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May 9, 2011
U7-C-NINA-NRC-110075

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
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South Texas Project
Units 3 and 4
Docket Nos. 52-012 and 52-013
Supplemental Response to Request for Additional Information

During an audit on March 14-18, 2011 and with subsequent phone call clarifications, the NRC Staff requested that Nuclear Innovation North America LLC (NINA) provide additional information to support the review of the Combined License Application (COLA). Attached is a supplemental response to NRC staff question included in Request for Additional Information (RAI) 03.07.02-29 related to COLA Part 2, Tier 2, Section 3.7.

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.

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

Executed on 5/9/11

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

jep

Attachment:
RAI 03.07.02-29, Supplement 1

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NRO

STI 32866304

cc: w/o attachment except*
(paper copy)

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RAI 03.07.02-29, Supplement 1

QUESTION:

RAI from Section 3.7 Audit, October 2010

For SSE ground motions, 10 CFR Part 50, Appendix S requires that SSCs will remain functional and within applicable stress, strain, and deformation limits and the evaluation must take into account soil-structure interaction (SSI) effects. Criterion III, "Design Control," of Appendix B to 10 CFR Part 50 states, in part, that "measures shall also be established for the selection and review for suitability of application of materials, parts, equipment, and processes that are essential to the safety related functions of the structures, systems and components." Additionally, Criterion III states in part that, "the design control measures shall provide for verifying or checking the adequacy of design,..." SRP Review guideline 3.8.1.II.4.F specifies that computer programs used in the design and analysis should be described and validated.

During the STP audit of Section 3.7, the verification and validation (V&V) documents of computer programs SASSI2000, SAP2000, and SHAKE2000 used in the seismic analysis of Category I structures were reviewed. The following issues were identified regarding these V&V documents:

SASSI2000 Version 3.0:

The SSI analysis performed with SASSI2000 is used to obtain the maximum accelerations, acceleration response spectra, and dynamic soil pressures that are used for seismic evaluation and design of the RB, CB, UHS Basin, RSW Pump House, and other seismic Category I structures. The dynamic forces, moments, and stresses are also calculated from the SASSI2000 analysis but are not used as design basis.

The V&V of three SASSI codes were reviewed. These codes are S&L SASSI2000-v3.0, SGH SASSI2000-v3.0 and SGH SASSI2000-v3.0-SGH. All three program V&V documentations do not adequately address all the program features that are used to calculate and obtain maximum accelerations, acceleration response spectra, and dynamic soil pressures. In particular, the scope of the test problems does not address the adequacy of the following program features that may be used in STP applications:

- General direction of load application in the model
- General orientation of elements in the model
- Accuracy of triangular elements (solid, shell and plane-strain) that may be used
- Acceptable aspect ratio of rectangular elements (solid, shell and plane-strain) to obtain accurate results, as used in the models
- Required mesh refinement to output out-of-plane responses in shell element
- Accuracy of the subtraction method for calculating foundation impedance

In addition, potential numerical instabilities with the use of high Poisson's ratio for modeling the saturated soil behavior in SASSI2000 may be of concern, as the Poisson's ratio approaches 0.5. As a result, the SASSI2000-v3.0 limitations with respect to capping the Poisson's ratio to avoid possible stability problems should be validated and stated.

Significant differences in the out-of-plane acceleration response of thick versus thin shell element models have also been observed in the analysis results with the thick shell model producing lower responses. This also needs to be further evaluated for SASSI2000-v3.0 as to the adequacy and limitations of the specific shell element type.

Without further demonstration that encompasses validation of the program features discussed above for STP applications, the staff cannot make a determination in the SER that the programs used in the seismic analysis will not adversely affect the SSI analysis result and meet the applicable regulations. As such, the applicant is requested to further demonstrate acceptability of SASSI2000 with additional test problems addressing the issues discussed above.

SAP2000 Version 10.1 and 14.1:

SAP2000 is used to calculate forces, moments and stresses for design of the site-specific seismic Category I structures such as UHS Basin, RSW Pump House, and RSW tunnel. The forces and moments are calculated by integrating stresses across design sections. It also appears that the thick shell element is used for modeling and design of slabs. Mesh sensitivity studies are also performed using time-history modal superposition method of fixed-base structure to assess the adequacy of the structural mesh refinement for calculation of accelerations and acceleration response spectra. To that extent, the SAP2000 V&V does not provide adequate validations for the following items:

- Accuracy of forces and moments calculated from section cuts in shell models
- Accuracy of thick shell element for calculating out-of-plane dynamic responses
- Accuracy of time-history modal analysis of fixed-base structures modeled using shell elements

As such, the applicant is requested to supplement the SAP2000 V&V with additional test problems to address the items discussed above. The staff needs this information to be able to conclude in the SER that the use of SAP2000 in STP applications will not adversely affect calculation of seismic forces and moments and the evaluation of SSI effects for Category I structures.

SHAKE2000 Version 3.5:

SHAKE2000 is used to calculate SSE-based foundation motions for SSI analysis of UHS Basin, RSW Pump House, and other Seismic Category I structures. The SHAKE2000 V&V has only tested soil models with up to 8 soil layers while the STP profile is a deep soil site that is modeled using large number of soil layers.

As such, the applicant is requested to further demonstrate acceptability of SHAKE2000 with additional test problems that check the use of large number of soil layers to encompass STP soil site. The staff needs this information to be able to conclude that the SSE-based foundation motion determined using SHAKE2000 computer program is adequate for STP application and meets the requirement of Appendix S to 10 CFR Part 50.

SUPPLEMENTAL RESPONSE:

The revision 1 response to this RAI was submitted with NINA letter U7-C-NINA-NRC-110043, dated March 15, 2011. This supplement provides responses for the following items related to SASSI2000 and SAP2000 validation and verification (V&V):

- Audit Action Item 3.7-28 discussed in the NRC Audit held during March 14-18, 2011.
- Clarification Issues #6 and #7 provided by the NRC staff subsequent to the NRC Audit

The descriptions of the above items along with their respective responses are provided below.

A. Audit Action Item 3.7-28

Action Item:

During the March 14-18 NRC Audit, NRC staff requested the following:

- For the S&L SASSI2000 aspect ratio test problem for two-way slab action, S&L was requested to provide transfer functions at the center of the roof slab for vertical excitation using the corresponding SGH model and considering very high soil shear wave velocity (rigid).
- For the SGH SASSI2000 aspect ratio test problem for two-way slab action provide transfer functions at the center of the roof slab for vertical excitation considering very high soil shear wave velocity (rigid).
- S&L was requested to add a cautionary note to the SASSI2000 release memorandum for users to examine transfer functions for any sign of instability.

Response:

As requested, the S&L aspect ratio test problem for two-way slab action was re-analyzed using the corresponding SGH model shown in Figures 03.07.02-29.68 through 03.07.02-29.70 provided in the Revision 1 response to this RAI which was submitted with NINA letter U7-C-NINA-NRC-110043, dated March 15, 2011. These Figures are presented as Figures 03.07.02-29 S1.1 through 03.07.02-29 S1.3 in this response.

For the aspect ratios of 1:1 and 1:5, the test problem is the same as shown in Figures 03.07.02-29 S1.1 and 03.07.02-29 S1.2, except that the excavation soil elements shown in Figure 03.07.02-29 S1.3 are changed to have shear wave velocity of 20,000 ft /sec (rigid soil). Other aspect ratio models (aspect ratios 1:2, 1:3 and 1:4) are constructed similarly but node and element numberings vary between the models. These models are analyzed by both S&L and SGH for vertical excitation and vertical direction transfer functions are calculated.

Figure 03.07.02-29 S1.4 shows the comparison of vertical direction transfer functions, for various aspect ratios at the center of the two-way roof slab from S&L SASSI2000 analysis. All transfer functions compare well for aspect ratios from 1:1 to 1:5.

Figure 03.07.02-29 S1.5 shows the comparison of vertical direction transfer functions, for various aspect ratios at the center of the two-way roof slab from SGH SASSI2000 analysis. All transfer functions compare well for aspect ratios from 1:1 to 1:5.

The comparison of Figures 03.07.02-29 S1.4 and 03.07.02-29 S1.5 also shows that the results from S&L SASSI2000 and SGH SASSI2000 are identical. This is as expected, because both programs have same executable and have been obtained from Isatis (agent for the Regents of the University of California).

Detailed cautionary checks are already specified on Pages 3-5 of the existing S&L SASSI2000 release memorandum requiring the users of the program to review the transfer functions and the results for any sign of instability.

B. Post Audit Clarification Issue #6

Clarification Issue:

In reviewing the SGH SASSI2000 V&V of the subtraction method, it was found that the test problems (SAS-3C, SAS-4C and SAS-8) are not analyzed to sufficiently high enough frequencies that can validate the stability and accuracy of the subtraction method for passing frequency of $V_s/5h$, where V_s is the lowest shear wave velocity of the foundation media and h is the largest element size in the soil model. In the case of S&L SASSI2000 V&V Test problems 4 and 8 used in validation of the subtraction method, the analyses were carried out to sufficiently high frequencies to cover the passing frequency requirement of $V_s/5h$. However, the conclusion does not address the stability and accuracy of the subtraction method used in the context of the calculated results. In both cases, the applicant is requested to revisit the test problems and provide validation that adequately addresses the stability and accuracy of the subtraction method in relation to the acceptable passing frequency of $V_s/5h$ used in the STP 3&4 design.

Response:

SGH's test Problem SAS-4C compares the response transfer functions of a circular embedded foundation over elastic half space to theoretical solutions calculated by Day (References 1 & 2). The test problem models a circular rigid foundation with a 65 ft radius, embedded 32.5 ft. The analyses were performed for cases with values of a_o up to 3.6, where a_o is a non-dimensional parameter = $2\pi fr/V_S$, with f being the frequency of analysis, r the radius, and

V_s the shear wave velocity of the soil. The SASSI2000 solutions for these cases show agreement with the theoretical solutions, verifying the SASSI2000 impedance calculations. Calculations were not performed beyond a_o of 3.6 because theoretical solutions obtained for similar problems by Apsel and Luco (Reference 3) are in agreement with the results of Day for a_o less than about 3, but the results start deviating at a_o of higher than 3. For the V&V test problem the mesh refinement was such that the analyses to a_o of 3.6 are performed to a frequency equal to about Vs/7h where h is the maximum element size along an axis.

In order to test the V_s/5h passing frequency limitation, a similar problem of a circular embedded foundation over elastic half space was performed with a less refined mesh, such that the V_s/5h passing frequency can be obtained with $a_o < 3$. The example problem models a circular rigid foundation with a 64 ft radius, embedded 32 ft. The results demonstrate agreement with the theoretical solutions at all frequencies analyzed up to the V_s/5h passing frequency, as shown in Figures 03.07.02-29 S1.6 through 03.07.02-29 S1.8.

The above test problem and test problem SAS-2A (Lotung model with 15 ft embedment) which was reviewed by the NRC staff during the March Audit, show the adequacy of the V_s/5h passing frequency for subtraction method and running the additional equivalent test examples of SAS-3C and SAS-8 are not needed.

Test problem 4 in S&L SASSI2000 V&V, which was also reviewed by the NRC staff during the March audit, is the Lotung model with 15 ft embedment. The model has been analyzed using both direct method and subtraction method. The analysis was carried out to sufficiently high frequencies to cover the passing frequency requirement of V_s/5h. The 5% damping response spectra at several locations of the model, obtained from direct method and subtraction method are compared with the recorded motion. The comparisons show that the results from the direct method and subtraction method are almost the same and they compare sufficiently well with the recoded motion.

Test problem 8 in S&L SASSI2000 V&V is for an embedded massless rigid cylinder, taken from Reference 4. The analysis of this problem was also reviewed by the NRC staff during the March audit. The problem description and the results in terms of transfer functions are provided in Reference 4. S&L has analyzed this problem using both the direct method and the subtraction method. The analysis was carried out to sufficiently high frequencies to cover the passing frequency requirement of V_s/5h. The passing frequency of the model, based on V_s/5h criteria is about 7 Hz. The comparisons of the transfer functions show that in case of subtraction method, the results compare well with the results shown in Reference 4 for frequencies up to about 5 Hz and then it starts deviating. In case of direct method, the results compare well with the results shown in Reference 4 for frequencies up to about 8 Hz and then it starts deviating. In S&L SASSI2000 V&V document it has been noted that at low frequencies the agreement between various methods are very good and that at higher frequencies there are some differences between the various methods.

Both S&L SASSI2000-v3.0 and SGH SASSI2000-v3.0 programs have the same executable and have been obtained from Isatis (agent for the Regents of the University of California).

Considering the results for the SGH and S&L V&V subtraction test problems SASSI2000-v3.0 subtraction method of analysis shows no sign of instability and is considered validated and verified.

C. Post Audit Clarification Issue #7

Clarification Issue:

The response to RAI.03.07.02-29, Rev. 1, documents additional validation problems for SAP2000. The validations include:

1) Section cuts
2) Thick shell out-of-plane response
3) Time history modal superposition with shell elements
4) Spectra calculation using thick shell elements

Validation of item "1" was done by hand calculation. For items "2", "3" and "4", the benchmark solutions for validation were developed with ANSYS utilizing "SHELL43 "element, which is well suited to model linear, warped, moderately-thick shell structures according to ANSYS User's Manual. For items "2", "3" and "4", the following acceptance criteria were used: 5% for frequencies, 10% for forces, and 15% for spectra. The 5% difference is considered acceptable within the engineering accuracy, while the 10% and 15% criteria may be excessive. The applicant is requested to assess the impact of the above acceptance criteria on the STP 3&4 design.

Response:

The higher difference in forces and spectra is mainly due to differences in the SAP2000 and ANSYS element formulations. As a result of these differences, the generated acceleration time histories from the two programs are somewhat different. Figures 03.07.02-29 S1.9 through 03.07.02-29 S1.12 show the comparison of the generated acceleration time histories.

The forces and spectra generated from the SAP2000 program application used for the mesh sensitivity study are not used for design. Therefore, the above acceptance criteria have no impact on STP 3&4 design.

No COLA mark-up is required for items A, B, and C above as a result of this supplemental response.

References:

1. Day. S.M., "Seismic Response of Embedded Foundations," ASCE Convention & Exposition, Chicago, October 16-20, 1978.
2. Day, S.M., "Finite Element Analysis of Seismic Scattering Problem," Ph.D. Dissertation, University of California, San Diego, 1977.
3. Apsel, R.J. and Luco J.E. "Impedance Functions for Foundations Embedded in a Layered Medium: An Integral Equation Approach," Earthquake Engineering and Structural Dynamics Vol. 15, 213-231, Revised 2 June 1986.
4. Kausel E., Whitman R. V., Morray J. P., and Elsabee F., "The Spring Method for Embedded Foundations", Nuclear Engineering and Design 48 (1978) 377-392

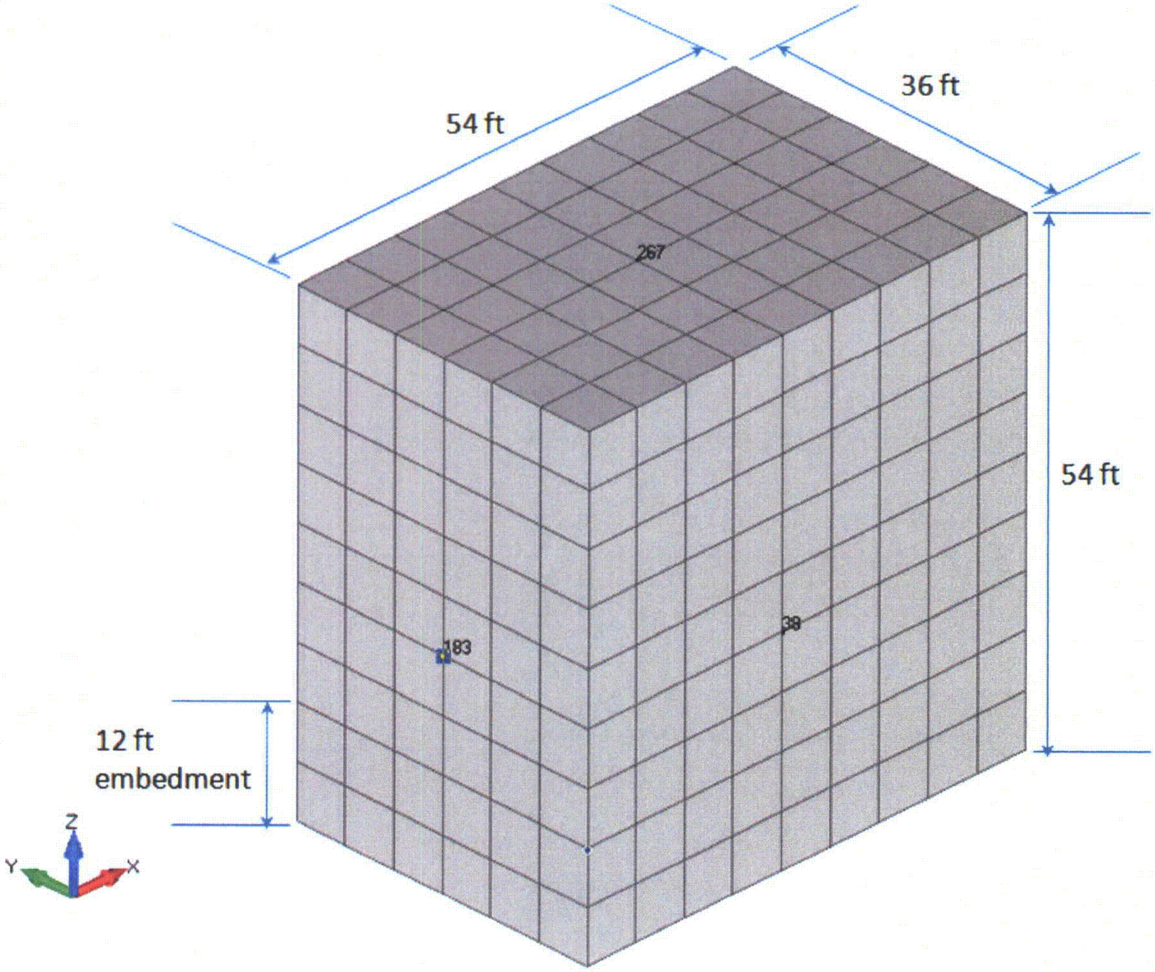

Figure 03.07.02-29 S1.1: Isometric View of the Box Structure (Element Aspect Ratio 1:1), Indicating the Nodes of Interest on Long Wall, Short Wall and Roof

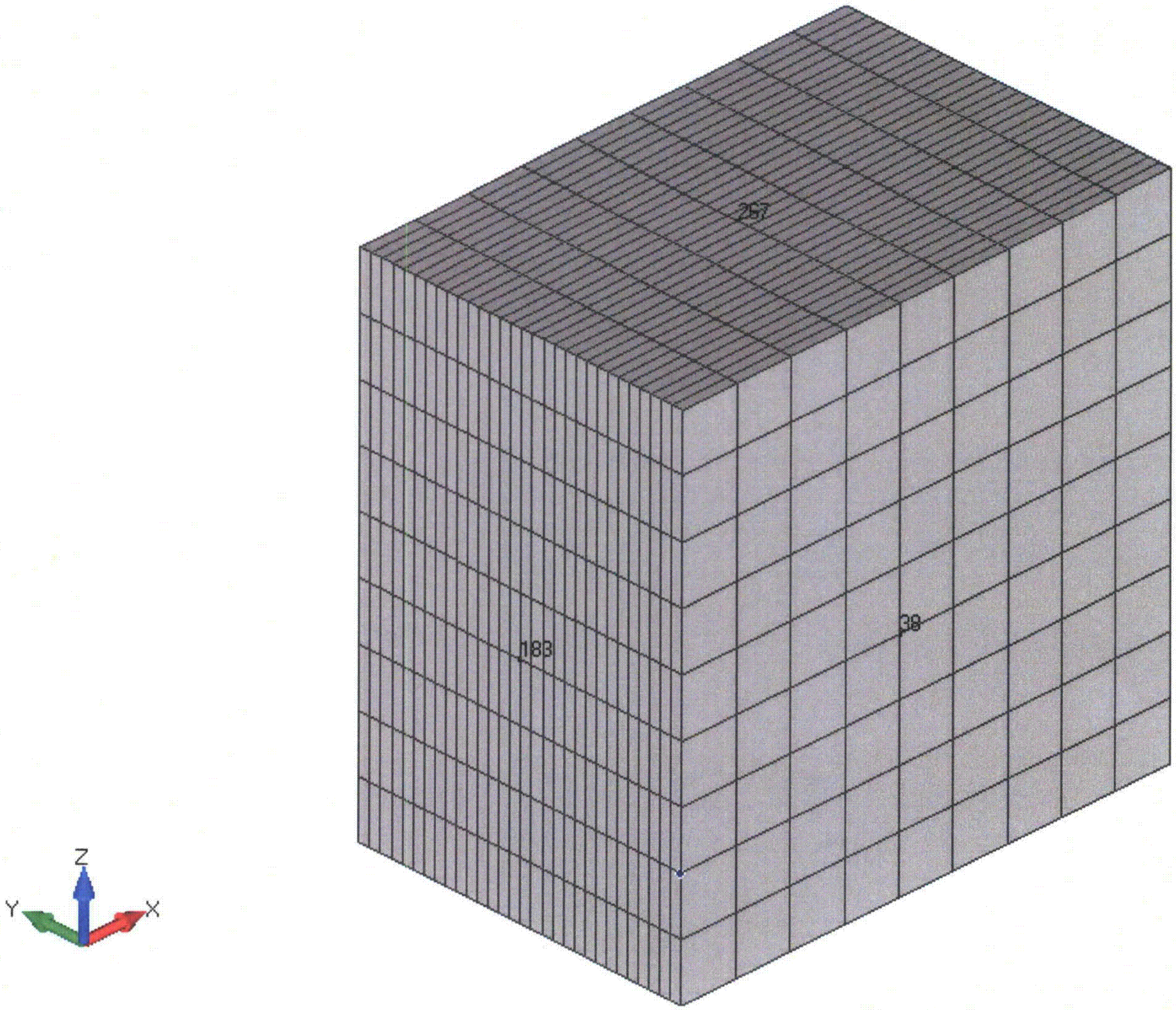

Figure 03.07.02-29 S1.2: Isometric View of the Box Structure (Element Aspect Ratio 1:5), Indicating the Nodes of Interest on Long Wall, Short Wall and Roof

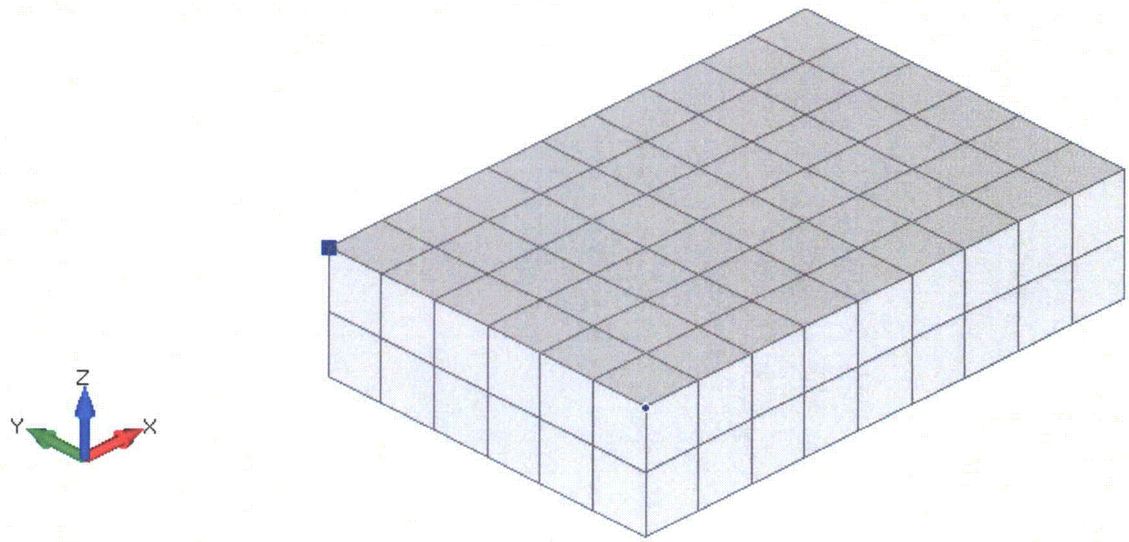

Figure 03.07.02-29 S1.3: Isometric View of the Excavation Soil Elements

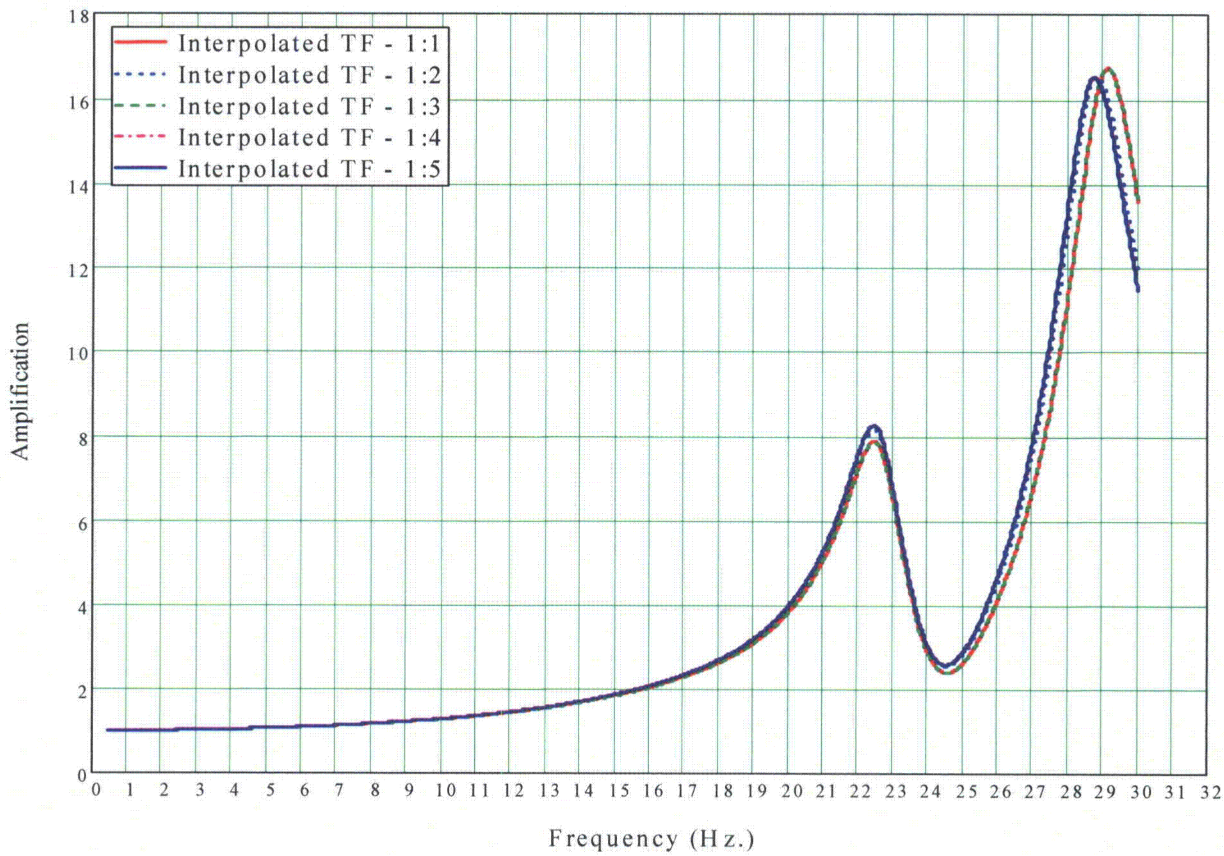

Figure 03.07.02-29 S1.4: Comparison of Vertical Direction Transfer Functions at the Roof Center (S&L SASSI2000-v3.0)

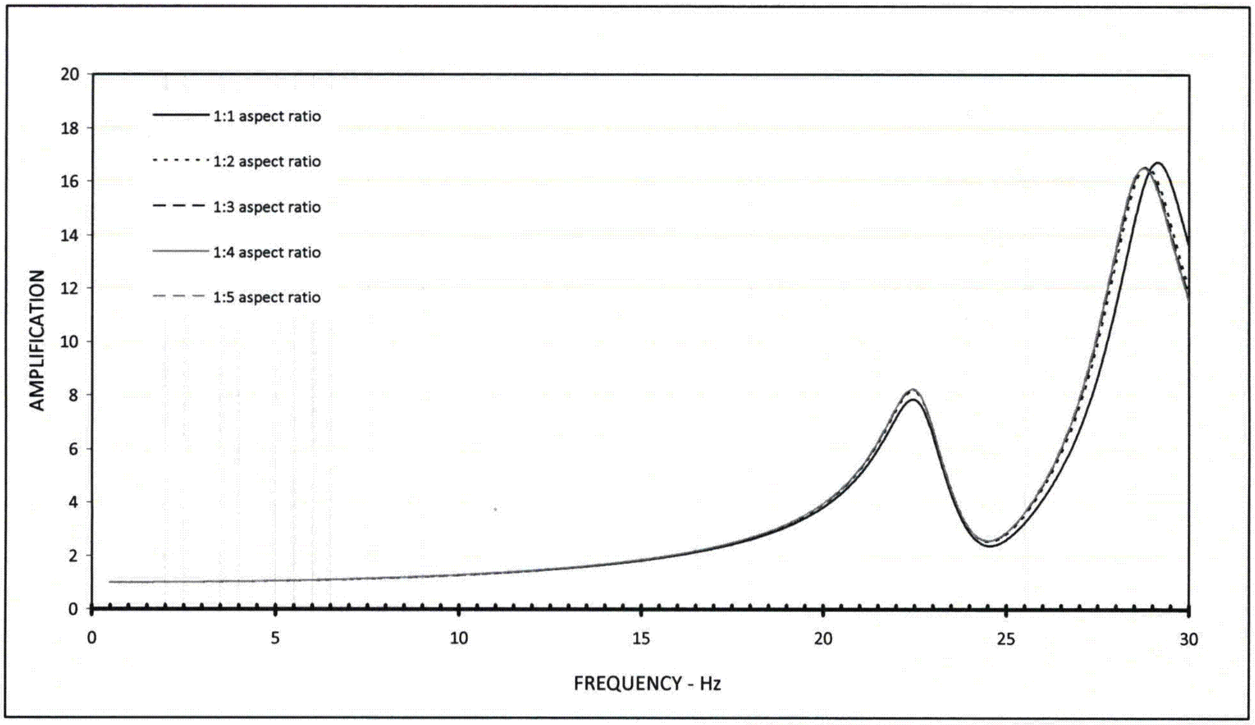

Figure 03.07.02-29 S1.5: Comparison of Vertical Direction Transfer Functions at the Roof Center (SGH SASSI2000-v3.0)

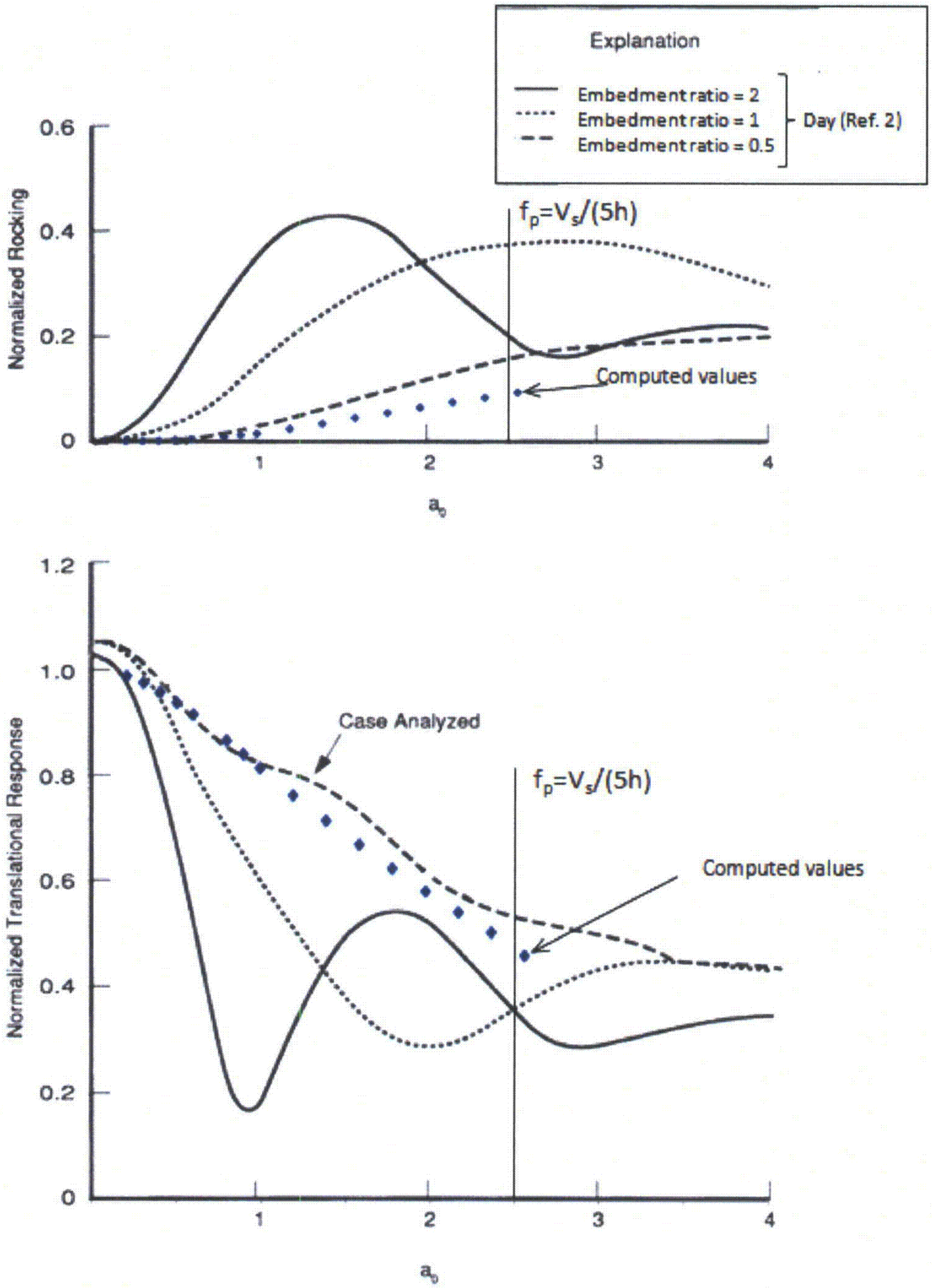

Figure 03.07.02-29 S1.6: Comparison of Response due to Vertically Propagating SV-Wave; Analysis Performed for Embedment Ratio = 0.5

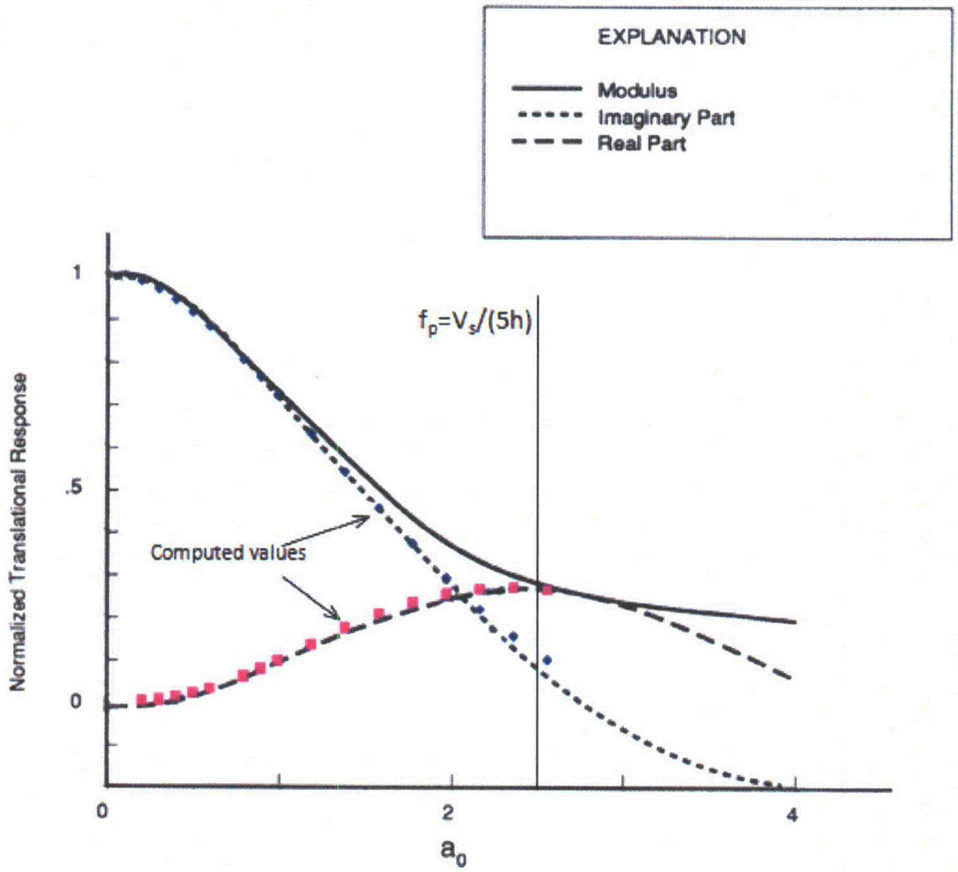

Figure 03.07.02-29 S1.7: Comparison of Translational Response due to Horizontally Propagating SH-Wave; Analysis Performed for Embedment Ratio = 0.5

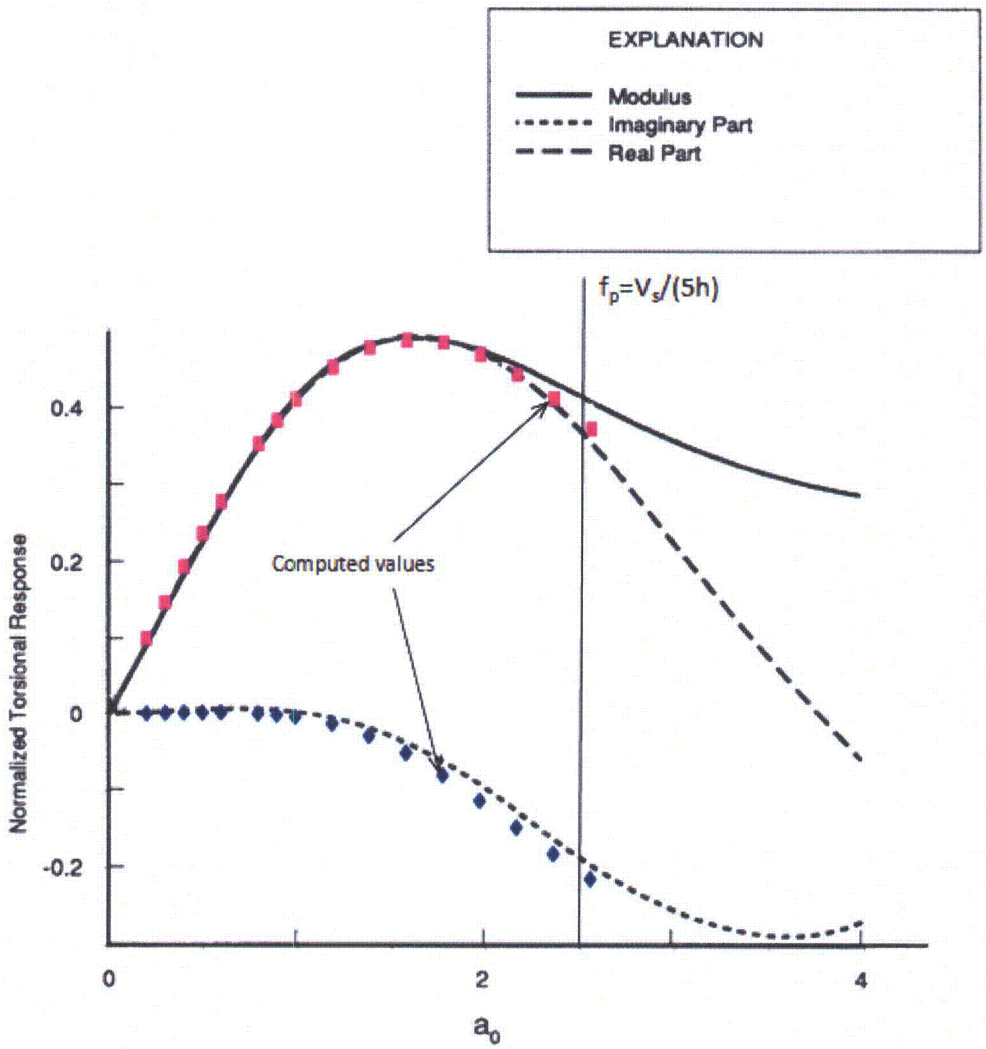

Figure 03.07.02-29 S1.8: Comparison of Torsional Response due to Horizontally Propagating SH-Wave; Analysis Performed for Embedment Ratio = 0.5

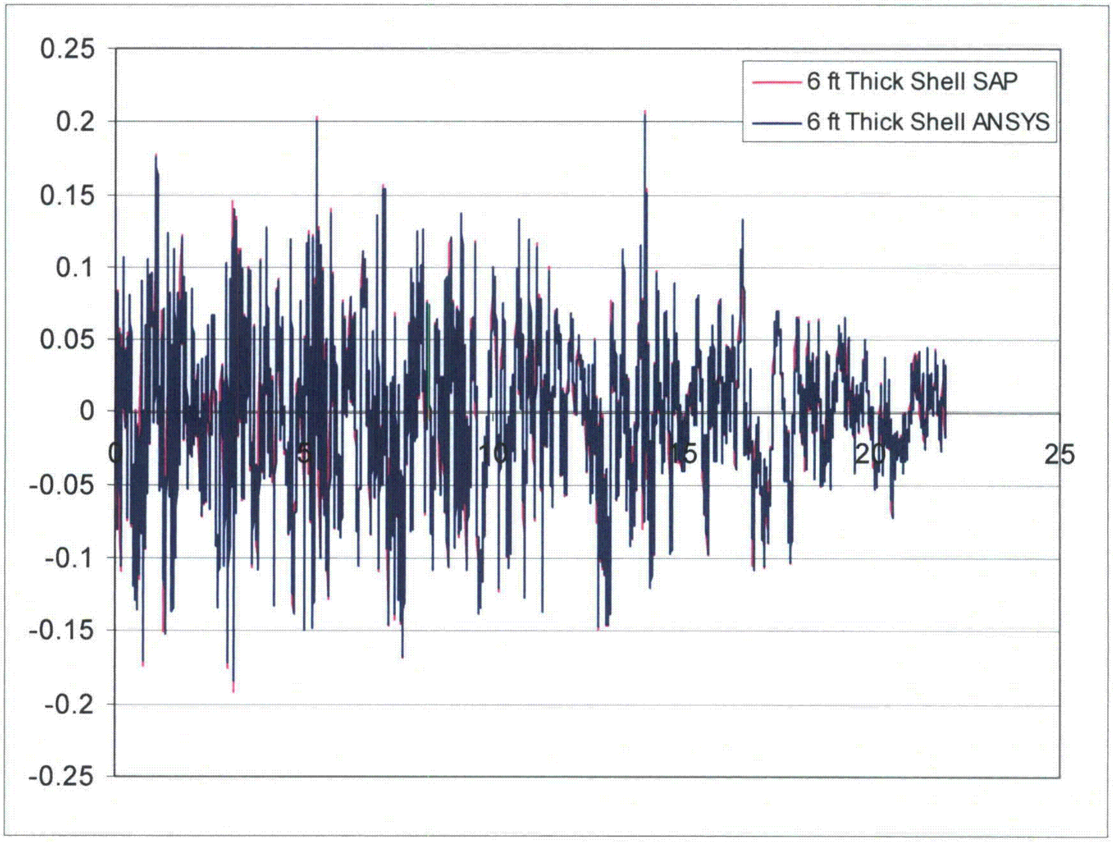

Figure 03.07.02-29 S1.9: Comparison of Generated Acceleration Time Histories from SAP2000 and ANSYS Programs for 6 ft Thick Slab Using Thick Shell Elements

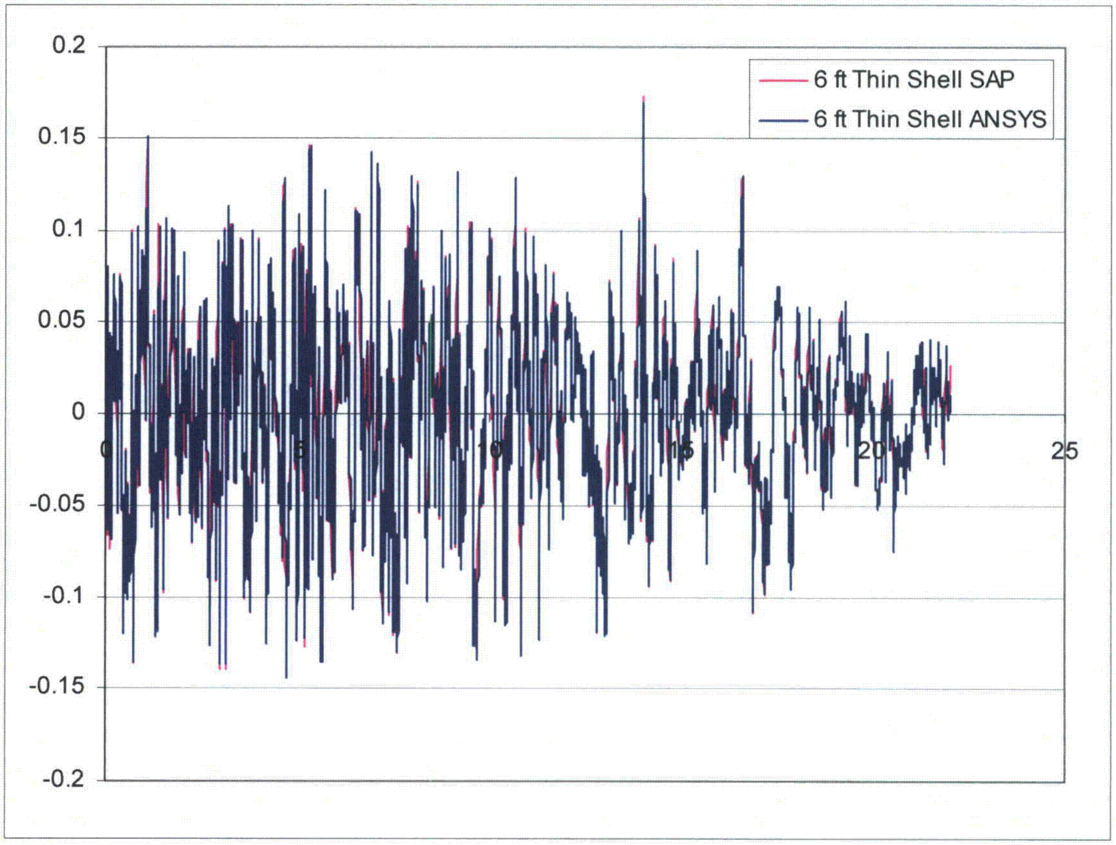

Figure 03.07.02-29 S1.10: Comparison of Generated Acceleration Time Histories from SAP2000 and ANSYS Programs for 6 ft Thick Slab Using Thin Shell Elements

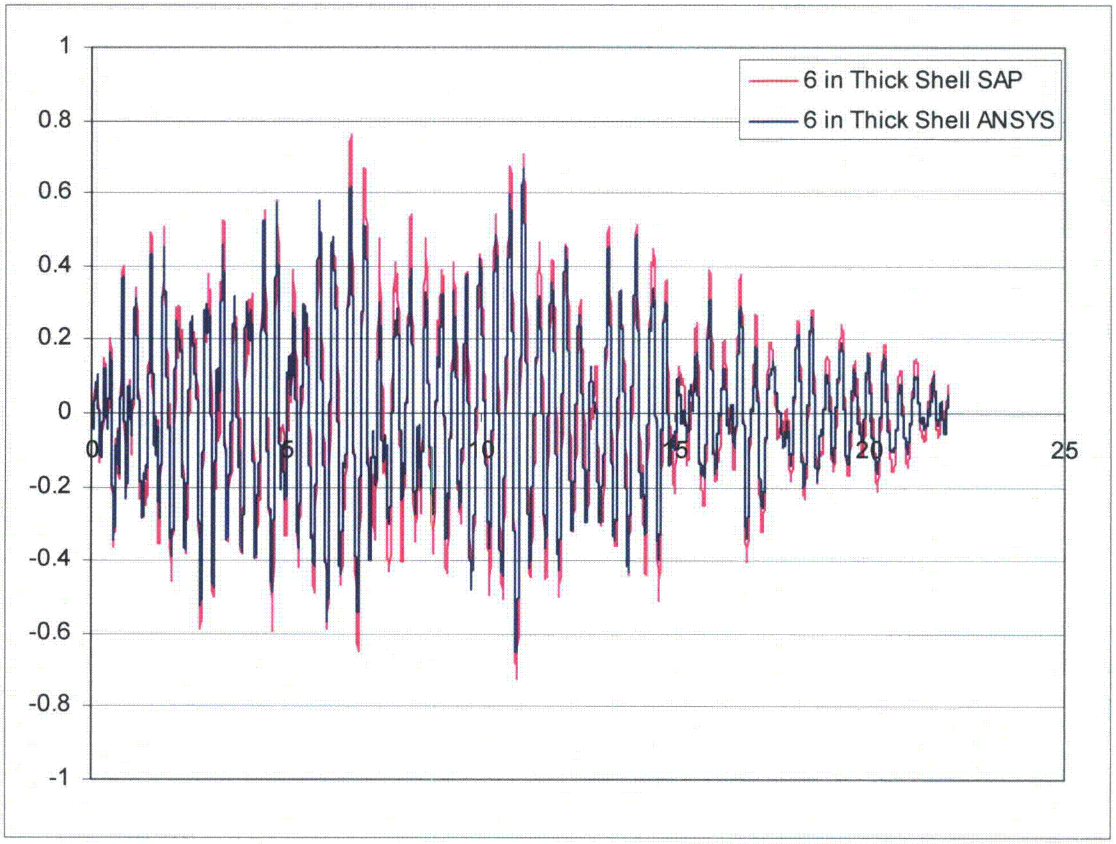

Figure 03.07.02-29 S1.11: Comparison of Generated Acceleration Time Histories from SAP2000 and ANSYS Programs for 6 in Thick Slab Using Thick Shell Elements

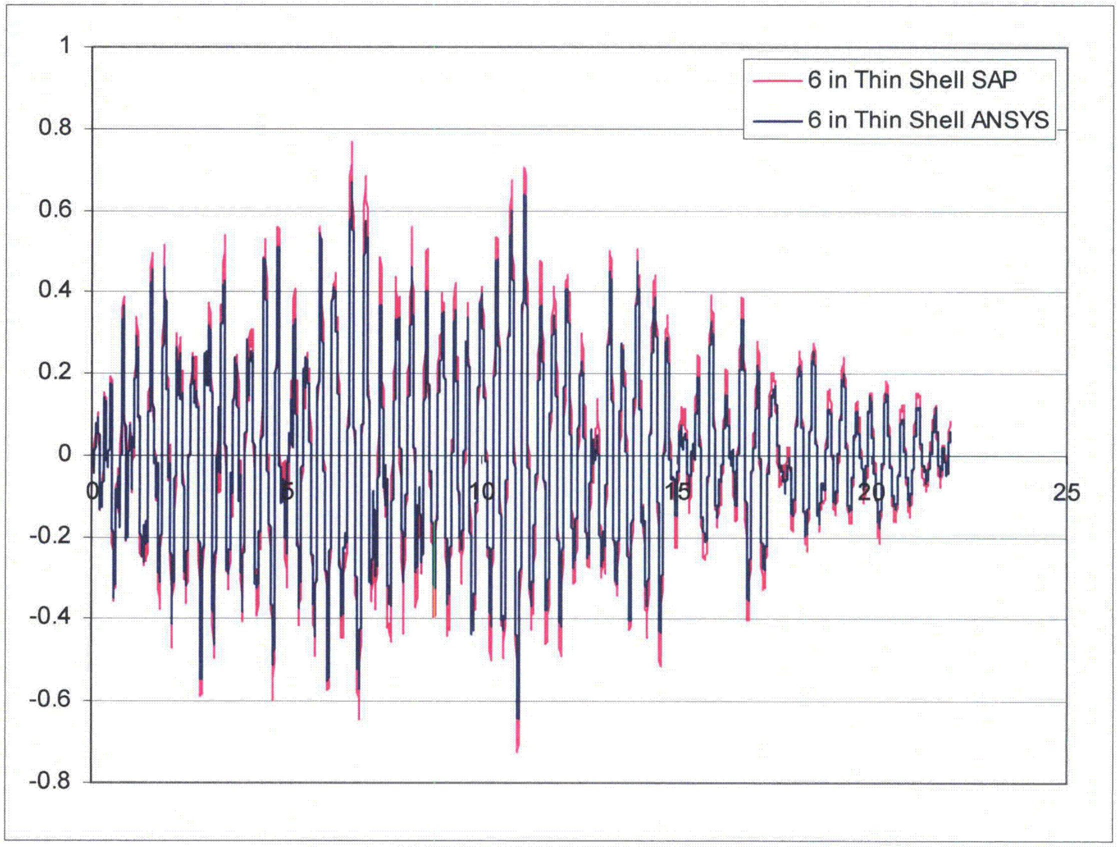

Figure 03.07.02-29 S1.12: Comparison of Generated Acceleration Time Histories from SAP2000 and ANSYS Programs for 6 in Thick Slab Using Thin Shell Elements