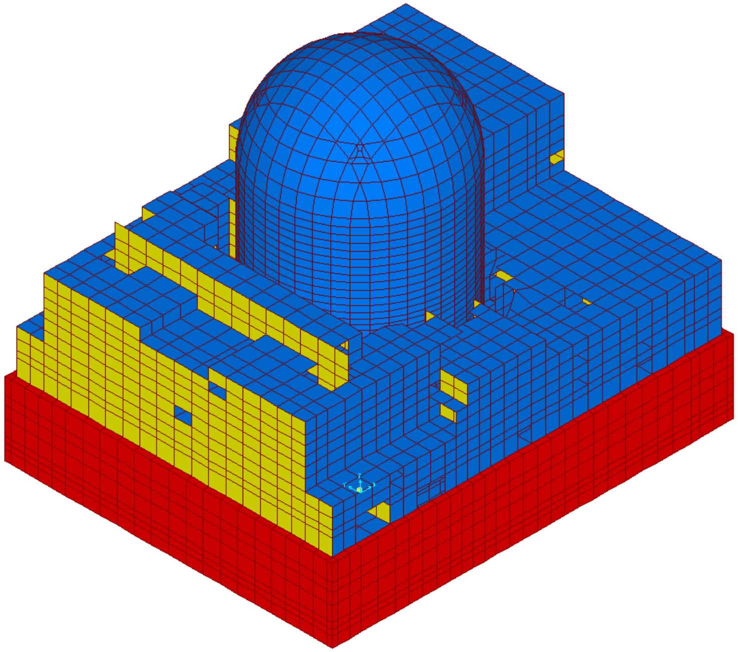
Pre-Application Review Meeting

1. Seismic Analysis of APR1400
2. Seismic Design of RCS, RI and Core
3. Plan for New CSDRS

Pre-Application Review Meeting
Seismic Analysis of APR1400

Introduction



- Overview
- Scope and Classification
- Regulatory Requirements
- Computer Programs
- Analysis and Design Flow

Overview

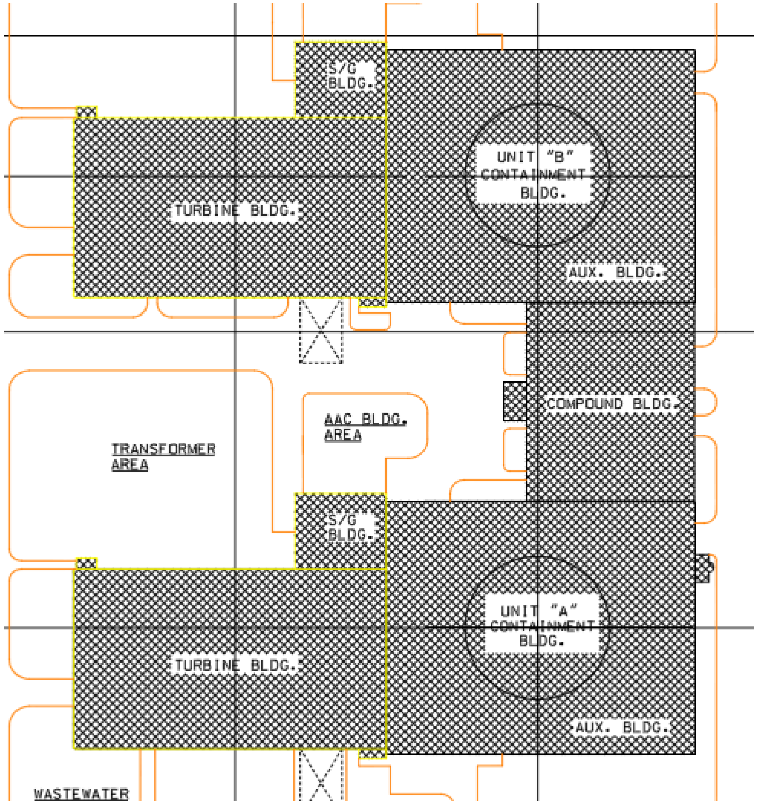
- Purpose
  - Introduce seismic analysis procedures performed for APR1400 (received DC from Korean Regulatory Agency in 2002)
  - Examine proposed seismic analysis update plan for APR1400 to meet new information and updated regulatory requirements
    - CEUS seismic source study
    - SSI methodology including incoherent input motion effects

Overview (cont'd)

- Standard design
  - Design ground response spectra (DGRS) reinforced over RG1.60 design response spectra are defined
  - Various soil conditions cover most of potential site characteristics
- Seismic design requirements
  - SSE PGA: 0.3g
  - OBE elimination in design base
    - OBE = 1/3 · SSE

Scope and Classification

- Design scope : Nuclear Island structures (Containment and Auxiliary Buildings), Turbine Building, Compound Building, and Switchgear Building
- Seismic classification in scope
  - Seismic Category I
    - Containment Building
    - Auxiliary Building
  - Seismic Category II
    - Turbine Building
    - Compound Building
    - Switchgear Building



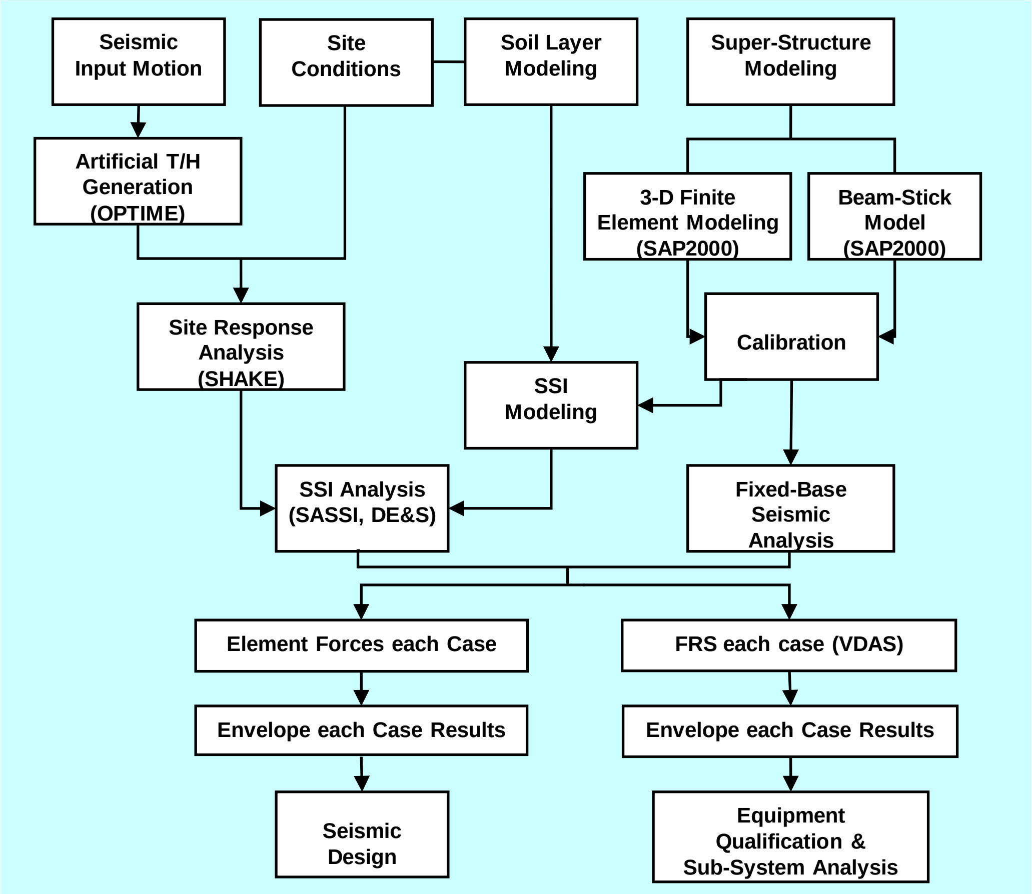
Regulatory Requirements

- 10 CFR Part 50, App. S: Earthquake Engineering Criteria for Nuclear Power Plants
- 10 CFR Part 100, App. A: Seismic and Geologic Siting Criteria for Nuclear Power Plants
- Reg. Guide 1.60: Design Response Spectra for Seismic Design of Nuclear Power Plants
- Reg. Guide 1.61 (Rev.1): Damping Values for Seismic Design of Nuclear Power Plants
- Reg. Guide 1.92 (Rev.2): Combining Modal Responses and Spatial Components in Seismic Response Analysis
- SRP 3.7.1 (Rev.3): Seismic Design Parameters
- SRP 3.7.2 (Rev.3): Seismic System Analysis

Computer Programs

- Design ground motion
  - OPTIME: artificial time history generation
- Modal analysis
  - SAP2000: modeling and modal analysis of super-structures
- Soil/Structure Interaction
  - SHAKE: site response analysis
  - SASSI(Rev. 4.0, DE&S): SSI analysis used for SYSTEM 80+ design
- Response spectrum generation
  - VDAS (Rev. 1): FRS calculation and plot

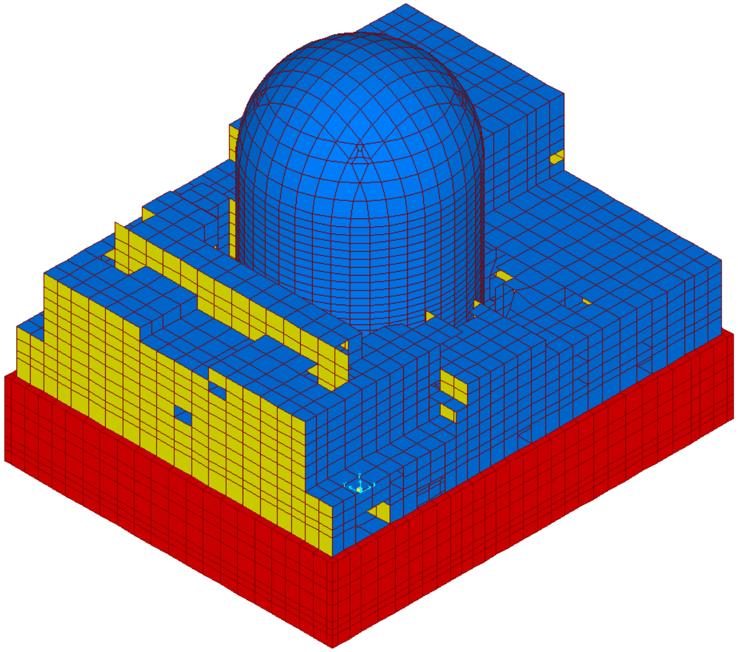
Analysis and Design Flow



Design Ground Motion

Design Ground Motion Response Spectra

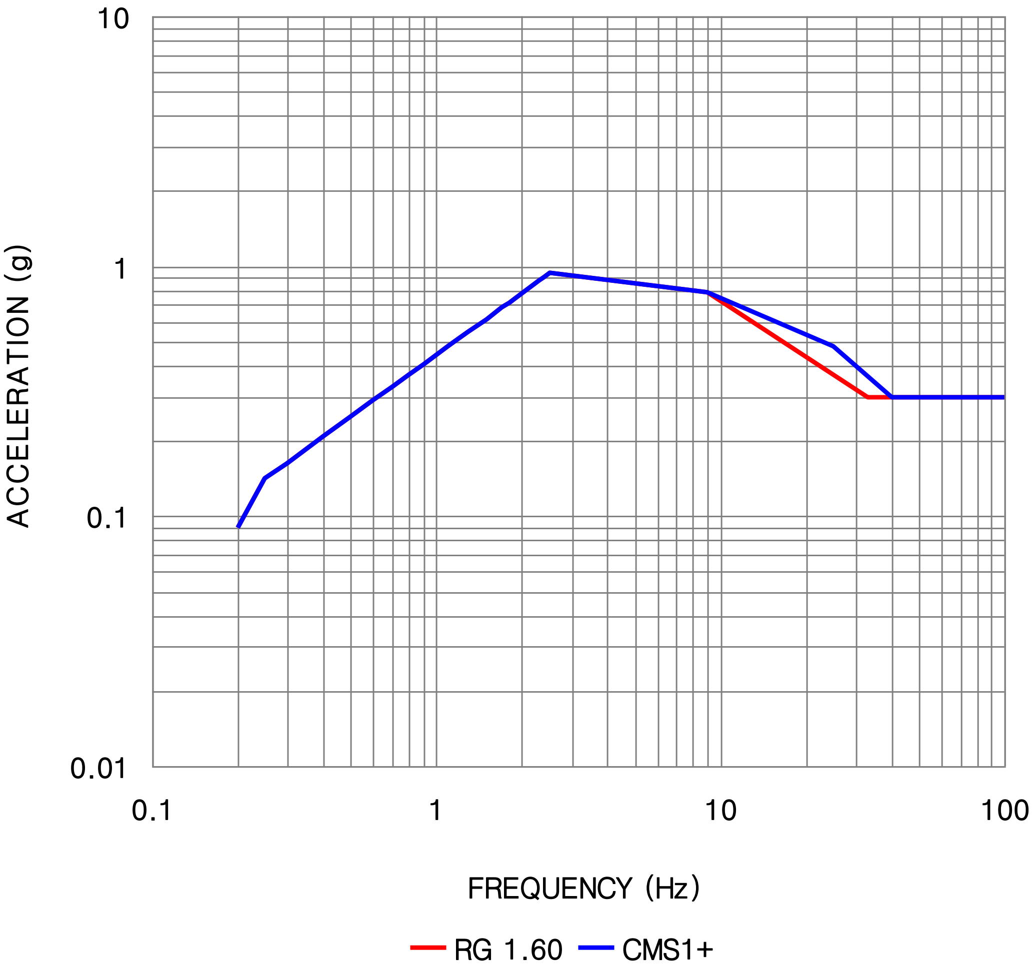
Design Ground Motion Time History



Design Ground Motion Response Spectra

- CMS1+ was used for APR1400 design
  - 30% higher at 25 Hz than RG 1.60
  - LLNL & EPRI research results on the seismic hazard analysis of CEUS
    - "Revised Livermore Seismic Hazard Estimates for Sixty-Nine Nuclear Power Plant Sites East of Rocky Mountains," NUREG-1488, April 1994.
    - "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountain," NUREG/CR-5250, January 1989.
    - "Seismic Hazard Methodology for the Central and Eastern United States," EPRI Report NP-4726, November 1988.
- We are aware of CEUS source characterization ongoing study

Design Ground Motion Response Spectra (cont'd)

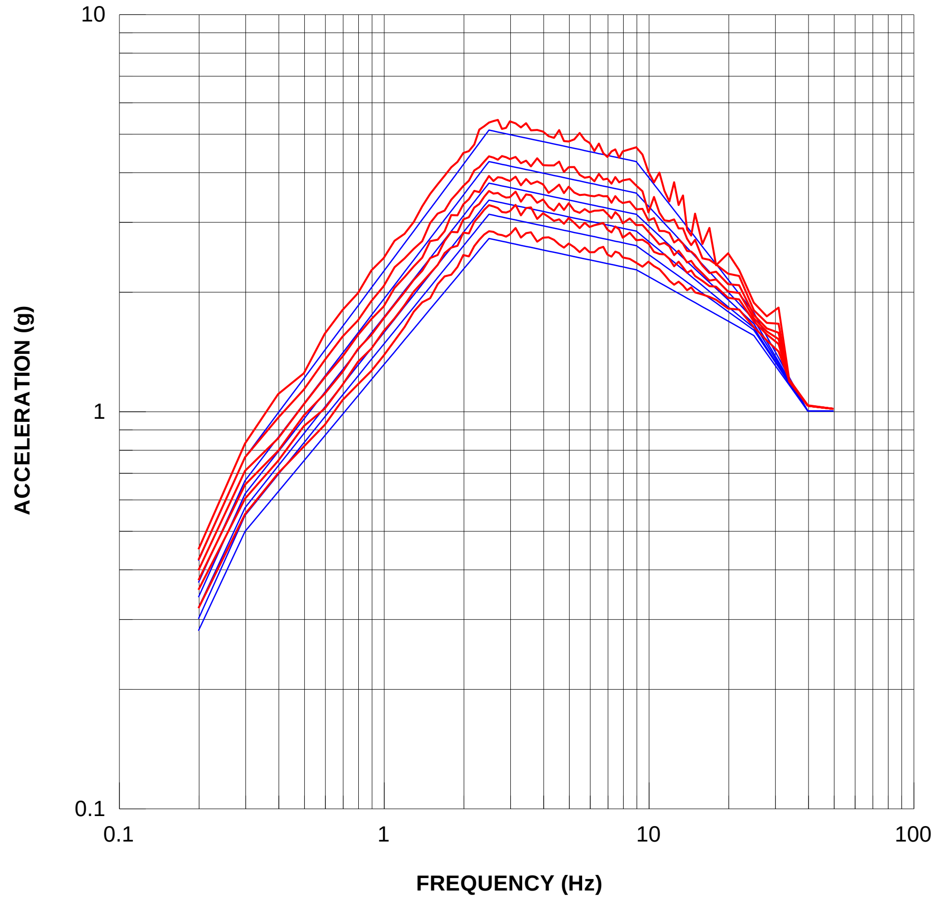


Horizontal Spectral Amplifications for CMS1+ and RG 1.60 Spectrum (5% Damping)

Design Ground Motion Time History

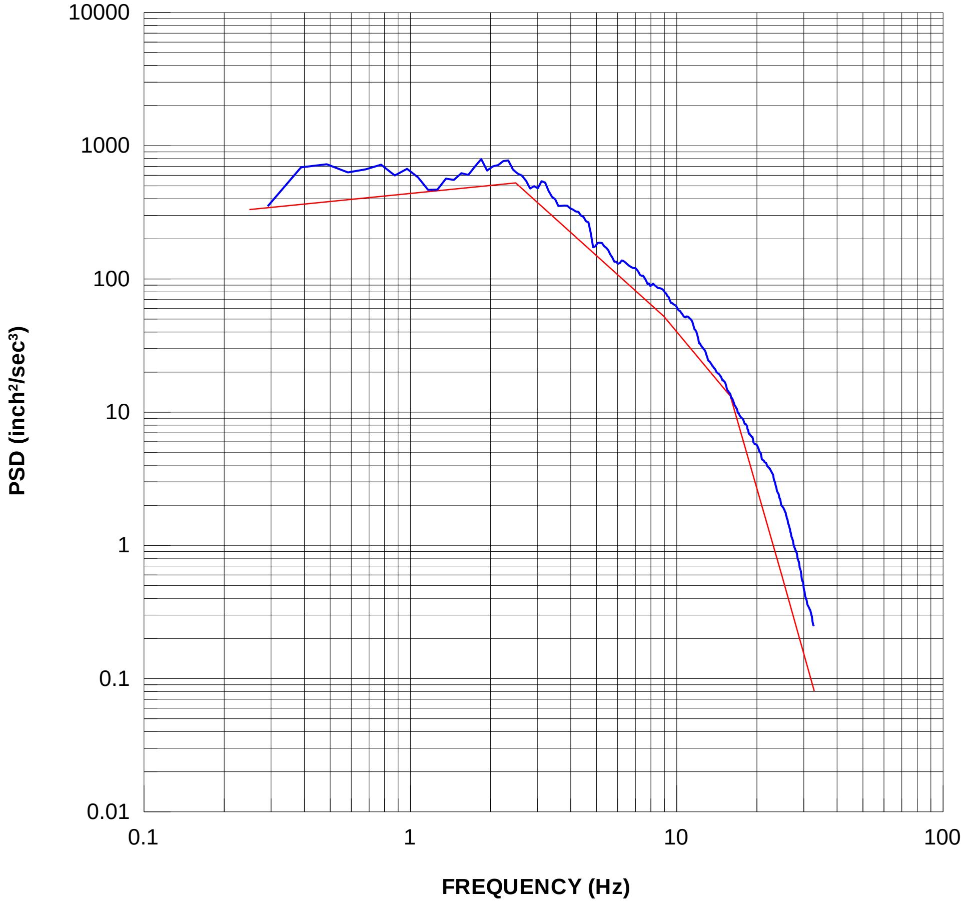
- Three orthogonal design acceleration time histories were used.
  - Artificial earthquake motion using random vibration theory
  - Enveloping multi-damping design response spectra of TH's responses
  - Satisfying PSD requirements of SRP 3.7.1, Appendix A.
  - Cross-correlation coefficients: less than 0.3 (ASCE 4-98)
- We will generate new design ground motion time history to meet revised SRP 3.7.1
  - The recorded earthquake motion instead of artificial TH will be used in accordance with SRP 3.7.1(Rev. 3)
  - Cross-correlation coefficients: less than 0.16 (SRP 3.7.1, Rev. 3)

Design Ground Motion Time History (cont'd)



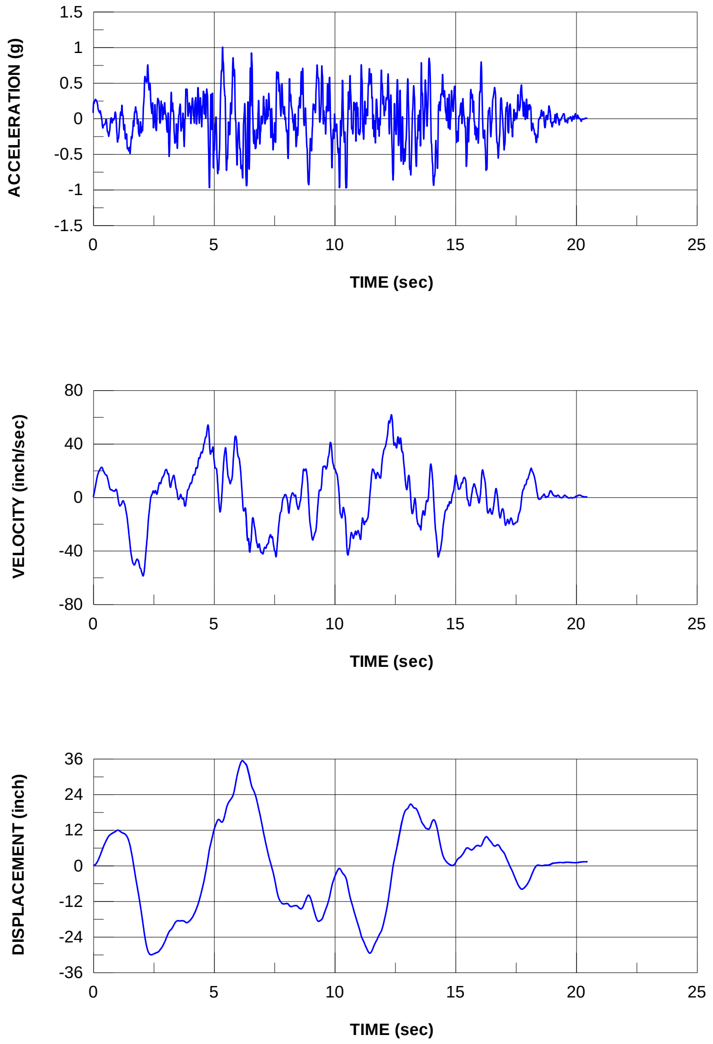
Comparison of Response Spectra for N-S Component and DGRS
(Anchored to 1.0g,1, 2, 3, 4, 5 and 7% Damping)

Design Ground Motion Time History (cont'd)



Comparison of PSD Function (N-S Component)

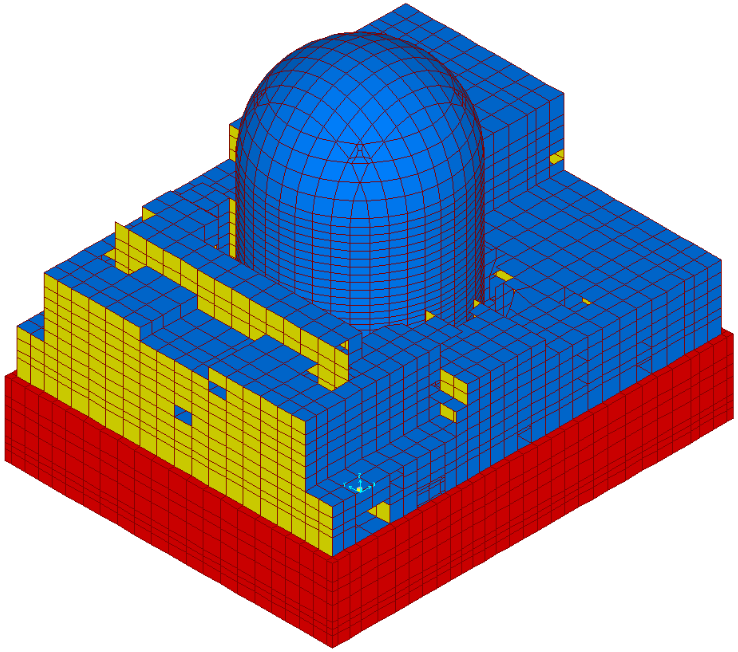
Design Ground Motion Time History (cont'd)



Time History Plots for N-S Component (Anchored to 1.0g)

Site Soil Condition

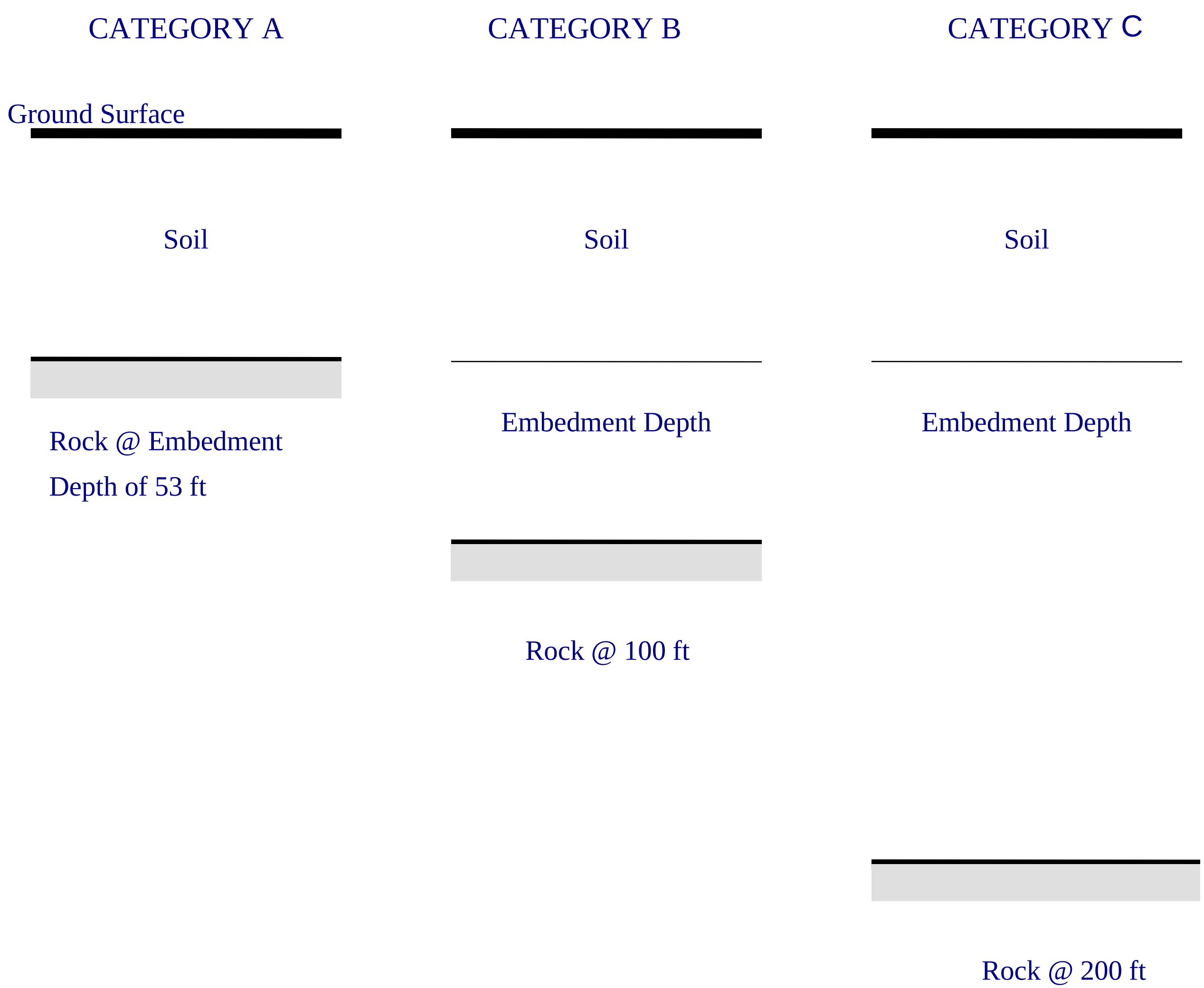
- Site Soil Condition
- Soil Cases
- Generic Soil Profiles



Site Soil Condition

- Generic sub-surface profile: one hard rock case & 8 soil cases (9 cases)
- Based on bed rock depth, divided into 3 categories
  - 53 ft (to foundation bottom)
  - 100 ft
  - 200 ft
- For each category, soil cases are defined based on shear wave velocity distribution

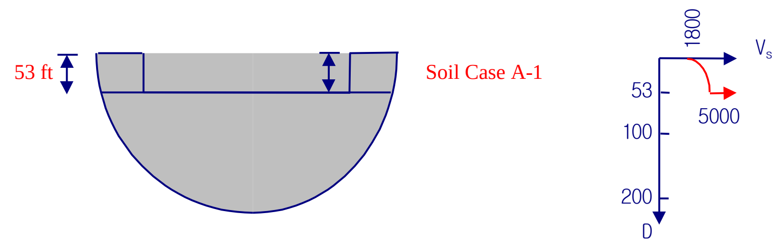
Site Soil Condition



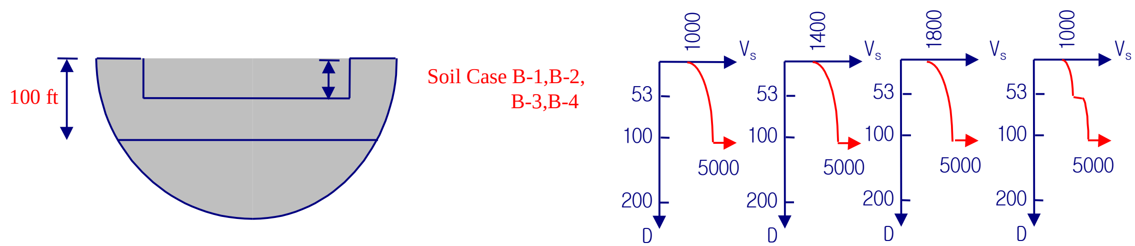
Soil Cases

- Category A: bed rock depth 53 ft below ground surface
  - Vs = 1,800 fps at GS: A1 (stiff)
- Category B: bed rock depth 100 ft below ground surface
  - Vs = 1,000 fps at GS : B1 (soft)
  - Vs = 1,400 fps : B2 (medium)
  - Vs = 1,800 fps : B3 (stiff)
  - Vs = 1,000 fps + 1800 fps: B4 (stepwise)
- Category C: bed rock depth 200 ft below ground surface
  - Vs = 1,000 fps at GS : C1 (soft)
  - Vs = 1,800 fps : C2 (stiff)
  - Vs = 1,000 fps + 1800 fps: C3 (stepwise)

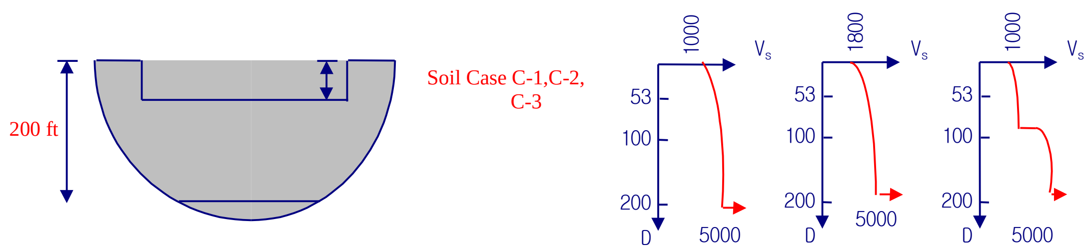
Soil Cases (cont'd)



Site Category A



Site Category B



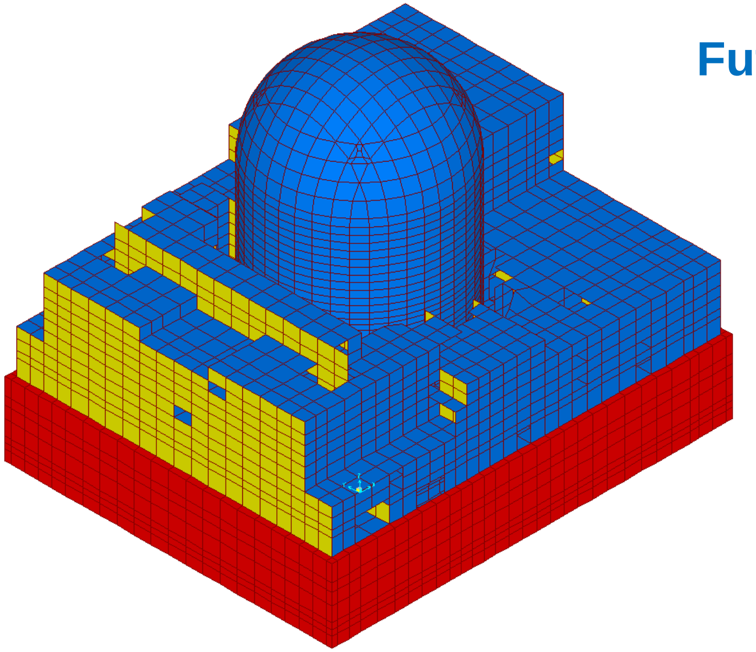
Site Category C

Generic Soil Profiles

- Criterion for fixed base assumption has been changed from 3,500 fps to 8,000 fps (SRP 3.7.2, Rev.3).
  - Will be incorporated in new soil profiles
- After reviewing CEUS information, we will revise generic soil profile.

Seismic Analysis Method

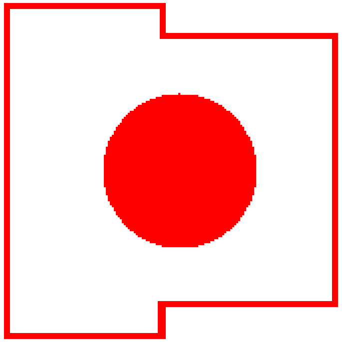
- Modeling
- Soil/Structure Interaction Analysis
- SSI Analysis Results (Design Parameters)
- Future Plan for SSI evaluation

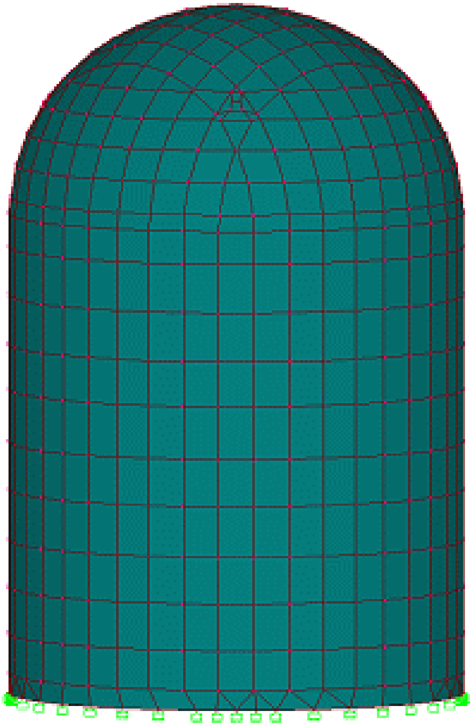


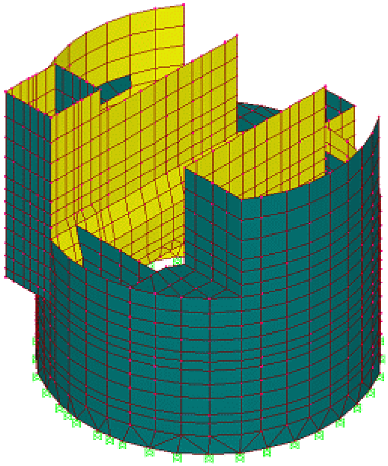
Modeling

- Super-structure model
  - Common basemat: shared by Containment and Auxiliary Buildings
  - Containment and Auxiliary Buildings are separated above basemat
- Three-dimensional finite element model
  - Verification for lumped mass beam-stick model
    - Mode shapes, frequencies, mass participation factors
  - Structural analysis
- Lumped mass beam-stick model
  - Containment Building: Containment, Internal Structure (PSW,SSW), RCS, etc
  - Auxiliary Building: four areas are converted independently to beam-stick model and linked with beams representing wall stiffness.
- Damping ratio in SSE: RG 1.61

Modeling (cont'd)





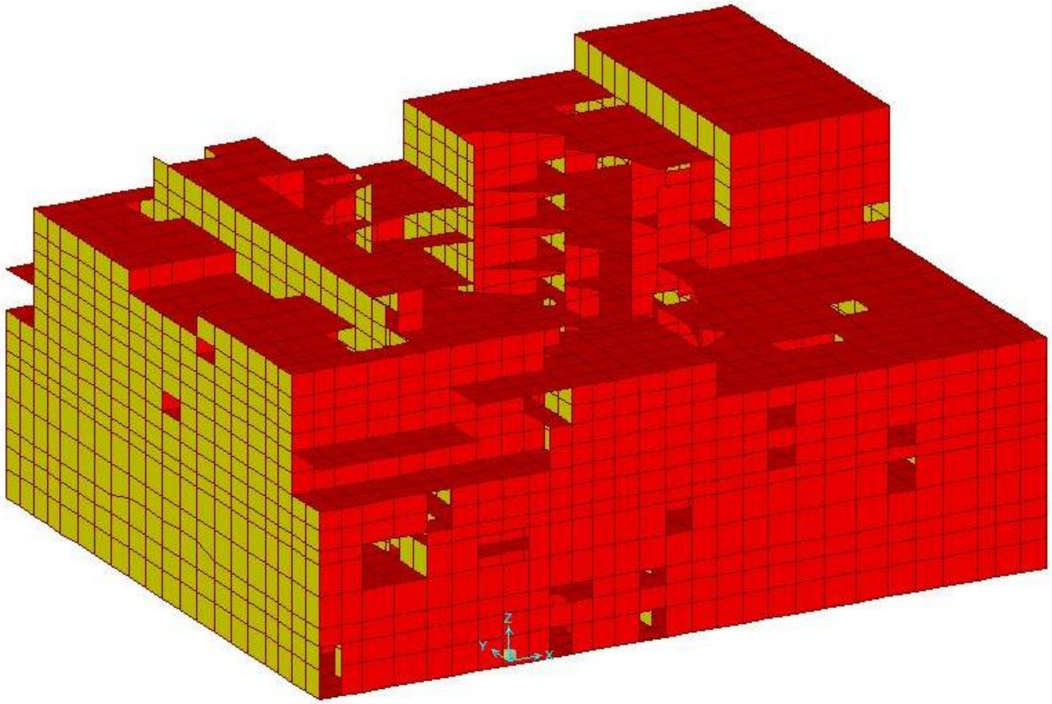


(a) Containment Shell

(b) Internal Structure

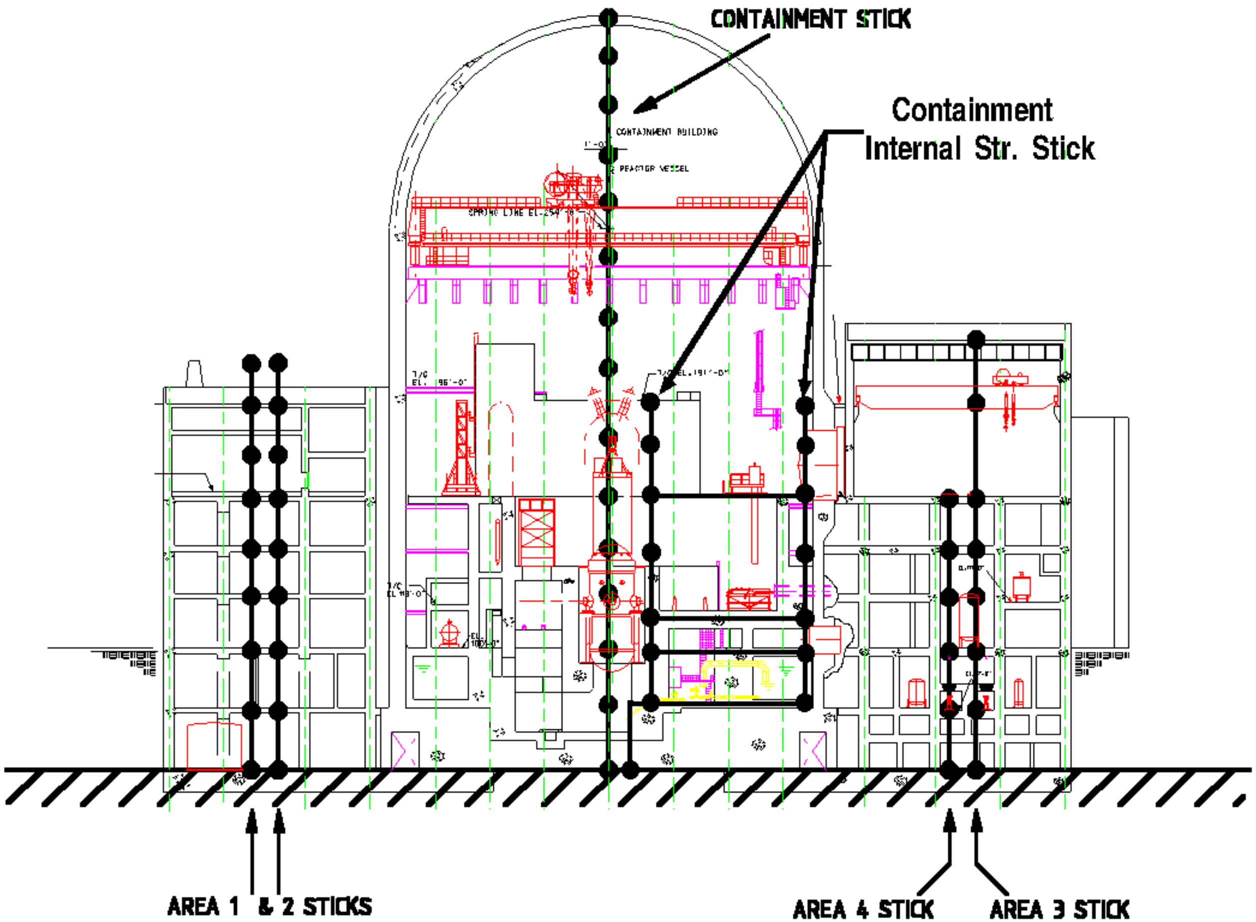
Model of Reactor Containment Building

Modeling (cont'd)



FE Model of Auxiliary Building

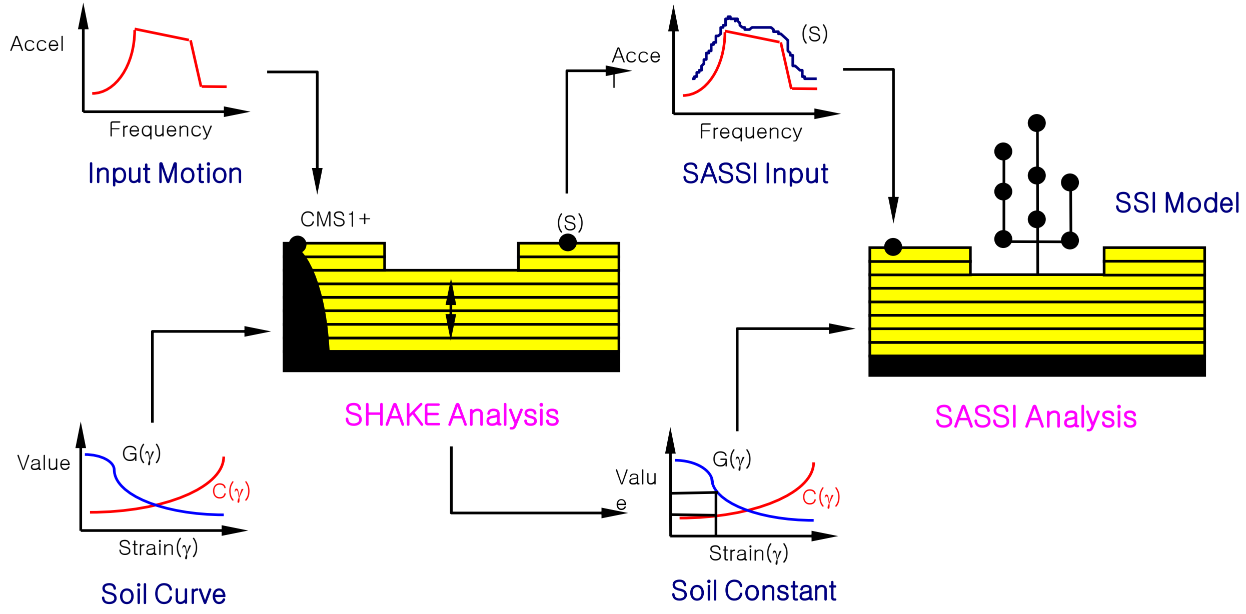
Modeling (cont'd)



Beam-Stick Model of NI

Soil/Structure Interaction

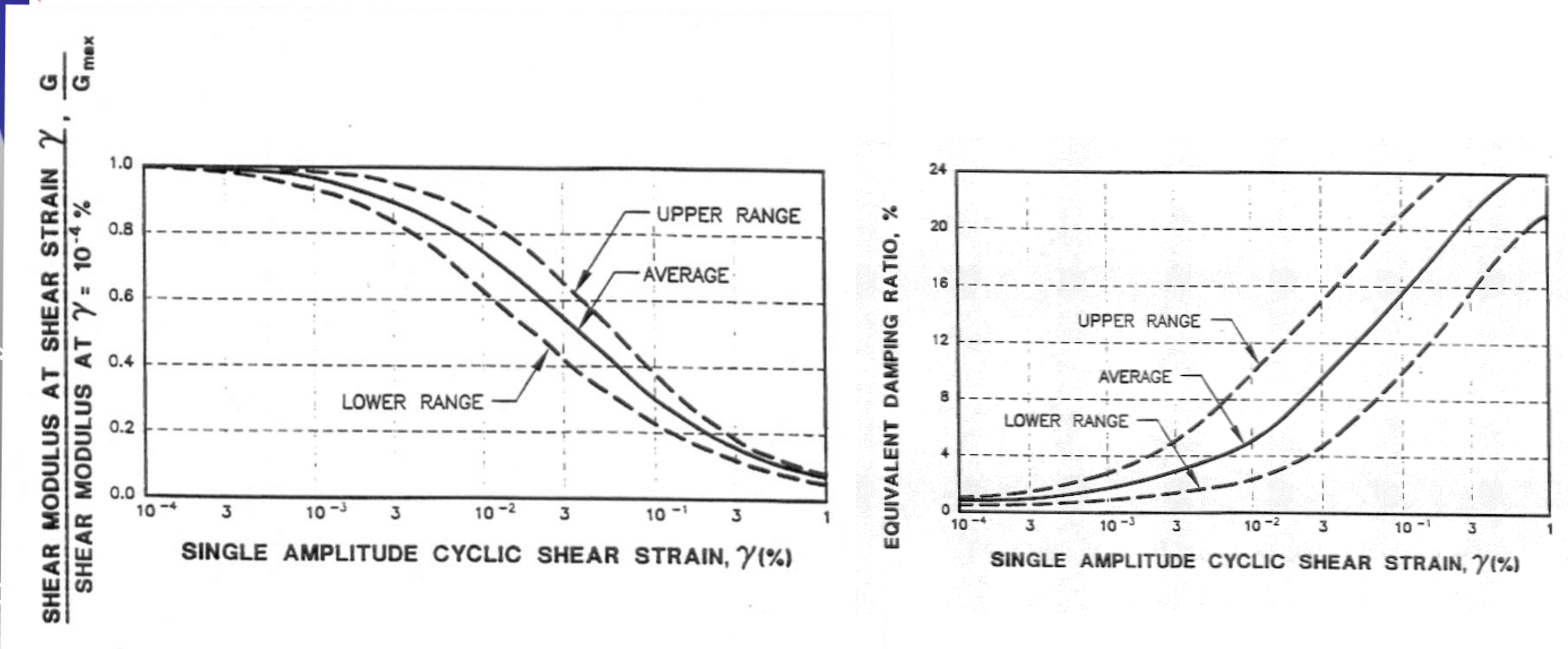
- Site response analysis
  - Input CMS1+ at free field ground surface
  - Eight soil cases
  - One-dimensional wave propagation analysis using SHAKE91



Site Response Analysis Flow

Soil/Structure Interaction (cont'd)

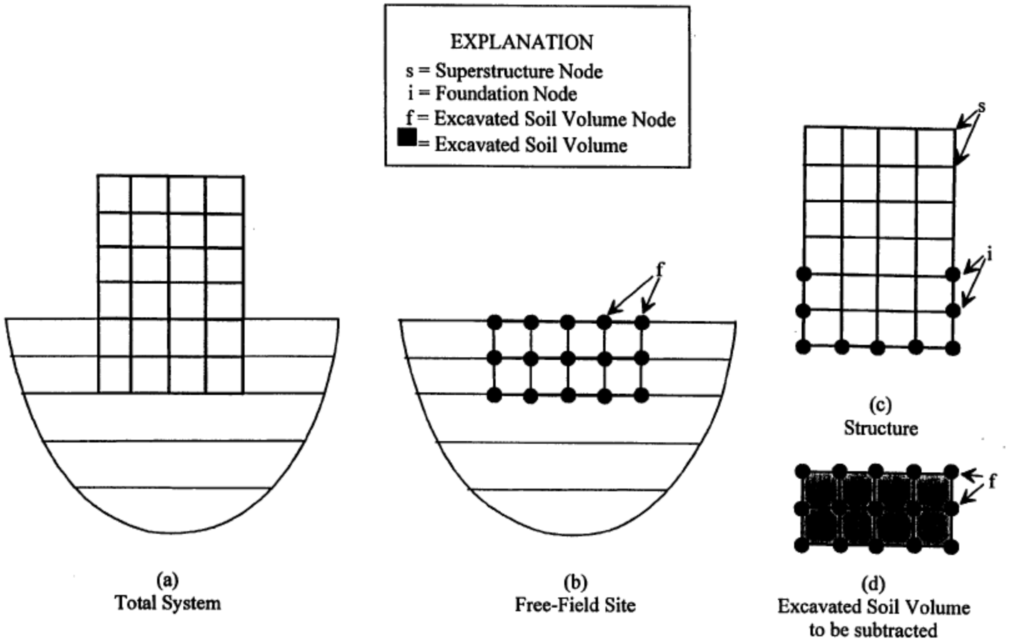
- Site response analysis (cont'd)
  - "Guidelines for determining design basis ground motions." EPRI, vol. 1-5, EPRI TR-102293, 1993.



Strain Dependent Shear Modulus and Damping Curve of Soils

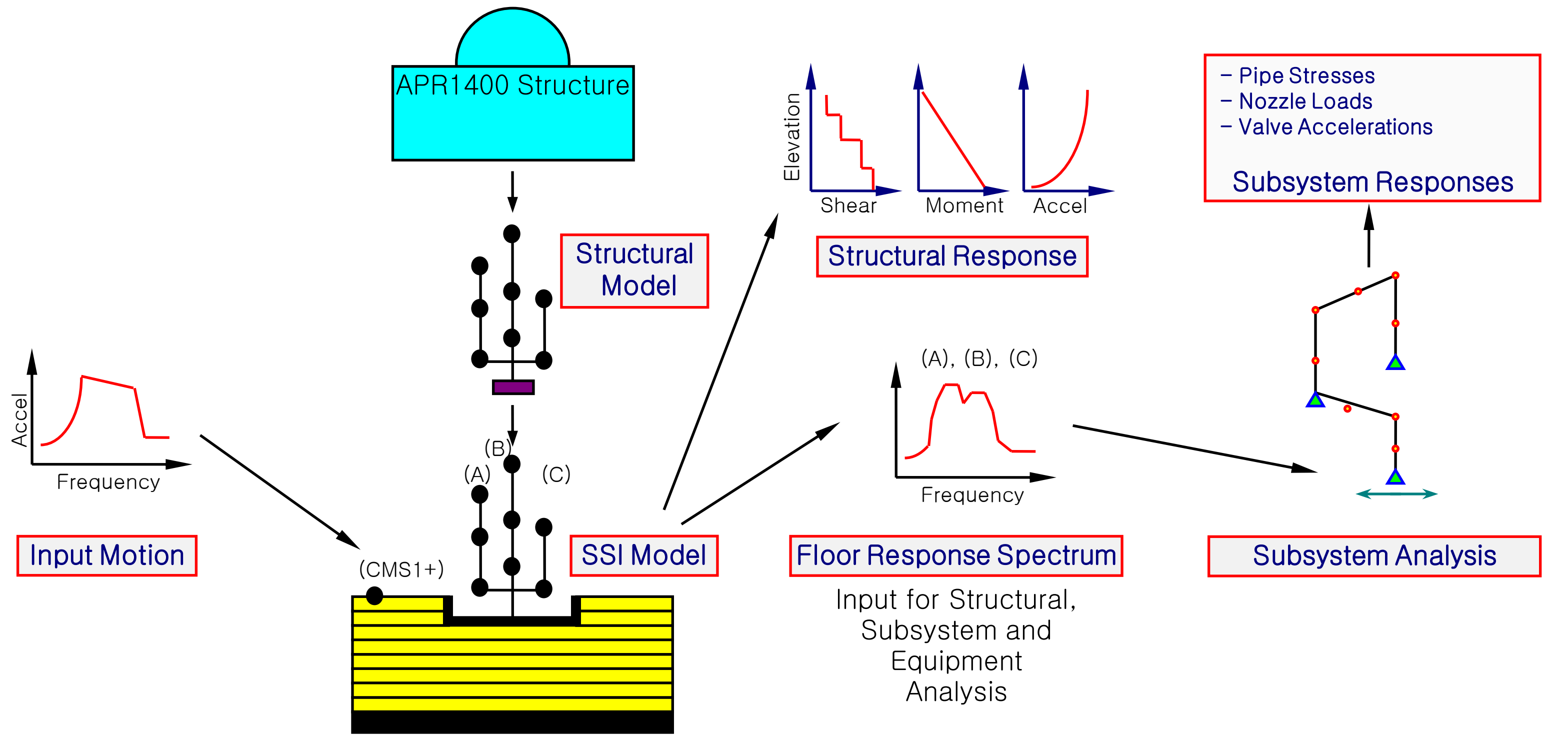
Soil/Structure Interaction (cont'd)

- SASSI(DE & S): sub-structure method
- Eight SSI analysis system: combining super-structure model with each different soil model
- SASSI analyses of each SSI System



SASSI Flexible Volume Sub-Structuring Method

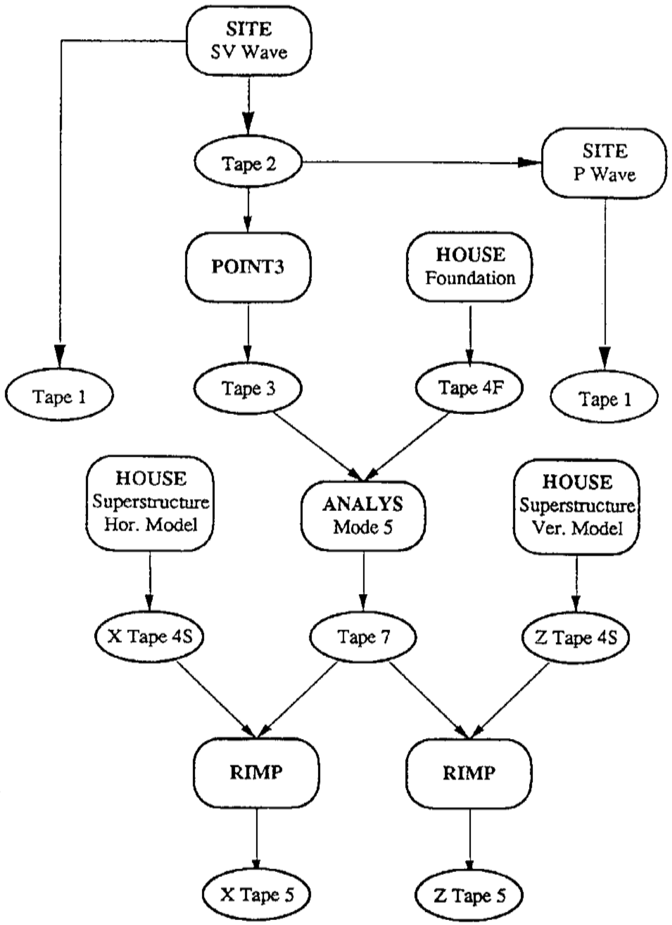
Soil/Structure Interaction (cont'd)



SSI Analysis Procedure

Soil/Structure Interaction (cont'd)

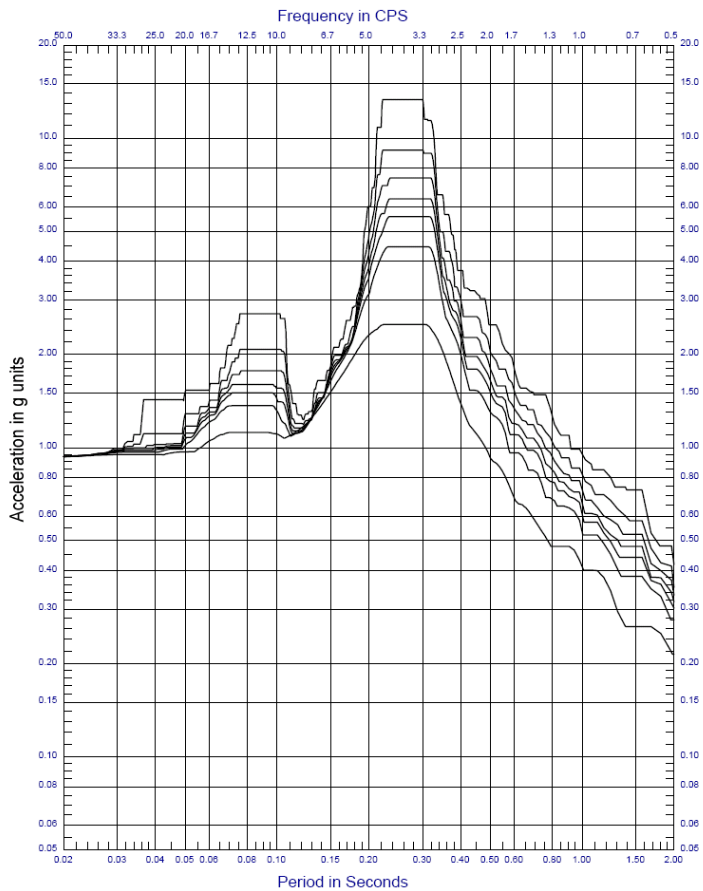
- RIMP module
  - An alternative method to obtain impedance matrix on the large size foundation model is used for APR1400 SSI analysis
  - Using SASSI module RIMP, foundation can be treated as a rigid body
  - In SASSI module ANALYS, flexibility matrix of all interaction nodes can be transformed into the flexibility matrix of a single point



SSI Analysis Flow using RIMP module

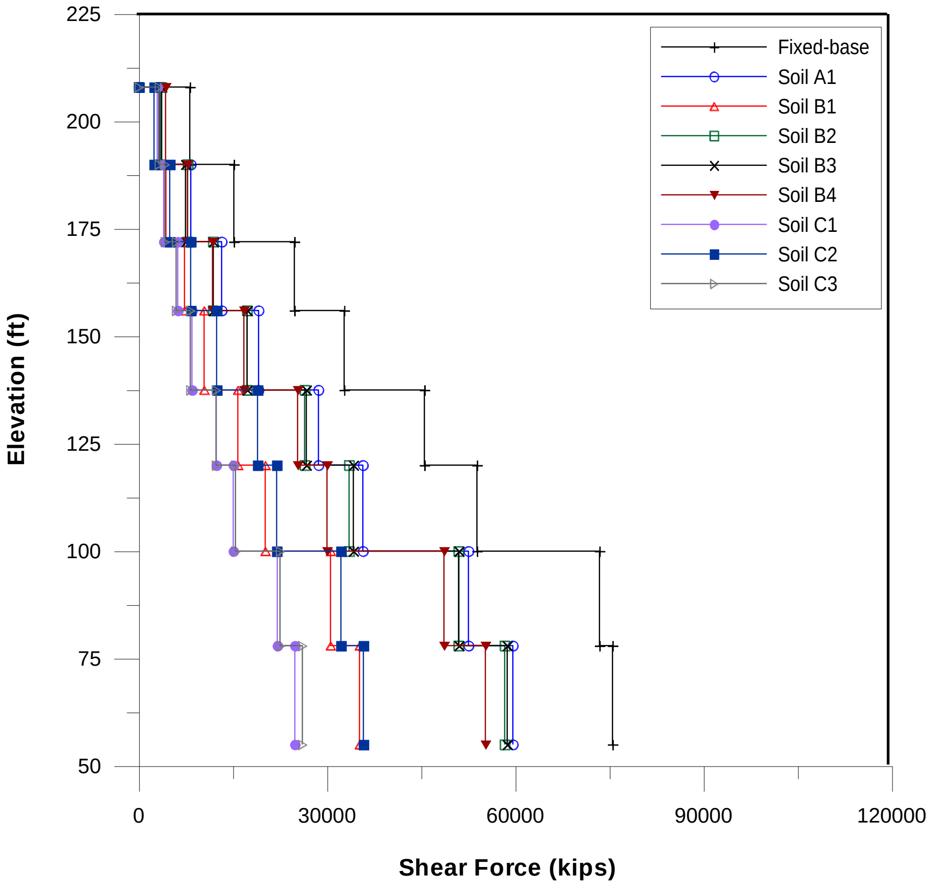
SSI Analysis Results (Design Parameters)

- All seismic design parameters such as forces, displacement and in-structure response spectra are obtained from SSI analyses using SASSI program.
  - Member forces: axial and shear forces, moments, displacements, etc.
  - Broadened In-Structure FRS calculation
  - Envelope of all soil cases
  - FRS peak: 15% widening



Example FRS of Containment Building (El. 241.5ft)

SSI Analysis Results (Design Parameters)

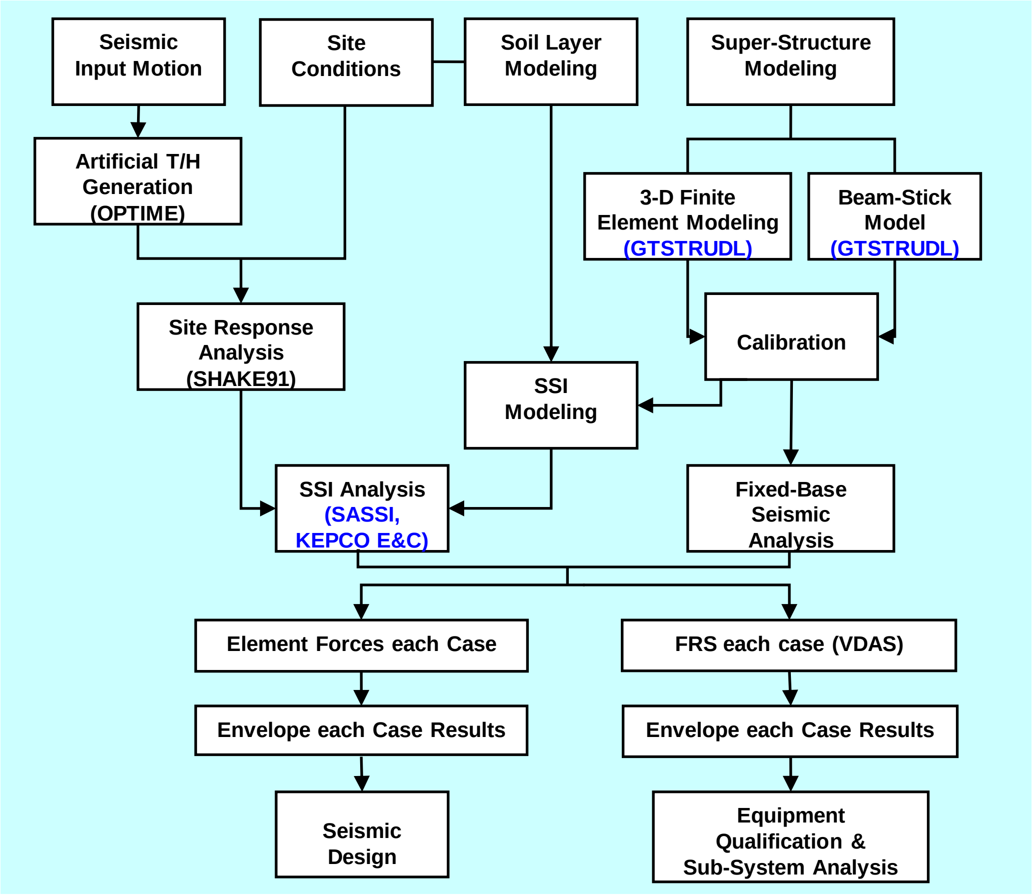


Shear Force Diagram of Auxiliary Building

Future Plan for SSI evaluation

- KEPCO E&C's Experiences of SASSI evaluation
  - We adopted SASSI, UC-Berkeley V. since 1994.
  - Joint efforts with KEPCO E&C and DE&S on modeling and analysis
  - SASSI program has been used for SSI analysis for various nuclear power plant structures by KEPCO E&C engineers.
  - KEPCO E&C has participated in international research projects.
    - Hualien LSST by EPRI
    - IAEA CRP: Safety Significance of Near Field Earthquakes
    - IAEA-EBP: Seismic Safety of Existing Nuclear Power Plants

Future Plan for SSI evaluation (cont'd)

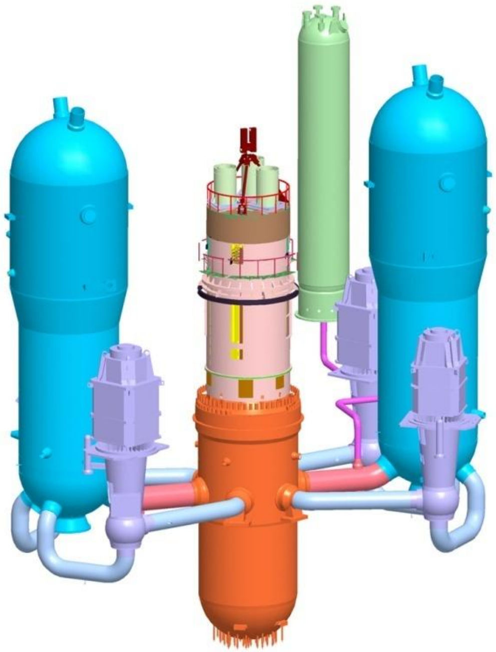


Conclusions

- Seismic analysis of APR1400 was performed for standard NPP development in accordance with the regulatory requirements in effects as of 2002.
- We reviewed revised regulatory requirements
  - Recorded earthquake will be used for design time history and modified to satisfy all codified requirements.
  - New site soil conditions will be extended to stiffer site according to the recently revised rigid base assumption.
- An approach to incorporate new CEUS source information will be discussed in upcoming session

Seismic Design of RCS, RI and Core

- Overview of Seismic Design
- Seismic Analysis for RCS, RI and Core
- Revised Regulatory Guides
- Summary



Overview of Seismic Design

Regulations and Guides

Codes and Standards

Seismic Classification

Regulations And Guides

- Regulations
  - 10 CFR Part 50 Appendix A, General Design Criteria 2,
    "Design Bases for Protection against Natural Phenomena"
  - 10 CFR Part 50 Appendix S,
    "Earthquake Engineering Criteria for Nuclear Power Plants"
    - OBE elimination
      - Safe Shutdown Earthquake (SSE) : 0.3g
      - Operating Basis Earthquake (OBE) : 1/3 SSE

Regulations And Guides

- Regulatory Guides
  - R.G. 1.29, Seismic Design Classification, Rev.04
  - R.G. 1.61, Damping Values for Seismic Design, Rev.01
  - R.G. 1.92, Combining Modal Responses and Spatial Components in Seismic Response Analysis, Rev.02
  - R.G. 1.122, Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components, Rev.01
- Standard Review Plan
  - SRP 3.2.1, Seismic Classification
  - SRP 3.7.2, Seismic System Analysis
  - SRP 3.7.3, Seismic Subsystem Analysis

Codes and Standards

- ASME Code Section III, Division 1 Appendices Nonmandatory Appendix N, “Dynamic Analysis Methods”
- ASCE Standard 4-98, “Seismic Analysis of Safety-Related Nuclear Structures”

Seismic Classification

- Seismic classification : R.G. 1.29 Rev.04
  - Seismic Category I

    SSCs which are important to safety and designed to remain functional in the event of SSE
  - Non-Seismic Category I
    - Seismic Category II

      SSCs whose continued function is not required but whose failure could reduce the function of a Seismic Category I structures, systems, and components to an unacceptable safety level or could result in incapacitating injury to occupants of the control room
    - Non-Seismic Category

      Structures, systems and components classified as neither Seismic Category I nor II.

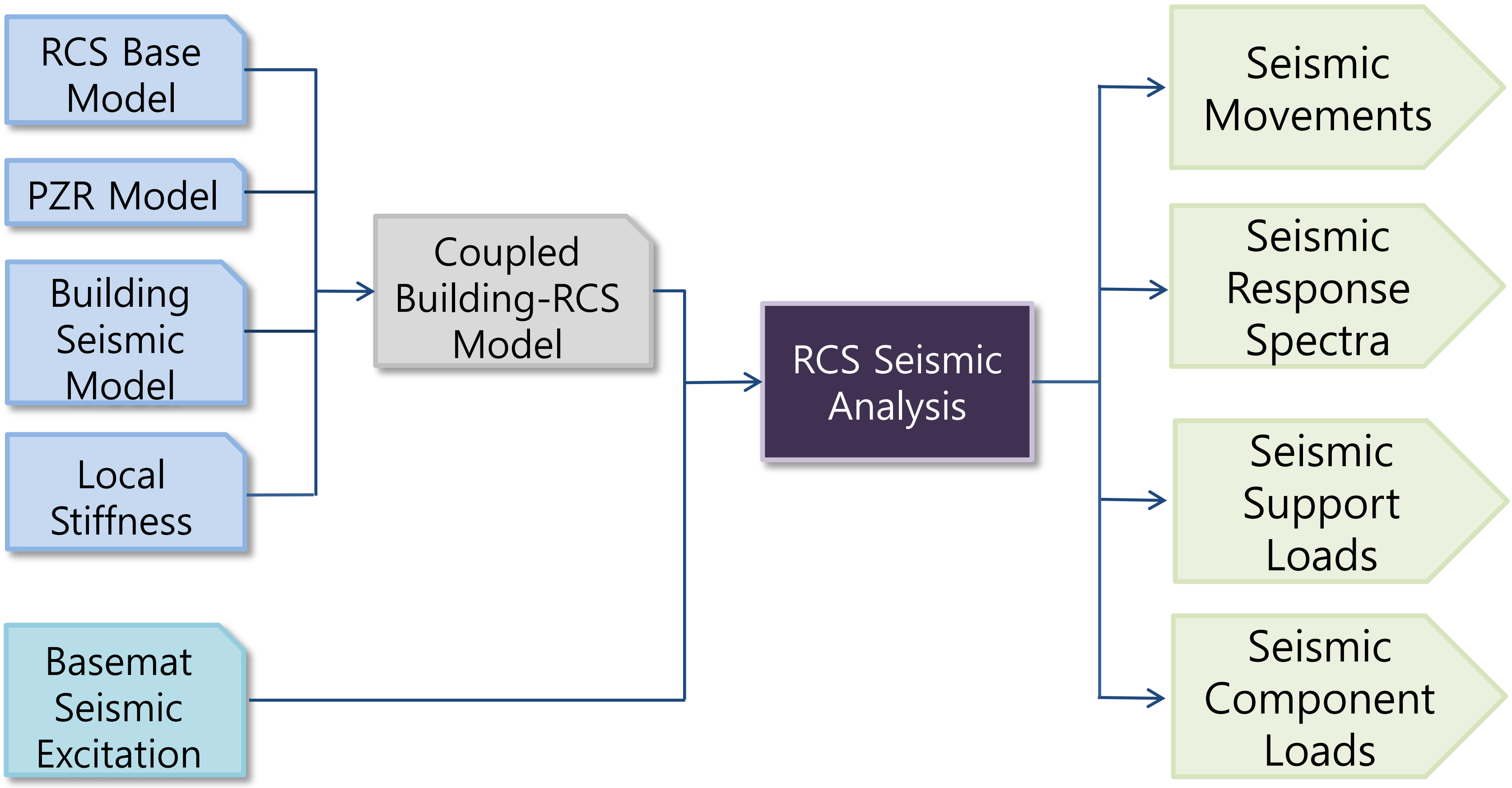
Seismic Analysis for RCS, RI and Core

- Seismic Analysis for RCS
- Seismic Analysis for RI
- Seismic Analysis for Core

Seismic Analysis for RCS

- Procedure of RCS Seismic Analysis
- RCS Seismic Analysis Methods
- Analytical Modeling of RCS
- Damping of RCS Seismic Analysis
- Outputs of RCS Seismic Analysis

Procedure of RCS Seismic Analysis

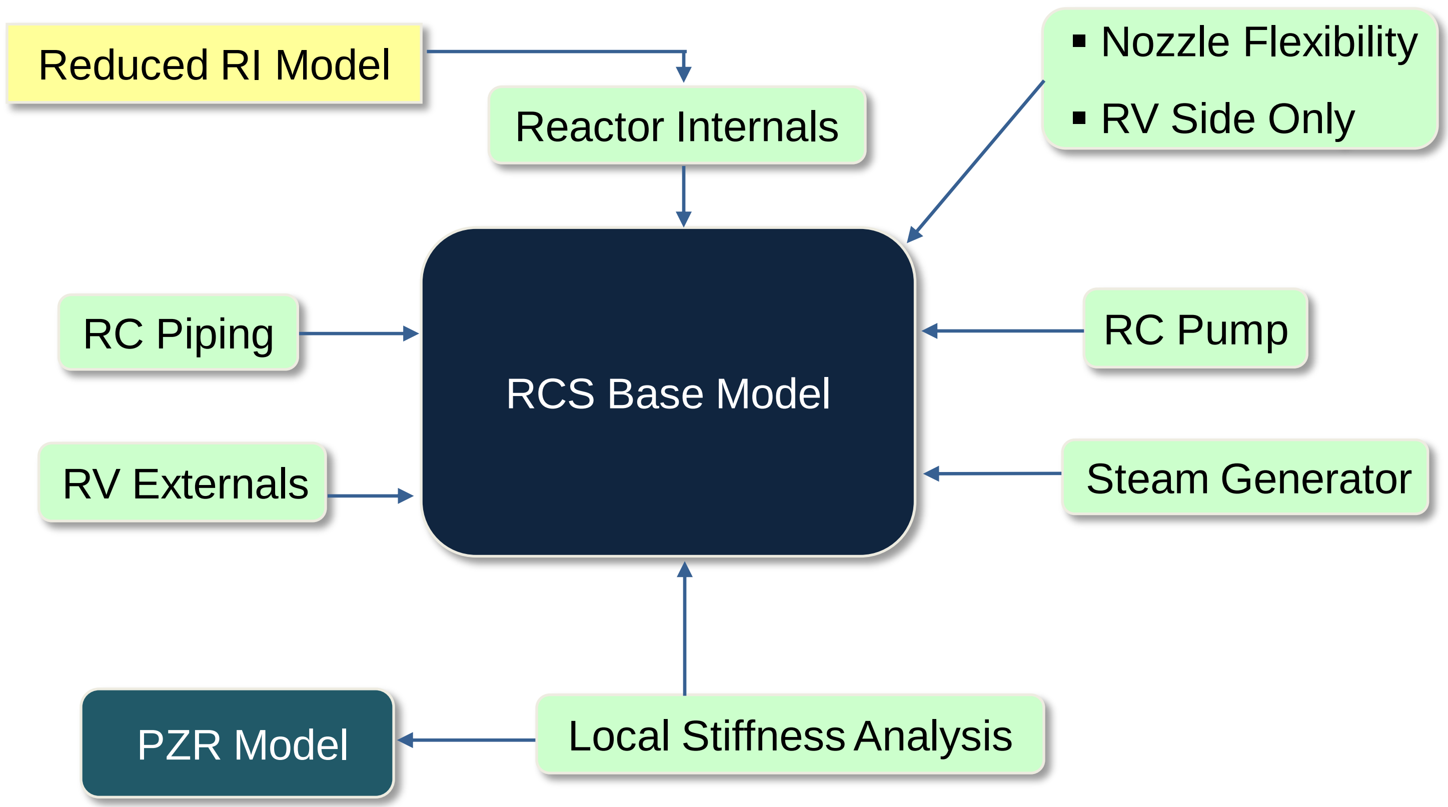


RCS Seismic Analysis Methods

- Model
  - Coupled Building-RCS model
- Excitation
  - Acceleration time histories at basemat
  - Time step : 0.005 sec
  - Duration : 20.48 sec
- Analysis Code : ANSYS
- Linear time history analysis
  - Mode superposition method

Analytical Modeling of RCS

- Components of RCS Base Model



Analytical Modeling of RCS

- RCS Modeling
  - 3D Lumped Mass Beam Model
  - RCS Base model includes
    - RV with RI, IHA and CEDM
    - Two SGs with Internals
    - Four RCPs with Motors
    - Two Hot Legs
    - Four Cold Legs
  - Pressurizer
  - RCS supports are modeled as linear supports
  - Local stiffness at the junctions of nozzles and lugs

Analytical Modeling of RCS

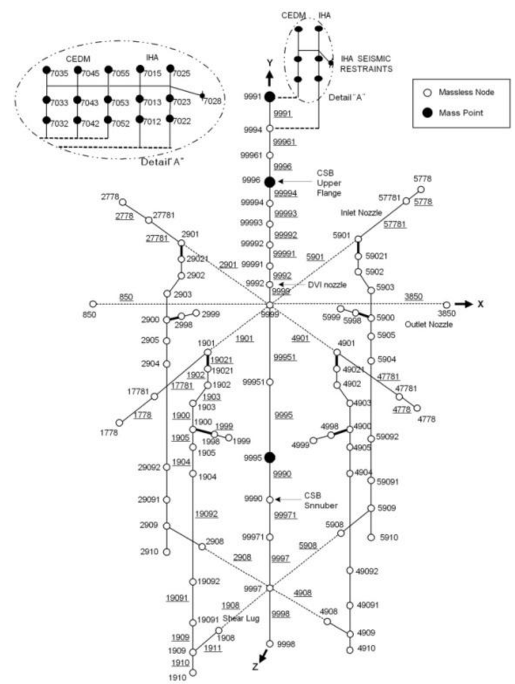
- RCS Modeling
  - Modeling Criteria
    - Maintain total mass
    - Maintain center of gravity
    - Maintain second moment of inertia
    - Maintain fundamental frequency

Analytical Modeling of RCS

- RCS Modeling

Reactor Vessel

Reactor Vessel Model



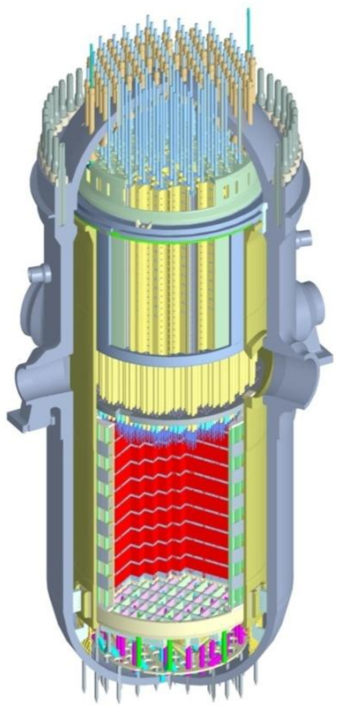
RV with RI, IHA and CEDM : 21 MPs, 61 DDOFs

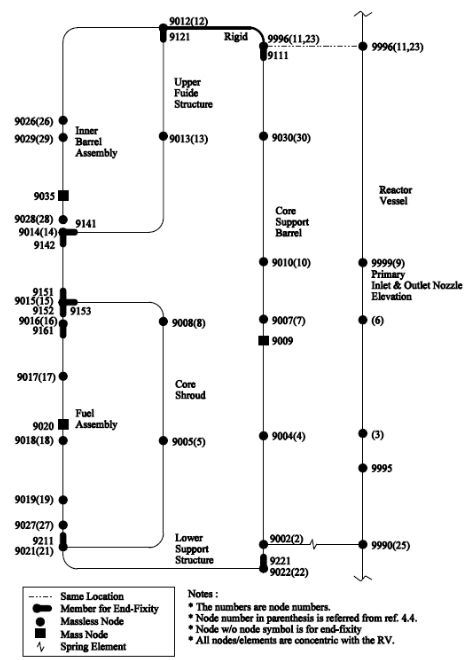
Analytical Modeling of RCS

- RCS Modeling

Reactor Internals

Reduced Reactor Internals Model





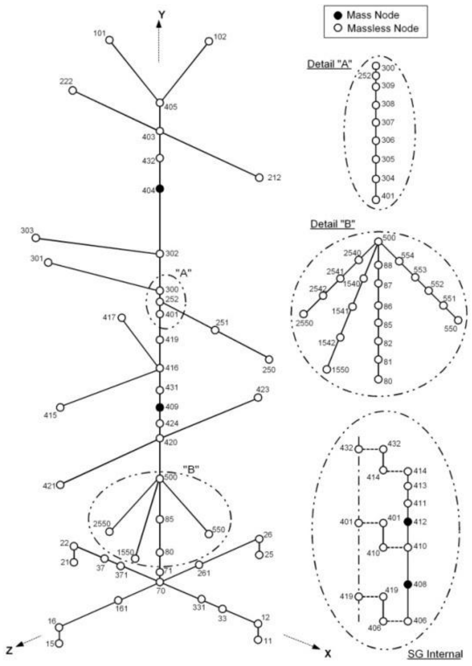
Reduced RI : 3 MPs, 9 DDOFs

Analytical Modeling of RCS

- RCS Modeling

Steam Generator

Steam Generator Model

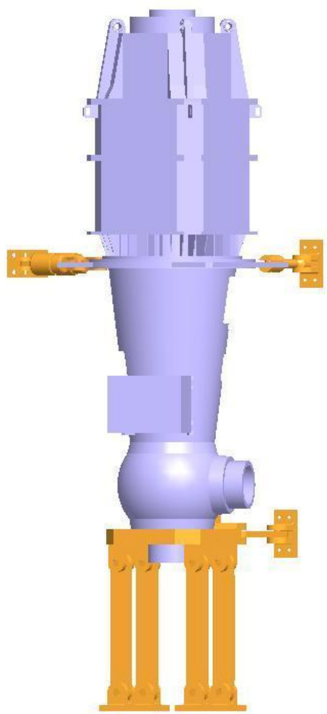


SG with Internals : 4 MPs/SG, 10 DDOFs/SG

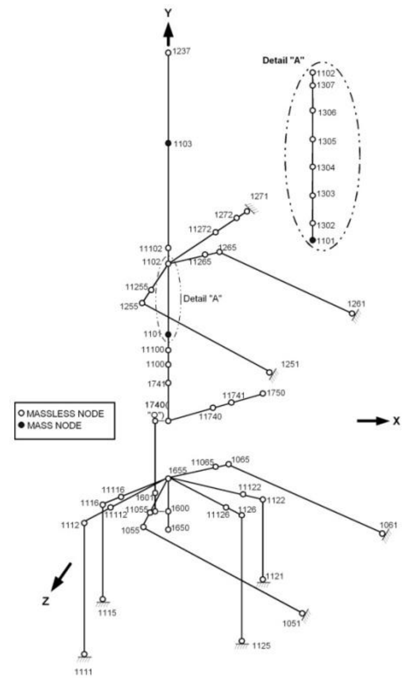
Analytical Modeling of RCS

- RCS Modeling

Reactor Coolant Pump



Reactor Coolant Pump Model

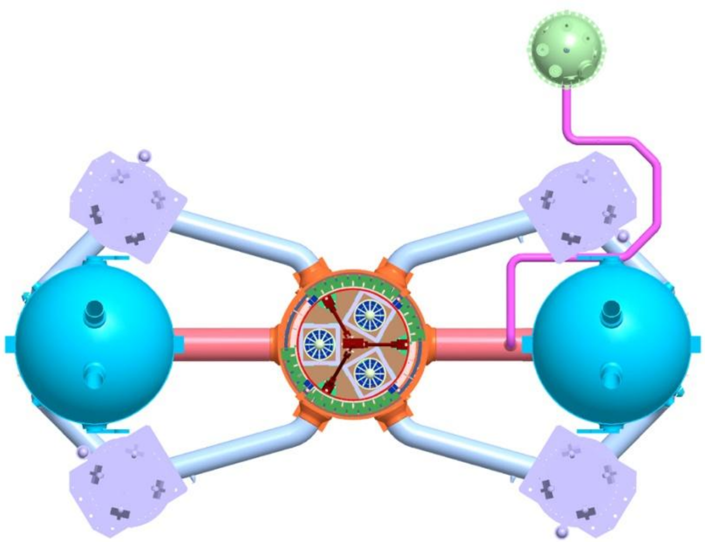


RCP with Motors : 2 MPs/RCP, 6 DDOFs/RCP

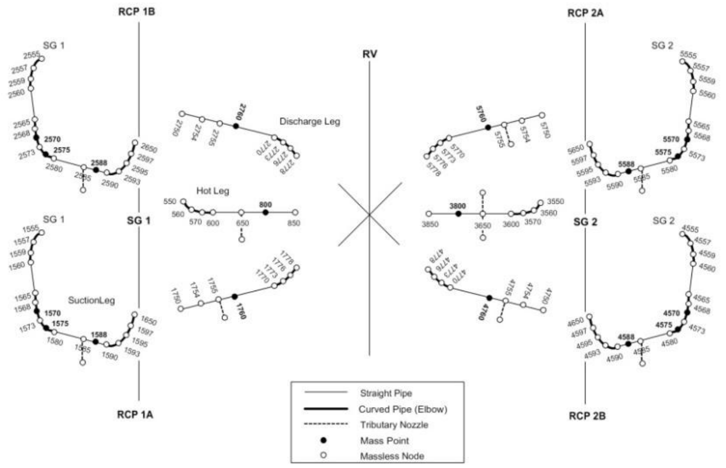
Analytical Modeling of RCS

- RCS Modeling

RC Piping



RC Piping Model



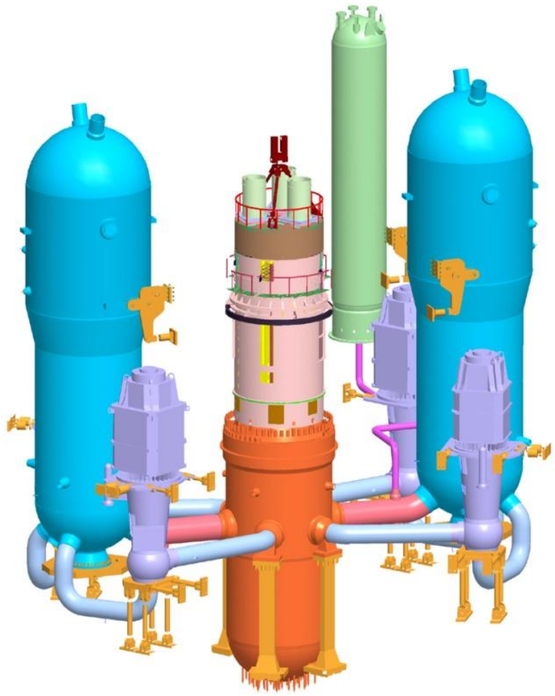
Hot Legs : 1 MP/HL, 2 DDOFs/HL

Cold Legs : 4 MPs/CL, 12 DDOFs/CL

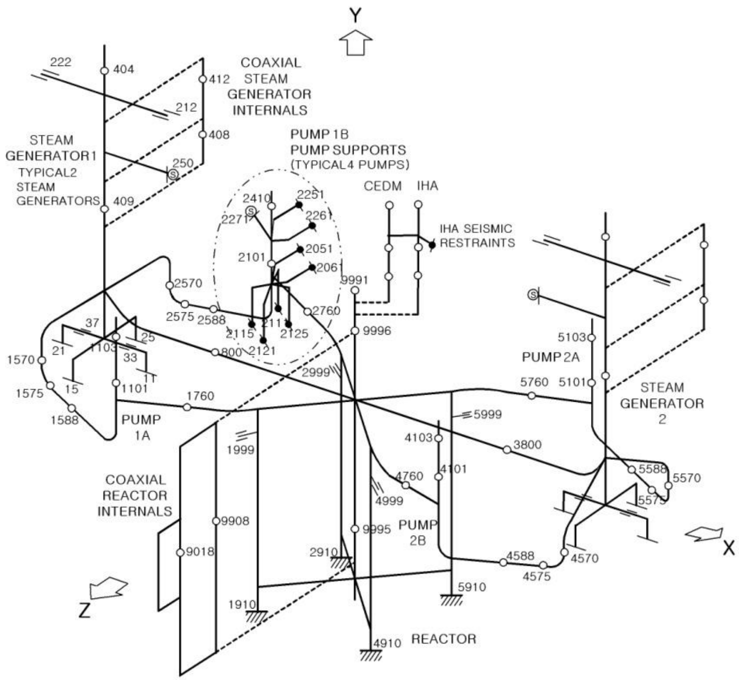
Analytical Modeling of RCS

- RCS Modeling

Reactor Coolant System



RCS Base Model



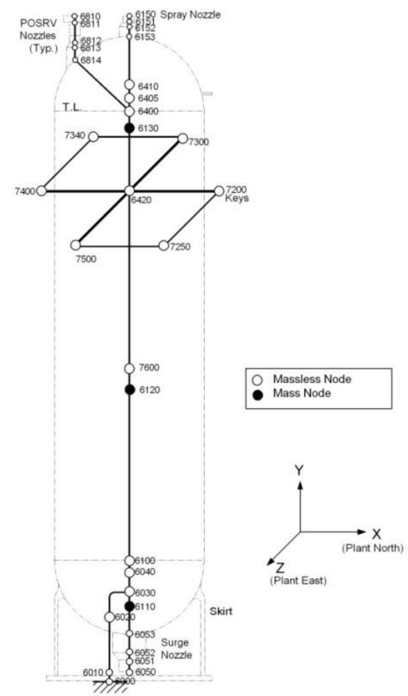
RCS Model : 55 MPs, 157 DDOFs

Analytical Modeling of RCS

- RCS Modeling

Pressurizer

Pressurizer Model



Pressurizer : 3 MPs, 7 DDOFs

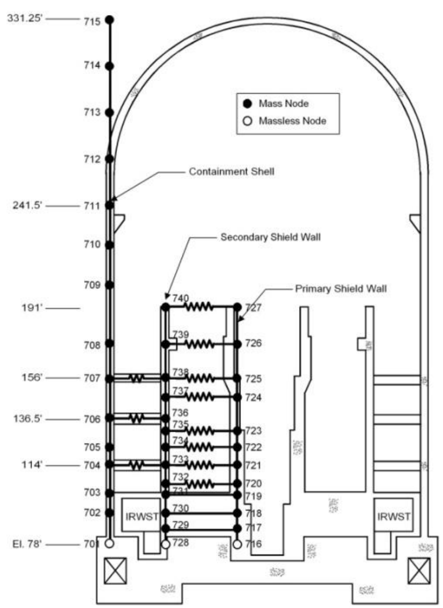
Analytical Modeling of RCS

- Coupled Building-RCS Model
  - Building model compatible with RCS model
    - 3-D beam model with lumped mass
    - 37 MPs and 222 DDOFs
    - Primary and Secondary Shield Wall
    - Containment Shell
  - Connect RCS supports members to building model using local stiffnesses
  - Maintain boundary conditions at support locations
  - Perform modal analysis to confirm coupling

Analytical Modeling of RCS

- Coupled Building-RCS Model

Containment Building Model



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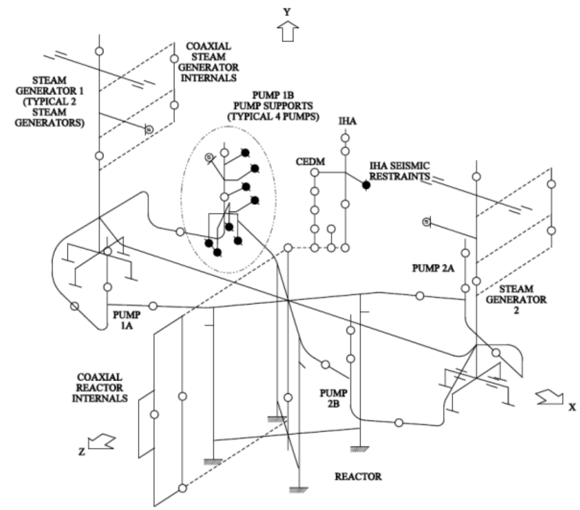
RCS Base Model



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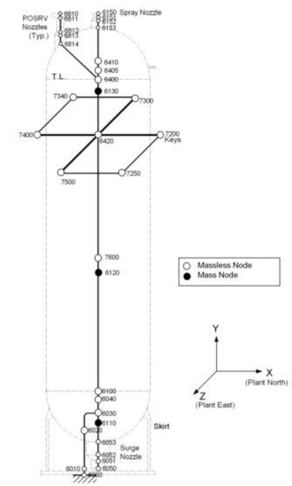
PZR Model



Damping for RCS Seismic Analysis

- Damping values consistent with R.G. 1.61 to each member
- Composite modal damping based on the stiffness of each member

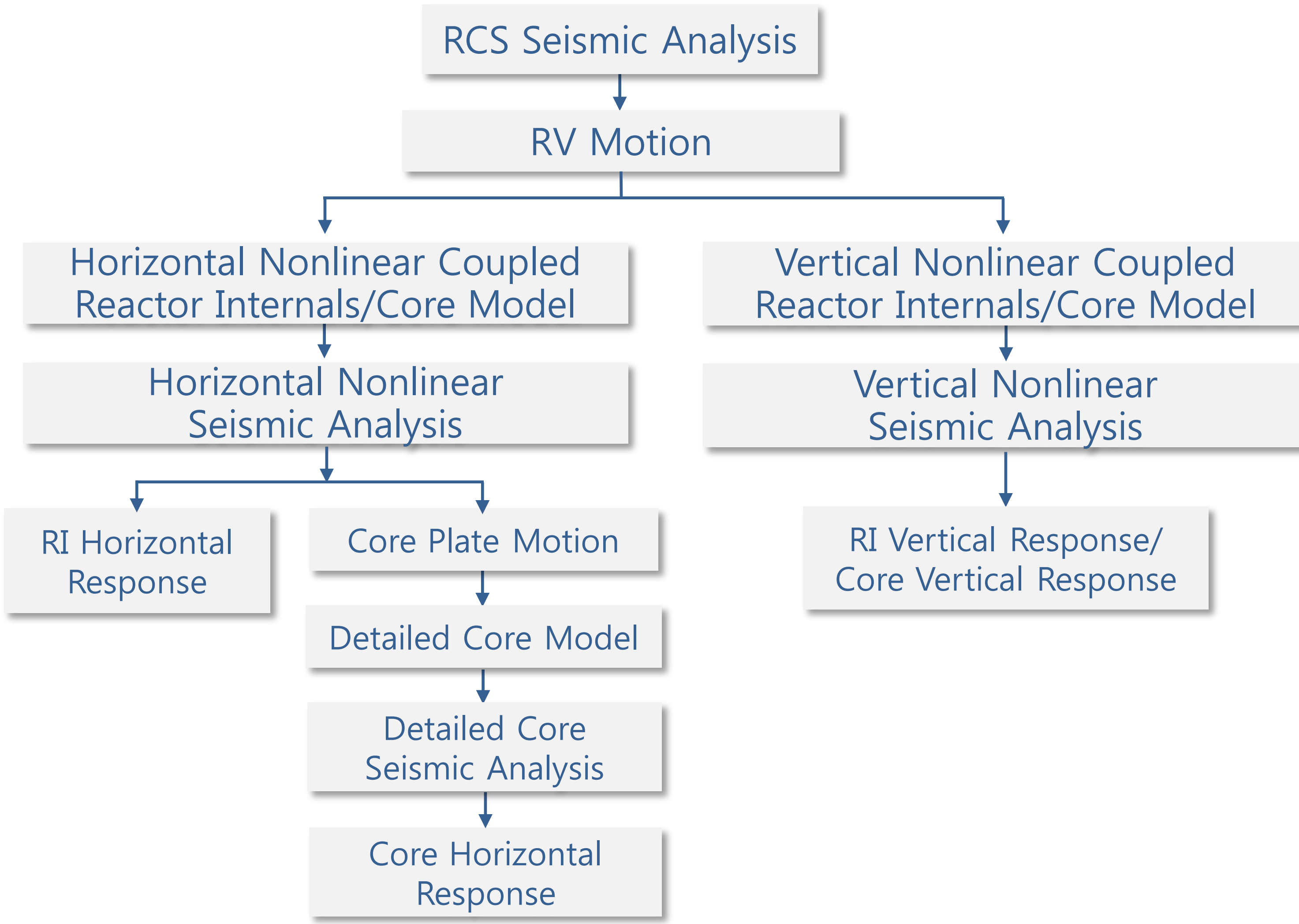
Outputs of RCS Seismic Analysis

- Forces and moments for RCS component supports and structural components
- Forces and moments for RCS piping & nozzle
- Max. displacements at branch nozzles
- Design response spectra for RCS components
- Response time histories and spectra for
  - RI analysis
  - CEDM, IHA & ICI analysis
  - Surge line analysis
  - Branch piping analysis

Seismic Analysis for RI

- Procedure of RI Seismic Analysis
- RI Seismic Analysis Methods
- Analytical Modeling of RI
- Damping of RI Seismic Analysis
- Outputs of RI Seismic Analysis

Procedure of RI Seismic Analysis



RI Seismic Analysis Methods

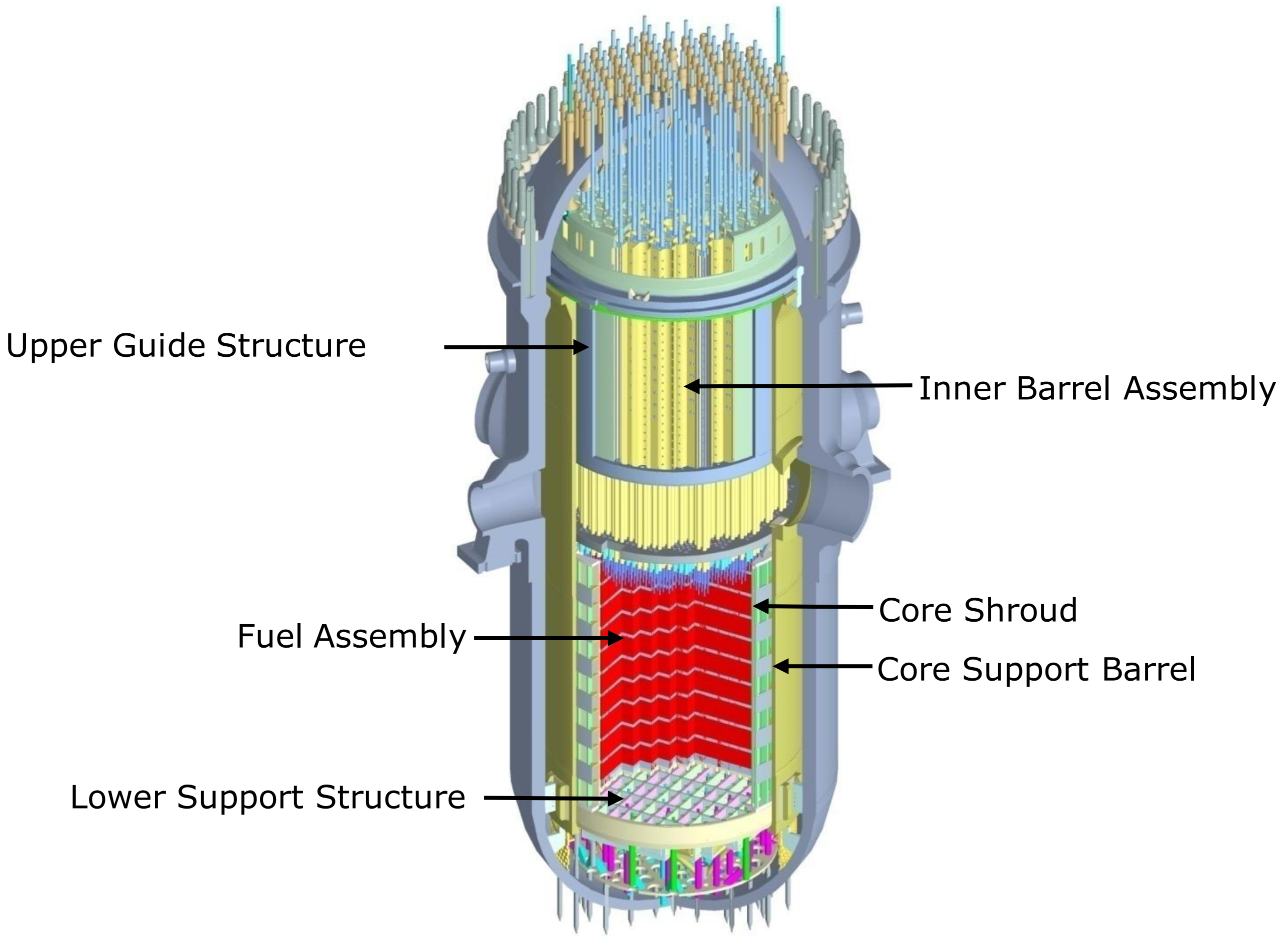
- Model
  - Coupled Reactor Internals and reduced Core model
- Excitation
  - Horizontal acceleration time histories at RV Flange and Core Stabilizing Lug
  - Vertical acceleration time history at RV Flange
- Analysis Code : CESHOCK
- Non-linear time history analysis
  - Direct integration method

Analytical Modeling of RI

- Reactor Internals Model includes
  - Core Support Barrel
  - Upper Guide Structure
  - Lower Support Structure
  - Inner Barrel Assembly
  - Core Shroud
  - Fuel Assemblies

Analytical Modeling of RI

- Reactor Internals



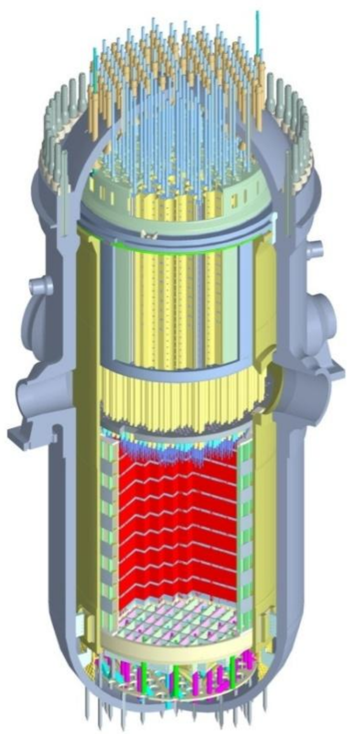
Analytical Modeling of RI

- Reactor Internals Model
  - 2-D lumped mass-spring model
    - Reactor Internals Horizontal Mass-Spring Model
    - Reactor Internals Vertical Mass-Spring Model
  - Coupled Reactor Internals and reduced Core model

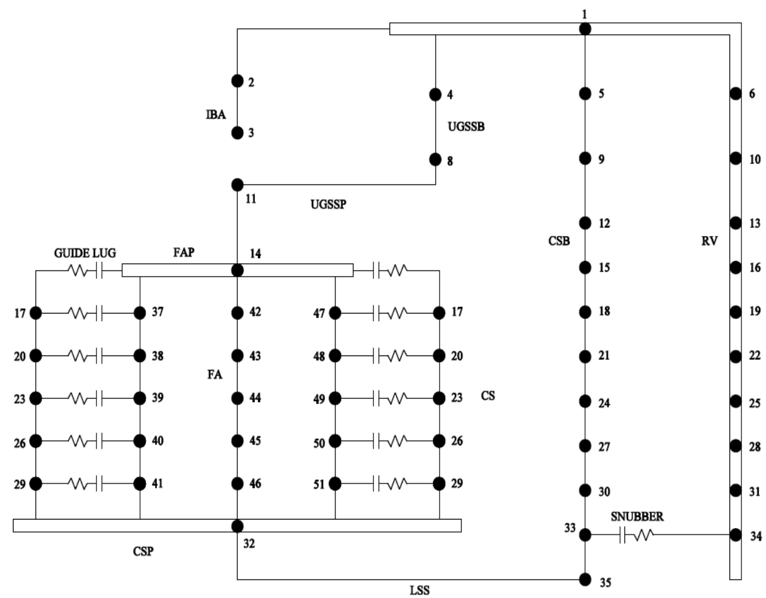
Analytical Modeling of RI

- Modeling of Reactor Internals

Reactor Internals



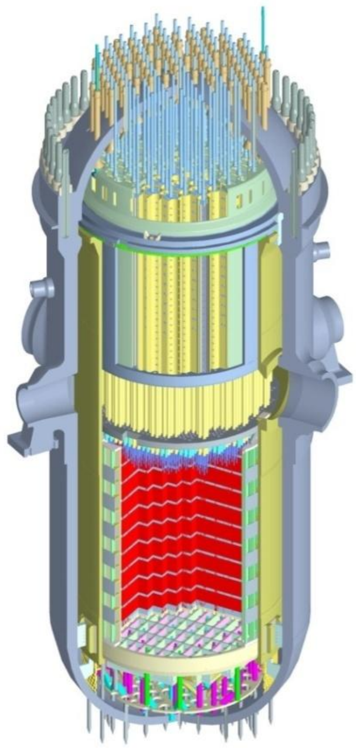
Reactor Internals
Horizontal Mass-Spring Model



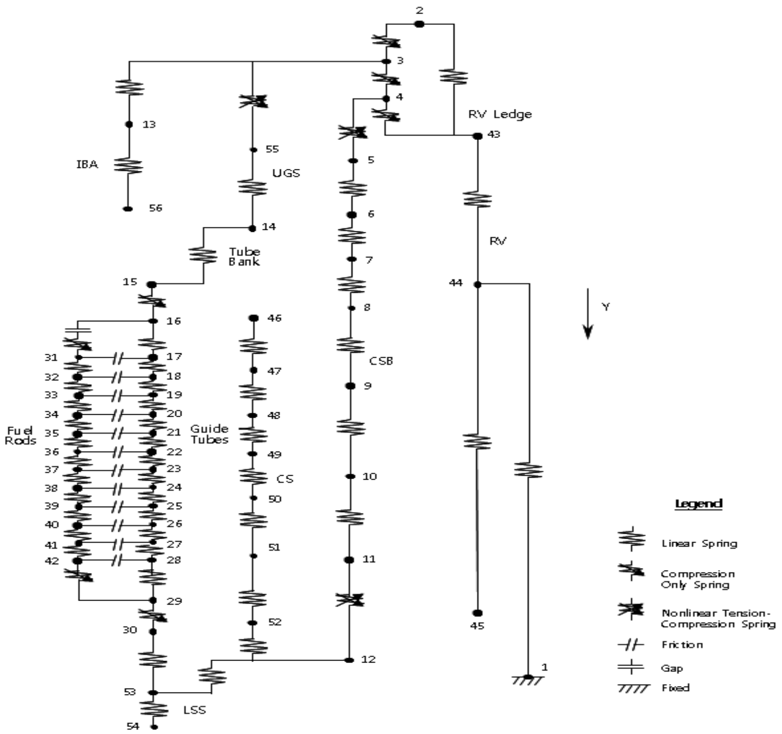
Analytical Modeling of RI

- Modeling of Reactor Internals

Reactor Internals



Reactor Internals
Vertical Mass-Spring Model



Damping of RI Seismic Analysis

- Reactor internal components for SSE : 4%
- Fuel assembly for SSE : based upon the results of full scale forced vibration tests for fuel assembly
- Composite mass damping and stiffness damping

Outputs of RI Seismic Analysis

- Forces and moments for Reactor Internal components
- Response spectra for subcomponent analyses
- Core Plate motions for the analysis of detailed Core

Seismic Analysis for Core

- Detailed Core Seismic Analysis Methods
- Analytical Modeling of Detailed Core
- Damping of Detailed Core Seismic Analysis
- Outputs of Detailed Core Seismic Analysis

Detailed Core Seismic Analysis Methods

- Model
  - Detailed core model
- Excitation
  - Horizontal displacement time histories at fuel alignment plate, core support plate and core shroud
- Analysis Code : CESHOCK
- Non-linear time history analysis
  - Direct integration method

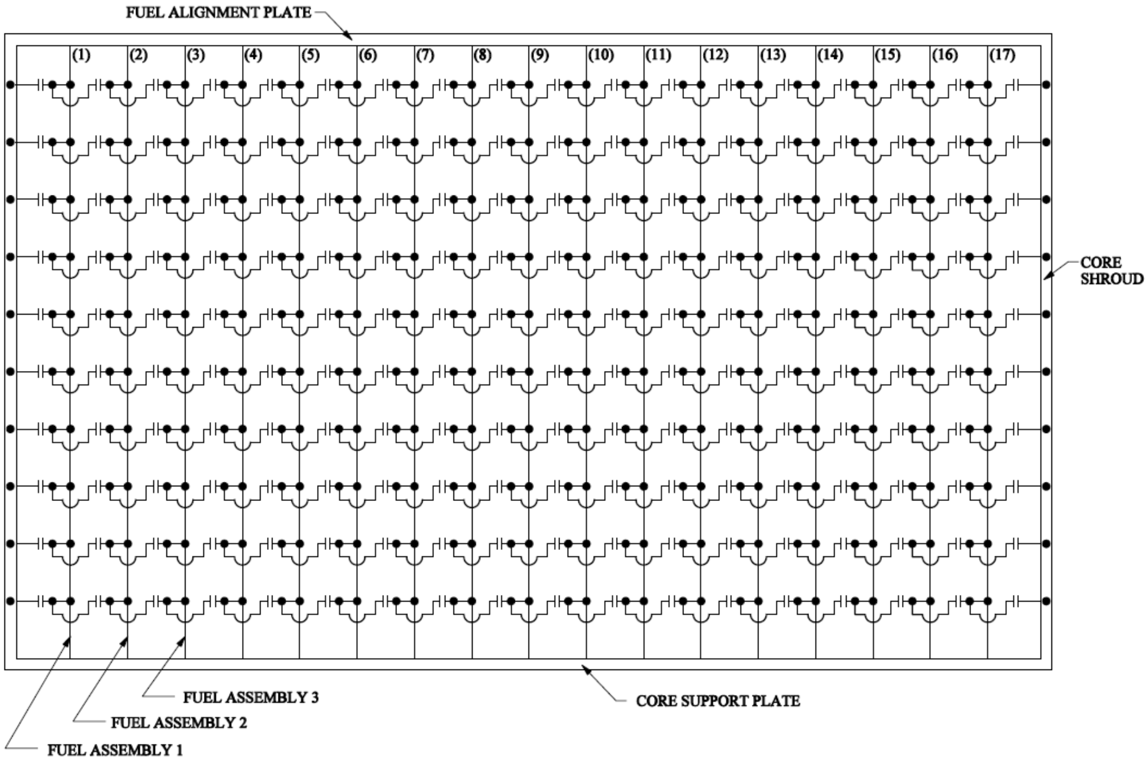
Analytical Modeling of Detailed Core

- Detailed Core Modeling
  - Non-linear core model for various numbers of fuel assemblies per row across the core
    - Nonlinear spring coupling for the gap
  - Energy dissipation during grid impact
    - Incorporated into the model by use of the coefficient of restitution
  - All fuel assembly properties are based upon test data for PLUS7 fuel

Analytical Modeling of Detailed Core

- Detailed Core Modeling

17 Row Core Model



Damping of Detailed Core Seismic Analysis

- Fuel assembly for SSE : based upon the results of full scale forced vibration tests for fuel assembly
- Mass and stiffness damping

Outputs of Detailed Core Seismic Analysis

- Peak spacer grid impact loads
- Maximum axial loads of fuel assembly
- Deflected shapes of fuel assembly at the time of peak displacement, shear force and moment

Revised Regulatory Guides

R.G. 1.61 : Damping Values for Seismic Design of Nuclear Power Plants

R.G. 1.92 : Combining Modal Responses and Spatial Components in Seismic Response Analysis

Regulatory Guide 1.61 Rev. 1

- Title

  Damping Values for Seismic Design of Nuclear Power Plants
- Issue date : March, 2007
- Major Change of Regulatory Guide from Rev. 0
  - More realistic damping values for seismic design and analysis of SSCs
    - Structural Damping
      - √ To use the damping-compatible structural response for in-structure response spectra generation
- Plan
  - R.G. 1.61 Rev.1 will be applied to seismic analysis for RCS, RI and Core of the APR1400.

Regulatory Guide 1.92 Rev. 2

- Title

  Combining Modal Responses and Spatial Components in Seismic Response Analysis
- Issue Date : July, 2006
- Major Change of Regulatory Guide from Rev. 1
  - Combination of Individual Modal Responses
    - The residual rigid response of the missing mass mode should be addressed.
  - Combination of Spatial Components
    - 100-40-40 percent combination rule can be used as an alternative to the SRSS method.
- Plan
  - R.G. 1.92 Rev.2 will be applied to seismic analysis for RCS, RI and Core of the APR1400.

Summary

- The seismic analyses for RCS,RI and Core of the APR1400 are performed according to the regulations and guides, and codes and standards of U.S.
- Regulatory guides issued after the current design of the APR1400 regarding the seismic analysis will be implemented.
  - We do not expect any substantial change in the seismic analyses for RCS,RI and Core of the APR1400

Pre-Application Review Meeting Plan for New CSDRS

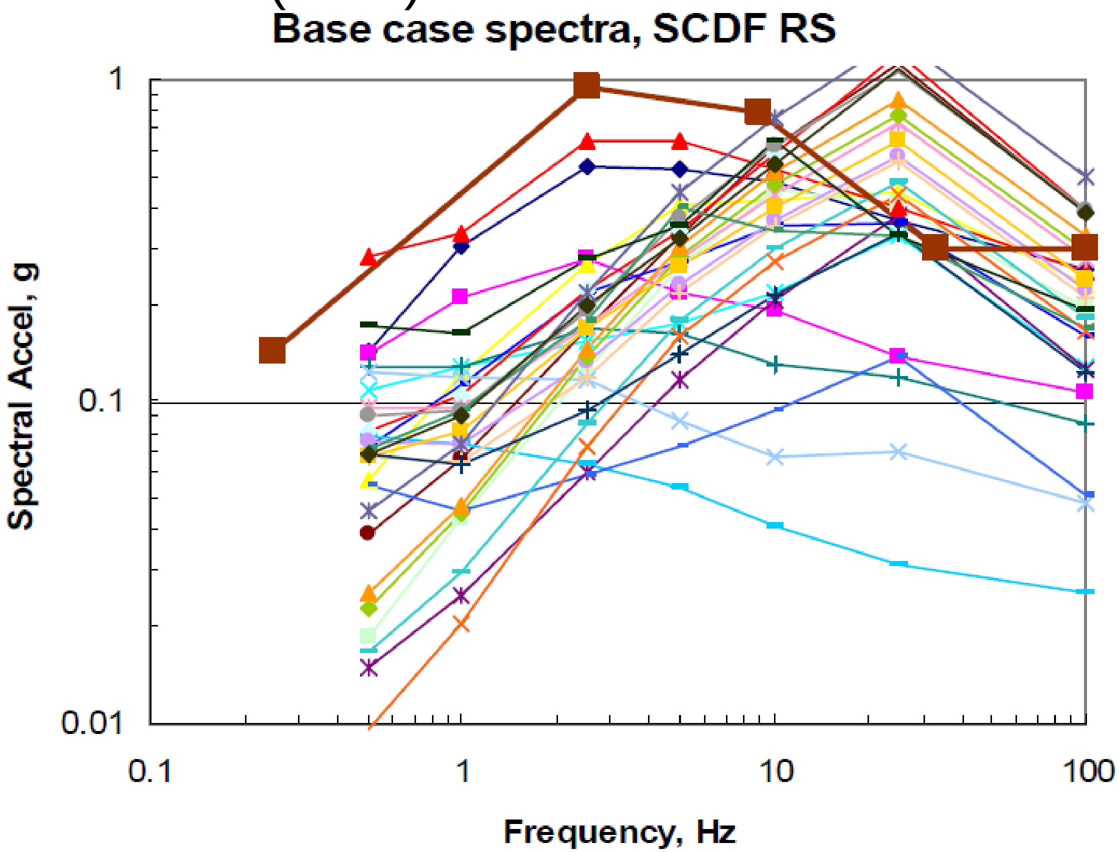
- Background
- ISG-01 Review
- Approach for Incoherent Input Motion Effects
- KEPCO E&C’s Experience with Incoherent Input Motion Techniques
- Incoherent Input Motion Effects
- Considerations on Incorporating Incoherent Input Motion Effects
- Points of Discussion

Background

- Recent studies on CEUS seismic hazard show an increase in the high frequency motion, particularly for rock sites.
  - Program on Technology Innovation: Sensitivity of Performance-Based Approaches for Determining the Safe Shutdown Earthquake Ground Motion for New Plant Sites(EPRI, 2006)
  - Assessment of Seismic Hazard at 34 U.S. Nuclear Plant Sites(EPRI, 2008)
- Ongoing EPRI/DOE CEUS project will generate an updated seismic source characterization in the near future.
- KEPCO is examining its impact on the APR1400 design to define a new CSDRS.
- We would like to better understand NRC staff position on incoherent input motion consideration during DC/COL stage.
  - COL-DC-ISG01 states NRC's position on the incoherent input motion effects in SSI analysis.

Background (cont'd)

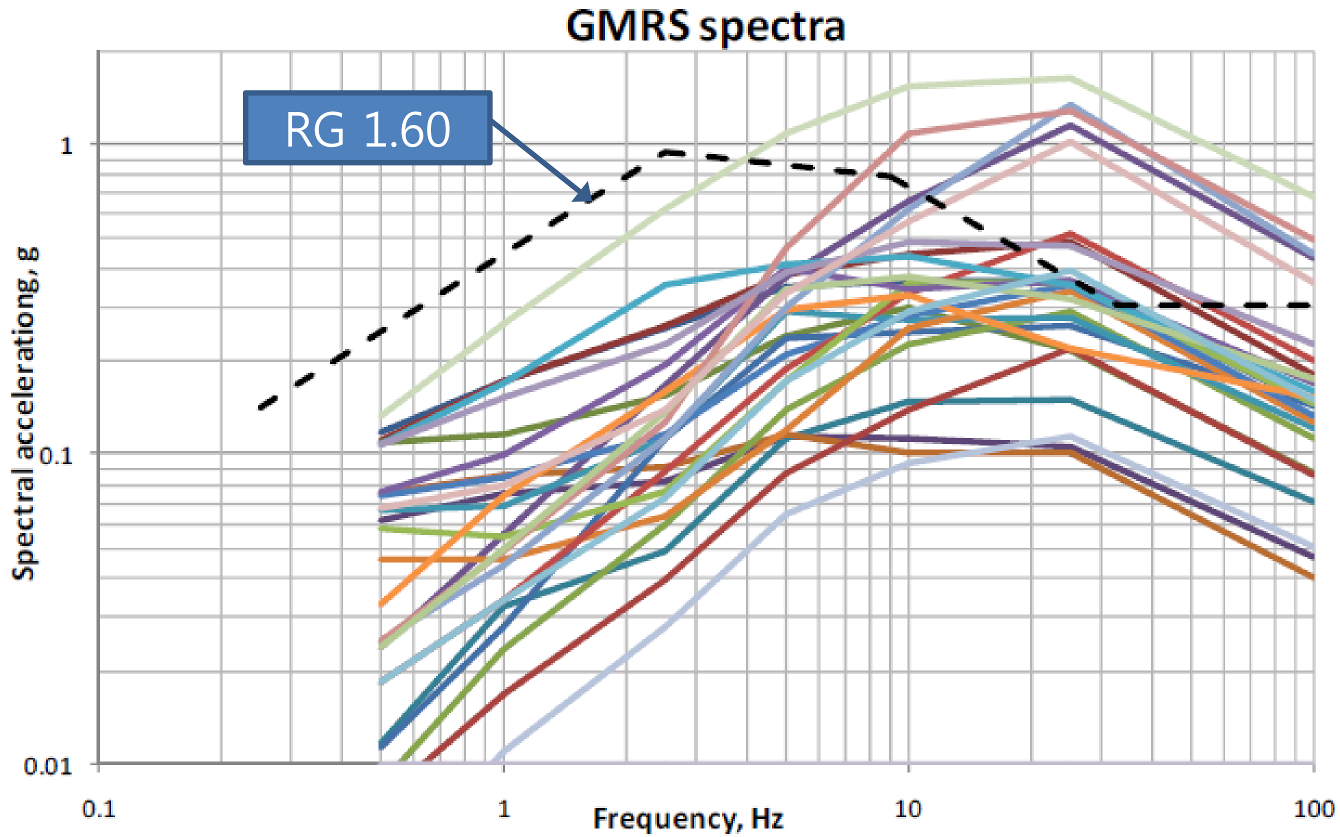
- GMRS for 28 Sites (2006)



Program on Technology Innovation: Sensitivity of Performance-Based Approaches for Determining the Safe Shutdown Earthquake (SSE) Ground Motion for New Plant Sites(2006)

Background (cont'd)

- GMRS for 34 Sites (2008)

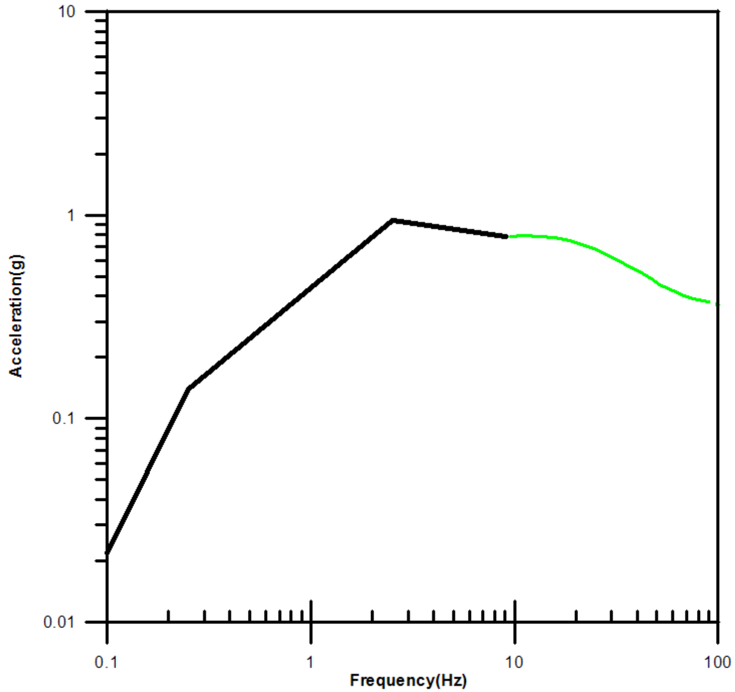


Assessment of Seismic Hazard at 34 U.S. Nuclear Plant Sites(2008)

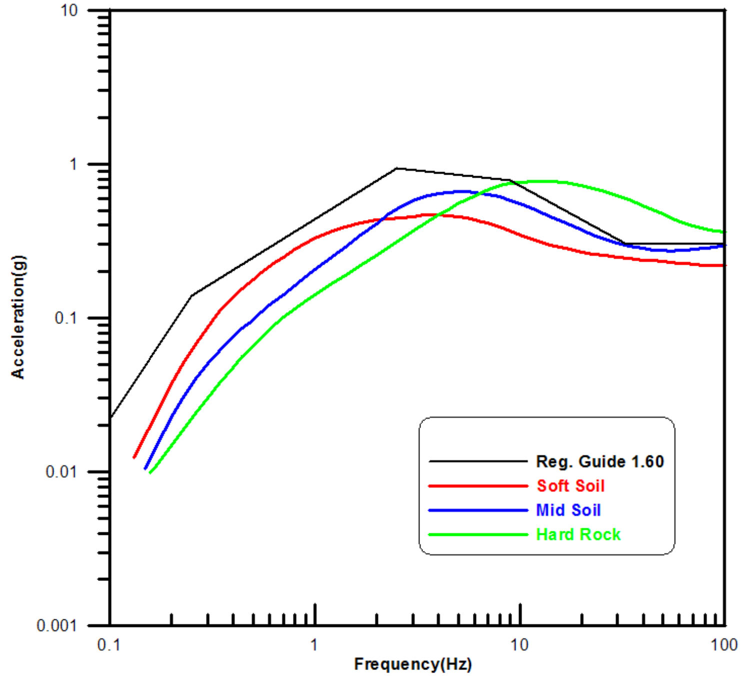
Background (cont'd)

- In collaboration with EPRI, we are planning to generate GMRS early next year
  - EPRI program "Site-Specific Hazard Using New CEUS Seismic Source Model"
- CSDRS will be generated from the GMRS information.
- Options for CSDRS
  - Single CSDRS based on RG 1.60 DGRS with high frequency content reinforced
  - Multiple CSDRS representing different soil profiles
- KEPCO expects high frequency content of new CSDRS would be higher than that of CMS1+.
  - We need credit for the application of incoherency input motion technique.

Background (cont'd)



Single CSDRS: an example



Multiple CSDRSs: an example

ISG-01 Review

- Crediting incoherent input motion technique at COL stage
- Use of computer codes for incoherency analysis
  - SASSI-SRSS, SASSI-SIMULATION, CLASSIinco-SRSS
- Coherency function
  - Hard-rock coherency functions based on the Pinyon Flat Array data
- Evaluation of SSCs
  - Structural modeling including incoherency
  - Show enveloping FRS
- Identification and evaluation of HF sensitive mechanical & electrical equipment/components
  - Screening procedure and justification of HF sensitive equipment/components
  - Justification for screened-out equipment/components
  - Evaluation of screened-in equipment/components

Approach for Incoherent Input Motion Effects

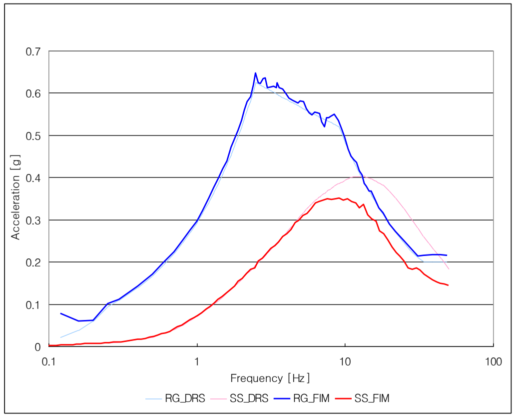
- Response spectrum ratio method
  - Newmark Tau-filtering factor (Newmark, 1976)
  - Reduction factors to ground response spectra (ASCE 4-98, 1999)
  - Ratios of response spectrum (FEMA 440, 2005)
- Cross-correlation method
  - Long Term Seismic Program of Diablo Canyon NPP (PG&E, 1988; U.S. NRC, 1991)
  - EPRI's studies from 1997 through 2007(EPRI TR-102631; EPRI and U.S. DOE 1015110 & 1015111, 2007)
  - US NRC Regulation (SRP3.7.2, Rev. 3)

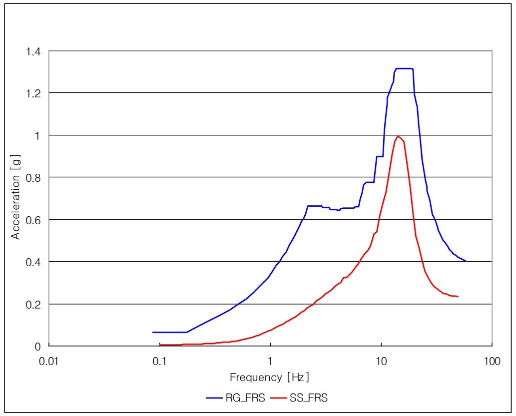
KEPCO E&C's Experiences on Incoherent Input Motion Technique

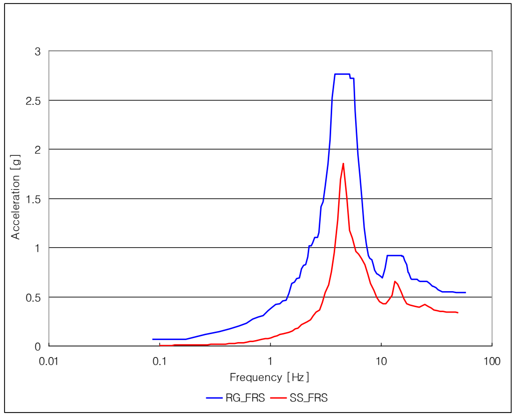
- Parametric studies were carried out in research project.
  - V&V of computer program (ACS-SASSI, SASSI-INCOH)
  - Sensitivity analysis for embedment, basemat dimension, etc
- Evaluation experiences at Wolsong site
  - Seven safety-related PWR structures including Reactor and Auxiliary buildings
  - Fourteen safety-related CANDU type structures including Reactor and Service buildings
  - Under review with Korean nuclear regulatory agency

KEPCO E&C's experiences on incoherent input motion technique (cont'd)

- FRS comparison of w/o incoherency effects to the containment building (FIM, Middle level, and Top level, N-S component)







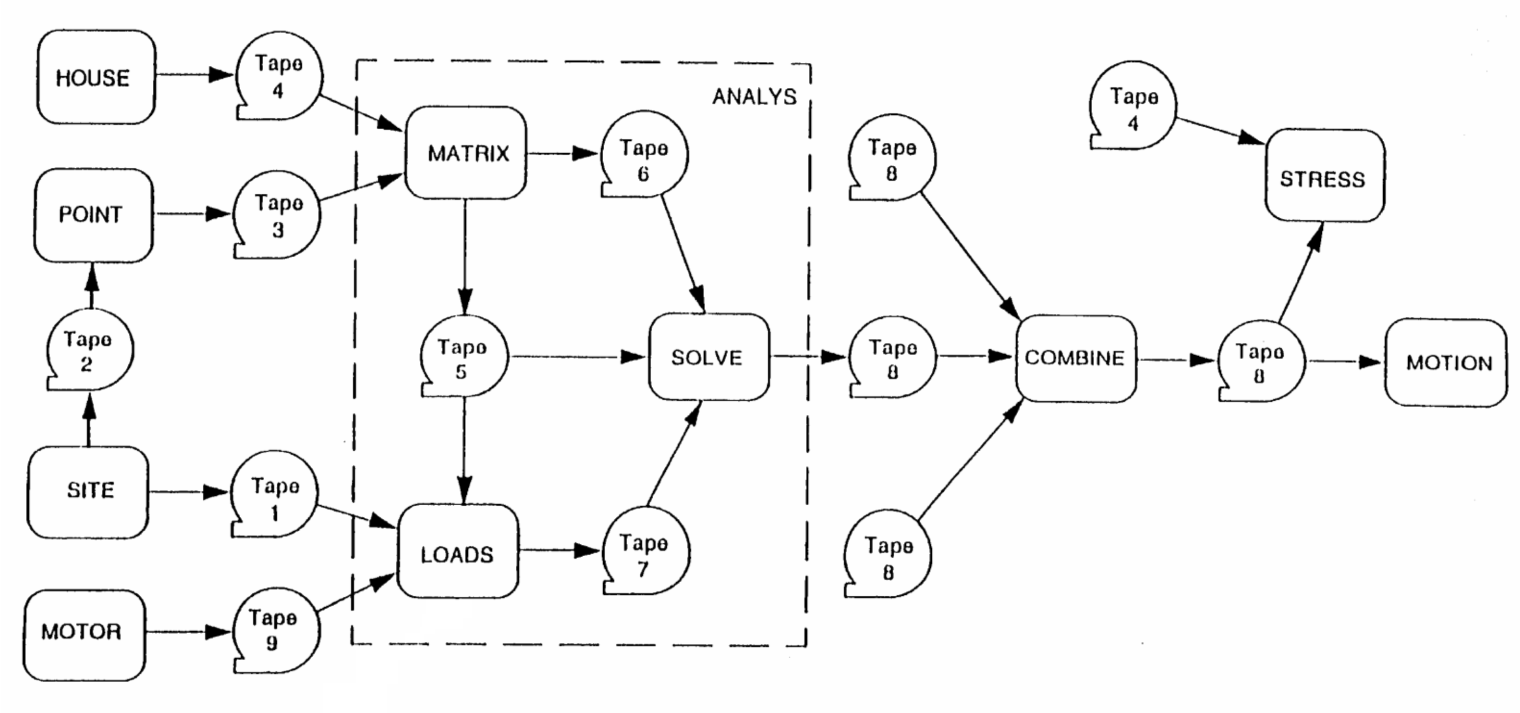
Incoherent Input Motion Effects

- Implementation of incoherent input motion via SASSI.
- We chose SASSI, UC Berkeley version.
- Methodology
  - Coherency function
    - Empirical coherency function developed by Abrahamson (2007)
      - Hard rock site
      - Soil site

$$|\gamma(f,\xi)| = \left[1+\left(\frac{f}{a_1 f_c(\xi)}\tanh(a_3\xi)\right)^{n_1}\right]^{-1/2}\left[1+\left(\frac{f}{a_2 f_c(\xi)}\tanh(a_3\xi)\right)^{n_2(\xi)}\right]^{-1/2}$$

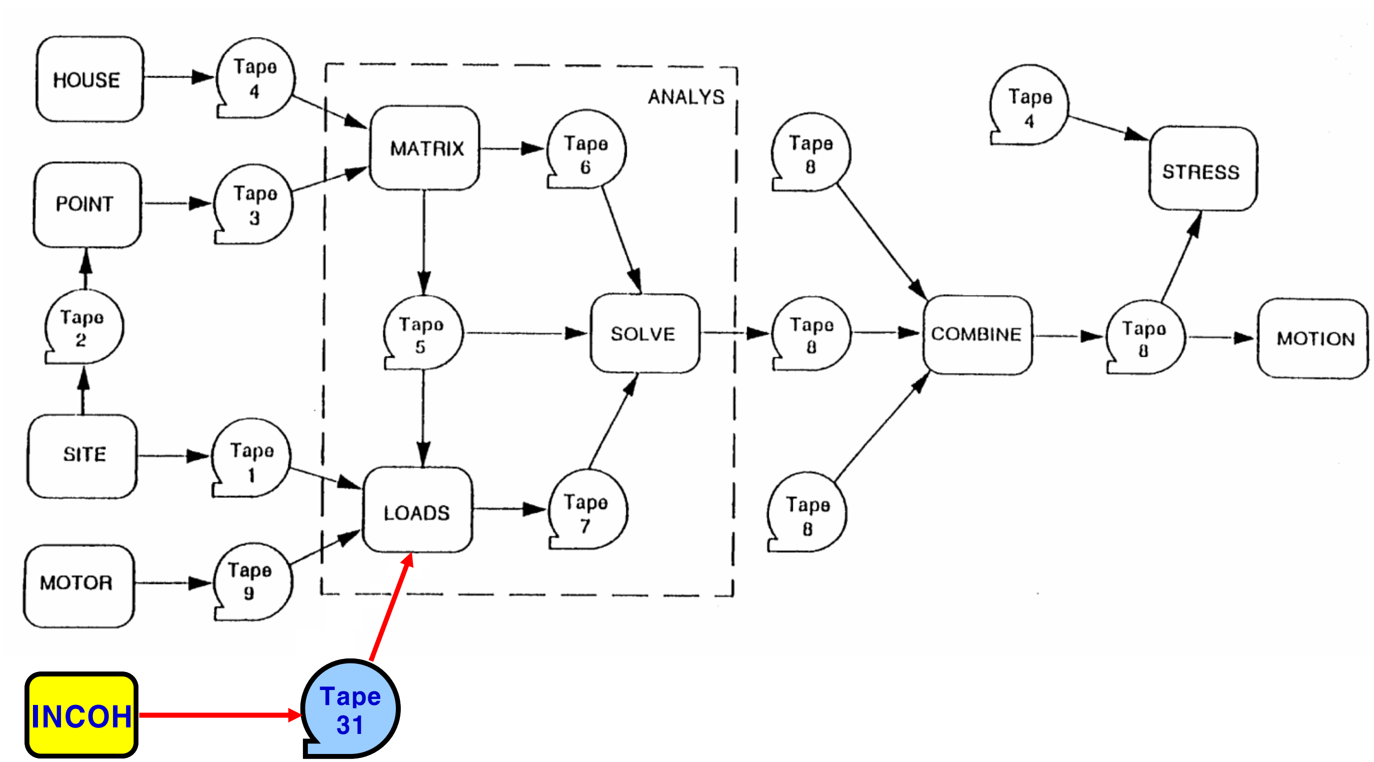
  - SASSI-INCOH (KEPCO E&C version, 2009)
    - Recent coherency functions for hard rock and soil sites were implemented
    - INCOH module has been verified for all coherency functions and methodologies by comparing with Abrahamson's coherency models and EPRI verification problems.
      - EPRI and U.S. DOE (2007) *Program on Technology Innovation: Effects of Spatial Incoherence on Seismic Ground Motions*, 1015110.
      - Tseng, W. S. and Lilhanand, K. (1997). Soil-Structure Interaction Analysis Incorporating Spatial Incoherence of Ground Motion, EPRI, TR-102631.

Incoherent Input Motion Effects (cont'd)



SASSI (UC, Berkeley version)

Incoherent Input Motion Effects (cont'd)



SSI Analysis Flow using SASSI-INCOH

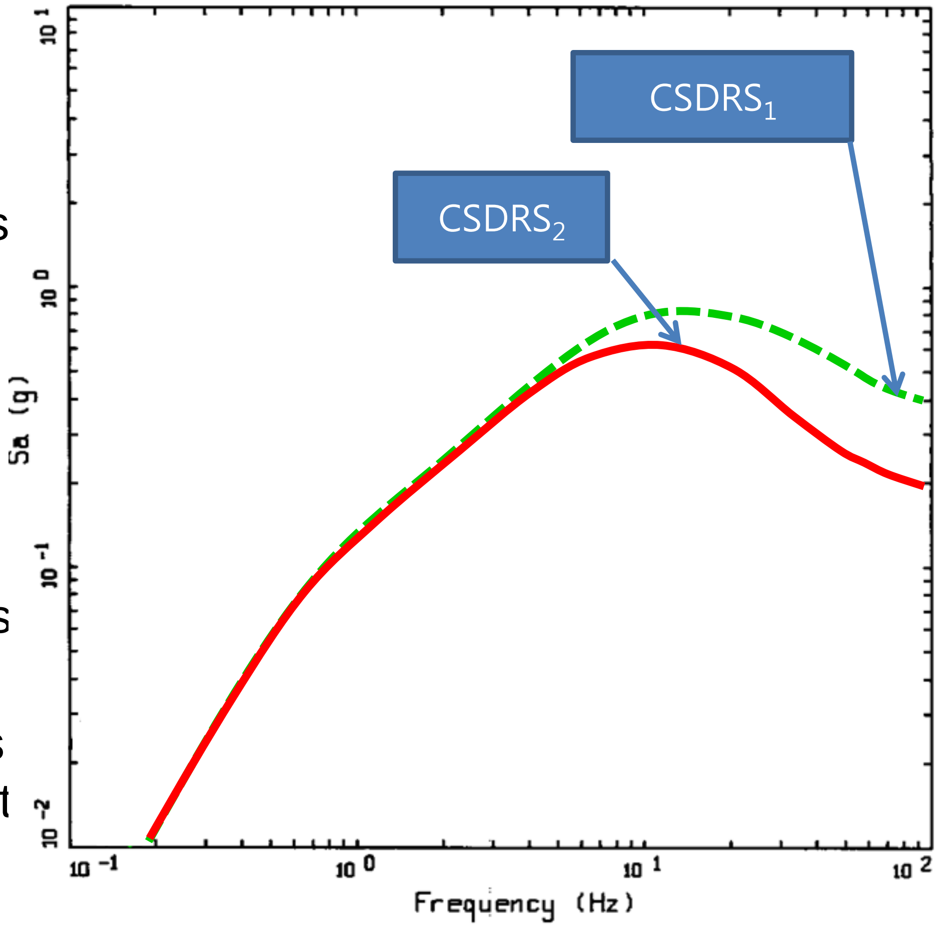
Considerations on Incorporating Incoherent Input Motion Effects

- Option 1: Incoherency at the DC stage
  - Coherency model proposed by Abrahamson (2007) will be used.
  - Target high percent CEUS sites to be covered by CSDRS.
  - CSDRS response calculated incorporating incoherency effects
  - Since this would be the first application incorporating incoherency in DC stage, KEPCO is evaluating potential challenges.

  - $CSDRS_1$ = takes into account incoherency effects
  - $CSDRS_2$ = does not take into account incoherency at the DC stage

Considerations on Incorporating Incoherent Input Motion Effects (cont'd)

- Option 2: Incoherency at the COL stage
  - CSDRS$_2$ will be defined to cover most CEUS sites once incoherent input motion effects are credited
    - Decrease due to incoherent input motion effects will be calculated from preliminary study(matching FRS from Option 1)
  - Incoherent input motion effects will be applied at COL stage.
  - CSDRS would cover less sites than those of DC stage without taking specific credit for incoherency.



Points of Discussion

- Validation of Incoherency effect analysis considering generic soil profiles in DC stage
- Applicability of coherency function for soil
- Coverage level of APR1400 CSDRS to CEUS in DC stage
- Cutoff frequency above 50 Hz in SSI analysis