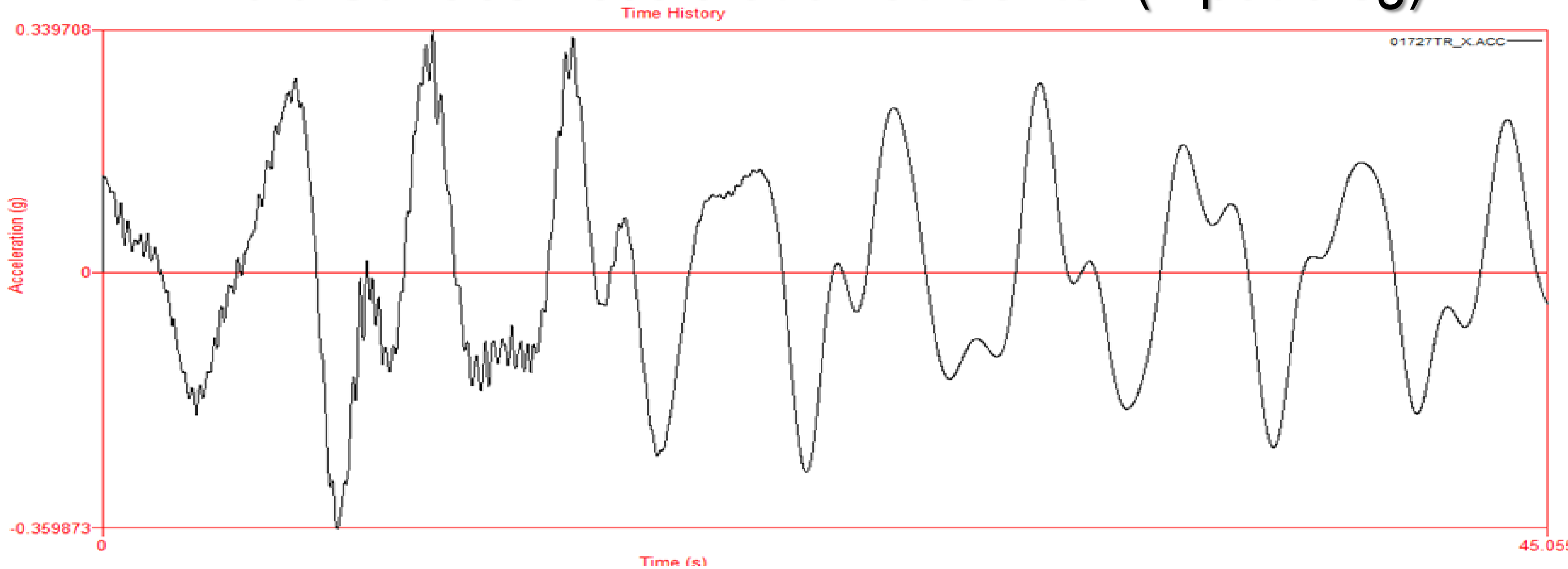
ANSYS FE Types Compatible with Option AA

- 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*). It may also work for FLUID30, but no V&V test problem was run for this. To be tested soon.*

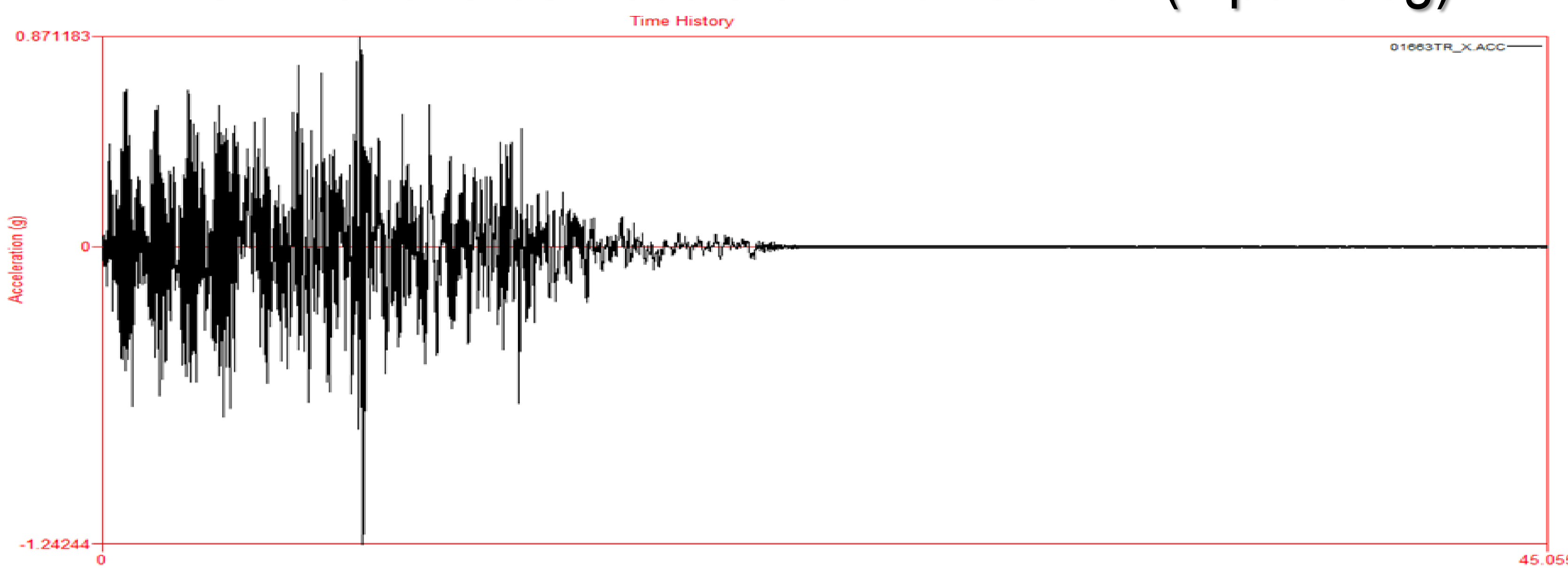
- MATRIX50 Super Element
  - Included in Option AA using ANSYS model
  - Converted to General Matrix Element for the ACS SASSI Model

REMARK: Not all keyopt or othere parameter values work!

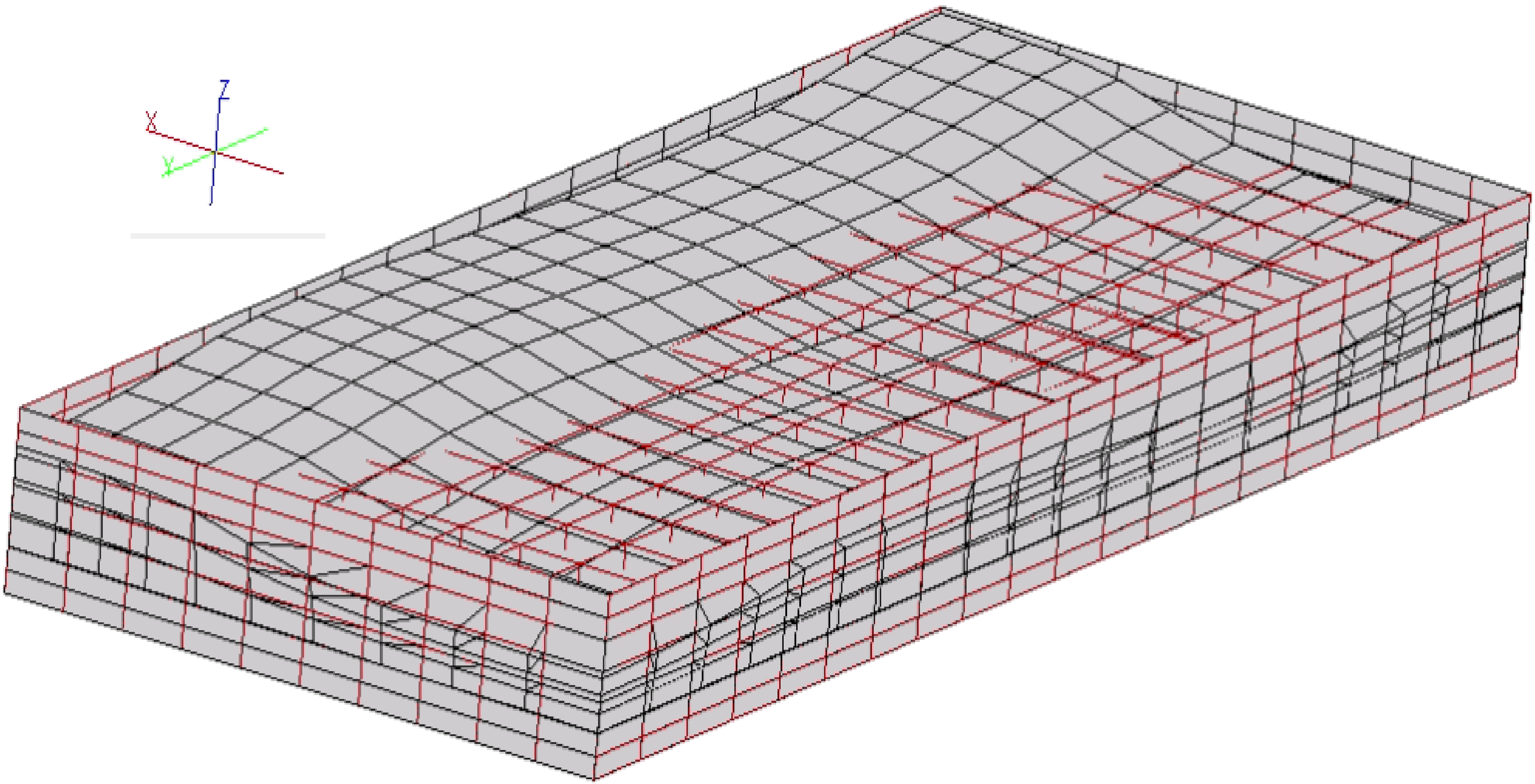
Fluid Surface Acceleration at Center (Input 0.3g)



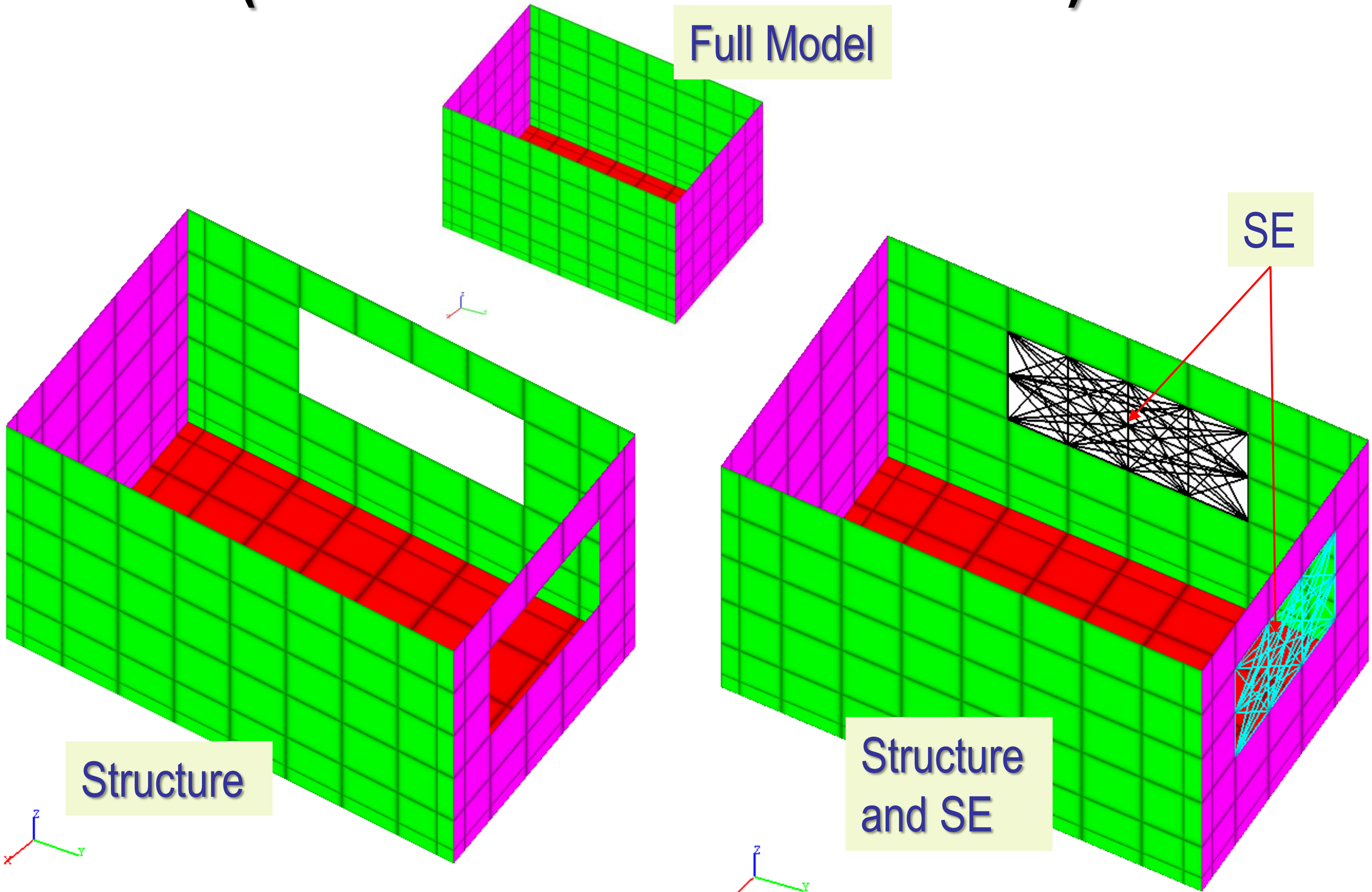
Wall Transverse Acceleration at Center (Input 0.3g)



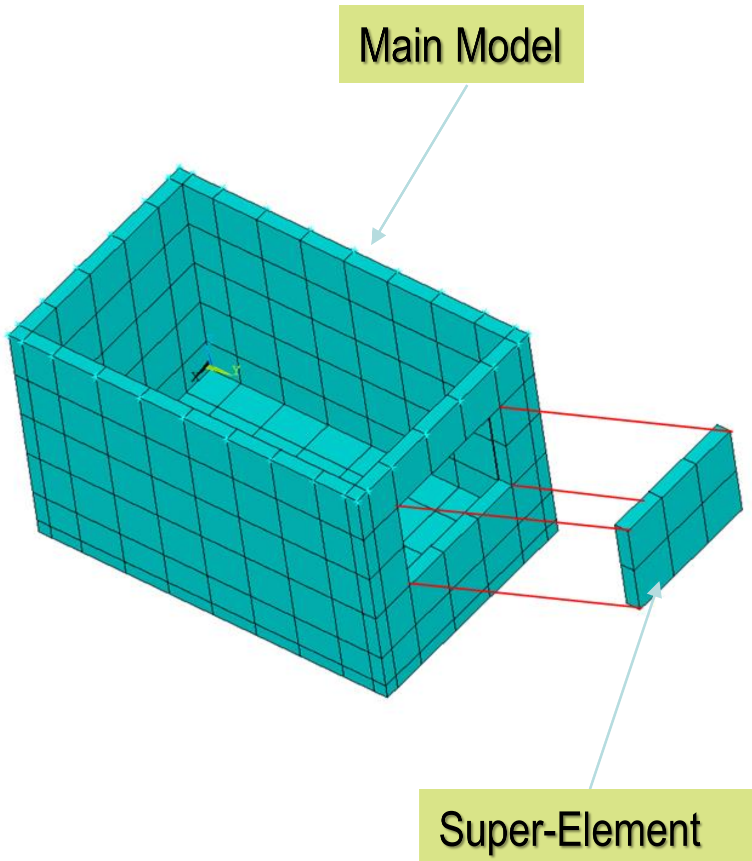
Water Displacement Response (Sloshing)

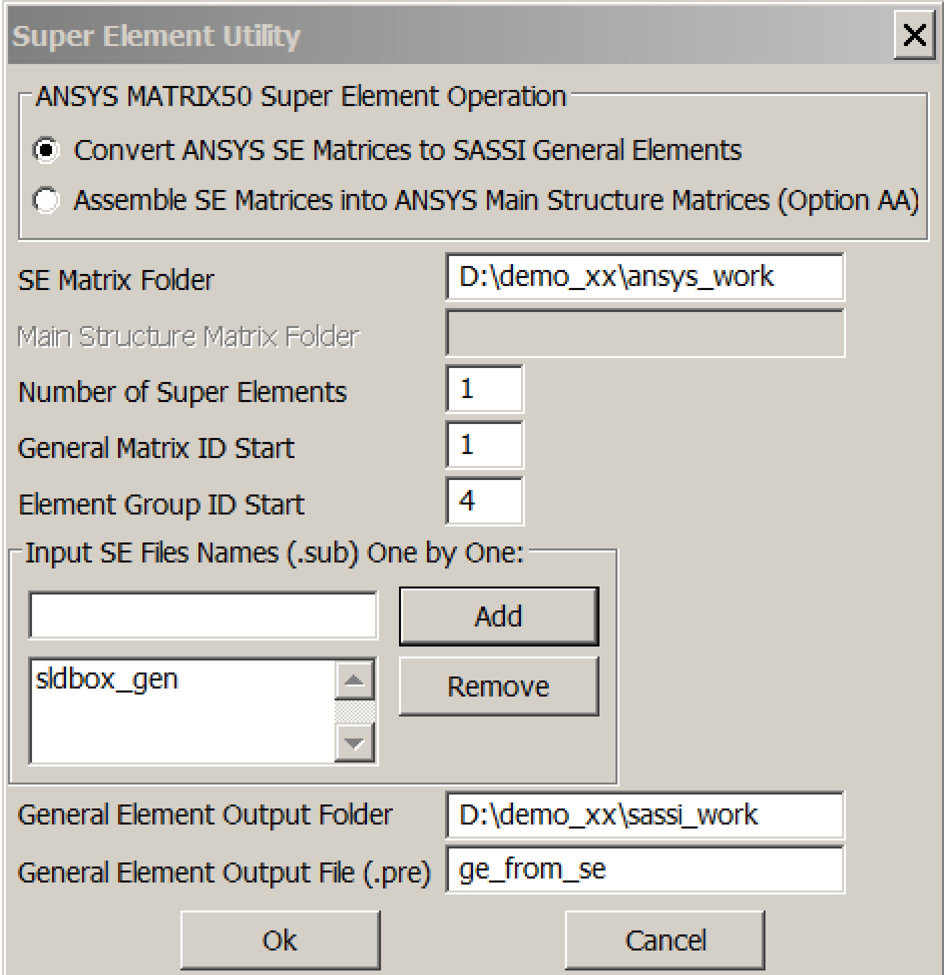


Using ANSYS MATRIX50 to Build Super Elements (see Demo 11 and V&V Pb 52)

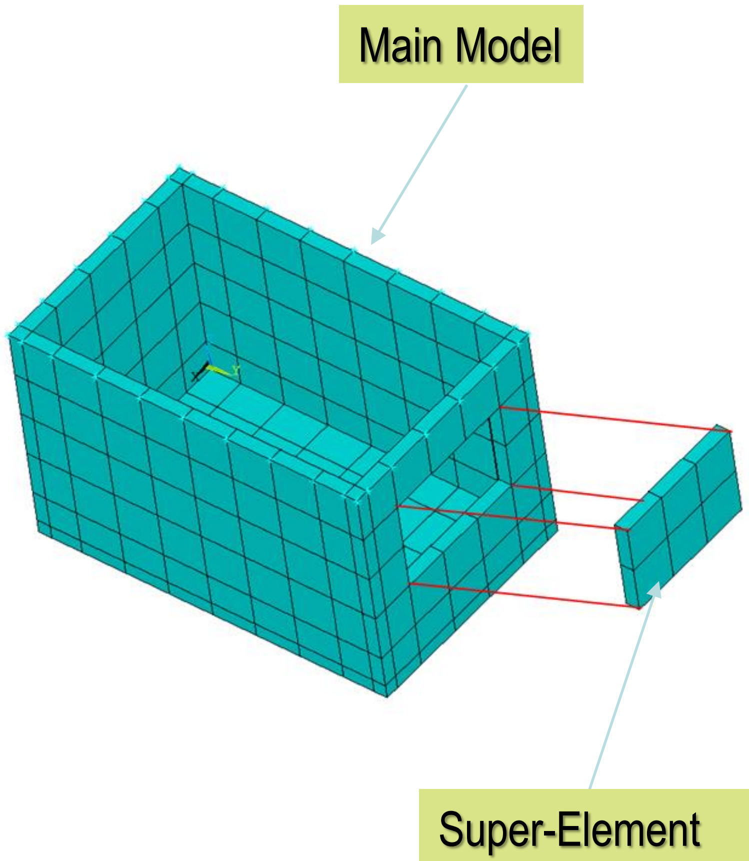


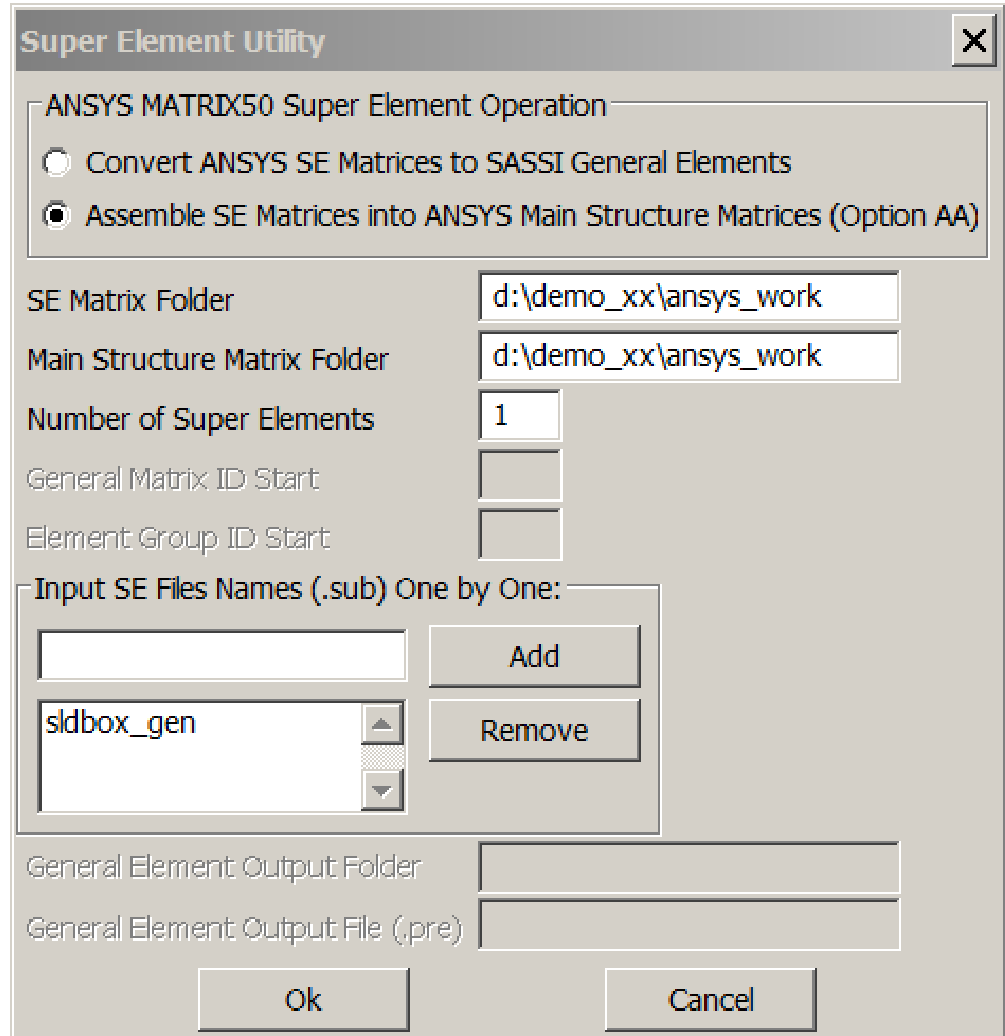
ANSYS Super Element (SE) Converted to ACS SASSI Using General Matrix Elements (GM)





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



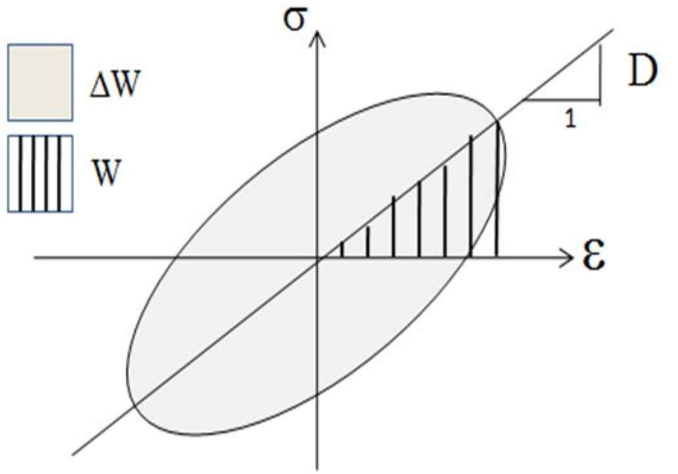


6. Option NON

Nonlinear Structure Behavior for Concrete Structures

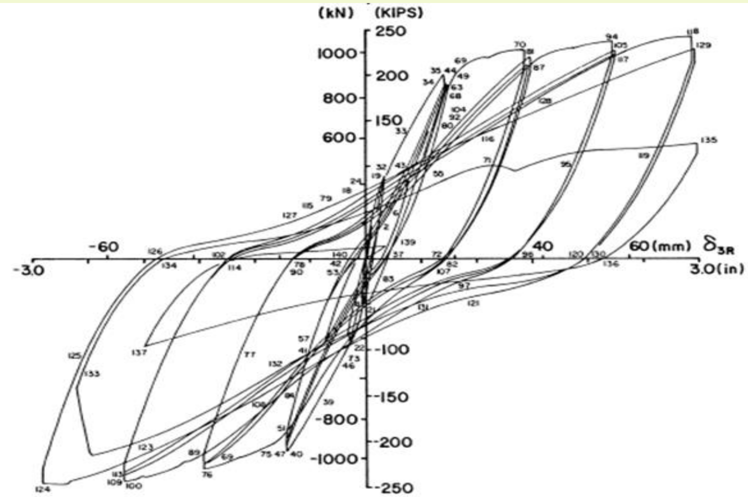
Option NON Modeling of Hysteretic Behavior

Linearized Hysteretic Model



Frequency Domain
Equivalent Linearized Hysteretic Model

Experimental Hysteretic Model



Time Domain
Hysteretic Model

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 (about 5-6 iterations are sufficient).

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

ACS SASSI Nonlinear SSI Analysis Procedure

Nonlinear 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

Option NON Applicability to Concrete Structures

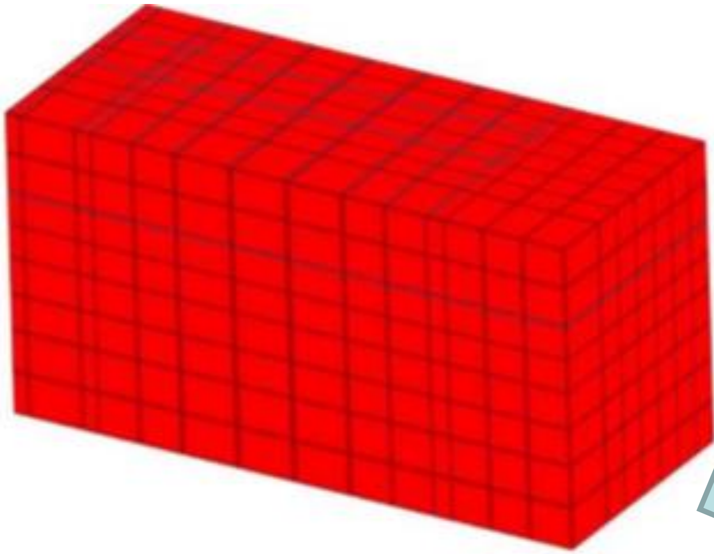
Option NON is applicable to the reinforced concrete structures for simulating the *concrete cracking* and *post-cracking behavior* in the low-rise shearwalls for *the design-level* and/*or beyond-the-design-level* seismic inputs.

The Option NON was validated for the low-rise reinforced concrete shearwall buildings that fail primarily due to the *in-plane shear deformation*. 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 concrete behavior is considered.

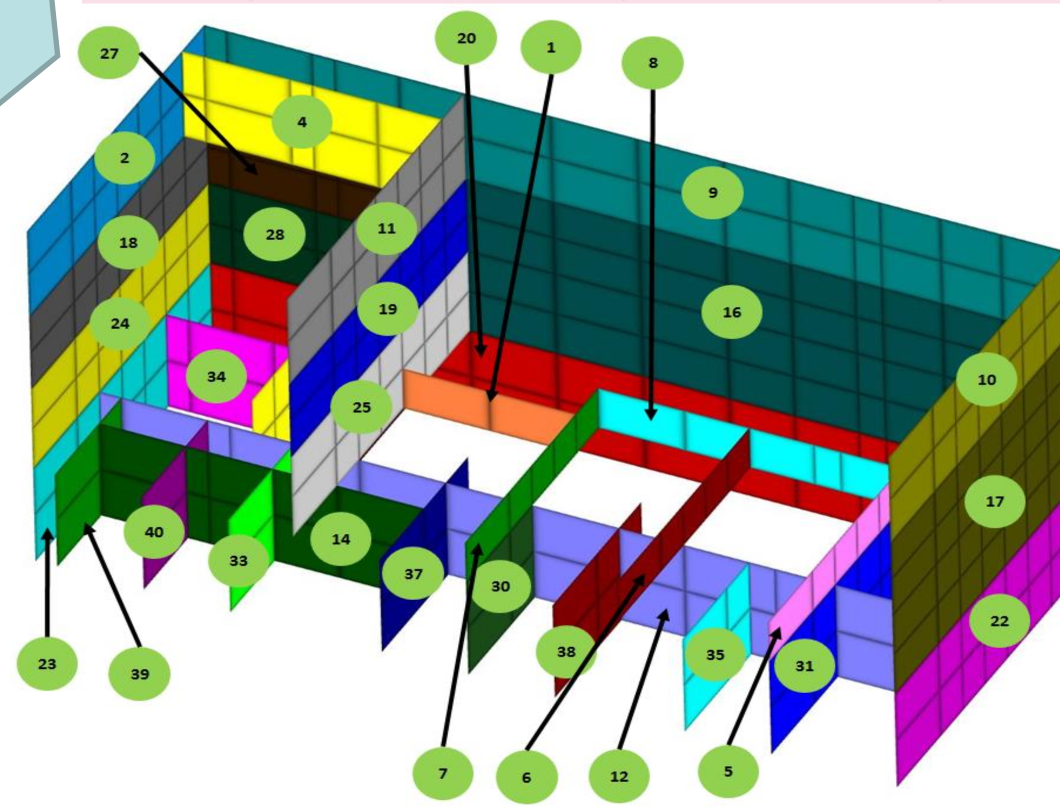
However, Option NON can also consider the nonlinear concrete behavior due to *the in-plane bending deformation* effects.

In the same nonlinear structure FE model, the analyst can include wall panels (parts of walls) that fail primarily either due to the shear deformation or the bending deformation, respectively. This has an useful practicality.

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, SPLITWALL, 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)

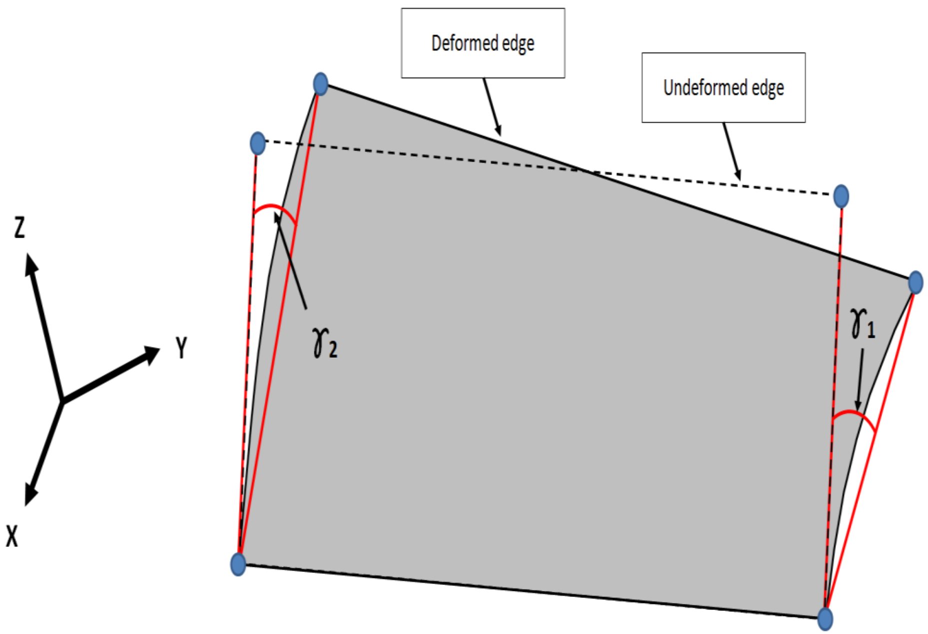
Applicable to Low-Rise Shearwall Structures

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.

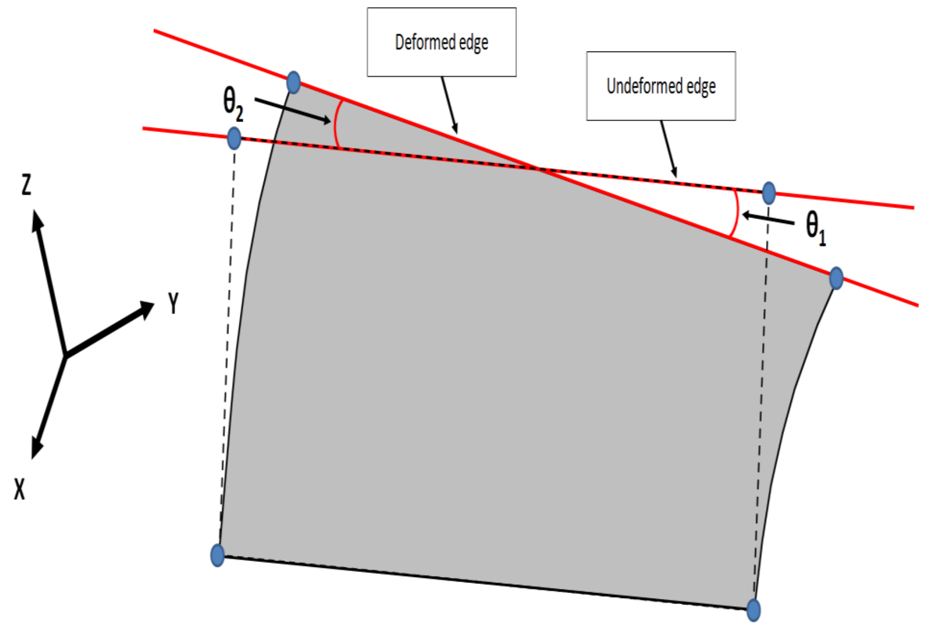
The wall panel shear stiffness modification as a result on nonlinear behaviour is fully coupled with the bending stiffness. This is a reasonable assumption *only f*or the low-rise shearwalls for which the nonlinear behaviour is governed by the shear deformation, while bending effects play an insignificant 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 in the modern nuclear power plants, the flexural distortions and associated vertical yielding play a negligible role. This was also recognized by many other research studies, including the EPRI report on “Methodology for Developing Seismic Fragilities” (Reed and Kennedy, 1994).

Computation of Shear and Bending Deformation



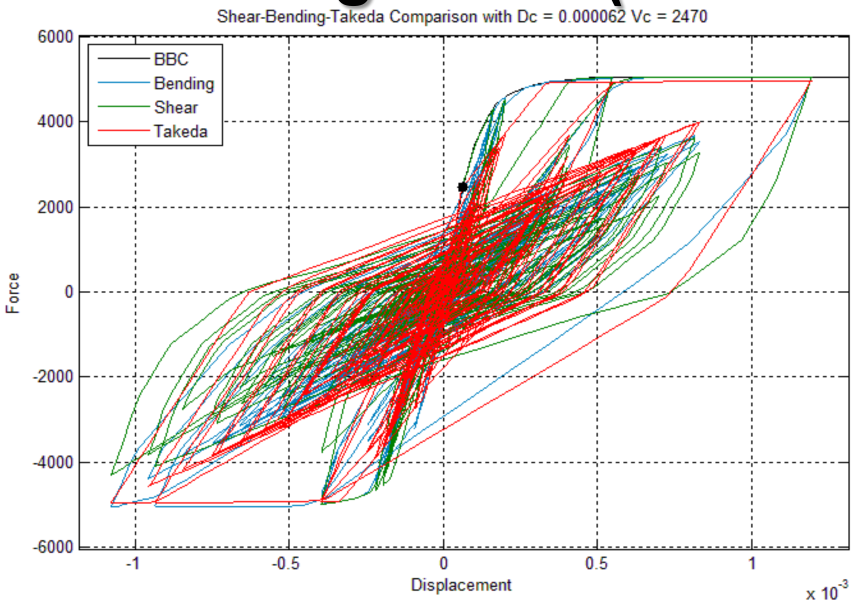
Shear Strain

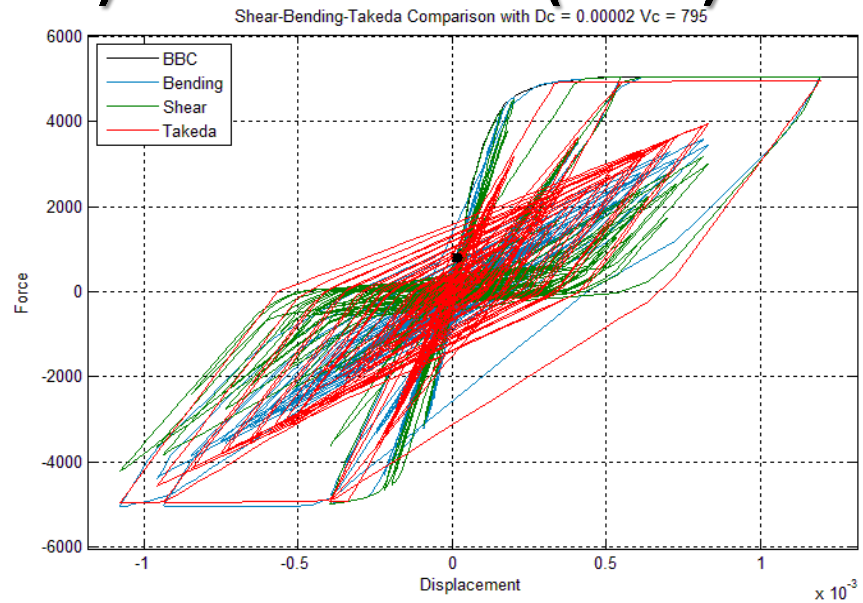


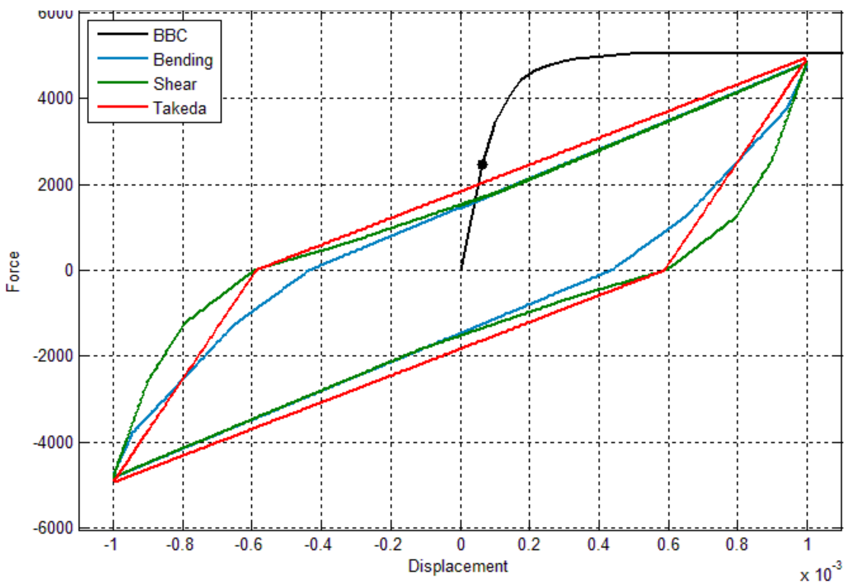
Bending Strain

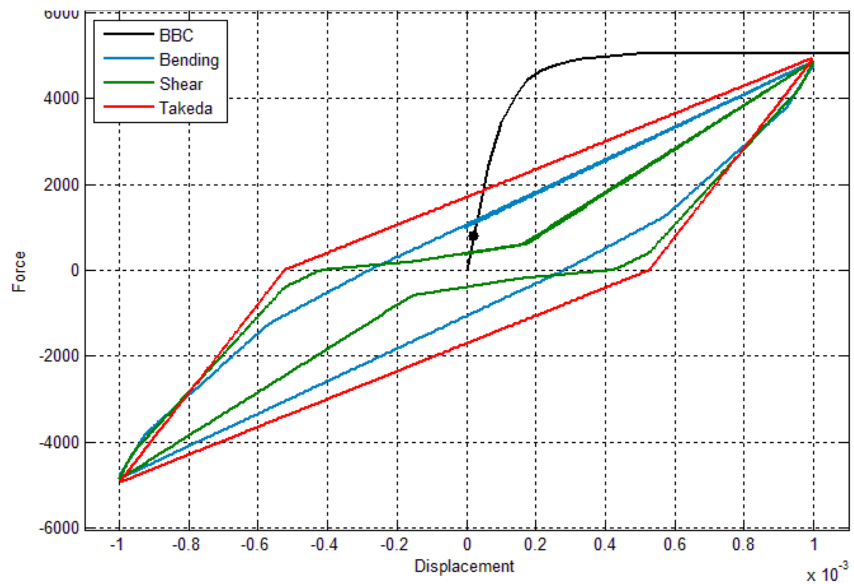
Remark: Rigid body motion is removed

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

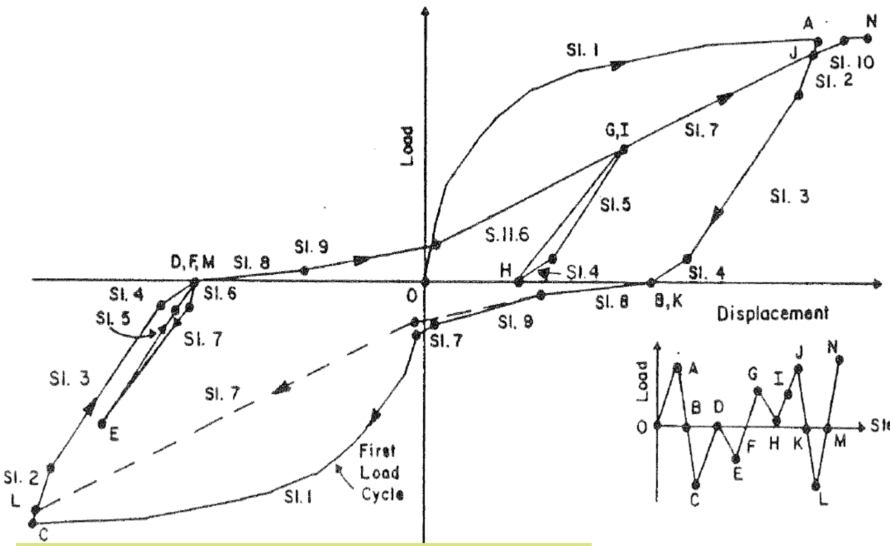




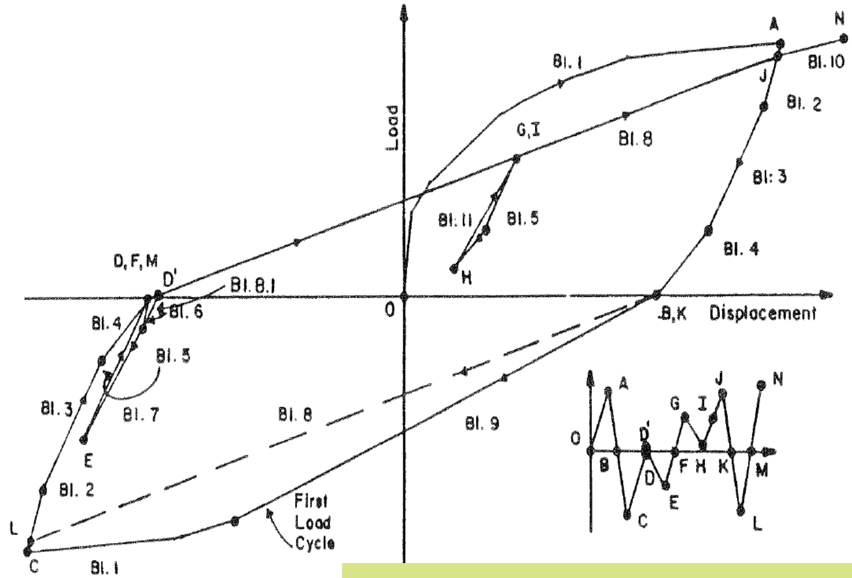




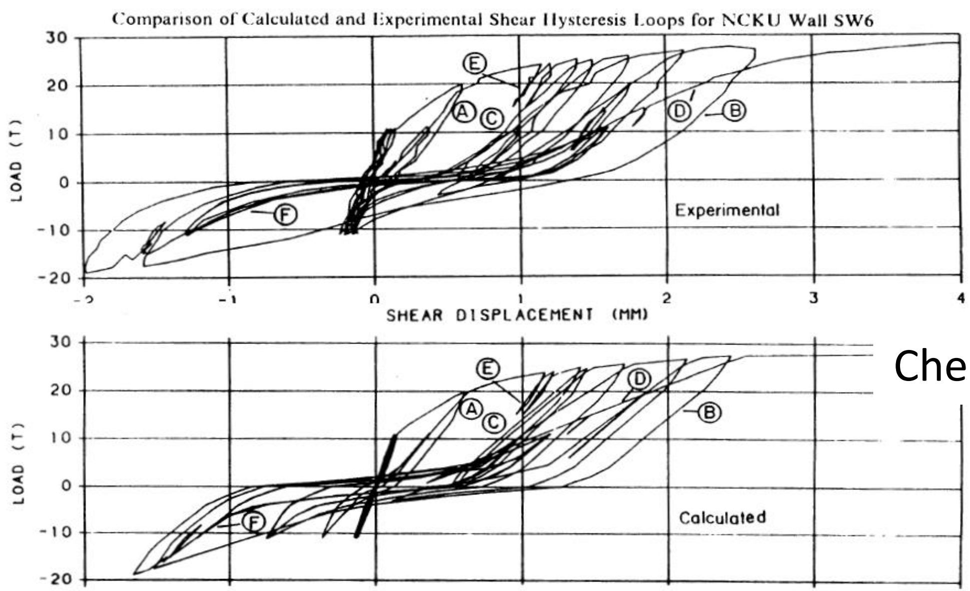
Chen-Mertz Hysteretic Model for Low-Rise Shearwalls



Wall In-Plane Shear



Wall In-Plane Bending



Cheng and Mertz, 1989

Nonlinear XYZ Response at Each SSI Iteration

In the current Option NON there is no hysteretic model included 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).

Building BBC 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. After selecting the shear capacity equation model, using the BBCGEN command smooth BBC curves can be automatically generated for many wall panels.

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 43-05, 2005 Eqs. 4-3/4 based on Barda, ASCE 43-19 took out it
- ACI 349-06, 2006, Section 11.10, 21.4, based on Barda
- Wood, 1990 – small bias, typically less 10% lower, for median capacity
- Gulec and Whittaker, 2009, Eqs. 6.9-6.10, small bias for median capacity

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

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.

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. For a single panel command, a title with names of equation is provided.

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.

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

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.

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

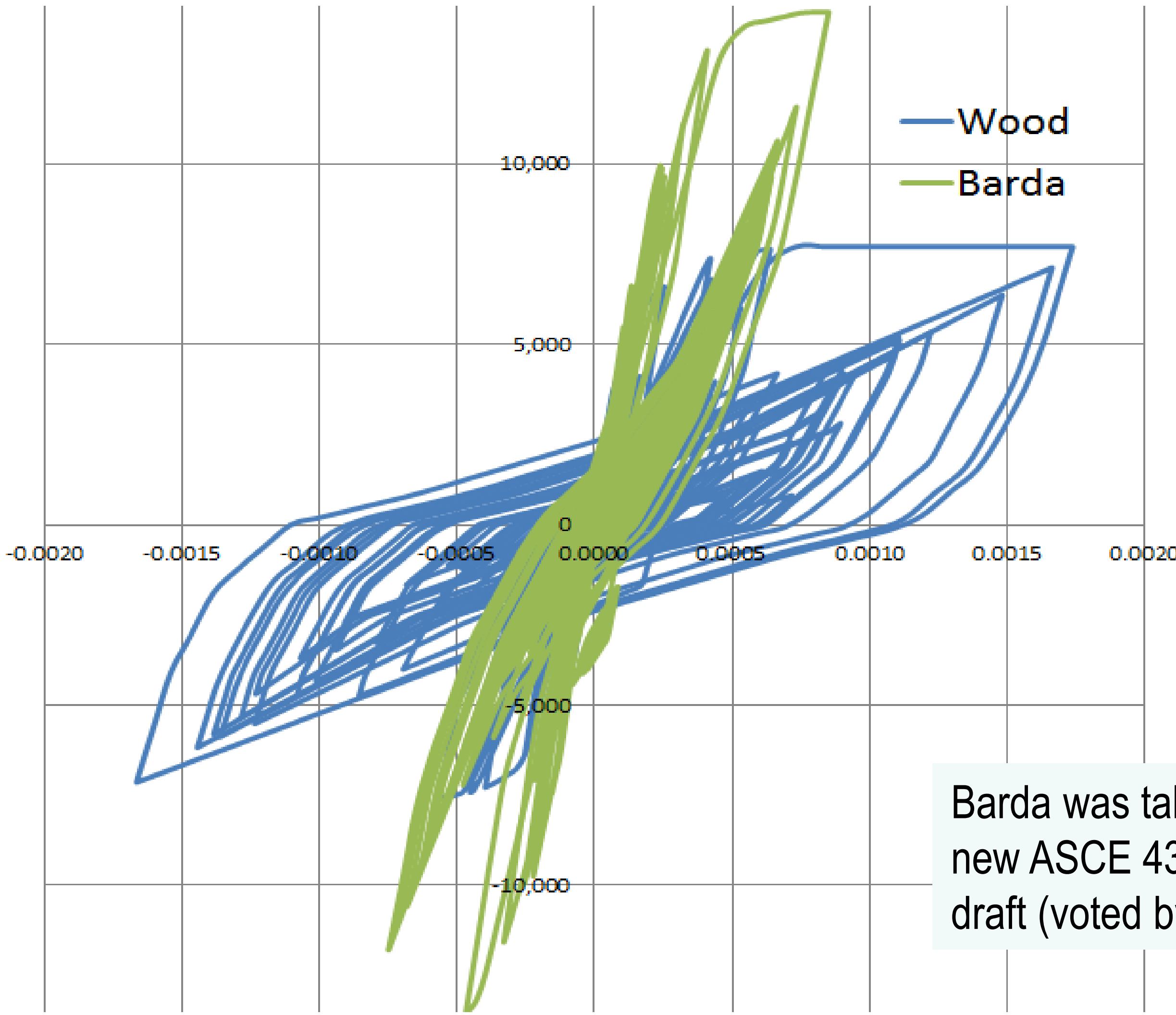
Gulec-Whittaker, 2009:

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.

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

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

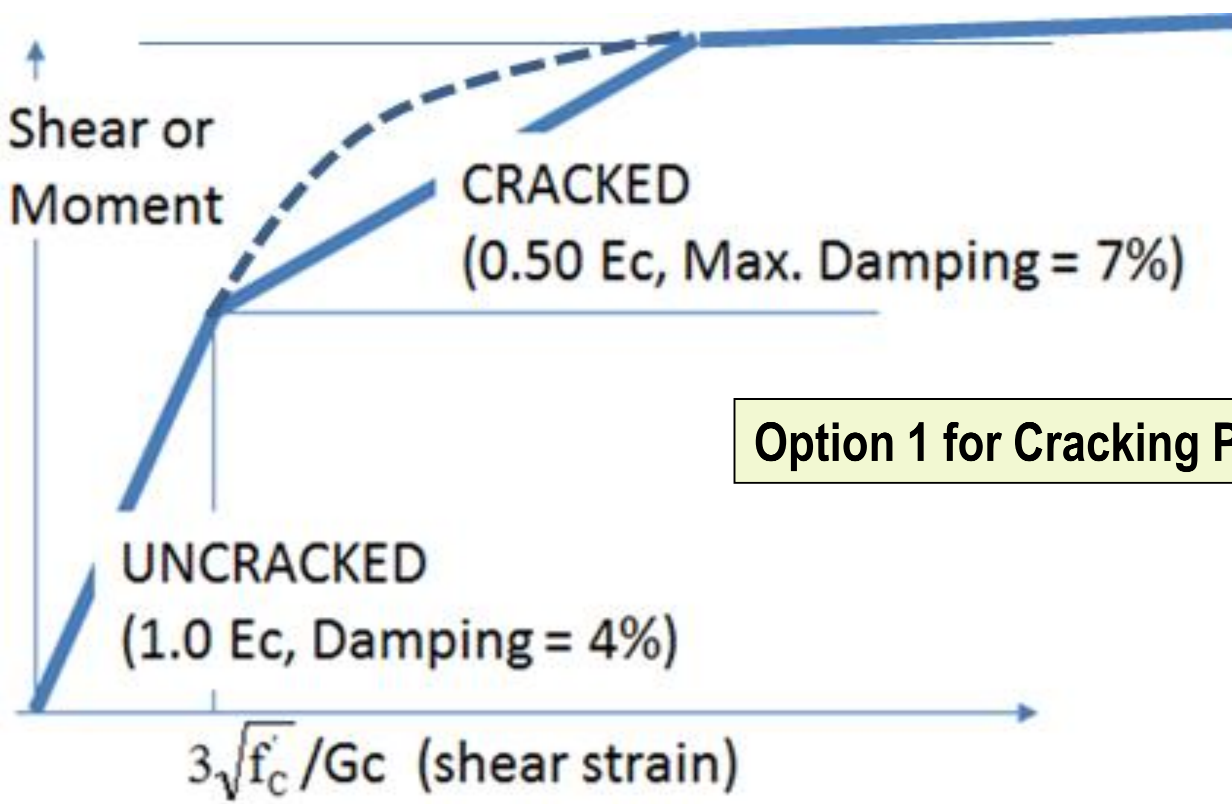


Barda was taken out of the new ASCE 43-19 standard draft (voted by DANS)

Automatic Building of BBCs Using BBCGEN

2 Using the BBCGEN command smooth BBC curves can be automatically generated for many wall panels in the model/submodel. For each panel the concrete strength, fc, reinforcement yielding strength, fy, and reinforcement ratio, rp, should be input. Two options for defining cracking point are included.

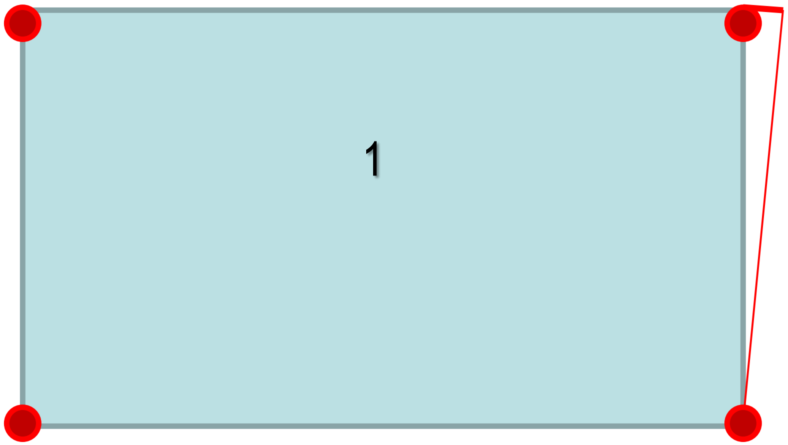
BBCGEN,<Panel>,<ShearModel>,[fc],[fy],[rp], ….



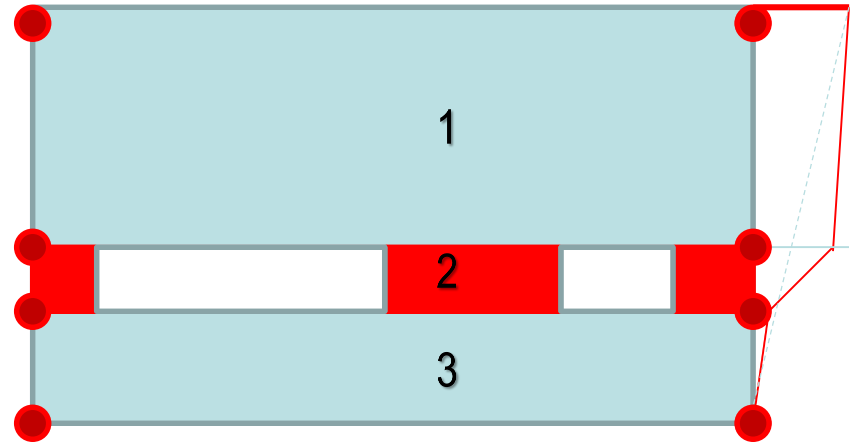
Option 1 for Cracking Point

Including Wall Openings Semi Automatically

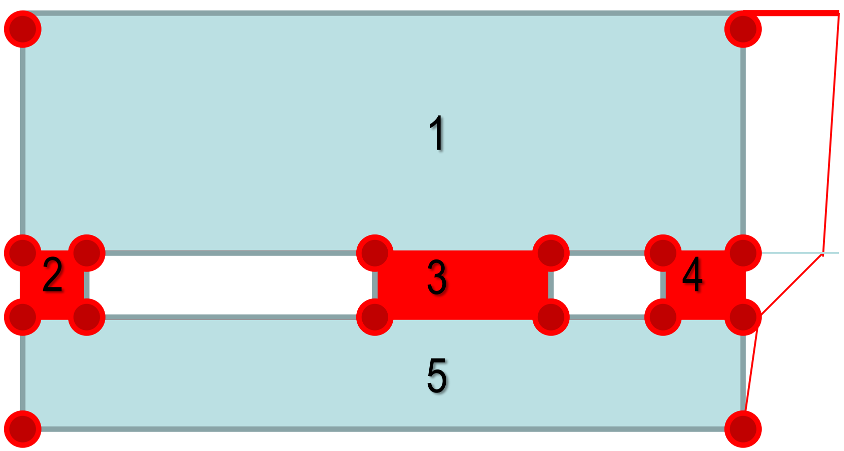
Solid Wall – 1 Panel

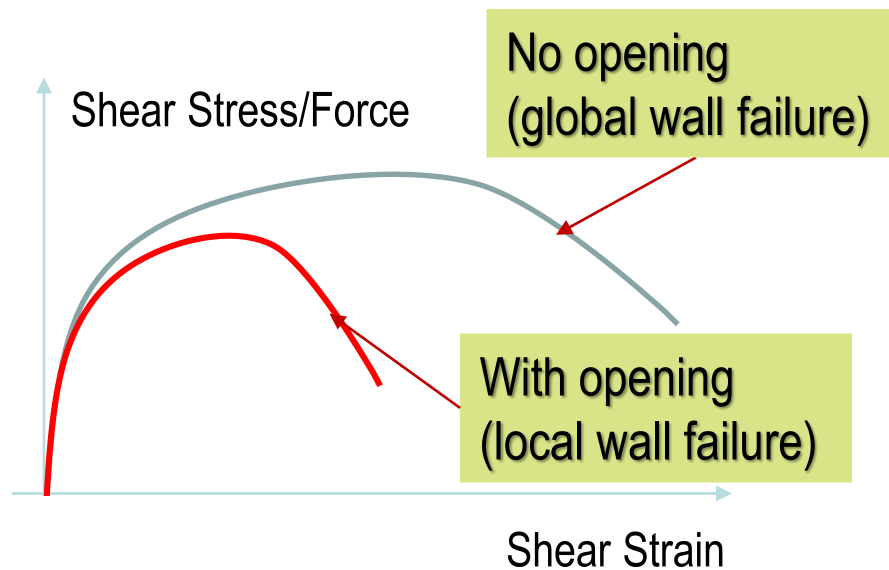


Wall with Two Openings – 3 Panels



Wall with Two Openings – 5 Panels

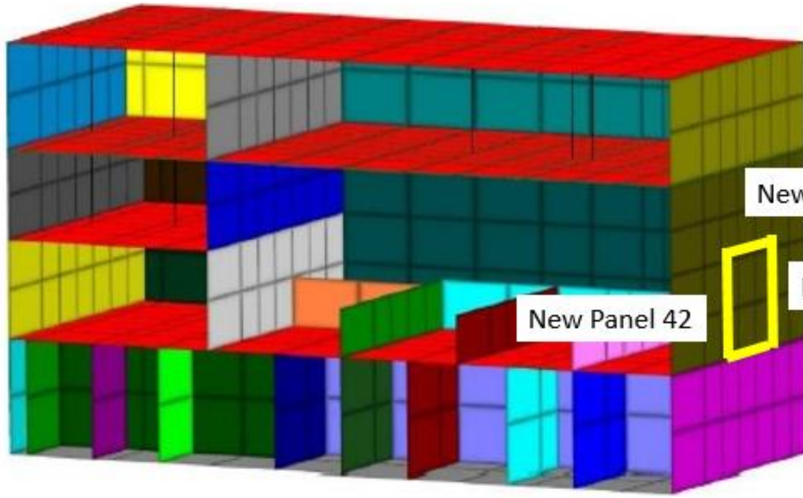




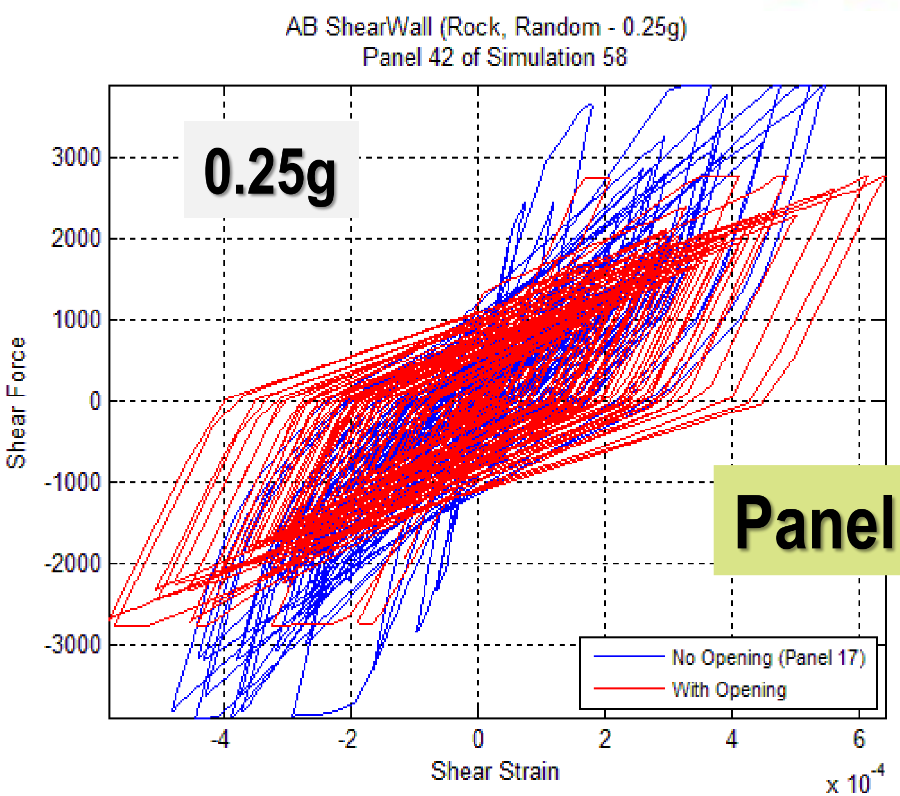
UI Commands: **EDGE, 1,0,0,1**, and then **EDGE,2**

Nonlinear SSI Effects Due Openings in Walls

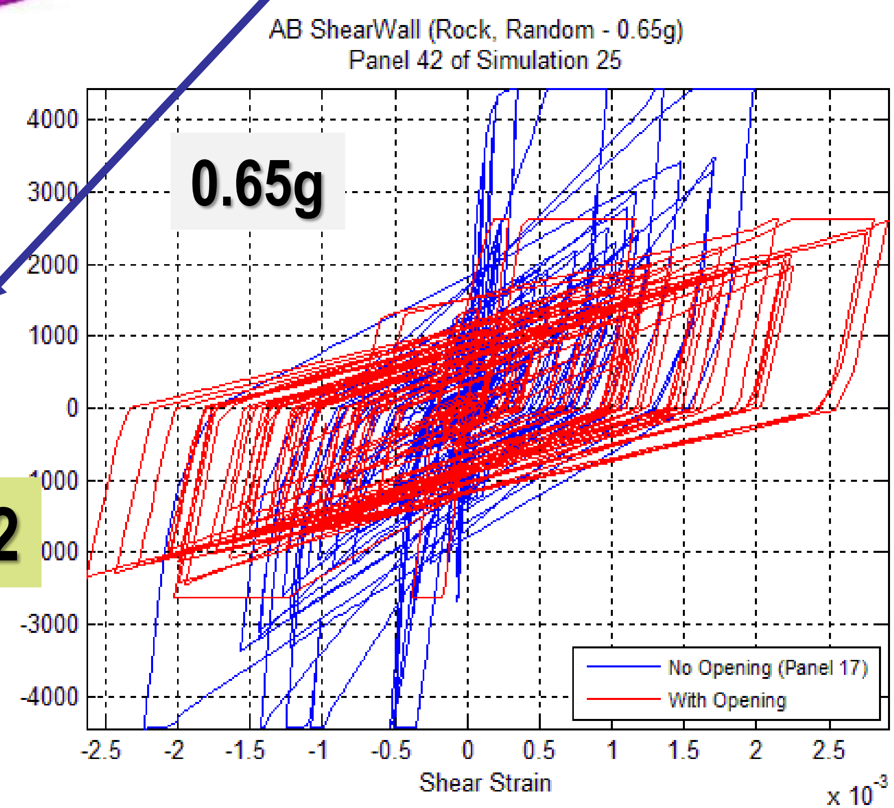
4



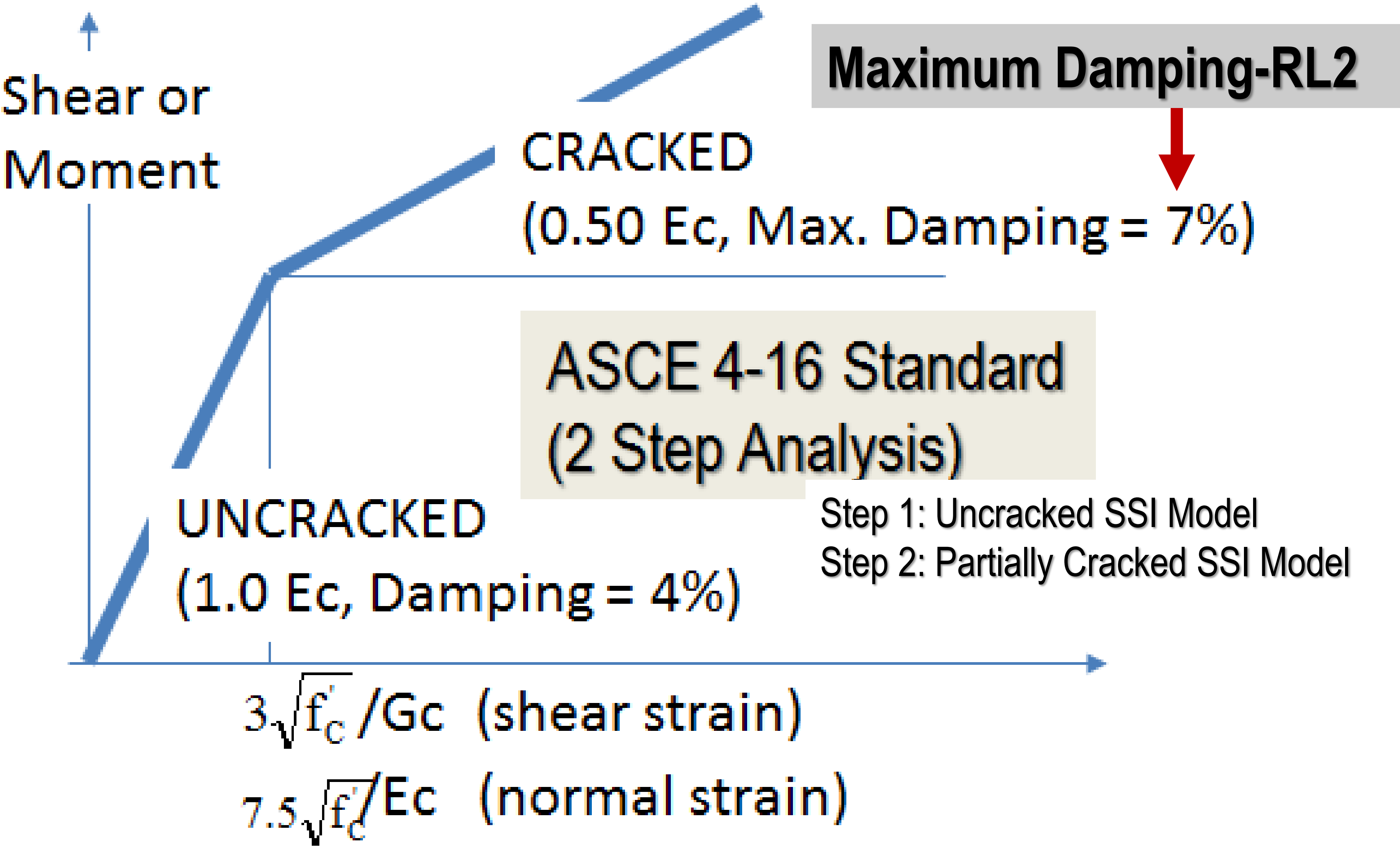
Wood1990 Equation
CMS Hysteretic Model



Panel 42



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



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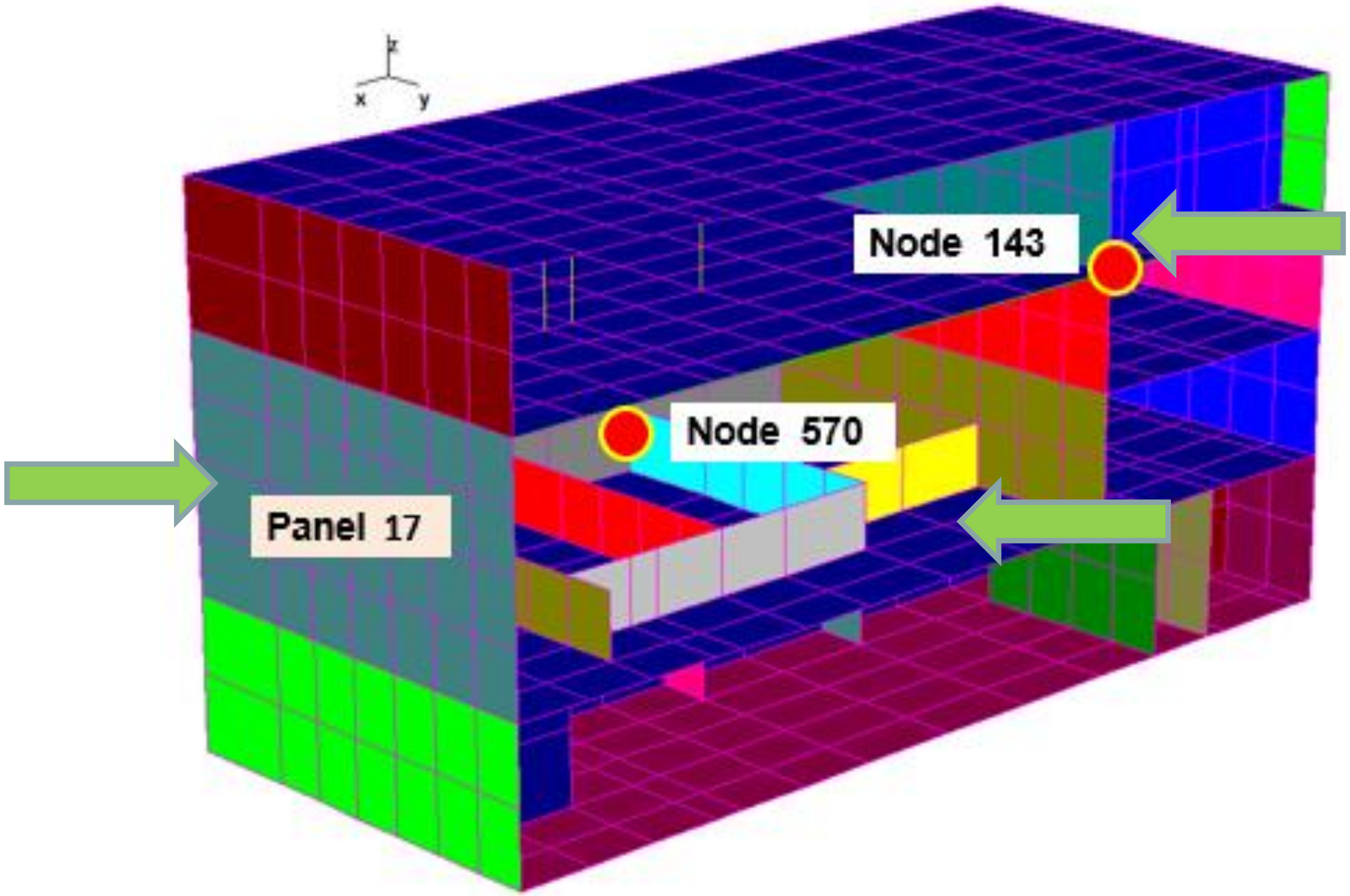
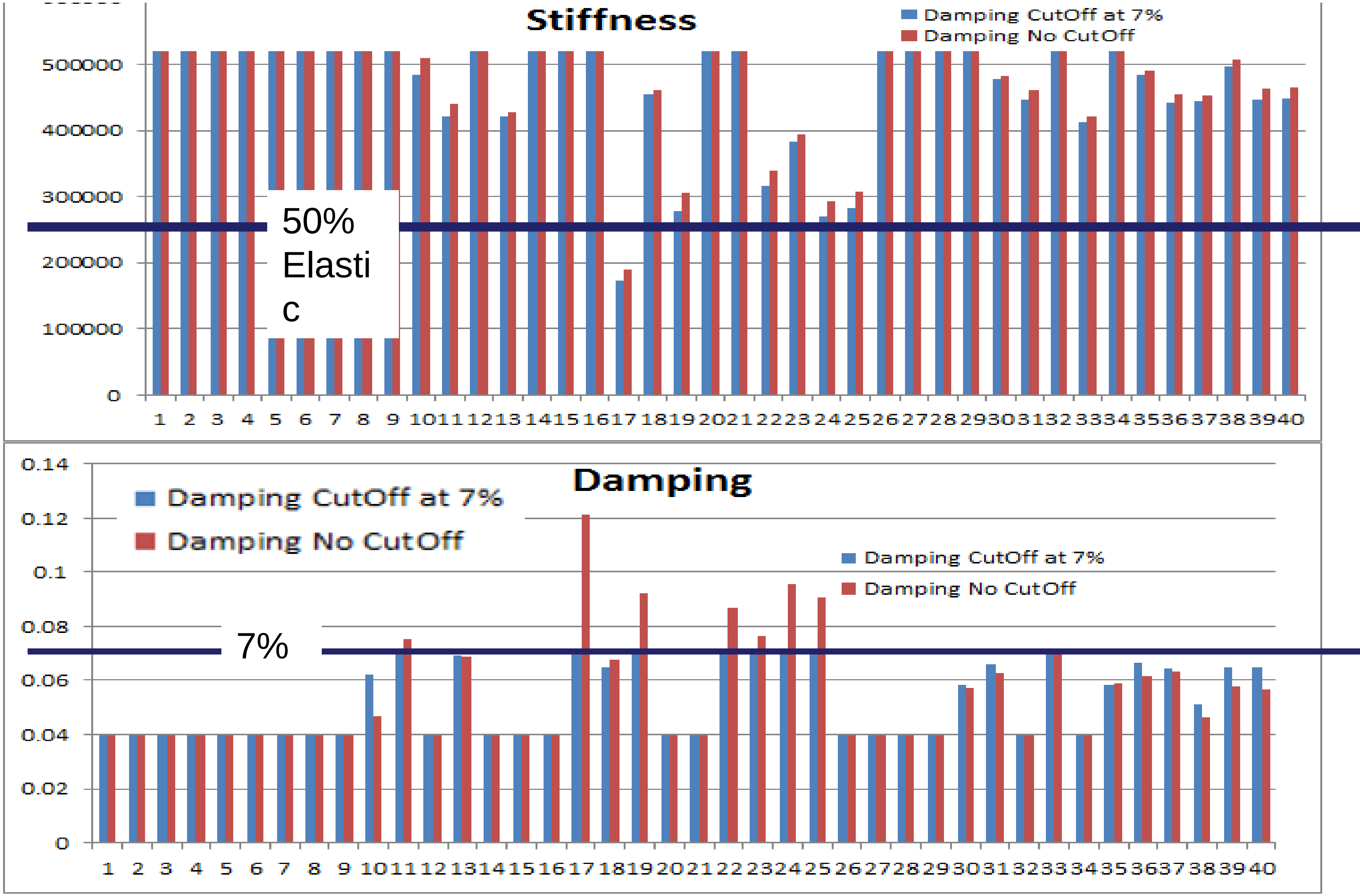
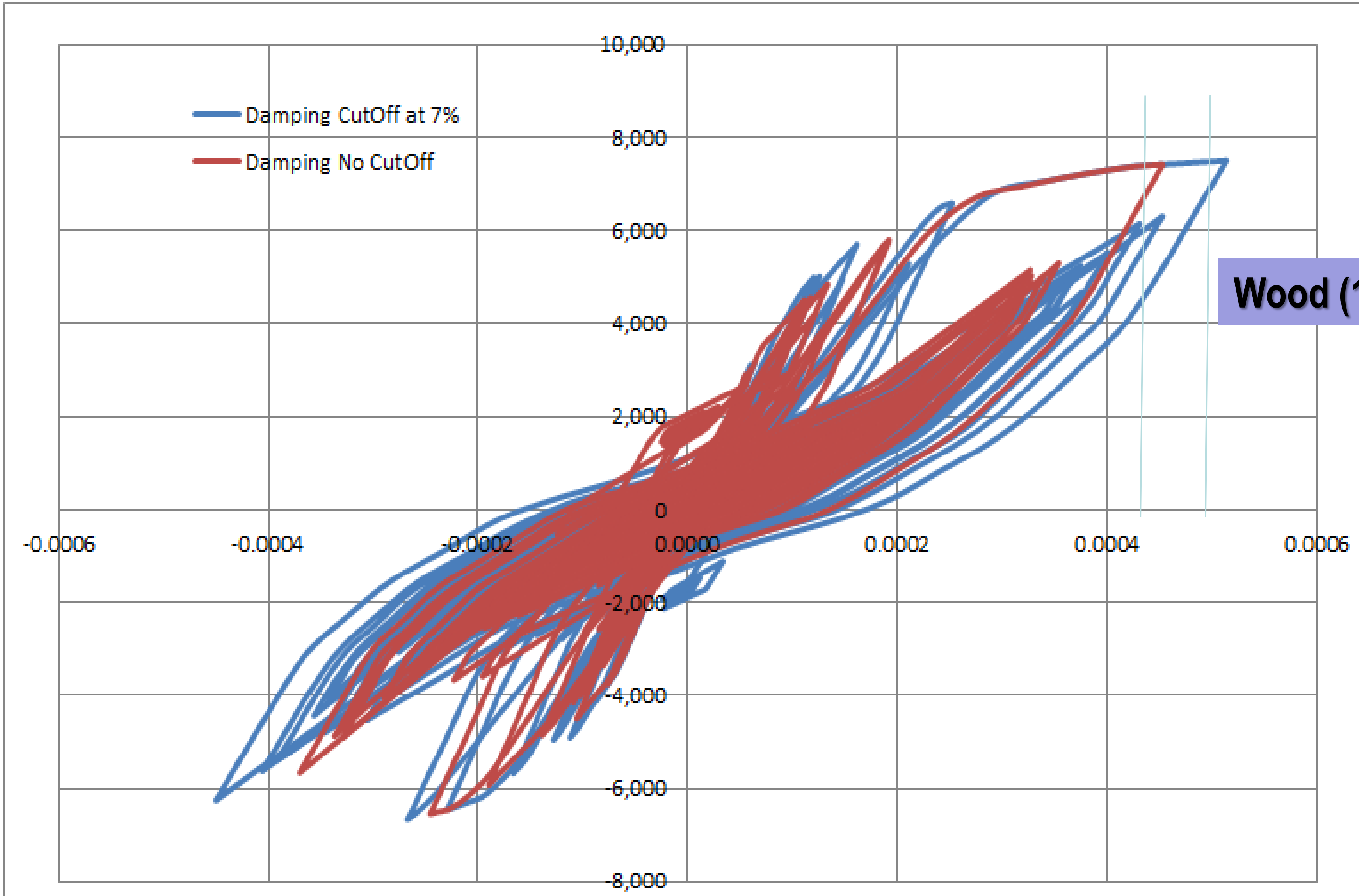
Selected Building Locations for Comparisons of Seismic SSI Responses



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

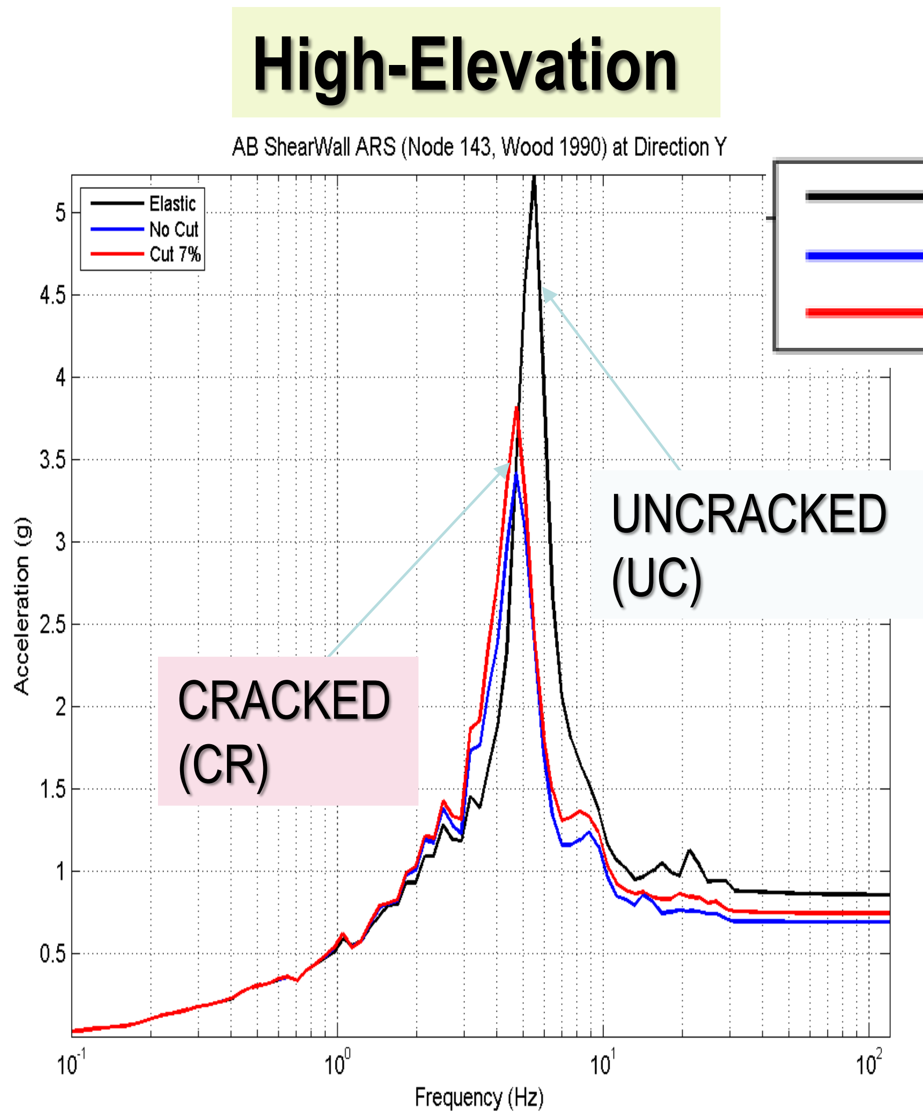


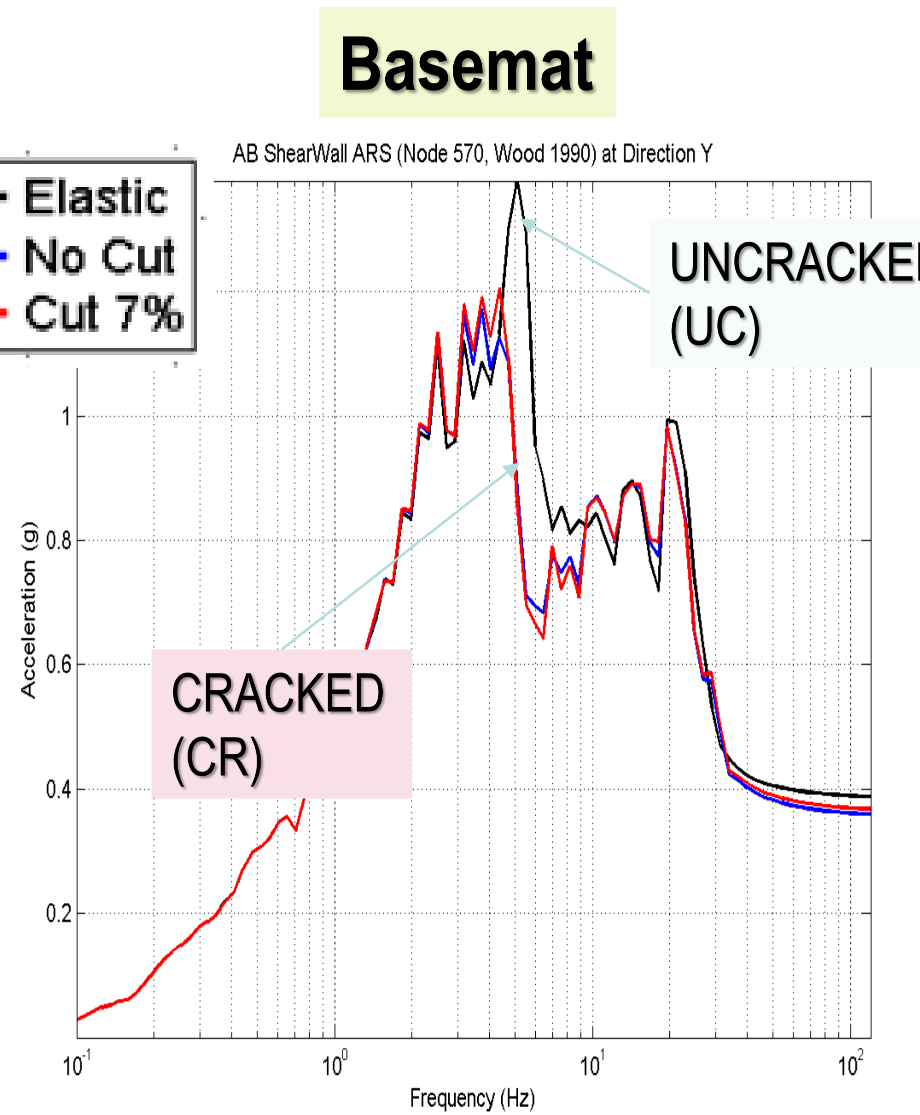
Panel 17 Hysteretic Behavior w/ and w/o 7% Damping Cut-Off for DBE 0.30g Input



Wood (1990)

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

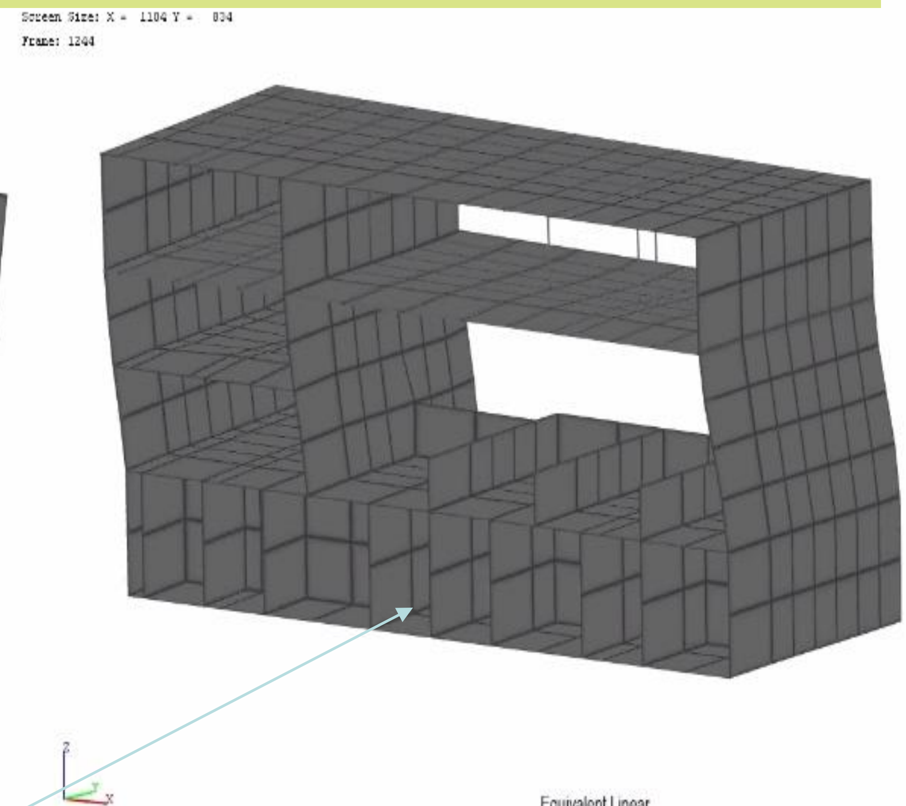




ACS SASSI Linear vs. Nonlinear SSI for Soil Site. Structural Displacements

Foundation motion is sensitive to nonlinear structure behavior! SSI iterations required!

ACS SASSI Linear SSI

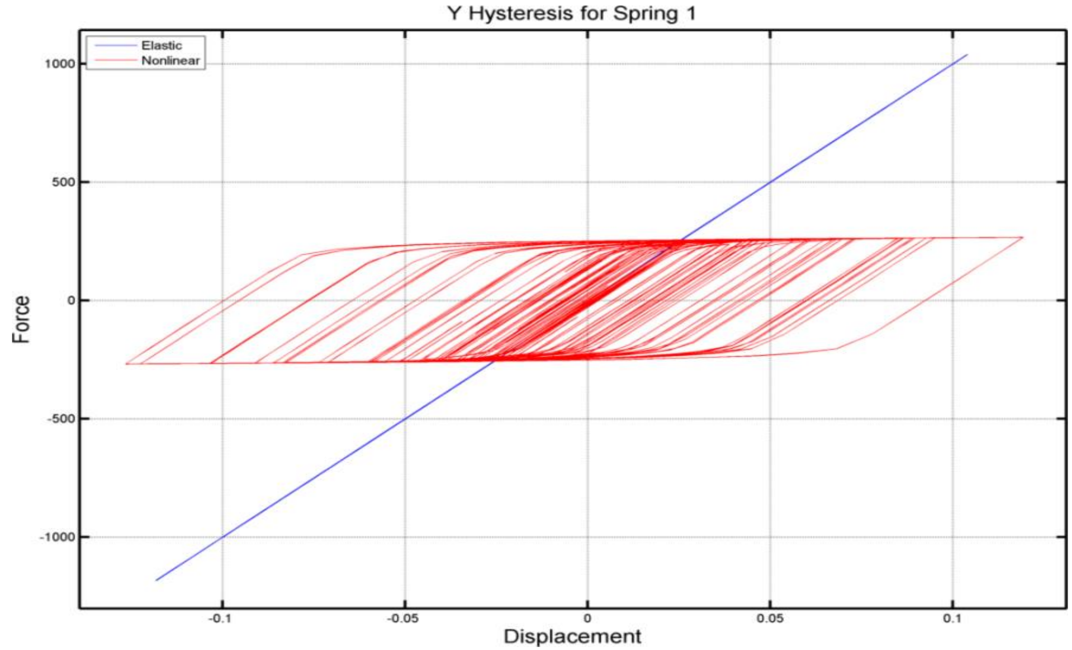


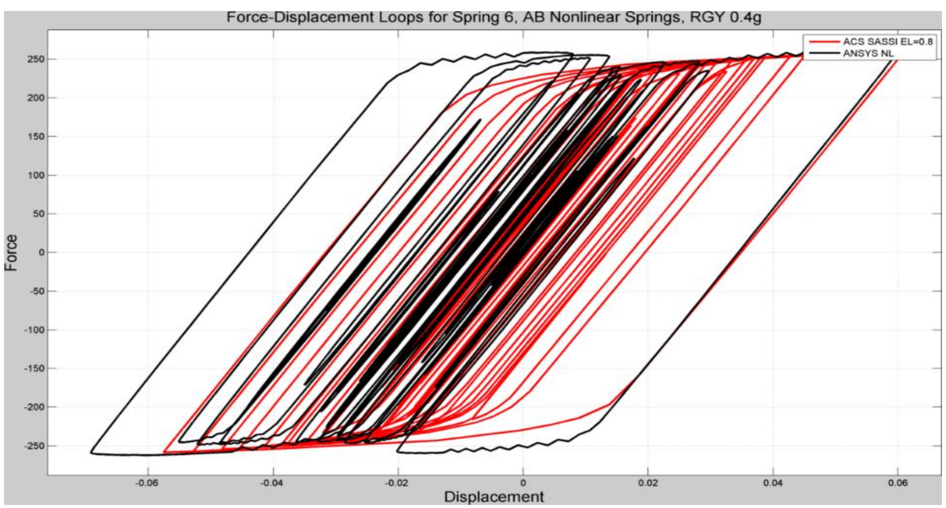
ACS SASSI Nonlinear SSI

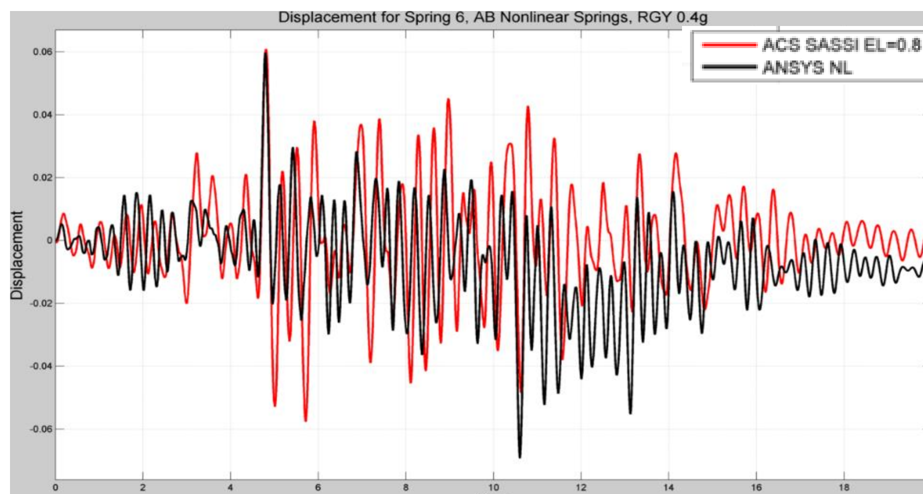
Nonlinear Springs Used for Modeling Base-Isolators or Checking Building Sliding

Base-Isolators

Small-Moderate Sliding







7. Option PRO

Probabilistic SRA and SSIA

ASCE 4-16 Probabilistic Site Response Analysis (PSRA) and Probabilistic SSI Analysis (PSSIA)

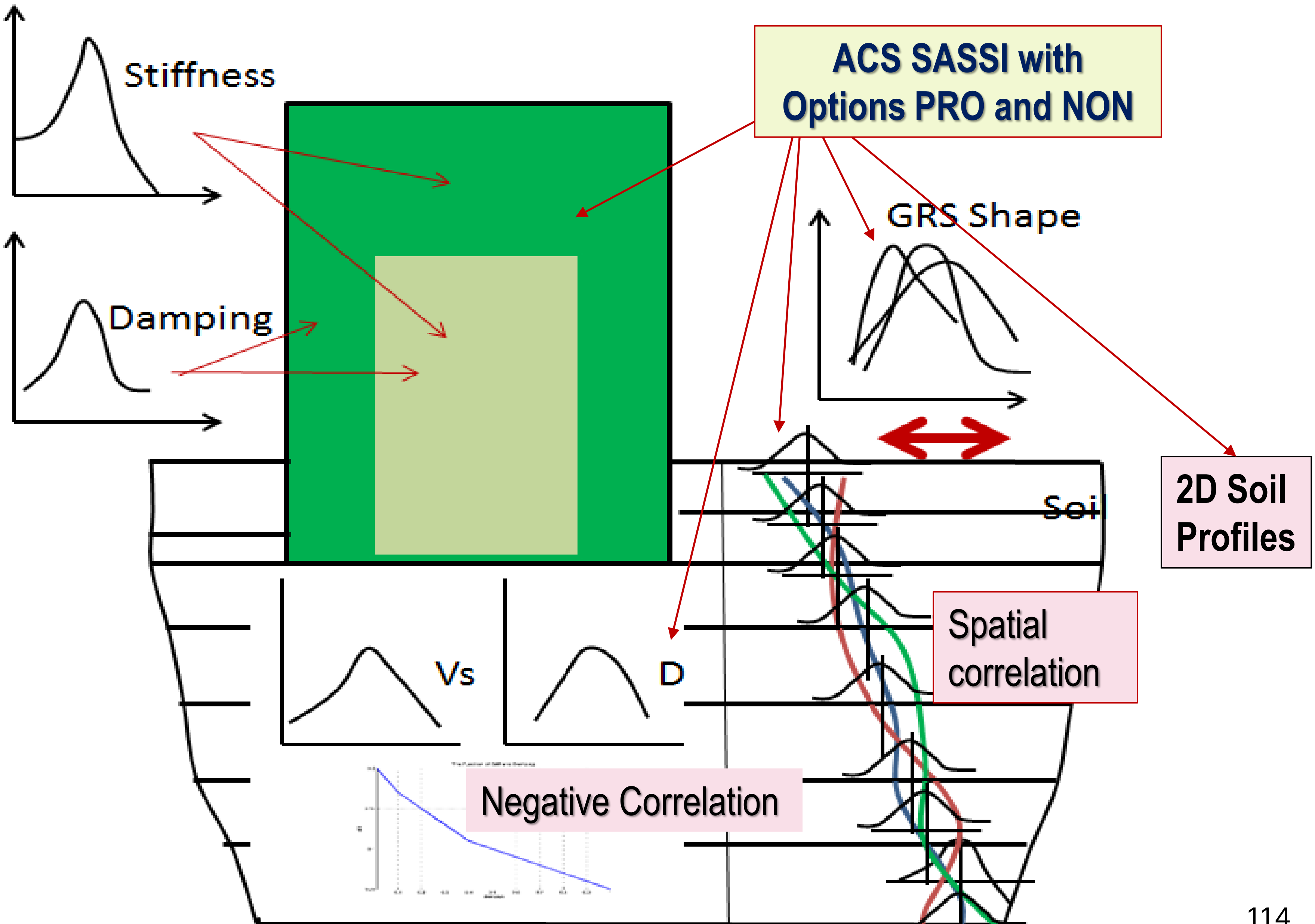
Based on the new ASCE 04-2016 recommendations:

- *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)*.

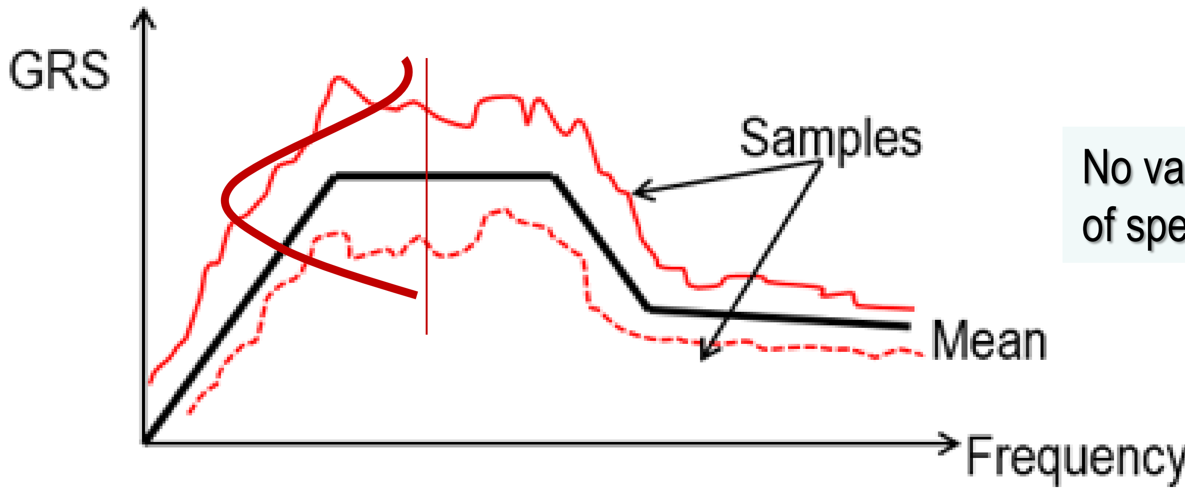
- Probabilistic modeling should minimally include:
  - SEISMIC INPUT: GMRS/UHRS amplitude assumed to randomly varying (Methods 1 and 2).
  - SOIL PROFILE: Vs and D soil profiles
  - STRUCTURE: Effective stiffness and damping, as functions of stress/strain level in different parts of structure.

ASCE 4-16 Probabilistic SSI Simulation Concept



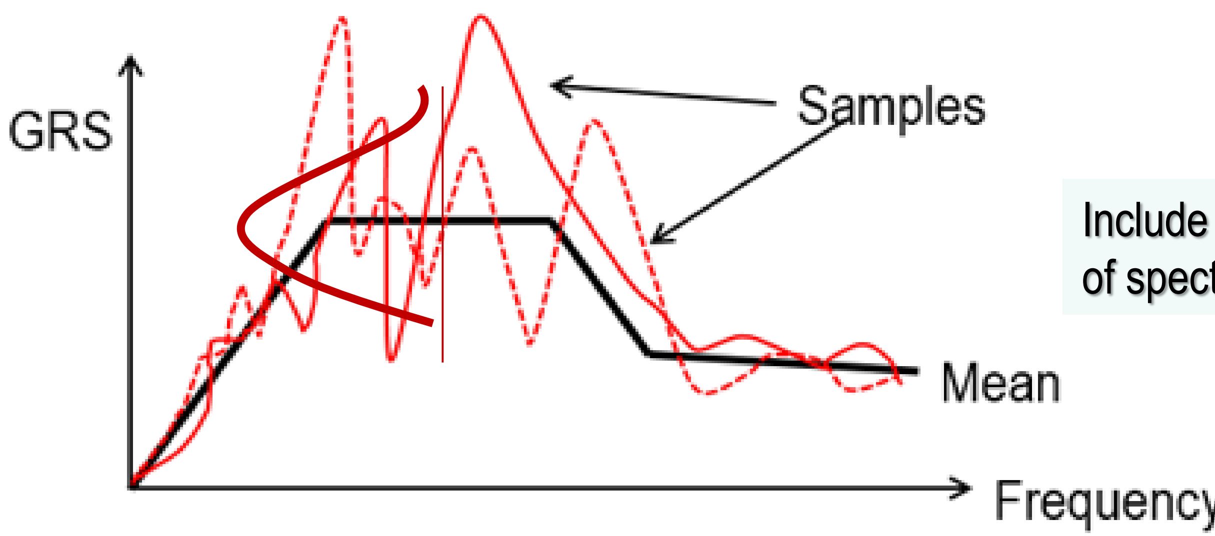
Probabilistic Seismic Input Models

ASCE 04-2015 Method 1



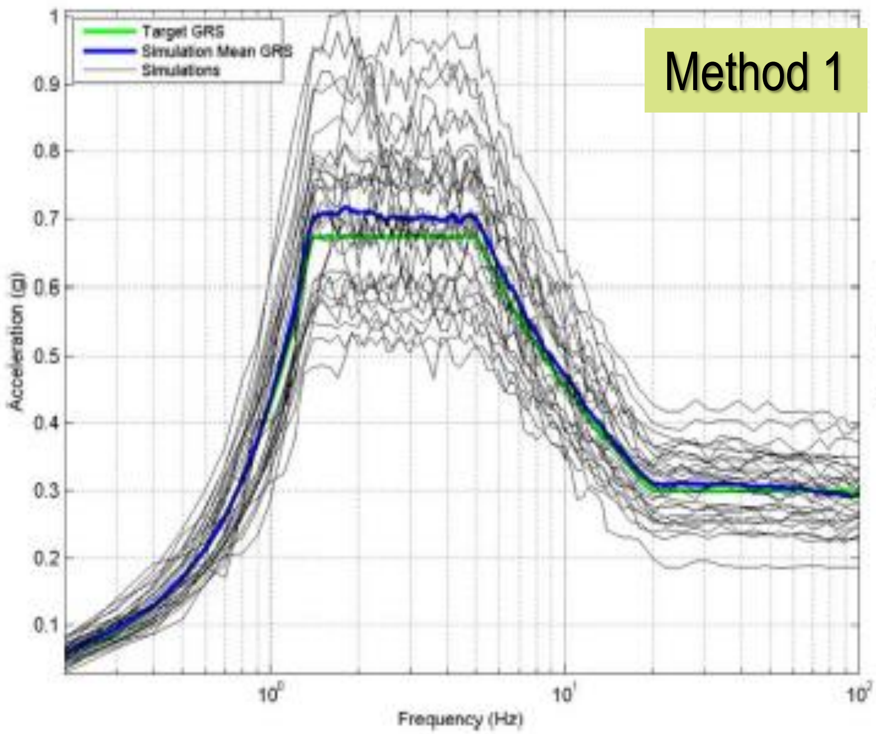
No variation
of spectral shape

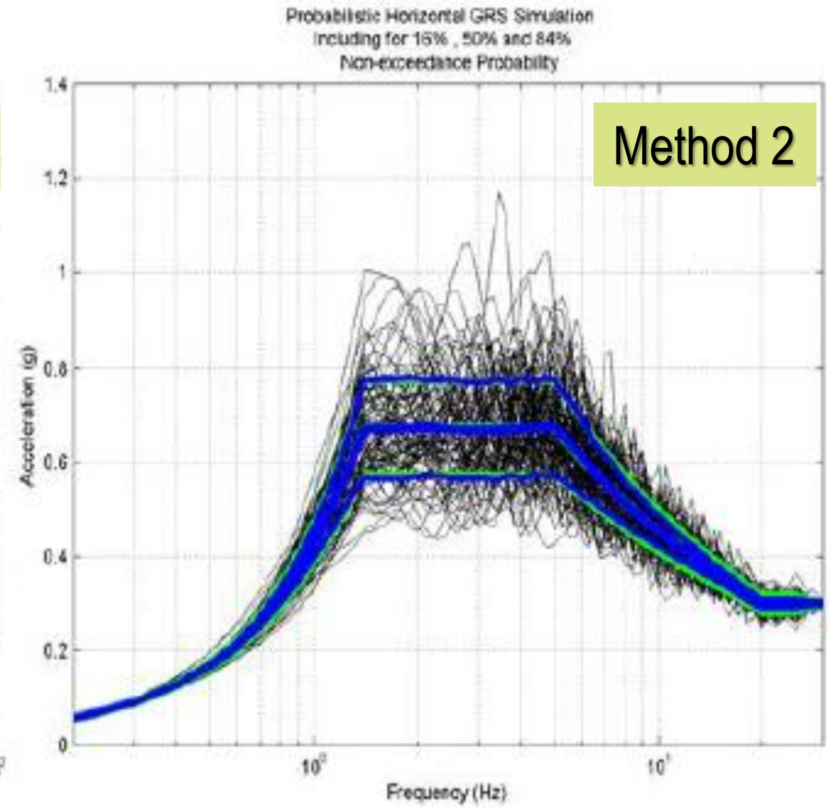
ASCE 04-2015 Method 2



Include variation
of spectral shape

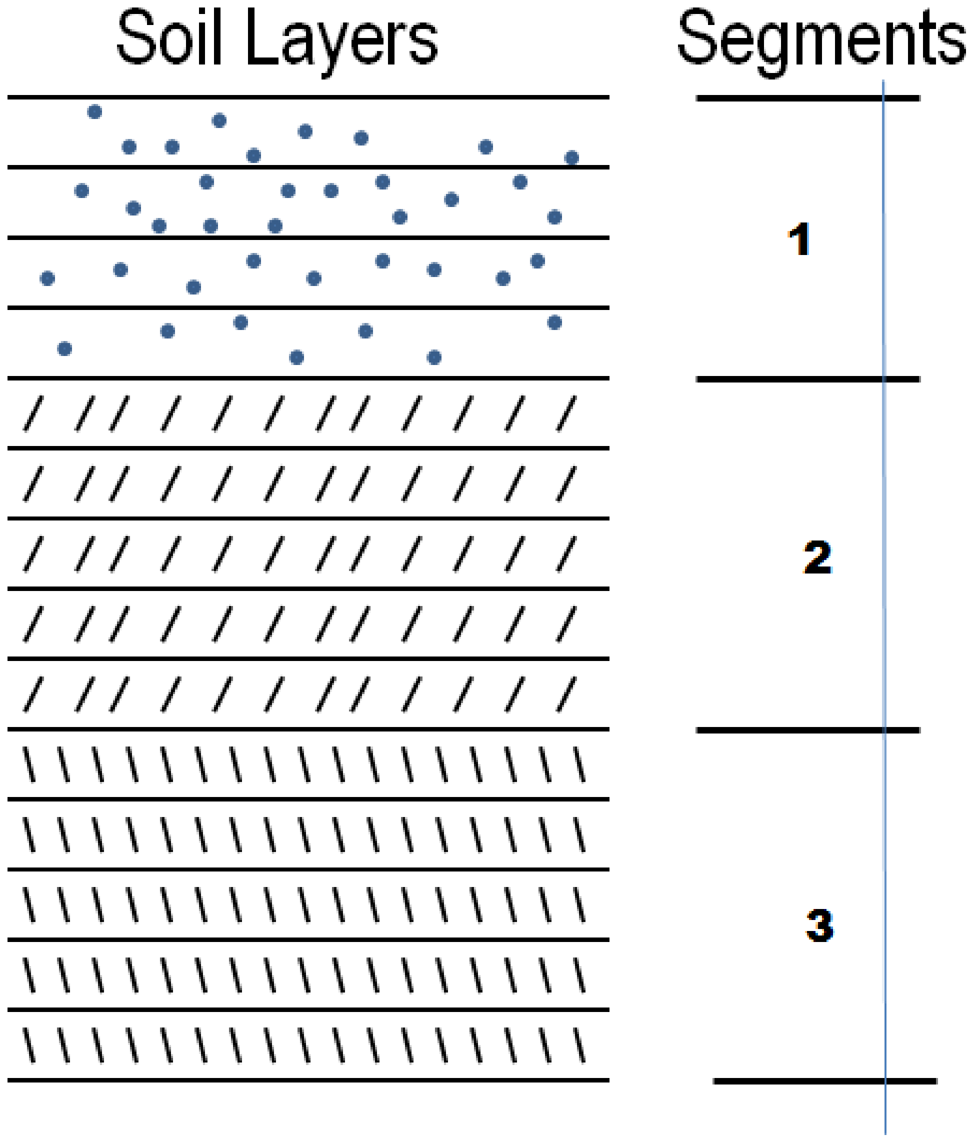
Probabilistic Seismic GRS Input Models





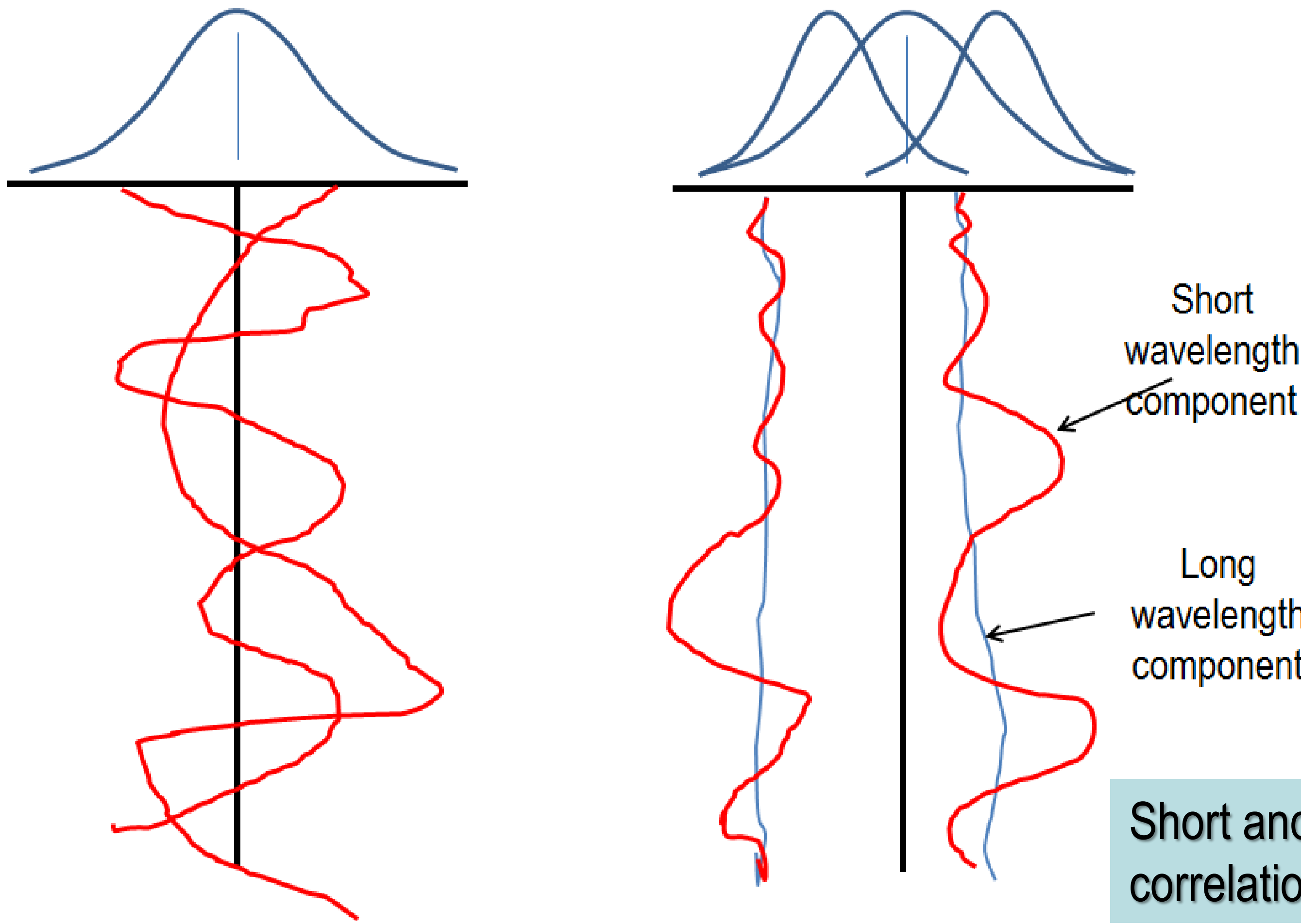
Probabilistic GRS and Its Simulated GRS Samples using
ASCE 4 Methods 1 (left) and Method 2 (right)

Vs and D Soil Profile Probabilistic Models Using Multiple Segments Split



Different statistical properties for different soil profile segments in depth

Vs and D Soil Profile Probabilistic Models. Two Variation Scale Models Based on Field Data



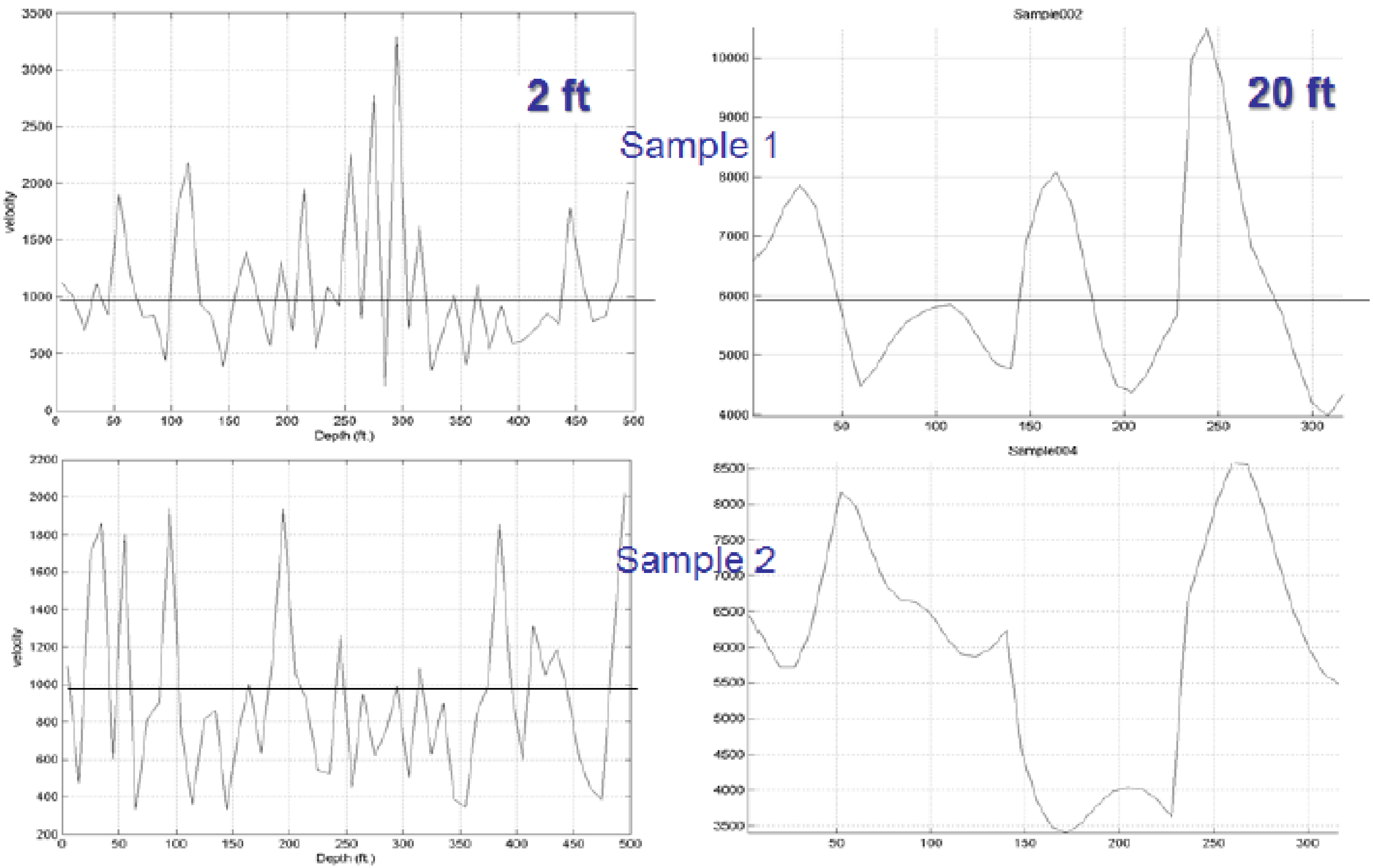
Short and large correlation lengths

Model 1 (Simple)

Model 2 (Composite)

(Popescu, 1996)

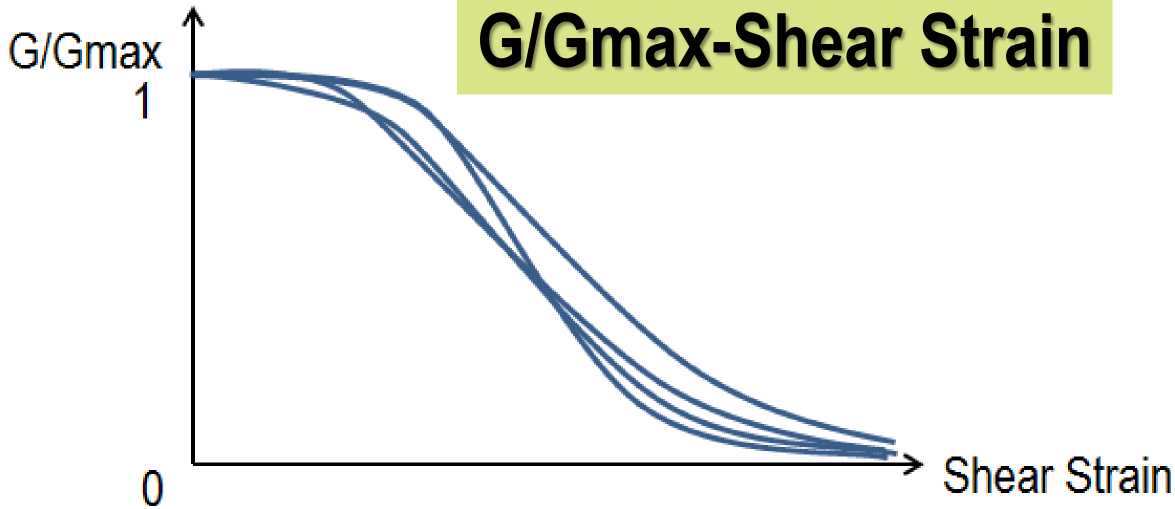
Correlation Length Effects on Soil Profile Shapes



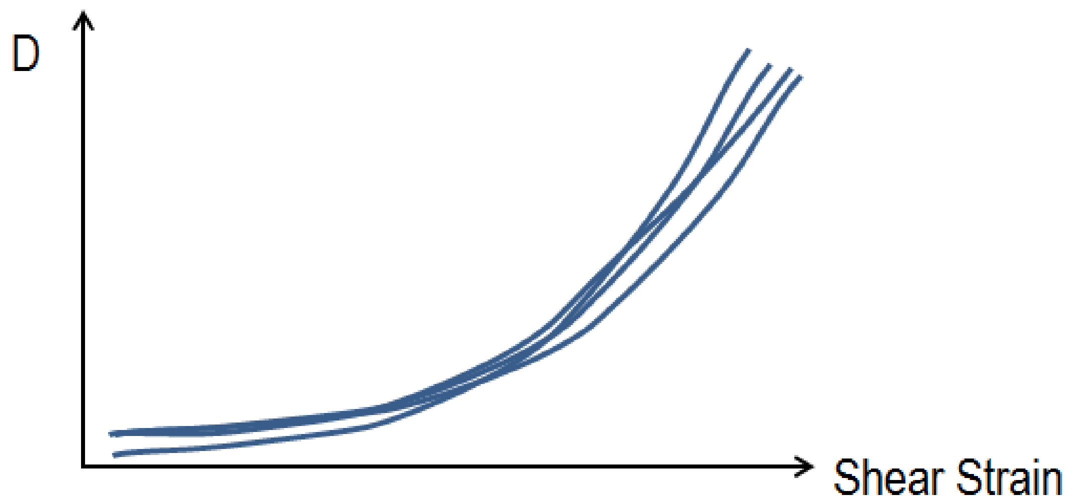
Two Soil Profile Random Samples Simulate Using Method 1 for Two Correlation Lengths; 2ft Correlation Length (left) and 20ft Correlation Length (right)

Probabilistic Soil Material Curve Models

G/Gmax-Shear Strain



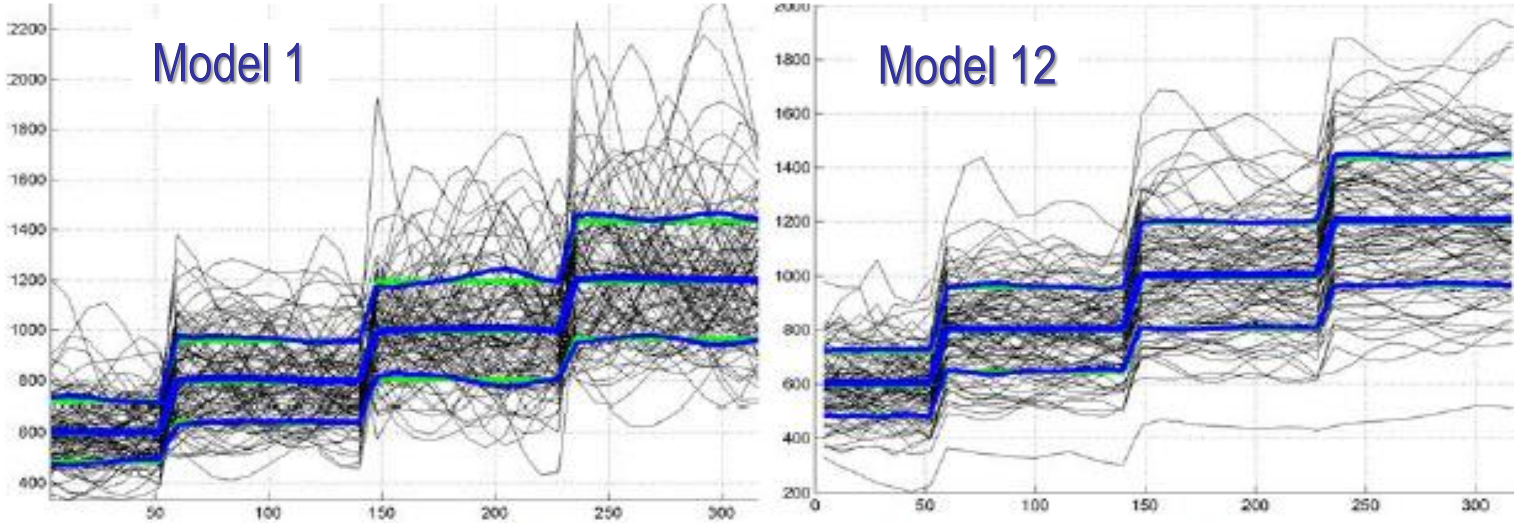
Damping-Shear Strain



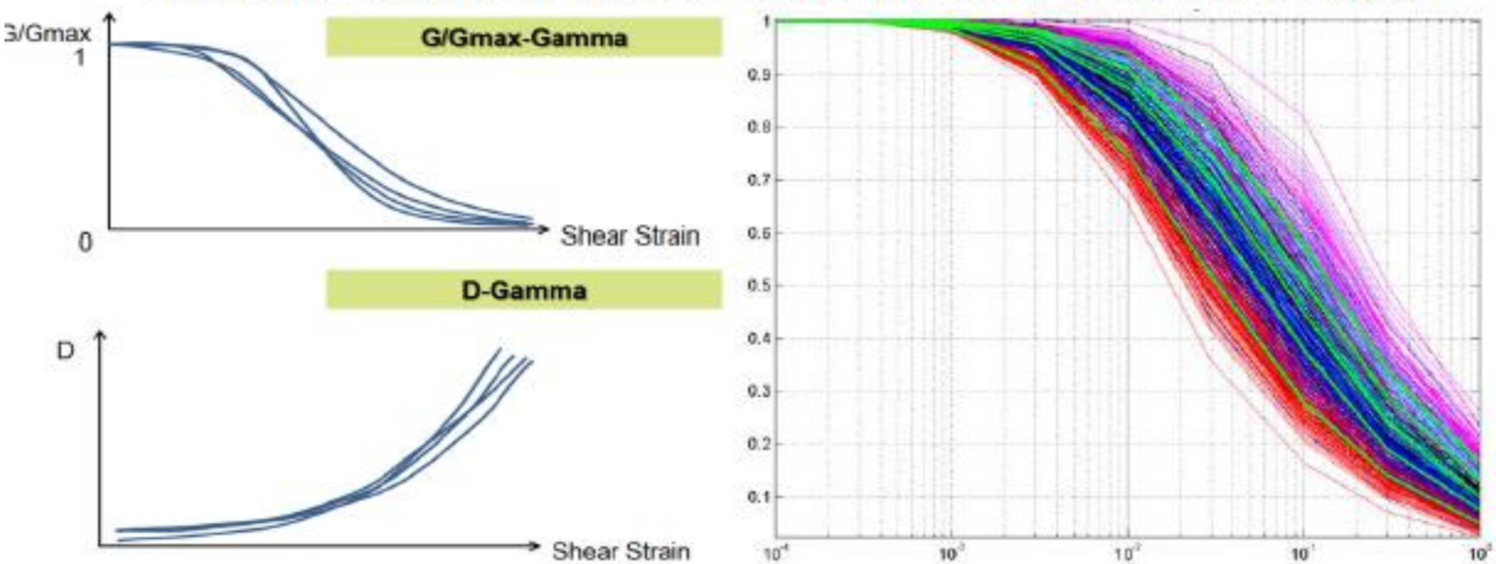
Soil curves show large correlation lengths along the shear strain axis.

Probabilistic Soil Profiles & Material Curves

1



Simulated vs. Target Soil Vs Profiles Using Method 1 (left) and Method 2 (right)

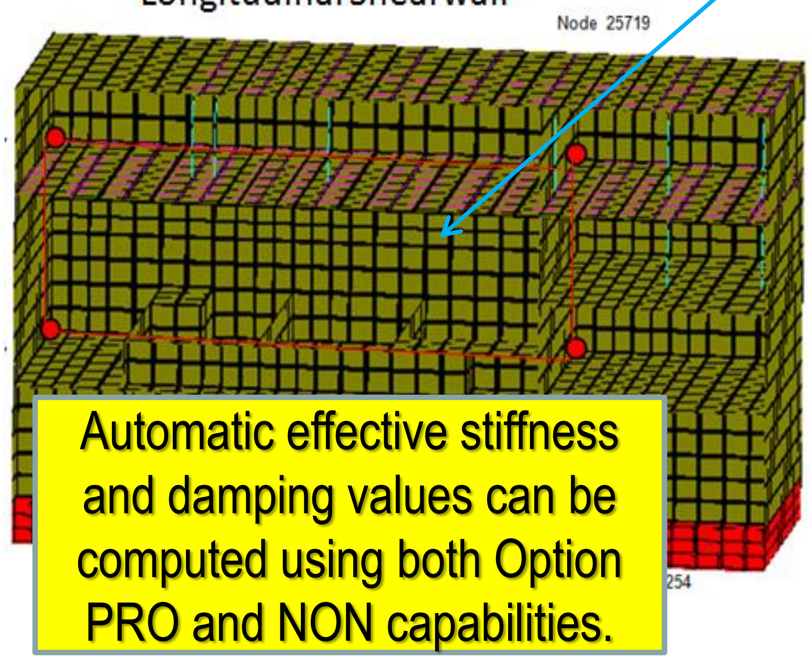


Soil G/Gmax and D Curve Random Variations (left); Simulated G/Gmax for 4 Soil Curves (right). The Mean Values of 4 Soil Curves Are Plotted with Green Lines.

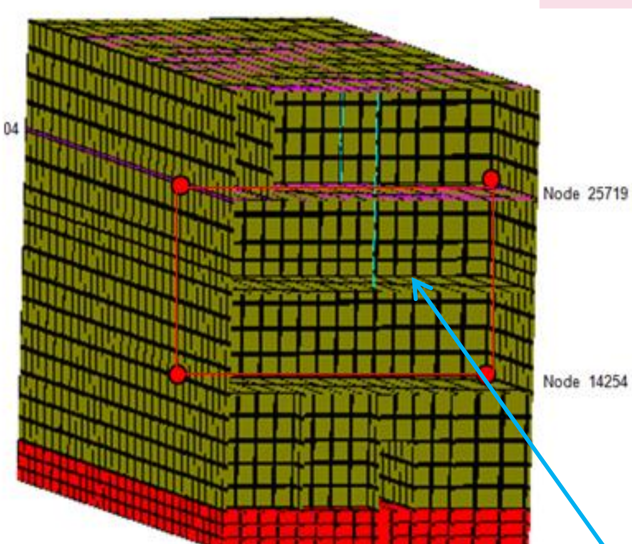
Probabilistic Structural Models; Effective Stiffness and Damping of Panels Dependent on Strain Levels

- 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.

Longitudinal Shearwall



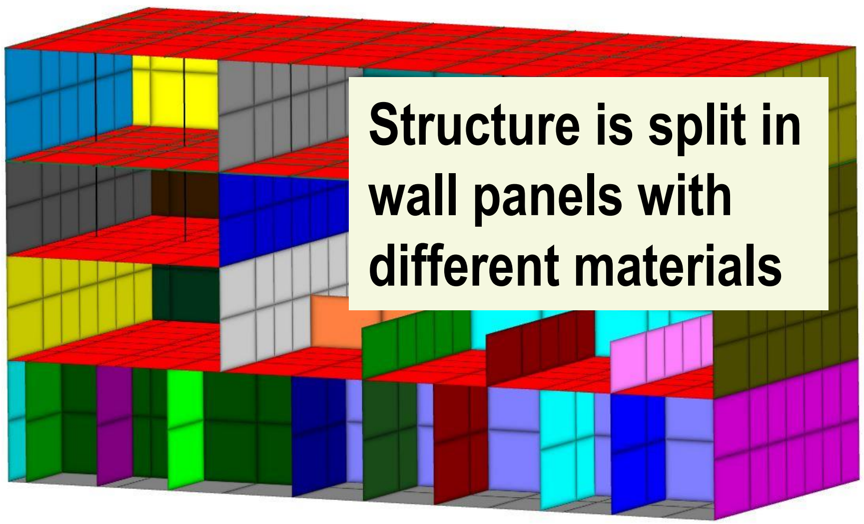
Transverse Shearwall



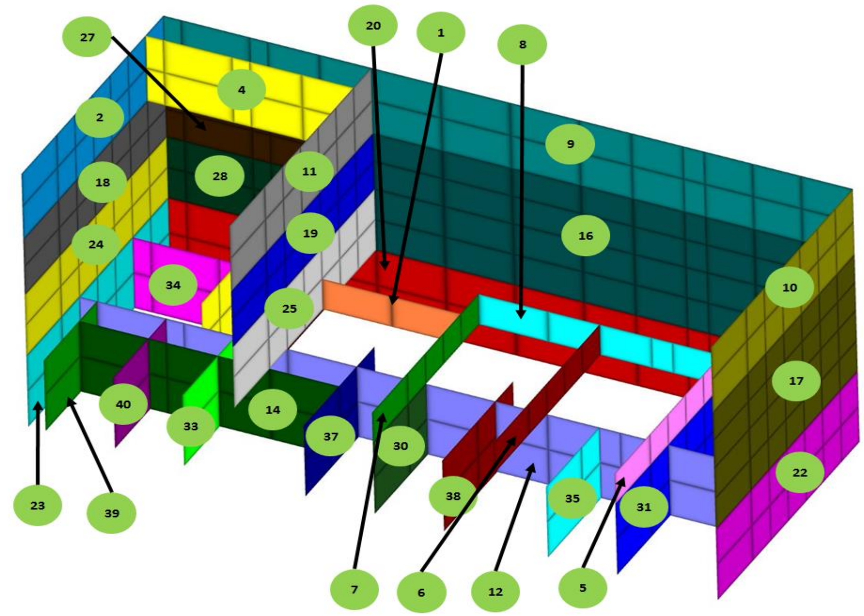
Deff = f (Keff/Kelastic)

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

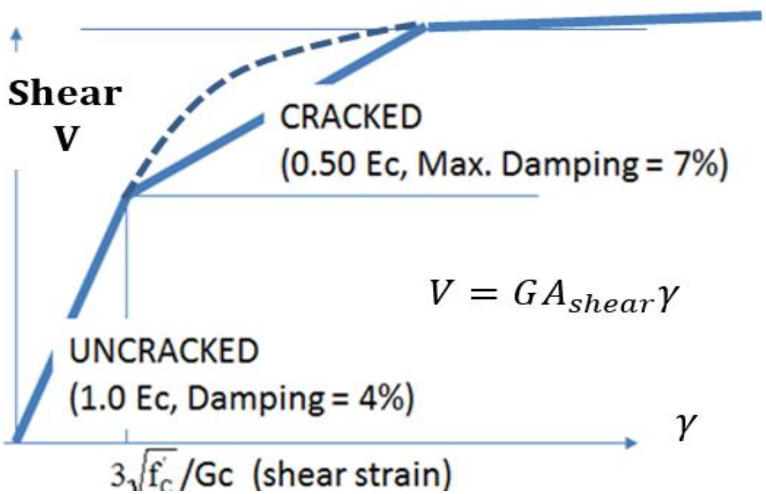
Reinforced Concrete Structural Behavior Consistent with Wall (Panel) Strains for Each Seismic Input



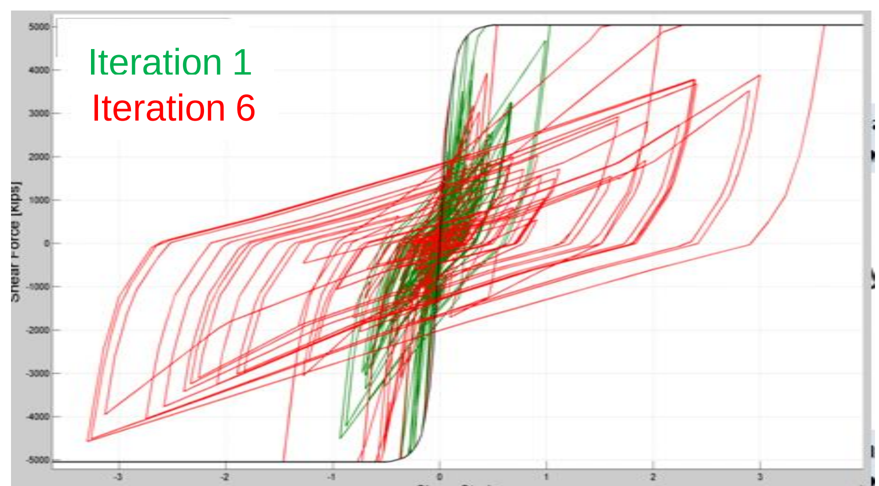
Structure is split in wall panels with different materials



Backbone Curves Automatically Generated



Iterative SSI Fast Analyses Until Convergence



Probabilistic SRA and SSIA Steps

1) **PREPARE SSI INPUTS:** Using *ACS SASSI PRO modules*, generate statistical ensembles for Probabilistic SRA and/or Probabilistic SSI analysis 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)*

8. Show Demos 1, 7, 13

Thank you!