DTE Energy

APPROACH TO RESOLVING RAI LETTERS 77 AND 79

Fermi 3 COLA

November 29, 2012

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APPLICANT'S OPENING REMARKS

Michael Brandon

Detroit Edison

Fermi 3 COLA

November 29, 2012

Site Specific Seismic Analysis – Agenda

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- Applicant's Opening Remarks
  - Introductions
  - Purpose
  - Background
  - Approach
- CEUS SSC Model Evaluation
- Site-Specific Soil-Structure Interaction (SSI) Input Development
- SSI Analysis Methodology and Modeling
  - Purpose
  - Issues Addressed in RAI 03.07.02-9
  - Proposed Method of SSI Analysis
  - SSI Out-of-Plane Responses
  - Structure-Soil-Structure Interaction (SSSI) Effects
  - Lateral Wall Pressures
- Modified Subtraction Method (MSM)
- Schedule
- Summary
- Supplemental Material
  - Model Size Limitations
  - Benchmarking – Eccentricity Effects – Investigation of FRS at Building Edges

Introductions

Detroit Edison

- Peter Smith
- Michael Brandon
- Ryan Pratt

Black & Veatch

- Ed Meyer

AMEC

- Bob Youngs

Industry Expert Panel

- A. K. Singh (Sargent & Lundy)
- Wen Tseng (Paul C. Rizzo & Associates, Inc.)

GE - Hitachi

- Skip Schumitsch
- Taylor Blake
- Patricia Campbell
- Matthew Heiser
- Tanya Kirby

Sargent & Lundy

- Farid Berry
- Bob Hooks
- Javad Moslemian
- Surendra Singh

Purpose

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- The purpose of this meeting is to discuss and obtain NRC Staff Feedback regarding Detroit Edison's approach to addressing:
  - NRC RAI Letter No. 79 questions regarding previously submitted Soil-Structure Interaction (SSI) analyses for Fermi 3; and,
  - NRC RAI Letter No. 77 questions regarding the impacts of the Central and Eastern United States (CEUS) Seismic Source Characterization (SSC) model for the Fermi 3 site.
- Detroit Edison's letter dated October 12, 2012 (NRC3-12-0030), provides a detailed discussion of the SSI approach.
- We will discuss comments from the October 18, 2012, Open Items call.

Background

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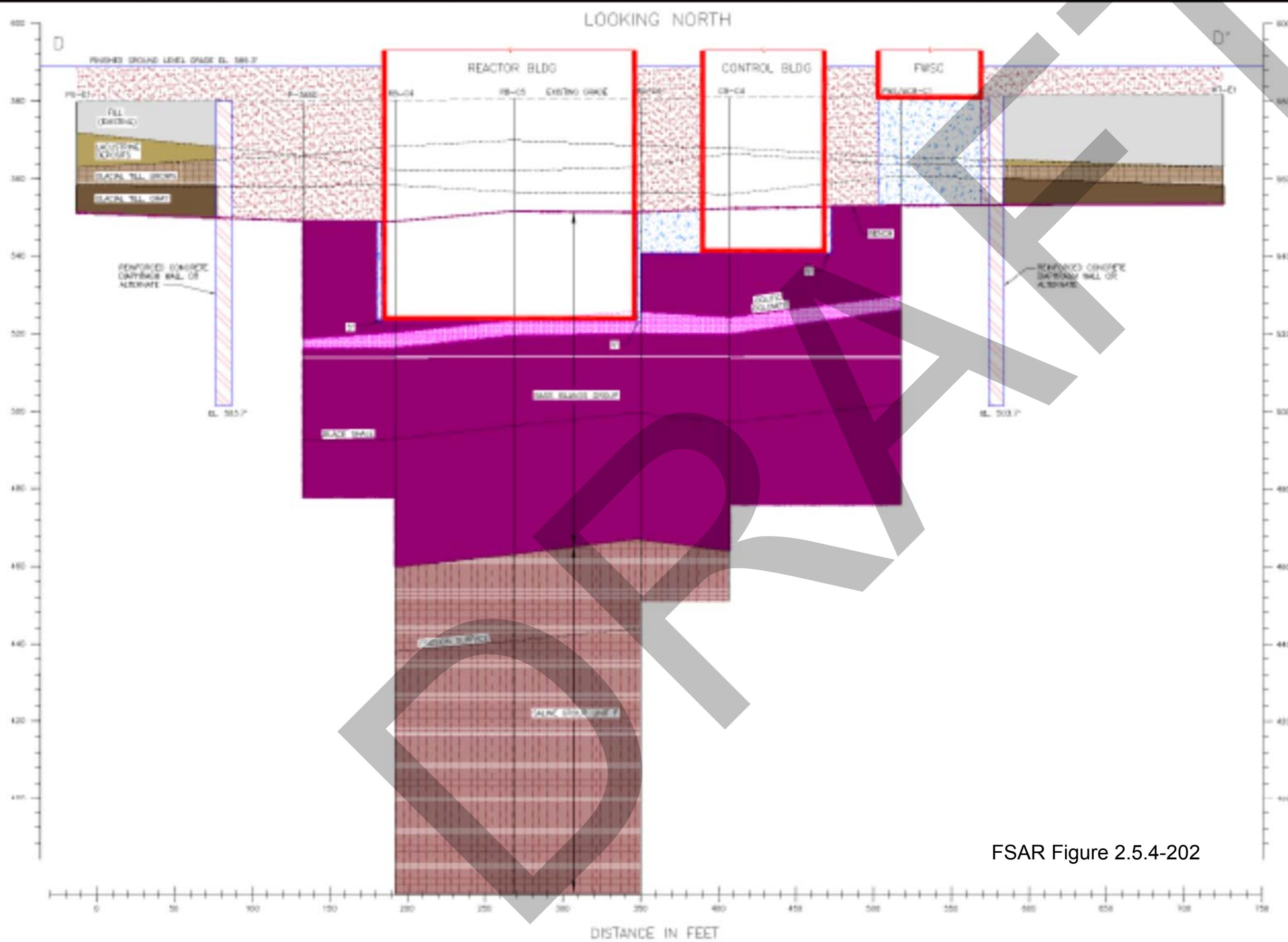
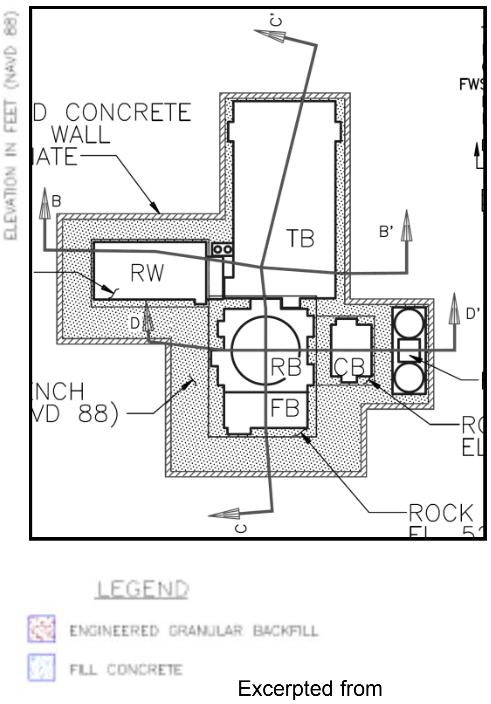
- Final Safety Analysis Report (FSAR) Revision 0 was based on Design Control Document (DCD) Revision 4 – all DCD requirements were satisfied and a site-specific SSI was not needed or required.
- DCD Revision 7 imposed a new requirement of 300 m/s (1000 ft/s) Minimum Shear Wave Velocity for seismic Category I backfill. The DCD continued to provide the option of performing a site-specific SSI to demonstrate the DCD standard design was adequate for a specific site.
- Detroit Edison concluded there was no practical side backfill design satisfying the DCD backfill requirements for the Fermi 3 site, and in June 2011, Detroit Edison submitted the results of the site-specific SSI analyses.
- Accordingly, FSAR Revision 4 (February 2012) demonstrates the DCD requirements are satisfied by the site-specific SSI without the need to credit seismic Category I backfill. Thus the Minimum Shear Wave Velocity requirement does not apply to Fermi 3.

Background (continued)
Fermi 3 Cross Section



FSAR Figure 2.5.4-202



Excerpted from
FSAR Figure 2.5.4-201

Background (continued)

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- The June 2011 Licensing Bases Analyses (without backfill) submittal demonstrated significant structural margin for site-specific SSI forces, accelerations, and floor response spectra compared to DCD values. Additionally, the stability analyses demonstrated high factors of safety compared to SRP Section 3.8.5 minimum factor of safety of 1.1.

- By letter dated January 18, 2012, NRC issued RAI No. 70 that, in part, requested evaluation of the impacts of the non-Seismic Category I backfill above the top of bedrock on the RB/FB and CB.

- By letter dated February 16, 2012, Detroit Edison's initial response to RAI Letter No. 70 provided a description of additional Confirmatory SSI analyses to address potential impacts of backfill and other SSSI questions.

- During the week of April 23, 2012, NRC conducted an audit of the SSI analyses.

Background (continued)

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- By letter dated June 15, 2012, Detroit Edison submitted the remaining responses to RAI Letter No. 70 and supplemented other previously submitted RAI responses to address issues discussed at the audit.
- Audit report issued July 27, 2012, with related NRC Letter No. 79 issued on August 7, 2012.
- By letter dated May 17, 2012, NRC issued RAI Letter No. 77, that requested evaluation of the impacts of the CEUS SSC model for the Fermi site.
- By letter dated August 24, 2012, Detroit Edison's initial response to RAI Letter No. 77 (CEUS SSC model) indicated more than minimal increases to the Fermi 3 Foundation Input Response Spectra (FIRS) and that would be addressed in conjunction with RAI Letter No. 79.

Summary of Remaining Open Items from RAI Letters 77 and 79

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	Item	Proposed Resolution
1.	CEUS SSC for Fermi 3 not bounded by current SSI Inputs	Replace previous inputs with new ones based on the CEUS SSC
2.	Consistency of SSI inputs used for various analyses	Replace previous inputs with new ones based on the CEUS SSC model in all cases
3.	Use of 7% SSE Structural Damping Ratios vs 4% OBE Structural Damping Ratios	Perform new SSI analyses with 4% OBE Structural Damping Ratio
4.	Finite element mesh size/aspect ratio insufficient to capture full range of frequencies	Use finite element mesh size/aspect ratio capable capturing range of frequencies up to about 50 Hz
5.	Use of SASSI Subtraction Method (SM) for Confirmatory Analyses cases	New SSI analyses using Direct Method (DM) or Modified Subtraction Method (MSM)
6.	Comparison of out-of-plane slab and wall responses with DCD values	Compare results from revised analyses with DCD values
7.	Reevaluate the SSSI comparative analysis results with common reference point	Reperform SSSI analyses with displacements from common reference points
8.	Evaluation of lateral wall pressure results from SSI analyses	Evaluate wall pressures and compare with wall capacities

Detroit Edison has concluded that the impacts of the new CEUS SSC model and resolution of NRC SSI related RAIs are best addressed by performing additional Fermi 3 SSI Analyses

Approach to Resolution of NRC SSI Issues

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- Detroit Edison developed a plan with industry SSI experts providing oversight and guidance
  - The approach to resolve SSI items was developed by GEH, B&V, AMEC, S&L, and DTE
  - The resolution has been reviewed by an Industry Expert Panel:
    - Farhang Ostadan (Bechtel International)
    - A. K. Singh (Sargent & Lundy)
    - Wen Tseng (Paul C. Rizzo & Associates, Inc.)
- The proposed approach provides opportunities for in-process NRC interaction and expert review

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FSAR SUBSECTION 2.5.2 – CEUS SSC MODEL EVALUATION

Bob Youngs

AMEC

Fermi 3 COLA

November 29, 2012

DRAFT 11/16/2012

FSAR Subsection 2.5.2 – Site Response CEUS SSC Model

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- Use CEUS SSC model (NUREG-2115) and EPRI (2004, 2006) ground motion models as the basis for the Fermi 3 Probabilistic Seismic Hazard Analysis (PSHA)
  - Use corrected magnitude-area relationship to calculate the Fermi 3 PSHA
  - Rewrite FSAR Subsection 2.5.2 using CEUS SSC model as basis
- Following RG 1.208, update CEUS SSC model, as needed, considering the following:
  - Earthquakes from end of 2008 to September 30, 2012, within 200 miles of the site
  - The largest recent earthquakes that have occurred beyond 200 miles (e.g., August 23, 2011, Mineral, VA, and November 6, 2011, Oklahoma Earthquakes)
- Apply a lower-bound magnitude cutoff of moment magnitude **M** 5.0
  - Cumulative Absolute Velocity (CAV) model no longer used, as application to only **M** < 5.5 earthquakes provides only small reduction in ground motions
- Develop the site-specific Ground Motion Response Spectrum (GMRS)
  - Define at the top of the Bass Islands Group bedrock (Elevation 552 Feet NAVD88) as glacial till will be removed in vicinity of Seismic Category I Structures in accordance with definition of GMRS given in DC/COL-ISG-17
  - Calculate new GMRS amplification functions using CEUS SSC model deaggregation results to develop new target deaggregation earthquake spectra

FSAR Subsection 2.5.2 (Continued) – Schedule

• Complete CEUS SSC seismic hazard analysis	December 2012
• Complete GMRS site response analysis	December 2012
• Available to support NRC audit of CEUS SSC seismic hazard and GMRS	January 2013
• Submit revised FSAR markups for Subsection 2.5.2	March 2013

FSAR SUBSECTION 3.7.1 – SITE-SPECIFIC SSI INPUT DEVELOPMENT

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FSAR Subsection 3.7.1 –
RB/FB FIRS, CB FIRS, and PBSRS

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- Incorporate impact of updated CEUS SSC model on the Fermi 3 Foundation Input Response Spectra (FIRS) for RB/FB and CB
- To address NRC comments provided during the Open-Items Call on October 18, 2012, RB/FB and CB FIRS will be developed using the subsurface profile that includes engineered granular backfill above the bedrock to finished ground level grade (full subsurface profile) following approach given in Sections 3.1.3 and 3.2.3 of the 2009 NEI white paper (ML091680715)
  - Perform site response with the full subsurface profile (including engineered granular backfill) to develop Performance-Based Surface Response Spectrum (PBSRS) at finished ground level grade using CEUS SSC model based input motions
  - Develop Soil Column Outcrop Response (SCOR) FIRS for RB/FB and CB
  - Use existing engineered granular backfill properties (Lower Range, Intermediate Range, and Upper Range) defined in FSAR Tables 3.7.1-201, 3.7.1-202, and 3.7.1-203 (Revision 4)
- Compare SCOR FIRS for RB/FB and CB with ESBWR CSDRS in accordance with DC/COL-ISG-017

FSAR Subsection 3.7.1 (Continued) –
SSI Subsurface Profiles for RB/FB and CB SSI Analyses

DTE Energy

Develop SSI subsurface profiles for Licensing Basis Analyses and Sensitivity Studies (Lower Bound [LB], Best Estimate [BE], and Upper Bound [UB])

- Licensing Basis Analyses and Sensitivity Studies profiles based on statistics of iterated properties for the randomized subsurface profiles used for the SCOR FIRS and PBSRS (profile to finished ground level grade) as discussed in FSAR Subsection 3.7.1 (Revision 4), and the minimum variation requirement of SRP 3.7.2.
- Lower-Lower Bound (LLB) Profile – Developed to address potential future increases in the seismic hazard and/or site response associated with future modifications in industry standards and NRC guidance (e.g., new ground motion models)
  - The LLB will be a SSI profile with shear wave velocities that are less than the LB SSI profile

FSAR Subsection 3.7.1 (Continued) –
SSI Time Histories for RB/FB and CB SSI Analyses

DTE Energy

Develop SSI time histories for Licensing Basis Analyses and Sensitivity Studies

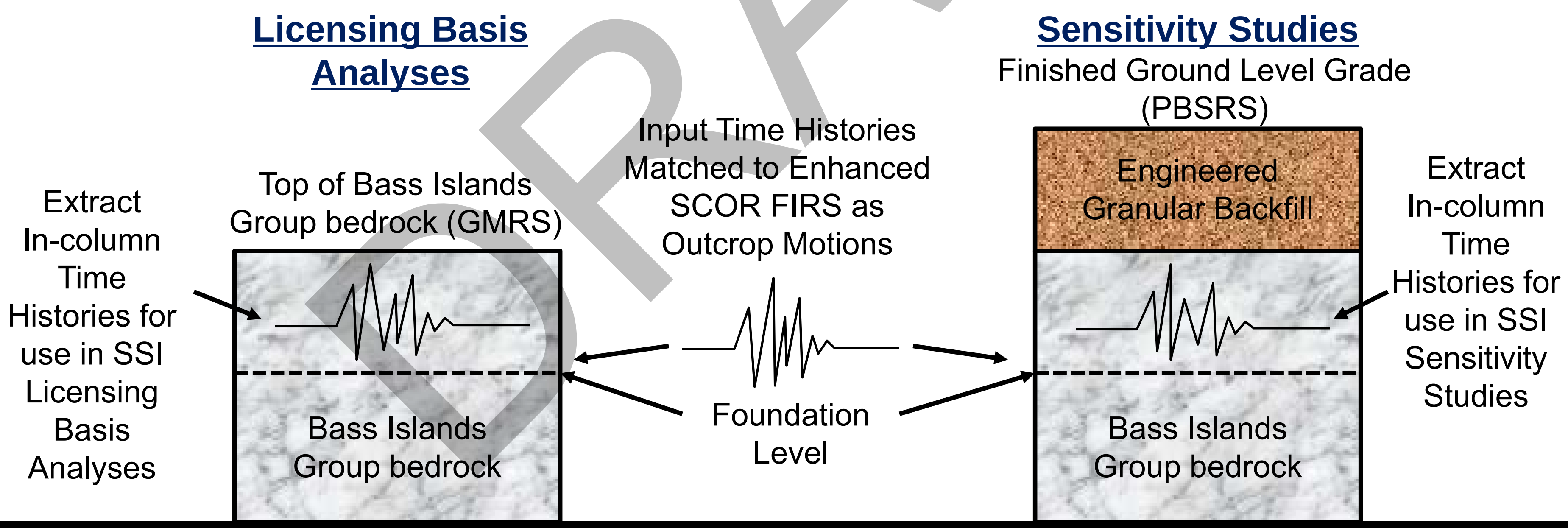
- Produce a single set of time histories matched to the SCOR FIRS
- Use current seed time history (1999 Chi-Chi Taiwan Earthquake, KAU078 Station)
- Match seed time history to RB/FB and CB SCOR FIRS using Option 1, Approach 2 of SRP 3.7.1
- Check the matched time histories against target power spectral density (PSD) from SRP 3.7.1, Appendix B
- Enhance the matched time histories to envelop the PBSRS at the top of the full subsurface profile (finished ground level grade) in accordance with DC/COL-ISG-017
- Enhance the time histories (if needed) to also envelop the GMRS for the Licensing Basis Analyses profile (at the top of the Bass Islands Group bedrock).
- Further enhancement will be applied to the time histories beyond that required to envelop the PBSRS and/or the GMRS. The intent of the further enhancement is to address potential future increases in the seismic hazard and/or site response associated with future modifications in industry standards and NRC guidance (e.g., new ground motion models)

FSAR Subsection 3.7.1 (Continued) – SSI Time Histories for RB/FB and CB SSI Analyses

DTE Energy

Develop SSI time histories for Licensing Basis Analyses and Sensitivity Studies (Continued)

- Use the time histories matched to the SCOR FIRS for both the Licensing Basis Analyses and the Sensitivity Studies
- Produce in-column acceleration time histories using the SSI profiles for the Licensing Basis Analyses and Sensitivity Studies, without iteration of properties, similar to FSAR Subsection 3.7.1.1.5 (Revision 4)



FSAR Subsection 3.7.1 (Continued) – FWSC FIRS

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- Incorporate impact of updated CEUS SSC model on the Fermi 3 Fire Water Service Complex (FWSC) FIRS
- The FWSC is essentially a surface founded structure
- Develop FIRS at foundation level of FWSC (Elevation 582 feet NAVD88) following Sections 3.1.1 and 3.2.1 of the 2009 NEI white paper (ML091680715)
- FWSC FIRS will use a subsurface profile that includes Fill Concrete from the top of bedrock to the FWSC foundation level, and includes two-dimensional (2D) effects to account for the limited extent of the Fill Concrete (Response to RAI 03.07.01-3)
  - Amplitude of 2D effects will be checked using input motions consistent with CEUS SSC hazard results
- The FWSC FIRS will be compared to 1.35 times the CSDRS in accordance with the ESBWR DCD
- Since the ESBWR DCD requirements for the FWSC are expected to be met, no SSI Inputs are proposed for the FWSC

FSAR Subsection 3.7.1 (Continued) – Schedule

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• Complete SSI inputs	January 2013
• Available to support NRC Audit of SSI inputs*	April 2013
• Submit Revised FSAR Markups for Subsection 3.7.1	May 2013

* Coordinated with MSM Benchmark Audit

SSI ANALYSIS METHODOLOGY AND MODELING

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Sargent & Lundy

Fermi 3 COLA

November 29, 2012

DRAFT 11/16/2012

Purpose – Licensing Basis SSI Analyses

DTE Energy

- To confirm that the Referenced DCD design is applicable under Fermi 3 site-specific conditions, Licensing Basis Analyses for RB/FB and CB will be performed without taking credit for engineered granular backfill above the top of bedrock considering partial embedment in the Bass Islands Group bedrock of the RB/FB and CB Seismic Category I structures
- The Licensing Basis Analyses require three separate SSI analysis cases (UB, BE, and LB) for both the CB and the RB/FB
- Results from these analyses will be used to demonstrate:
  - Stability (Sliding factors of safety) shows margin
  - Response spectra, accelerations, and soil pressures on walls at key locations are bounded by the Referenced DCD design

Purpose – Sensitivity Studies

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- Detroit Edison will perform Sensitivity Studies to demonstrate that the backfill above bedrock does not adversely impact Seismic Category I structures:
  - One SSI analysis case each for the CB and for the RB/FB taking into account the engineered granular backfill surrounding the structures to demonstrate that response spectra, accelerations, forces and moments, and soil pressures on walls at key locations are bounded by the Referenced DCD design
  - One SSSI analysis case for the CB with input motions derived from RB/FB SSI analyses to demonstrate that RB/FB has negligible effect on the CB and negligible effect on lateral soil pressures on walls for either structure
  - One SSSI analysis case for a combined CB-FWSC model to demonstrate that the FWSC has negligible effect on the CB lateral soil pressures on walls

RAI 03.07.02-9 Basic Issue – SSI Modeling

DTE Energy

In order to respond to the questions raised in the individual items within RAI 03.07.02-9, the basic analysis needs to address:

1. CEUS SSC model inputs for Fermi 3 not bounded by current SSI Inputs
2. Inconsistent input time history motions used in the analysis
3. Structural Damping Ratios used in the analysis
4. Validity of analysis results where the mesh size does not capture frequencies up to about 50 Hz. and using mesh elements with aspect ratios as high as 4:1
5. Validity of analysis results using the SASSI2000 SM and uncertainties in results computed using the SM vs. the DM

RAI 03.07.02-9 Basic Issue – SSI Modeling

DTE Energy

- To address these issues, Fermi 3 plans to develop revised RB/FB, CB, and FWSC SASSI models and perform new analyses
- The following analyses will be performed:
  - Licensing Basis Cases
    - Control Building
      - CB1-UB
      - CB1-BE
      - CB1-LB
    - Reactor/Fuel Building
      - RBFB1-UB
      - RBFB1-BE
      - RBFB1-LB
  - Sensitivity Studies – SSI
    - Control Building
      - CB2-UB
    - Reactor/Fuel Building
      - RBFB2-UB
  - Sensitivity Studies – SSSI
    - Control Building
      - CB3-UB
    - Control Building – Fire Water Service Complex
      - CB4-FWSC1-UB

RAI 03.07.02-9 Basic Issue – SSI Modeling

Analysis will be performed with the following conditions:

- Use the DCD "Base" structural model* for the RB/FB and for the CB so that all comparisons to DCD values and envelopes are made on a consistent basis
- Perform the analysis using OBE structural damping values, unless SSE structural damping is justified by stress demand
- Consistent time history input motions for all SSI analysis
- Use a mesh size for the excavated volume in compliance with the SASSI2000 Manual and capable of capturing frequencies up to about 50 Hz as defined in DC/COL-ISG-1:
  - For Licensing Basis analyses (without backfill)
  - For Sensitivity Study analyses (with backfill) for the UB subsurface profile

* As shown in DCD Table 3A.6-1, there are some models with minor modifications to evaluate the modeling effects. For this Fermi 3 SSI analysis, the most basic model, "Base" is applied.

Proposed Methods of Analysis

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- The Frequency for 90% Cumulative Power for Fermi 3 Input FIRS:

Input Time History (UB Profile)	Frequency for 90% Cumulative Power (Energy)	
	CB*	RB/FB**
H1 Time History	42 Hz	26 Hz
H2 Time History	48 Hz	37 Hz
Vertical Time History	50 Hz	48 Hz

* RAI 03.07.01-6, Figures 10, 11 & 12

** RAI 03.07.01-6, Figures 1, 2 & 3

Capturing frequencies up to about 50 Hz will capture the energy

- Maximum horizontal mesh dimension must be less than 20 percent of the shear wave length of the subsurface material at the highest frequency of interest or analysis
- The refinements of the models for the analysis cases with backfill make the number of Interaction Nodes so large that it exceeds the capability of both SASSI2000 and SASSI2010 using the DM

Proposed Methods of Analysis – Software Capabilities

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- All of the SSI analyses reported in the Fermi 3 COLA have been performed using SASSI2000
- Recently, SASSI2010 Version 1.0 has been released. There is no change in the methodology of the SSI analysis, the program solution remains same
- Important enhancements, as they relate to the refined models:
  - SASSI2010 can handle much larger models (Interaction Nodes up to about 20,000 and structural nodes in excess of 100,000)
  - SASSI2010 has an upgraded solver and runs much faster (about 10 times faster) than SASSI2000
- As with SASSI2000, SASSI2010 Version 1 is provided (Licensed) by Isatis, LLC, under contract with the Regents of the University of California
- Detroit Edison plans to use SASSI2010 Version 1.0
- The program will be verified and validated (V&V) in accordance with S&L procedures under S&L's Nuclear Quality Assurance Program.
- S&L has developed a substantial library of SASSI V&V problems (test cases)
- S&L's SASSI2000 V&V problems (test cases) have been extensively reviewed by NRC Staff on a different project

Proposed Methods of Analysis – Licensing Basis Analysis Cases

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LICENSING BASIS ANALYSES								
Building	Case	Case ID	Highest Frequency	Soil	Method	Total number of Interaction Nodes	< 20,000 Interaction Nodes?	Method
CB	CB1	CB1-UB	50 Hz	UB	DM	<200	Yes	DM
		CB1-BE	50 Hz	BE	DM	<200	Yes	DM
		CB1-LB	50 Hz	LB	DM	<200	Yes	DM
RB/FB	RBFB1	RBFB1-UB	50 Hz	UB	DM	<1,500	Yes	DM
		RBFB1-BE	50 Hz	BE	DM	<1,500	Yes	DM
		RBFB1-LB	50 Hz	LB	DM	<1,500	Yes	DM

- For each Licensing Basis analysis case:
  - The passing frequency is about 50 Hz
  - The number of Interaction Nodes is less than 20,000
- SASSI2010 Version 1.0 will be used for the analysis
- DM will be used for all of the Licensing Basis cases

The CB and the RB/FB can be analyzed using the DM, capturing frequencies up to about 50 Hz

Proposed Methods of Analysis – Sensitivity Study Cases

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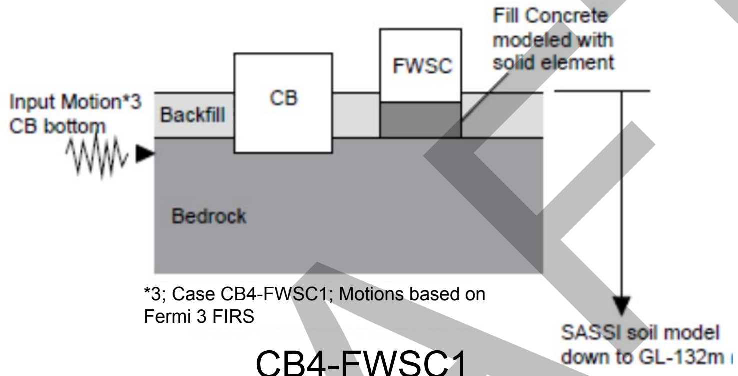
- Sensitivity Study cases have been selected based upon the following:
  - SASSI2010 is limited to 20,000 Interaction Nodes
  - The passing frequency is about 50 Hz
  - The DM will be used wherever possible, the MSM will be used where the excavated volume mesh size is such that analysis using the DM is not practical
  - While analyses performed in support of Sensitivity Studies would normally be performed using one case with BE soil properties, it is not practical to perform SASSI analysis and capture frequencies up to about 50 Hz for BE or LB soil properties for either the CB with DM or the RB/FB with MSM

SENSITIVITY STUDIES									
Building	Case	Case ID	Highest Frequency	Parameters	Soil	Method	Total number of Interaction Nodes	< 20,000 Interaction Nodes?	Method
CB	CB2	CB2-UB	50 Hz	Note 1	UB	DM	11,400	Yes	DM
						MSM	4,000	Yes	
RB/FB	RBFB2	RBFB2-UB	50 Hz	Note 1	UB	DM	54,900	No	MSM
						MSM	16,000	Yes	
CB	CB3	CB3-UB	50 Hz	Note 2	UB	DM	11,400	Yes	DM
						MSM	4,000	Yes	
CB+FWSC	CB4-FWSC1	CB4-FWSC1-UB	50 Hz	Note 1	UB	DM	27,000	No	DM/MSM
						DM/MSM	18,000	Yes	

Notes:
1. Engineered granular fill is modeled, input motion is the Fermi 3 FIRS
2. Engineered granular fill is modeled, input motion is from RBFB2

The CB can be analyzed using DM and UB soil, capturing frequencies up to about 50 Hz
The RB/FB can be analyzed using MSM and UB soil, capturing frequencies up to about 50 Hz

Proposed Methods of Analysis – Sensitivity Study Cases



CB4-FWSC1

CB and FWSC Structure-Structure Interaction Analysis

- The CB4-FWSC1-UB combined model using the DM contains ~27,000 Interaction Nodes:
  - CB4 has 11,400 Interaction Nodes
  - FWSC1 has ~16,000 Interaction Nodes
- Considering SASSI2010 limit of 20,000 for interaction nodes, a combination of DM and MSM will be used for definition of interaction nodes for the excavated volumes
  - CB4 has ~11,000 Interaction Nodes (Modeled as DM)
  - FWSC1 has ~7,000 Interaction Nodes (Modeled as MSM)
- With the above, the proposed CB4-FWSC1-UB model will contain ~18,000 Interaction Nodes

Proposed Methods of Analysis – UB Justification for Sensitivity Study Analysis Cases

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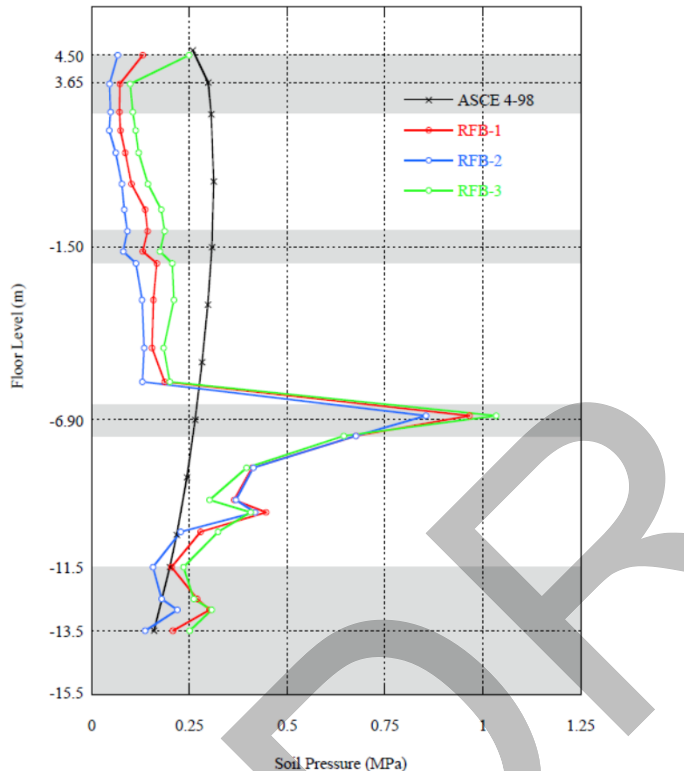
Analyses performed for Sensitivity Studies will utilize UB subsurface profiles:

- The highest priority for the sensitivity studies is to assure that site specific conditions are enveloped by DCD spectra
- For high frequency, the cases using UB subsurface profiles will generally govern in-structure response spectra
- Soil pressures are a low frequency phenomenon; the effects are captured at frequencies < ~10 Hz
- Seismic soil pressure is only a portion of total lateral load on exterior walls and for Fermi 3 site-specific conditions, the DCD design of exterior walls has significant design margin:
  - Site-specific out-of-plane inertia due to self-weight is lower
  - Site-specific in-plane loads are lower
  - At any time step, seismic soil load on a wall panel is significantly lower than lateral load based on absolute of maximum soil pressures
- Previous studies (SER-DTF-008, Rev.1) have shown that for the regions where the lateral wall pressures are not enveloped by the ASCE 4-98 curve, the lateral wall pressure values for the UB case generally equal or exceed the values for the BE and LB cases; in the limited number of cases where the UB case does not control, the values are comparable
- Wall pressure diagrams from SER-DTF-008, Rev.1 are shown on the following slides (note that UB is the green curve)

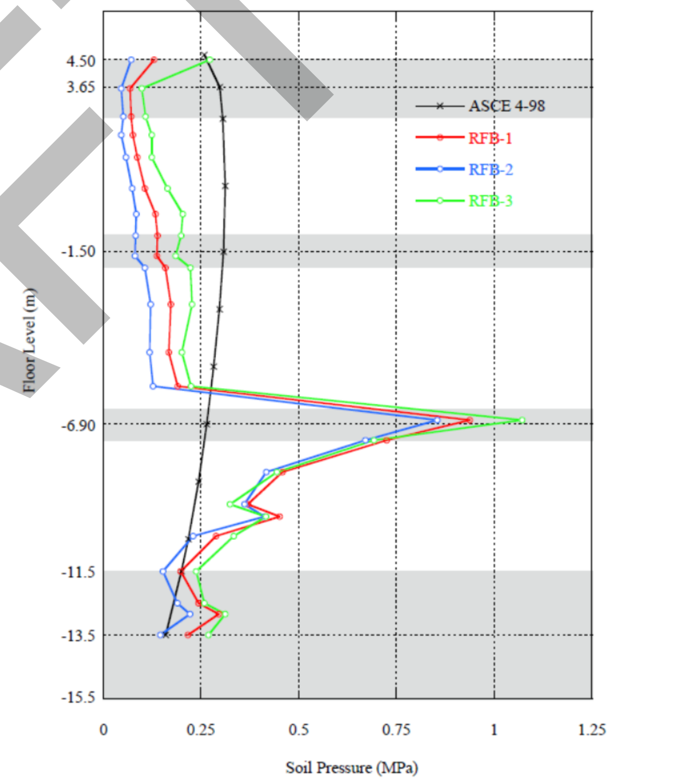
Proposed Methods of Analysis – UB Justification for Sensitivity Study Analysis Cases



Values for the UB case generally comparable or exceed the values for the BE and LB cases

Note: The shaded area shows thickness of the floor slabs and basemat.

Figure 03.07.02-6(13)a Lateral Soil Pressure - RB/FB R1 Wall – Case RFB



Values for the UB case generally comparable or exceed the values for the BE and LB cases

Note: The shaded area shows thickness of the floor slabs and basemat.

Figure 03.07.02-6(13)b Lateral Soil Pressure - RB/FB F3 Wall – Case RFB

Proposed Methods of Analysis – UB Justification for Sensitivity Study Analysis Cases

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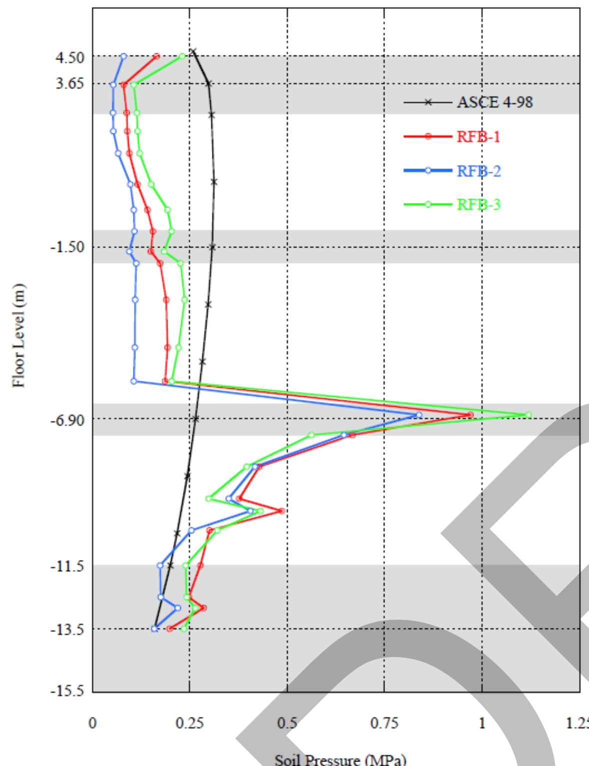
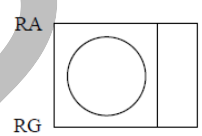
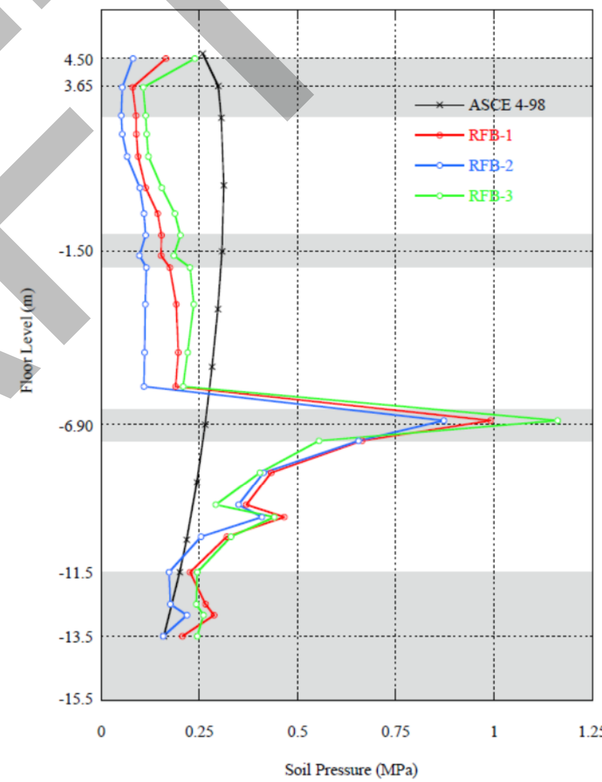


Values for the UB case generally comparable or exceed the values for the BE and LB cases

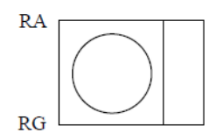


Note: The shaded area shows thickness of the floor slabs and basemat.

Figure 03.07.02-6(13)c Lateral Soil Pressure - RB/FB RA Wall – Case RFB



Values for the UB case generally comparable or exceed the values for the BE and LB cases



Note: The shaded area shows thickness of the floor slabs and basemat.

Figure 03.07.02-6(13)d Lateral Soil Pressure - RB/FB RG Wall – Case RFB

Proposed Methods of Analysis – UB Justification for Sensitivity Study Analysis Cases

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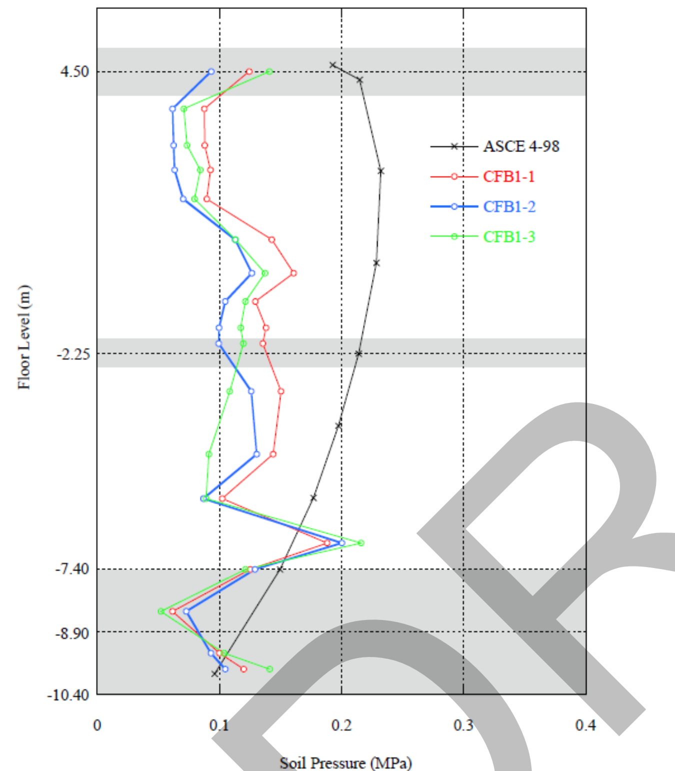
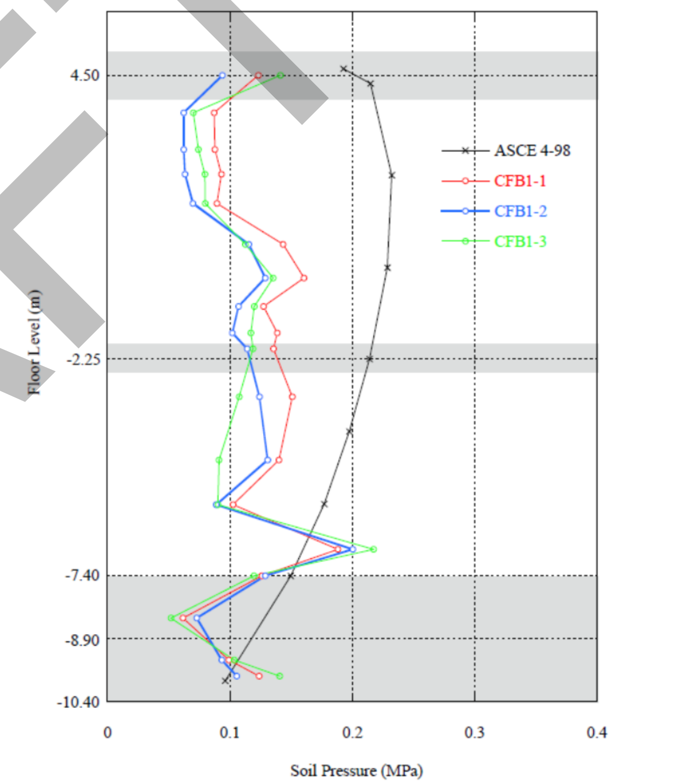


Where values exceed the ASCE 4-98 values, values for the UB case generally exceed the values for the BE and LB cases

Note: The shaded area shows thickness of the floor slabs and basemat.

Figure 03.07.02-6(14)a Lateral Soil Pressure - CB C1 Wall – Case CFB1



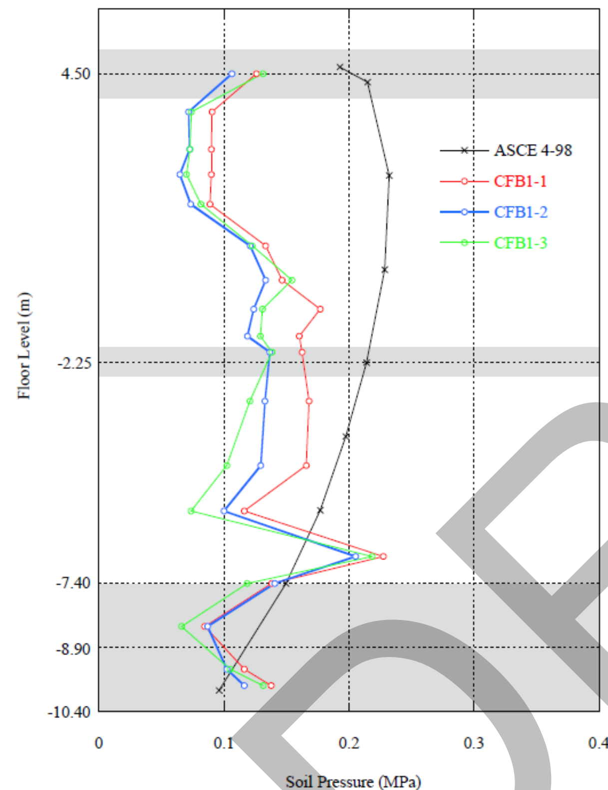
Where values exceed the ASCE 4-98 values, values for the UB case generally exceed the values for the BE and LB cases

Note: The shaded area shows thickness of the floor slabs and basemat.

Figure 03.07.02-6(14)b Lateral Soil Pressure - CB C5 Wall – Case CFB1

Proposed Methods of Analysis – UB Justification for Sensitivity Study Analysis Cases

DTE Energy

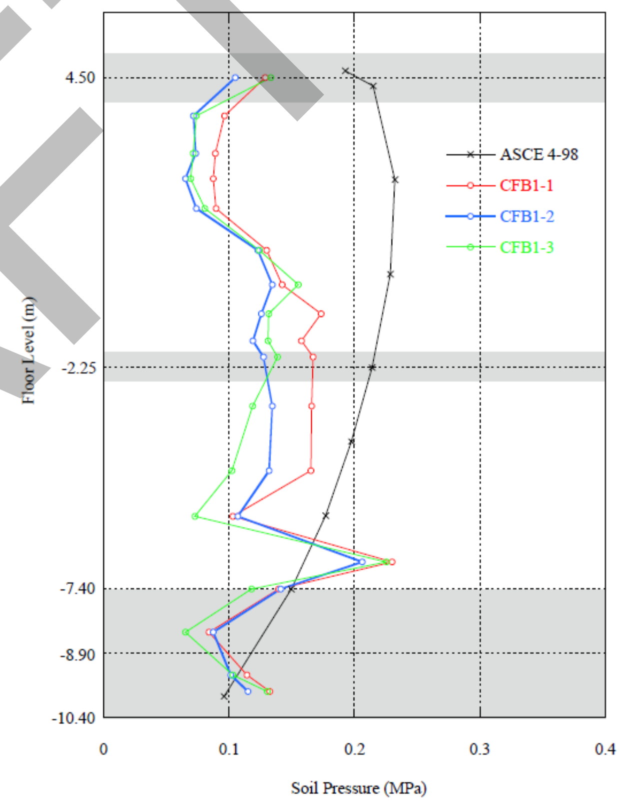


Where values exceed the ASCE 4-98 values, values for the UB case are comparable to the values for the BE and LB cases

CA CD

Note: The shaded area shows thickness of the floor slabs and basemat.

Figure 03.07.02-6(14)c Lateral Soil Pressure - CB CA Wall – Case CFB1



Where values exceed the ASCE 4-98 values, values for the UB case are comparable to the values for the BE and LB cases

CA CD

Note: The shaded area shows thickness of the floor slabs and basemat.

Figure 03.07.02-6(14)d Lateral Soil Pressure - CB CD Wall – Case CFB1

RAI 03.07.02-9 Remaining Issues

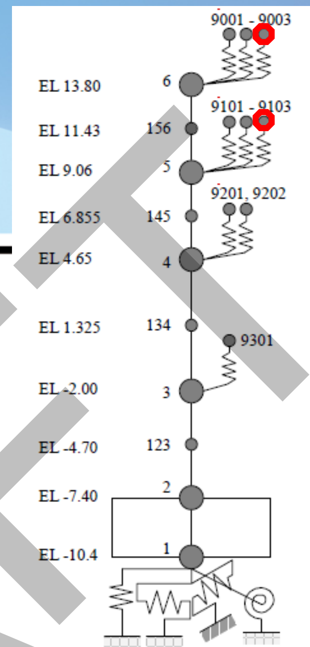
DTE Energy

Results from the revised analyses will be used to address:

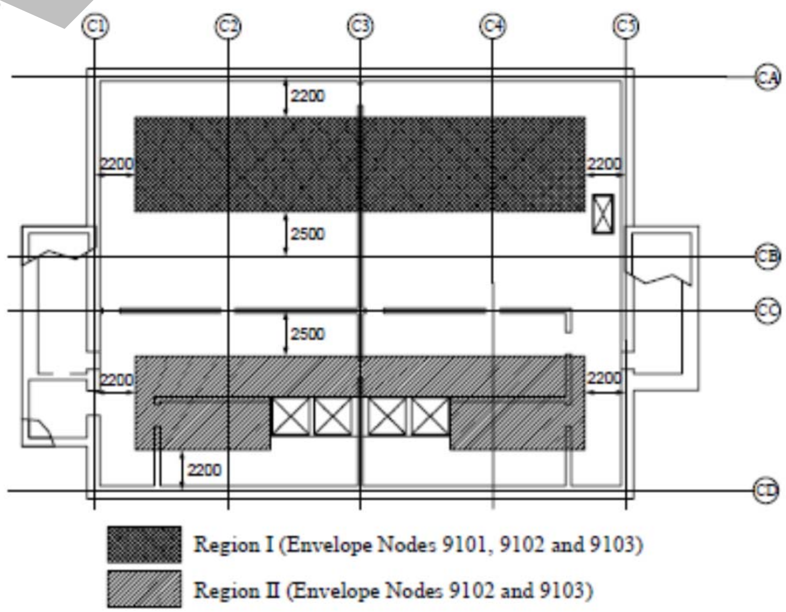
6. Out-of-Plane Responses
   - Comparison of out-of-plane slab and wall accelerations with DCD values
7. Evaluation of SSSI Effects to address:
   - Relative displacements of the basemats toward each other
   - Provide the maximum displacement of each reference point relative to a fixed reference system for all the SSI analyses cases considered
8. Lateral Wall Pressures
   - Application of lateral wall pressure results from SSI analysis
   - Providing a quantitative assessment of the sidewall design (bending moments and shears) at the locations where the DCD design pressures are exceeded
   - Demonstrating how the sharp increase in lateral soil pressures at elevations close to the backfill-to-bedrock transition are accounted for in the design

Control Building Out-of-Plane Responses

- **Purpose:** Oscillators are single degree-of-freedom systems that are used to represent modes of out-of-plane vibration for portions of floors and walls that are flexible below 50 Hz
- **Issue:** RAI response 03.07.02-6 indicated that the maximum vertical accelerations of CB oscillators 9003 and 9103 exceeded DCD values. However, the effect on the equipment/piping design was not discussed
- **Proposed solution:**
  - Use results from revised SSI analysis for the two critical CB oscillators 9003 and 9103, and compare with maximum accelerations in the DCD
  - SSI analysis is expected to show the ESBWR DCD results bound the Fermi 3 SSI results, if not, the seismic design process accounting for site specific differences will be provided



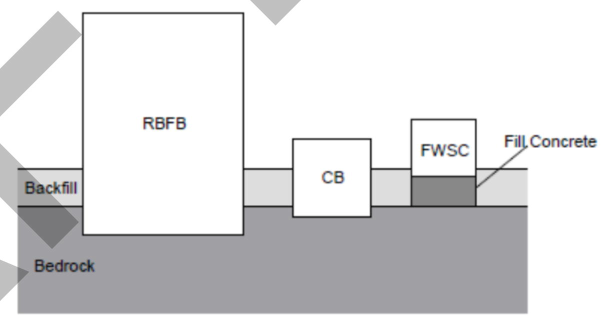
DCD Figure 3A.7-6. Control Building Seismic Model

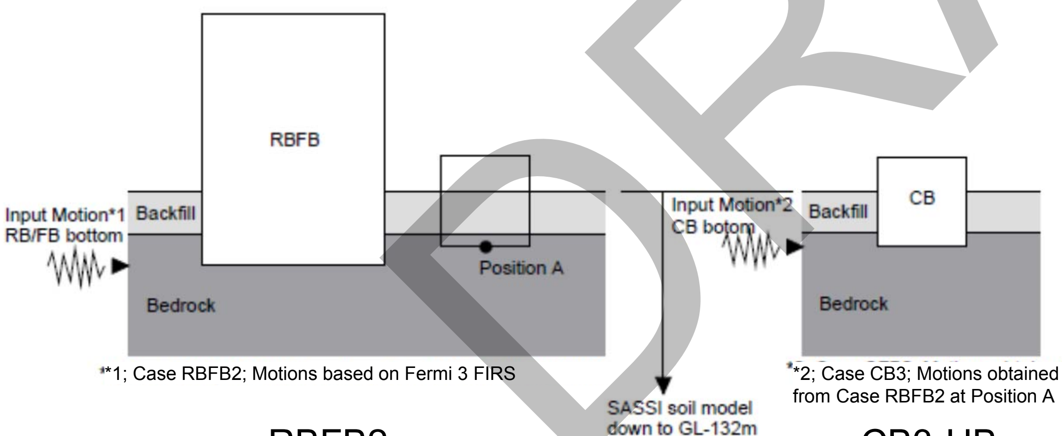


Structure-Soil-Structure Interaction (SSSI) Effects

DTE Energy

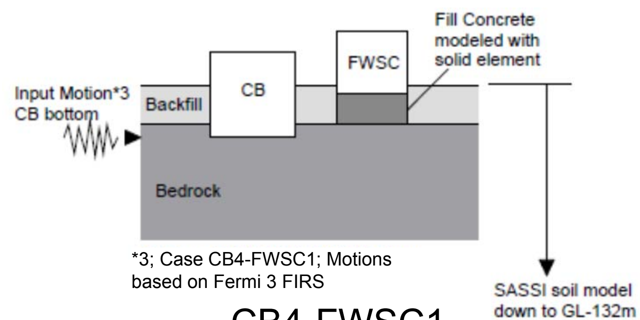
- Evaluation of SSSI effects will be based upon reperformance of previous cases as follows:
  - Relative motions between the RB/FB basemat and the CB basemat will be the maximum displacement between points on the RB/FB basemat and “Position A” from Case RBFB2
  - Relative motions between the CB basemat and the FWSC basemat will be the maximum displacement between points on the respective basemats from Case CB4-FWSC1





RBFB2 CB3-UB

RB/FB and CB Structure-Structure Interaction Analysis



CB4-FWSC1

CB and FWSC Structure-Structure Interaction Analysis

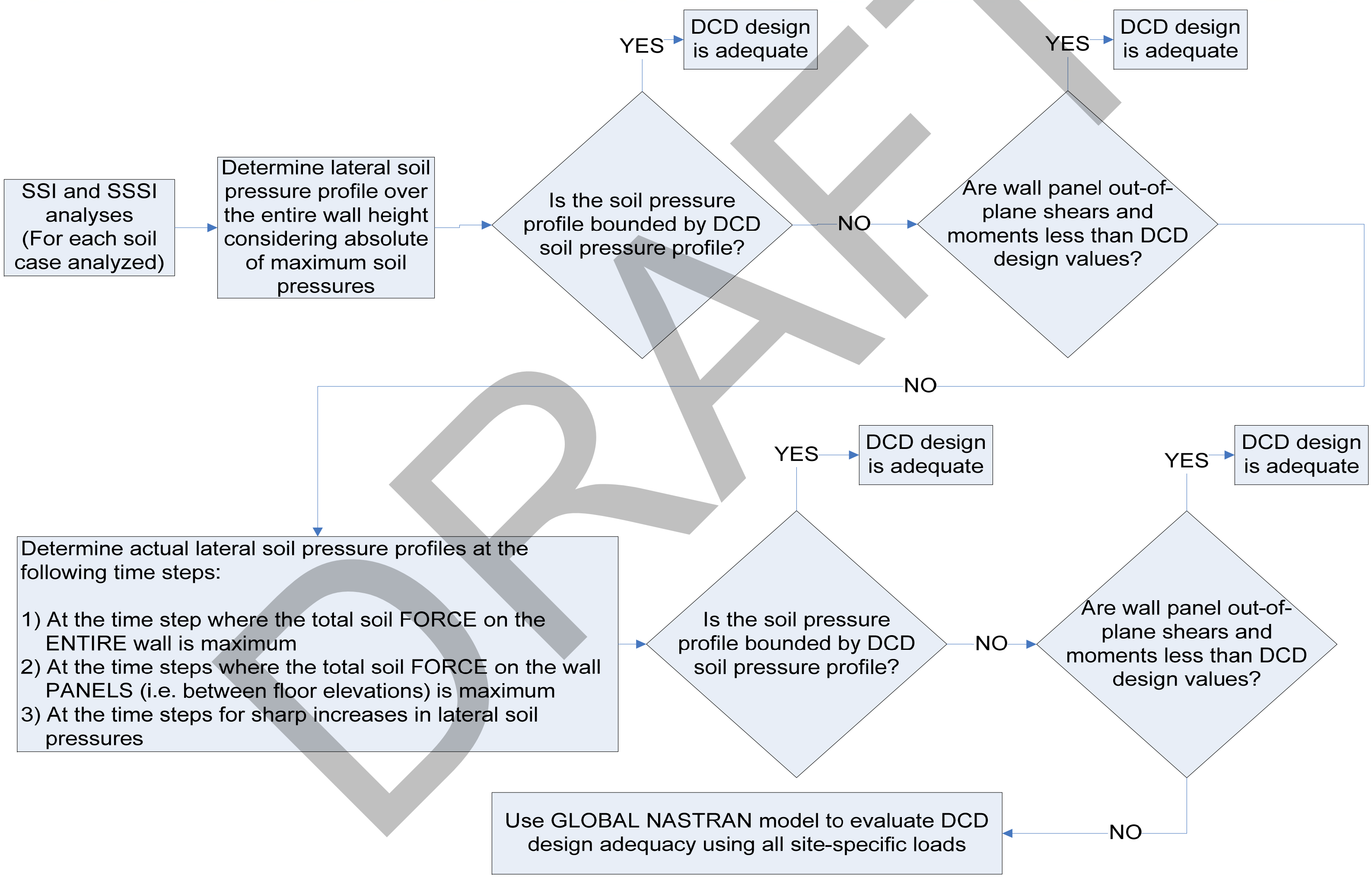
Lateral Wall Pressures

DTE Energy

- Lateral soil pressures from the applicable SSI and SSSI analyses and all subsurface profiles will be addressed as follows:
  - Profile of lateral soil pressures over the height of the wall will be used
  - Sharp increases in the lateral soil pressures at elevations close to backfill-to-bedrock transition and any other location will be part of the lateral soil pressure evaluations
  - Soil pressures along the abutting shear walls will be excluded since they are taken as in-plane loads in the abutting shear walls
  - The assessment will initially use a conservative approach – if the results are unfavorable, then a more refined approach will be used

Lateral Wall Pressures

DTE Energy



SSI – Schedule

DTE Energy

• Complete MSM Benchmarking	April 2013
• Available to support NRC Audit of MSM Benchmarking	April 2013
• Complete Licensing Basis SSI Analyses	April 2013
• Complete Sensitivity Study SSI Analyses	July 2013
• Complete Evaluations (e.g., wall pressures, SSSI, oscillators)	August 2013
• Submit RAI Response and FSAR Markups	September 2013

This schedule will be expedited wherever possible.

Partial responses to the RAIs will be made available as analyses are completed.

DTE Energy

MODIFIED SUBTRACTION METHOD

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Sargent & Lundy

Fermi 3 COLA

November 29, 2012

DRAFT 11/16/2012

The SASSI Subtraction Method

- Recent studies have shown that use of the subtraction method in SASSI can produce spurious results, especially when applied to wide, shallow embedded foundations
- The important difference between the DM and SM methods is that the excavated soil volume in the SM solution can vibrate independently from the layered soil halfspace (*The SASSI Subtraction Method Anomaly*, Carl J. Costantino and Associates, October 4, 2011)
- This independent vibration, when it occurs, causes the spurious response that has been identified as the subtraction error

The SASSI Subtraction Method

- MSM has been proposed where additional interaction nodes are added to the surface of the excavation, as well as at intermediate points within the excavated volume
- The constraint from the additional interaction nodes increases the natural frequency of the excavated soil volume
- With a higher natural frequency of the excavated soil volume, MSM results diverge from the DM results at a higher frequency, and increases the frequency at which the subtraction error occurs
- MSM can be used to increase the error frequency to a frequency beyond the SSI frequency of interest
- MSM modeling techniques should be benchmarked on a case-by-case basis

Modified Subtraction Method – Proposed Application

- For Sensitivity Study Case RBFB2-UB, MSM will be used
- For Sensitivity Study Case CB4-FWSC1:
  – DM will be used for definition of interaction nodes of the CB excavation volume
  – MSM will be used for definition of interaction nodes of the FWSC excavation volume
- MSM will be benchmarked against the DM
- In order to show that MSM results will converge with DM, it is necessary to Benchmark MSM against the DM using a "representative structure" with similar soil properties and input motions
- Properties that define a "representative structure" include
  – width/depth ratio
  – embedment depth
  – weight of each structure

Modified Subtraction Method – Benchmarking

- The Benchmarking Model has the same Minimum Requirements as the final SSI model:
  - Must be capable of capturing the energy of the seismic event, where Time Histories are rich in content up to about 50 Hz
  - Maximum horizontal and vertical mesh dimensions must be less than 20 percent of the shear wave length of the subsurface material at the highest frequency of interest or analysis
- The number of Interaction Nodes for the RB/FB Sensitivity Study (with backfill) is so large that the capability of both SASSI2000 and SASSI2010 using the DM is exceeded
- In order to reduce the DM model size to within the software capabilities, a quarter model for the RB/FB (Case RBFB2BM-UB) will be used for benchmarking

Modified Subtraction Method – Benchmarking Using a Quarter Model

DTE Energy

- Using quarter models is a common technique used to reduce large complex structural models to practical sizes
- Quarter model results are comparable when the structures are relatively symmetrical about each principal horizontal axis
- Two separate evaluations have been performed to determine the effects of eccentricity on the results
  - FRS at the building edges were investigated using the analysis results for the Licensing Basis Analysis case RFI-1 (BE site condition) provided in SER-DTF-006 and for the Confirmatory Analysis case RFB-1 (BE site condition) provided in SER-DTR-008
- The results of these evaluations show that the effects of eccentricity (i.e., the torsional response) are very small

Modified Subtraction Method – Criteria for Developing Quarter Model

- The RB/FB model is idealized as symmetric about two horizontal axes (X – along the length and Y – along the width)
- For symmetric structure idealization, a quarter of the model can be used for the SSI analysis (Benchmarking of MSM against the DM)
- Three separate quarter SASSI models will be developed, one for each direction of excitation with appropriate boundary conditions
- The basic boundary conditions of the models for each of the three directions of excitation are shown on the following slide

Modified Subtraction Method – Criteria for Developing Quarter Model

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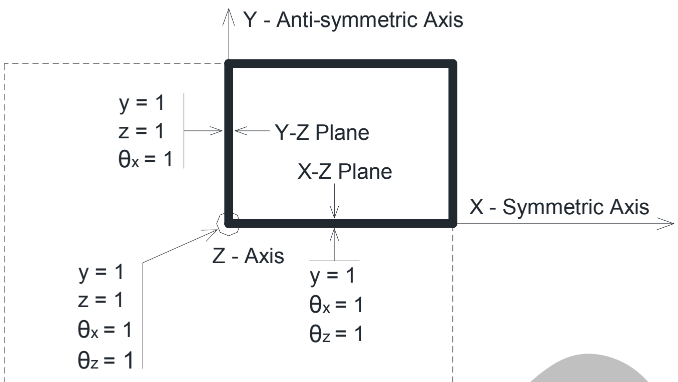
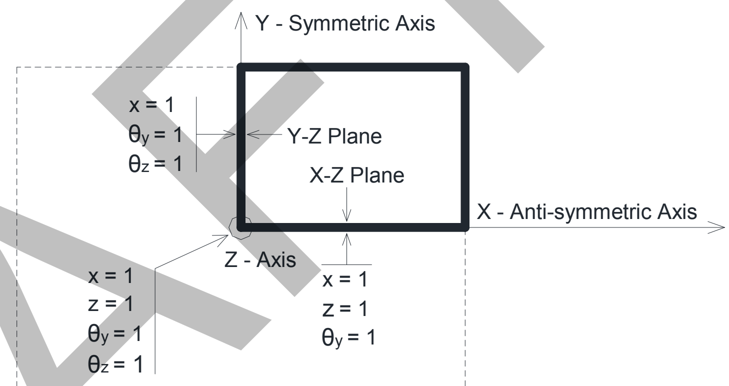
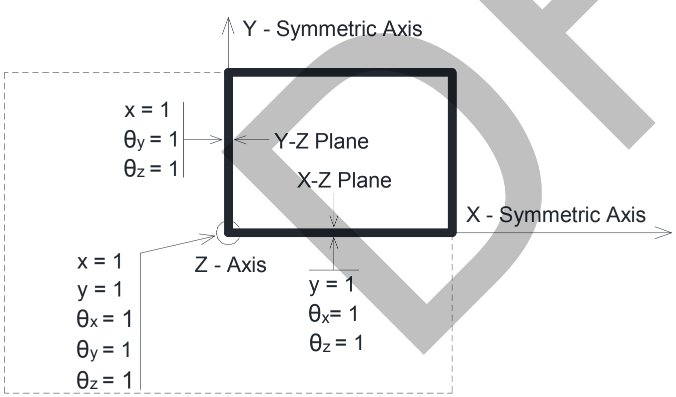
X - Excitation



Y - Excitation



Z - Excitation



Note:
The general rule for a SYMMETRY displacement boundary condition is that the displacement vector component perpendicular to the plane is zero and the rotational vector components parallel to the plane are zero. For an ANTI-SYMMETRY condition the reverse conditions apply.

Legend:
X = 1, X translation fixed
Y = 1, Y translation fixed
Z = 1, Z translation fixed
θ_x = 1, Rotation about X fixed
θ_y = 1, Rotation about Y fixed
θ_z = 1, Rotation about Z fixed

Reference:
How to use Symmetry and Anti-Symmetry Boundary Conditions, SolidWorks Express, Tech Tips.

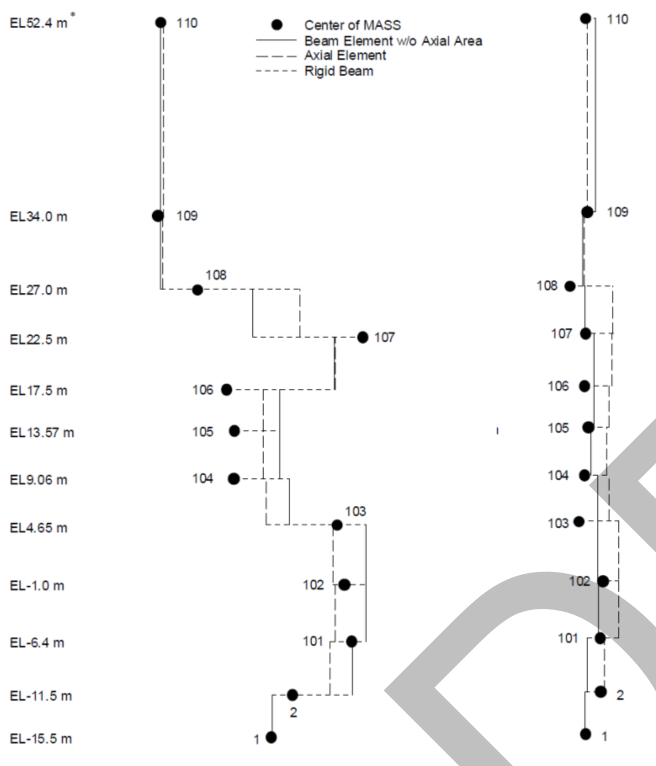
Modified Subtraction Method – Criteria for Developing Quarter Model

DTE Energy

- The following summarizes the mass and stiffness characteristics of the quarter model as they relate to the full design model:
  - In the quarter model, the excavated volume properties are the same as in the full model (in the full model, the excavated volume is symmetric about two horizontal axes)
  - In the quarter model, the exterior walls below grade and the foundation basemat along with supporting soil medium properties are the same as in the full model (in the full model, these structural elements are symmetric about two horizontal axes)
  - In the quarter model, the RB/FB stick models at the base are connected to the center of the basemat, along the height there are no eccentricities between the centers of mass and centers of rigidity
  - In the full model, the base of the RB/FB sticks are connected to the center of the basemat, along the height the there are eccentricities between the centers of mass and centers of rigidity (DCD Figures 3A.7-1 through 3A.7-3)
  - In the quarter model, the RB/FB stick model is connected to the side walls at floor EL -11.5 m , -6.4 m, -1.0 m and 4.5 m by a set of rigid links; this is same as in full model
  - In the quarter model, the translation mass and stiffness values of RB/FB sticks are one fourth (1/4) of the respective values in the full model

Modified Subtraction Method – Criteria for Developing Quarter Model

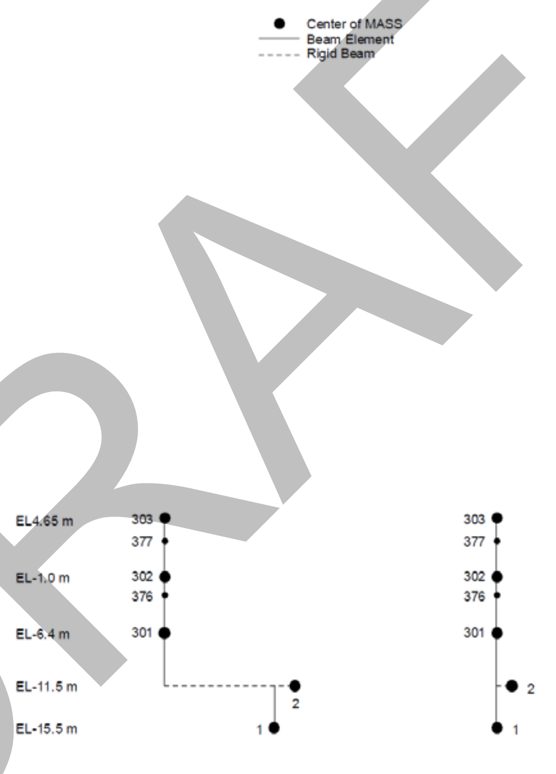
DTE Energy



(a) XZ Plane (b) YZ Plane

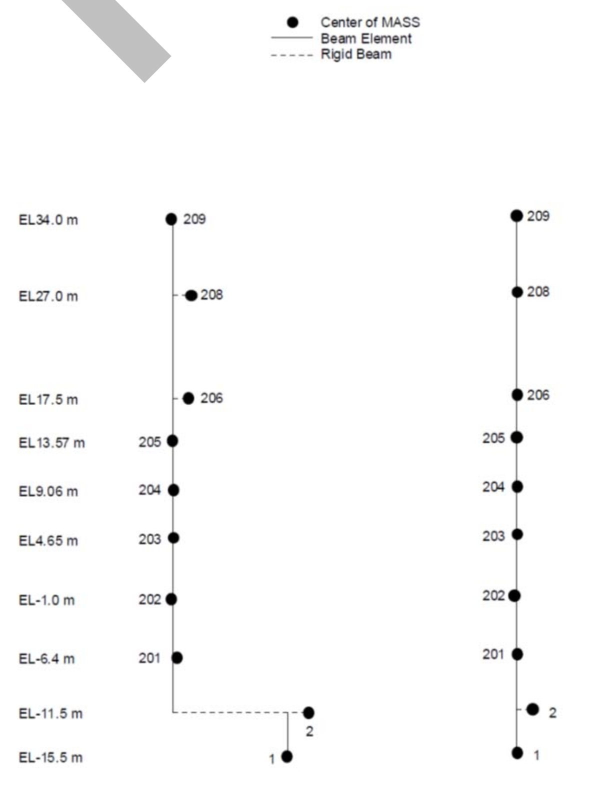
The difference between the modeled elevation 52.4 m and the actual elevation 52.7 m at the RB roof is negligibly small.

[*Figure 3A.7-1. RB/FB Stick Model*



(a) XZ Plane (b) YZ Plane

Figure 3A.7-3. Pedestal Stick Model



(a) XZ Plane (b) YZ Plane

Figure 3A.7-2. RCCV Stick Model

Excerpted from ESBWR, Design Control Document/Tier 2, 26A6642AL Rev. 9

Modified Subtraction Method – Benchmarking

DTE Energy

- The quarter model is used to benchmark the MSM to show that the frequency at which the subtraction error occurs has been raised above the frequency of interest
  - Results from the quarter model are not used for any direct evaluations
  - The effects of eccentricity (i.e., torsional response) are shown to be very small
  - The quarter model will use proper symmetric / anti-symmetric boundary conditions (Option available in SASSI)

Modified Subtraction Method – Benchmarking

DTE Energy

- Benchmarking will be performed with a full model of the FWSC and a quarter model of the RB/FB with the same subsurface properties and same input motions as the final SSI models

BENCHMARKING STUDY								
Building	Case	Case ID	Highest Frequency	Parameters	Soil	Method	Total number of Interaction Nodes	< 20,000 Interaction Nodes?
FWSC1	FWSC1BM	FWSC1BM-UB	50 Hz	Note 1	UB	DM	16,000	Yes
		FWSC1BM-BE	50 Hz	Note 1	BE	DM	31,000	No
		FWSC1BM-LB	50 Hz	Note 1	LB	DM	71,000	No
RB/FB	RBFB2BM	RBFB2BM-UB	50 Hz	Note 2	UB	DM	14,600	Yes
		RBFB2BM-BE	50 Hz	Note 2	BE	DM	27,100	No
		RBFB2BM-LB	50 Hz	Note 2	LB	DM	61,700	No

Notes:
1. Full SSI model, engineered granular fill is modeled,input motion is the Fermi 3 FIRS
2. 1/4 SSI model, engineered granular fill is modeled, input motion is the Fermi 3 FIRS

The highlighted cases have been selected based upon the following:

- SASSI2010 is limited to 20,000 Interaction Nodes and the passing frequency must be about 50 Hz
- The DM must be used for Benchmarking the MSM

Modified Subtraction Method – Benchmarking

- Benchmarking acceptance criteria includes review to assure close correlation between the DM model and the MSM model results for:
  – Transfer Functions
  – Forces and Moments
  – Response Spectra

The MSM Benchmark analyses for the RB/FB and the FWSC will be made available for audit by NRC Staff prior to proceeding with further SSI or SSSI analysis

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SCHEDULE

Michael Brandon
Detroit Edison

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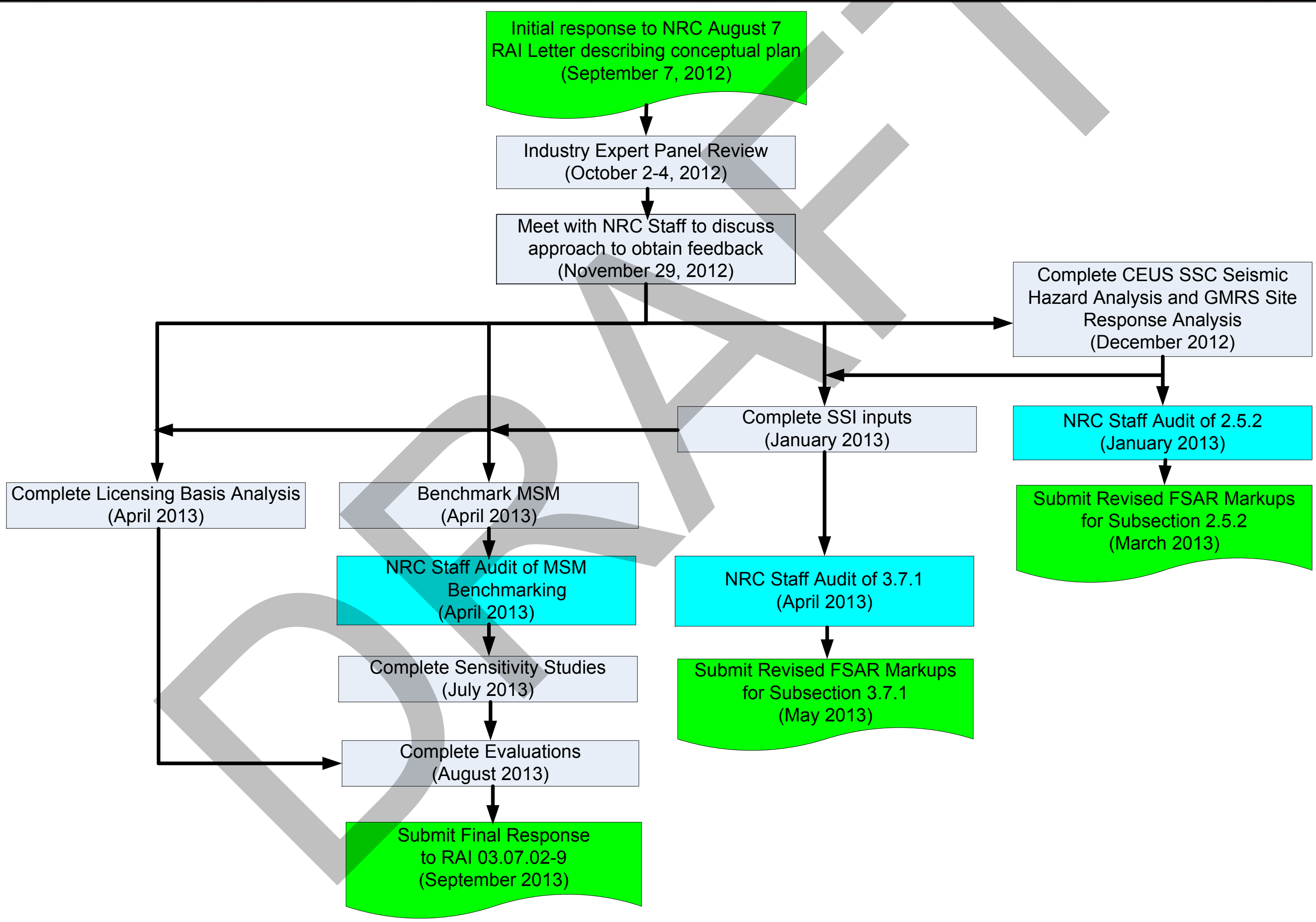
November 29, 2012

DRAFT 11/16/2012

Schedule


Initial response to NRC August 7 RAI Letter describing conceptual plan (September 7, 2012)
Industry Expert Panel Review (October 2-4, 2012)
Meet with NRC Staff to discuss approach to obtain feedback (November 29, 2012)
Complete CEUS SSC Seismic Hazard Analysis and GMRS Site Response Analysis (December 2012)
Complete SSI inputs (January 2013)
NRC Staff Audit of 2.5.2 (January 2013)
Submit Revised FSAR Markups for Subsection 2.5.2 (March 2013)
Complete Licensing Basis Analysis (April 2013)
Benchmark MSM (April 2013)
NRC Staff Audit of MSM Benchmarking (April 2013)
NRC Staff Audit of 3.7.1 (April 2013)
Submit Revised FSAR Markups for Subsection 3.7.1 (May 2013)
Complete Sensitivity Studies (July 2013)
Complete Evaluations (August 2013)
Submit Final Response to RAI 03.07.02-9 (September 2013)

SUMMARY

Michael Brandon
Detroit Edison

Fermi 3 COLA

November 29, 2012

Summary

DTE Energy

- Detroit Edison has concluded that the impacts of the new CEUS SSC model and the remaining NRC SSI-related RAIs are best addressed by reperforming previous site-specific SSI analyses
- Appreciate the opportunity to interact with the Staff and to detail the path forward to support the completion of the Safety Evaluation on these topics
- It is Detroit Edison's objective to provide a clear, defendable, and durable Licensing Basis for the Fermi 3 application
- The schedule provided is deliberate and is designed to maintain a healthy engagement with the Staff to ensure issues can be identified promptly and addressed without delay

Summary (continued)

Resolution of Open Items

Item 1: CEUS SSC for Fermi 3 not bounded by current SSI Inputs
Resolution: Replace previous inputs with new ones based on the CEUS SSC model
(refer to slide 13)

Item 2: Consistency of SSI inputs used for various analyses
Resolution: Replace previous inputs with new ones based on the CEUS SSC model in all cases
(refer to slides 16 - 20)

Item 3: Use of 7% SSE Structural Damping Ratios vs. 4% OBE Structural Damping Ratios
Resolution: Perform new SSI analyses with 4% OBE Structural Damping Ratio
(refer to slide 27)

Item 4: Finite element mesh size/aspect ratio insufficient to capture full range of frequencies.
Resolution: Use finite element mesh size/aspect ratio capable capturing range of frequencies up to about 50 Hz
(refer to slides 27, 28, 30, and 32)

Summary (continued)

Resolution of Open Items

Item 5: Use of SASSI SM for Sensitivity Study cases
Resolution: New SSI analyses using DM or MSM
(refer to slide 31)

Item 6: Comparison of out-of-plane slab and wall responses with DCD values
Resolution: Compare results from revised analyses with DCD values
(refer to slide 39)

Item 7: Reevaluate the SSSI comparative analysis results with common reference point
Resolution: Reperform SSSI analyses with displacements from common reference points
(refer to slide 40)

Item 8: Evaluation of lateral wall pressure results from SSI analyses
Resolution: Evaluate wall pressures and compare with wall capacities
(refer to slides 41 and 42)

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SITE-SPECIFIC SOIL-STRUCTURE INTERACTION ANALYSIS

Supplemental Material

Model Size Capabilities

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November 29, 2012

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SENSITIVITY STUDIES

Building	Case	Case ID	SSI Building Model / Highest Frequency	Parameters	Soil	Method	Total number of Interaction Nodes	< 20,000 Interaction Nodes?	Method
CB	CB2	CB2-UB	Full Model / 50 Hz	With Backfill Fermi 3 FIRS	UB	DM	11,400	Yes	DM
						MSM	3,300	Yes	
		CB2-BE1	Full Model / 50 Hz	With Backfill Fermi 3 FIRS	BE	DM	21,600	No	MSM
						MSM	5,900	Yes	
		CB2-BE2	Full Model / 36 Hz	With Backfill Fermi 3 FIRS	BE	DM	11,400	No	DM
						MSM	3,300	Yes	
		CB2-LB1	Full Model / 50 Hz	With Backfill Fermi 3 FIRS	LB	DM	50,000	No	MSM
						MSM	12,000	Yes	
		CB2-LB2	Full Model / 26 Hz	With Backfill Fermi 3 FIRS	LB	DM	11,400	No	DM
						MSM	3,300	Yes	
RB/FB	RBFB2	RBFB2-UB	Full Model / 50 Hz	With Backfill Fermi 3 FIRS	UB	DM	54,900	No	MSM
						MSM	13,000	Yes	
		RBFB2-BE1	Full Model / 50 Hz	With Backfill Fermi 3 FIRS	BE	DM	104,000	No	N/A
						MSM	21,000	No	
		RBFB2-BE2	Full Model / 36 Hz	With Backfill Fermi 3 FIRS	BE	DM	54,900	No	MSM
						MSM	13,000	Yes	
		RBFB2-LB1	Full Model / 50 Hz	With Backfill Fermi 3 FIRS	LB	DM	241,000	No	N/A
						MSM	41,800	No	
		RBFB2-LB2	Full Model / 26 Hz	With Backfill Fermi 3 FIRS	LB	DM	54,900	No	MSM
						MSM	13,000	Yes	
CB	CB3	CB3-UB	Full Model / 50 Hz	With Backfill Motion from RBFB2	UB	DM	11,400	Yes	DM
						MSM	3,300	Yes	
		CB3-BE1	Full Model / 50 Hz	With Backfill Motion from RBFB2	BE	DM	21,600	No	MSM
						MSM	5,900	Yes	
		CB3-BE2	Full Model / 36 Hz	With Backfill Motion from RBFB2	BE	DM	11,400	Yes	DM
						MSM	3,300	Yes	
		CB3-LB	Full Model / 50 Hz	With Backfill Motion from RBFB2	LB	DM	50,000	No	MSM
						MSM	12,000	Yes	
		CB3-LB	Full Model / 26 Hz	With Backfill Motion from RBFB2	LB	DM	11,400	Yes	DM
						MSM	3,300	Yes	
CB+FWSC	CB3-FWSC1	CB4-FWSC1-UB	Coupled Model / 50 Hz	With Backfill Fermi 3 FIRS	UB	DM	27,000	No	MSM
						MSM	8,700	Yes	
		CB4-FWSC1-BE	Coupled Model / 50 Hz	With Backfill Fermi 3 FIRS	BE	DM	52,000	No	MSM
						MSM	15,500	Yes	
		CB4-FWSC1-LB1	Coupled Model / 50 Hz	With Backfill Fermi 3 FIRS	LB	DM	121,000	No	N/A
						MSM	30,500	No	
		CB4-FWSC1-LB2	Coupled Model / 35 Hz	With Backfill Fermi 3 FIRS	LB	DM	52,000	No	MSM
						MSM	15,500	Yes	
		CB4-FWSC1-LB3	Coupled Model / 26 Hz	With Backfill Fermi 3 FIRS	LB	DM	27,000	No	MSM
						MSM	8,700	Yes	

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SITE-SPECIFIC SOIL-STRUCTURE INTERACTION ANALYSIS
Supplemental Material
Benchmarking – Eccentricity Effects
Investigation of FRS at Building Edges
Fermi 3 COLA

November 29, 2012

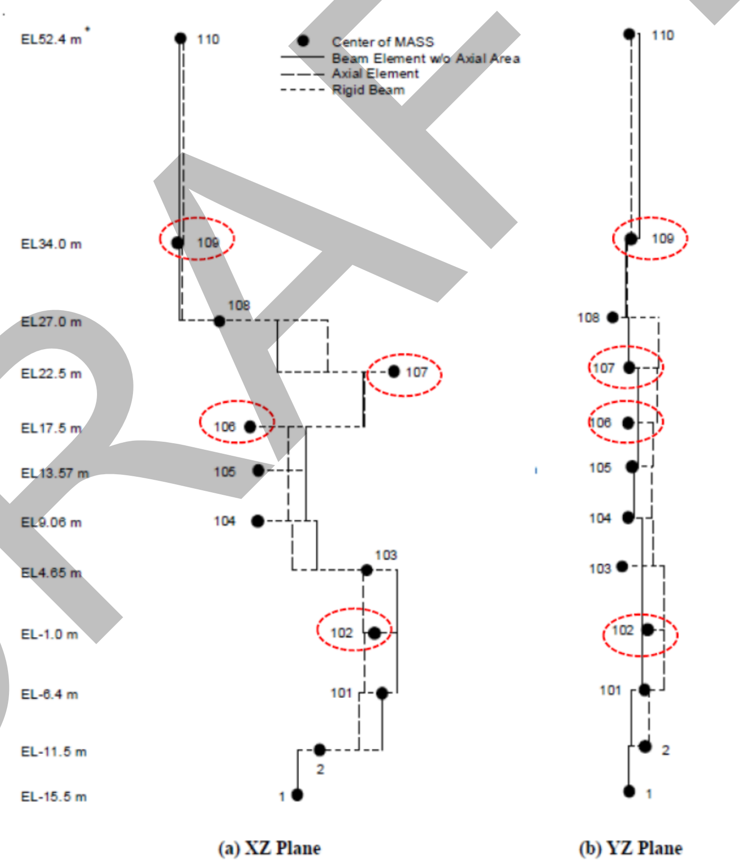
MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

DTE Energy

- To evaluate the effect of RB/FB eccentricity, the FRS at the building edges were investigated using the analysis results for the Licensing Basis Analysis case RFI-1 (BE site condition) provided in SER-DTF-006 and for the Confirmatory Analyses case RFB-1 (BE site condition) provided in SER-DTR-008
- The effect of RB/FB eccentricity on FRS is evaluated by comparison of the FRS between the 3D Full Model with and without the torsion components (cross terms)
- The calculated floor elevations are selected at nodes N109, N107, N106 and N102 (Figure 1)
- Figures 2 through 5 show the comparison of the FRS between the 3D Full Model with and without the torsion components
  - Figures 2 and 3 show the results from the Licensing Basis Analysis for the X and Y directions, respectively
  - Figures 4 and 5 show the results from the Confirmatory Analysis with Backfill for the X and Y directions, respectively
- The differences in FRS in X direction are small
- The difference of FRS in Y direction are larger but not significant

MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

ESBWR 26A6642AL Rev. 09 Design Control Document/Tier 2



*: The difference between the modeled elevation 52.4 m and the actual elevation 52.7 m at the RB roof is negligibly small.

[Figure 3A.7-1. RB/FB Stick Model

Figure 1a RB/FB Stick Model

MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

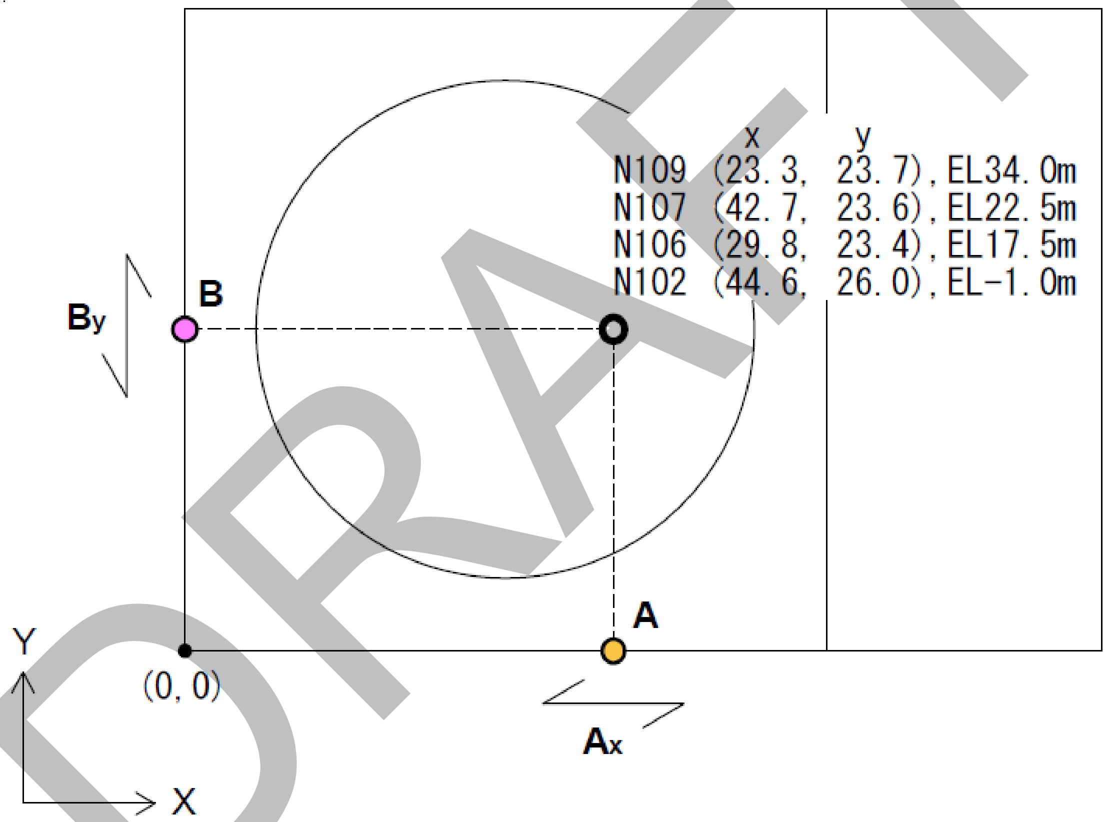


Figure 1b Node Locations

MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

Full Model - With Torsion Contribution vs. Without Torsion Contribution
FRS at Edge of Building (Licensing Basis Analysis)

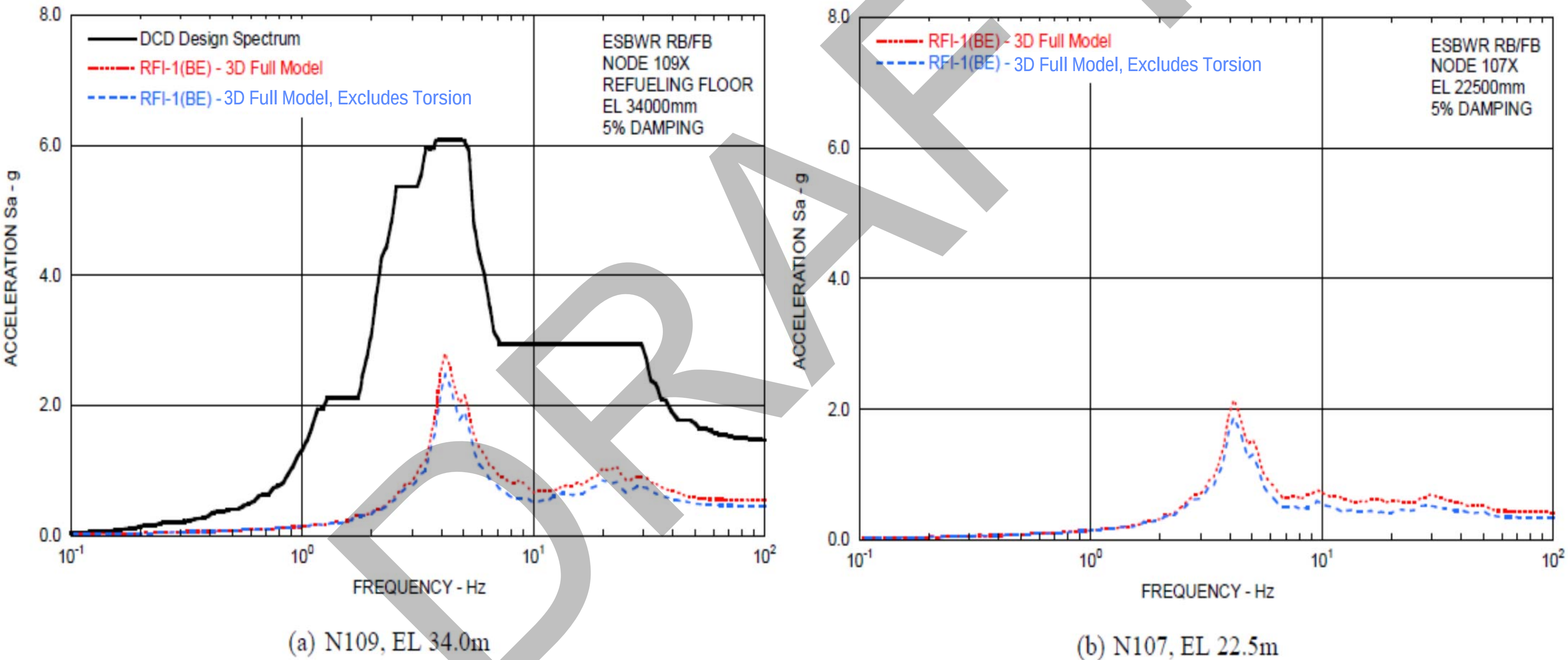


Figure 2a FRS - X-Direction from SER-DTF-006 (Licensing Basis Analysis)

MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

Full Model - With Torsion Contribution vs. Without Torsion Contribution
FRS at Edge of Building (Licensing Basis Analysis)

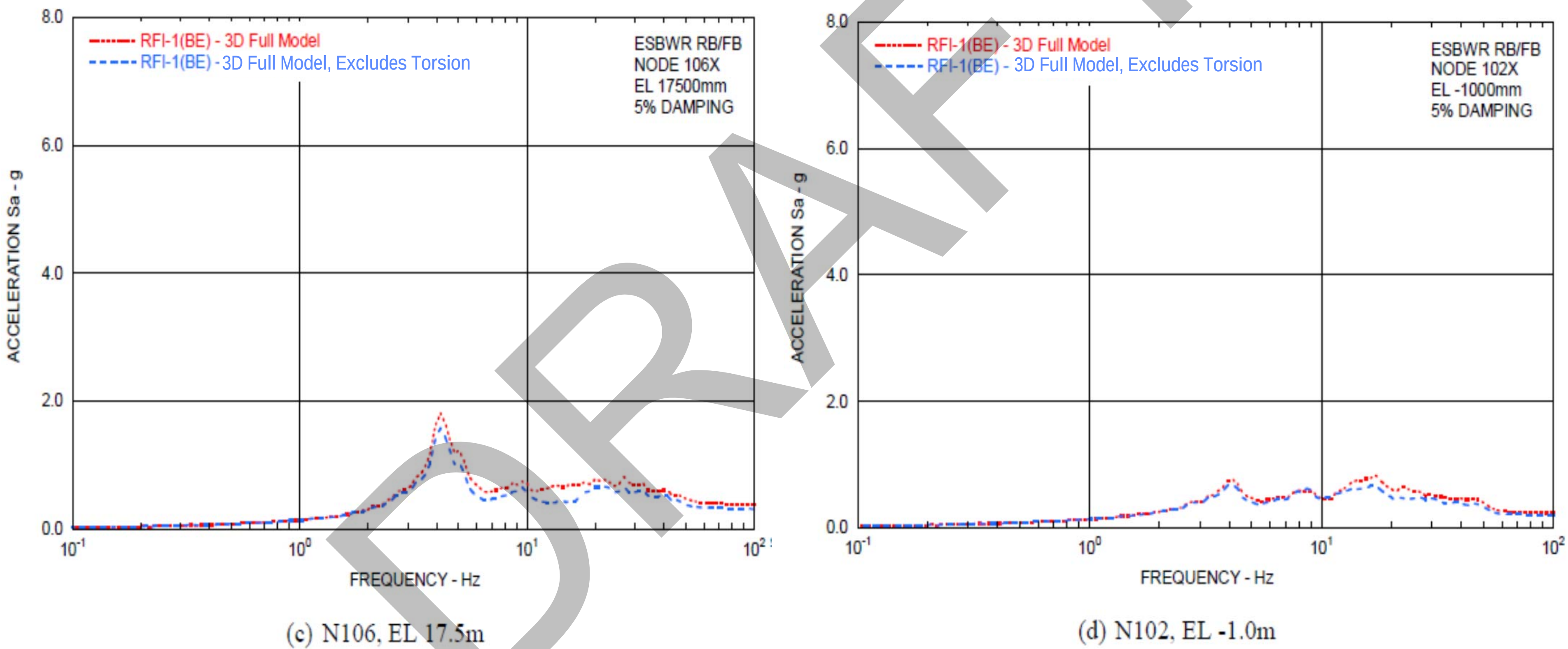
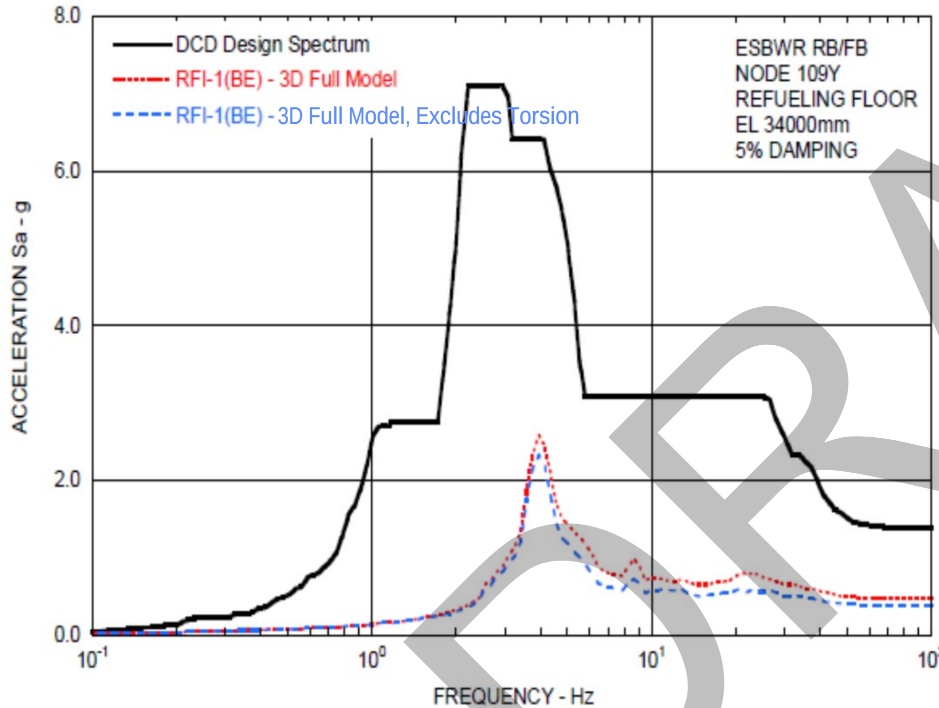


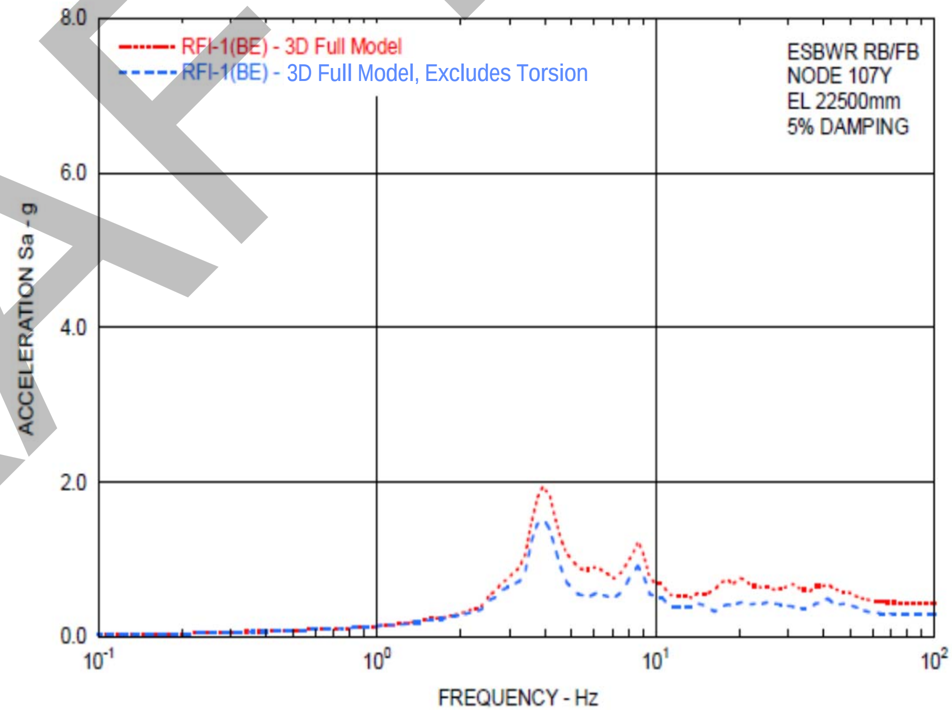
Figure 2b FRS - X-Direction from SER-DTF-006 (Licensing Basis Analysis)

MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

Full Model - With Torsion Contribution vs. Without Torsion Contribution
FRS at Edge of Building (Licensing Basis Analysis)



(a) N109, EL 34.0m

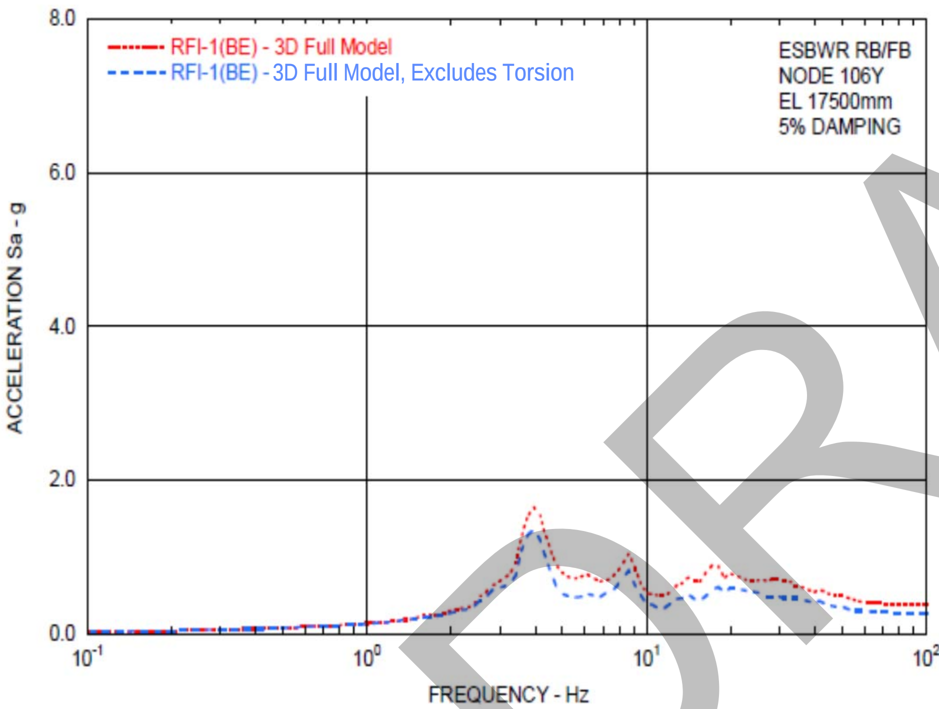


(b) N107, EL 22.5m

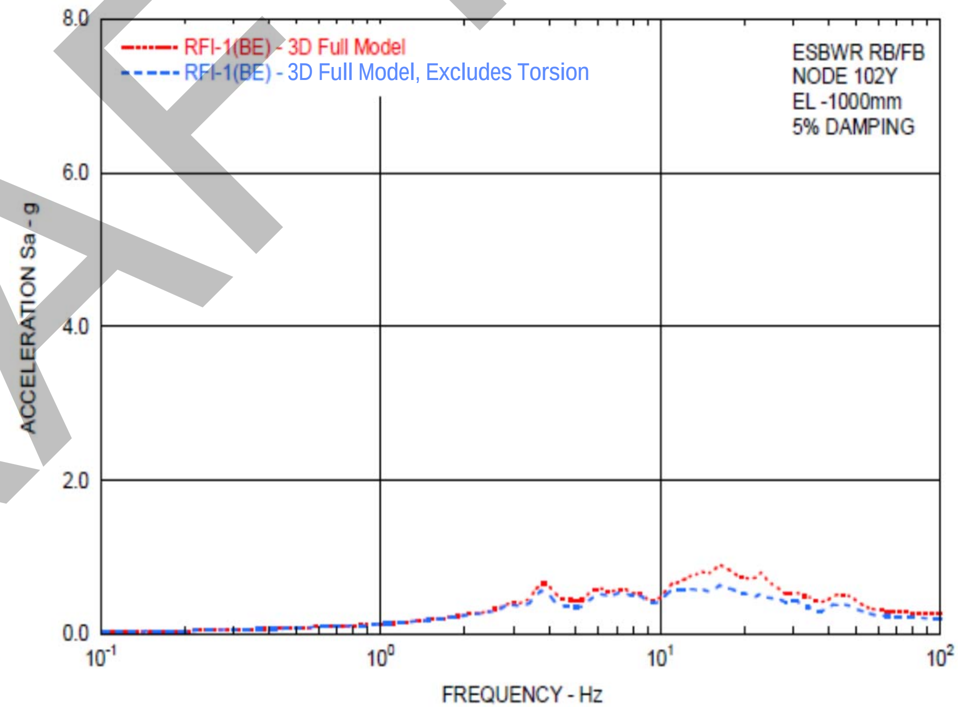
Figure 3a FRS - Y-Direction from SER-DTF-006 (Licensing Basis Analysis)

MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

Full Model - With Torsion Contribution vs. Without Torsion Contribution
FRS at Edge of Building (Licensing Basis Analysis)



(c) N106, EL 17.5m



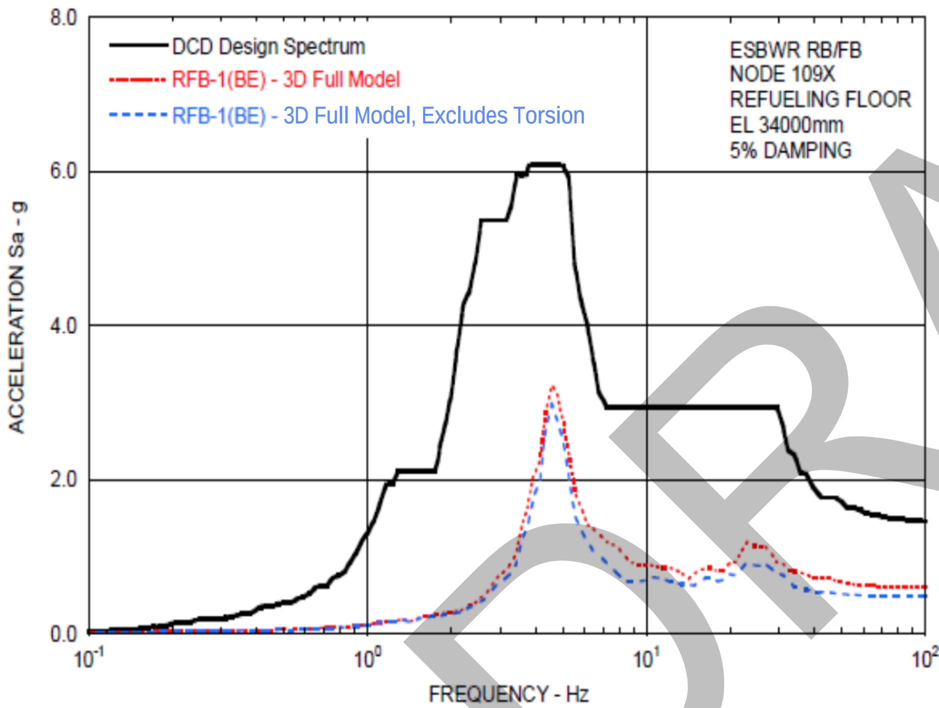
(d) N102, EL -1.0m

Figure 3b FRS - Y-Direction from SER-DTF-006 (Licensing Basis Analysis)

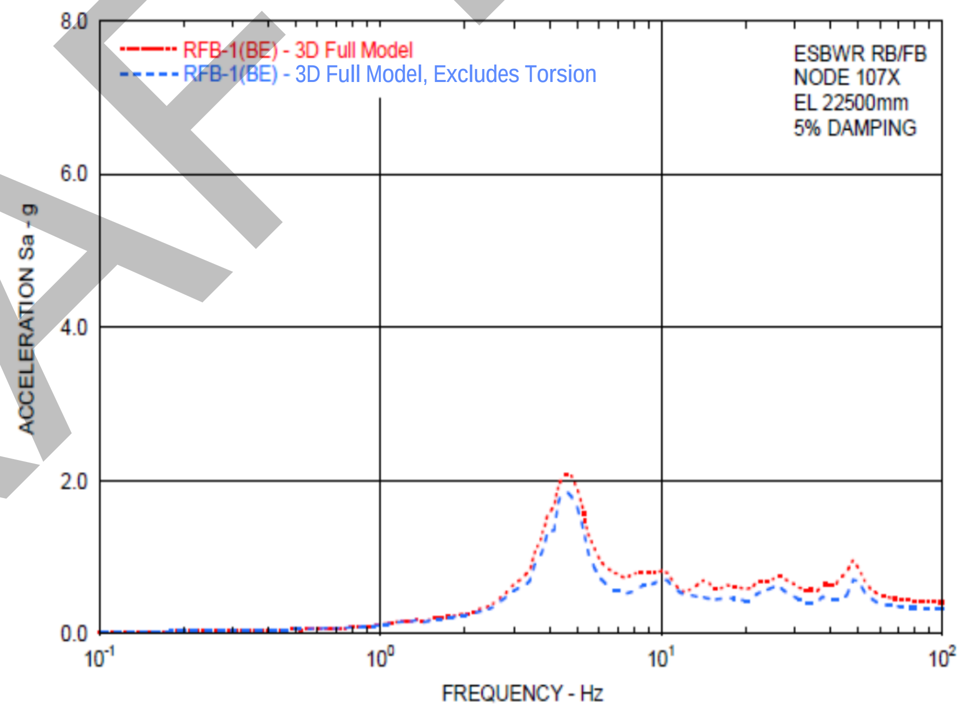
MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

DTE Energy

Full Model - With Torsion Contribution vs. Without Torsion Contribution
FRS at Edge of Building (Confirmatory Analysis with Backfill)



(a) N109, EL 34.0m

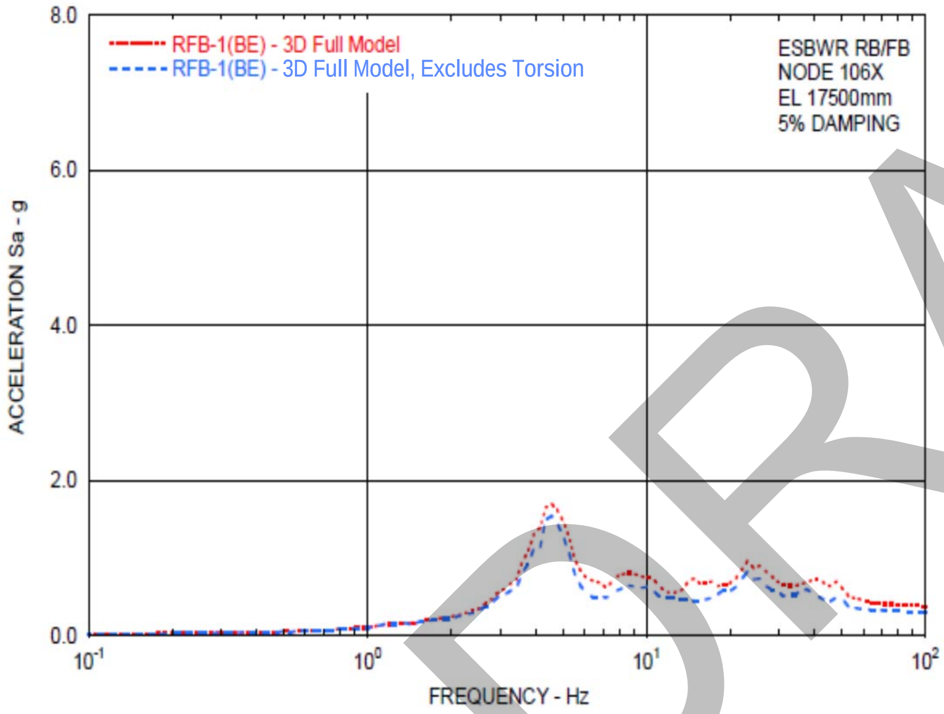


(b) N107, EL 22.5m

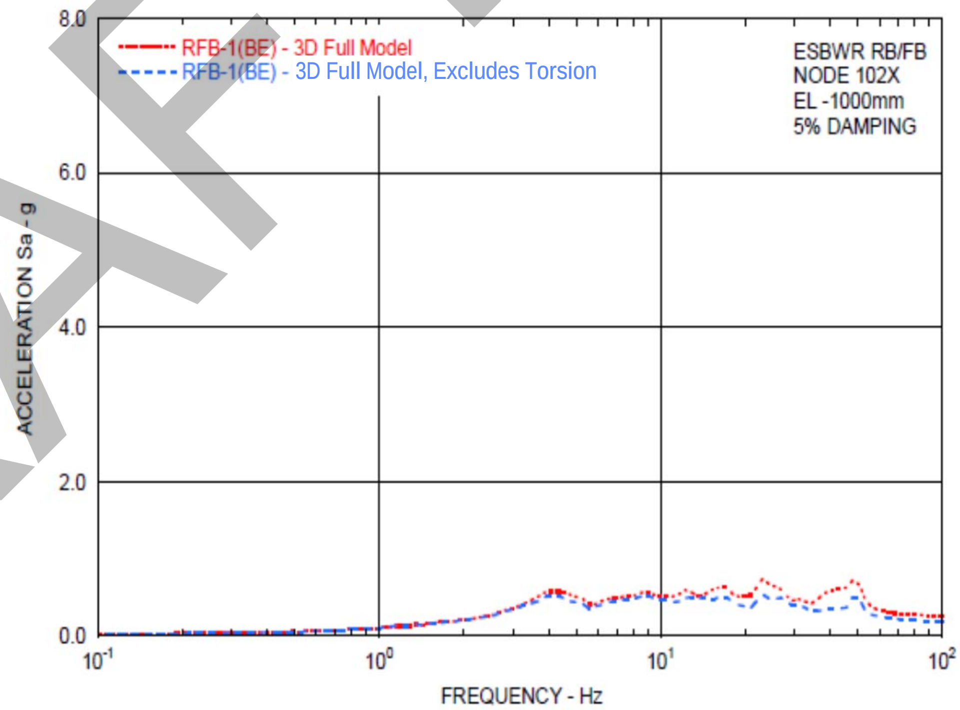
Figure 4a FRS - X-Direction from SER-DTF-008 (Confirmatory Analysis with Backfill)

MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

Full Model - With Torsion Contribution vs. Without Torsion Contribution
FRS at Edge of Building (Confirmatory Analysis with Backfill)



(c) N106, EL 17.5m



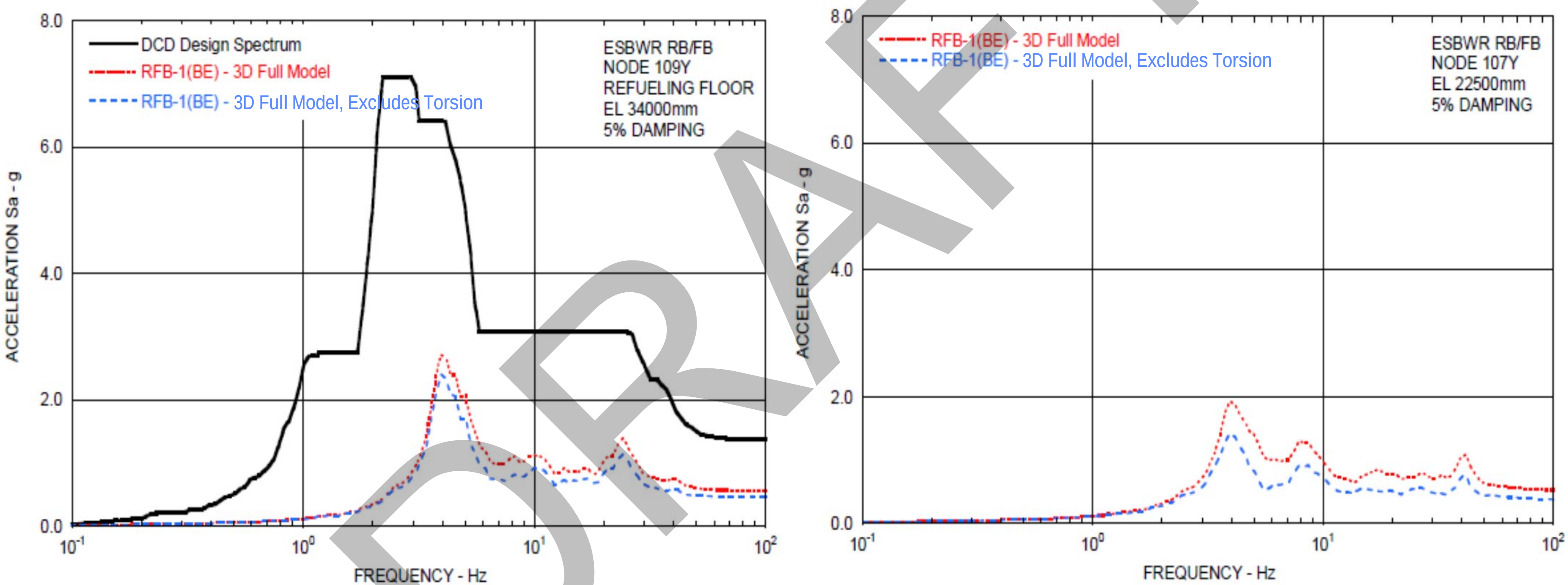
(d) N102, EL -1.0m

Figure 4b FRS - X-Direction from SER-DTF-008 (Confirmatory Analysis with Backfill)

MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

DTE Energy

Full Model - With Torsion Contribution vs. Without Torsion Contribution
FRS at Edge of Building (Confirmatory Analysis with Backfill)



(a) N109, EL 34.0m

(b) N107, EL 22.5m

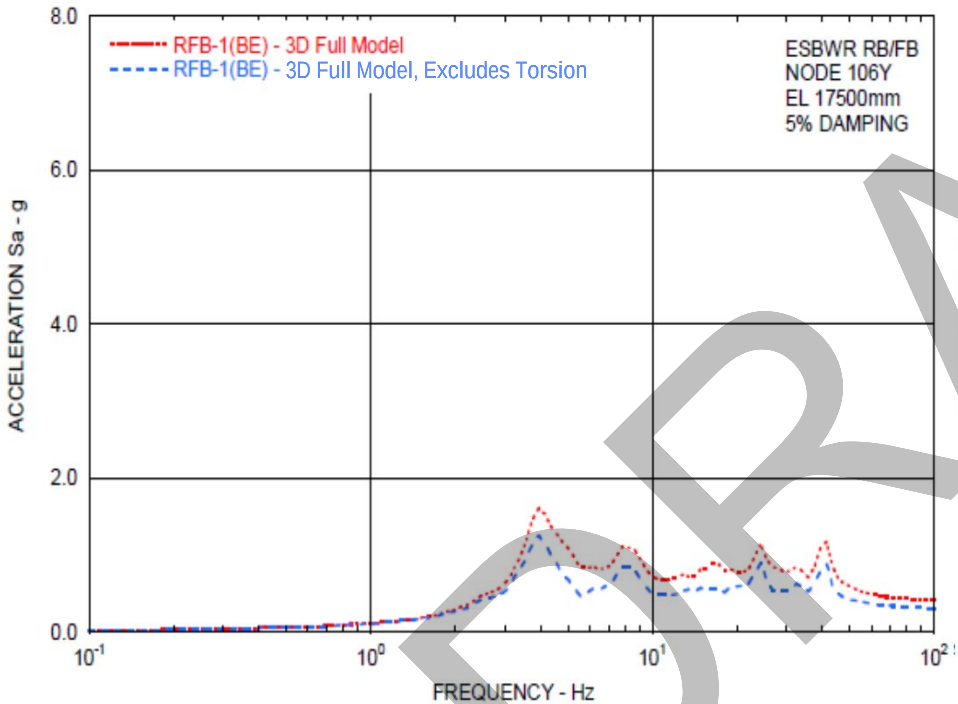
Figure 5a FRS - Y-Direction from SER-DTF-008 (Confirmatory Analysis with Backfill)

MSM Benchmarking – Eccentricity Effects (FRS at Building Edges)

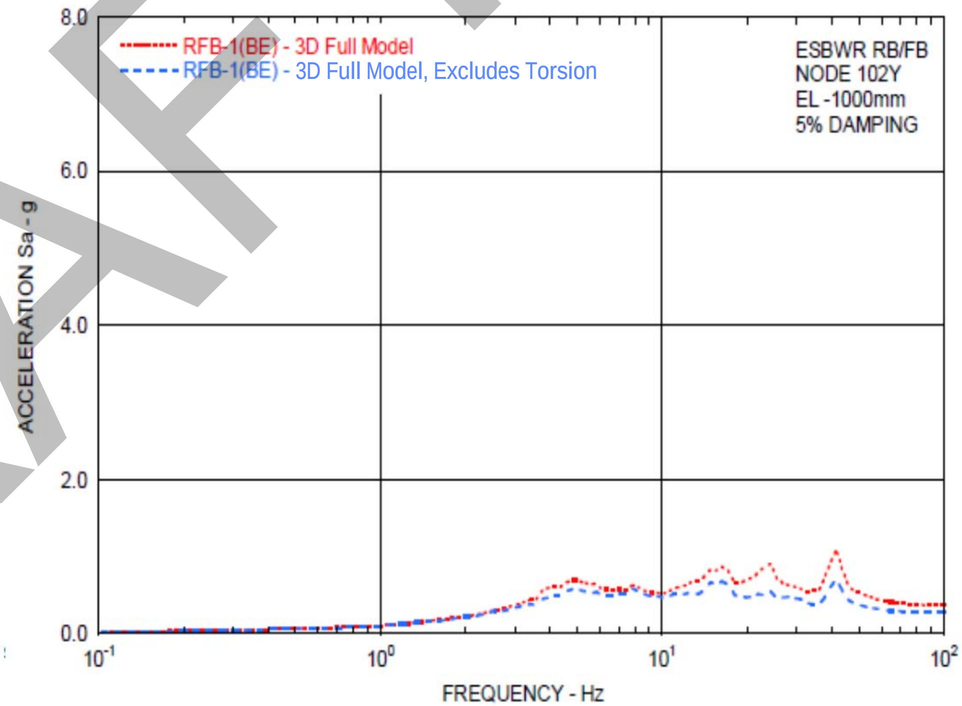
DTE Energy

Full Model - With Torsion Contribution vs. Without Torsion Contribution

FRS at Edge of Building (Confirmatory Analysis with Backfill)



(c) N106, EL 17.5m



(d) N106, EL -1.0m

Figure 5b FRS - Y-Direction from SER-DTF-008 (Confirmatory Analysis with Backfill)