

North Anna

3

North Anna 3 COLA

Seismic Update

October 31, 2013 Meeting with NRC

Introduction and Agenda

- Introduction
- Purpose
- Background
- Overview of Seismic Analysis Approach
- Details of Significant Changes

Presenters

- Purpose, Background, Overview: R. Millikan (Dominion)
- Mineral, VA Earthquake: D. Fenster (Bechtel)
- Vibratory Ground Motion: J. Marrone (Bechtel)
- Site Response Analysis, FIRS, GMRS, and SSI Input Development: A. Hashemi (Bechtel)
- V_s Profiles: J. Davie (Bechtel)
- Time History Development: N. Gregor (Bechtel)
- Seismic Analyses: S. Schumitsch (GE-Hitachi)
- Summary: R. Millikan (Dominion)

Purpose of Meeting

- Provide NRC staff with overview of geotechnical and seismic analyses and planned revisions to COLA resulting from seismic analysis
- Answer NRC questions

Background

- Using new CEUS SSC model
- Addressing August 23, 2011 Mineral earthquake
- Performing site-specific SSI analysis for ESBWR technology

Overview of Seismic Analysis

- Use latest NRC guidance and industry information to perform seismic-related work
- Follow methodologies used in DCD and Fermi 3 seismic analysis, as appropriate
- Gather geologic information and perform field reconnaissance activities related to August 23, 2011 Mineral, VA earthquake
- Develop revised site-specific hard rock PSHA and GMRS
- Update V_s profiles for structures to reflect revised Unit 3 layout for ESBWR and additional borings

Overview of Seismic Analysis(cont)

- Develop revised FIRS for comparison with CSDRS
- Develop SSI input response spectra and strain-compatible SSI input soil profiles for each seismic Category I structure to evaluate CSDRS exceedance

Overview of Seismic Analysis(cont)

- Perform site-specific SSI analyses for seismic Category I buildings:
 - Reactor Building (RB)/Fuel Building (FB)
 - Control Building (CB)
 - Firewater Service Complex (FWSC)

Overview of Seismic Analysis(cont)

- COLA changes will:
 - Use the new CEUS SSC model and RG 1.208 to develop PSHA, GMRS, and FIRS
 - Address RAIs associated with Vs development and site subsurface variability
 - Address NRC considerations regarding time history development methodology
 - Update seismic analyses to incorporate the new seismic inputs, with departures as required
 - Update miscellaneous chapters impacted by seismic changes

Details: FSAR 2.5.1 and 2.5.3

Basic Geologic Information & Surface Faulting

- Revised FSAR 2.5.1 and 2.5.3 submitted to NRC in mid-2012 for US-APWR S-COLA
 - Generally technology-independent
- **M** 5.8 Mineral, VA, earthquake on August 23, 2011 in Central Virginia Seismic Zone
- Geologic field reconnaissance in vicinity of site:
 - Discussions with VGS, USGS and others
 - Compiled geologic maps
 - Obtained LiDAR data, derivative maps and photos
 - Reviewed aftershock seismology data
 - Performed field study
- No evidence of surface faulting

Details: FSAR 2.5.1 and 2.5.3

Basic Geologic Information & Surface Faulting (cont)

- Impact on ESBWR COLA
 - Update information on tectonic features in Section 2.5.1.1.4 consistent with CEUS-SSC report
 - Add a description of the event in a new Section 2.5.1.1.7
 - Update information on absence of Quaternary surface faulting in Section 2.5.3
 - Geologic descriptions in Sections 2.5.1 and 2.5.3
 - Geologic aspects of seismic sources for PSHA

Overview: FSAR 2.5.2

Vibratory Ground Motion

- SSAR Section 2.5.2 supplemented completely:
 - Use 2012 CEUS SSC report:
 - New seismicity catalog through 2008
 - New seismic source characterization [SSC] model
 - Updated seismicity catalog through mid-December 2011 and addressed implications of the Mineral VA earthquake
 - Re-ran PSHA using the new/updated SSC
 - Developed GMRS and FIRS based on RG 1.208 at the common basemat foundation elevation for the RB/FB
 - Corresponding changes to ESP VAR 2.0-4 - Vibratory Ground Motion

Overview: FSAR 2.5.2

Vibratory Ground Motion (cont)

- CEUS SSC, updated seismicity catalog, and Mineral earthquake will require a revision to Section 2.5.2
 - 2.5.2.1 Seismicity
 - 2.5.2.2 Geologic and Tectonic Characteristics of the Site and Region
 - 2.5.2.3 Correlation of Seismicity with Seismic Sources
 - 2.5.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes
 - 2.5.2.5 Seismic Wave Transmission Characteristics of the Site
 - 2.5.2.6 Design Response Spectra (*FIRS included here*)

Details: FSAR 2.5.2.1

Seismicity

- CEUS SSC report (Chapter 3) presents a new seismicity catalog
 - Following same procedure as in the CEUS SSC report, seismicity is updated for the entire CEUS SSC coverage area:
 - For 2009 to mid-December 2011, there were 200 additional independent events of **M** 2.9 and greater within the CEUS
 - For 2009 to mid-December 2011, there were only 6 additional independent events of **M** 2.9 and greater within 322 km of NA3

Details: FSAR Sections 2.5.2.2, 2.5.2.3

- CEUS SSC report presents a completely new seismic source characterization model
 - Regional source zones
 - **Mmax Zones** – 3 versions [Wide, Narrow, Study]
 - **Seismotectonic Zones** – 4 versions [Wide PEZ/RCGr, Wide PEZ/RCGm, Narrow PEZ/RCGr, Narrow PEZ/RCGm]
 - RLME [Repeated Large-Magnitude Earthquakes] sources
- Updated CEUS SSC based on new information
 - Seismicity update [after 2008]
 - Evaluation of hazard input regarding 2011 Mineral, VA, earthquake [SSHAC Level 2]

Details: FSAR 2.5.2.4

Probabilistic Seismic Hazard Analysis

- New SSC required new PSHA
 - Same median GMPE – EPRI (2004)
 - Updated GMPE uncertainties – EPRI (2006)
 - M_{\min} for PSHA = **M** 5.0, no CAV filtering [as before]
 - Logic tree branches were trimmed or compressed (see Chapter 9 of CEUS SSC Report), analogous to identification of 99%-hazard contribution EPRI-SOG sources
- Deaggregation of 10^{-4} , 10^{-5} , and 10^{-6} rock hazard for North Anna determined using updated seismicity files within 1000 km inclusion distance

Details: FSAR 2.5.2.5

Seismic Wave Transmission Characteristics of the Site

- New PSHA required re-evaluation of site response [still follows NUREG/CR-6728 Approach 2A]
 - GMRS horizon elevation at bottom of RB/FB foundation
 - Both RB/FB and CB soil columns are considered in GMRS calculation
 - Explicitly following RG 1.208, site response was run using horizontal high-frequency [HF] and low-frequency [LF] deaggregated hard rock 10^{-4} and 10^{-5} uniform hazard response spectra (UHRS)
 - The soil profile simulation (randomization) and site response analysis were presented that yield the 10^{-4} and 10^{-5} UHRS at GMRS and FIRS horizons

Details: FSAR 2.5.2.6

Design Response Spectra

- New PSHA and site response analysis lead to new GMRS and new FIRS
 - Reg. Guide 1.208 performance-based procedure results in horizontal DRS at the GMRS and FIRS horizons
 - Envelope of the Geologic outcrop DRS at GMRS horizon from RB/FB and CB soil columns were used as the GMRS
 - The DRS at FIRS horizons are used to define the FIRS for each SC-I structure
 - Envelope of the DRS at surface from RB/FB and CB soil columns were used to define the PBSRS
 - V/H, developed following procedure from NUREG/CR-6728, Appendix J, applied to horizontal GMRS to obtain vertical GMRS

Details: FSAR 2.5.2.7

Operating Basis Earthquake

- Site-dependant operating basis earthquake (OBE) is addressed in FSAR Section 3.7.1.1.6
- Therefore, FSAR 2.5.2.7 will be deleted

Overview: FSAR 2.5.4

Stability of Subsurface Materials and Foundations

- Update current shear wave velocity (V_s) profiles to address Unit 3 layout using configuration of ESBWR standard plant:
 - 2 new V_s borings not used since they are far from structures
 - Concrete fill replaces structural fill beneath FWSC
- Update sections affected by new earthquake motion i.e., liquefaction, seismic lateral earth pressure and slope stability

Details: FSAR 2.5.4

V_s for RB/FB

- In-situ V_s profile used for the RB/FB basemat configuration considers 3 powerblock area V_s borings
 - 2 V_s borings directly beneath RB/FB and one immediately adjacent
 - Log mean of 2 profiles (weathered/fractured rock and unweathered/unfractured rock) used to develop best estimate

Details: FSAR 2.5.4

V_s for CB & FWSC

- V_s profile for CB profiles based on V_s boring beneath the CB
 - Previously had used the same V_s profile as used for the RB/FB
 - Changes learned from US-APWR S-COLA
- V_s profile for the FWSC:
 - Used V_s boring beneath the adjacent CB with adjustments for average soil thickness based on borings under FWSC

Details: FSAR 2.5.4

Liquefaction, Slope Stability, Lateral Earth Pressure

- Peak ground acceleration (PGA) did not increase based on the revised seismic analysis. Small increases in magnitude for both LF and HF
- Revised analyses for liquefaction (Section 2.5.4.8), dynamic lateral earth pressure (Section 2.5.4.10) and slope stability (Section 2.5.5):
 - Factors of safety (FS) against liquefaction and slope failure for the existing PGA remain adequate
 - Because dynamic lateral earth pressure is proportional to the PGA, no change

Details: FSAR 3.7.1

SSI Input Soil Profiles, and SSI Input Time-Histories

- Revision of Section 3.7.1 due to:
 - Updated soil and rock profiles and their variation due to plant layout changes (Section 2.5.4)
 - Updated FIRS and strain compatible soil profiles based on new PSHA results (Sections 2.5.2.5 and 2.5.2.6)
 - Revised licensing basis from RG 1.165/Draft ASCE 43-05 to RG 1.208

Details: FSAR 3.7.1

FIRS, SSI Input Soil Profiles

- Step-by-step Methodology:
 - Soil Profile Simulation (No change in methodology but used different best estimate profiles)
 - Site Response Analysis (updated per RG 1.208)
 - Horizontal and Vertical FIRS Development (updated per RG 1.208)
 - SSI Soil Profile Development (updated per RG 1.208)
 - SSI Input Response Spectra Development
 - NEI Check (ISG-017) (No change)
 - Minimum Required Spectrum (per 10 CFR 50, App. S) (No change)
 - RB/FB and CB FIRS and SSI input response spectra were calculated for these buildings as partially embedded and fully embedded foundations per ISG-017
 - FWSC FIRS and SSI input response spectra were calculated for this building as a surface foundation per ISG-017

Details: FSAR 3.7.1

FIRS, SSI Input Soil Profiles (cont)

- Time History Generation
 - SRP 3.7.1, Option 1, Approach 2 (One TH set, matched to 5% damped SSI input response spectra) was used (No change)
 - Three component set (2 horizontal and 1 vertical) of spectrum compatible acceleration time histories was developed (No change)
 - Selection of time history from CEUS magnitude-distance database bin of NUREG/CR-6728 (No change)
 - PSD Check is used to confirm not less than 80% of reference PSD
 - In-Column Time-Histories (for SSI analysis as embedded or partially embedded) (No change)
- Site-dependant OBE calculation (No change)

Details: Sections 3.7.1.2 & 3.7.1.3

- 3.7.1.2 Percentage of Critical Damping Values
 - OBE damping values used in the site specific SSI analysis unless SSE damping justified per DCD Table 3.7-1 by stress demand
- 3.7.1.3 Supporting Media for Category I Structures
 - Seismic Category 1 structures have concrete mat foundations on rock or concrete fill on rock

Overview: 3.7.2

Transmission System

- Licensing Basis: Partially embedded in rock without consideration of in-situ soil/structural backfill above Zone III rock/concrete fill.
- Sensitivity Study: Fully embedded including in-situ soil/structural backfill above Zone III rock/concrete fill.
- Similar to Fermi 3 COLA

Details: Section 3.7.2.4

Seismic System Analysis

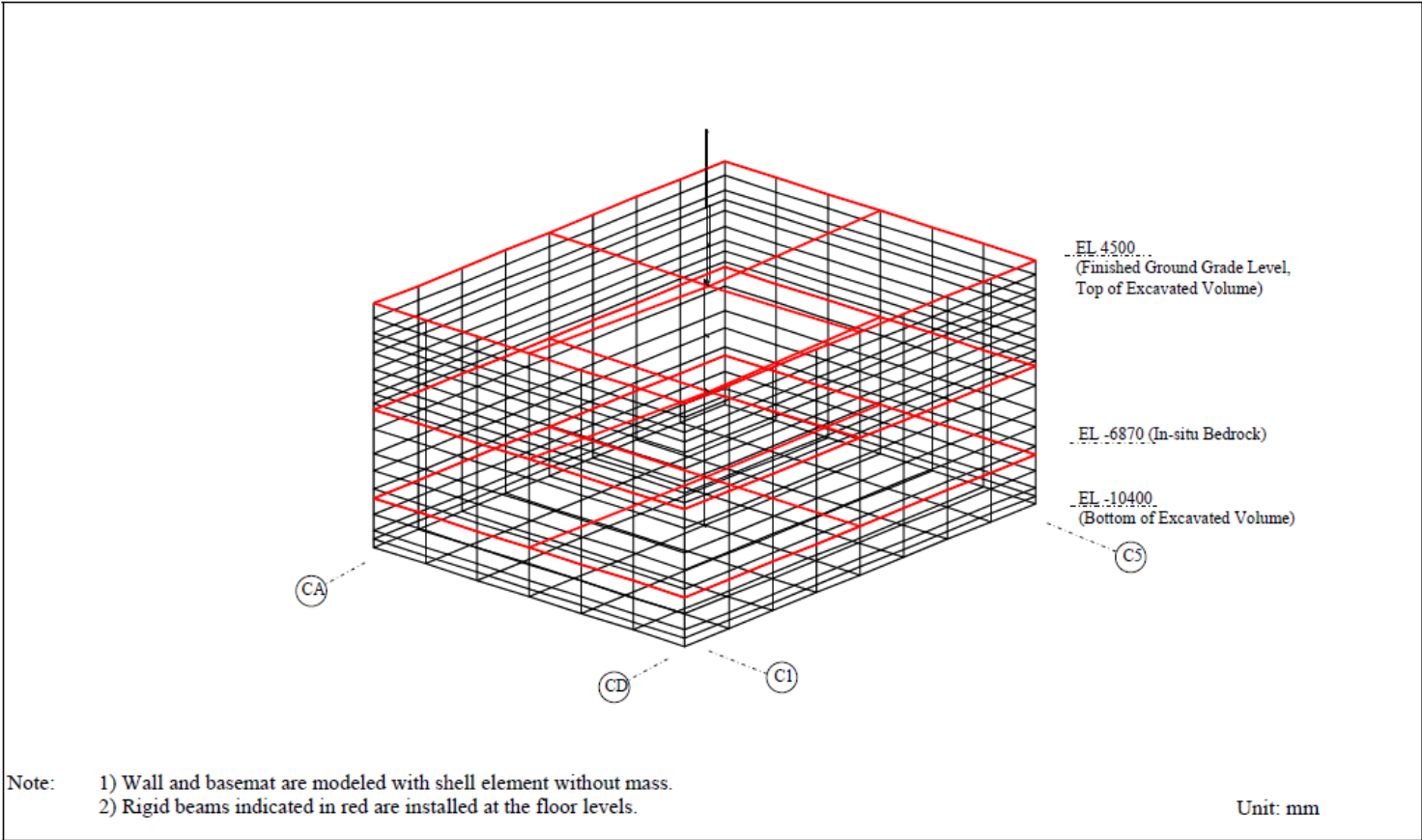
- 3.7.2.4 Soil-Structure Interaction
 - Site-specific SSI analysis for RB/FB, CB and FWSC
- 3.7.2.4.1 North Anna 3 Site-Specific Soil-Structure Interaction Analysis
 - Present site-specific SSI analysis per SRP 3.7.2. FIRS developed in S 2.5.2 not fully enveloped by ESBWR CSDRS
 - Same methodology as DCD and EF3 COLA using SASSI 2010
- 3.7.2.4.1.1 Strain Compatible Dynamic Subsurface Material Properties
 - Strain compatible BE, LB and UB profiles are developed from site response analysis as discussed in 3.7.1
- 3.7.2.4.1.2 SSI Input Response Spectra Compatible Ground Motion Time Histories
 - Refers to 3.7.1.1.5 for ground motion time histories used for input motions at bottom of RB/FB, CB and FWSC basemat levels

Details: Section 3.7.2.4

Seismic System Analysis (cont.)

- 3.7.2.4.1.3 Soil-Structure Interaction Analysis Method
 - Follows DCD Section 3A.5.2 using SASSI2010
 - V&V of SASSI2010
- 3.7.2.4.1.4 Soil-Structure Interaction Analysis Structural Models
 - Describes site specific SSI SASSI2010 model configurations
- 3.7.2.4.1.5 Soil-Structure Interaction Analysis Cases
 - Use BE, LB and UB profiles in site specific SSI analysis
- 3.7.2.4.1.6 Soil-Structure Interaction Analysis Results
 - Results for site specific SSI for BE, LB and UB profiles presented & compared to key locations with seismic envelopes specified in DCD Section 3A.9 for max seismic structural loads, accelerations and floor response spectra

ESBWR SSI Methodology



Control Building

ESBWR SSI Methodology (cont.)

The lumped mass-beam model is coupled with the finite element soil model using site-specific strain compatible dynamic subsurface properties in SASSI. Used at DCD and EF-3.

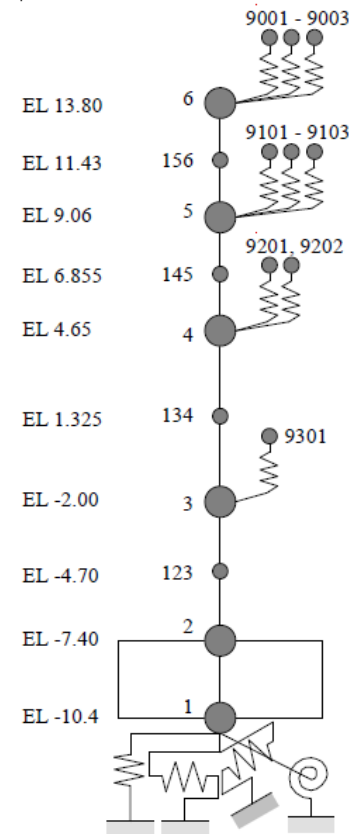


Figure 3A.7-6. Control Building Seismic Model

Enveloping Floor Response Spectra (From ESBWR DCD)

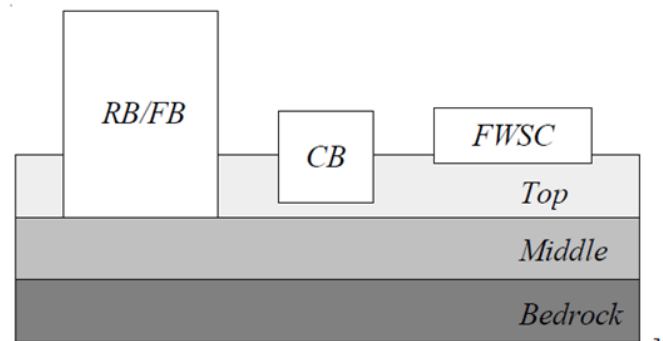
DCD Table 3A.3-3

Layered Site Cases

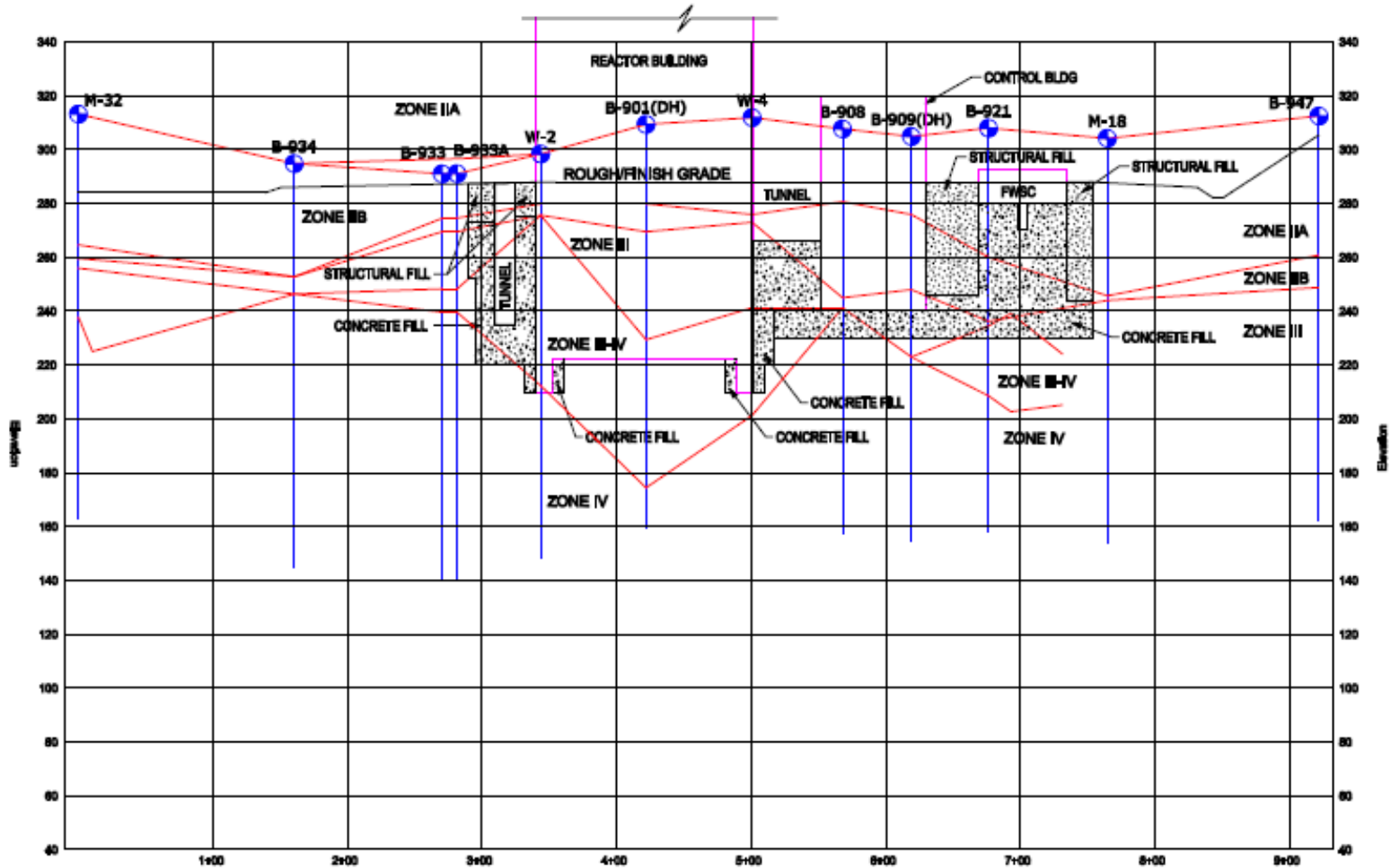
Layer ⁽²⁾	Shear Wave Velocity (m/s)/Depth (m)			
	CASE 1	CASE 2	CASE 3	CASE 4
Top	300/20	300/20	300/20	300/20
Middle ⁽¹⁾	300/20	800/20	300/40	800/40
Bedrock	1700	1700	1700	1700

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 25.4 mm = 1 in

- (1) The 20 m depth of the middle layer corresponds to the embedded depth of the RB/FB and the 40 m depth corresponds to about one-half the largest plan dimension of the RB/FB foundation.
- (2) Properties of the three layers of soils are the same as the generic site properties for soft, medium, and hard soils in Table 3A.3-1.



Subsurface Profile with Foundation Outline



Details: Section 3.7.2

Seismic System Analysis (cont.)

- 3.7.2.4.1.6.1 SSI Enveloping Maximum Structural Loads
 - Seismic loads are compared to the DCD
 - RB/FB structures
 - Diaphragm floor
 - Reinforced Concrete Containment Vessel
 - Vent Wall/Pedestal
 - Reactor shield wall
 - CB
 - FWSC

Details: Section 3.7.2

Seismic System Analysis (cont.)

- If exceeded, then verify combined stresses are less than allowable
 - The maximum value of the ratios of NA3 to DCD seismic responses of X-shear, Y-shear, X-moment, Y moment, torsion and vertical acceleration at each elevation are calculated. This is a conservative approach since not all response components contributing to stresses experience the same degree of increase in response.
 - The values determined are used as scale factors applied to the highest stress ratio of DCD governing seismic load combination and compared to Code allowable stresses. This provides an upper bound stress estimate as the scale factor determined from the seismic load alone is applied to the combined stress of seismic loads plus other loads.

Details: Section 3.7.2

Seismic System Analysis (cont.)

- 3.7.2.4.1.6.2 Comparison of the Site-Specific SSI Floor Response Spectra
 - Compare results with enveloping floor response spectra at 5% in DCD Section 3A.9.2
 - Additional NA3 specific spectra provided if not enveloped for equipment qualification
- 3.7.2.4.1.7 Conclusions

Details: Section 3.8.4.5

Structural Acceptance Criteria

- 3.8.4.5.6 Exterior Wall Design
 - The exterior wall designs for the RB/FB and CB will be evaluated against lateral earth pressures based on the results from the site-specific SSI analyses for the RB/FB and CB presented in Section 3.7.2.4.1

Details: Section 3.8.5

Foundations

- 3.8.5.5.1 Foundation Stability
 - Evaluated against overturning, sliding, and floatation
 - According to the procedure presented in referenced DCD Section 3.8.5.5 and EF3
- 3.8.5.5.2 Soil Bearing Pressures
 - SSI maximum dynamic soil bearing pressure demands

Details: Other COLA Parts and FSAR Chapters Impacted

- FSAR Chapter 1, Introduction:
 - Sect 1.8 : Update of Departures
 - Sect 1.9: Revise conformance evaluations for RG 1.208 and RG 1.165

Details: Other COLA Parts and FSAR Chapters

- COLA Part 7, Departures/Variations
 - NAPS DEP 3.7(1): CSDRS exceedance
 - ESP VAR 2.0-4 - Vibratory Ground Motion
- COLA Part 10, Tier 1, ITAAC, and License Conditions

Summary

- Revising COLA to address new CEUS SSC model, August 23, 2011 Mineral earthquake, and ESBWR technology
- FSAR 2.5.1 and 2.5.3 essentially the same as version transmitted in 2012
- Seismic methodologies are consistent with NRC guidance and DCD and Fermi 3 COLA methodologies
- COLA revision will be submitted December 2013

Questions?
