Lisa Feizollahi

From: EARLS, Chris [cee@nei.org]
Sent: Friday, August 08, 2008 6:42 AM
To: Ram Subbaratnam
Cc: Nilesh Chokshi; BELL, Russ; KASS, Leslie; [redacted] bob@rpkstruct.com; HEYMER, Adrian; BELL, Russ; Kassawara, Bob; Moore, Don P.; Ostadan, Farhang; EARLS, Chris
Subject: Meeting on ISG Section 3
Attachments: seismic ISG May 2008-Marked.rtf; GSto40_Spectra-1.doc

Ex. 6

NRC

Hello Ram,

I'm sorry for the delay in getting back to you. It's been difficult coordinating the consultants schedules regarding the meeting on ISG section 3. Unfortunately, the only two day block of time that seems to work for all the key players is September 25th & 26th. This puts the meeting a little further out then I had hoped, but I'm also hoping that it will make it easier for you to coordinate your folks. As you recall, we want to have the meeting at the EPRI offices for two full days and that it will be a public meeting. If at all possible, please give me some feedback this morning. I go on a week-long vacation at noon today and I'd like to get this resolved before I leave. In my absence, Russ Bell (202-739-8087) can be contacted to follow-up on any logistical issues that arise during my absence.

I have attached the draft paper that Farhang has put together for the discussion at the meeting. Please pass it along to the appropriate NRC personnel for review and preparation. (Farhang's Notes regarding the attachments: **I have converted the ISG May 2008 version PDF to a WORD file, added the comments and suggestions under Section 3 as marked in red. I have also summarized the results of a recent site amplification study for a NUGEN project and repeated the analysis following what is intended by the ISG to make the case for issues when the ISG approach is used.**)

Thanks for your help in setting up this meeting.

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Interim Staff Guidanceon Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications

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Purpose

This interim staff guidance (ISG) supplements the guidance provided to the staff in Section 3.7.1, "Seismic Design Parameters," of NUREG-0800, "Standard Review Plan (SRP) for the Review of Safety Analysis Reports for Nuclear Power Plants (NPPs)," regarding the review of seismic design information submitted to support design certification (DC) and combined license (COL) applications.

Background

The industry initiated the New Reactor Seismic Issues Resolution Program to work with and coordinate its efforts with the Nuclear Regulatory Commission (NRC) to address issues pertaining to the seismic designs of new reactors. The program addressed two critical issues pertaining to new reactor seismic designs.

The first issue was the implementation of the performance-based approach for determining the site-specific ground motion to satisfy the requirements of Title 10, Section 100.23, "Geologic and Seismic Siting Criteria," of the Code of Federal Regulations (10 CFR 100.23). This issue was addressed by Regulatory Guide (RG) 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," dated March 2007.

The second issue was the implementation of evaluation methodology to determine the effects of high frequency (HF) ground motion. In March 2007, the NRC revised SRP Section 3.7.1 to provide guidance to the staff in its review of seismic analysis information contained in DC and COL applications. The SRP recognized that for some sites the site-specific ground motion may exceed the ground motion used in the certified design. The staff developed and incorporated into the SRP a framework for a graded process to address these exceedances. For Central and Eastern US sites, this exceedance is generally in the HF range of the ground motion. The ISG focuses on two specific areas to address issues with exceedances in the HF range of ground motion. First, the ISG provides technical positions defining specific acceptance criteria or an acceptable approach to addressing HF exceedances and, second, the ISG identifies information to be included in the DC and COL applications to adequately address the HF issue.

The ISG was developed through stakeholder participation and was first published as a draft on August 16, 2007. The staff held public meetings on December 20, 2007, and February 13, 2008, to detail staff expectations with respect to seismic design information used in support of review of DC and COL applicants to address the effect of HF ground motions. Discussions among the nuclear industry, prospective COL applicants, and the staff indicated a need to supplement the guidance provided in SRP Section 3.7.1 and RG 1.206 in order to clarify the staff's expectations consistent with the requirements of 10 CFR Part 52. This revised version of ISG has incorporated changes resulting from the consideration of the industry comments and the discussions at these public meetings.

Rationale

Applicable regulations:

1 10 CFR Part 50, Appendix A, General Design Criterion 2, as it pertains to the seismic design of structures, systems, and components (SSCs) important to safety to withstand the effects of natural phenomena such as earthquakes without loss of capability to perform their intended safety functions as part of construction permit (CP), operating license (OL), COL, early site permit (ESP) reviews, or for site parameters in the case of DCs.
2 10 CFR Part 100.23, as it provides the criteria and nature of investigations required to obtain the geologic and seismic data necessary to determine the suitability of the proposed site and the plant design bases. 10 CFR 100.23 also refers to 10 CFR Part 50, Appendix S for the definition of the minimum safe-shutdown earthquake (SSE) ground motion for use in design.
3 10 CFR Part 50, Appendix S, which provides the seismic analysis and design requirements applicable to a DC or COL pursuant to 10 CFR Part 52 or a CP or OL. Appendix S also requires that the horizontal component of the SSE ground motion in the free field at the foundation level of the structures must be an appropriate response spectrum with a peak ground acceleration of at least 0.1g.
4 10 CFR 52.79(b) for a COL referencing an ESP as it relates to information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.
5 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the COL, the provisions of the Atomic Energy Act, and the NRC's regulations.

Applicability

This ISG will be implemented on the day following its issuance. It will remain in effect until it has been superseded, withdrawn, or incorporated into a revision of the SRP and RG 1.206.

Proposed ISG

The following six sections contain the ISG on seismic issues related to HF ground motion.

Section 1: Seismic Issues addressed in this Interim Staff Guidance

The NRC developed an umbrella framework to address this issue and incorporated it into Section 3.7.1, "Seismic Design Parameters," of NUREG-0800, "SRP for the Review of Safety Analysis Reports for NPPs," Revision 3, issued March 2007. The SRP recognizes that for some sites the site-specific ground motion may exceed the ground motion spectra used in a certified design and defines a progressive, stepwise process to address these exceedances. This ISG for resolution of the new reactor seismic issues was developed through stakeholder participation and was first published as a draft on August 16, 2007 (ML072200566). The August 2007 draft contained detailed background and discussions of issues addressed in this ISG. The staff received industry comments dated September 12, 2007, and held a public meeting addressing these guidelines on December 20, 2007 (ML080100612). The staff again held a public stakeholders' meeting on February 13, 2008 (ML080560592). This revised version incorporated changes resulting from the disposition of the industry comments and as a result of discussions at the December 20, 2007 and the February 13, 2008 meetings. This ISG provides methods and criteria to supplement the SRP criteria, and is discussed in the accompanying Sections 2, 3, 4 and 5. The guidance on soil testing has not changed from the original draft ISG; it is included as Section 5. Section 6 provides the references.

The seismic issues addressed in this ISG are as follows:

1 Definitions of various ground motions used in the design and site-specific analyses,
2 Definitions of SSEs and operating-basis earthquakes (OBEs),
3 Clear understanding of ground motions to be used in the certified design portion, site-specific design portion, and operability considerations,
4 OBE exceedance and location of seismic instrumentation,
5 Development and justification of coherency functions,
6 Use and validation of CLASSI/SASSI computer codes for incoherency analysis,
7 Scope of the analyses and approaches to be used to address HF responses for structures, systems, and components.

Final Resolution:

COL/DC-ISG-01 will be incorporated into Section 3.7.1 of the SRP, appropriate sections of RG 1.206, and other guidance documents.

Section 2: Ground Motion Definitions

Certified Seismic Design Response Spectra (CSDRS)—Site-independent seismic design response spectra that have been approved under Subpart B, "Standard DCs," 10 CFR Part 52, "ESPs: Standard DCs; and COLs for NPPs," as the seismic design response spectra for an approved certified standard design NPP.

Ground Motion Response Spectra (GMRS)—Site-specific ground motion response spectra characterized by horizontal and vertical response spectra determined as free-field motions on the ground surface or as free-field outcrop motions on the uppermost in-situ competent material using performance-based procedures in accordance with RG 1.208.

Foundation Input Response Spectra (FIRS)—When the site-specific GMRS and the site-independent CSDRS are determined at different elevations, the site-specific GMRS need to be transferred to the base elevations of each Seismic Category I foundation. These site-specific GMRS at the foundation levels in the free field are referred to as FIRS and are derived as free-field outcrop spectra.

Section 3: Staff Guidance/Position on the Definitions of Safe-Shutdown and Operating-Basis Earthquakes, Use of Various Ground Motions, Seismic Instrumentation and Operating-Basis Earthquake Exceedance

1. Definition of Safe-Shutdown Earthquake

The SSE for the site is the GMRS as defined in Section 2, which also satisfy the minimum requirement of paragraph IV(a)(1)(i) of Appendix S, "Earthquake Engineering Criteria for NPPs," 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," or is modified to meet this requirement.

Section 3 below outlines the use of CSDRS and GMRS for a COL application referring to a certified design.

2. Definition of Operating-Basis Earthquake

To satisfy and meet the requirements of paragraph IV(a)(2)(A) of Appendix S to 10 CFR Part 50, for COL applications that involve the use of a certified design, the OBE ground motion is defined below:

1 For the certified design portion of the plant, the OBE ground motion is one-third of the CSDRS.
2 For the safety-related non-certified design portion of the plant, the OBE ground motion is one-third of the design motion response spectra, as stipulated in the design certification conditions specified in the design control document (DCD).
3 The spectrum ordinate criterion to be used in conjunction with RG 1.166, "Pre-Earthquake Planning and Immediate NPP Operator Post-earthquake Actions," issued March 1997, is the lower of (1) and (2) of the above.

The above OBE definition meets the intent of the requirement associated with OBE in Appendix S to 10 CFR Part 50 which is that no explicit response or design analyses are required for OBE.

3. Use of Various Ground Motions

The stipulations in the DCD of a certified design govern the use of the CSDRS and GMRS (terminology used in currently certified designs is site-specific SSE).

For the certified design portion of the plant, the CSDRS is the design basis and must be maintained as the design basis. The use of any alternative ground motion would require an exemption or amendment.

The GMRS is the ground motion for certain features as stipulated in the DCD of a certified design. For example, the DCD of most certified designs specify the use of site-specific SSE (GMRS) ground motion for slope stability and liquefaction analyses. The use of GMRS is acceptable to demonstrate plant safety/operability for the as-found condition. However, unless the facility licensing bases are revised in accordance with formal processes in Parts 50 and 52, the condition must be restored to meet the original design basis and the design criteria.

In the standard design, the design motion is applied either at the free field or at the foundation level. During the COL application, the site-specific GMRS are produced at the surface through a site response analysis using strain-dependent properties of the site soil profile. As described in Section 5, the strain-dependant properties of the site soil should be determined from the soil dynamic tests. To define the FIRS for individual structures during COL stage, the site-specific GMRS (as provided in Section 2.5.2 of the final safety analysis report (FSAR)) are used. The following criteria apply to the process of deriving the FIRS from the GMRS:

1 When the GMRS are determined as free-field outcrop motions on the uppermost in-situ competent material, the site response analysis is based on the soil profile beneath the chosen location of the GMRS (not including the soil above). The outcrop GMRS motion is two times the incoming wave at the outcrop elevation and is influenced by all the layers below.

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Discussion:
Based on this section, if GMRS horizon is at some depth in the soil column, for development of the GMRS, the soil layers above the GMRS horizon should not be included in the soil model used for site amplification. This is consistent with Section 5.3 of RG 1.208 (March 2008). Using the "geological outcrop" definition (removing soil layers above GRMRS) instead of typical "SHAKE outcrop" definition introduces several major difficulties as noted below.

- The expectation that the GMRS based on "geological outcrop" definition will remain intact from any excavation and backfilling that are likely to take place during construction will not be met. The soil shear wave velocity that is measured at the site in early phase of investigation and used in soil amplification analysis would include the effects of soil layer above the GMRS horizon on the velocity of the layers below.
- The strain-dependent soil properties used for soil column analysis are also a function of overburden pressure. It is not clear if the overburden pressure should be considered (for realistic analysis) or shall be excluded in the analysis of the GMRS generation.
- The GMRS with "geologic outcrop" definition represents the seismic hazard at the site under the conditions that in reality never exits at the site.
- **Most importantly**, development of GMRS with the above definition results in a motion that can not be readily used in the companion soil column where soil layers above GMRS are included in order to develop FIRS for structural analysis. This point is further discussed in the later section.

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2 When the site-specific GMRS and the CSDRS are determined at different elevations, the site-specific GMRS needs to be transferred to the base elevations of each seismic Category I foundation. These site-specific GMRS at the foundation levels in the free field are referred to as FIRS, as defined in Section 2, and are derived as free-field outcrop spectra.
3 Whenever motions are computed at a given elevation, all soil layers impacting the response must be included; specifically, any transfer of ground motion from one elevation to another elevation needs to consider the entire soil column down to the effective uniform half space.
4 Transfer of GMRS to individual foundation elevations should be consistent with the same process of randomization of soil properties and the site soil profile as that used to establish the site-specific GMRS.
5 The FSAR should clearly describe the soil column model, its associated properties and how it is used in the soil-structure interaction (SSI) analysis and how the criteria of the SRP Section 3.7 are followed.
6 The FSAR should clearly show the SSI analysis input at the foundation level.

Discussion:

- Once GMRS is developed as "geological outcrop" motion, it can no longer be used as input directly in the elongated soil column with additional soil layers above the GMRS horizon. Using GMRS as input at GMRS horizon to a full height soil column violates the fundamental principles of one dimensional wave propagation and results in erroneous responses.
- The only way to use the GMRS to obtain companion FIRS is to de-convolve the GMRS motion is the same set of soil columns that generated the GMRS and obtain the de-convolved response motion as outcrop in a layer that can be modeled as uniform half space. The outcrop response motion can be subsequently used as input to the soil column analysis with a full soil column above it. This approach causes the following difficulties:
  - In most application, the uniform half space is the rock medium with shear wave velocity of 9200 ft/sec for which the PSHA has been performed and rock motion has been developed. This, de-convolving to such layer and performing subsequent convolution analysis to develop FIRS is an unnecessary analysis that can be avoided.
  - GMRS is a design motion after applying design factors. It is not clear if GMRS or the associated uniform hazard spectra should be de-convolved and subsequently convolved. Design factors are likely to be different at different horizons due to soil amplification effects.
  - **GMRS is a broad band spectrum that includes the effects of a range of randomized soil profiles with high frequency contents controlled by the stiffer soil profiles. De-convolution of the broad band spectrum particularly in the softer set**

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of soil profiles results in unrealistic ground motion at depth (see the example).

INDUSTRY PROPOSED APPROACH

- Development of the ground motion (GMRS and FIRS) can be based on one full height soil column profile. The column in its full height can be used to obtain GMRS as "SHAKE outcrop" at the top of the competent soil layers. The same analysis also generates the outcrop motion at any other horizon that FIRS is needed for structural analysis.
- The soil profile used in the soil amplification analysis should be consistent with the soil profile used in the free-field modeling of the SSI model. This implies that for structures that are modeled with embedment consideration, the soil layers along the embedment depth of the structure should be included in the soil column amplification analysis as well as the SSI free-field model. For structures with no embedment or which embedment is ignored, the soil column should be terminated at the foundation level.
- Development of GMRS and FIRS based on the same soil column using convolution analysis avoids issues with de-convolution analysis of a broad band spectrum.
- If the same soil column in soil amplification model is used in the SSI model, the FIRS can be directly used as control motion in the SSI analysis providing a consistent modeling of the ground motion between the SSI and site response modeling.

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4. Seismic Instrumentation and OBE Exceedance

To meet the requirements of paragraphs IV(3) and IV(4) of Appendix S to 10 CFR Part 50, the staff has provided guidance in RG 1.12, "NPP Instrumentation for Earthquakes," Revision 2, issued March 1997, and RG 1.166, "Pre-Earthquake Planning and Immediate NPP Operator Post-earthquake Actions," issued March 1997. The staff will conduct a case-by-case review if a COL applicant proposes an alternative instrumentation plan, locations, or other deviations from the two RGs.

Section 4: Staff Guidance/Position on Addressing HF Ground Motion Evaluations

When the GMRS (or FIRS) exceed the CSDRS (or associated foundation level spectra), the staff will follow the review process outlined in Section 3.7.1 of NUREG-0800, "SRP for the Review of Safety Analysis Reports for NPPs" (hereafter referred to as the SRP). These exceedances are expected in the HF range. The staff positions/guidance to conduct the "HF ground motion analysis" are grouped into five categories—(1) use of computer codes for incoherency problems, (2) coherency functions (CFs) to be used in the analysis, (3) evaluation of SSCs, (4) evaluation of HF sensitive mechanical and electrical equipment and components, and (5) interface requirements and proposed inspections, tests, analysis, and acceptance criteria (ITAAC). The SRP process is progressive and can stop when it is clear that the design demands resulting from the GRMS are bounded by CSDRS design demands for SSCs.

The following staff guidance is based on a review of the information provided by the industry (Section 6), and it consists of two categories—(1) specific criteria needed to conduct HF response analysis and (2) guidance on the scope of evaluations to be performed and included in an application.

1.0 Use of Computer Codes for Incoherency Analysis

1.1 The use of CLASSI and SASSI incoherency approaches, embodied in the codes CLASSIinco-SRSS, SASSI-SRSS, and SASSI-Simulation, are considered acceptable for treatment of random phasing effects, provided it is demonstrated that the code used is properly implemented for a particular application taking into account site and foundation conditions.

1 Use of any other code should be validated through the approaches and benchmarks given in the industry report entitled, "Validation of CLASSI and SASSI to Treat Seismic Wave Incoherence in SSI Analysis of NPP Structures," dated July 9, 2007. Review of the validation will provide a basis for determining the acceptability of the alternative code.

2 **Coherency Functions**

The staff accepts the use of the proposed horizontal and vertical CFs, as detailed in the Electric Power Research Institute (EPRI) report entitled, "Hard-Rock Coherency Functions Based on the Pinyon Flat Array Data," dated July 5, 2007 (ADAMS Accession No. ML071980104).

3.0 Evaluation of SSCs

3.1 Structural Modeling:

3.1.1 Information should be provided to demonstrate that the SSI and structural models are adequately refined to sufficiently capture the HF content of the horizontal and vertical GMRS/FIRS in the structural response. The range of HF to be transmitted should cover a model refinement frequency of at least equal to 50 Hz.
Any subsequent in-structure response spectra (ISRS) computed using a refined model should contain spectral responses up to 100 Hz.

The criterion for structural model refinement to ensure fidelity of response at least up to 50 Hz, also applies to all seismic Category I structures included in a COL application that are outside the scope of the referenced certified design.

3.1.2 Information should be provided to demonstrate that the structural model captures the increased rotational and torsional components that would result from the inclusion of ground motion incoherency in the analysis.

3.1.3 The procedure used to generate the ISRS will follow the procedure used in the certified design. Deviations from the procedure may be acceptable, if adequate justifications are provided.

3.2 Evaluation of SSC's other than HF Sensitive Mechanical and Electrical Equipment and Components

3.2.1 If the GMRS/FIRS-based ISRS do not exceed the CSDRS-based ISRS below 50 Hz, no further assessment of structural integrity and functionality evaluations are required.

3.2.2 For those cases where the GMRS/FIRS-based ISRS exceed the CSDRS-based ISRS below 50 Hz, further structural integrity and functionality evaluations are required.

3.2.3 If a screening approach is used, the following information will be provided.

3.2.3.1 The selection criteria for screening and their bases for Seismic Category I SSCs. Examples of screening criteria are: safety significance, location in the vicinity of the HF response, potential for significant effects of rotational components, and significant increase in forces on supports and anchorages of rigid equipment.

3.2.3.2 For the selected SSCs, describe the evaluation methodologies (including selection of failure modes) used for the assessment and their basis. Provide a comparison of parameters such as: shear, overturning moment, support/anchorage forces, valve locations, and nozzles along with the bases for the selection of these parameters to demonstrate adequacy.

3.2.3.3 Using the results of evaluations/comparisons, show the disposition of all instances where the GMRS/FIRS-based design demand exceeds the CSDRS-based demand.

2 **Identification and Evaluation of HF Sensitive Mechanical and Electrical**

Equipment/Components

For those cases where the GMRS/FIRS-based ISRS exceed the CSDRS-based ISRS below 50 Hz, further equipment and component functionality evaluations are needed, and a screening approach is considered appropriate. These evaluations are in addition to the CSDRS-based seismic qualification program as stipulated in an approved certified design. The purpose of evaluation of HF sensitive equipment/components is to demonstrate their safety-related functionality. The following information should be provided when a screening approach is adopted:

4.1 Screening Procedure and Justification of HF Sensitive Equipment/Components

Describe the steps used in the screening procedure, and provide a basis for the criteria used for each screening step that is used to identify equipment/components with potential for HF sensitivity.

4.1.1 If existing test data are used to demonstrate functionality, the use of such data should be evaluated over the required frequency range of interest in accordance with IEEE Standard 344 to demonstrate that the proper frequency content with sufficient amplitude was used as input to the component that has been previously tested.

4.1.2 If a HF screening test is conducted with sine beat testing, an interval of 1/6 octave spacing should be used extending up to the frequency of interest shown in the Required Response Spectra (RRS).

4.2 Justification for Screened-Out Equipment and Components

Provide a list of each type or group of mechanical, electrical, and instrumentation and control equipment/components that is screened out with justifications.

4.3 Evaluation of Screened-In Equipment/Components

Describe the process for evaluating equipment and components that are screened in. Provide a table containing the list of HF sensitive mechanical and electrical equipment/ components that will be qualified by testing or analysis, along with a reference for RRS for each item of equipment. Explain the method of generating the RRS at the location of support or attachment point within a structure or a cabinet that will be used in the evaluation. If a bounding input value or response spectrum is used, describe the methodology for developing the bounding input.

4.3.1 The test procedure is to be consistent with the requirements of IEEE-344 as supplemented by NRC RG 1.100. The method for ensuring proper input in the amplified portion of the RRS should be clearly stated along with the basis for the acceptance criteria used to demonstrate functionality.

4.3.2 If a generic testing result is used, justify its applicability for the component specific considerations (e.g., mounting, natural frequencies, location specific response) to ensure adequate in-structure response and in-cabinet response amplifications.

4.3.3 Provide the results from the application of item 4.1.1, 4.1.2, 4.3.1, and 4.3.2 above and the disposition of equipment/components that do not meet the acceptance criteria.

5.0 Interface Requirements and Proposed ITAACs

5.1 An application referencing a certified design should provide information to demonstrate compliance with the interface requirements as it pertains to the issue of HF ground motion analysis.

5.2 The DC or COL application should provide inspections, tests, analyses, and the associated acceptance criteria, as necessary, for the HF ground motion effects on qualification of equipment and components.

Section 5: Staff Comments on the Industry Draft White Paper on "Testing of Dynamic Soil Properties for Nuclear Power Plant Combined License Applications" and Guidance on Information for Review

The white paper summarizes regulatory requirements and the NRC staff positions in the relevant guidance documents regarding the soil dynamic tests, specifically, the resonant column/torsional shear (RC/TS) testing. The RC/TS testing yields soil modulus reduction and damping curves, which are critical data for site response calculation. The paper also proposes a protocol to accommodate as many COL applications as possible while considering the limited testing facilities available. The NRC staff reviewed the paper and found that this protocol could provide a strategy to deal with the shortage of soil dynamic testing facilities. However, the paper also left some key questions to be answered and key terminologies to be defined.

The staff also expects COL applicants to address the following five issues in their applications:

1 Define a soil site quantitatively in terms of soil dynamic properties (e.g., shear wave velocity and/or shear wave velocity gradient) to make it clear what kind of soil/rock needs to have RC/TS testing. Furthermore, define hard rock, firm rock, competent rock, and deep soil, which the paper refers to frequently with respect to the same criteria.
2 Identify the criteria to be used to determine the initial number of testing samples.
3 Elaborate on the randomization processes to be used to demonstrate that limited initial sample testing will cover the variation when more sample testing results are available or, if a bounding analysis is used, the choices of the appropriate margin or bounding factor.
4 Describe the measures to be taken to incorporate the final results. If the final testing results prove that the initial testing results did not provide sufficient safety margins for site-specific soil dynamic properties, explain the potential impact on relevant calculations that are based on limited sample testing.
5 If possible, include a case study using limited soil sample testing to characterize the soil dynamic properties.

Section 6: References

Documents and meeting summaries that were used in the development of the ISG are listed below:

1. EPRI Report, "Validation of CLASSI and SASSI to treat Seismic Wave Incoherence in SSI Analysis of NPP Structures," July 9, 2007 (Accession No. ML071980151).
2 EPRI Draft White Paper, "Considerations for NPP Equipment and Structures Subjected to Response Levels Caused by HF Ground Motions," March 19, 2007 (Accession No. ML071010497).
3 EPRI White Paper, "Seismic Screening of Components Sensitive to HF Vibratory Motions," June 28, 2007 (Accession No. ML071930427).
4 Summary of December 20, 2007 Public Meeting -Seismic Site Response Analysis -Workshop on Seismic ISG and HF Issues (Accession No. ML080100612).

5 Summary of February 13, 2008 Public Meeting -Seismic Site Response Analysis -Workshop on Seismic ISG and HF Spectra for DC and COL Applicants (Accession No. ML080560598).
6 NUREG/CR-6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines," (Accession Number ML013100232).
7 EPRI Report "Use of Cumulative Absolute Velocity in Determining Effects of Small Magnitude Earthquakes on Seismic Hazard Analyses" DRAFT Final Report, June 2006 (Accession No. ML062350456).
8 "Program on Technology Innovation: Truncation of the Lognormal Distribution and Value of the Standard Deviation for Ground Motion Models in the Central and Eastern US" 1013105, Nuclear Energy Institute (NEI) Report (Accession No. ML062350429).
9 "Hard-Rock Coherency Functions Based on the Pinyon Flat Array Data" by Norman A. Abrahamson" Norman A. Abrahamson, Inc., Piedmont, CA (Accession No. ML072190359).
10 RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," March 2007 (Accession No. ML070310619).
11 Summary Of December 14, 2006, Category 2 Public Meeting With NEI to Discuss Seismic Issues Related to Future Reactor Siting (Accession No. ML063610506).
12 NEI paper on performance-based spectra definitions and site acceptability standards, February 2, 2007 (Accession No. ML070600662).
13 Draft Outline of Industry Presentation on "SSE & OBEs Definitions" for the NRC Meeting of May 31, 2007 (Accession No. ML071660304).
14 Summary Of May 31, 2007, Public Meeting With Industry On Seismic Issues Related to New Plant Licensing (Accession No. ML071630037).
15 EPRI Report "Hard-Rock Coherency Functions Based on the Pinyon Flat Array Data" July 5, 2007 (Accession No. ML071980104).

List of Acronyms

ADAMS – Agency-wide Documents Access and Management System CF – coherency function CFR – Code of Federal Regulations COL – combined license CP – construction permit CSDRS – Certified Seismic Design Response Spectra DC – design certification DCD – design control document EPRI – Electric Power Research Institute ESP – early site permit FIRS – Foundation Input Response Spectra FSAR – final safety analysis report GMRS – Ground Motion Response Spectra HF – high frequency ISG – interim staff guidance ISRS – in-structure response spectra ITAAC – inspection, test, analysis, and acceptance criteria NEI – Nuclear Energy Institute NPP – nuclear power plant NRC – Nuclear Regulatory Commission OBE – operating-basis earthquake OL – operating license PDR – Public Document Room RC – resonant column RG – regulatory guide RRS – required response spectra SRP – Standard Review Plan SSCs – structures, systems, and components SSE – safe-shutdown earthquake SSI – soil-structure interaction TS – torsional shear US – United States

Study of Alternative Methods to Develop Input Motion for SSI Analysis

Soil Profile

- Deep profile (approximately 1500 ft to 2200 ft to base rock)
- Site specific measurement of velocity
- Upper 86 ft is engineered fill
- The velocity profile and soil nonlinear curves were randomized (60 sets)

Input Motion

- Rock motion is based on PSHA
- De-aggregated spectra (HF and LF) were computed at 10-4 and 10-5 levels
- Time histories were generated to match each response spectrum (30 time history for each spectrum)

Soil Amplification

- Method 2A of NUREG 6728 was used to compute soil amplification factors
- The soil column used in the analysis is the full soil column from ground surface (top of backfill) to varying (randomized) base rock depth at about 1500 to 2200 ft depth
- Spectral amplification factors were computed at the ground surface level and at the foundation horizon at the depth of 40 ft as outcrop motion

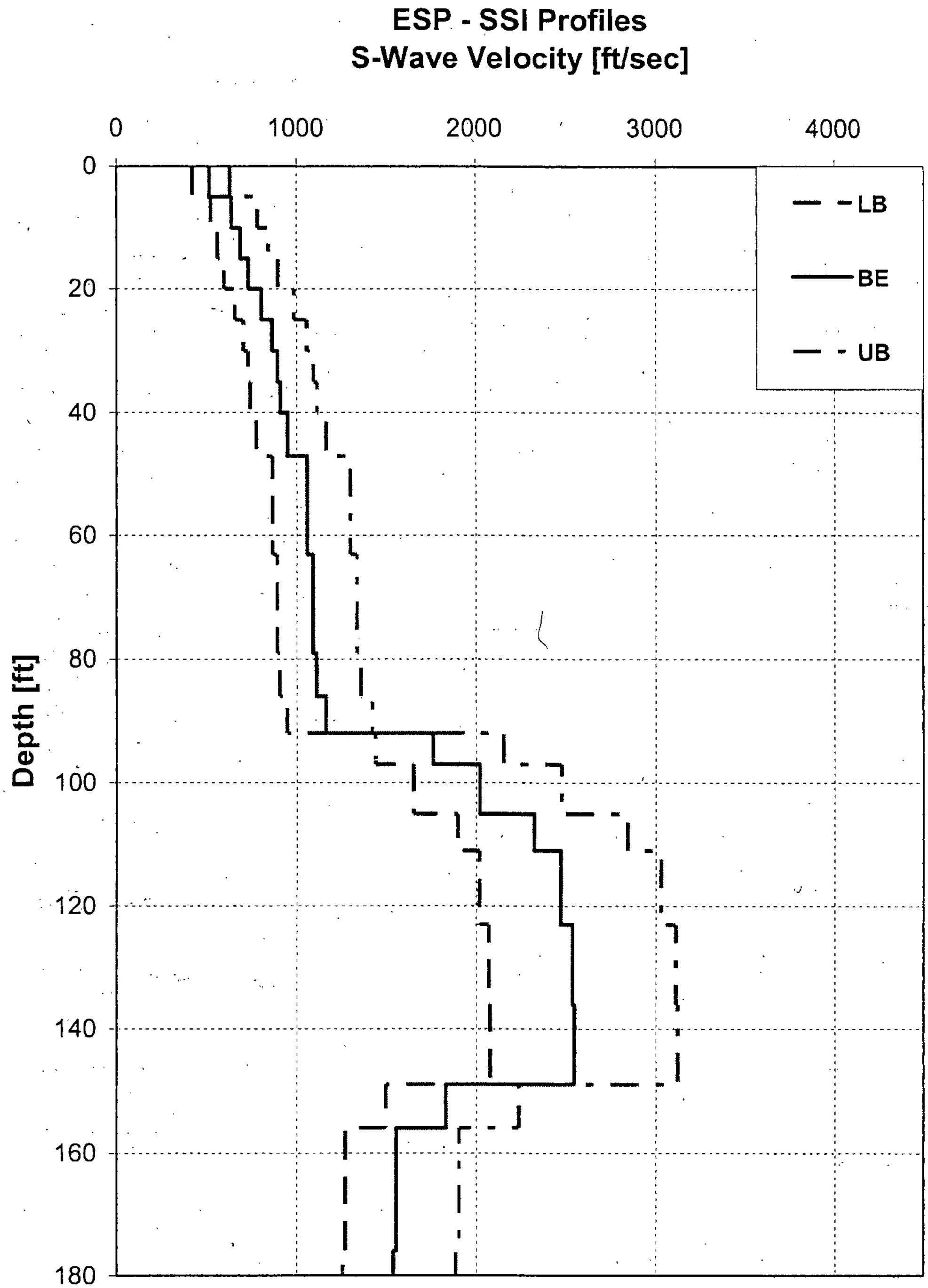
Design Spectra

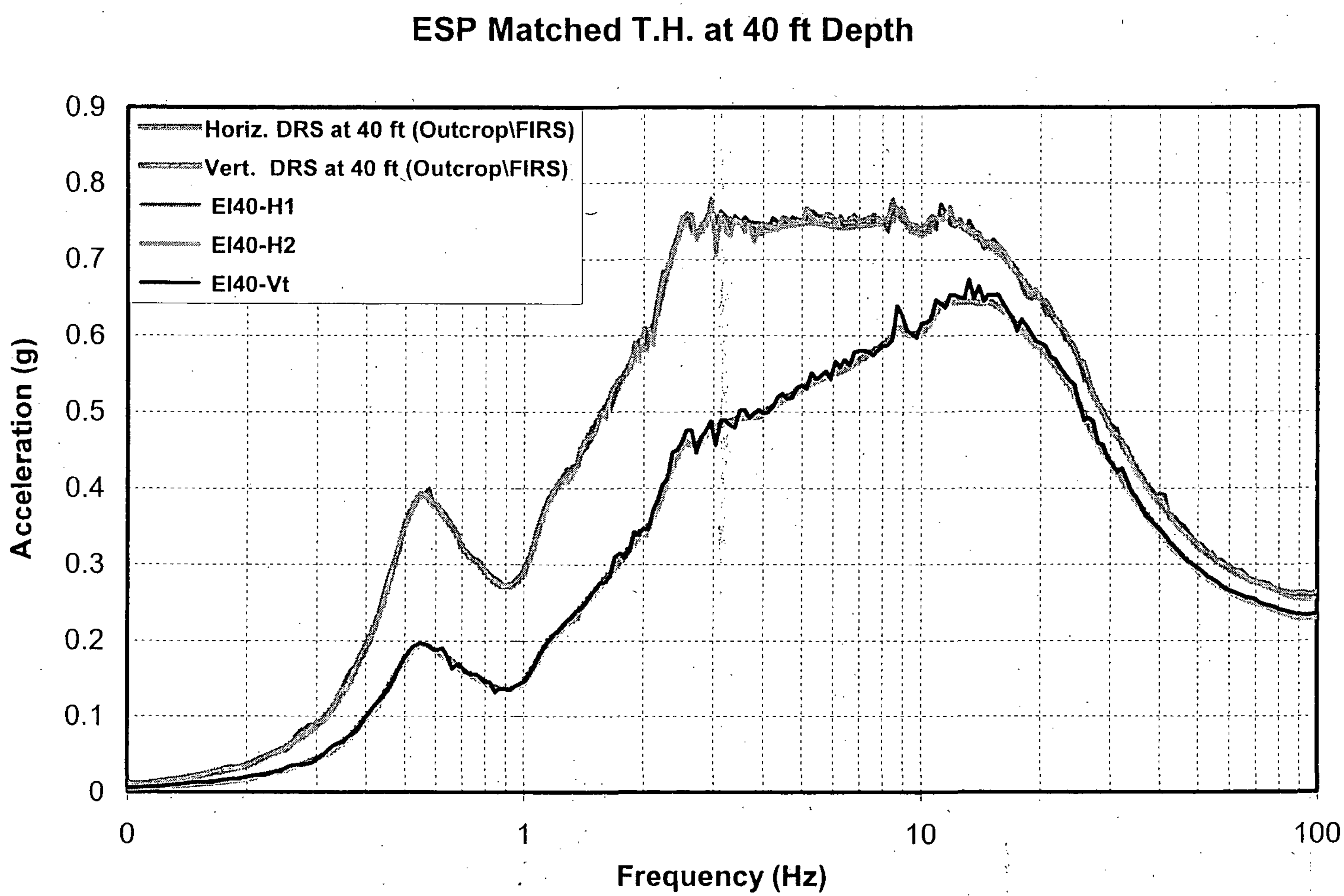
- The log-mean (median) of 60 soil amplification functions were used to develop soil uniform hazard spectra
- The design factors were applied to the uniform hazard spectra to obtain design spectra
- Vertical design spectra was obtained using V/H ratio
- The design spectra at the ground surface is labeled as GMRS, the design response spectra at the depth of 40 ft (the outcrop motion) is labeled as FIRS

Time Histories and Soil Profiles for SSI

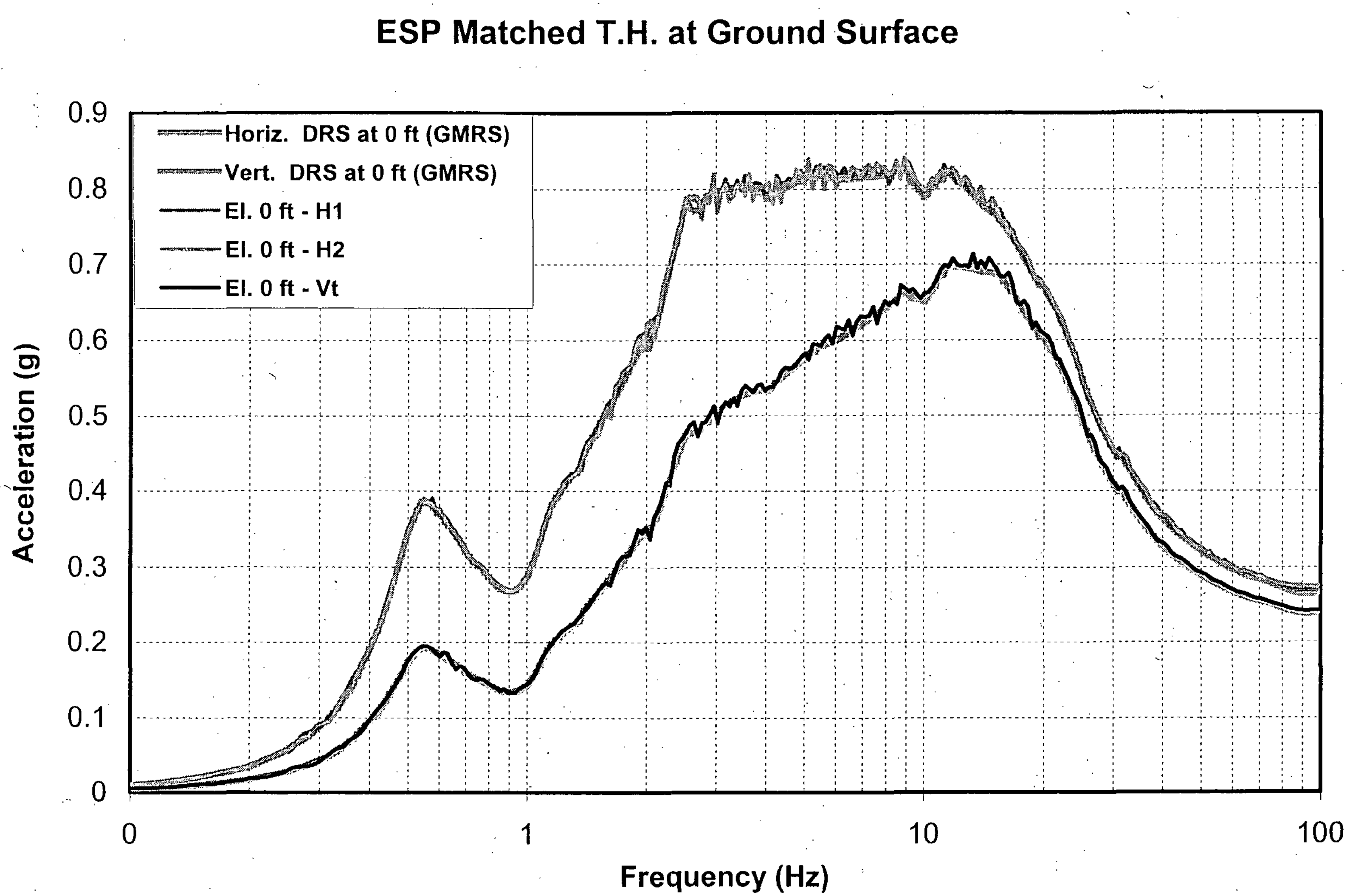
- One set of 3-component time histories were generated to match each of FIRS and GMRS spectra
- From the set of 60-randomized strain-compatible velocity profiles, the median and upper and lower bound were obtained maintaining the minimum coefficient of variation of 0.5 on soil shear modulus
- The FIRS-based time histories were used as outcrop input motion for the 3 soil profiles and the response at the top of the soil column are compared with GMRS, the same analysis produced the in-column motion at the depth of 40 ft
- In the follow up analysis, GMRS-based time histories were used as input at the top of 3 soil columns and the de-convolution analysis was performed. The outcrop response motion at the depth of 40 ft is compared with FIRS. In

addition the outcrop in-column motion is compared with the in-column motion obtained from previous FIRS-based input motion


ESP - SSI Profiles
S-Wave Velocity [ft/sec]
0
1000
2000
3000
4000
0
20
40
60
80
100
120
140
160
180
Depth [ft]
LB
BE
UB

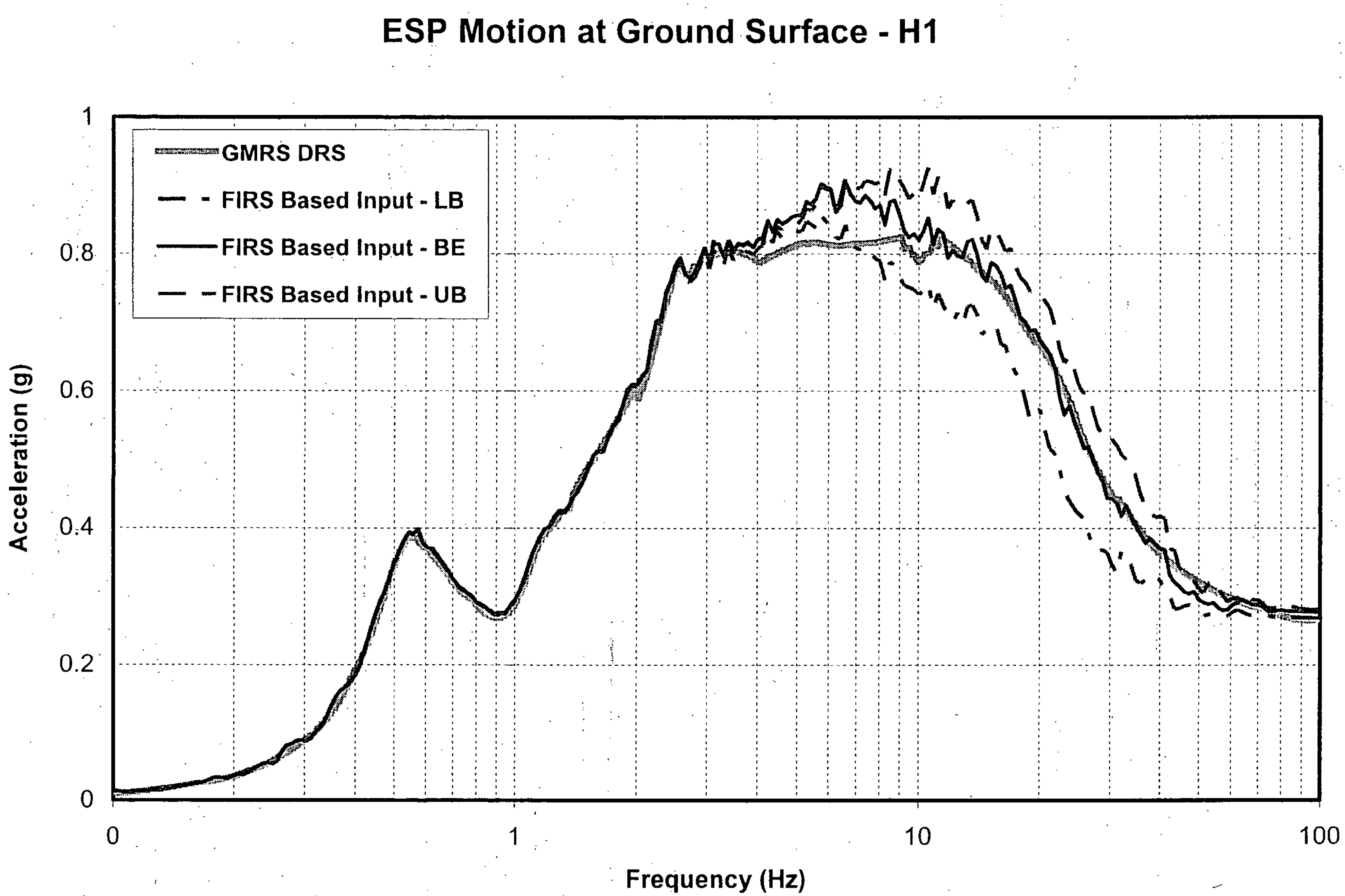


Time histories were generated to match the FIRS

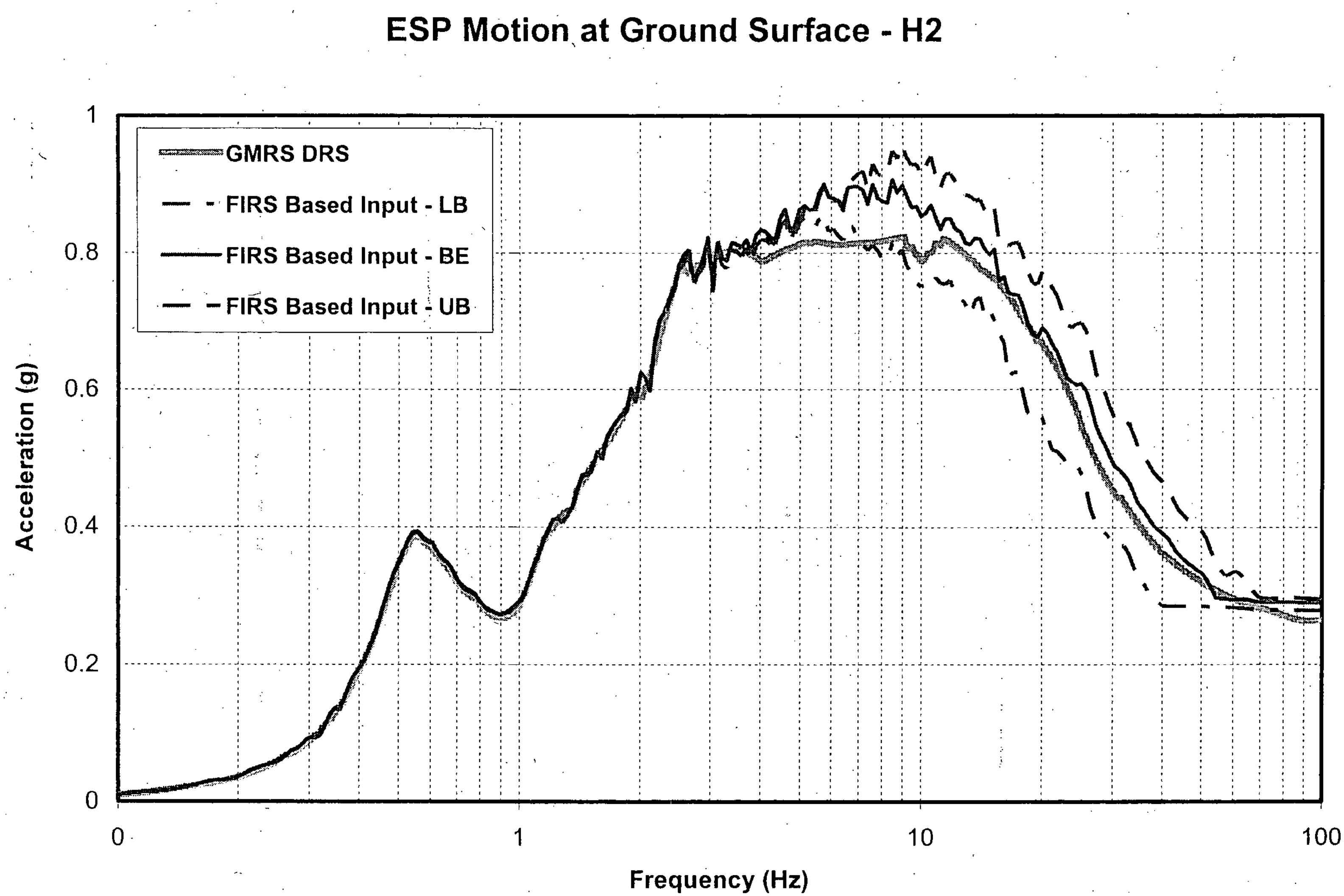


Time histories were generated to match the GMRS

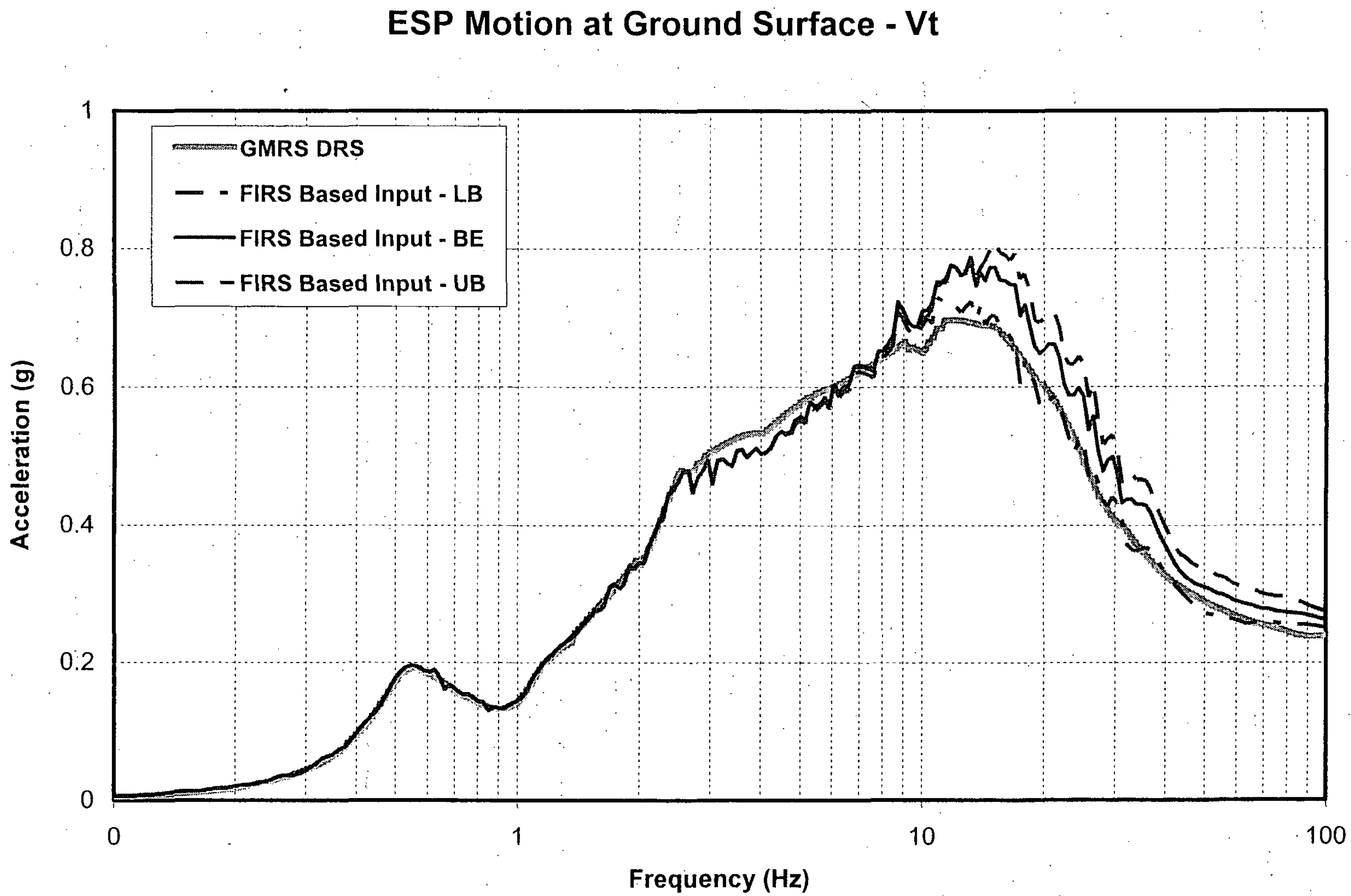
CONVOLUTION ANALYSIS USING FIRS AS INPUT MOTION



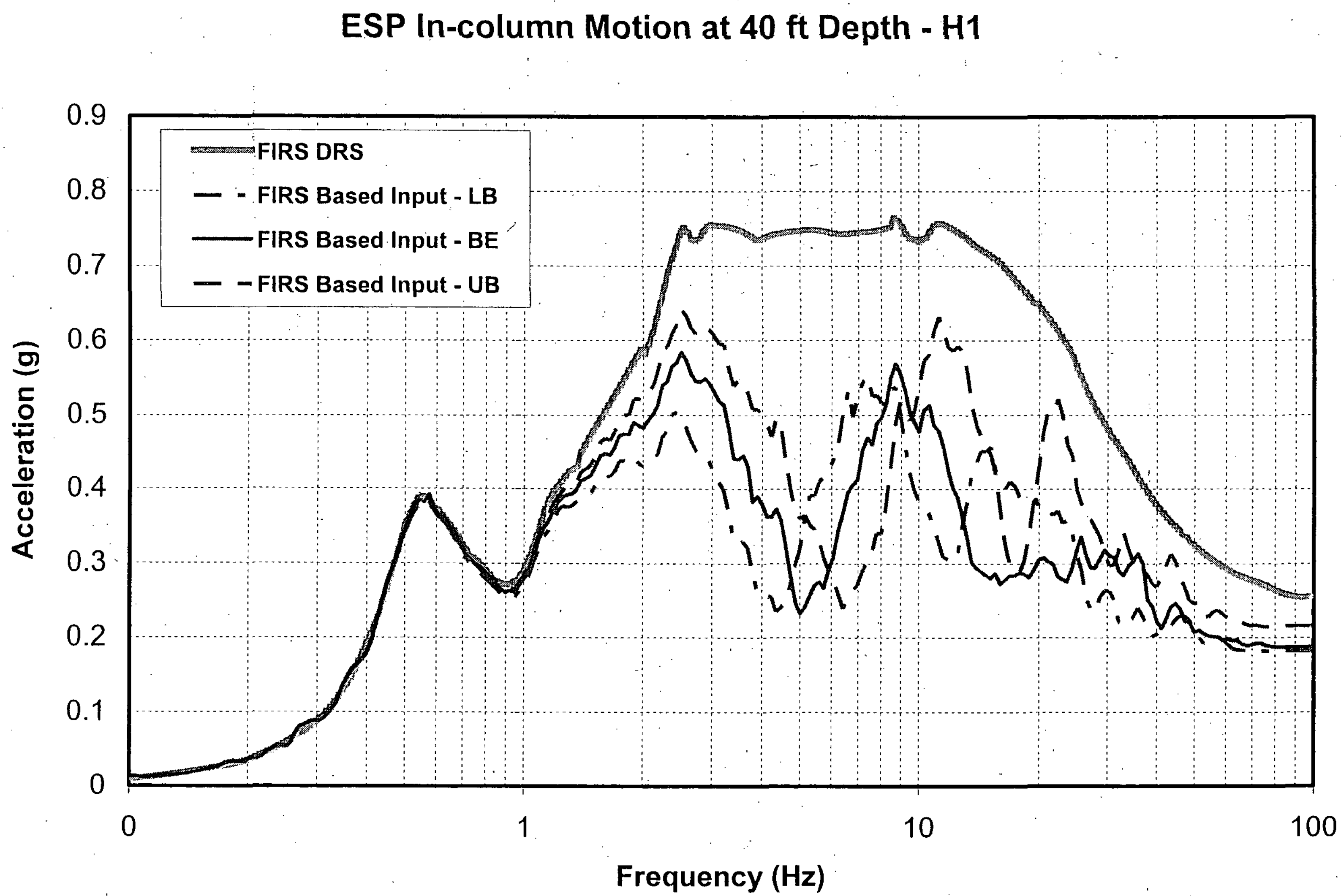
Green lines designate outcrop response motion at ground surface using FIRS-based H1 time history as input



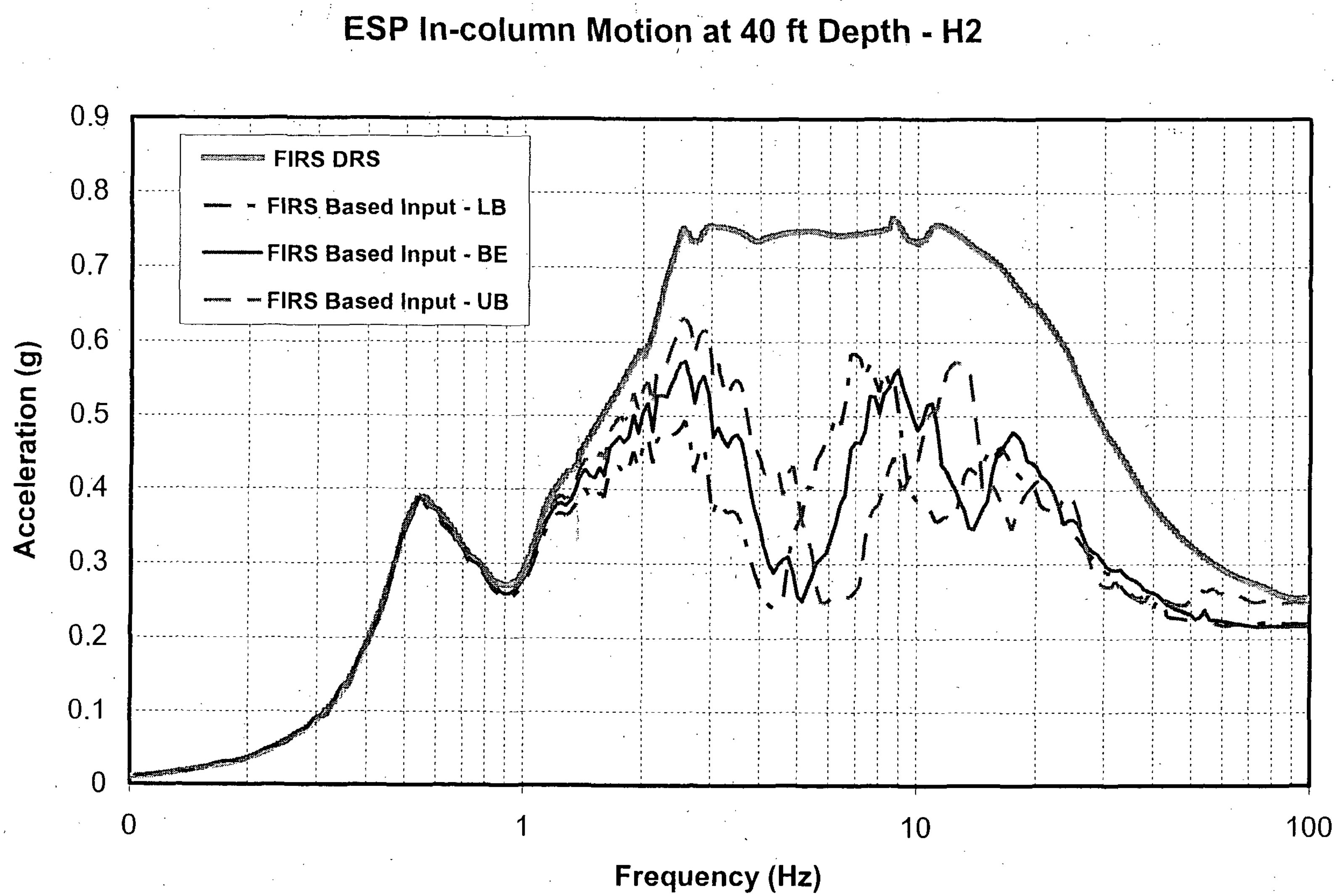
Green lines designate outcrop response motion at ground surface using FIRS-based H2 time history as input



Green lines designate outcrop response motion at ground surface using FIRS-based Vt time history as input

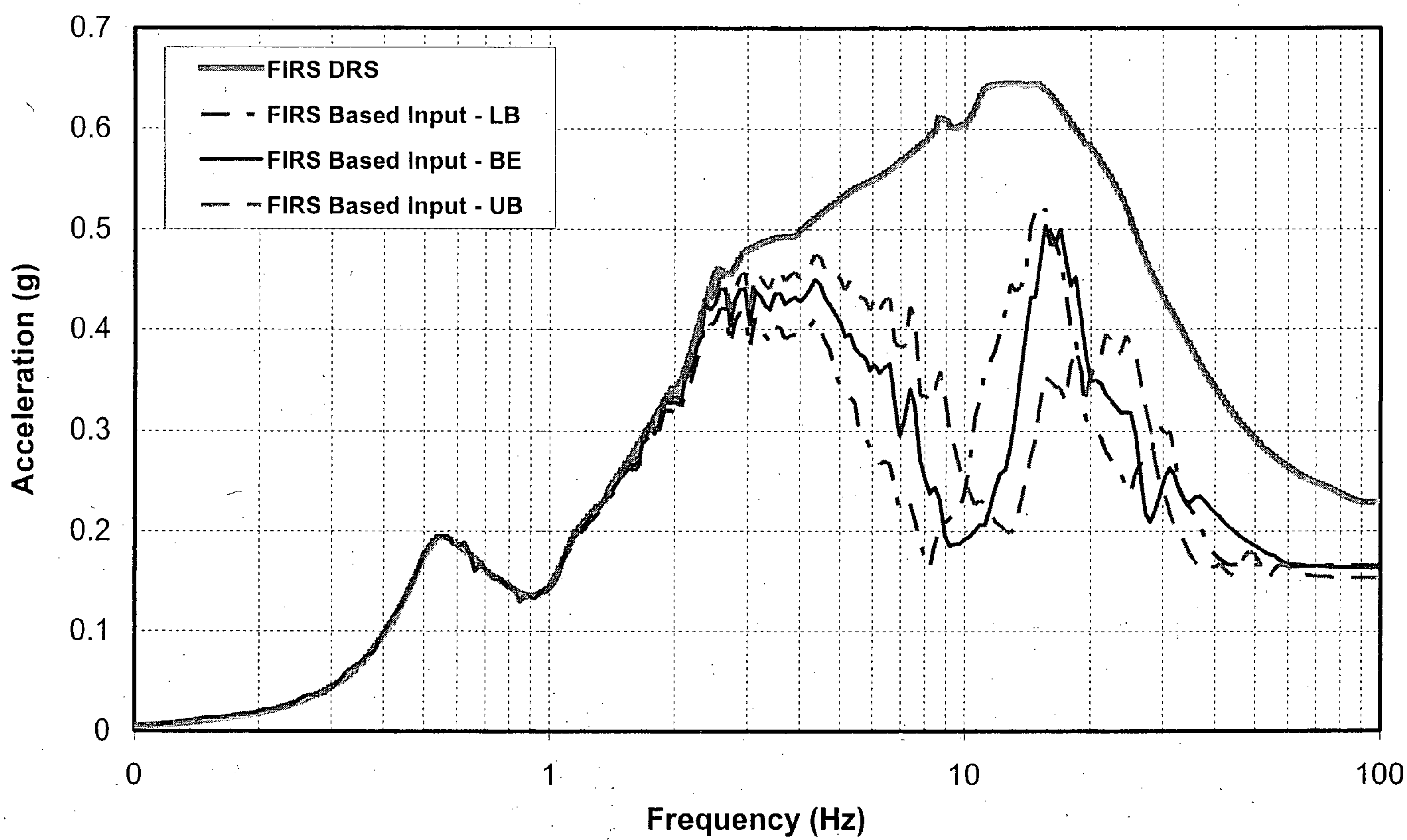


Green lines designate in-column response motion at the depth of 40 ft using FIRS-based H1 time history as input



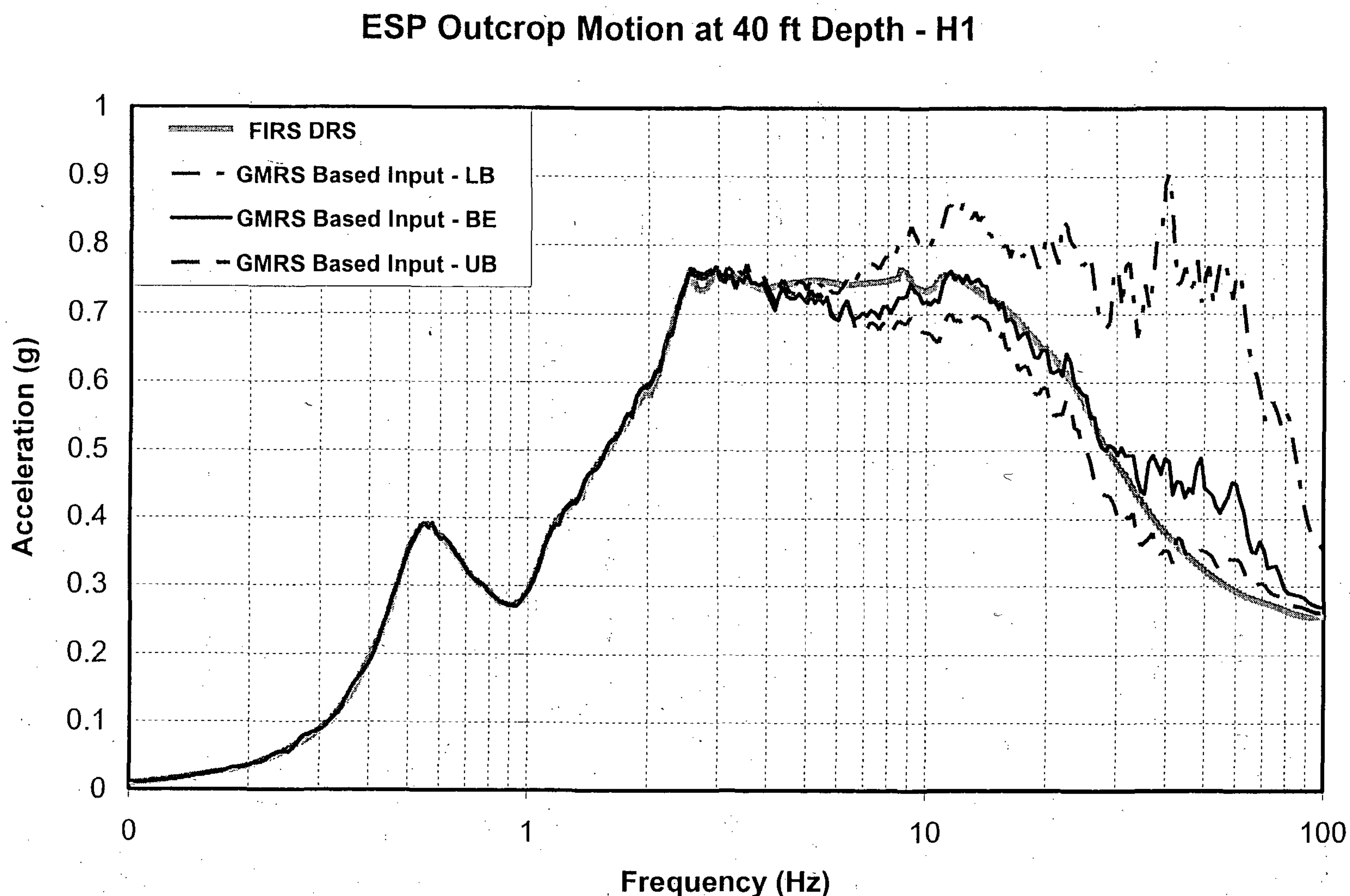
Green lines designate in-column response motion at the depth of 40 ft using FIRS-based H2 time history as input

ESP In-column Motion at 40 ft Depth - Vt

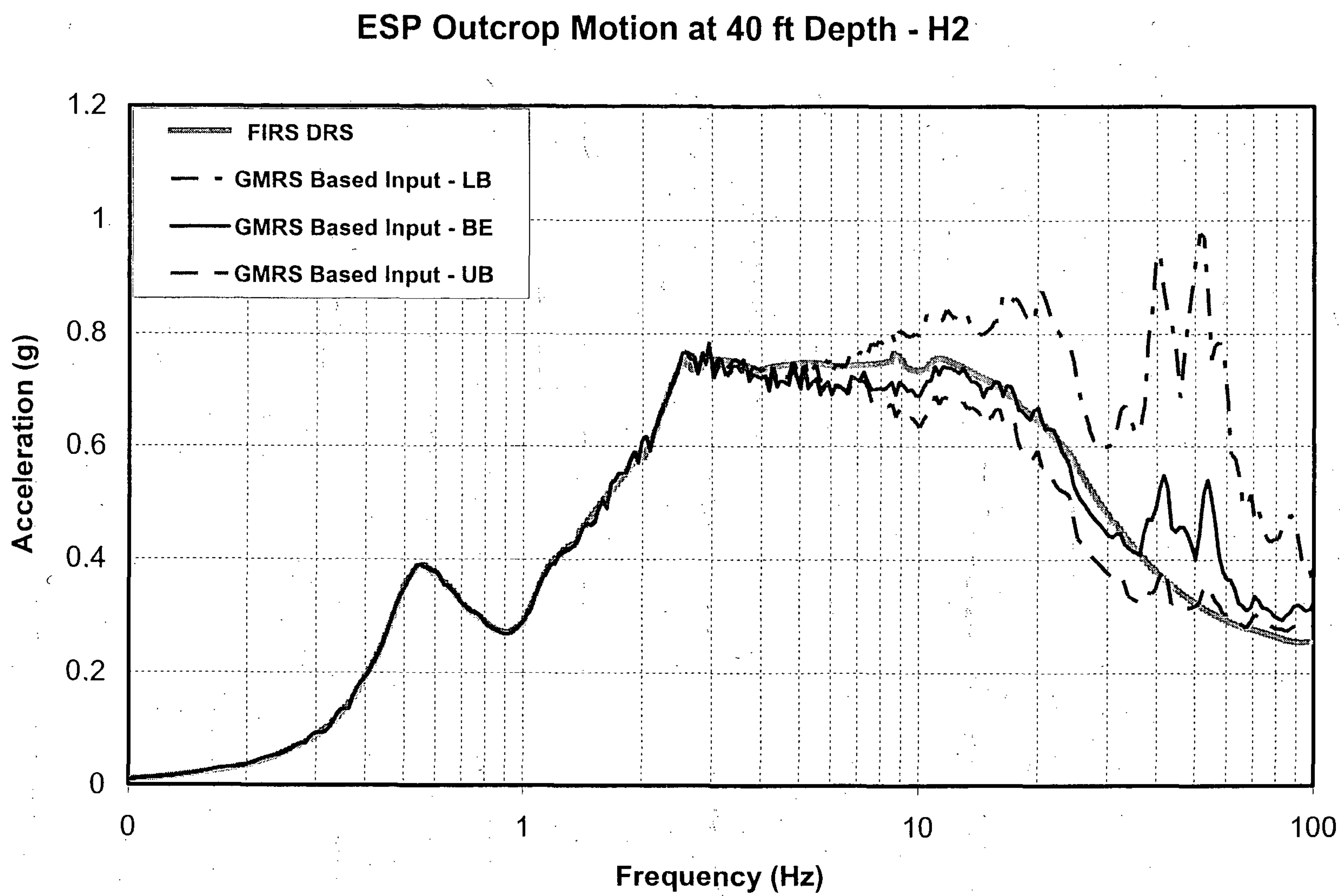


Green lines designate in-column response motion at the depth of 40 ft using FIRS-based Vt time history as input

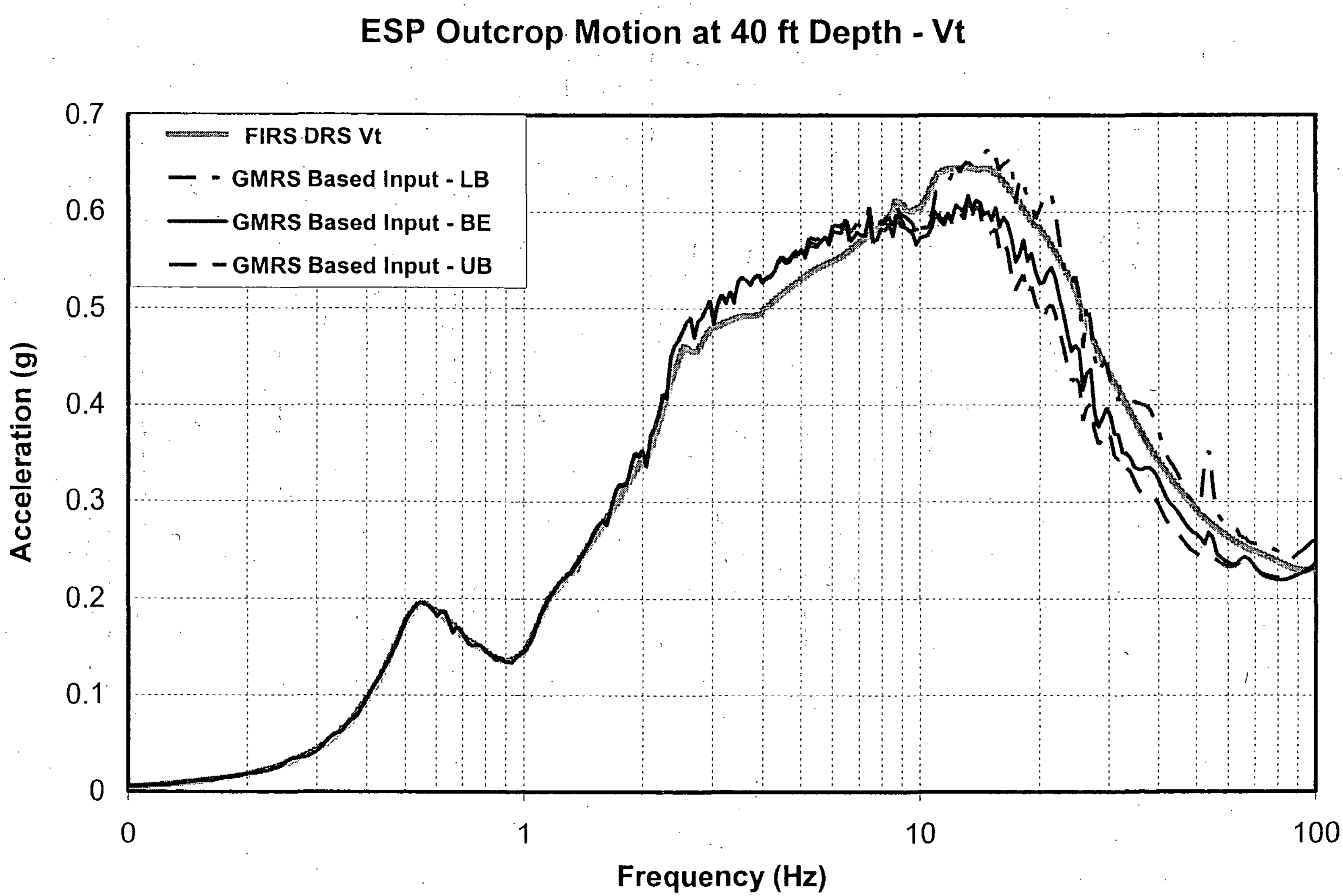
DE-CONVOLUTION ANALYSIS USING GMRS AS INPUT MOTION



Purple lines designate outcrop response motion 40 ft depth using GMRS-based H1 time history at the ground surface

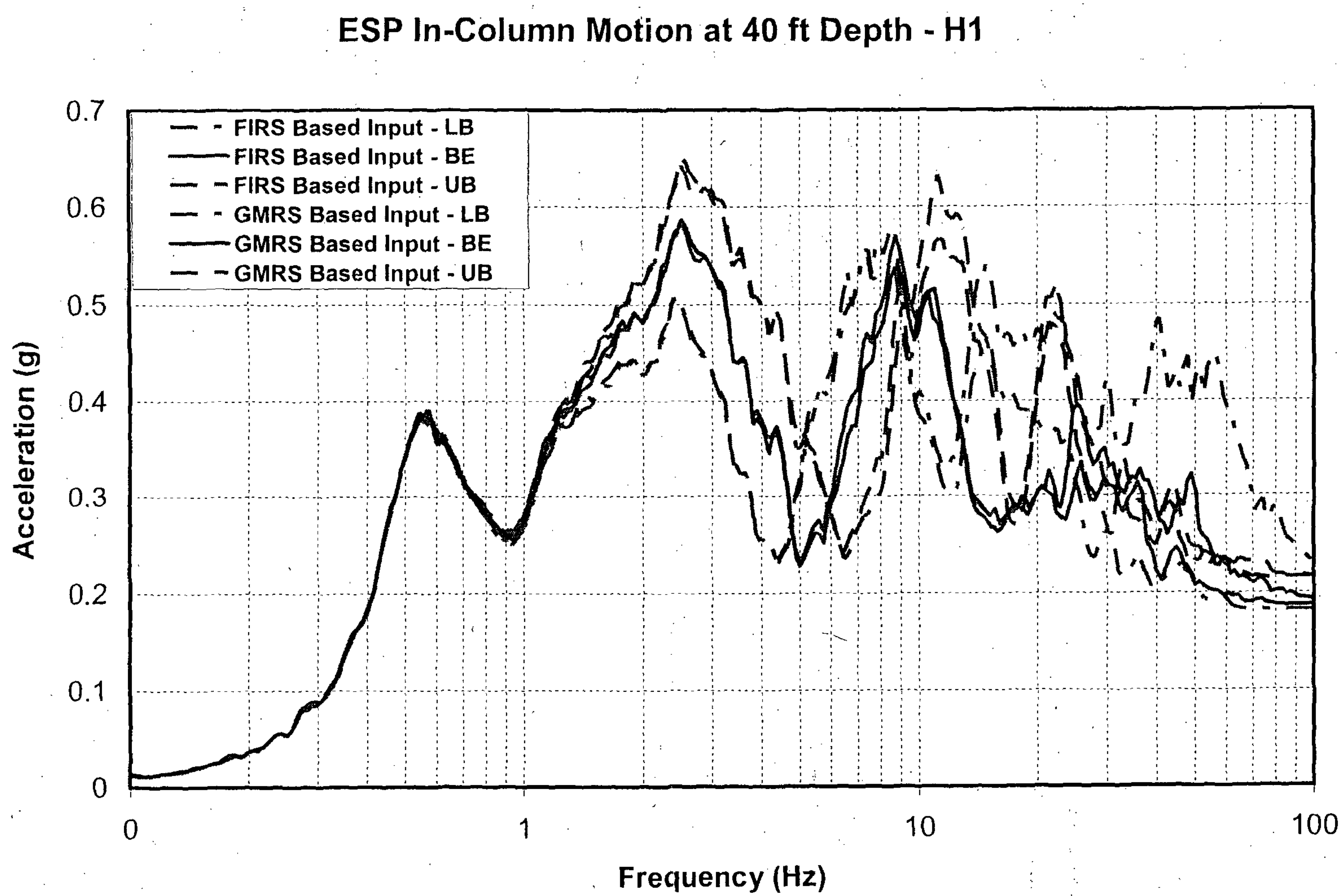


Purple lines designate outcrop response motion 40 ft depth using GMRS-based H2 time history at the ground surface

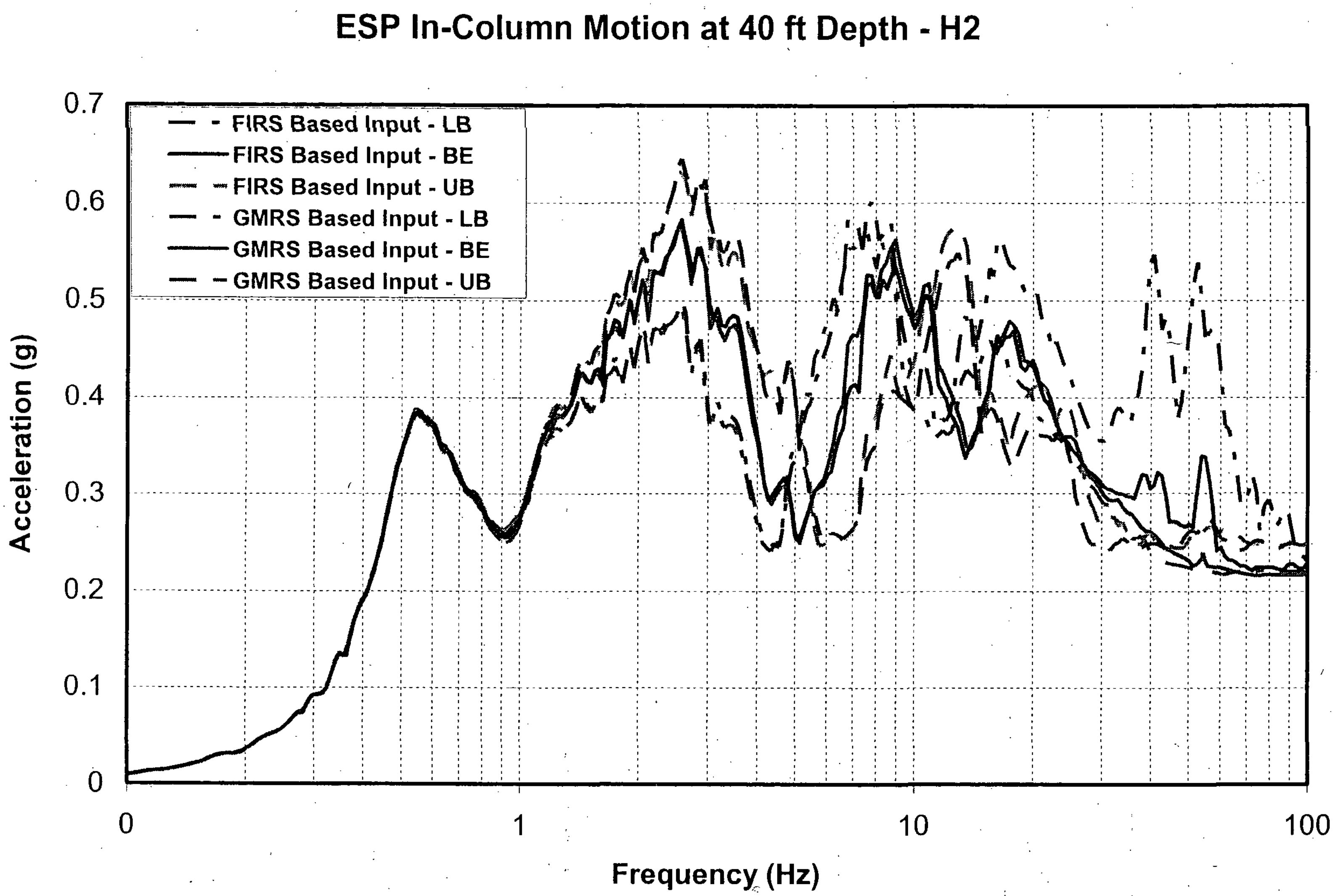


Purple lines designate outcrop response motion 40 ft depth using GMRS-based Vt time history at the ground surface

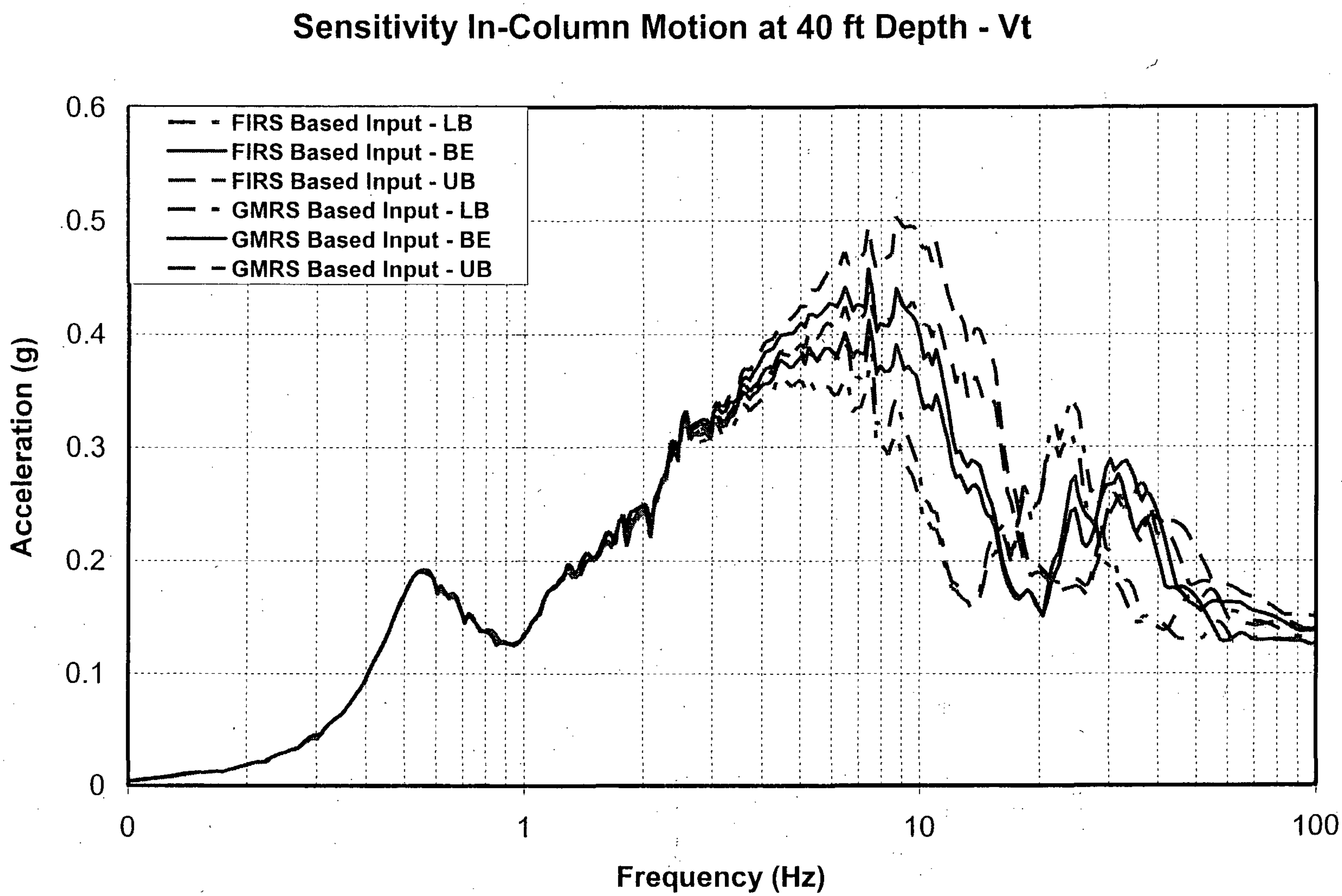
COMPARISON OF THE RESULTS FROM TWO METHODS



Green lines designate in-column response motion at the depth of 40 ft using FIRS-based H1 time history as input, purple lines designate in-column response motion using GMRS-based H1 time history as input



Green lines designate in-column response motion at the depth of 40 ft using FIRS-based H2 time history as input, purple lines designate in-column response motion using GMRS-based H2 time history as input



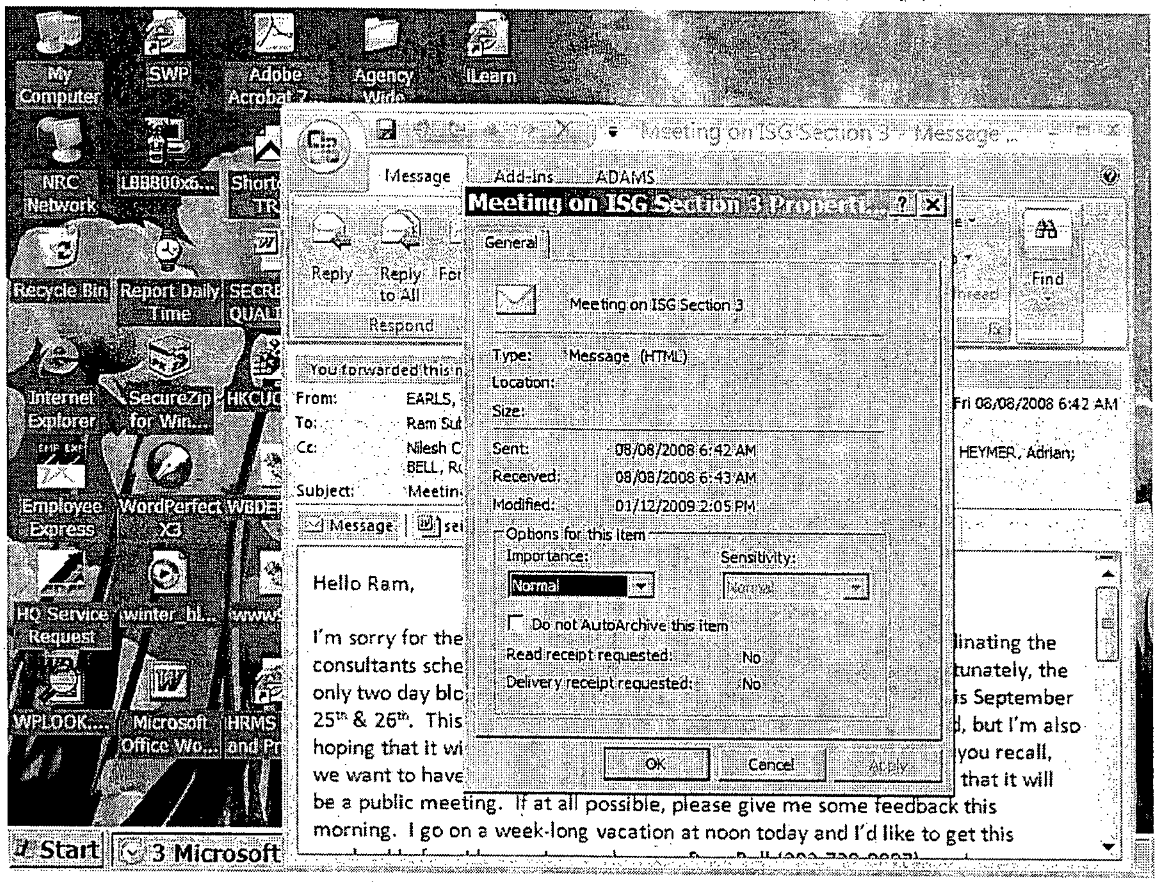
Green lines designate in-column response motion at the depth of 40 ft using FIRS-based Vt time history as input, purple lines designate in-column response motion using GMRS-based Vt time history as input

OBSERVATION

1. Developing input motion for SSI analysis using FIRS as outcrop motion as defined by the program SHAKE results in adequate characterization of the ground motion at the foundation level and along the embedment depth of the structure comparing favorably with GMRS at the ground surface.

2. The entire soil profile can be used to develop FIRS and GMRS. As long as the 3 profiles selected for SSI analysis are obtained from the same set used for generation of GMRS/FIRS, the modeling of ground motion will be fully consistent with SSI analysis.

3. The HF part of the GMRS at the ground surface is the result of stiffer soil columns used to generate the GMRS. De-convolution of GMRS particularly for the lower bound soil profile results in unrealistic ground motion at the depth even at shallow depth of foundation.


My Computer
SWP
Adobe Acrobat 7
Agency Wide
iLearn
NRC Network
Recycle Bin
Report Daily Time
Internet Explorer
SecureZip for Win...
Employee Express
WordPerfect X3
HQ Service Request
winter_bl...
WPLOOK...
Microsoft Office Wo...
Start
3 Microsoft
Meeting on ISG Section 3 - Message ...
Message
Add-Ins
ADAMS
Reply
Reply to All
Respond
Find
You forwarded this
From:
To:
Cc:
Subject:
Fri 08/08/2008 6:42 AM
HEYMER, Adrian;
Meeting on ISG Section 3 Properti...
General
Meeting on ISG Section 3
Type: Message (HTML)
Location:
Size:
Sent: 08/08/2008 6:42 AM
Received: 08/08/2008 6:43 AM
Modified: 01/12/2009 2:05 PM
Options for this item
Importance:
Normal
Sensitivity:
Do not AutoArchive this item
Read receipt requested: No
Delivery receipt requested: No
OK
Cancel
Apply
Hello Ram,
I'm sorry for the
consultants sche
only two day blo
25th & 26th. This
hoping that it wi
we want to have
be a public meeting. If at all possible, please give me some feedback this
morning. I go on a week-long vacation at noon today and I'd like to get this