Nuclear Innovation
North America LLC
4000 Avenue F, Suite A
Bay City, Texas 77414

November 28, 2011
U7-C-NINA-NRC-110144

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville MD 20852-2738

South Texas Project
Units 3 and 4
Docket Nos. 52-012 and 52-013
Response to Request for Additional Information

Attachment 1 provides the response to NRC staff question 03.07.01-30 included in the Request for Additional Information (RAI) letter number 386 related to COLA Part 2, Tier 2, Section 3.7. This attachment completes the response to this RAI letter.

Attachments 2 and 3 provide revised and supplemental responses to NRC staff question 03.07.02-13 related to COLA Part 2, Tier 2, Section 3.7. During audits of May 23-27, 2011, July 25-29, 2011, and September 27-30, 2011, the NRC Staff requested that Nuclear Innovation North America LLC (NINA) provide additional information to support the review of the Combined License Application (COLA). These attachments complete the responses to this RAI and the actions requested by the NRC Staff.

There are no commitments in this letter.

If you have any questions regarding these responses, please contact me at (361) 972-7136 or Bill Mookhoek at (361) 972-7274.

D091
NRO

STI 33137378

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 11/28/11

Scott Head
Manager, Regulatory Affairs
South Texas Project Units 3 & 4

jep

Attachments:

1. RAI 03.07.01-30
2. RAI 03.07.02-13, Supplement 3, Revision 1
3. RAI 03.07.02-13, Supplement 4

cc: w/o attachment except*

(paper copy)

Director, Office of New Reactors
U. S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

Regional Administrator, Region IV
U. S. Nuclear Regulatory Commission
1600 E. Lamar Blvd
Arlington, TX 76011–4511

Kathy C. Perkins, RN, MBA
Assistant Commissioner
Division for Regulatory Services
Texas Department of State Health Services
P. O. Box 149347
Austin, Texas 78714-9347

Alice Hamilton Rogers, P.E.
Inspection Unit Manager
Texas Department of State Health Services
P. O. Box 149347
Austin, Texas 78714-9347

*Steven P. Frantz, Esquire
A. H. Gutterman, Esquire
Morgan, Lewis & Bockius LLP
1111 Pennsylvania Ave. NW
Washington D.C. 20004

*Tom Tai
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852

(electronic copy)

*George F. Wunder
*Tom Tai
*Stacy Joseph
Charles Casto
U. S. Nuclear Regulatory Commission

Jamey Seely
Nuclear Innovation North America

Peter G. Nemeth
Crain, Caton and James, P.C.

Richard Peña
Kevin Pollo
L. D. Blaylock
CPS Energy

RAI 03.07.01-30

QUESTION:

The Defense Nuclear Facilities Safety Board (DNFSB) has identified a technical issue in SASSI that when subtraction method is used to analyze embedded structures, the results may be non-conservative. Consequently, the staff issued RAI 03.07.01-29 requesting NINA to demonstrate acceptability of the STP design and analyses completed using SASSI subtraction method to meet the requirements of 10 CFR 50 Appendix S. On July 27 and 28, 2011, an audit was conducted at the Sargent & Lundy (S&L) office in Chicago, Illinois, to discuss the status and results of the evaluation performed in support of responding to RAI 03.07.01-29. Based on this audit, the staff has identified additional concerns on the evaluation performed by the applicant. As such, the applicant is requested to address and clarify the following issues:

1. Demonstrate that the amplified seismic input **(i.e., amplified input spectra due to presence of the nearby heavy structures)**, if generated by using the Subtraction Method (SM) for DGFOT, RSWPT, DGFOSV, and any other structures as applicable would be conservative as compared to those obtained using the Modified Subtraction Method (MSM) or the Direct Method (DM). Alternatively, the applicant may use amplified spectra derived from the use of MSM or the DM.

2. While SSI soil pressures obtained using both the SM and the MSM were in general comparable (See Figure 4.13 of July 27 & 28 audit presentation, SASSI Issues Raised by the DNFSB Letter to DOE), the results, presented at July 27, audit, did not fully demonstrate acceptability of the soil pressure distribution obtained from either the MSM or SM in comparison to results obtained from the DM. STP's project specific confirmation of the MSM method (using CB SSI analysis) or the SSSI analysis performed for one model (consisting of RWB, RSW Tunnel, and RB) did not include any comparison of the transfer functions of the soil pressure parameter at the interaction nodes at the exterior walls and the interacting adjacent building walls. The applicant is requested to further demonstrate that the soilpressure distribution obtained from the SM or MSM method is acceptable and is conservative for use in seismic design.

3. For SSSI analysis (for soil pressure determination considering interaction of adjacent building), only one model (consisting of RWB, RSW Tunnel, and RB) was evaluated using the DM, SM, and MSM. STP has completed the analysis only for the lower bound soil case (UB case using backfill will also be performed). Preliminary results indicate that absolute soil pressure profile obtained from SM and MSM in some instances (particularly for exterior walls) did not compare well with those obtained from the DM. However, maximum total wall force (obtained from the TH analysis) due to soil pressure in general is within 5% for all three methods (Table 5.1 of July 27 & 28 audit presentation, SASSI Issues Raised by the DNFSB Letter to DOE). Based on this analysis, STP preliminarily concluded that the total soil pressure on the embedded wall obtained from SM is acceptable. However, the applicant is requested to further clarify the entries (including how they were computed) as presented in Table 5.1 provided by STP at July 27 Audit.

4. The applicant is requested to reassess the seismic demand for stability evaluation of any applicable Category I and II/I structures in light of the DNFSB issue and confirm acceptability of the factors of safety against stability during an SSE.

5. The applicant is requested to review all the Punch List Items and any applicable RAI responses to determine if any of the responses previously provided should be revised as a result of the assessment performed for addressing DNFSB issues.

6. The issue of zero SSSI pressure on portions of the RSWPH North wall (Figure 3H.6-219, letter U7-C-NINA-NRC-110096) was further discussed with STP at July 27, 2011 meeting. It was indicated that there is a gap at these locations between the RSWPT south wall and the RSWPH north wall filled by the compressible material. However, for better clarity and understanding of the analysis model, STP is requested to provide an engineering sketch showing typical sections between the RSWPT and RSWPH including the tunnel entries to the RSWPH.

   In addition it was noted that Section 7 of Figure 1 (see seismic soil pressure handout of July 27 & 28, 2011 meeting) was cut through RSWPH north wall, inter space between the tunnel entries to the RSWPH north wall, RSW tunnel cross section, and other buildings. However Figure 3H.6-211 (see letter U7-C-NINA-NRC-110042 - 2D SSSI model of RSWPH, RSWPT, DGFOSVs, and RB) indicates that the actual SSSI model section has been cut through the tunnel entries to the RSWPH instead of the inter space between the tunnel entries as depicted in Section 7. While the SSSI model analyzed appears to be consistent with the soil pressure shown in Figure 3H.6-219, the resulting SSSI pressure may not conservatively represent the interaction pressure that could develop on the RSWPH North wall and RSWPT south wall through interaction of soil in the space enclosed by the tunnel entries, RSWPH North wall, and RSWPT south wall. The applicant is requested to address this issue and demonstrate that SSSI interaction pressure used for design is still conservative.

RESPONSE:

For response to questions 1 through 3, 5 and 6, see responses to Punch List Items 143 through 145, 147 and 148 provided in Sections "G", "H", "I", "K", and "L" of RAI 03.07.01-29 Supplement 1, Revision 1, respectively. For response to question 4, see response to Punch List Item 146 provided in Section "D" of RAI 03.07.02-13 Supplement 4. RAI 03.07.01-29 Supplement 1, Revision 1 and RAI 03.07.02-13 Supplement 4 are being submitted concurrently with this response.

RAI 03.07.02-13, Supplement 3, Revision 1

QUESTION:

(Follow-up Question to RAI 03.07.02-1)

With regard to Item c of the response to RAI 03.07.01-13, the applicant is requested to address the following:

1. The FSAR mark-up in the response to item (b) of RAI 03.07.02-1, did not include the list of non-Category I structures requiring the enhanced seismic design and analysis. The applicant is requested to include in FSAR 3.7.2.8 the five identified non-Category I structures that could interact with the Category I structures.

2. The response to item (c) of RAI 03.07.02-1 indicated that non-Category I structures with the potential to interact with Category I structures have not yet progressed to a point where sliding and overturning potential as a result of the SSE can be evaluated. However, as identified in SRP guidance 3.7.2I.8., the staff must review the applicant's seismic design of these non- Category I structures. As such, the applicant is requested to provide in the FSAR factors of safety against sliding and overturning including the basis of coefficient of friction used in the analysis during an SSE for Turbine Building, Radwaste Building, Service Building, Control Building Annex, and Plant Stack.

REVISED SUPPLEMENTAL RESPONSE:

The Supplement 3 response to this RAI was submitted with Nuclear Innovation North America (NINA) letter U7-C-NINA-NRC-110103 dated July 27, 2011. This supplement provided the response to the following action items discussed in the NRC audit performed during the week of May 23, 2011. This response is revised in accordance with Punch List Item 136 (Action Item 3.7-56) to clarify if there is any soil structure interaction (SSI) analysis for Service Building and also clarify the response for Turbine Building and Service Building. The revisions are indicated by revision bars in the margin.

a. *Clearly describe in the FSAR how seismic demand for non-seismic II/I structures for stability evaluation is determined (Clarification Issue 3, Punch List Item 14)*

   See revised COLA Sections 3.7.2.8 and 3.7.3.16 in Enclosure 1.

b. *Revise RWB stability calculation considering amplified motion at ground surface and revise COLA as necessary (Audit Action Item 3.7-39, Punch List Item 73)*

   The Radwaste Building (RWB) stability calculation has been revised using the amplified site-specific SSE motions at ground surface. These amplified motions are shown in new COLA Figures 3.7-44 through 3.7-46 in Enclosure 1. The revised sliding and overturning factors of safety are provided in revised Table 3H.6-14 in Enclosure 1.

c. *Clarify title for Figure 3H.6-137 to specify that it is applicable to Category I site-specific structures (Clarification Issue 17.5, Audit Action Item 3.8-33, Punch List Item 81)*

The title of Figure 3H.6-137 has been revised to specify that the figure is applicable to stability evaluation of Category I site-specific structures. See Enclosure 1 for revised Figure 3H.6-137.

d. *Add the factor of safety for flotation in Table 3H.6-14 (Audit Action Item 3.7-43, Punch List Item 88)*

COLA Table 3H.6-14 has been revised to include flotation safety factors. See Enclosure 1 for revised Table 3H.6-14.

e. *Turbine Building Seismic Calculation, Fluor calculation number U3-TB-S-CALC-DESN-2100 Rev B, should be revised for the following (Audit Action Item 3.7-45, Punch List Item 90):*

1) *Assumption 1 on sheet 9 of 288 should be clarified to clearly describe how mass and stiffnesses were derived from different Turbine Building models*

Design of the Turbine Building (TB) is being performed using a full scale three-dimensional (3D) model of the building which is created using RISA-3D software. The lumped masses for the fixed base stick models of the building were calculated from this 3D model. The stiffness values for the springs between the nodal masses of the stick models were also determined using this model. In order to determine the stiffness of a spring between two elevations, the following were performed:

- At the upper elevation, the translations perpendicular to the direction for which the stiffness was being determined were restrained.
- At the lower elevation all translations were restrained.
- A known load was applied at the upper elevation in the direction for which the stiffness was being determined to obtain the translation of the upper nodal mass in the corresponding direction.
- Knowing the applied load and the reported translation, the stiffness was determined as the ratio of the applied load over the reported translation.

Assumption 1 will be clarified to reflect the above.

2) *On sheet 8 of 288, correct Reference 3 document number from U3-TB-S-CALC-DESN-2001 to U7-TB-S-CALC-DESN-2001*

Reference 3 document number U3-TB-S-CALC-DESN-2001 will be replaced with document number U7-TB-S-CALC-DESN-2001.

3) *Revise Section 5.15 to clearly describe how the seismic demand was determined. For example, clarify the statement in the last paragraph of sheet 250 "after running the RSA static analysis is then run with the RSA results to determine the base shear". Also describe how the RISA analysis was done in 3 directions and how the 3 directional responses were combined*

The seismic demand is determined from Response Spectrum Analyses (RSA) of six fixed base stick models using RISA-3D computer program as outlined below:

- For each orthogonal direction (i.e. E-W, N-S and Vertical), two fixed base stick models are used, one representing the turbine generator pedestal and another representing the Turbine Building. Note that turbine generator pedestal shares a common basemat with the Turbine Building.
- Site-specific SSE input motions are used
- Complete Quadratic Combination (CQC) method of combination is used for modal combinations
- For each orthogonal direction, the seismic demand from the RSA of turbine generator pedestal and Turbine Building stick models are combined using absolute sum and further increased to account for base mass effect. This increase is calculated by exciting the base mass using the zero-period-acceleration (ZPA) of the corresponding site-specific SSE input motion.
- Finally the total seismic demand due to three seismic excitations is determined by combining the seismic demand for each orthogonal direction using the 100-40-40 rule outlined in Regulatory Guide 1.92, Rev. 2.

Section 5.15 of the calculation will be revised to reflect the above clarification.

For COLA revisions as a result of this part of the response see mark-up to COLA Sections 3.7.2.8 and 3.7.3.16 in Enclosure 1.

f. For Service Building stability calculation (U3-SB-S-CALC-DESN-2100 Rev. B), expand Section 5.14 to fully describe how the seismic analysis was performed and specifically address the following (Audit Action Item 3.7-47, Punch List Item 97):

1) *How the stick model mass and stiffness were calculated or provide a copy of Ref. No. 23, U3-SB-CALC-DESN-2001 Rev. 0, "Calculation of Service Building Mass and Stiffness Model" for review.*

No SSI analysis is performed for the Service Building. The seismic demand for the stability evaluation is determined from Response Spectrum Analyses (RSA) of two fixed base stick models using RISA-3D computer program as outlined below:

- For each horizontal direction (i.e. E-W and N-S), a fixed base stick model is used.

- The stick models' mass and stiffness are determined in a manner similar to that described for TB in part e.1 of this response.
- The input motions are amplified site-specific SSE motions accounting for the effect of nearby Reactor and Control buildings.
- Complete Quadratic Combination (CQC) method of combination is used for modal combinations.
- For each horizontal direction, the seismic demand from the RSA is increased to account for base mass effect. This increase is calculated by exciting the base mass using the zero-period-acceleration (ZPA) of the corresponding amplified site-specific SSE input motion.
- The seismic demand for the vertical excitation is computed using the ZPA of the vertical amplified site-specific SSE input motion.
- Finally the total seismic demand due to three seismic excitations is determined by combining the seismic demand for each orthogonal direction using the 100-40-40 rule outlined in Regulatory Guide 1.92, Rev. 2.

2) *RSA details:*
   a) *Modal combination method*
   b) *Combination of 3 directional responses*

See response to part 1 above.

3) *Attachment 01 sheets 4 and 5, what are modes 5 and 6 with frequency > $3.0x10^8$ Hz?*

Each stick model represents the mass and stiffness in one orthogonal direction and the model is restrained in the remaining two orthogonal directions. These modes represent rigid body motion in the restrained directions.

Section 5.14 of the calculation will be revised to reflect the above clarifications.

For COLA revisions as a result of this part of the response, see mark-up to COLA Sections 3.7.2.8 and 3.7.3.16 in Enclosure 1.

g. *Revise the Control Building Annex stability evaluation to use ASCE 7-05 instead of ASCE 7-88. Check for two cases, (1) with live load for both the stabilizing force and the driving force and (2) with no live load for either the stabilizing force or the driving force (Audit Action Item 3.8-42, Punch List Item 101)*

The Control Building Annex (CBA) stability evaluation calculation has been revised as requested. There is no change in the reported stability factors of safety reported in COLA Table 3H.6-14 due to the following:

- Wind loading per ASCE 7-88 is more critical than wind loading per ASCE 7-05
- Factors of safety for sliding and overturning when considering no live load are equal or higher than those with live load consideration.

h. *Staff requests additional description of foundations in FSAR 3.8.5. Applicant will provide a brief description of the foundations, foundation analysis, and differential settlement determination, including consideration of construction sequence (Punch List Item 108)*

See new COLA Sections 3.8.5.8 and 3.8.5.9 provided in Enclosure 1 for description of foundations for Diesel Generator Fuel Oil Tunnels (DGFOT) and Category I site-specific structures, respectively.

Enclosure 1

COLA MARK-UPS

These COLA Part 2, Tier 2 mark-ups are based on COLA Revision 5 and subsequent mark-ups provided in RAI responses submitted through March 25, 2011.

Note that additional changes to Table 3H.6-14 and Figure 3H.6-137 are provided in RAI 03.07.02-13, Supplement 4 which is being submitted concurrently with this response.

3.7.2.8 Interaction of Non-Seismic Category I Structures, Systems and Components with Seismic Category I Structures, Systems and Components

The Category I structures and their physical proximity to nearby non-Category I structures are shown in Figure 3.7-40. None of the non-Category I structures proposed as part of STP Units 3 and 4 is intended to meet Criterion (2) of DCD Section 3.7.2.8. Rather, for each non-Category I structure, either: (1) it is determined that the collapse of the non-Category I structure will not cause the non-Category I structure to strike a Category I structure; or (2) the non-Category I structure will be analyzed and designed to prevent its failure under SSE conditions in a manner such that the margin of safety of the structure is equivalent to that of Seismic Category I structures. Non-Category I structures that can interact with Seismic Category I structures include the Turbine Building (TB), Radwaste Building (RWB), Service Building (SB), Control Building Annex (CBA) and the stack on the Reactor Building roof. ~~Table 3H.6-14 provides sliding and overturning factors of safety under site-specific SSE for TB, RWB, SB, and CBA.~~

The seismic input motions for the II/I design of the five non-seismic category I structures noted above are described in the following:

- TB: 0.3g Regulatory Guide 1.60 spectra.
- RWB: as described in Sections 3.7.3.16 and 3H.3.5.3 and shown in Figures 3.7-~~40~~41 through 3.7-~~42~~43.
- SB: as described in Section 3.7.3.16 ~~0.3g Regulatory Guide 1.60 spectra.~~
- CBA: as described in Section 3.7.3.16 and shown in Figures 3.7-38 and 3.7-39.

Stack on the Reactor Building roof: seismic loading at its location, resulting from the SSE analysis of the Reactor Building.

The seismic input motions for II/I stability evaluations of TB, RWB, SB, and CBA are described in the following:

- TB: site-specific SSE
- RWB: as described in Sections 3.7.3.16 and 3H.3.5.3 and shown in Figures 3.7-44 through 3.7-46
- SB: as described in Section 3.7.3.16
- CBA: as described in Section 3.7.3.16

Sliding and overturning stability evaluations of TB, RWB, SB, and CBA are performed in accordance with the methodology outlined in Figure 3H3-52.

Seismic demands along each orthogonal direction for stability evaluation of TB, RWB, and SB are determined using response spectrum analysis of a fixed base stick model representing each of these structures. The input motions for these response spectrum analyses are as described above. The base shears and moments from these response spectrum analyses are adjusted manually to account for the additional shears and moments due to basemat excitation which are calculated considering zero period acceleration (ZPA) of the input motions. The three orthogonal seismic demands of each structure are combined using the 100%-40%-40% rule as outlined in Regulatory Guide 1.92, Revision 2.

Seismic demands along each orthogonal direction for stability evaluation of the CBA are calculated using manual calculation where the CBA is idealized as a single degree of freedom structure. The three orthogonal seismic demands of each structure are combined using the 100%-40%-40% rule as outlined in Regulatory Guide 1.92, Revision 2.

Table 3H.6-14 provides sliding and overturning factors of safety under site-specific SSE for TB, RWB, SB, and CBA.

3.7.3.16 Analysis Procedure for Non-Seismic Structures in Lieu of Dynamic Analysis

For the Control Building Annex (CBA) II/I design, the SSE input at the foundation level (Figures 3.7-38 and 3.7-39) is the envelope of 0.3g RG 1.60 response spectra and the induced acceleration response spectra due to site specific SSE that is determined from an SSI analysis which accounts for the impact of the nearby Control Building (CB). In this SSI analysis, five interaction nodes at the depth corresponding to the bottom elevation of the CBA foundation are added to the three dimensional SSI model of the CB. These five interaction nodes correspond to the four corners and the center of the CBA foundation. The average response of these five interaction nodes is enveloped with the 0.3g RG 1.60 spectra to determine the SSE input at the CBA foundation level.

For the stability evaluation of the CBA, the SSE input is the envelope of the average response of the five interaction nodes from the SSI analysis described above and the site specific SSE.

For the Radwaste Building (RWB) II/I design, the SSE input (see Figures 3.7-41 through 3.7-43) ~~at the foundation level~~ is the envelope of 0.3g RG 1.60 response spectrum and the induced acceleration response spectrum due to site-specific SSE that is determined from an SSI analysis which accounts for the impact of the nearby Reactor Building (RB). In this SSI analysis, five interaction nodes at the ~~depth~~ground surface ~~corresponding to the bottom elevation of the RWB foundation~~ are added to the three dimensional SSI model of the RB. These five interaction nodes correspond to the four corners and the center of the RWB foundation. The average response of these five interaction nodes is enveloped with the 0.3g RG 1.60 spectra to determine the SSE input at the foundation level.

For the stability evaluation of the RWB, the SSE input (see Figures 3.7-44 through 3.7-46) is the envelope of the average response of the five interaction nodes from the SSI analysis described above and the site specific SSE.

For the Service Building (SB) II/I design, the SSE input is the envelope of 0.3g RG 1.60 response spectrum and the induced acceleration response spectrum due to site-specific SSE that is determined from an SSI analysis which accounts for the impact of the nearby CB Building. In this SSI analysis, five interaction nodes at the ground surface are added to the three dimensional SSI model of the CB. These five interaction nodes correspond to the four corners and the center of the SB foundation. The average response of these five interaction nodes is enveloped with the 0.3g RG 1.60 spectra to determine the SSE input at the foundation level.

For the stability evaluation of the SB, the SSE input is the envelope of the average response of the five interaction nodes from the SSI analysis described above and the site specific SSE.

3.8.5.8.1 Description of Foundations for DGFOT

Diesel Generator Fuel Oil Tunnels (DGFOT) foundation is a 2 ft thick reinforced concrete basemat placed over two feet thick lean concrete mud mat. The foundation analysis and design is performed using a three dimensional finite element analysis (FEA). The flexibility of the basemat and the supporting soil is accounted for through use of foundation soil springs. For additional analysis and design details, see Section 3H.7.

Seismic gaps between the DGFOT and adjoining Reactor Building (RB) and Diesel Generator Fuel Oil Storage Vaults (DGFOSV) as well as the differential movements for design commodities communicating between the DGFOT and the adjoining RB and DGFOSV are determined considering settlement and tilts obtained from time rate of settlement analysis accounting for construction sequence, seismic movements from seismic analysis, and translations and/or rotations from sliding and overturning stability evaluations.

3.8.5.9 Description of Foundations for Category I Site-Specific Structures

3.8.5.9.1 UHS/RSW Pump House

Ultimate Heat Sink (UHS)/Reactor Service Water (RSW) Pump House foundation is a 10 ft thick reinforced concrete basemat placed over two feet thick lean concrete mud mat. The foundation analysis and design is performed using a three dimensional finite element analysis (FEA). The flexibility of the basemat and the supporting soil is accounted for through use of foundation soil springs. For additional analysis and design details, see Section 3H.6.

Seismic gaps between the RSW Pump House and the adjoining RSW Piping Tunnels as well as the differential movements for design of commodities communicating between the RSW Pump House and RSW Piping Tunnels are determined considering settlement and tilts obtained from time rate of settlement analysis accounting for construction sequence, seismic movements from seismic analysis, and translations and/or rotations from sliding and overturning stability evaluations.

3.8.5.9.2 Reactor Service Water (RSW) Piping Tunnels

RSW Piping Tunnels foundation is a three ft thick reinforced concrete basemat placed over 2 ft thick lean concrete mud mat. The foundation analysis and design is performed using conservative manual calculations as described in Section 3H.6.6.2.2.

Seismic gaps between the RSW Piping Tunnels and the adjoining Control Building (CB) and RSW Pump House as well as the differential movements for design of commodities communicating between the RSW Piping Tunnels and the adjoining CB and RSW Pump House are determined considering settlement and tilts obtained from time rate of settlement analysis accounting for construction sequence, seismic movements from seismic analysis, and translations and/or rotations from sliding and overturning stability evaluations.

3.8.5.9.3 Diesel Generator Fuel Oil Storage Vaults (DGFOSV)

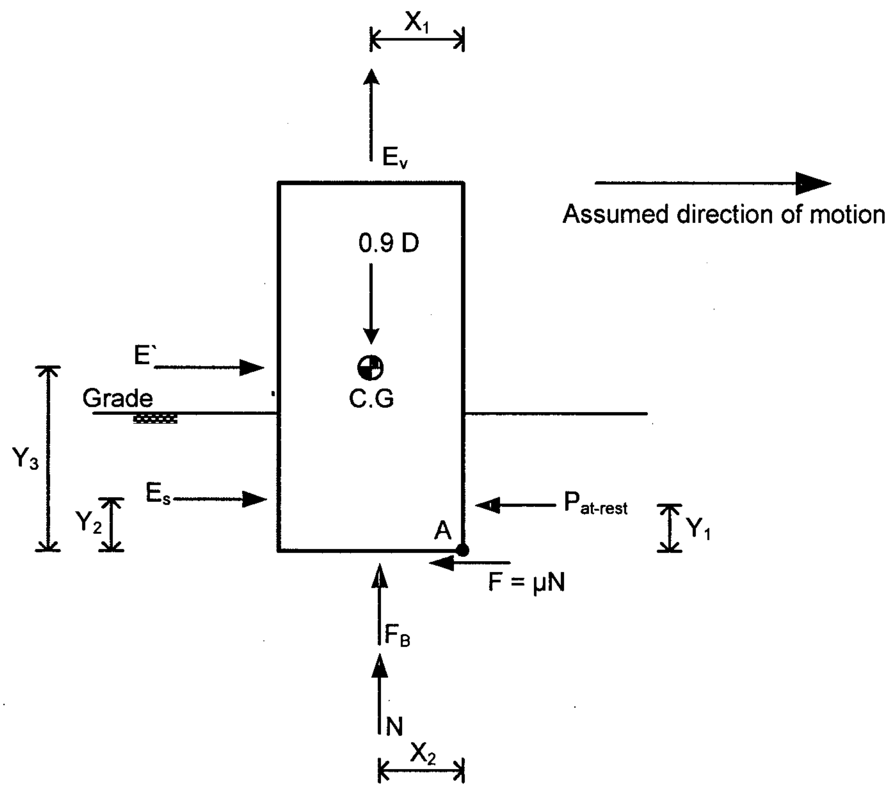
DGFOSV foundation is a 6 ft thick reinforced concrete basemat placed over 2 ft thick lean concrete mud mat. The foundation analysis and design is performed using a three dimensional finite element analysis (FEA). The flexibility of the basemat and the supporting soil is accounted for through use of foundation soil springs. For additional analysis and design details, see Section 3H.6.7.

Seismic gaps between the DGFOSV and the adjoining DGFOT as well as the differential movements for design commodities communicating between the DGFOSV and DGFOT are determined considering settlement and tilts obtained from time rate of settlement analysis accounting for construction sequence, seismic movements from seismic analysis, and translations and/or rotations from sliding and overturning stability evaluations.

Table 3H.6-14: Calculated Overturning and Sliding Factors of Safety Under Site-Specific SSE and Flotation Factors of Safety for TB, SB, RWB and CBA

Structure	Calculated Factor of Safety			Minimum Required Factor of Safety	Coefficient of Friction for Sliding Evaluation
	Overturning	Sliding	Flotation		
Turbine Building (TB)	2.18	1.11	1.46	1.1	0.30 (dynamic)
Service Building (SB)	~~2.65~~2.11	~~1.81~~1.11	1.40	1.1	0.39 (dynamic)
Radwaste Building (RWB)	~~4.23~~3.67	~~1.92~~1.75	1.51	1.1	0.39 (dynamic)
Control Building Annex (CBA)	2.03	1.16	1.18	1.1	0.58 (static)

Figure 3H.6-137: Formulations Used for Calculation of Factors of Safety Against Sliding and Overturning for Category I Site-Specific Structures



Factors of Safety against Sliding and Overturning about point A are calculated as follows:

$$SF_{sliding} = \frac{P_{at\_rest} + F}{E_s + E`}$$

$$SF_{OT\_A} = \frac{(P_{at\_rest})(Y_1) + (0.9D)(X_1)}{(F_B)(X_2) + (E_s)(Y_2) + (E`)(Y_3) + (E_v)(X_1)}$$

Where:

$SF_{sliding}$ = Safety factor against sliding

SF_{OT_A} = Safety factor against overturning about "A"

D = Dead load

P_{at_rest} = Total at-rest soil pressure (see Figures 3H.6-48 through 3H.6-50)

$F = \mu N$ = friction force and μ is the coefficient of friction

E_s = Static and dynamic soil pressure (see Figures 3H.6-45 through 3H.6-47)

E` = Self weight excitation in the horizontal direction

E_v = Self weight excitation in the vertical direction

F_B = Buoyancy force

N = Vertical reaction $= 0.9D - F_B - E_v$

Note: If passive pressure is utilized, $P_{passive}$ should be used instead of $P_{at\text{-}rest}$.

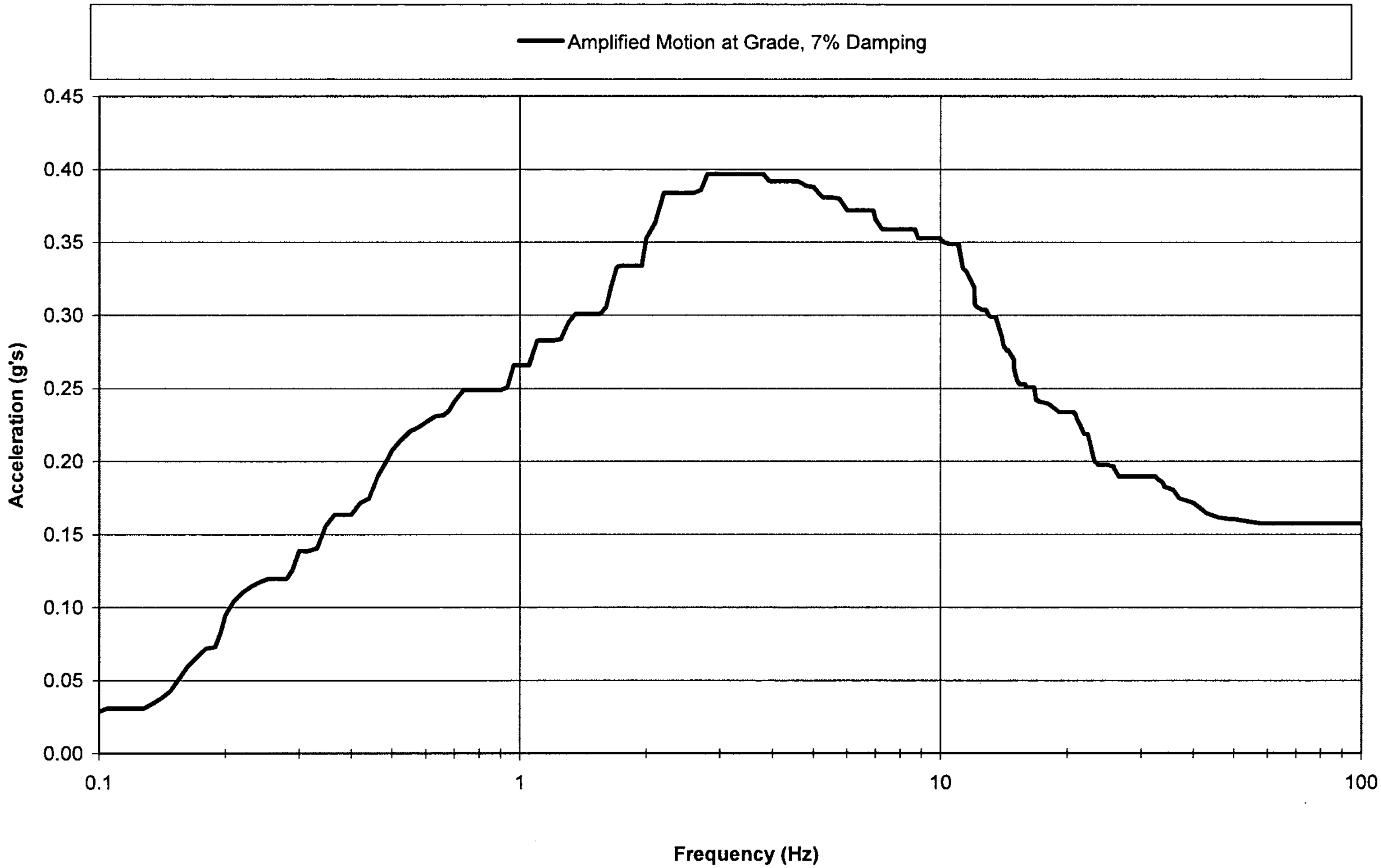


Figure 3.7-44 Radwaste Building East-West Input Motion for Stability Evaluations (7% Damping)

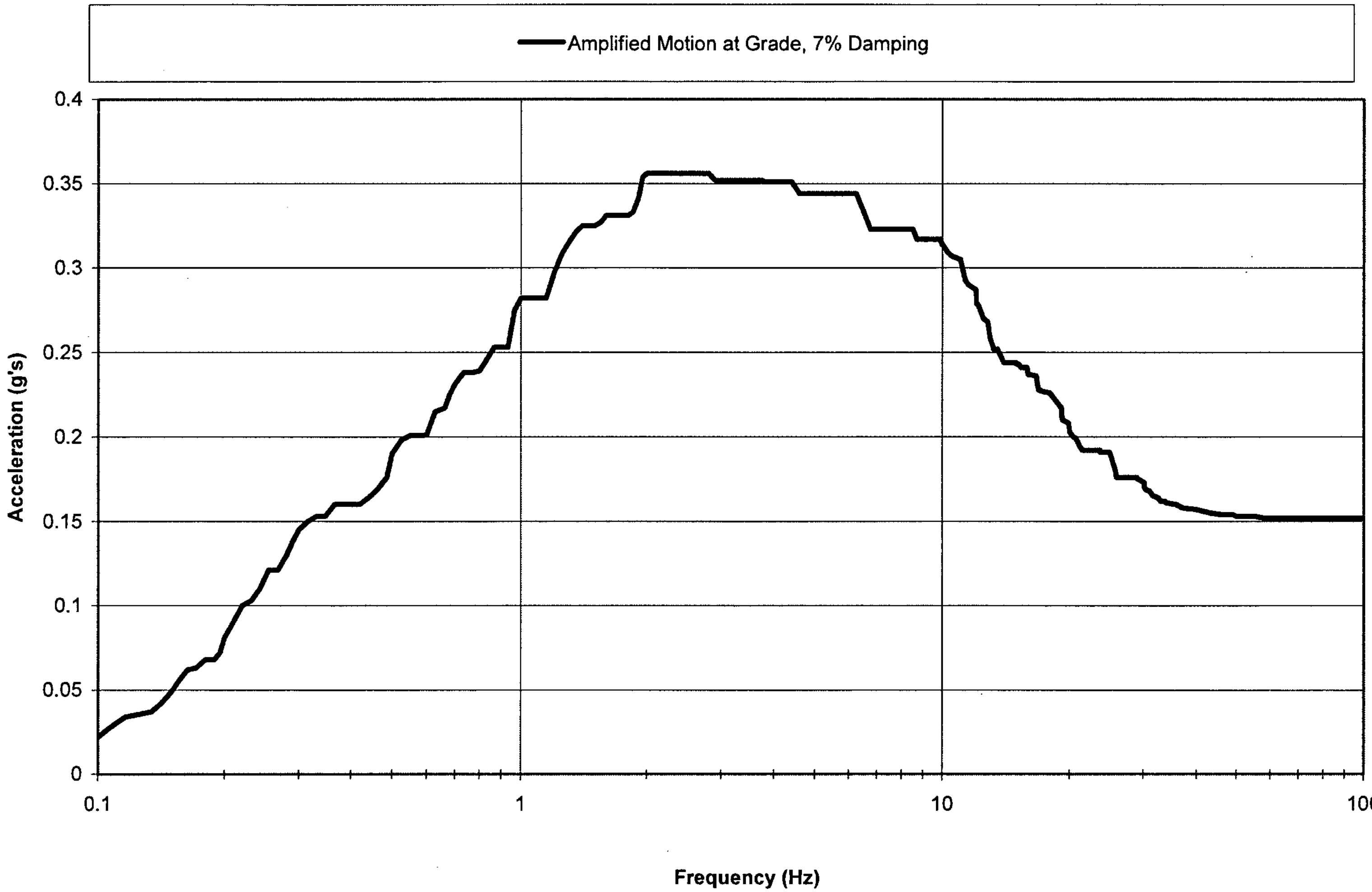


Figure 3.7-45 Radwaste Building North-South Input Motion for Stability Evaluations (7% Damping)

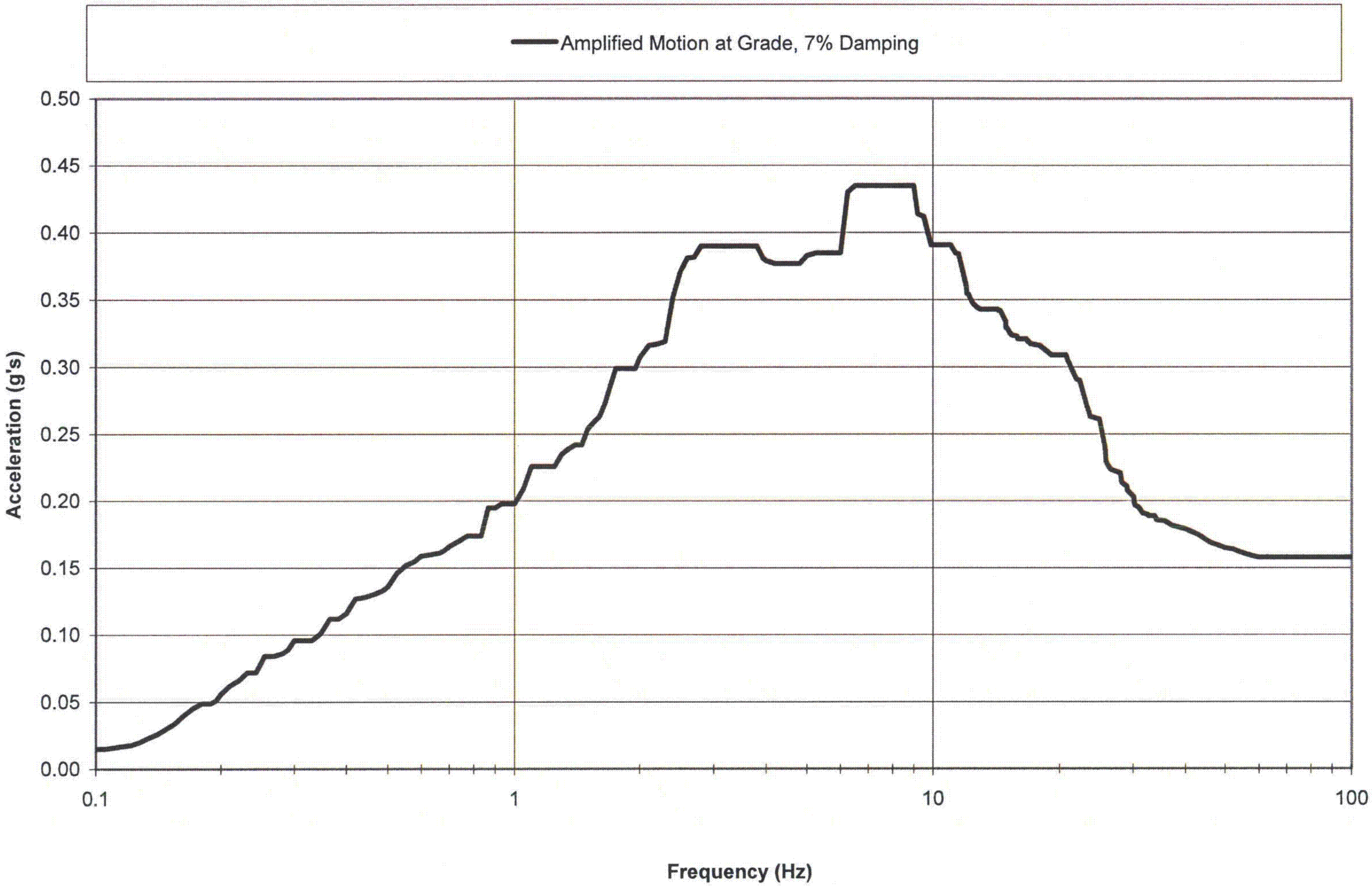


Figure 3.7-46 Radwaste Building Vertical Input Motion for Stability Evaluations (7% Damping)

RAI 03.07.02-13, Supplement 4

QUESTION:

(Follow-up Question to RAI 03.07.02-1)

With regard to Item c of the response to RAI 03.07.01-13, the applicant is requested to address the following:

1. The FSAR mark-up in the response to item (b) of RAI 03.07.02-1, did not include the list of non-Category I structures requiring the enhanced seismic design and analysis. The applicant is requested to include in FSAR 3.7.2.8 the five identified non-Category I structures that could interact with the Category I structures.

2. The response to item (c) of RAI 03.07.02-1 indicated that non-Category I structures with the potential to interact with Category I structures have not yet progressed to a point where sliding and overturning potential as a result of the SSE can be evaluated. However, as identified in SRP guidance 3.7.2I.8., the staff must review the applicant's seismic design of these non- Category I structures. As such, the applicant is requested to provide in the FSAR factors of safety against sliding and overturning including the basis of coefficient of friction used in the analysis during an SSE for Turbine Building, Radwaste Building, Service Building, Control Building Annex, and Plant Stack.

SUPPLEMENTAL RESPONSE:

The Supplement 3 response to this RAI was submitted with Nuclear Innovation North America (NINA) letter U7-C-NINA-NRC-110103, dated July 27, 2011. This supplement provides the response to the following Audit Action Items and/or Punch List Items discussed in the NRC audits performed during the weeks of May 23, 2011, July 25, 2011 and September 27, 2011.

For Es use the SSSI pressure diagram as the driving force in the stability evaluation and using passive on the resisting side for FOS Vault, RSW Piping Tunnel, FOS Tunnel. Provide requested information in RAI response ***(Audit Action Item 3.7-33, Punch List Item 27)***

Confirm for FOS Vault that E' is more than the inertial force for amplified site-specific SSI analysis in the stability evaluation. Provide requested information in RAI response ***(Audit Action Item 3.7-35, Punch List Item 28)***

Provide in COLA the discussion of stability evaluation for each structure including a discussion of the input motion ***(Clarification Issues 3 and 8, Audit Action Item 3.8-35, Punch List Item 83)***

Verify equivalent static loading for RSW Piping Tunnel and Fuel Oil Tunnel exceed that from SSI ***(Audit Action Item 3.8-36, Punch List Item 84)***

Follow up to Punch List Items 27, 28, 83 & 84 related to stability evaluations ***(Punch List Item 120) Note: this is simply a tracking Punch List item and it does not pose any new question and/or action.***

In response to RAI 03.07.02-13 S4 describe in the FSAR the source for E' and Es and discuss the comparison of E' and Es versus what is obtained from SSI or SSSI and add a statement that the conclusions are conservative ***(Audit Action Item 3.7-57, Punch List Item 136)***

The applicant is requested to reassess the seismic demand for stability evaluation of any applicable Category I and II/I structures in light of the DNFSB issue and confirm acceptability of the factors of safety against stability during an SSE. ***(Punch List Item 146)***

A) Audit Action Items 3.7-33, 3.7-35, 3.8-35 and 3.7-57 (Punch List Items 27, 28, 83 and 136)

As discussed in the NRC audit during the week of September 27, 2011, in order to show that the stability evaluations per formulations shown in Figure 3H.6-137 are conservative, the following were performed:

- Step 1: The reactions from the soil structure interaction (SSI) and/or structure-soil-structure (SSSI) analysis around the boundary of the structure were integrated to obtain the maximum total seismic sliding force and maximum seismic overturning moment (see Figure 03.07.02-13 S4.1).

- Step 2: The applied seismic loads per Figure 3H.6-137 were integrated to obtain the total seismic sliding force and seismic overturning moment (see Figure 03.07.02-13 S4.2) design values that were considered in STP 3&4 stability evaluations.

- Step 3: The resulting seismic sliding forces and seismic overturning moments from steps 1 and 2 were compared. Table 03.07.02-13 S4.1 compares the design values against those from the SSI analyses and Table 03.07.02-13 S4.2 compares the design values against those from the SSSI analyses. These comparisons show that the driving seismic sliding and overturning moments used in stability evaluations are in excess of those computed from SSI and/or SSSI analyses, and are thus conservative.

Also see part "D" of this response in regards to Defense Nuclear Facilities Safety Board (DNFSB) issues with Subtraction Method (SM) of analysis.

B) Audit Action Items 3.8-36 (Punch List Items 84)

Diesel Generator Fuel Oil Tunnel (DGFOT):

Table 03.07.02-13 S4.3 provides a comparison of the shear force, axial force, and moment of a 1-ft wide cross section of the DGFOT from the equivalent static Finite Element Model and those from the SSI analysis at a section cut just above the basemat. As seen from Table 03.07.02-13 S4.3, the use of the equivalent static loads yields seismic loads in excess of those from the SSI analysis. Thus, the use of the equivalent static loads is conservative.

Reactor Service Water (RSW) Piping Tunnel:

The RSW Piping Tunnel was designed using conservative manual calculations. In order to ensure that this design is conservative, the section cut forces from the SSI analysis at the base of the structure were compared to those used in the manual calculations. In this comparison, the SSI section cut forces were based on amplified motion of the RSW Piping determined in the SSI analysis of the Reactor Building (using Modified Subtraction Method). This comparison showed that the design based on simplified manual calculation is conservative with a minimum margin of about 50% for seismic loads from SSI analysis.

C) Audit Action Item 3.7-57 (Punch List Item 136)

In the STP 3&4 stability evaluations E' and Es represent the following:

- E' represents the inertia of the structure and it is either determined from equivalent static method or response spectrum analysis.
- Es represents the static and dynamic loads from soil which includes seismic loads from soil and hydrodynamic pressure from groundwater. These loads are computed in accordance with COLA Section 2.5S4.10.5.

Notes will be added to COLA Figures 3H.3-52 and 3H.6-137 to reflect the above. In addition, notes will be added to COLA stability tables indicating that the seismic sliding forces and overturning moments from SSI and/or SSSI were less than the seismic sliding forces and overturning moments used in the stability calculations.

D) Punch List Item 146

The issues with the SASSI subtraction method of analysis identified by the DNFSB may affect the SSI and SSSI results as well as amplified input motions used in stability evaluations of the Seismic Category I and II/I structures. Each of these items is addressed below.

SSI Results:

SSI analysis results are used in stability evaluations of Ultimate Heat Sink (UHS)/RSW Pump House, RSW Piping Tunnels, Diesel Generator Fuel Oil Storage Vaults (DGFOSV) and Diesel Generator Fuel Oil Tunnels (DGFOT). As noted in Table 03.07.02-13 S4.1 the SSI analyses of these structures and the SSI analysis of the structure used for determination of the applicable amplified input motion were performed using Modified Subtraction Method (MSM) or Direct Method (DM) of analysis. Therefore, no further evaluation is required.

SSSI Results:

SSSI analysis results have been used in stability evaluations of RSW Piping Tunnels, DGFOSV, DGFOT and Radwaste Building (RWB). The SSSI analysis for typical cross section of RSW Piping Tunnels and RWB was performed using SM, MSM and DM. For other structures, the SSSI analyses were performed using SM. The comparisons shown in Table 03.07.02-13 S4.2 are based on SM SSSI analysis results. Based on the detailed examination for the effect of SASSI method of solution on SSSI soil pressures provided in RAI 03.07.01-29 Supplement 1, Revision 1 which is being submitted concurrently with this RAI, the impact is expected to be within 10%. Referring to Table 03.07.02-13 S4.2, the minimum margin between the seismic sliding forces and overturning moments used in stability evaluations and those from the SSSI analysis is about 50%. Since this minimum margin of 50% is significantly more than the expected 10% difference due to SASSI method of analysis, no further evaluation is required.

Amplified Input Motions:

Changes in the amplified input motion of light structures located adjacent to heavy structures may impact the SSI analysis results that have been used in addressing the stability of the light structures. For STP 3&4, amplified input motions are applicable to DGFOSV, DGFOT, RSW Piping Tunnels, RWB, Service Building (SB), and Control Building Annex (CBA) structures. Figures 03.07.02-13 S4.3 through 03.07.02-13 S4.20 compare the amplified input motions for DGFOSV, DGFOT, RSW Piping Tunnels, RWB and SB obtained from MSM and SM SSI analyses of the Reactor Building (RB). Referring to these figures the following are noted:

- The impact of SASSI MSM on amplified horizontal input motion is negligible.

- SASSI MSM affects the amplified vertical input motion in frequencies in excess of about 8 HZ.

Referring to Table 03.07.02-13 S4.1, the amplified input motions used in stability evaluations of RSW Piping Tunnels, DGFOSV and DGFOT were obtained from SSI analysis using MSM. Therefore, no further evaluation is required for these structures.

The response spectra used for stability evaluation of SB envelopes the SB amplified input motions shown in Figures 03.07.02-13 S4.19 and 03.07.02-13 S4.20. Therefore, no further evaluation is required for the SB.

The RWB stability evaluation was re-analyzed considering the amplified input motions obtained from MSM SSI analysis of the RB. The calculated stability safety factors were found to exceed the required safety factors. Therefore, no further evaluation is required for the RWB.

Amplified input motions from MSM SSI analysis of the Control Building (CB) are not available for the CBA. However, current stability evaluation of the CBA has been performed using the following conservative measures:

- The superstructure mass lumped at the roof level was conservatively excited using a vertical acceleration equal to 1.5 times the peak spectral acceleration.
- In calculating the resisting forces and moments, as stated within the calculation, conservatively about 930 kips of the mass at the roof level was not considered.

Referring to COLA Table 3H.6-14, the stability safety factors for the CBA are as follows:

Sliding Safety Factor	= 1.16
Overturning Safety factor	= 2.03

Based on the above, the most critical safety factor is the sliding safety factor. Eliminating the second conservative measure noted above, will increase this safety factor from 1.16 to 1.44 which represents a 24% margin in the reported sliding safety factor. Considering this and the additional margin due to use of conservative vertical acceleration noted above, the existing margin in calculation of stability safety factors will be more than adequate for any change in amplified input motions due to use of MSM SSI analysis of the CB. Therefore, no further evaluation is required for the CBA.

COLA will be revised as shown in Enclosure 1 as a result of this response.

Table 03.07.02-13 S4.1: Comparison of Driving Seismic Sliding Force and Moment from Stability Evaluations and Those from SSI analysis

				Comparison of Design vs. SSI					
				Seismic Sliding Driving Force Units: kips for 3D and kips/ft for 2D			Seismic Overturning Moment Units: kip-ft for 3D and kip-ft/ft for 2D		
Structure	SSI Method of Analysis	Method of Analysis for Amplified Motion	Model	From SSI Analysis	Design Value	Ratio (Design/SSI)	From SSI Analysis	Design Value	Ratio (Design/SSI)
UHS/RSW Pump House	SM & MSM	NA	3D	43570	51478	1.18	5297334	5888907	1.11
DGFOSV	MSM	MSM		1029	1542	1.50	119230	133358	1.12
RSW Piping Tunnels	DM	MSM	2D	28.1	36.9	1.31	671.1	892.1	1.33
DGFOT	DM	MSM		2.8	6.9	2.44	16.4	28.7	1.75

Table 03.07.02-13 S4.2: Comparison of Driving Seismic Sliding Force and Moment from Stability Evaluations and Those from SSSI analysis

			Comparison of Design vs. SSSI					
			Seismic Sliding Driving Force (kips/ft)			Seismic Overturning Moment (kip-ft/ft)		
Structure	Method of Analysis	Model	From SSSI Analysis	Design Value	Ratio (Design/SSSI)	From SSSI Analysis	Design Value	Ratio (Design/SSSI)
UHS/RSW Pump House	SM	2D	NA (1)	NA (1)	NA (1)	NA (1)	NA (1)	NA (1)
RSW Piping Tunnels	SM, MSM & DM		3.8	36.9	9.70	156.8	892.1	5.69
DGFOSV	SM		17.5	42.6	2.43	1142	1771	1.55
DGFOT	SM		1.8	6.9	3.83	18.7	44.5	2.38
RWB	SM, MSM & DM		82.9	127.2	1.53	8186	20056	2.45

Note: (1) SSSI analysis result is only applicable to a portion of UHS/RSW Pump House structure.

Table 03.07.02-13 S4.3: Comparison of the Equivalent Static Finite Element Model and SSI Model Seismic Forces and Moments for DGFOT

	Uniform soil springs			Pseudo-coupled soil springs		
	Shear force (kip/ft)	Axial force (kip/ft)	Moment (kip-ft/ft)	Shear force (kip/ft)	Axial force (kip/ft)	Moment (kip-ft/ft)
Seismic design values	25.36	4.02	136.91	24.92	3.43	129.67
SSI values	3.64	2.94	7.18	3.64	2.94	7.18
Ratio	6.98	1.37	19.06	6.85	1.17	18.05

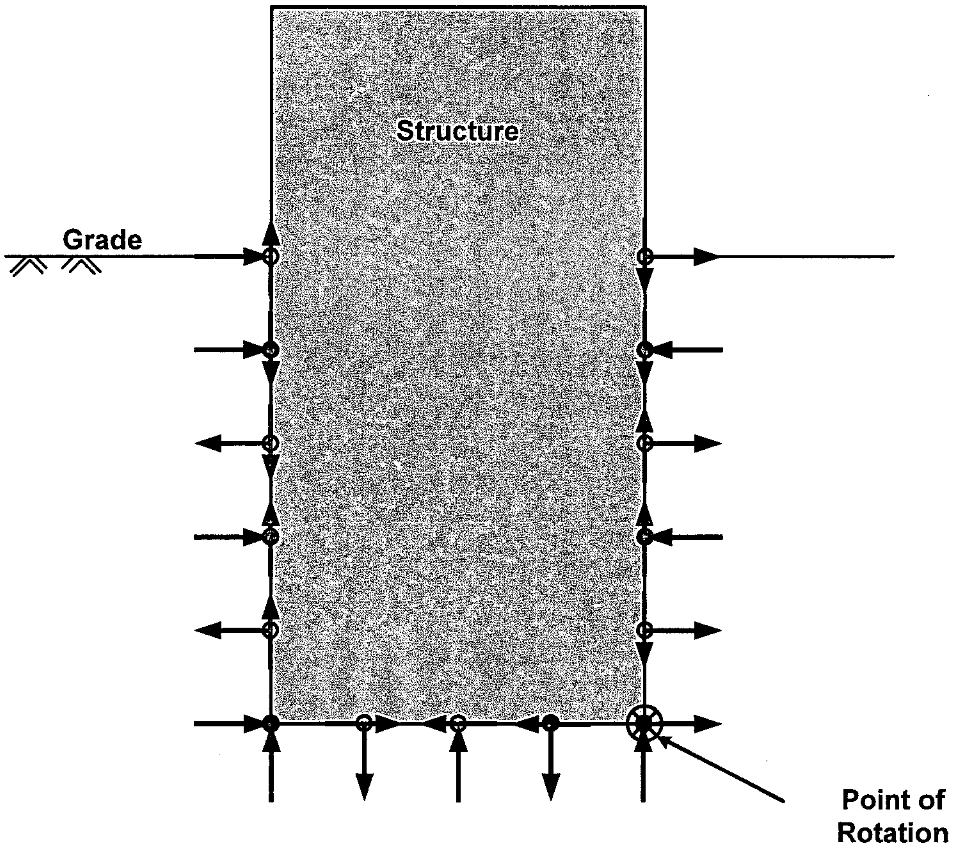


Figure 03.07.02-13 S4.1: Forces from SSI and/or SSSI analysis at the boundary of the structure that are integrated to obtain the maximum seismic sliding force and maximum seismic overturning moment about point of rotation

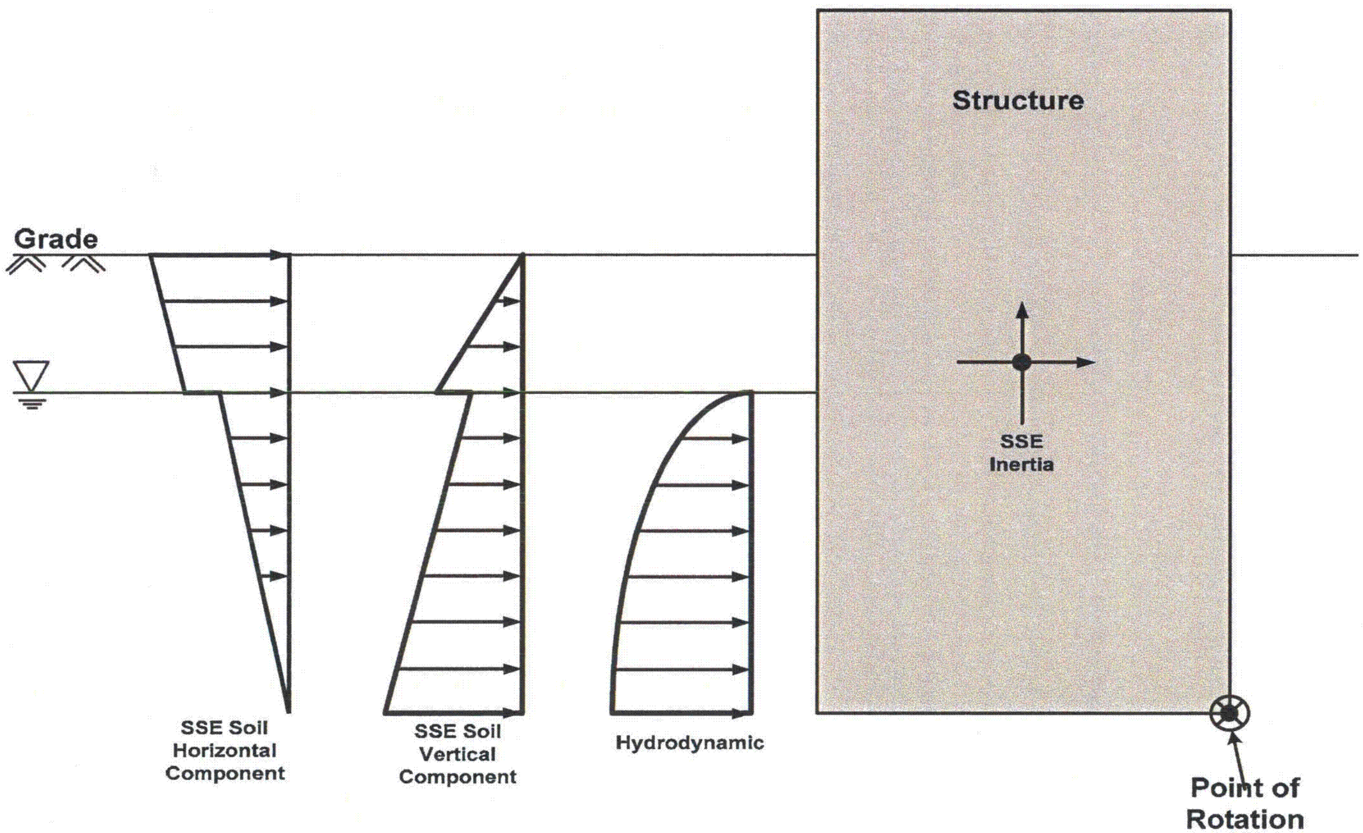


Figure 03.07.02-13 S4.2: Applied seismic soil, hydrodynamic and structure inertia loads that are integrated to obtain the seismic sliding force and seismic overturning moment about the point of rotation used in stability evaluations

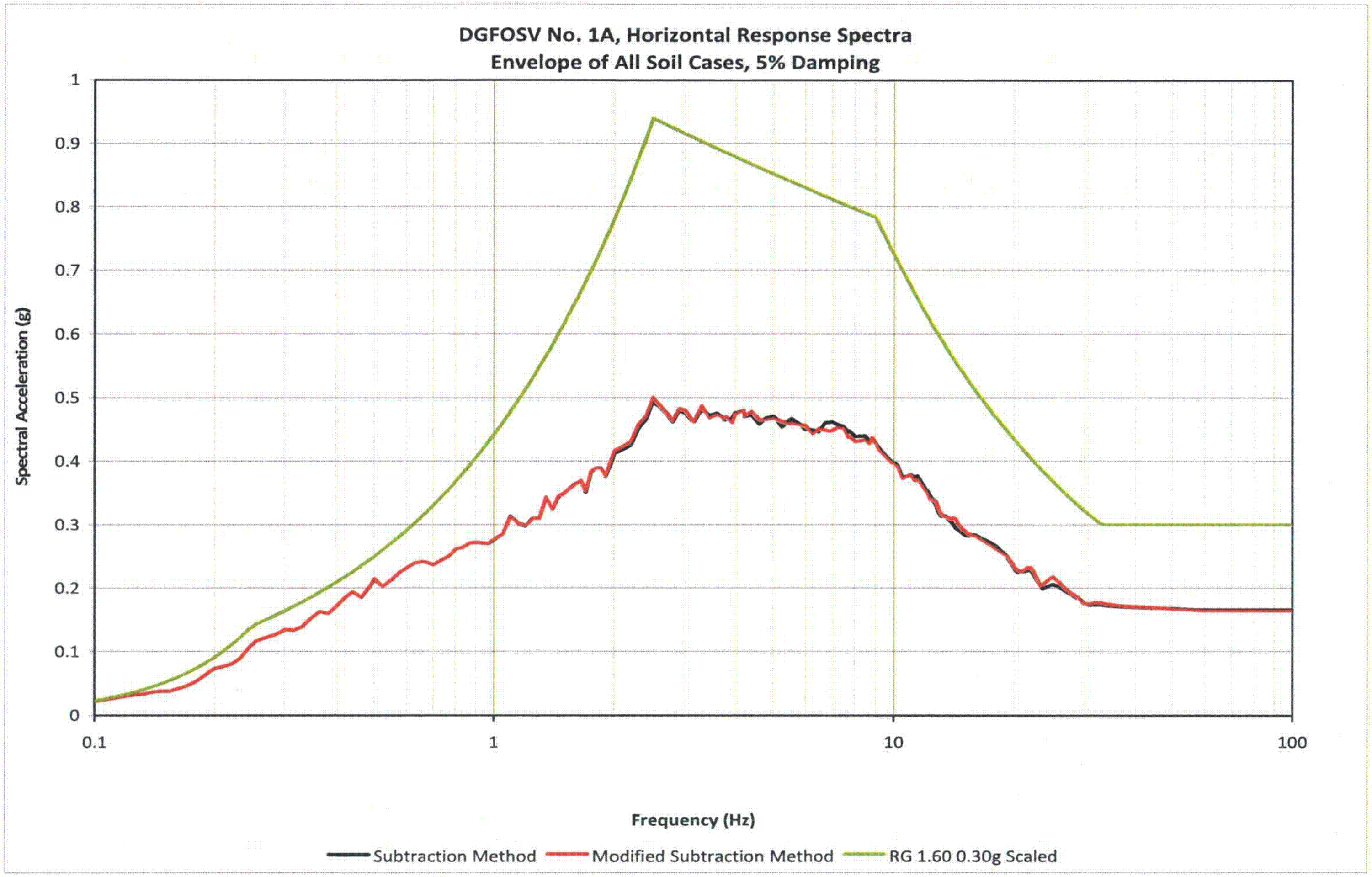


Figure 03.07.02-13 S4.3: Amplified Motion, MSM vs. SM

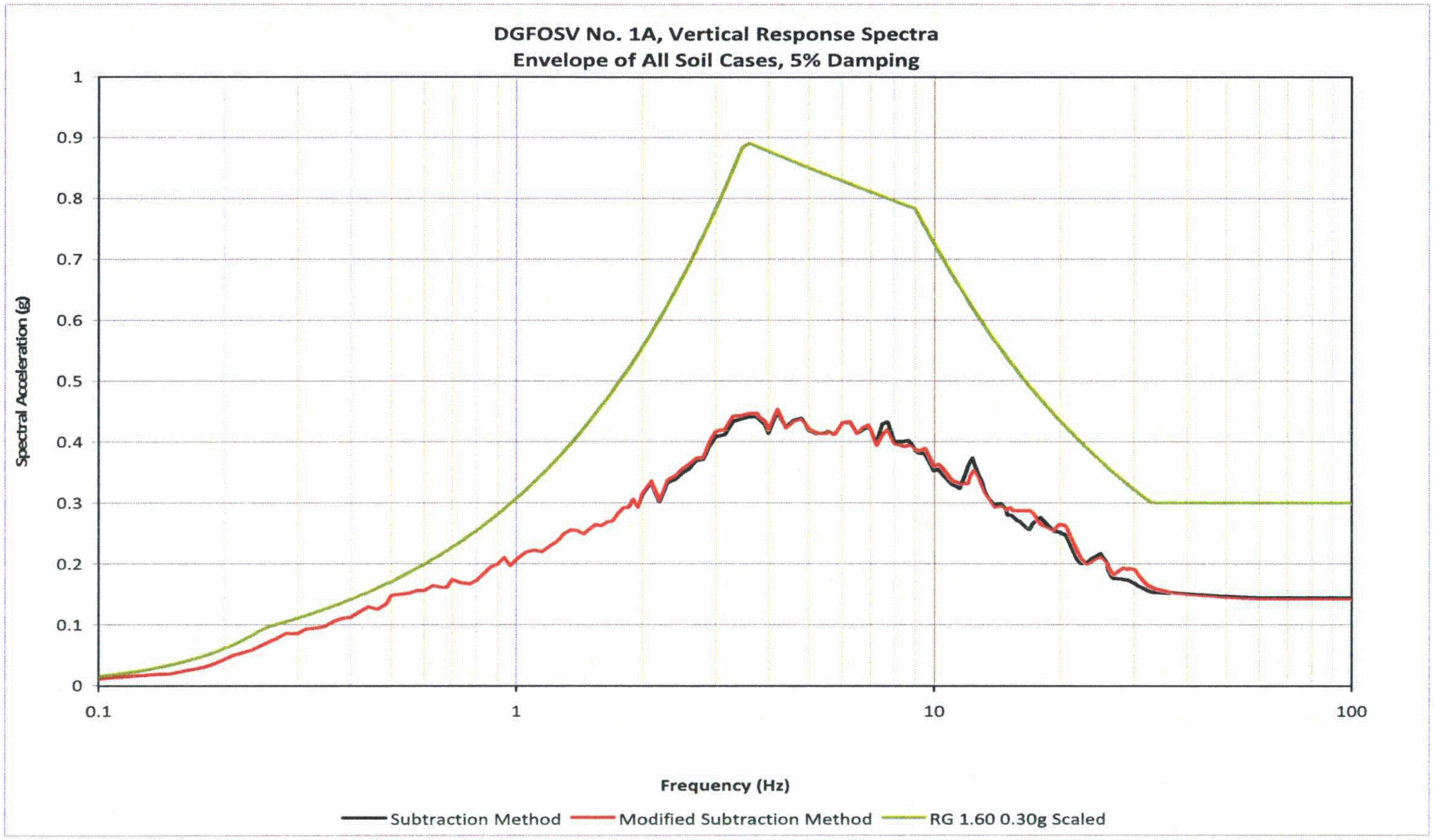


Figure 03.07.02-13 S4.4: Amplified Motion, MSM vs. SM

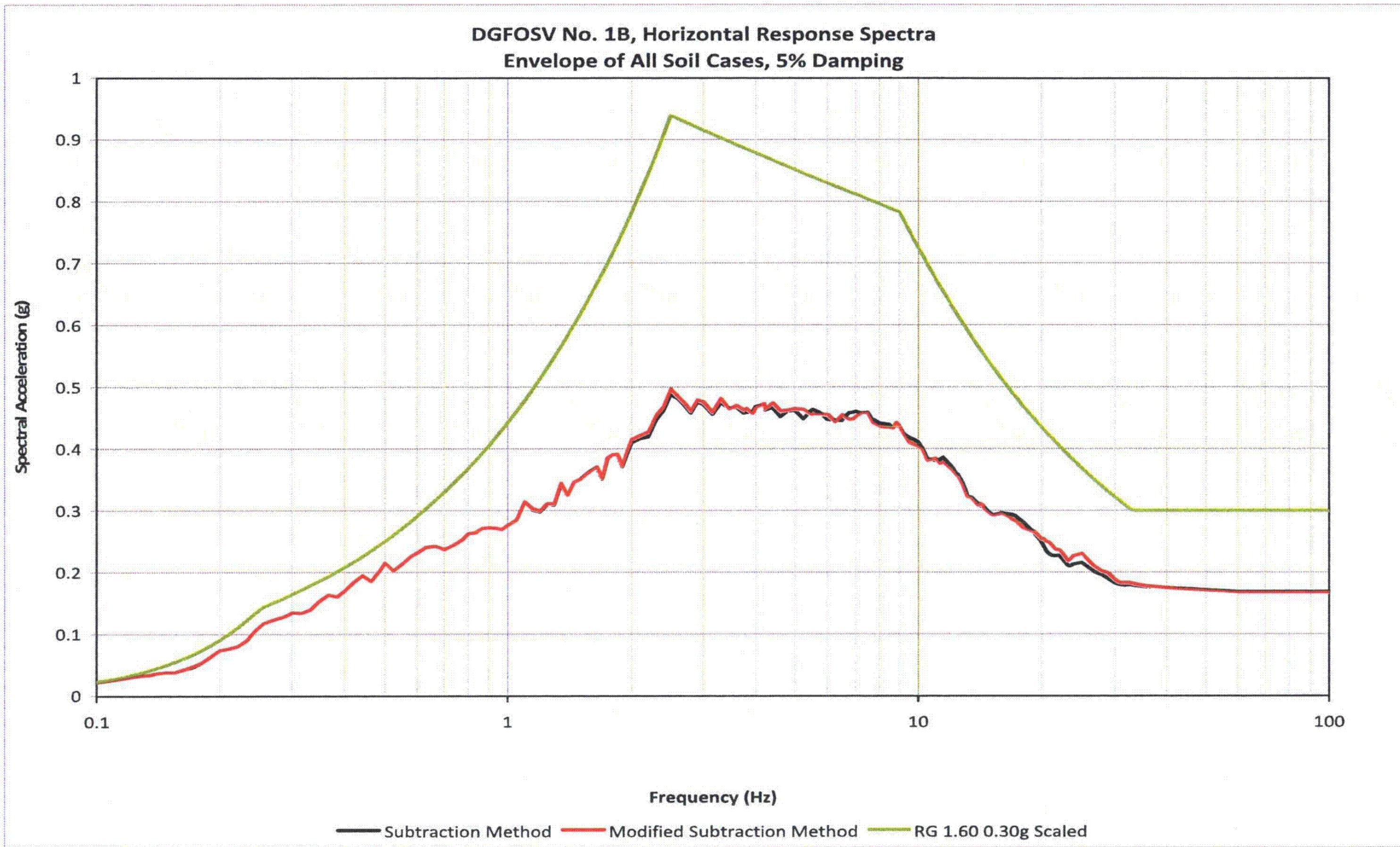


Figure 03.07.02-13 S4.5: Amplified Motion, MSM vs. SM

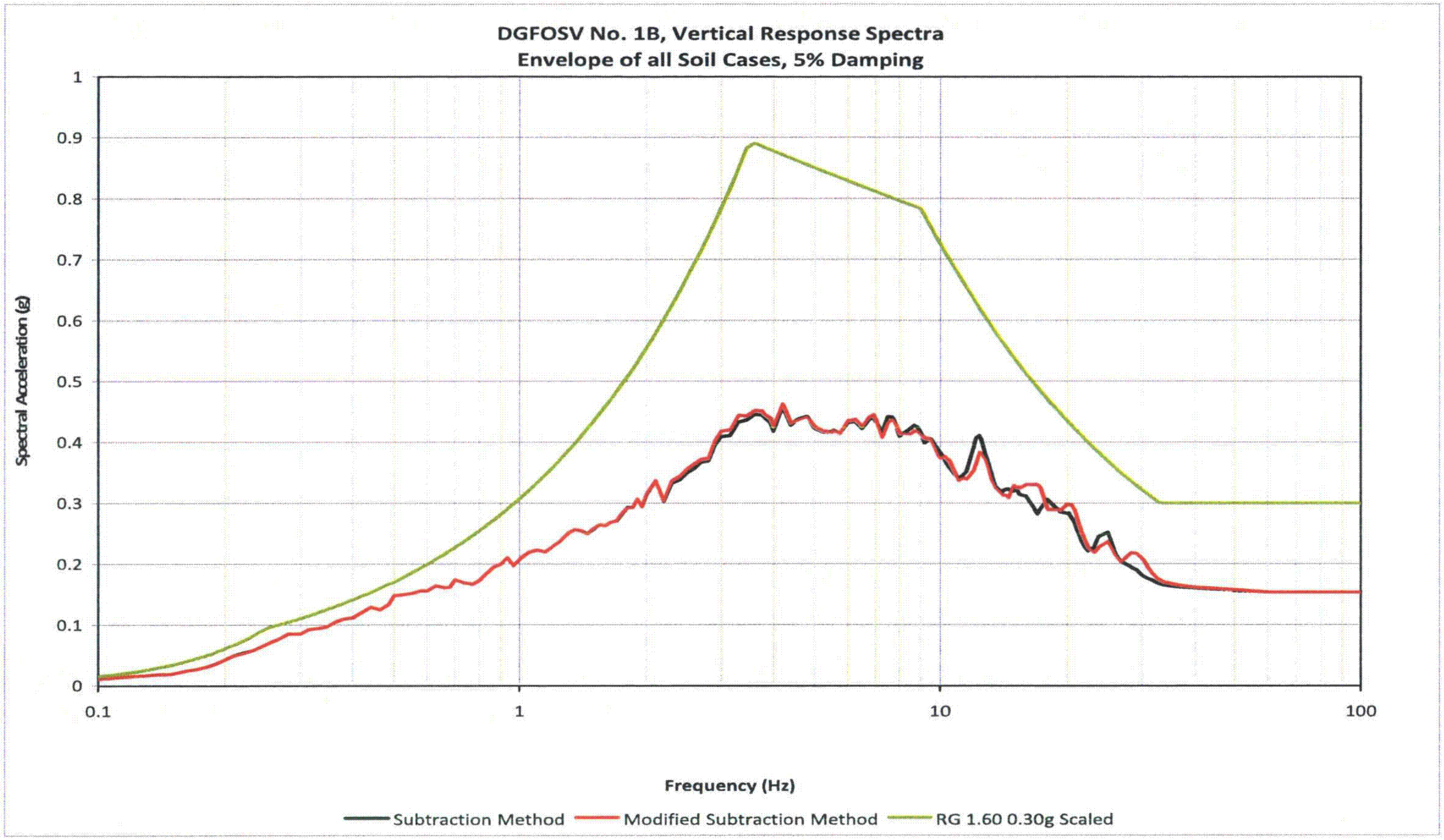


Figure 03.07.02-13 S4.6: Amplified Motion, MSM vs. SM

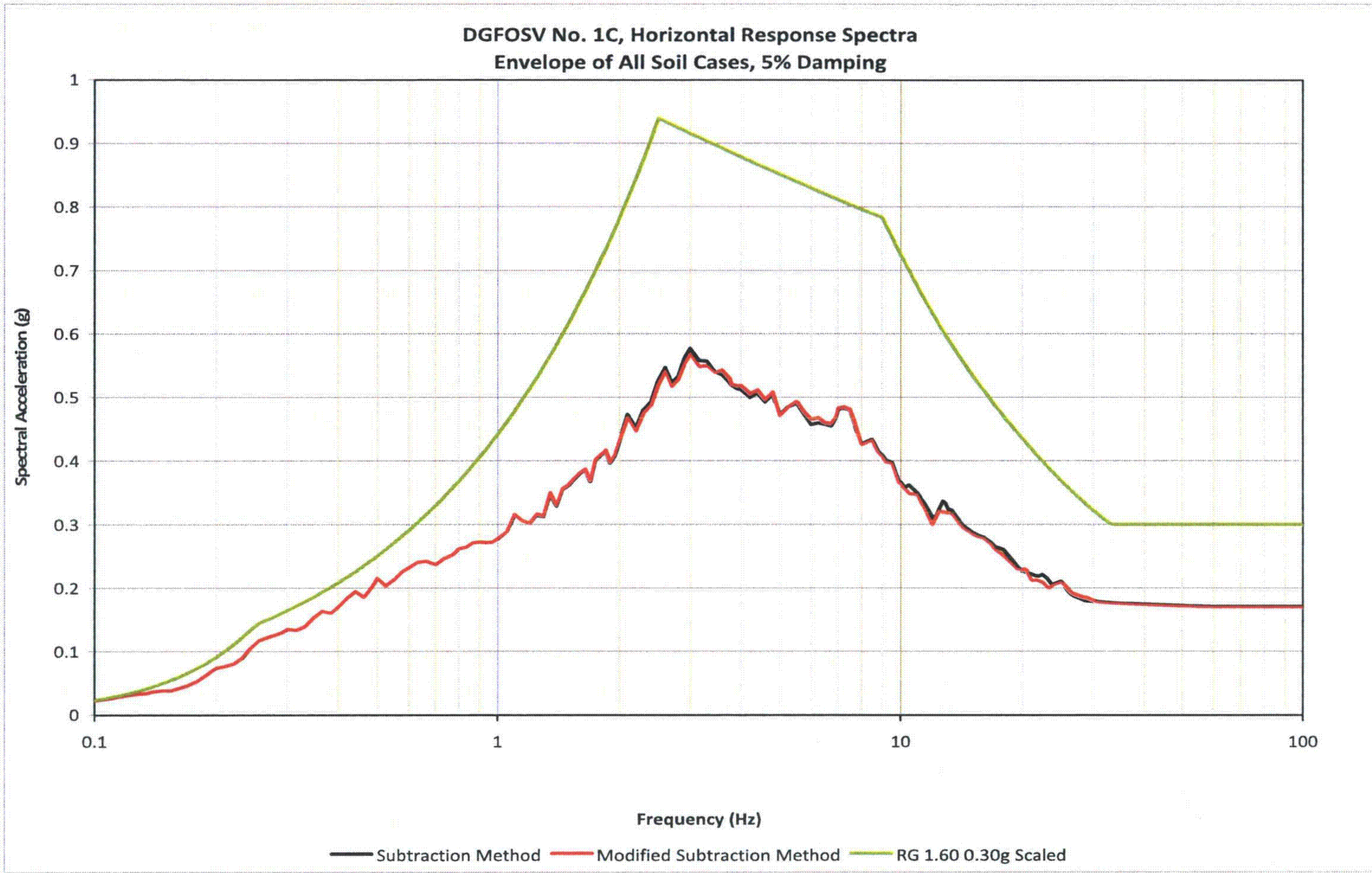


Figure 03.07.02-13 S4.7: Amplified Motion, MSM vs. SM

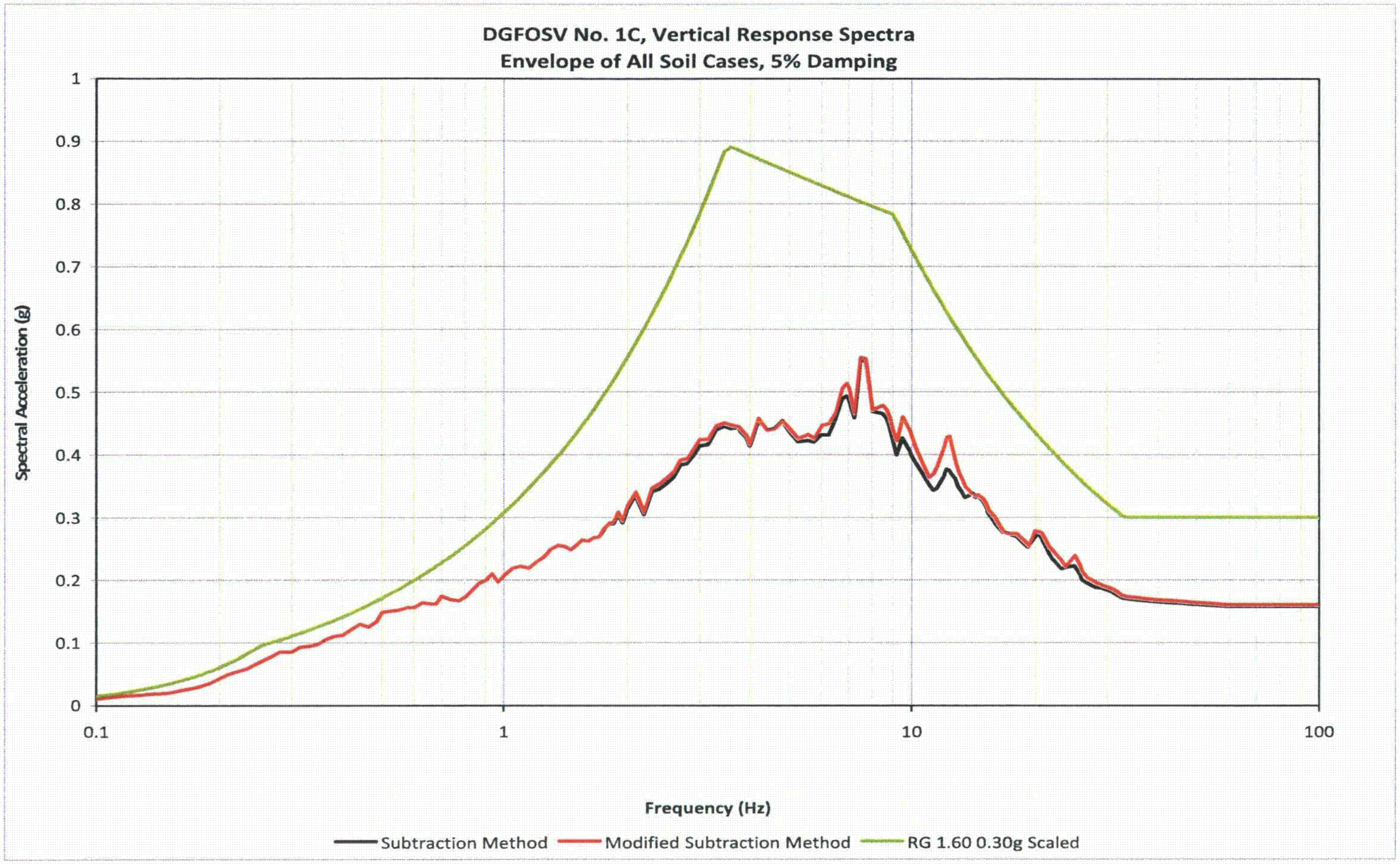


Figure 03.07.02-13 S4.8: Amplified Motion, MSM vs. SM

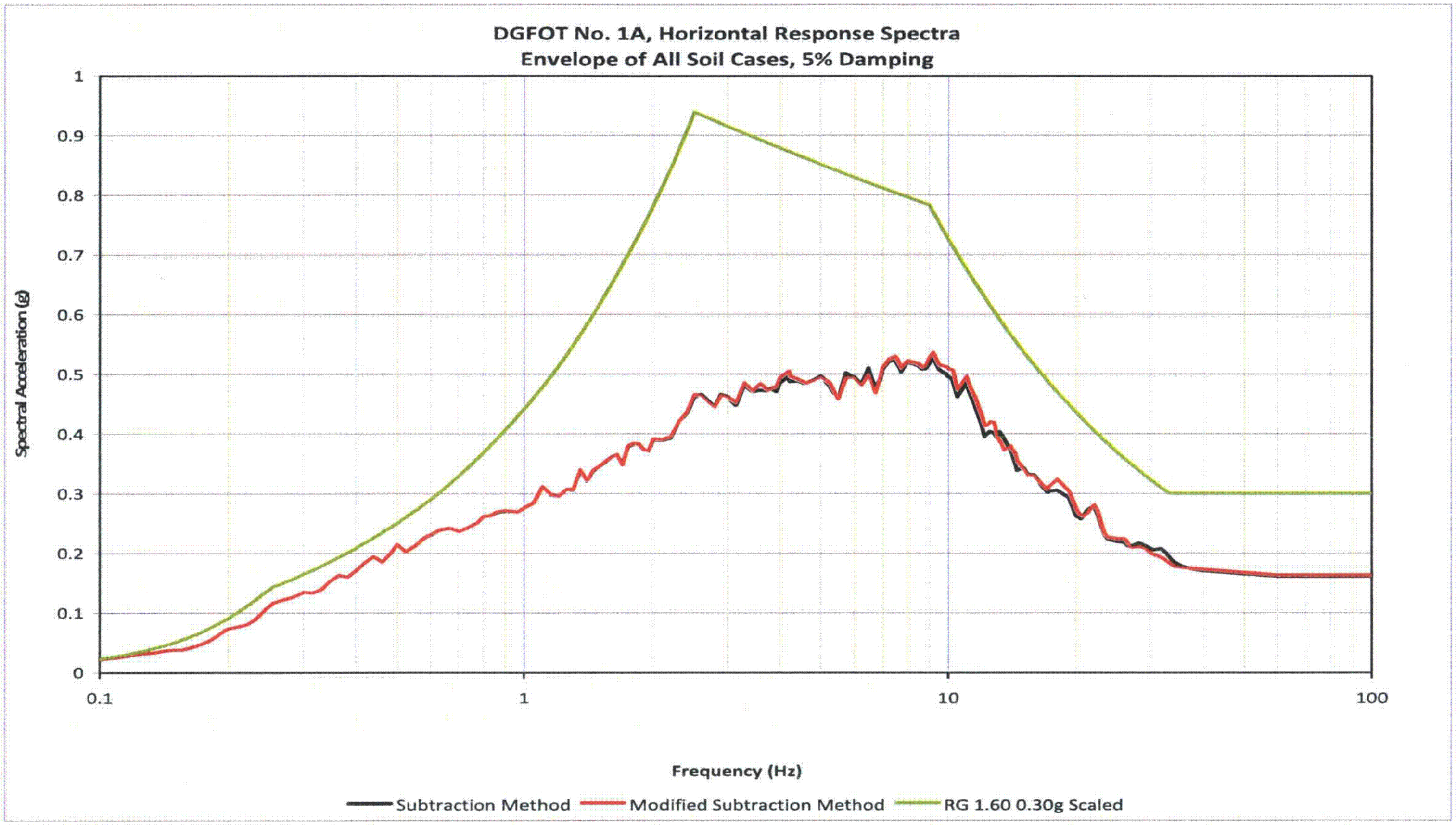


Figure 03.07.02-13 S4.9: Amplified Motion, MSM vs. SM

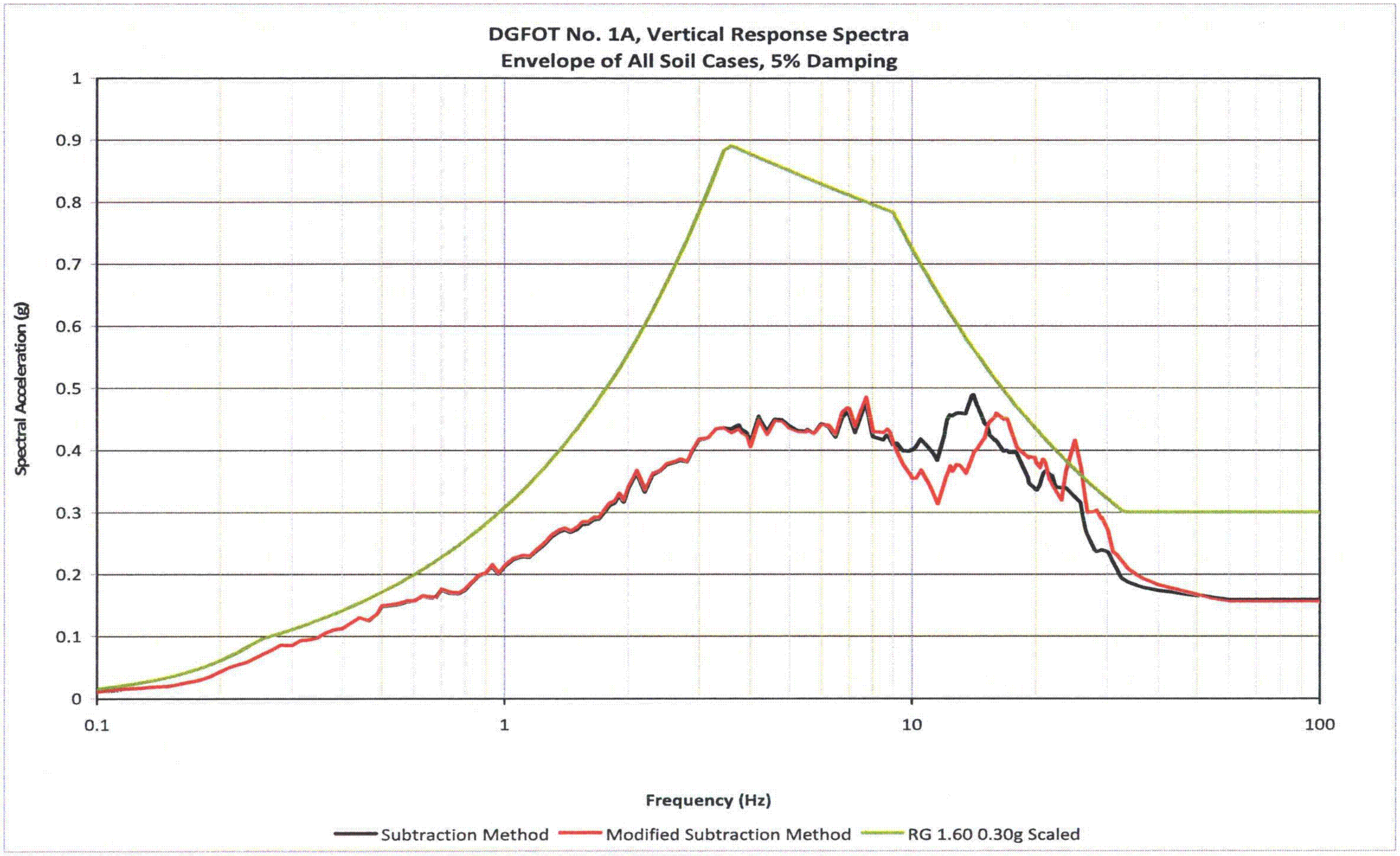


Figure 03.07.02-13 S4.10: Amplified Motion, MSM vs. SM

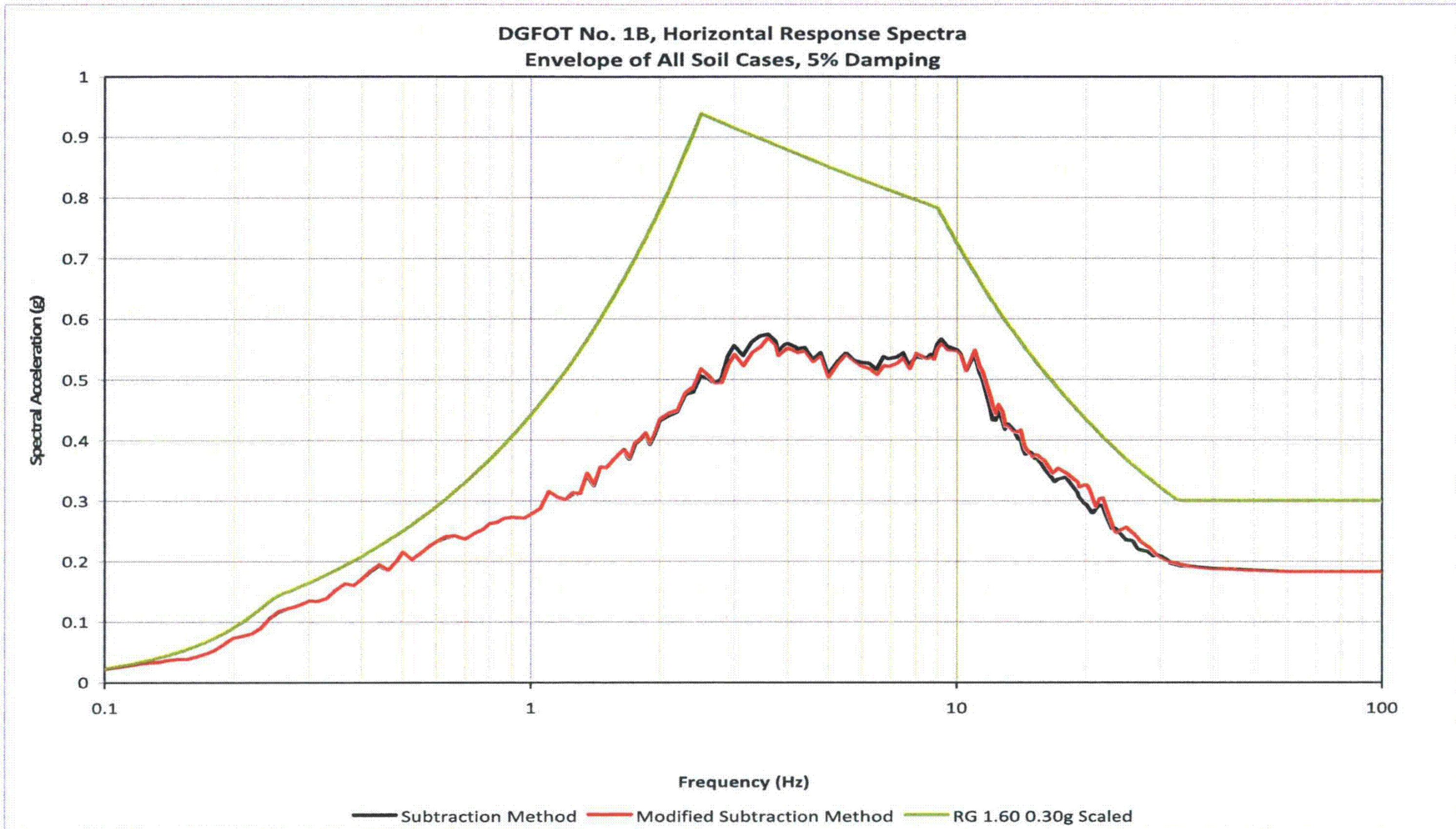


Figure 03.07.02-13 S4.11: Amplified Motion, MSM vs. SM

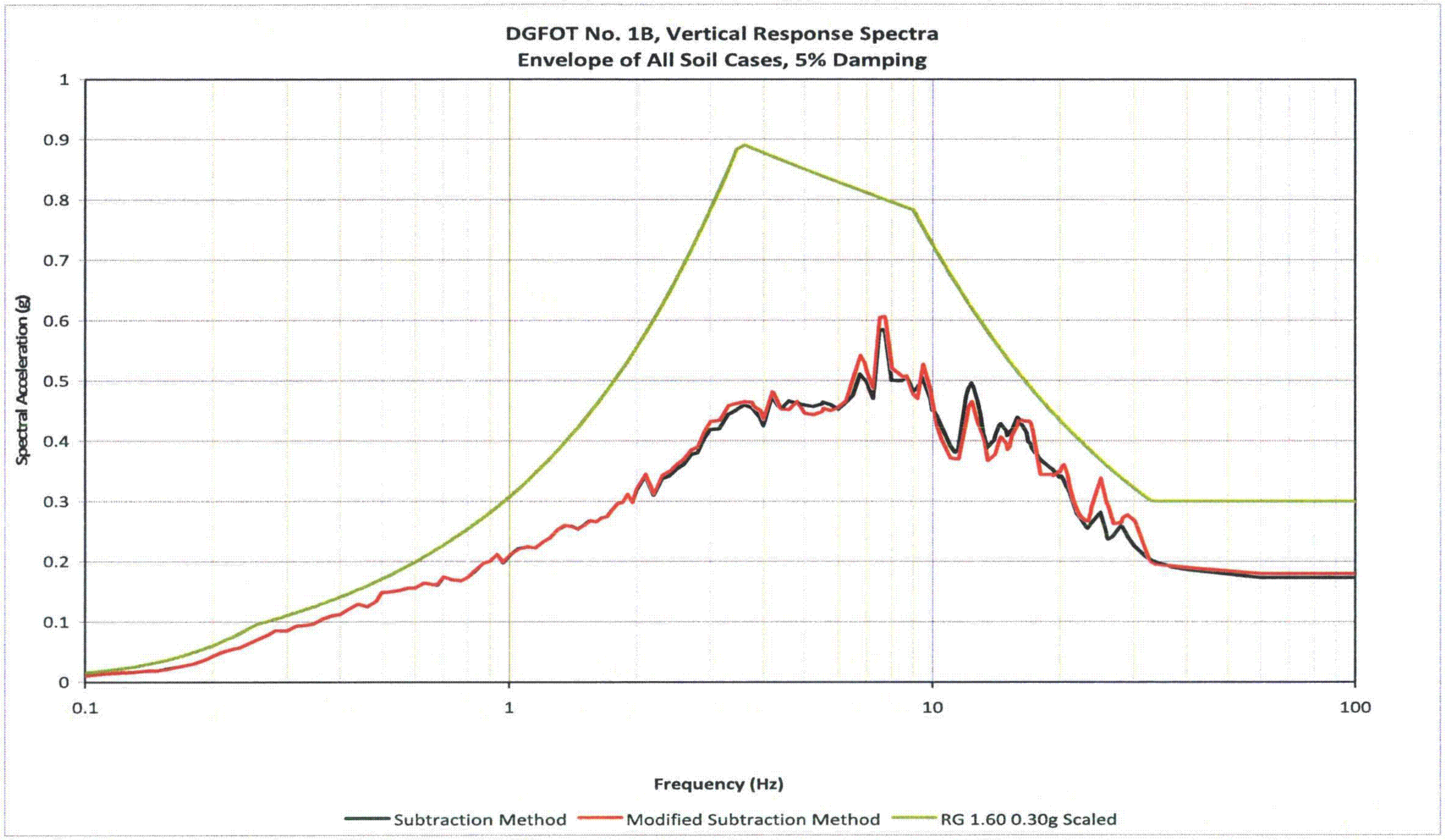


Figure 03.07.02-13 S4.12: Amplified Motion, MSM vs. SM

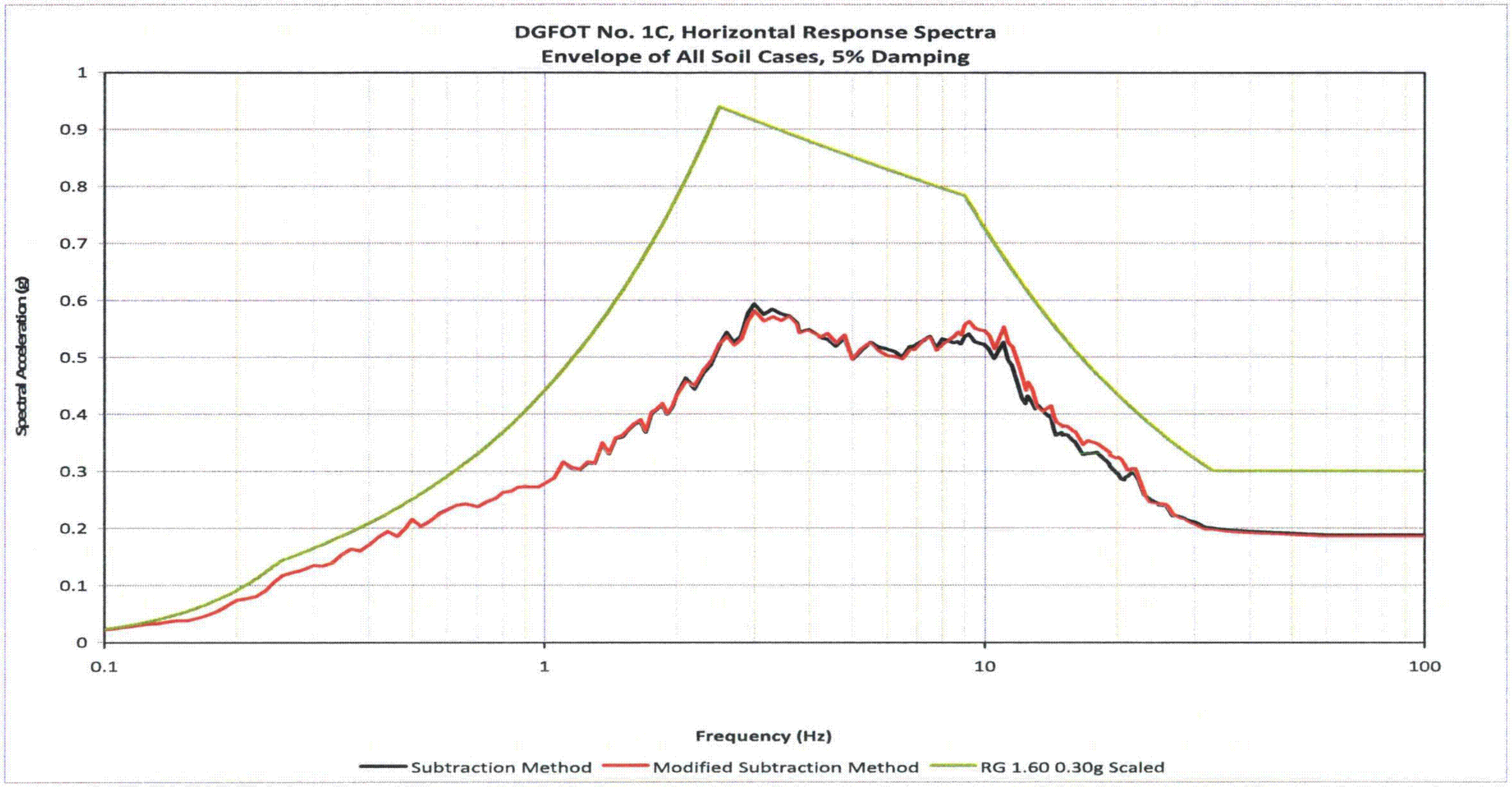


Figure 03.07.02-13 S4.13: Amplified Motion, MSM vs. SM

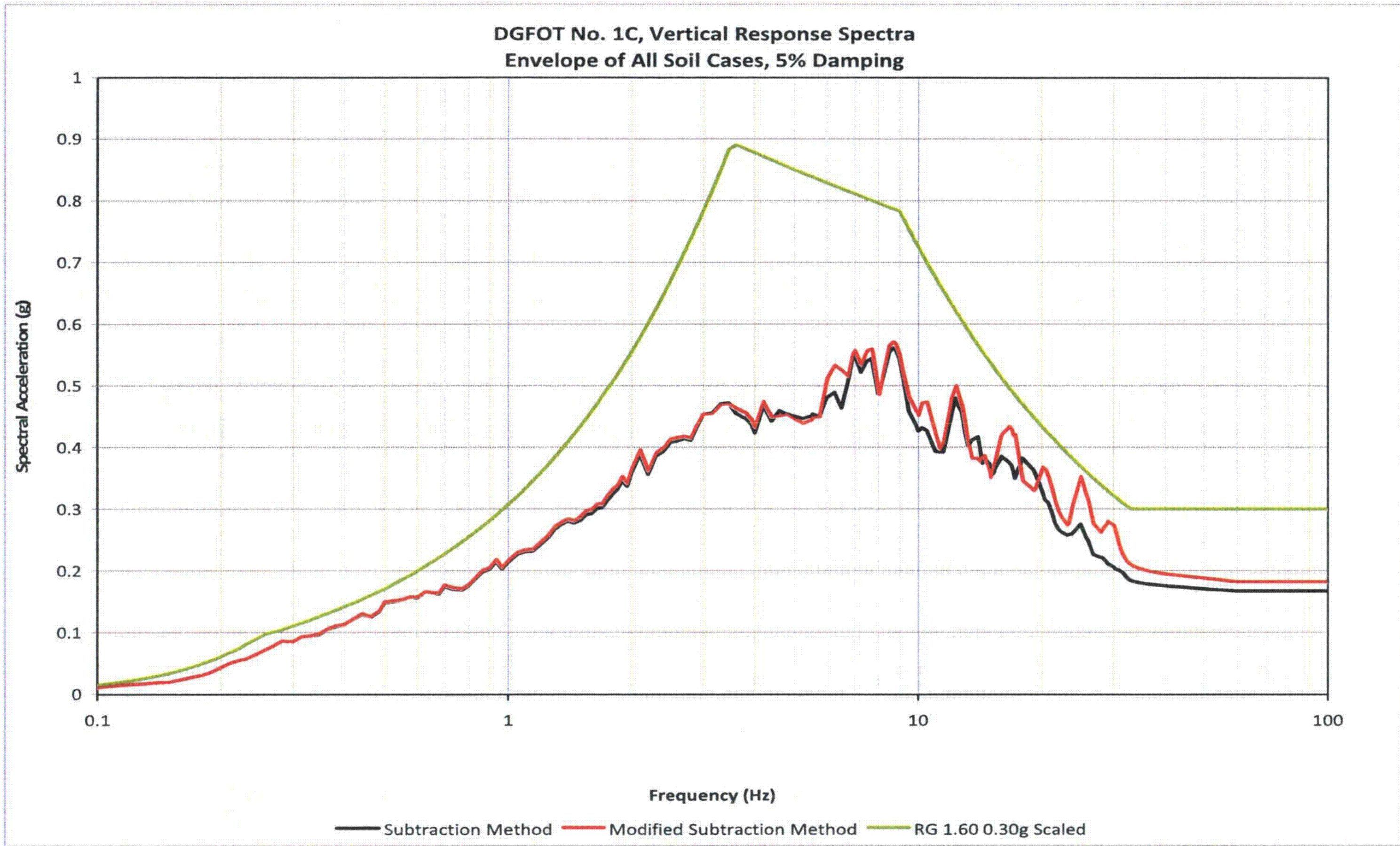


Figure 03.07.02-13 S4.14: Amplified Motion, MSM vs. SM

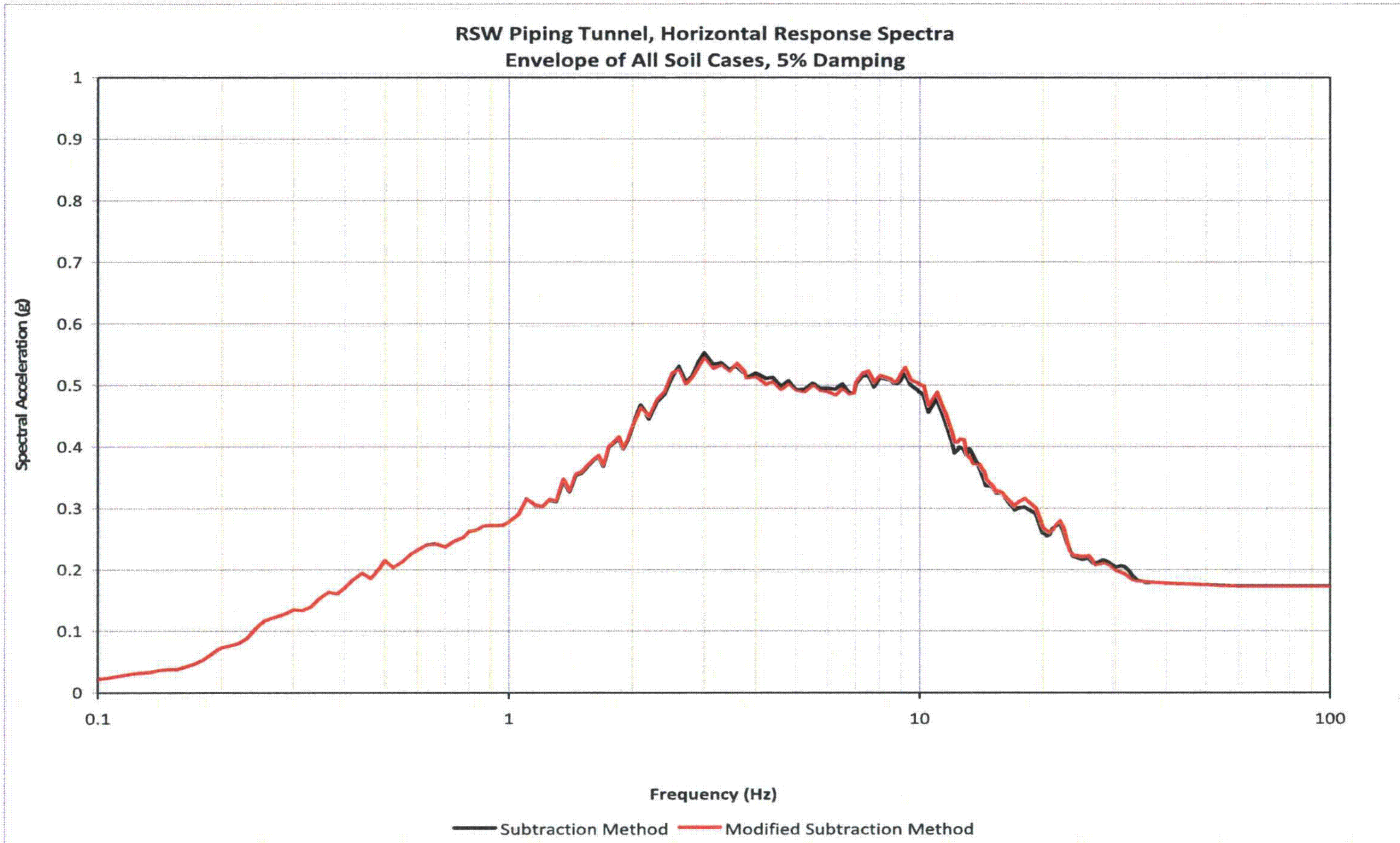


Figure 03.07.02-13 S4.15: Amplified Motion, MSM vs. SM

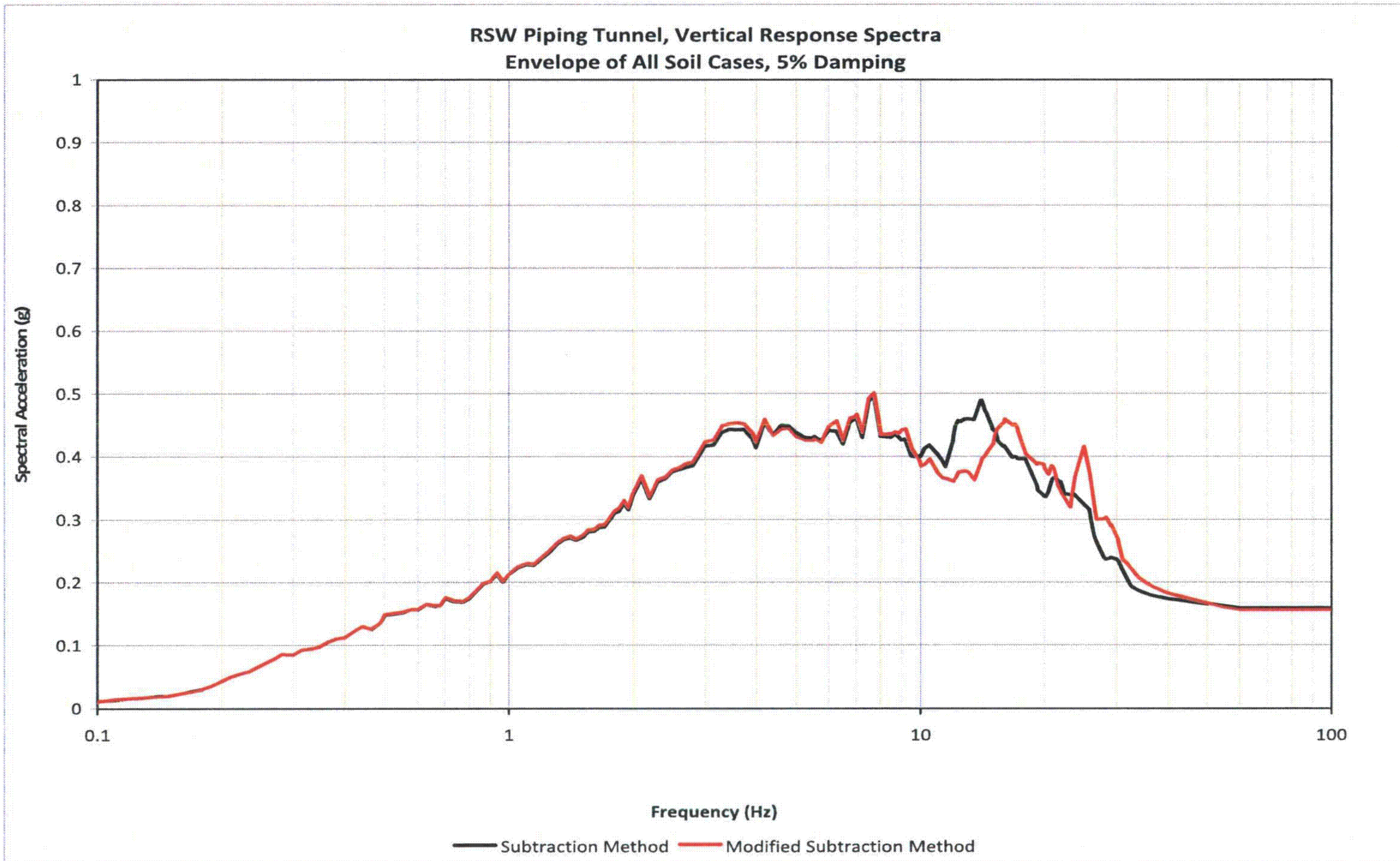


Figure 03.07.02-13 S4.16: Amplified Motion, MSM vs. SM

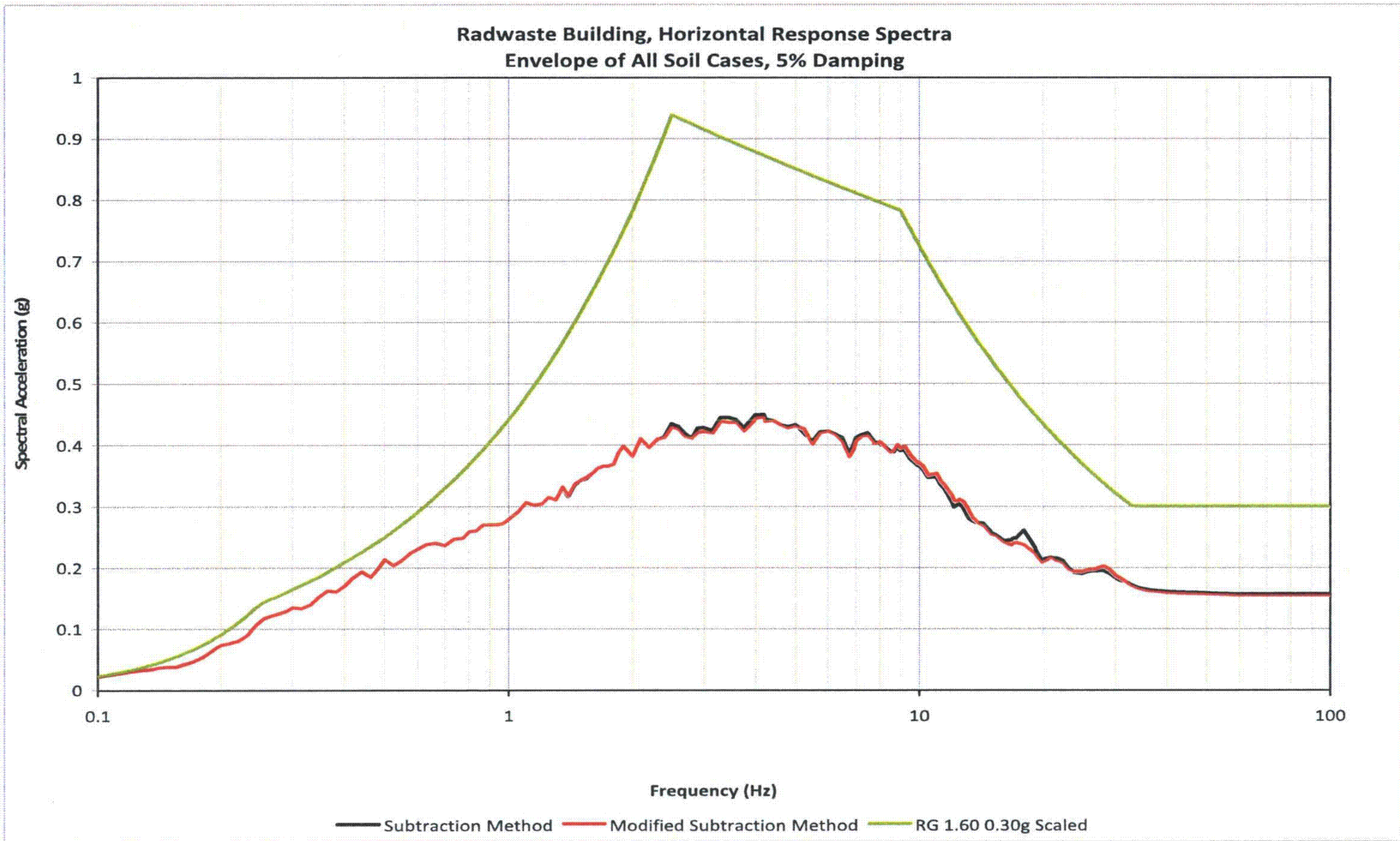


Figure 03.07.02-13 S4.17: Amplified Motion, MSM vs. SM

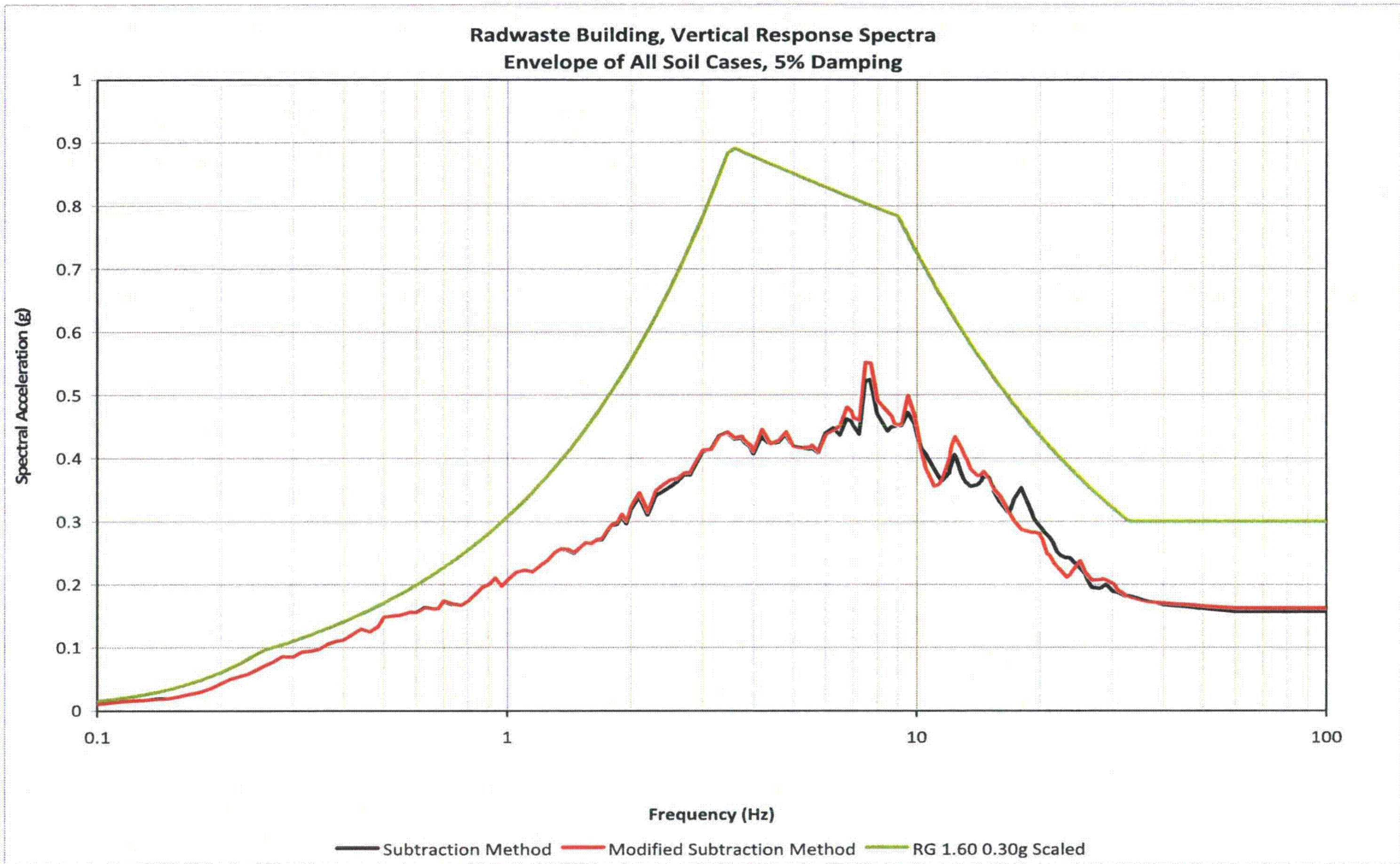


Figure 03.07.02-13 S4.18: Amplified Motion, MSM vs. SM

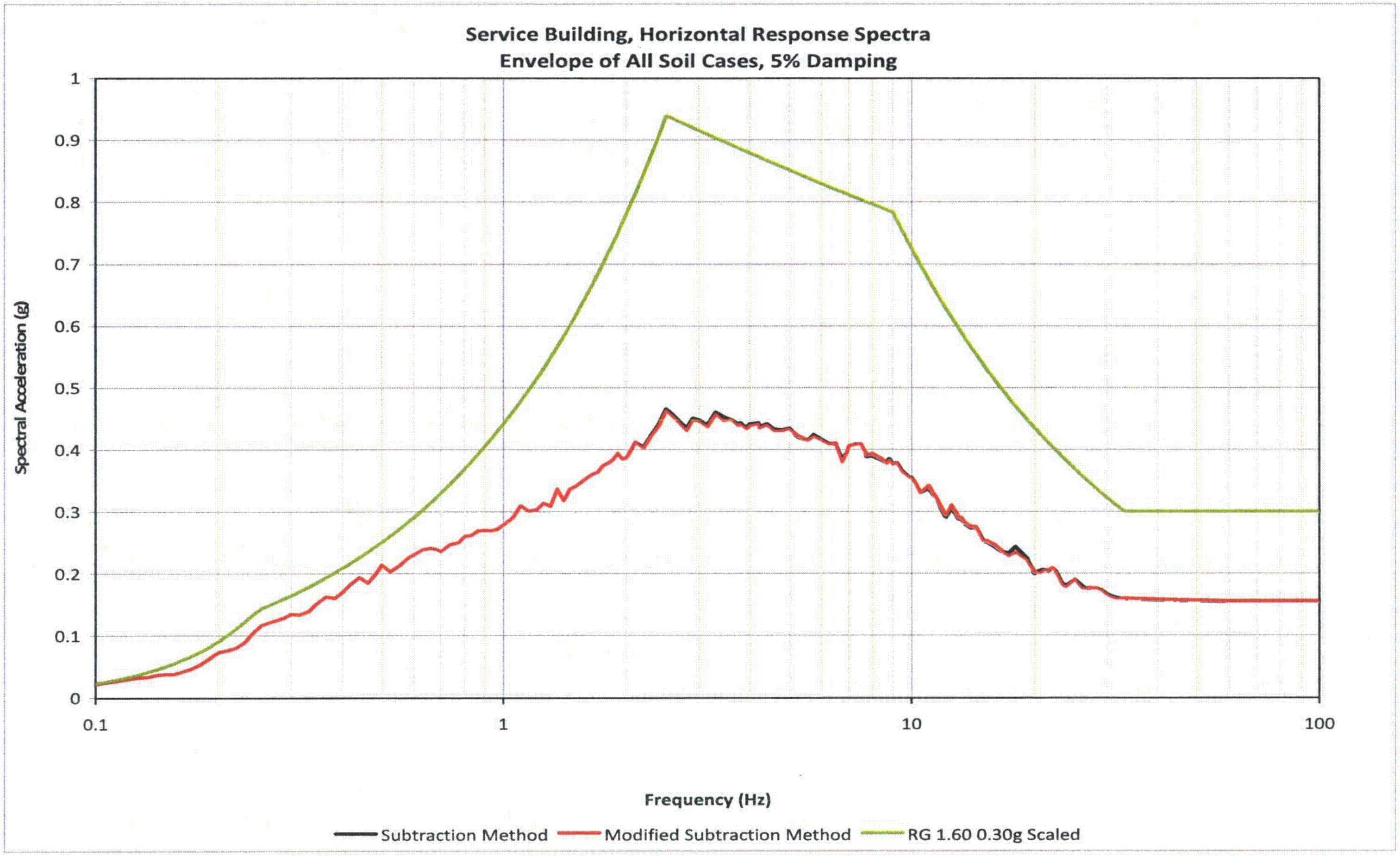


Figure 03.07.02-13 S4.19: Amplified Motion, MSM vs. SM

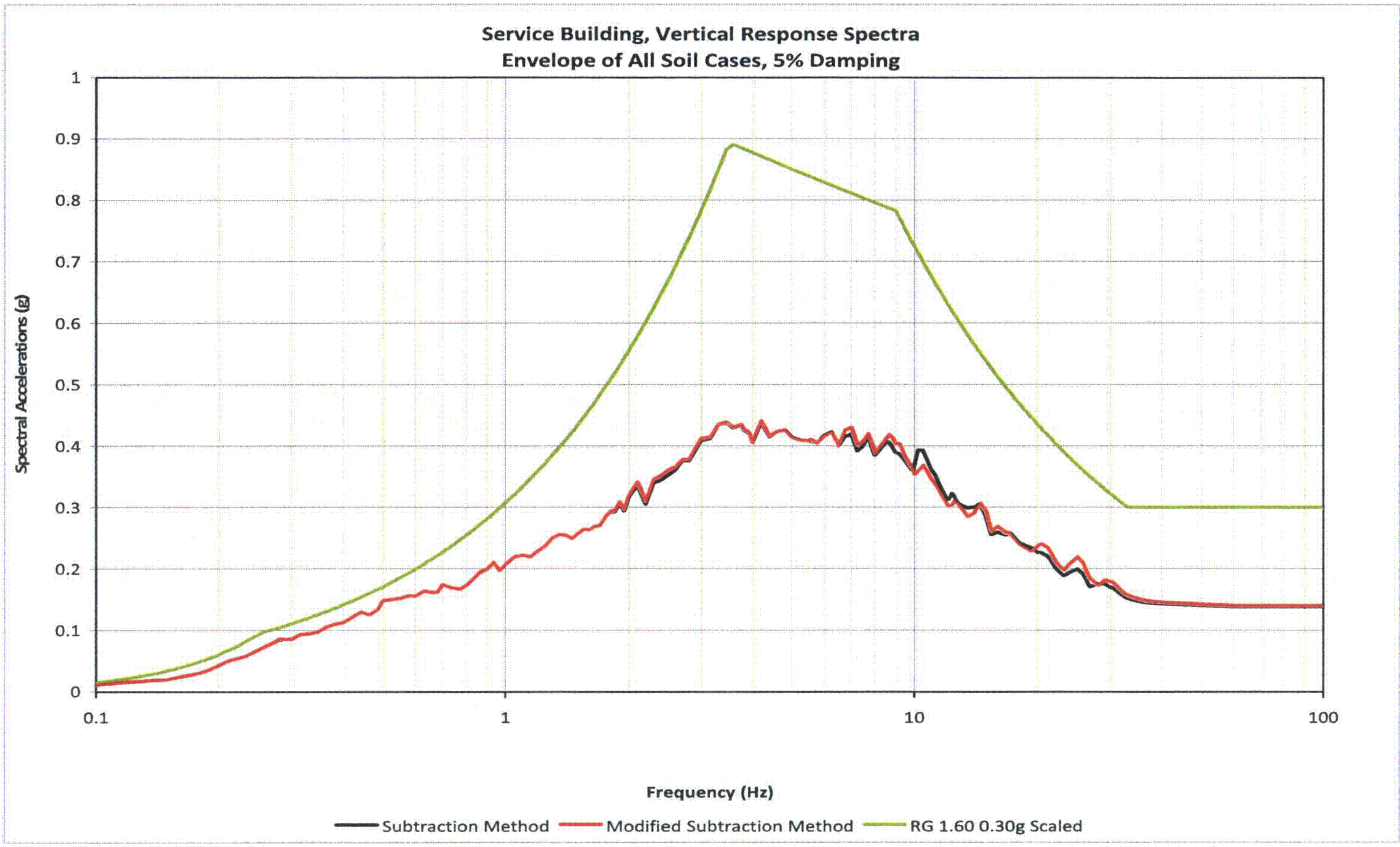


Figure 03.07.02-13 S4.20: Amplified Motion, MSM vs. SM

Enclosure 1

COLA MARK-UPS
(Based on COLA Revision 6)

Table 3H.6-5: Factors of Safety Against Sliding, Overturning, and Flotation for UHS Basin and RSW Pump House

Load Combination	Calculated Safety Factor			Notes
	Overturning	Sliding	Flotation	
D + F'	---	---	1.77	2, 3
D + H + W	2.15	11.5	---	2, 3
D + H + Wt	2.11	7.2	---	2, 3
D + H + E'	1.47	1.11	---	2, 3, 4, 5, 6

Notes:

(1) Loads D, H, W, Wt, and E` are defined in Subsection 3H.6.4.3.4.1. F` is the buoyant force corresponding to the design basis flood.

(2) Reported safety factors are conservatively based on considering empty weight of the UHS basin.

(3) Coefficients of friction for sliding resistance are 0.3 under the RSW Pump House and 0.4 under the UHS Basin

(4) The calculated safety factor for sliding requires less than half of the available passive pressure to be engaged for sliding resistance

(5) The seismic values considered for stability are based on the full basin case and the empty basin case.

(6) The seismic sliding forces and overturning moments from SSI analysis are less than the seismic sliding forces and overturning moments used in the stability evaluations.

Table 3H.6-12: Factors of Safety Against Sliding, Overturning, and Flotation for Diesel Generator Fuel Oil Storage Vaults

Load Combination	Calculated Safety Factor			Notes
	Overturning	Sliding	Flotation	
D + F'	---	---	1.28	2, 3
D + H + W	1.5	5.84	---	2, 3, 4
D + H + Wt	1.41	19.75	---	2, 3
D + H + E'	1.1	1.1	---	3, 4, 5

Notes:

1) Loads D, H, W, Wt, and E` are defined in Subsection 3H.6.4.3.4.1. F` is the buoyant force corresponding to the design basis flood.
2) Reported safety factors are conservatively based on considering empty weight of the fuel oil tank.
3) Coefficients of friction for sliding resistance are 0.58 for static conditions and 0.39 for dynamic conditions for the Diesel Generator Fuel Oil Storage Vault.
4) The calculated safety factors consider less than ~~half of the~~ full passive pressure. The calculated safety factors increase if full passive pressure (Kp = 3.0) is considered.
5) The seismic sliding forces and overturning moments from SSI and SSSI analyses are less than the seismic sliding forces and overturning moments used in the stability evaluations.

Table 3H.6-14: Calculated Overturning and Sliding Factors of Safety Under Site-Specific SSE and Flotation Factors of Safety for TB, SB, RWB and CBA

Structure	Calculated Factor of Safety			Minimum Required Factor of Safety	Coefficient of Friction for Sliding Evaluation
	Overturning	Sliding	Flotation		
Turbine Building (TB)	2.18	1.11	1.46	1.1	0.30 (dynamic)
Service Building (SB)	~~2.65~~2.11	~~1.81~~1.11	1.40	1.1	0.39 (dynamic)
Radwaste[1] Building (RWB)	~~4.23~~3.24	~~1.92~~1.68	1.51	1.1	0.39 (dynamic)
Control Building Annex (CBA)	2.03	1.16	1.18	1.1	0.58 (static)

Notes:

(1) The seismic sliding forces and overturning moments from SSSI analysis are less than the seismic sliding forces and overturning moments used in the stability evaluations.

Table 3H.6-16: Factors of Safety Against Sliding, Overturning, and Flotation for Reactor Service Water Tunnel

Load Combination	Calculated Safety Factor			Notes
	Overturning	Sliding	Flotation	
D + F'	---	---	1.18	2
D + H + W	2.29	50.76	---	2
D + H + Wt	2.23	21.31	---	2
D + H + E'	1.1	1.29	---	2, 3, 4

Notes

(1) Loads D, H, W, Wt, and E` are defined in Subsection 3H.6.4.3.4.1. F` is the buoyant force corresponding to the design basis flood.

(2) Coefficients of friction for sliding resistance are 0.45 for static conditions and 0.30 for dynamic conditions for the RSW Tunnel.

(3) The calculated safety factors consider less than half of the full passive pressure. The calculated safety factors increase if full passive pressure (Kp = 3.0) is considered.

(4) The seismic sliding forces and overturning moments from SSI and SSSI analyses are less than the seismic sliding forces and overturning moments used in the stability evaluations.

Table 3H.7-2: Factors of Safety against Sliding, Overturning and Flotation for DGFOT

Load Combination	Calculated Safety Factor			Notes
	Overturning	Sliding	Flotation	
D + F_b	--	--	1.70	
D + H + W	1.58	3.47	--	2, 3 (Sliding Only)
D + H + Wt	1.10	1.10	--	2, 4
D + H' + E'	1.30	1.28	--	2, 3, 5

Notes:

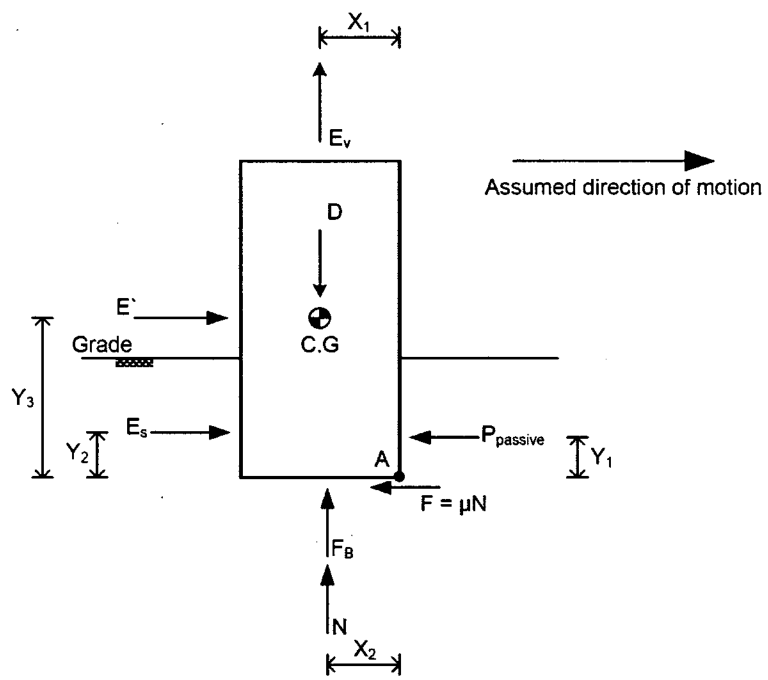
(1) Loads D, H, H', W, Wt, and E' are defined in Section 3H.7.4.3.4. F_b is the buoyant force corresponding to the design basis flood.

(2) Coefficients of friction for sliding resistance are 0.58 for static conditions and 0.39 for dynamic conditions for the Diesel Generator Fuel Oil Tunnel.

(3) The calculated safety factors consider the full passive pressure.

(4) The minimum calculated safety factor against sliding and overturning for tornado wind is 2.32. For tornado wind in conjunction with tornado missile, subsequent detailed design of the restraints for the Access Regions will provide sliding and overturning safety factors greater than 1.10.

(5) The seismic sliding forces and overturning moments from SSI and SSSI analyses are less than the seismic sliding forces and overturning moments used in the stability evaluations.



Factors of Safety against Sliding and Overturning about point A are calculated as follows:

$$SF_{sliding} = \frac{P_{passive} + F}{E_s + E`}$$

$$SF_{OT\_A} = \frac{(P_{passive})(Y_1) + (D)(X_1) - (F_B)(X_2)}{(E_s)(Y_2) + (E`)(Y_3) + (E_v)(X_1)}$$

Where:

$SF_{sliding}$ = Safety factor against sliding

SF_{OT_A} = Safety factor against overturning about "A"

D = Dead load

$P_{passive}$ = Total passive soil pressure

$F = \mu N$ = friction force and μ is the coefficient of friction

E_s = Static and dynamic soil pressure (active condition)

E` = Self weight excitation in the horizontal direction

E_v = Self weight excitation in the vertical direction

F_B = Buoyancy force

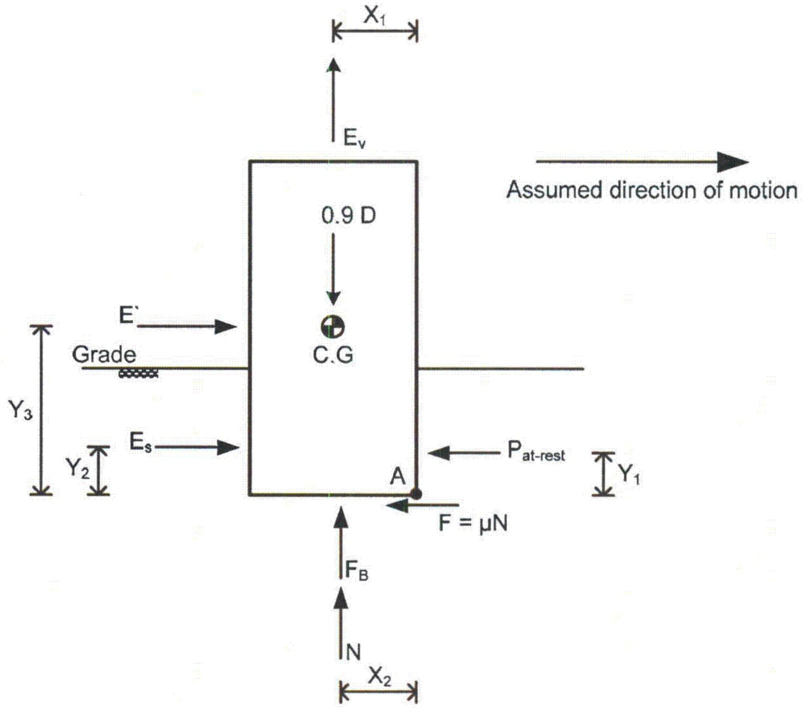
N = Vertical reaction $= D - F_B - E_v$

Notes:

(1) E' represents the inertia of the structure and it is either determined from equivalent static method or response spectrum analysis.

(2) E_s represents the static and dynamic loads from soil which includes seismic loads from soil and hydrodynamic pressure from groundwater. These loads are computed in accordance with Section 2.5S4.10.5.

Figure 3H.3-52: Formulations Used for Calculations of Factors of Stability Against Sliding and Overturning for Seismic II/I Considerations



Factors of Safety against Sliding and Overturning about point A are calculated as follows:

$$SF_{sliding} = \frac{P_{at\_rest} + F}{E_s + E`}$$

$$SF_{OT\_A} = \frac{(P_{at\_rest})(Y_1) + (0.9D)(X_1)}{(F_B)(X_2) + (E_s)(Y_2) + (E`)(Y_3) + (E_v)(X_1)}$$

Where:

$SF_{sliding}$ = Safety factor against sliding

SF_{OT_A} = Safety factor against overturning about "A"

D = Dead load

P_{at_rest} = Total at-rest soil pressure (see Figures 3H.6-48 through 3H.6-50)

$F = \mu N$ = friction force and μ is the coefficient of friction

E_s = Static and dynamic soil pressure (see Figures 3H.6-45 through 3H.6-47)

$E`$ = Self weight excitation in the horizontal direction

E_v = Self weight excitation in the vertical direction

F_B = Buoyancy force

N = Vertical reaction $= 0.9D - F_B - E_v$

Notes: ~~If passive pressure is utilized, $P_{passive}$ should be used instead of $P_{at\text{-}rest}$~~

(1) If passive pressure is utilized, $P_{passive}$ is used instead of $P_{at\text{-}rest}$

(2) E' represents the inertia of the structure and it is either determined from equivalent static method or response spectrum analysis.

(3) E_s represents the static and dynamic loads from soil which includes seismic loads from soil and hydrodynamic pressure from groundwater. These loads are computed in accordance with Section 2.5S4.10.5.

Figure 3H.6-137: Formulations Used for Calculation of Factors of Safety Against Sliding and Overturning for Category I Site-Specific Structures