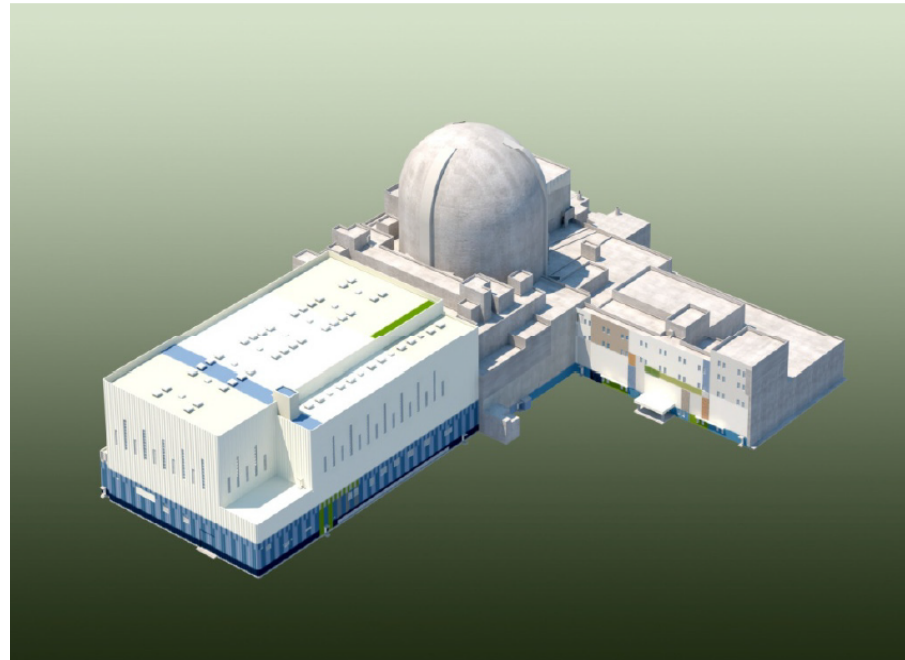


# APR1400 Seismic Design Analysis



**KEPCO/KHNP**  
April 20 ~ 21, 2016

# APR1400 Seismic Design Analysis

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- A. Seismic Design Parameters**
- B. SSI Analysis**
- C. HRHF RS**
- D. Summary**

# A. Seismic Design Parameters

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1. Purpose
2. Regulatory Basis
3. Main Computer Programs
4. Seismic Classification
5. Design Ground Motion
6. Soil Profiles

# A-1 Purpose

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- The purpose of this presentation is to introduce standard design features used in the seismic analysis of the APR1400 structures.
- All contents of this presentation can be also found in DCD seismic analysis Chapter 3.7.

(Refs: APR1400-E-S-NR-14001-P ~ APR1400-E-S-NR-14005-P)

## A-2 Regulatory Basis

- **Features**

- APR1400 seismic analysis and design follow US regulations and design procedures
- All regulations and design codes are up-to-date

- **Examples**

- **10 CFR Part 50, App. S:** Earthquake Engineering Criteria for Nuclear Power Plants
- **10 CFR Part 52, Subpart B:** Standard Design Certifications, Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants
- **RG 1.60 (Rev. 2):** Design Response Spectra for Seismic Design of Nuclear Power Plants
- **RG 1.61 (Rev. 1):** Damping Values for Seismic Design of Nuclear Power Plants
- **RG 1.92 (Rev. 3):** Combining Modal Responses and Spatial Components in Seismic Response Analysis
- **RG 1.208:** A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion

## A-2 Regulatory Basis (cont'd)

- **Examples (cont'd)**
  - **SRP 3.7.1 (Rev. 4)**: Seismic Design Parameters
  - **SRP 3.7.2 (Rev. 4)**: Seismic System Analysis
  - **SRP 3.7.3 (Rev. 4)**: Seismic Subsystem Analysis
  - **DC/COL-ISG-01**: Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications
  - **DC/COL-ISG-017**: Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses
  - **NUREG/CR-6728**: Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion Spectra Guidelines

## A-3 Main Computer Programs

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- **Features**

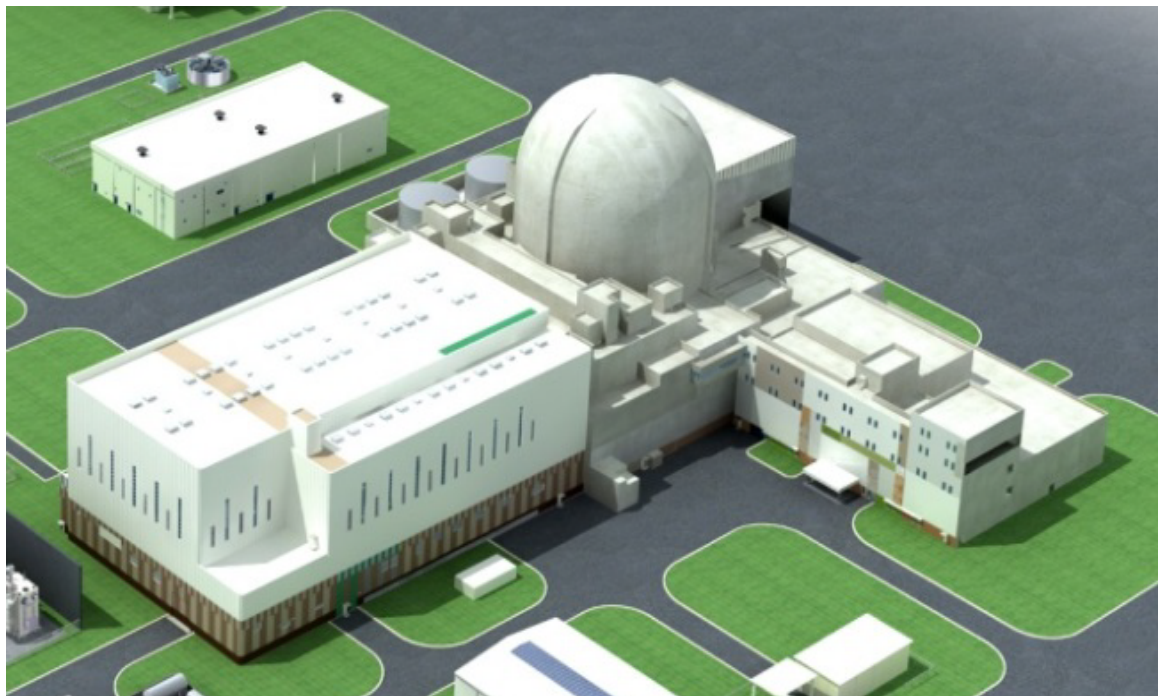
- NQA programs are used for main seismic analysis

- **Examples**

- Finite Element Modeling and Eigenvalue Analysis of Structures
    - Computer code: ANSYS Ver. 14
  - Soil-Structure Interaction Analysis with Coherent and Incoherent Seismic Input Motions
    - Computer code: ACS SASSI Fast Solver NQA Ver. 2.3.0

# A-4 Seismic Classification

## 1) Layout

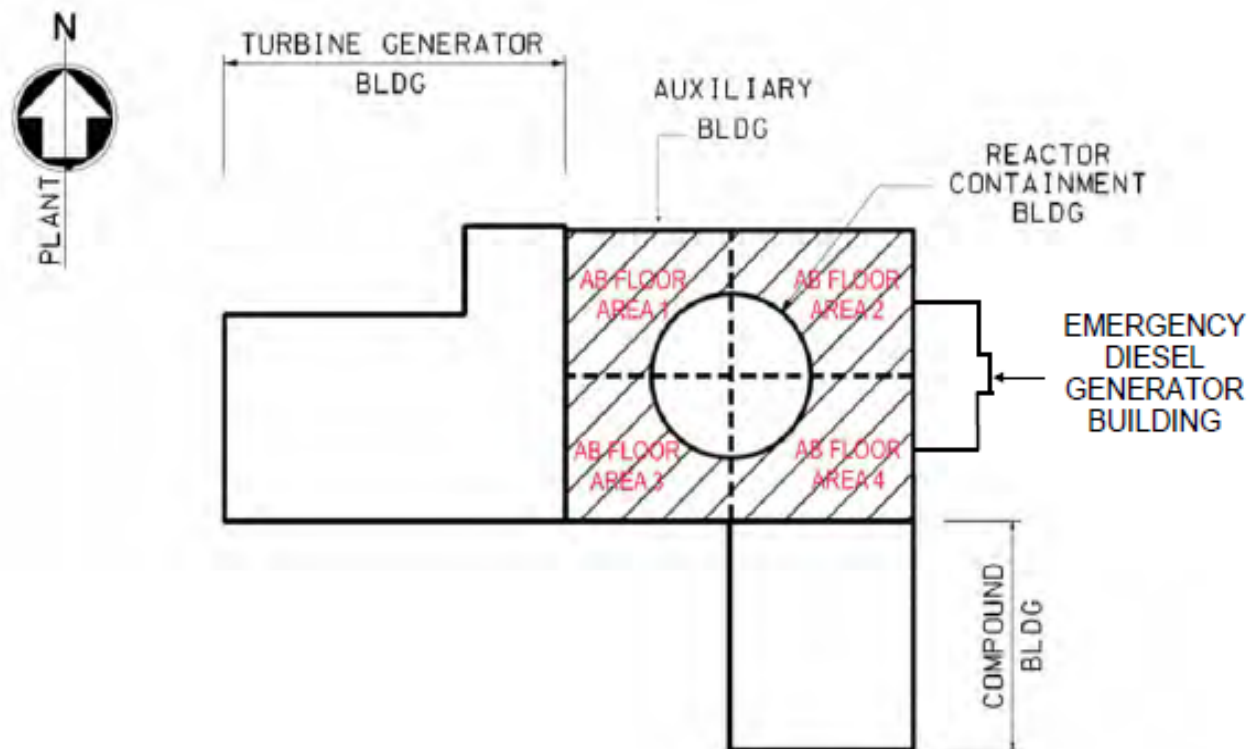


APR1400



# A-4 Seismic Classification (cont'd)

## 1) Layout (cont'd)



# A-4 Seismic Classification (cont'd)

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## 2) Seismic Analysis Scope

- Nuclear Island Structures
  - Reactor Containment Building (RCB)
  - Auxiliary Building (AB)
- Emergency Diesel Generator Building (EDGB)
- Turbine Generator Building (TGB)
- Compound Building (CPB)

## A-4 Seismic Classification (cont'd)

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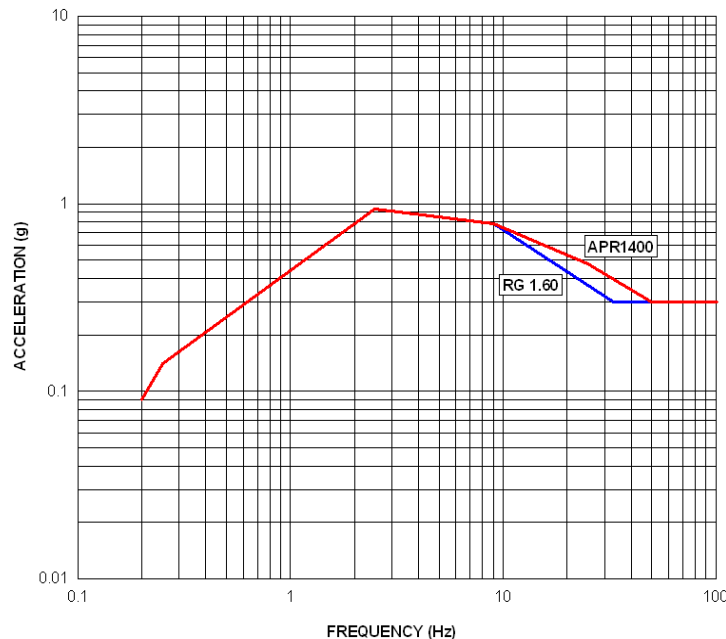
### 3) Seismic Classification of Buildings in Scope

- Seismic Category I
  - Reactor Containment Building
  - Auxiliary Building
  - Emergency Diesel Generator Building
- Seismic Category II
  - Turbine Generator Building
  - Compound Building

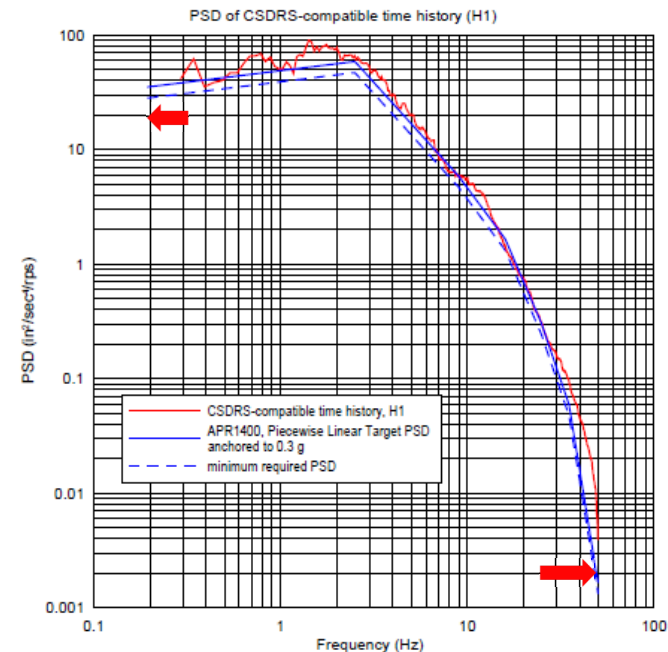
# A-5 Design Ground Motion

## • Features

- CSDRS: RG 1.60 design response spectra enriched high frequency range
  - High frequency contents from 9 Hz to 50 Hz are reinforced
  - PSD check is reinforced by considering wide frequency range (from 0.2 Hz to 50 Hz)



Horizontal CSDRS and RG 1.60  
Spectrum (5% Damping)



Comparisons of PSDs for  
CSDRS

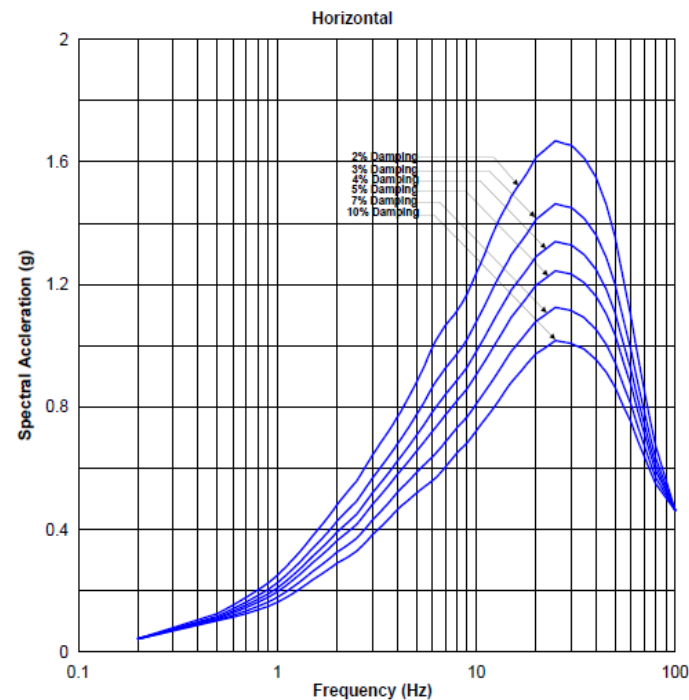
# A-5 Design Ground Motion

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- **Features (cont'd)**
  - Design time histories: Those are generated from real earthquake ground motion
    - Selected from the catalog in the NUREG/CR-6728, App. B (Northridge Earthquake: Jan. 17, 1994, M=6.7)
    - Applicable for CEUS sites
    - Appropriate earthquake magnitude, epicentral distance and adequate duration
    - Conforming with SRP 3.7.1, Rev. 4

# A-5 Design Ground Motion

- Features (cont'd)
  - HRHF response spectra reflecting CEUS hazard (2006, 2008 and 2011) are used for seismic analysis (EPRI Product ID: 1023389)

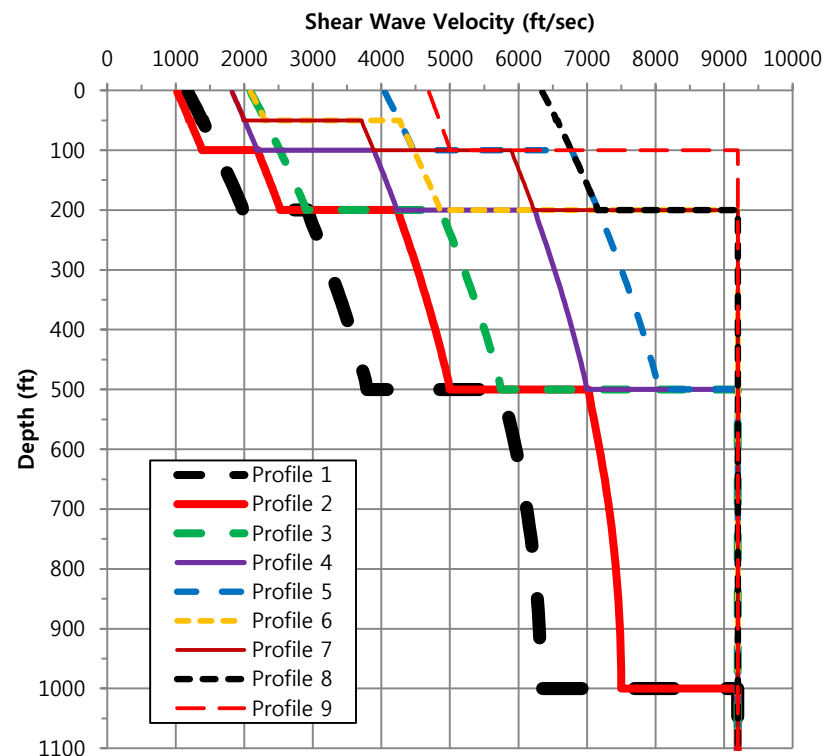


Horizontal Response Spectra for HRHF

# A-6 Soil Profiles

- **Features**

- A total of ten generic site profiles consider from the minimum confident soil site to hard rock and fixed-base sites
- Each generic soil profile is defined by its soil/rock shear wave velocity profile



## B. SSI Analysis

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1. Modeling
2. Soil-Structure Interaction Analysis

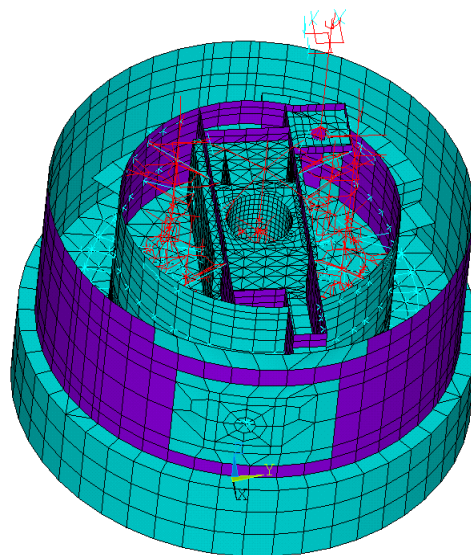


# B-1 Modeling

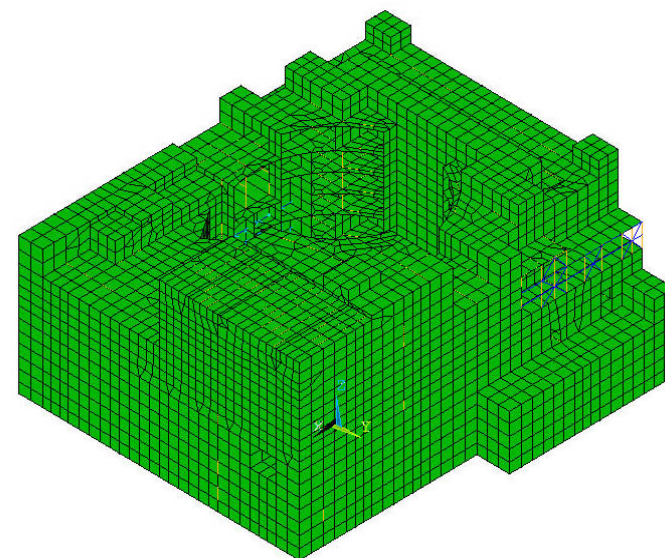
- **Description of NI Structure**

- Common basemat is shared by RCB and AB.
- RCB and AB structures are separated above basemat.
- Containment Structure: Prestressed Concrete Containment Vessel (PCCV)
- Internal Structure: Reinforced Concrete Structure
- Reactor Coolant System (RCS) is incorporated into the CIS.

TS



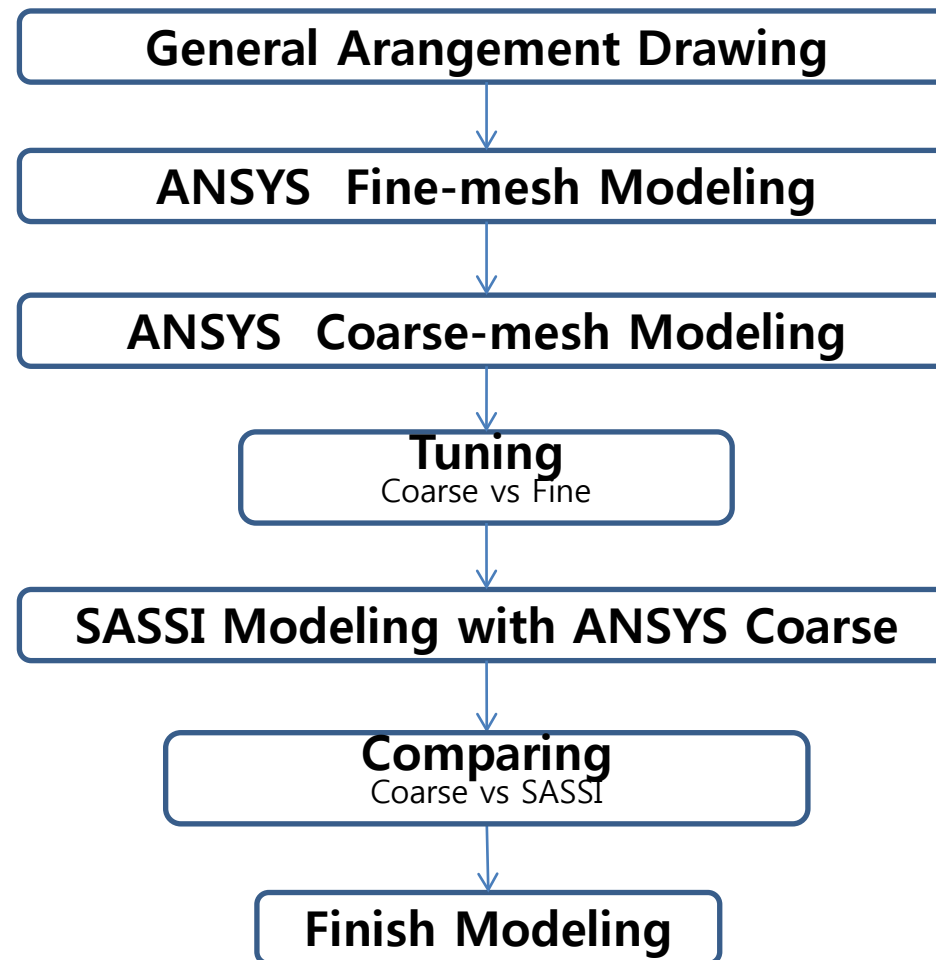
Containment Internal Structure  
including RCS



Auxiliary Building

# B-1 Modeling (cont'd)

- Modeling Process



# B-1 Modeling (cont'd)

- **Features**

- Every structural models are developed through validation process
  - Verifying ANSYS fixed-base model
  - ANSYS fixed-base fine mesh vs ANSYS fixed-base coarse mesh
  - ANSYS fixed-base coarse mesh vs SASSI fixed-base model
- All structural models are configured by 3-D FE meshes
  - To consider high frequency response at the structure
  - To consider flexibility of structure basemat
  - To compute accurate dynamic responses

# B-2 Soil-Structure Interaction Analysis

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- **Features**

- Embedment

- Excavated space is modeled by 3-D to consider embedment effects in SSI analysis
    - Direct Method is used for calculation of soil impedances and seismic input motion vectors for the excavated volume below ground surface
    - Subtraction Method and Modified Subtraction Method are not used for the APR1400 SSI analyses

## B-2 Soil-Structure Interaction Analysis

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- **Features (cont'd)**
  - SSI analyses for APR1400 envelope the all effects by the following design parameters
    - Nine generic soil profiles + Fixed-base
    - Embedment effects
    - Un-cracked concrete model and cracked concrete model
    - Underground water table effects
    - Structure-soil-structure interaction effects
    - Coherent ground input motion and incoherent ground input motion

## C. HRHF RS

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1. HRHF RS
2. Analysis Using Incoherent Input Motion

# C-1 HRHF RS

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- **Objective**

- To calculate the site-specific seismic hazards at 60 CEUS sites using up-to-date seismic source characterization model and ground motion equations

- **Development History**

- EPRI Product ID: 1023389, May 2011: “Evaluation of seismic hazard at Central and Eastern US nuclear power sites”
    - Site-specific hazard at 60 CEUS sites: 2008 USGS Seismic Source Model
    - Ground motion equations: EPRI equations (2004) for the CEUS
    - GMRS: Reg. Guide 1.208

# C-2 Analysis using Incoherent Input Motion

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- Features
  - Coherency functions: Abrahamson models for hard rock sites (2007)
  - SSI responses for at least seven principal coherency modes were combined by the SRSS combination rule to obtain the seismic response to incoherent motion input
  - Sensitivity to SSI responses due to higher principal coherency modes was checked in accordance with SRP guidelines
  - SASSI-simulation method was used based on DC/COL-ISG-01
  - The analysis results considering the incoherent-motion SSI analysis were compared with the results from the coherent-motion SSI analysis



# Summary

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- Seismic analysis of the APR1400 is performed in accordance with the NRC's guidelines and bases.
- The CSDRS referencing Reg. Guide 1.60 reinforce high frequency energy contents from 9 Hz through 50 Hz.
- HRHF RS develop by EPRI were used for evaluation to consider the high frequency contents of CEUS.
- Soil profiles of APR1400 consider various site conditions codified in the guides.
- The SSI analyses of the structure modeled by 3-D FE meshes were performed considering various design parameters.