North Anna 3

North Anna 3 COLA

RAIs 03.07.02-17, 03.07.02-19, & 03.08.05-7: Structural Evaluation

RAI 03.07.01-7: Modeling of Fill Material

July 30, 2014

Dominion

Agenda

- Objectives
- Plan for Site-Specific Structural Evaluation
- Modeling of Fill Extent

Dominion

Objectives

- Present a plan for explicit site-specific evaluations of Seismic Category I structures
- Respond to RAI questions
- Provide structural design margins for Unit 3 site
- Discuss FSAR changes
- Describe extent and properties of fill materials around RB/FB and CB
- Describe modeling approach used for considering effects of fill on RB/FB and CB seismic response and demonstrate its adequacy

Dominion

Site-Specific Structural Evaluation

Methodology used for site-specific evaluation of Seismic Category I structures in FSAR Section 3.7.2.4.1.6.1:

1. Site-specific seismic structural loads were developed from results of site-specific SSI analyses of partial column profiles following DCD methodology and then compared to DCD loads
2. When site-specific SSE loads exceeded DCD loads, site-specific stress demands were calculated by applying scaling factors to largest stress ratios of DCD governing seismic load combinations and then compared to DCD's allowable stresses. When site-specific stresses exceeded allowables, scaling factor was applied only to seismic stress component
3. Scaling factors used for stress checks of shear walls were determined at each elevation as maximum value of ratios of NA3 to DCD seismic responses for X-shear, Y-shear, X-moment, Y moment, torsion and maximum vertical acceleration
4. Scaling factors used for stress check of flexible slabs and walls were determined as ratio of site-specific and DCD out-of-plane loads including contribution of flexible and rigid modes of out-of-plane vibrations

Dominion

Site-Specific Structural Evaluation

Related RAI Questions

- RAI 123: Question 03.07.02-17
  - Provide detailed and direct stress calculations (without stress scaling factor) for checking integrity of structural members where site-specific seismic loads exceed DCD loads
  - Demonstrate that the resulting site-specific total stress demands are bounded by code-allowable stresses in all cases or provide technical basis if other approach is used for demonstrating structural integrity
- RAI 123: Question 03.07.02-19
  - Provide methodology and results of site-specific out-of-plane stress checks of RB/FB flexible walls
- RAI 125: Question 03.08.05-7
  - Evaluate whether site-specific bending moments and shears induced in the RB/FB and CB basemats, due to load combinations that include seismic loads, are bounded by the bending moments and shears considered in the standard design

Site-Specific Structural Evaluation

To address RAI 123 Questions 03.07.02-17 and 03.070.2-19 and RAI 125 Question 03.08.05-7, explicit site-specific evaluation will be performed that will provide:

- Actual site-specific stress demands on various structural members
- Detailed calculations of shear and flexural strength (allowable stresses) of reinforced concrete sections that depend on axial load magnitude
- Actual bending moments and shears induced in the RB/FB and CB basemats by seismic load combinations that include Unit 3 site-specific seismic loads
- Explicitly calculated design margins for Unit 3 Seismic Category I structures under Unit 3 site-specific loads
  - Conservative approach in FSAR, where all response components were considered to experience same degree of increase, yielded for many structural members very small values for calculated design margins

Dominion

Site-Specific Structural Evaluation

Explicit site-specific evaluations of RB/FB and CB structures will follow methodology consistent with standard design methodology per DCD Appendix 3G:

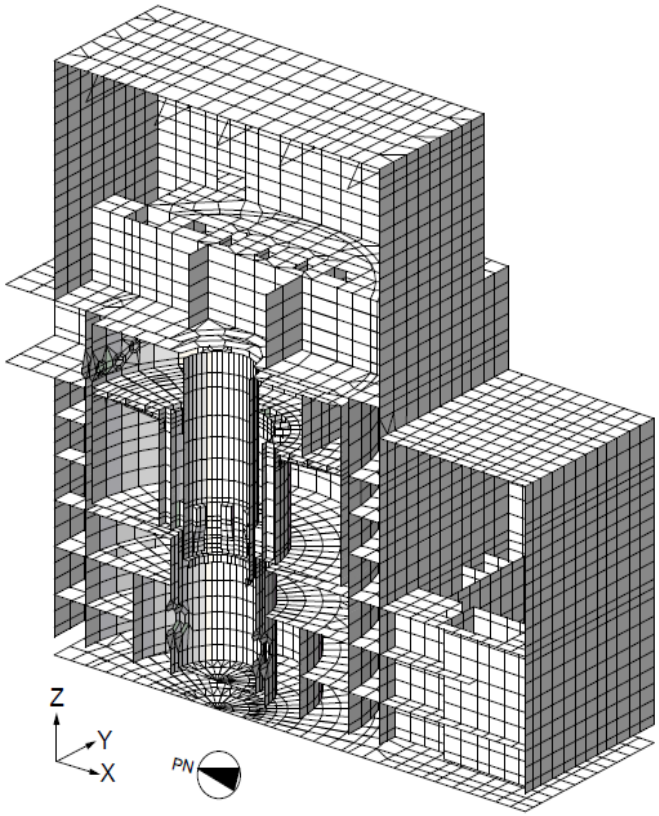
1. Develop site-specific seismic loads using envelope of results from site-specific RB/FB and CB SSI analyses for partial and full column profiles including any exceedances due to SSSI effects
2. Perform NASTRAN analysis on DCD RB/FB and CB finite element (FE) models using site-specific seismic loads calculated in Step 1 to calculate site-specific demands
3. Combine site-specific seismic demands calculated in Step 2 with DCD NASTRAN results for non-seismic load cases in critical load combinations
4. Perform SSDP for all DCD critical sections (including basemats) considering effects of interaction between load components (axial with bending and shear) and calculate available Unit 3 design margins
5. Verify applicability of standard design by showing that design margins for all critical sections shown in DCD Figure 3G.1-28 are higher than 1 (site-specific stress demands are enveloped by corresponding allowable stress)

Dominion

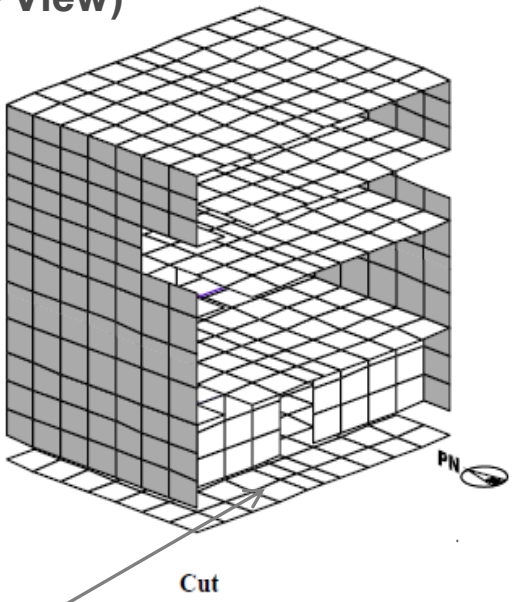
Site-Specific Structural Evaluation

- Site-specific seismic stress demands obtained from equivalent static analyses performed on same RB/FB and CB FE models used for standard design:

RB/FB NASTRAN FE Model (Cut View)



CB NASTRAN FE Model (Cut View)

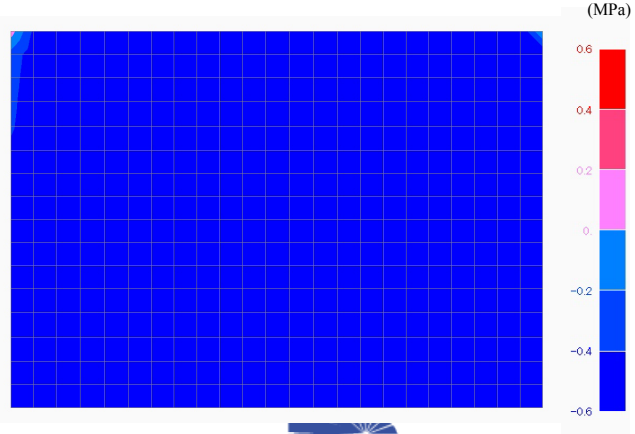


3 independent spring elements at each basemat node model horizontal and vertical stiffness of rock subgrade

Dominion

Site-Specific Structural Evaluation

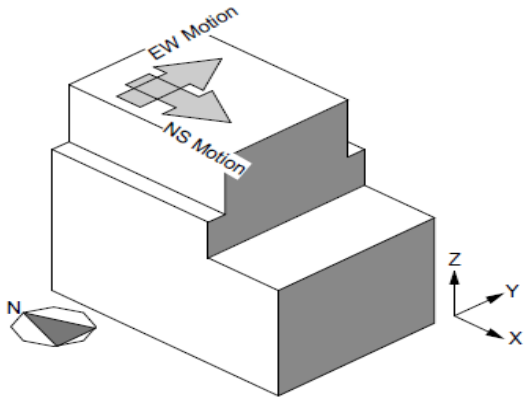
- Site-specific NASTRAN analyses of RB/FB and CB use same standard design foundation models described in DCD Section 3G.1.4.2:
  - Elastic (compression and tension) spring constants represent subgrade stiffness of soft generic site with shear velocity V_s = 1,000 ft/s
  - Soft soil spring constants provide bounding results for deformations and stresses of RB/FB and CB foundations resting on stiff Unit 3 subgrade with Vs ≥ 6,000 fps
- Site-specific uplift analysis performed for CB only following DCD Section 3G.1.5.5.1 methodology:
  - Iterative analyses performed on CB NASTRAN model where tension capability is removed in the next iteration for those vertical springs that are in tension until full convergence of results is reached (no more vertical springs are in tension)
  - Spring constants representing stiffness of Unit 3 stiff rock/concrete fill subgrade will be used to maximize foundation uplift
  - Base contact pressure results from SSI analyses of partial column profiles indicate that effects of uplift on RB/FB foundation can be neglected



Dominion

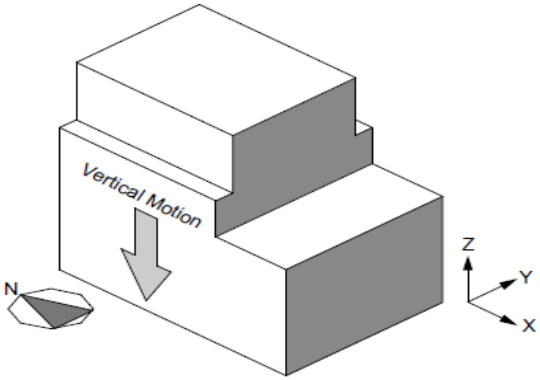
Site-Specific Structural Evaluation

- Site-specific seismic structural loads:



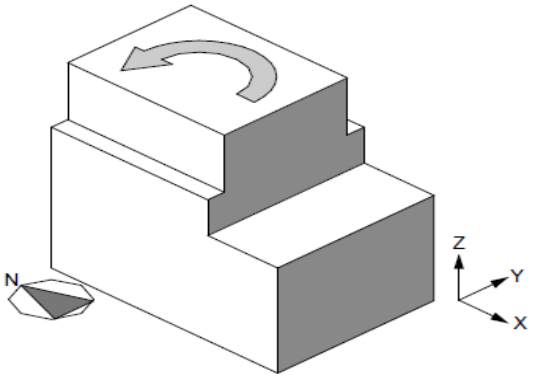
Horizontal Seismic Load

Developed from SSI results for beam shear force and bending moment



Vertical Seismic Load

Developed from SSI results for maximum vertical accelerations of lumped masses



Torsional Seismic Load

Developed from SSI results for beam torsion moment + accidental torsion from 5% of floor shear

Dominion

Site-Specific Structural Evaluation

- Site-specific seismic lateral pressure loads are applied on below grade external walls that are envelope of:
  - Dynamic lateral pressure results for SASSI analyses of LB, BE and UB truncated and full column profiles amplified if necessary for SSSI effects based on results of CB-RB/FB and CB-FWSC SSSI analyses
  - Required lateral passive resistance pressures obtained from RB/FB and CB sliding stability calculations

Dominion

Site-Specific Structural Evaluation

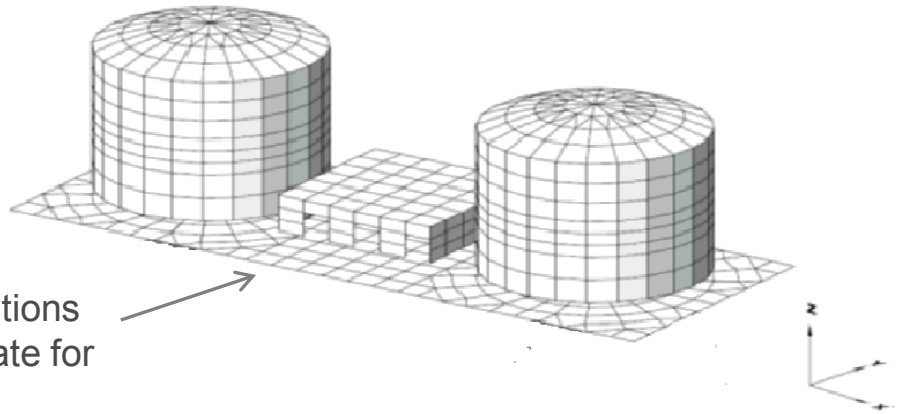
- Seismic hydrodynamic pressures are applied on RB/FB pool walls and floors following same methodology as one used for standard design:
  - Pressure magnitudes calculated per TID-4500, Chapter 6 and Appendix F
  - Impulsive hydrodynamic pressures due to two horizontal components and one vertical component of input motion are calculated using envelope of results of SSI analyses for maximum accelerations of lumped floor masses that include pool water
  - Convective (sloshing) pressures calculated from corresponding 0.5% damping site-specific design ISRS using pool water sloshing frequencies
  - Envelope of site-specific and standard design sloshing load is used for site-specific structural evaluation to address concerns raised in RAI 121 Question 03.07.01-12 (a) that SSI input motion time histories are deficient at frequencies below 0.2 Hz

Dominion

Site-Specific Structural Evaluation

- Site-specific evaluation of FWSC structures:

1. Develop site-specific seismic loads as envelope of results of SSI analyses of FWSC with ground motion specified at ground surface and at bottom of concrete fill
2. Perform site-specific stress evaluation if site-specific load demands calculated in Step 1 exceed SSE loads used for standard design of FWSC structures based on NASTRAN analysis on DCD, FWSC FE model using seismic loads calculated in Step 1 and fixed base conditions



Fixed base boundary conditions established at base adequate for stiff concrete fill subgrade

Dominion

Site-Specific Structural Evaluation

FSAR Changes:

- FSAR Section 3.8 will present site-specific structural evaluation with comparison to DCD Tier 2 Appendix 3G, “Design Details and Evaluation Results of Seismic Category I Structures” :
  - DCD 3G.1 Reactor Building (33 Tables/ 12 Figures)
  - DCD 3G.2 Control Building (12 Tables/ 2 Figures)
  - DCD 3G.3 Fuel Building (6 Tables)
  - DCD 3G.4 Firewater Service Complex (9 Tables/ 2 Figures)
  - DCD 3G.5 Structural Evaluation for TRACG Calculated LOCA Temperatures (13 Tables)
- FSAR Section 3.7.2.4.1.6.1 will also be revised, as appropriate, to present only comparisons of site-specific load demands on RB/FB, CB and FWSC with corresponding seismic loads used for standard design and to be consistent with information added to FSAR Section 3.8

Dominion

RAI 03.07.01-7: Modeling of Fill Extent

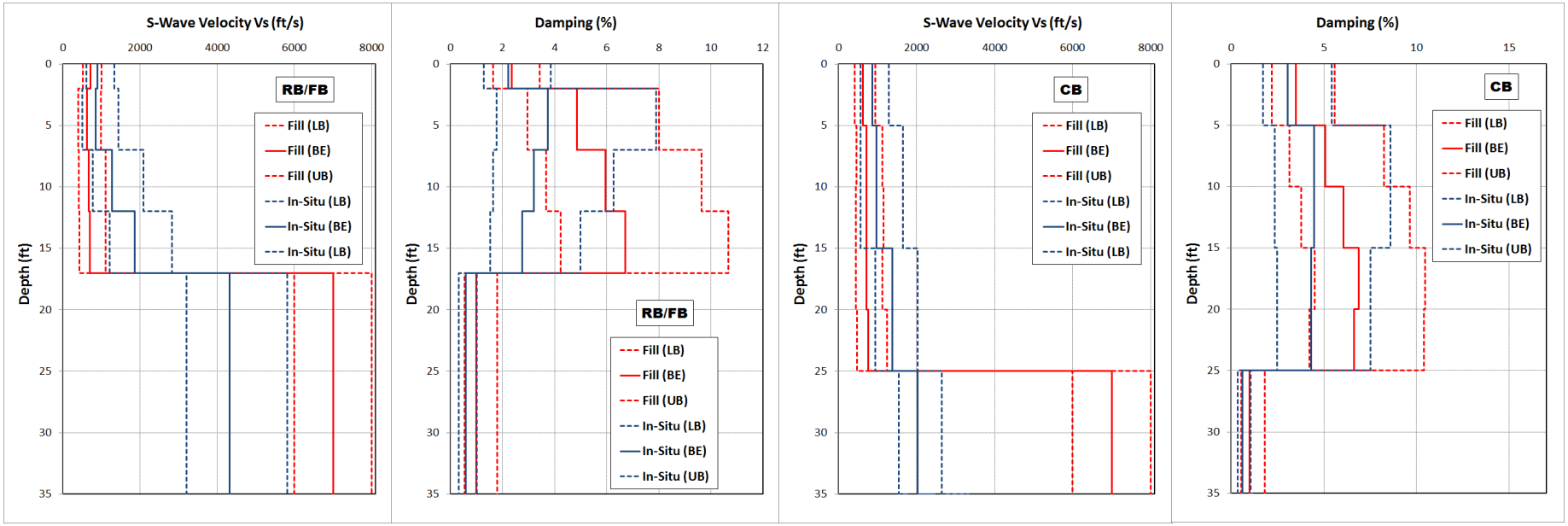
- Prior to RB/FB and CB construction, in-situ materials will be excavated to ensure foundations are supported by Zone III/IV rock or concrete fill
- Excavation secured by sheet piles around perimeter
- Excavated materials around RB/FB and CB will be backfilled with
  - Concrete fill up to surface of Zone III rock
  - Engineered fill from Zone III rock surface up to plant grade
- Depending on plant configuration, subgrade variations and construction demands, extent of fill materials around RB/FB and CB is:
  - Horizontal extent of fill around RB/FB varies from 3.1 m to 15 m
  - Horizontal extent of fill around CB varies from 3.7 m to 17 m
  - Depth of concrete fill around RB/FB ≈ 15 m from El. 224.4 ft to El. 273 ft
  - Depth of engineered fill around RB/FB ≈ 5.2 m from El. 273 ft to El. 290 ft
  - Depth of concrete fill around CB ≈ 7.3 m from El. 241 ft to El. 265 ft)
  - Depth of concrete fill below CB basemat ≈ 5m from El. 225 ft to El. 241 ft

Dominion

RAI 03.07.01-7: Modeling of Fill Extent

Strain-Compatible Properties of Fill Materials

- Concrete fill has higher stiffness and lower damping than surrounding in-situ Zone III rock
- Engineered fill has lower stiffness and higher damping than surrounding in-situ saprolite



Dominion

RAI 03.07.01-7: Modeling of Fill Extent

Embedment Dynamic Properties

- Average strain-compatible shear wave velocities ($V_{s\ ave}$) and shear column frequencies (f_{sc}) of fill and in-situ materials for RB/FB and CB profiles

	Soil Case	Concrete Fill/ Zone III Rock Embedment					Engineered Fill/ Saprolite Embedment				
		Depth	Backfill		In-Situ		Depth	Backfill		In-Situ	
			$V_{s\ ave}$	f_{sc}	$V_{s\ ave}$	f_{sc}		$V_{s\ ave}$	f_{sc}	$V_{s\ ave}$	f_{sc}
		m	m/s	Hz	m/s	Hz	m	m/s	Hz	m/s	Hz
RB/FB	LB	14.9	1829	30.9	978	16.4	5.2	128	6.2	218	10.5
	BE		2134	36.0	1317	22.0		203	9.8	352	17.0
	UB		2438	41.2	1774	29.7		321	15.5	566	27.3
CB	LB	7.3	1829	56.6	518	18.9	7.6	136	4.5	206	6.8
	BE		2134	66.0	689	25.1		214	7.0	325	10.7
	UB		2438	75.5	917	33.4		337	11.0	512	16.8

Dominion

RAI 03.07.01-7: Modeling of Fill Extent

Site-Response Analyses

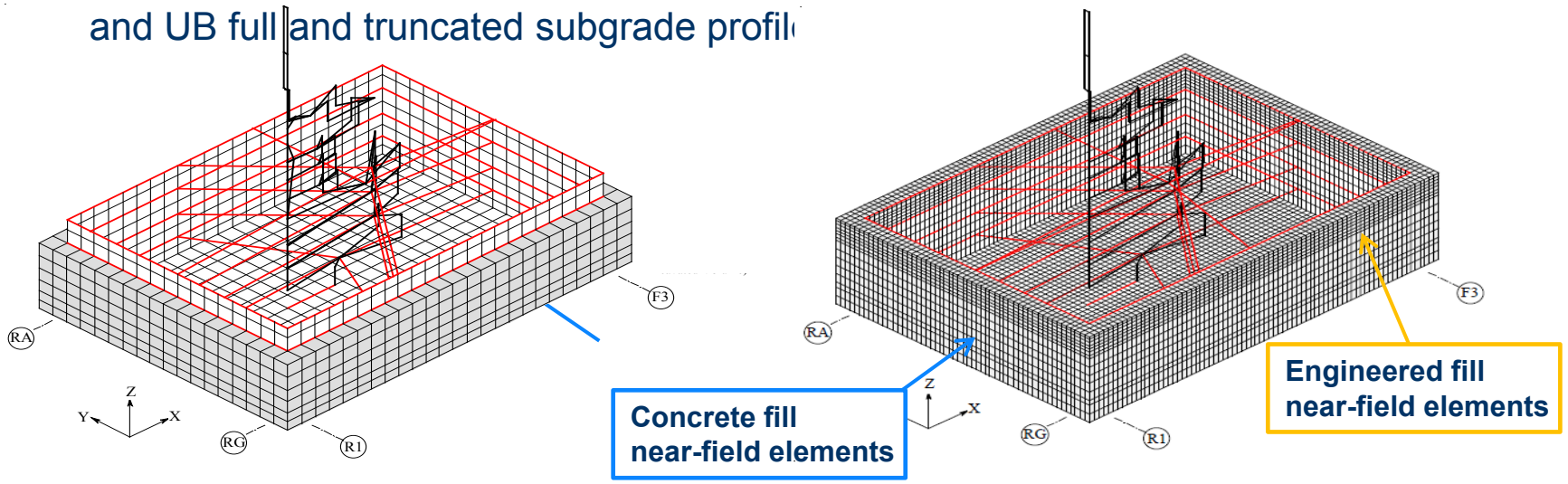
- Site-Response analyses performed on randomized in-situ soil profiles provide:
  - Site amplification factors for development of design ground motion spectra
  - LB, BE and UB dynamic properties of in-situ materials compatible to strain generated by site-specific design ground motion
  - In SSI models, strain compatible in-situ properties are assigned to far field elements (SASSI SITE models)
- Site response analyses performed on randomized fill profiles provide:
  - LB, BE and UB dynamic properties of fill materials compatible to strain generated by site-specific design ground motion
  - In SSI models, strain compatible fill properties are assigned to near-field elements (SASSI HOUSE models)

Dominion

RAI 03.07.01-7: Modeling of Fill Extent

RB/FB Stand-Alone SSI Models

- Two models are used for site-specific RB/FB SSI analyses performed for LB, BE and UB full and truncated subgrade profil



Partially embedded stand-alone RB/FB model

Fully embedded sand-alone RB/FB model

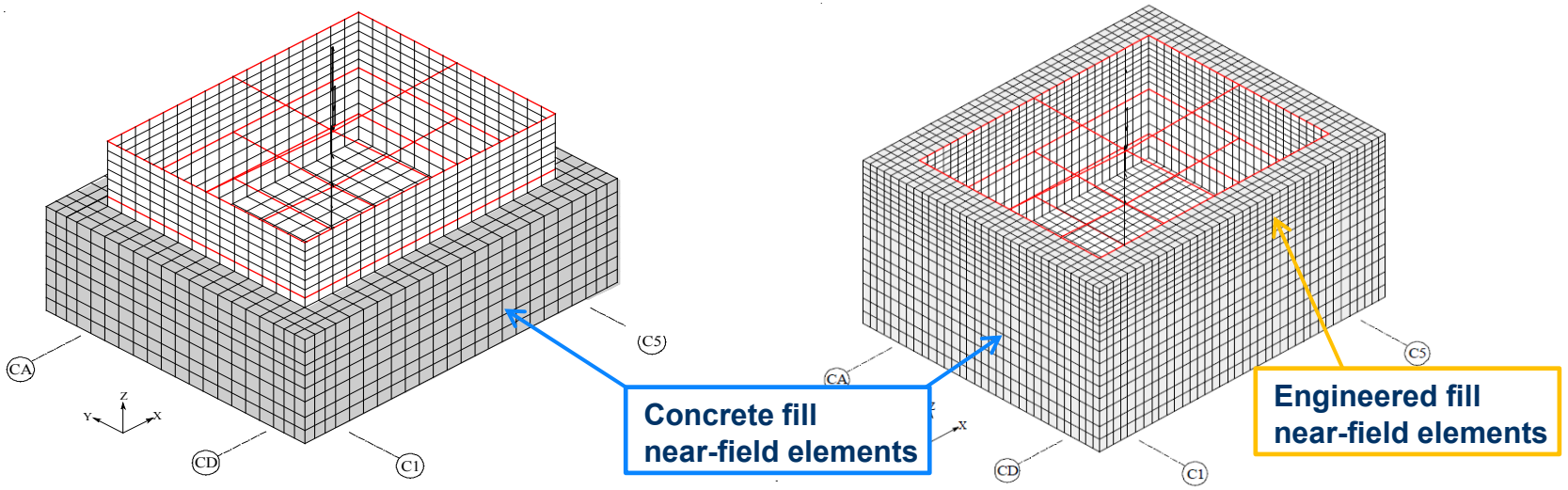
- Horizontal extent used for near-field concrete and engineered fill elements at four sides of RB/FB is same and equal to 3.13 m (10.27 ft)
  - Lower bound value for fill extent of 3.13 m is determined as half of distance between RB/FB and TB

Dominion

RAI 03.07.01-7: Modeling of Fill Extent

CB Stand-Alone SSI Models

- Two models are used for site-specific CB SSI analyses performed for LB, BE and UB full and truncated subgrade profiles:



Partially embedded stand-alone CB model **Fully embedded stand-alone CB model**

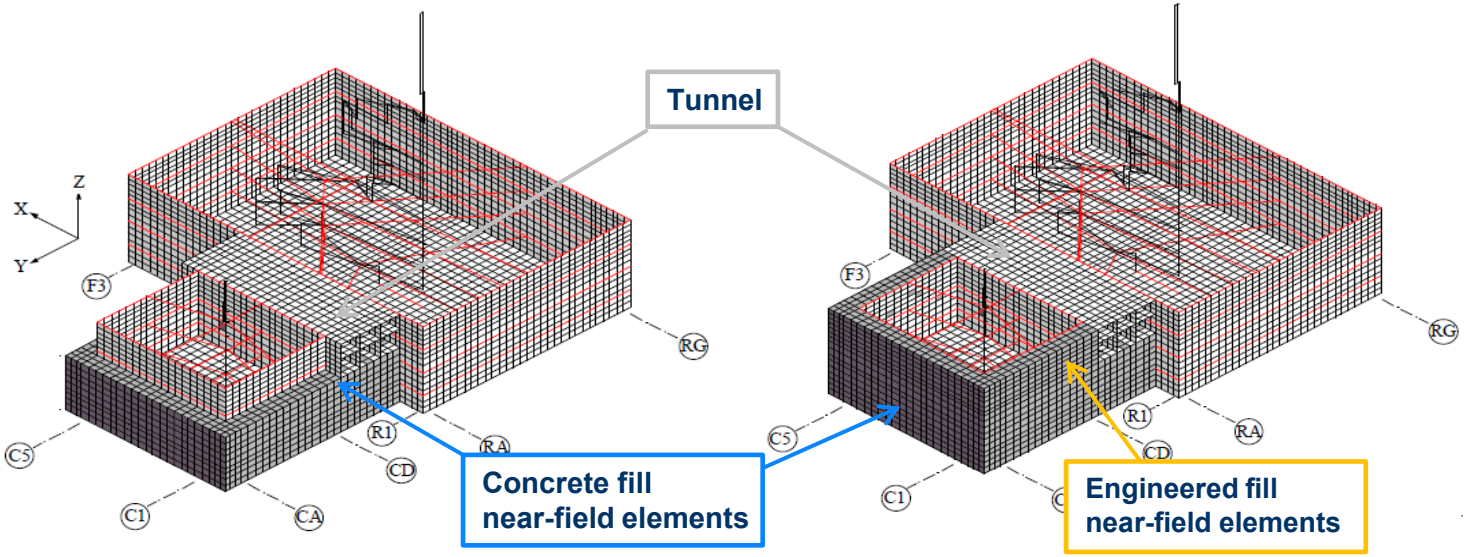
- Horizontal extent of near-field concrete and engineered fill elements at four sides of CB is same and equal to 3.73 m (12.24 ft)
  - Lower bound value for fill extent of 3.73 m is determined as half of distance between CB and Service Bldg
  - CB model also includes 4.9 m (16 ft) thick concrete fill block below basemat

Dominion

RAI 03.07.01-7: Modeling of Fill Extent

CB-RB/FB Combined SSSI Model

- Two CB-RB/FB combined models are used for site-specific SSSI analyses:



Partially embedded combined CB-RB/FB model

Fully embedded combined CB-RB/FB model

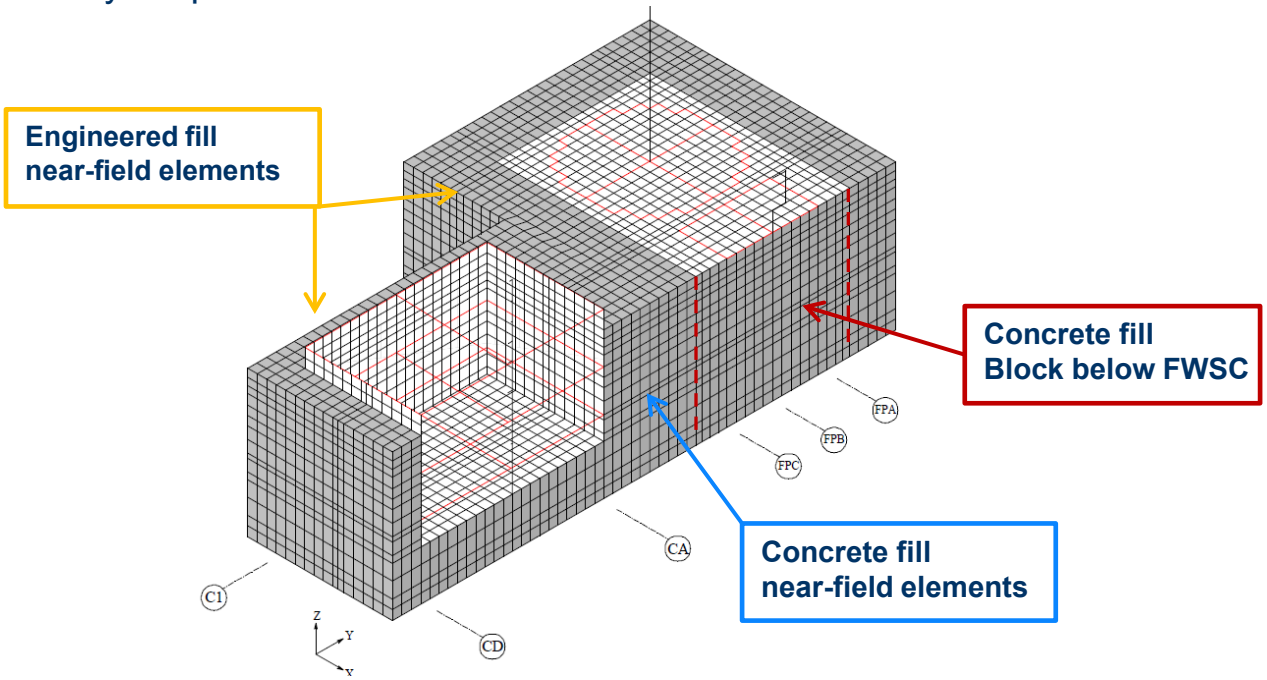
- Concrete fill and tunnel between CB and RB/FB are explicitly modeled to accurately capture SSSI
- Horizontal extent of near-field concrete and engineered fill elements at other three sides of CB is 3.73 m (12.24 ft), same as stand-alone CB model
- Fill around RB/FB is excluded from CB-RB/FB combined model because it has minor effect on CB response which is focus of SSSI analyses

Dominion

RAI 03.07.01-7: Modeling of Fill Extent

CB-FWSC Combined SSSI Model

- Site-specific SSSI analyses performed on CB-FWSC combined model for LB and UB full column profiles :



- Concrete fill and engineered fill between CB and FWSC are explicitly modeled to accurately capture SSSI between CB and concrete fill below FWSC basemat
- Horizontal extent of near-field concrete and engineered fill elements at other three sides of CB is 3.73 m (12.24 ft), same as stand-alone CB model

Dominion

RAI 03.07.01-7: Modeling of Fill Extent

- Envelope of responses obtained from site-specific SSI analyses of partially and fully embedded models bound variations of subgrade stiffness related to backfill horizontal extent and soil separation effects
- Fully embedded models represent upper bound stiffness of CB and RB/FB embedment :
  - Engineered fill has lower stiffness and higher damping properties than the surrounding in-situ saprolite
  - Use of lower bound estimate values for horizontal extent of engineered fill maximizes stiffness and minimizes damping of embedment above Zone III rock
- Partially embedded models represent lower bound stiffness of CB and RB/FB embedment :
  - Excluding subgrade materials above Zone III rock results in model that minimizes stiffness and damping of subgrade
- SSSI analyses are performed on models that accurately represent configuration of backfill material between CB and RB/FB and CB and FWSC

Dominion

Questions?

Dominion