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DTE Energy

10 CFR 52.79

July 9, 2013
NRC3-13-0023

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

References:
1) Fermi 3
Docket No. 52-033
2) Letter from Tekia Govan (USNRC) to Peter W. Smith (DTE Electric), "Request for Additional Information Letter No. 85 Related to Chapters 03.07.02 for the Fermi 3 Combined License Application," dated April 15, 2013
3) Letter from Peter W. Smith (DTE Electric) to USNRC, "DTE Electric Company Response to NRC Request for Additional Information Letter No. 85," NRC3-13-0018, dated May 15, 2013

Subject: DTE Electric Company Revised Response to NRC Request for Additional Information Letter No. 85

In Reference 2, the NRC requested additional information to support the review of certain portions of the Fermi 3 Combined License Application (COLA). The Request for Additional Information (RAI) in Reference 2, RAI 03.07.02-11, is related to the Verification and Validation (V&V) of the SASSI2010 software that is being used in the Fermi 3 site-specific soil-structure interaction (SSI) analyses.

The initial response to RAI 03.07.02-11 (Revision 0) was provided in Reference 3. During a public meeting on June 13, 2013, the NRC staff provided feedback on the initial response to RAI 03.07.02-11. As a result of that feedback, a revised response to RAI 03.07.02-11 is being provided. The revised response to RAI 03.07.02-11 (Revision 1) is provided in Attachment 1. The revised response provided in Attachment 1 supersedes the initial response in its entirety.

If you have any questions, or need additional information, please contact me at (313) 235-3341.

DD95
NRO

I state under penalty of perjury that the foregoing is true and correct. Executed on the 9th day of July 2013.

Sincerely,

Peter W. Smith, Director
Nuclear Development – Licensing and Engineering
DTE Electric Company

Attachment: 1) Response to RAI Letter No. 85 (Question No. 03.07.02-11, Revision 1)

cc: Adrian Muniz, NRC Fermi 3 Project Manager
Tekia Govan, NRC Fermi 3 Project Manager
Michael Eudy, NRC Fermi 3 Project Manager (w/o attachment)
Bruce Olson, NRC Fermi 3 Environmental Project Manager (w/o attachment)
Fermi 2 Resident Inspector (w/o attachment)
NRC Region III Regional Administrator (w/o attachment)
NRC Region II Regional Administrator (w/o attachment)
Supervisor, Electric Operators, Michigan Public Service Commission (w/o attachment)
Michigan Department of Natural Resources and Environment
Radiological Protection Section (w/o attachment)

Attachment 1
NRC3-13-0023
(15 pages)

Response to RAI Letter No. 85
(eRAI Tracking No. 7077)

Revision 1

RAI Question No. 03.07.02-11

NRC RAI 03.07.02-11

DTE Electric Company provided verification and validation (V&V) plan (NRC3-13-0005) for SASSI2010 software to be used for seismic Soil Structure Interaction (SSI) analyses in support of the Fermi 3 Combined License application. During the Fermi 3 audit conducted on March 19 – 21, 2013, the staff reviewed the SASSI validation document entitled "Validation of SASSI2010 Version 1.0-250USER-M01," Revision 1, dated March 18, 2013, which contains the verification and validation performed for the SASSI2010 software, to verify that it is adequate for the Fermi 3 site conditions and site-specific seismic SSI analyses.

During the audit the staff determined that the test problems did not include validation for transfer functions or impedance functions, for frequencies above approximately 20 Hz up to 50 Hz for the Fermi 3 site.

In accordance with 10 CFR Part 50, Appendix S, to ensure that the seismic SSI analyses performed using SASSI2010 in support of the Fermi 3 Combined License application are adequate for the full frequency of interest at the Fermi 3 site, the applicant is requested to supplement the SASSI2010 V&V with additional test problems that address the issue identified above. This RAI also supplements RAI 03.07.02-9.

Revised Response

The initial response to this RAI was provided in letter NRC3-13-0018 (ML13137A549), dated May 15, 2013. This response (Revision 1) supersedes the initial response in its entirety.

The Reactor Building/Fuel Building (RB/FB) and Control Building (CB) at the Fermi 3 site are embedded structures founded on bedrock. Of these two structures, the RB/FB will require consideration of a higher range of dimensionless frequency, A_0 (where $A_0 = 2\pi f R/ V_S$, f = frequency of interest, R = foundation equivalent radius, and V_S = shear wave velocity). The shear wave velocity profiles of the rock below the RB/FB basemat are shown in Table 1. Columns 3, 6, and 9 of this table show the lower bound (LB), best estimate (BE), and upper bound (UB) shear wave velocity profiles, respectively, which are based upon the Central and Eastern United States (CEUS) Seismic Source Characterization (SSC) model. Columns 4, 7, and 10 of Table 1 show the calculated equivalent shear wave velocity profiles (equivalent shear wave velocity for the cumulative depth shown in column 2 and using equivalent shear wave travel time) for the LB, BE, and UB cases, respectively. Columns 5, 8, and 11 of Table 1 provide the calculated dimensionless frequency (A_0) values based on the equivalent shear wave velocity (V_{eq}) and frequency value of 50 Hz ($A_0 = 2*\pi*50*R/ V_{eq}$, where R = 108.4 ft is the equivalent radius of the RB/FB basemat). The largest A_0 value is 10.11, occurring for the LB case at a cumulative depth of 185.4 ft. The largest A_0 value for the CB is less than 5.

A review of the available technical papers and literature for transfer functions and impedance functions for a range of A_0 values up to 10 yielded a single reference (Reference 1), which is for a homogeneous, elastic, isotropic soil profile. For a layered soil profile, Reference 2 has results for A_0 values up to 8. Other references have results for A_0 values up to 6.

Sargent & Lundy developed an in-house computer program, DIMFU (Reference 3), which calculates impedance functions for a rigid circular foundation placed on a layered soil profile using the method proposed by Luco (Reference 2). Since the DIMFU program was developed in

1981, it uses 16-bit DOS based single precision computations and may show some numerical problems at high frequencies.

To address RAI 03.07.02-11, two additional test problems are included in the SASSI2010 validation document. These problems are identified as problem numbers 46 and 47 within the validation document. These test problems examine the transfer functions or impedance functions for frequencies up to 50 Hz. The test problem number 46 is for embedded structures in a homogeneous, elastic, isotropic half-space. The test problem number 47 is for a foundation on a layered soil profile. The following provides detailed description of the test problems and the solution results.

Problem No. 46

This test problem examines scattering response motions of a rigid, massless cylindrical foundation embedded in a homogeneous, elastic, isotropic half-space, and subjected to vertically propagating SV-waves for frequencies up to 50 Hz. The problem is analyzed using SASSI2010 and the translational and rocking transfer functions obtained from SASSI2010 are compared with the results reported by Day (Reference 1).

Model

The geometry of the model is shown in Figure 46-1 and the isometric view of the finite element model of the rigid, massless structure is shown in Figure 46-2. Figure 46-2 also shows the excavated volume. The excavated soil and the rigid, massless structure are attached to independent internal node sets. On the perimeter of the excavation, the excavated soil and the rigid, massless structure are attached to the same nodes. As shown in Figure 46-2, only half of the foundation is modeled. Symmetry about the XZ plane is used to reduce the size of the problem. The foundation radius, R, is equal to 65 ft, and the embedment depth is 32.5 ft. This results in an embedment depth to foundation radius ratio of 0.5 (dimensionless parameter H). The parameter H = 0.5 is selected because Day's solution is provided for H = 0.5, H = 1.0, and H = 2.0. For the Fermi 3 RB/FB, the H value is 0.6 (embedment depth of about 65.6 ft and equivalent radius of about 108.4 ft.), which is close to Day's reported value of H = 0.5.

The soil properties in the model are:

Shear wave velocity, V_S = 2,000 ft/sec

Material damping = 0.01

Weight density = 128.68 pcf

Poisson's ratio = 0.25

Compression wave velocity, V_P = 3464.1 ft/sec

The SASSI2010 soil layer model consists of four top layers and a half-space below. The thickness of each top layer is 8.125 ft. The cylindrical excavated volume and the foundation are modeled using solid elements. There are 512 solid elements in the excavated volume and 512 solid elements in the cylindrical foundation. There are 570 interaction nodes. The element sizes of the excavated volume are such that none exceed 8.125 ft. Per the SASSI2010 User's Manual, the passing frequency of the model is:

$f = V_S / (5*h)$ = 49.22 Hz (about 50 Hz)

This gives a dimensionless frequency of

$A_0 = 2 \pi f R / V_S = 10$

SASSI2010 Analysis

The direct (flexible volume) method is used for the analysis and the control motion is specified at the ground surface.

Comparison of SASSI2010 Results with Day's Solution

Figure 46-3 shows the comparison of translational responses (transfer functions) from SASSI2010 and Day's solution. Figure 46-4 shows the comparison of rocking responses (transfer functions) from SASSI2010 and Day's solution. The results are plotted for A_0 values up to 10 (about 50 Hz). The transfer functions are for the center node at the base of the rigid massless cylindrical foundation.

Based on these comparisons, it is concluded that the results from SASSI2010 and the results reported by Day (Reference 1) are in good agreement, except at an A_0 value of about 6.8, where the SASSI2010 response value is about 30% higher. This is an isolated deviation and its impact on the total response from SASSI2010 analysis is negligible.

Problem No. 47

The test problem is to validate the impedance functions of a rigid, massless foundation on a layered soil profile for frequencies up to about 50 Hz.

Model

The model consists of 65 ft radius, rigid, massless foundation on a layered rock profile. The isometric view of the structural model of the rigid foundation is shown in Figure 47-1. The foundation is modeled by 10 ft thick concrete solid elements. The concrete foundation is on the top of a layered rock profile, which is representative of the Fermi 3 site underneath the RB/FB foundation. The shear wave velocity profiles of the rock below the RB/FB basemat are shown in Table 1. Columns 3, 6, and 9 of this table show the LB, BE, and UB shear wave velocity profiles, respectively, which are based upon the CEUS SSC model. Columns 4, 7, and 10 of Table 1 show the calculated equivalent shear wave velocity profiles (equivalent shear wave velocity for the cumulative depth shown in column 2 and using equivalent shear wave travel time) for the LB, BE, and UB cases, respectively.

The LB shear wave velocity profile shown in column 3 of Table 1 is adjusted for an A_0 value of 10 for the equivalent shear wave velocity for the model depth of twice the diameter of foundation (260 ft). The adjusted shear wave velocity profile for the model is shown in column 6 of Table 47-1. The rock layers are further divided into sub-layers with thicknesses for transmitting the minimum passing frequency of 50 Hz using the 20% shear wave length criteria.

SASSI2010 and DIMFU Analyses

The model described above is analyzed using SASSI2010 and DIMFU for calculating the impedance functions for A_0 values up to 10. In SASSI2010 analysis, the direct (flexible volume) method is used.

Comparison of SASSI2010 Results with DIMFU Results

The comparisons of the impedance functions calculated from SASSI2010 and DIMFU are provided in Figure 47-2 through Figure 47-5. The comparisons show the following:

- The horizontal stiffness constants from SASSI2010 match well with DIMFU results for A_0 values up to about 10.
- The horizontal damping coefficients from SASSI2010 match well with DIMFU results for A_0 values up to 10.
- The rocking stiffness constants from SASSI2010 match well with DIMFU results for A_0 values up to about 7.2 (from A_0 values of 1.5 to about 3.6, the rocking stiffness coefficients from SASSI2010 are about 17% higher than from DIMFU). Above A_0 values of 7.2, DIMFU results show some numerical instability. Between A_0 values of 7.2 and 8.6, the difference is about 50%. The A_0 value of 7.2 corresponds to a frequency of 36 Hz.
- The rocking damping coefficients from SASSI2010 match well with DIMFU results, for A_0 values up to 10.

The foundation total rocking stiffness, [$K = Kmm(A_0) + i \times A_0 \times Cmm(A_0)$], is the sum of equivalent stiffness constants (real part of the impedance functions, Kmm) and equivalent damping coefficients (imaginary part of the impedance functions, Cmm). The discrepancies in total rocking stiffness above A_0 of 7.2 will be less than 50%.

In addition, calculation of the cumulative power (energy) of the two horizontal direction input acceleration time histories for Fermi 3 RB/FB shows that more than 90% of energy is captured at a frequency of 36 Hz (see Figure 47-6). The 36 Hz frequency corresponds to an A_0 value of 7.2. Note that the rocking response is a small contributor to the overall horizontal response. In addition, for high frequency, typically the response is controlled by the UB soil profile for which the A_0 value is below 7. Hence, any possible deficiency in the calculation of rocking stiffness / damping coefficients for A_0 values greater than 7.2 will have insignificant effect on the SSI results. Furthermore, this will have no impact on the calculated soil pressures from the SSI analyses since soil pressures are a low frequency phenomenon.

Based on the above, it is concluded that for a layered soil profile, impedance functions calculated by SASSI2010 are adequate for the SSI analysis of the RB/FB and CB at the Fermi 3 site.

Conclusion:

Based on the results of test problems 46 and 47 presented above, it is concluded that for the RB/FB and CB at Fermi 3 site, the SASSI2010 transfer functions are adequate for the full frequency range of interest (i.e., up to 50 Hz).

References:

1. Day, S. M. 1977, “Finite Element Analysis of Seismic Scattering Problem,” Doctoral dissertation, University of California, San Diego.
2. Luco, J. E, “Vibration of Rigid Disc on a Layered Viscoelastic Medium,” Nuclear Engineering and Design, No. 35, 1976, pp. 325-340.
3. S&L Propriety Program DIMFU (Dynamic Impedance Function), Program No. 03.7.385-1.0o.

Proposed COLA Markup

None.

Table 1: Fermi 3 Soil (Rock) Profile Shear Wave Velocity Characteristics for Rock Below RB/FB Basemat

Soil (Rock) Shear Wave Velocity Below Building Foundation – Reactor Building / Fuel Building										
Layer Thickness (ft)	Cumul-ative Depth (ft)	Lower Bound Soil			Best Estimate Soil			Upper Bound Soil		
		Shear Wave Velocity (ft/sec)	Equiv. Shear Wave Velocity (ft/sec)	Dimension-less Frequency Ao	Shear Wave Velocity (ft/sec)	Equiv. Shear Wave Velocity (ft/sec)	Dimensionl-ess Frequency Ao	Shear Wave Velocity (ft/sec)	Equiv. Shear Wave Velocity (ft/sec)	Dimensio-nless Frequency Ao
2.1	2.1	5460	5460	6.23	6687	6687	5.09	8189	8,189	4.16
9.7	11.8	5436	5440	6.26	6658	6663	5.11	8154	8,160	4.17
11.1	22.9	5383	5412	6.29	6593	6629	5.13	8074	8,118	4.19
12	34.9	5356	5393	6.31	6560	6605	5.15	8035	8,089	4.21
12.1	47	5389	5392	6.31	6600	6604	5.15	8083	8,088	4.21
15	62	3734	4869	6.99	4573	5963	5.71	5601	7,303	4.66
20.3	82.3	2779	4107	8.29	3403	5030	6.77	4187	6,170	5.52
20	102.3	2793	3761	9.05	3455	4618	7.37	4231	5,663	6.01
20	122.3	2768	3553	9.58	3390	4360	7.81	4151	5,345	6.37
21	143.3	2718	3400	10.01	3328	4170	8.16	4370	5,175	6.58
21	164.3	3254	3380	10.07	4091	4160	8.18	5190	5,177	6.57
21.1	185.4	3273	3368	10.11	4166	4161	8.18	5260	5,187	6.56
10.1	195.5	4532	3413	9.97	5551	4215	8.07	6798	5,251	6.48
20.2	215.7	7726	3601	9.45	9462	4446	7.66	11589	5,534	6.15
21	236.7	7701	3780	9.01	9432	4665	7.30	11552	5,803	5.87
21	257.7	7763	3945	8.63	9507	4867	6.99	11644	6,050	5.63
20.3	278	7614	4089	8.32	9325	5043	6.75	11421	6,265	5.43
45	323	7312	4356	7.81	8956	5370	6.34	10968	6,663	5.11
45.2	368.2	7331	4585	7.42	8978	5649	6.03	10996	7,002	4.86

Table 47-1: Adjusted Shear wave Velocity for 65 ft Diameter Foundation

Adjusted Rock Shear Wave Velocity from LB of RB/FB for Massless Foundation Analysis					
Layer Thickness (ft)	Cumulative Depth (ft)	Shear Wave Velocity (ft/sec)	Equivalent Shear Wave Velocity (ft/sec) at Cumulative Depth	Dimensionless Frequency (A_o) of RB/FB	Adjusted Shear Wave Velocity (ft/sec) for A_o = 10 and R = 65 ft
2.1	2.1	5460	5460	6.23	2814.3
9.7	11.8	5436	5440.26	6.26	2801.9
11.1	22.9	5383	5412.35	6.29	2774.6
12	34.9	5356	5392.84	6.31	2760.7
12.1	47	5389	5391.85	6.31	2777.7
15	62	3734	4868.86	6.99	1924.6
20.3	82.3	2779	4107.04	8.29	1432.4
20	102.3	2793	3761.09	9.05	1439.6
20	122.3	2768	3552.65	9.58	1426.7
21	143.3	2718	3399.66	10.01	1401.0
21	164.3	3254	3380.32	10.07	1677.2
21.1	185.4	3273	3367.75	10.11	1687.0
10.1	195.5	4532	3413.05	9.97	2336.0
20.2	215.7	7726	3601.32	9.45	3982.3
21	236.7	7701	3779.85	9.01	3969.4
21	257.7	7763	3944.79	8.63	4001.3
2.3	260	7614	3961.68	8.59	3924.5

Figure 46-1: Geometry of Cylindrical Foundation Cross Section

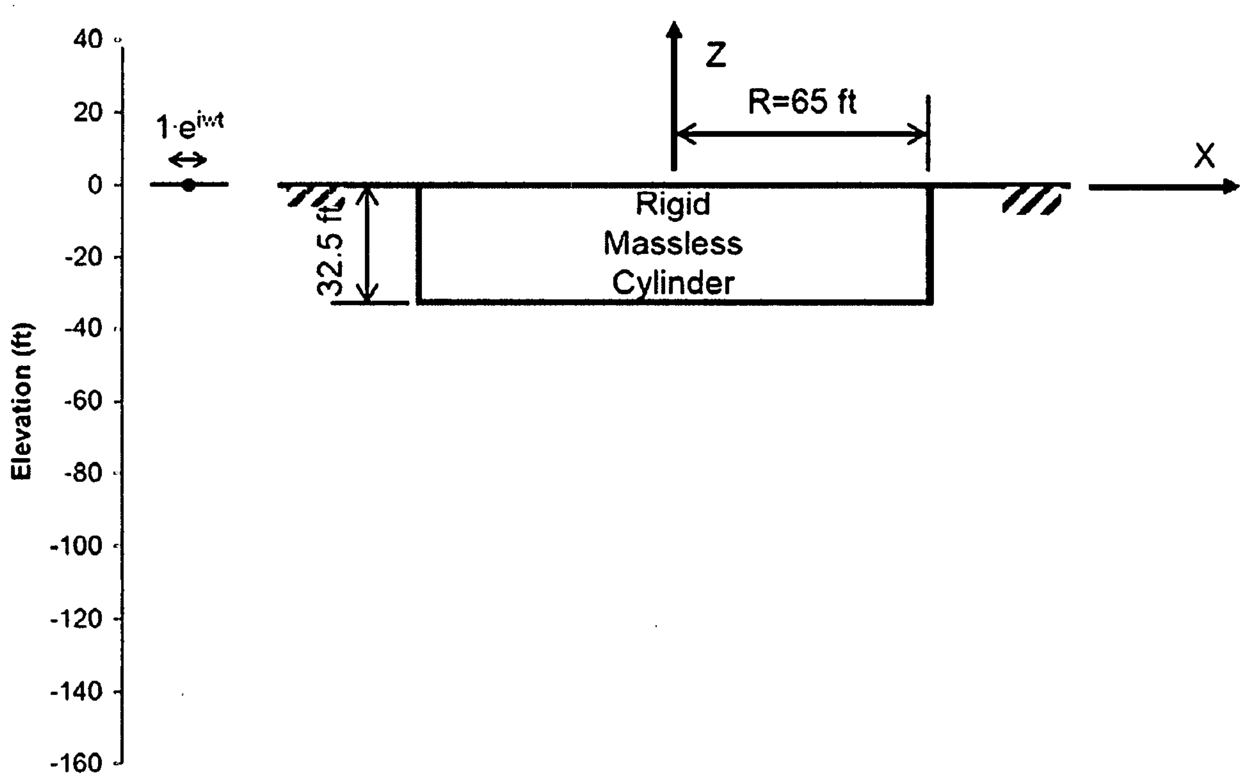

Figure 46-2: Isometric View of Finite Element Model

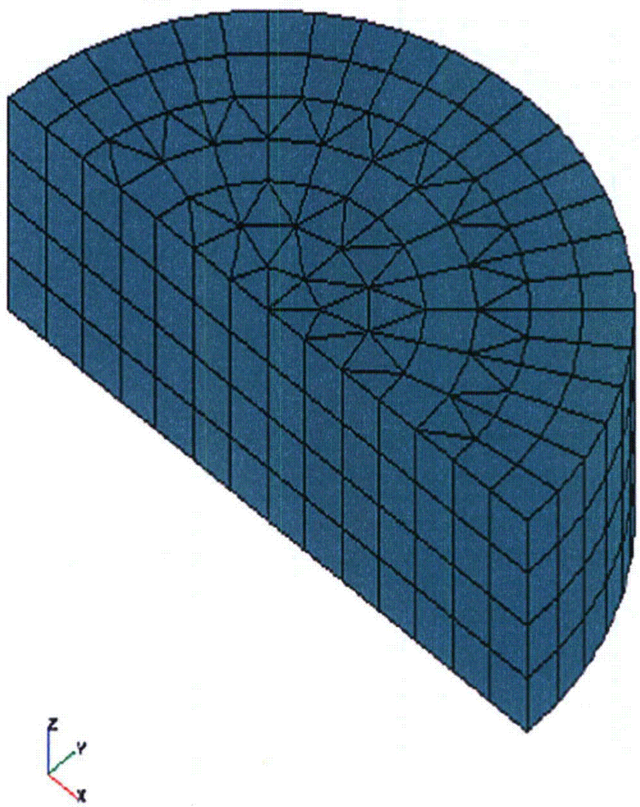

Figure 46-3: Translational Response due to Vertically Propagating SV-Wave, H = 0.5

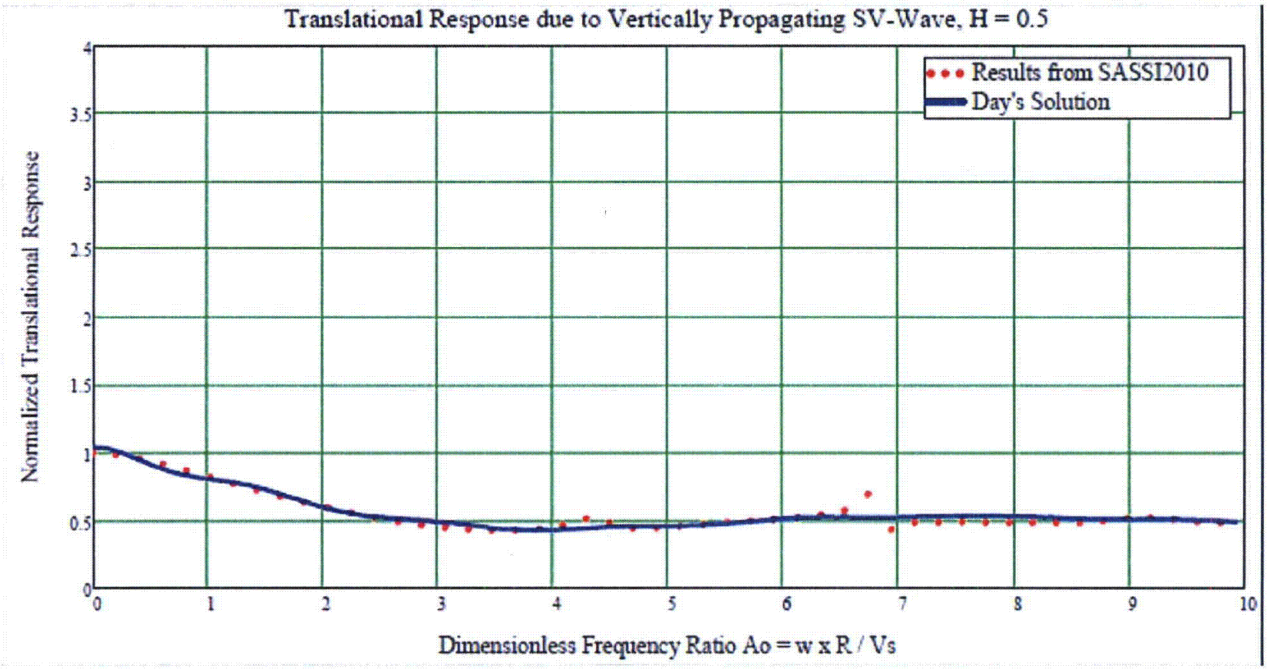

Figure 46-4: Rocking Response due to Vertically Propagating SV-Waves, H = 0.5

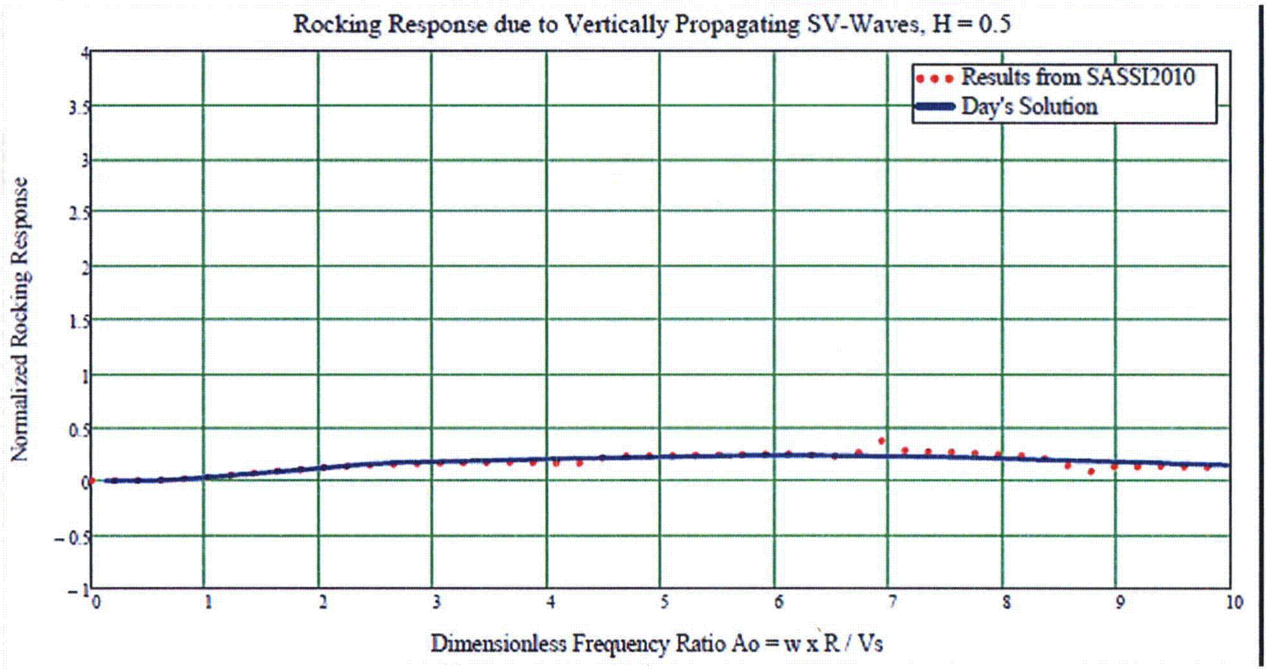

Figure 47-1: Isometric View of 65 ft Radius Rigid Massless Foundation

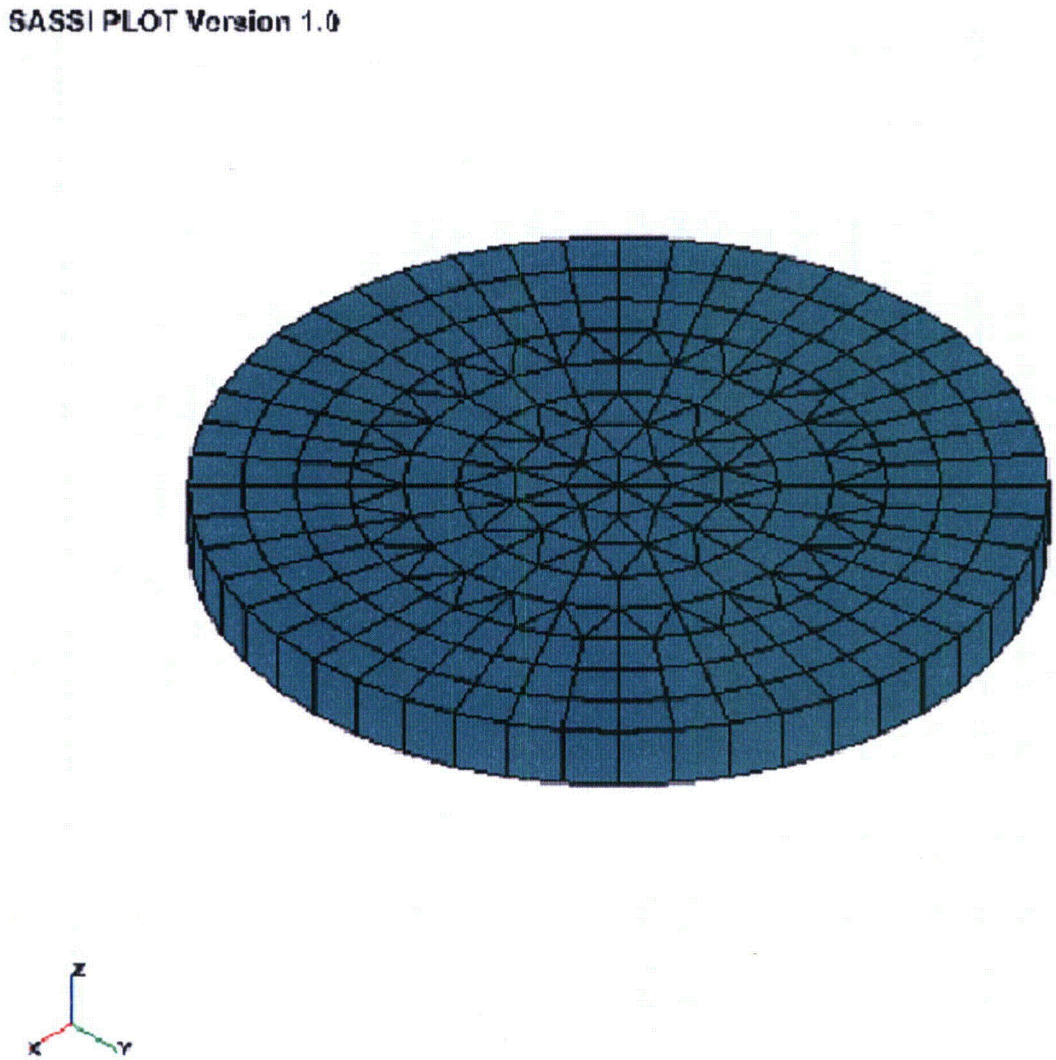

Figure 47-2: Comparison of Horizontal Stiffness Constants Between SASSI2010 and DIMFU

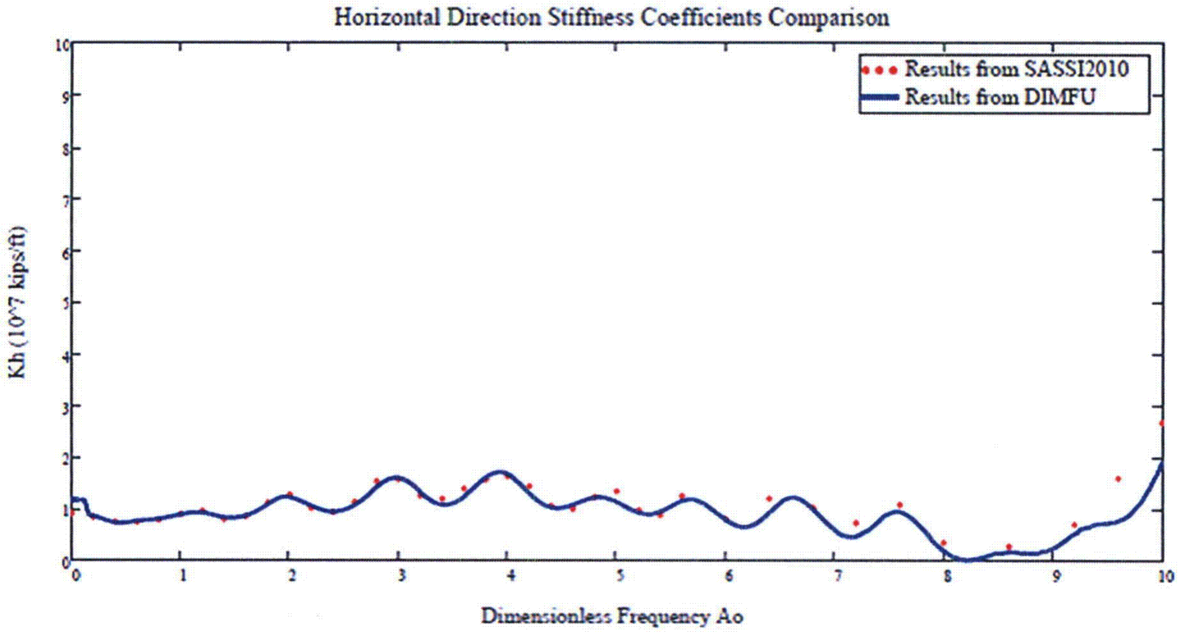

Figure 47-3: Comparison of Horizontal Damping Coefficients Between SASSI2010 and DIMFU

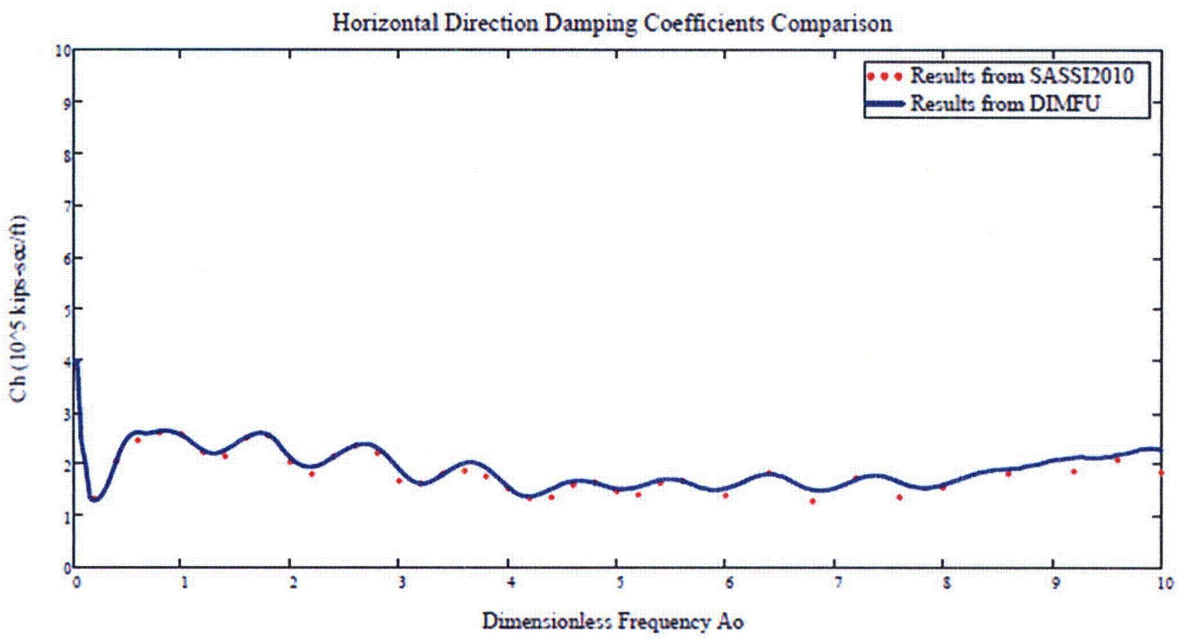

Figure 47-4: Comparison of Rocking Stiffness Constants Between SASSI2010 and DIMFU

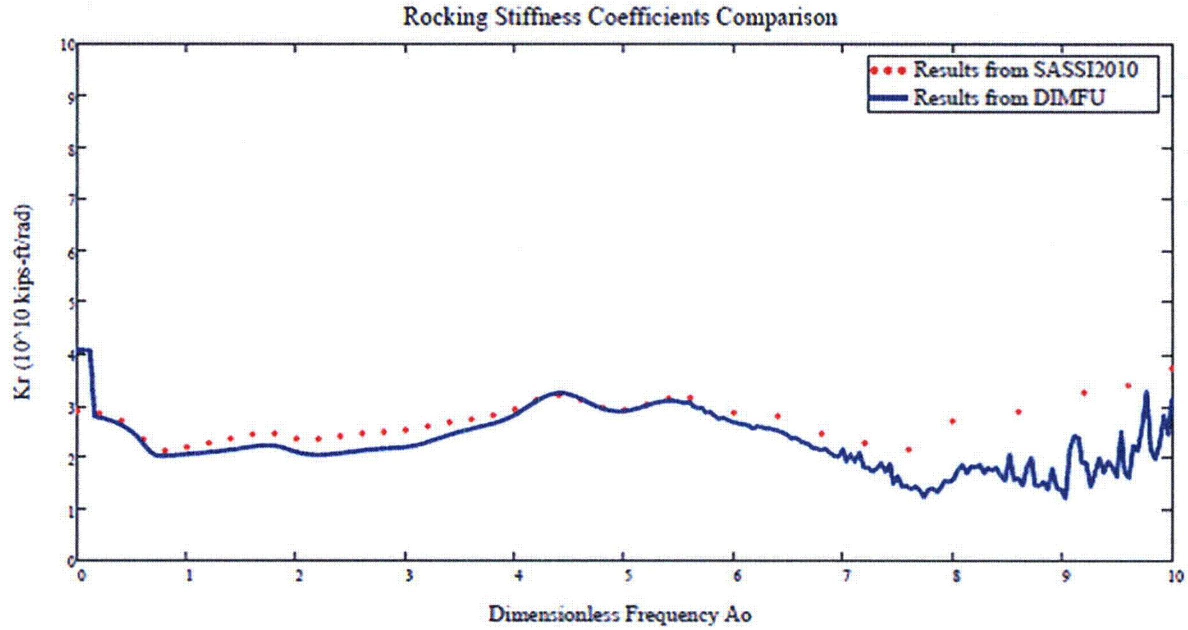

Figure 47-5: Comparison of Rocking Damping Coefficients Between SASSI2010 and DIMFU

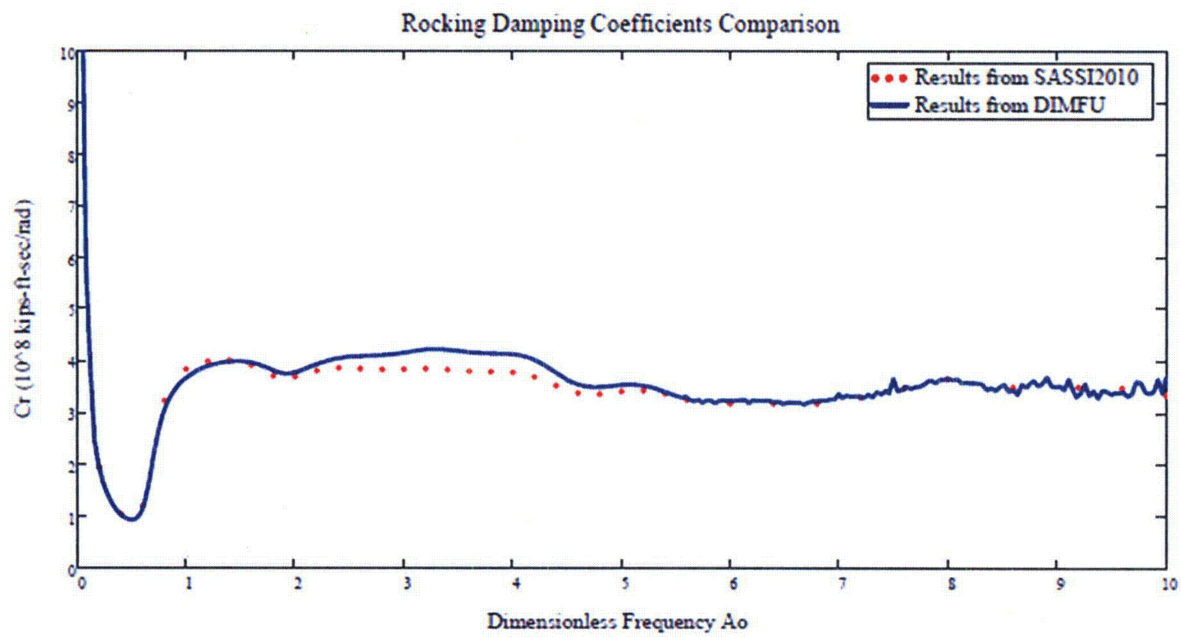

Figure 47-6: RB/FB Cumulative Power for UB SSI Profile for H2 Time History, PBSRS Profile (90.2% at 36 Hz)