Beverly Sweeney

From: Nilesh Chokshi /NRO
Sent: Tuesday, January 13, 2009 2:46 PM
To: Beverly Sweeney
Subject: FW: Draft Sept 25/26 Mtg Summary
Attachments: Mtg Summary Workshop on Seismic Ground Motion Issues 9_25_26_08.doc; NRC-NEI-9-25-26-08.pdf; SSI, FIRS, GMRS Input final.pdf

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From: HEYMER, Adrian [mailto:aph@nei.org]
Sent: Monday, October 06, 2008 7:54 AM
To: Nilesh Chokshi /NRO
Subject: RE: Draft Sept 25/26 Mtg Summary

My apologies, I was working from the Blackberry.

From: Nilesh Chokshi [mailto:Nilesh.Chokshi@nrc.gov]
Sent: Monday, October 06, 2008 7:49 AM
To: HEYMER, Adrian
Cc: KEITHLINE, Kimberly
Subject: RE: Draft Sept 25/26 Mtg Summary

Adrian,

Looks like you did not attach the meeting summary. I was out on Friday and just saw your message this morning.

Nilesh

From: HEYMER, Adrian [mailto:aph@nei.org]
Sent: Friday, October 03, 2008 5:21 PM
To: Nilesh Chokshi
Subject: Draft Sept 25/26 Mtg Summary

Nilesh,
Here is the draft summary for the meeting on SSI that was held on the 25th and 26th September. It has been reviewed by industry participants.

The draft white paper ready is being reviewed by the industry over the weekend. WE should be in a position to send you the draft next week.

If you or other members of the NRC staff has questions or comments, please contact me or Kimberly Keithline, 202-739-8121, kak@nei.org.

D-50

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WORKSHOP ON SEISMIC ISSUES CONSISTENT SITE-RESPONSE-SSI CALCULATION

Date: September 25-26, 2008

Location: EPRI Palo Alto, CA

Purpose: Develop a common understanding of the NRC guidance provided in ISG Section 3, "Use of Various Ground Motions."

Attendees: Attachment 1

Formal Presentations:

Attachment 2 "Consistent site-specific/soil-structure Interaction Calculations Workshop on Seismic Issues" by R. Kennedy and F. Ostadan. These slides provide industry understanding of the fundamentals for performance based ground motion and the associated issues, and the need for consistency in developing ground motions at different horizons.

Attachment 3 "Ground Motion Considerations Developing GMRS, FIRS, and SSI Input Motion" by Cliff Munson. These slides provides a summary of the NRC's SSE and siting regulations, current regulatory guidance on ground motion, and fundamental ground motion issues.

Definitions Agreed to at Workshop:

Geologic Outcrop ground motion is the free field ground motion with no soil above (no down coming waves) but the confining pressure of any soil above is considered for G/Gmax and damping vs. strain. (Note the term Geologic Outcrop may be revised to better capture its meaning.)

Full Column Outcrop ground motion is an outcrop motion that includes the full effect of the soil above, e.g. outcrop ground motion from a 1D iterative dynamic soil column analysis program like SHAKE. (Note the term Full Column Outcrop may be revised to better capture its meaning.)

Performance Based Surface Response Spectra (PBSRS) is the performance based derived ground response spectra at the free ground surface, i.e., plant grade.

The term FIRS (Foundation Input Response Spectra), which is a probabilistic based ground response spectra, is only used for the probabilistic based site ground motion at the foundation horizon. The term FIRS should not be used to describe the CSDRS consistent foundation outcrop ground response spectra which is deterministically based.

GMRS is a Geologic Outcrop probabilistic based ground response spectra; i.e. no soil column above.

Summary of issues, agreements and action items:

Key issue is NRC states FIRS are defined as a Geologic Outcrop motion but the transfer of this Design Response Spectra (DRS) for site-specific SSI must consider the entire soil column. Industry proposes, depending on the COLA site conditions and the DCD location of the CSDRS for the DCD SSI analyses, using the Full Column Outcrop FIRS in the site-specific SSI analyses.

There was full agreement on the information provided on slide 2 of Attachment 2. The calculated ground motions at various elevations must be performed using the performance based method using the same suite of soil profiles.

In addition, there was agreement that the FIRS be used as the basis for defining the input motion for a site-specific SSI analysis.

There are potentially up to three separate checks requiring response spectra at various elevations at a COLA site:

Check 1: FIRS greater or less than the CSDRS:

The development of the FIRS for comparison to a DCD's design needs to be consistent with the DCD SSI modeling, i.e., if the CSDRS is input at foundation horizon with no soil above (no embedment) then the FIRS needs to be developed with no soil above the foundation. If the DCD SSI included embedment then the FIRS should include the soil above the foundation.

Check 2: The minimum foundation input ground motion for design shall be at least an appropriate broad band response spectrum with a 0.1g PGA:

- The NRC's expectation is that the minimum required ground motion check per 10CFR50 Appendix S will be RG 1.60 0.1g PGA unless otherwise justified. The NRC will further look at clarification of the term "appropriate response spectra."
- Depending on the SSI model of the structure for the site specific SSI analysis and consistent with the free-field SSI model, Full Column Outcrop FIRS which are calculated using the soil above or the Geologic Outcrop FIRS can be used to make this check.
- If the FIRS is less than RG 1.60 0.1g PGA, it was agreed that to satisfy this minimum ground motion design requirement, an applicant can design the safety related structure using two separate analyses; one using the site-specific FIRS and

one using RG 1.60 0.1g PGA. Alternately, applicant may use the envelop of the two spectra.

Check 3: If Check 1 is not satisfied (CSDRS foundation input motion < FIRS) then a site-specific SSI is required:

- For this check there needs to be a clear transition from the probabilistic performance based development of the FIRS to the deterministic linear SSI analysis typically performed using a program such as SASSI and three soil profiles (LB, BE, and UB).
- For surface structures or structures modeled as surface structures in the Certified Design, it was agreed that for site-specific SSI analysis the Geologic Outcrop FIRS at the horizon corresponding to the horizon of the foundation should be used.
- NRC was not sure if using the Full Column Outcrop FIRS and convolving it up through the three soil profiles to the ground surface would bound the Performance Based Surface Response Spectra, i.e., PBSRS. For the Vogtle ESP/COLA the convolved spectra at plant grade did bound the PBSRS. (See Attachment 2 page 26.)
- Different approaches to performing the deterministic site-specific SSI based on the performance bases DRS and the randomization of the soil profile used in the performance based method were discussed. Two options were outlined. The details of these options will be provided as described below.
- Option 1 is the option that the industry representatives at the workshop preferred. The NRC outlined an alternate option, Option 2. It was agreed that the industry will provide in a NEI White Paper the complete details, justification, and checks for Option 1. The NRC participants thought Option 1 would be acceptable if a check of the convolved Full Column Outcrop FIRS to the ground surface bounded the PBSRS. NRC stated they will provide details for Option 2.

Outline of Option 1:

- Full Column Outcrop FIRS at the various foundation depths, e.g., FIRS from SHAKE using the full soil column.
- Calculate the Performance Based Surface Response Spectra (PBSRS). These spectra, by definition, would be at the ground surface, i.e., plant grade.
- Determine the LB, BE, and UB soil profiles based on the mean of the randomized soil profiles and the +/- one standard deviation; but if necessary applying the minimum requirement for variation of the soil shear modulus.
- Determine the in-column motion at foundation using the Full Column Outcrop FIRS for use in the site-specific SASSI SSI analysis. Alternately, the surface motion consistent with the in-column motion of the LB, BE, and UB soil profiles can be used in the SSI analysis.
- Convolve the Full Column Outcrop FIRS using the LB, BE, UB soil profiles to the ground surface (plant grade) and verify that the PBSRS is bounded.

- If the PBSRS is not bounded, the in-column motion or the companion surface motion for SSI needs to be modified. Alternately, additional soil columns in the range of the soil profiles used for the FIRS can be selected for SSI analysis as long as the extended group of soil profiles results in a set of surface motions that bound the PBSRS.

Actions and Schedules:

- Don Moore to draft workshop meeting summary for the industry and send to the NEI technical subgroup for review and comment. Draft summary due no later than Tuesday September 30th.
- NEI will provide the final workshop meeting summary by the industry to the NRC for information. This is scheduled for early October.
- Farhang Ostadan will prepare a draft NEI White Paper that provides definitions of various ground motion terms, use of various ground motion spectra for the different checks required for a COLA, and a full description of Option 1 for a site-specific SSI analysis. A reference will be made to an alternate option, Option 2 that is to be provided by the NRC staff and their consultant.
- Farhang Ostadan will draft a short version of the NEI White Paper by COB October 3rd and send out to the NEI technical subgroup for review and comment.
- The NEI technical subgroup will provide comments with changes to Farhang by COB Monday October 6th.
- Farhang will revise and send the complete the short version of the White Paper to NEI by October 13th.
- NEI to issue short version of White Paper to both the NEI SITF (see Note 1 below) and the NRC for parallel review.

Note 1: NRC requested a careful review of the White Paper by the CD NSSS Vendors and the COLA applicants. The NRC wants to limit the number of RAIs related to these ground motion issues and does not want to impact current reviews. They stated these ground motion issues need to be resolved as quickly as possible so there is no impact on schedule and work being performed by the NRC, COLA applicants, and the CD NSSS vendors.

Attachment 1: Attendees NRC-NEI Workshop Ground Motion-SSI Sept 25-16-08.pdf

Attachment 2: NRC-NEI-9-25-26-08.pdf

Attachment 3: SSI, FIRS, GMRS Input final.pdf

CONSISTENT SITE-RESPONSE/ SOIL-STRUCTURE INTERACTION CALCULATIONS
WORKSHOP ON SEISMIC ISSUES

R Kennedy
F Ostadan

NRC-NEI
September 25-26, 2008
EPRI, Palo Alto, California

Consistent Motions at Various Elevations

- In most currently used methods, hazard curves are defined at 9200 fps Rock
- Must start with 9200 fps Rock Motions & Convolve through soil profile to the various elevations of interest
  - A) Obtain Mean 10^{-4} & 10^{-5} UHRS at each elevation of interest
  - B) Determine DRS from 10^{-4} & 10^{-5} UHRS at each elevation of interest
- This approach is the only rigorous approach to obtain DRS at various elevations when the hazard is defined initially at 9200 fps Rock
- See Section 2.3 and Commentary C2.3 of ASCE/SEI 43-05

Specification of Input for Deterministic SSI Analysis of Embedded Structure

- Most appropriate elevation for specifying seismic input is at the foundation level of the structure

- Specifying the seismic input at any other location can lead to unrealistic response spectra at the foundation level (either seriously unconservative, or unrealiazably high)

Heart of Issue

NUREG 0800 States:

- The site-specific GMRS need to be transferred to the foundation elevations (FIRS)
- Implies that can be done by LB, BE, UB deterministic convolution evaluations
- However, this process does not produce a mean 10^{-4}, 10^{-5}, or performance goal based FIRS at foundation elevation

Better to State:

- FIRS need to be defined at the foundation elevation consistent with the GMRS
- The change will enable the FIRS to be “Performance Goal Based” consistent with the GMRS

One Dimensional Wave Propagation Program SHAKE

- Analytical solution to 1-D wave propagation
- Maintain compatibility of displacement and stresses

$$\rho \frac{\partial^2 u}{\partial t^2} = G \frac{\partial^2 u}{\partial x^2} + \eta \frac{\partial^3 u}{\partial x^2 \partial t}$$

$$U(x) = Ee^{ikx} + Fe^{-ikx}$$

One Dimensional Wave Propagation Program SHAKE

- For system with m layers, the motion in each layer has two components

$$k^2 = \frac{\rho\omega^2}{G + i\omega\eta} = \frac{\rho\omega^2}{G^*}$$

$$\alpha_m = \frac{k_m G_m}{k_{m+1} G_{m+1}} = \sqrt{\frac{\rho_m G_m^*}{\rho_{m+1} G_{m+1}^*}}$$

$$E_{m+1} = \frac{1}{2} E_m (1 + \alpha_m) e^{ik_m h_m} + \frac{1}{2} F_m (1 - \alpha_m) e^{-ik_m h_m}$$

$$F_{m+1} = \frac{1}{2} E_m (1 - \alpha_m) e^{ik_m h_m} + \frac{1}{2} F_m (1 + \alpha_m) e^{-ik_m h_m}$$

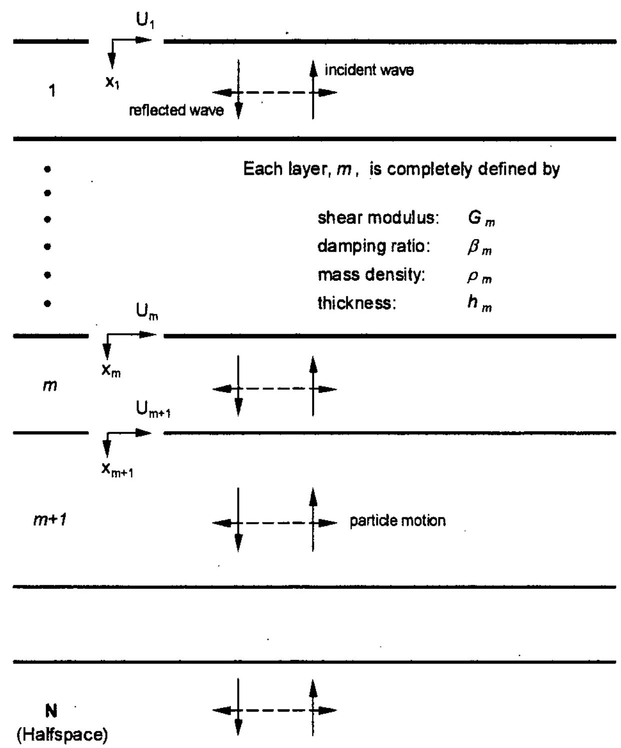


Figure 1 One-Dimensional Idealization of a Horizontally-Layered Soil Deposit Overlying a Uniform Halfspace

One Dimensional Wave Propagation Program SHAKE

Outcrop Definition in SHAKE

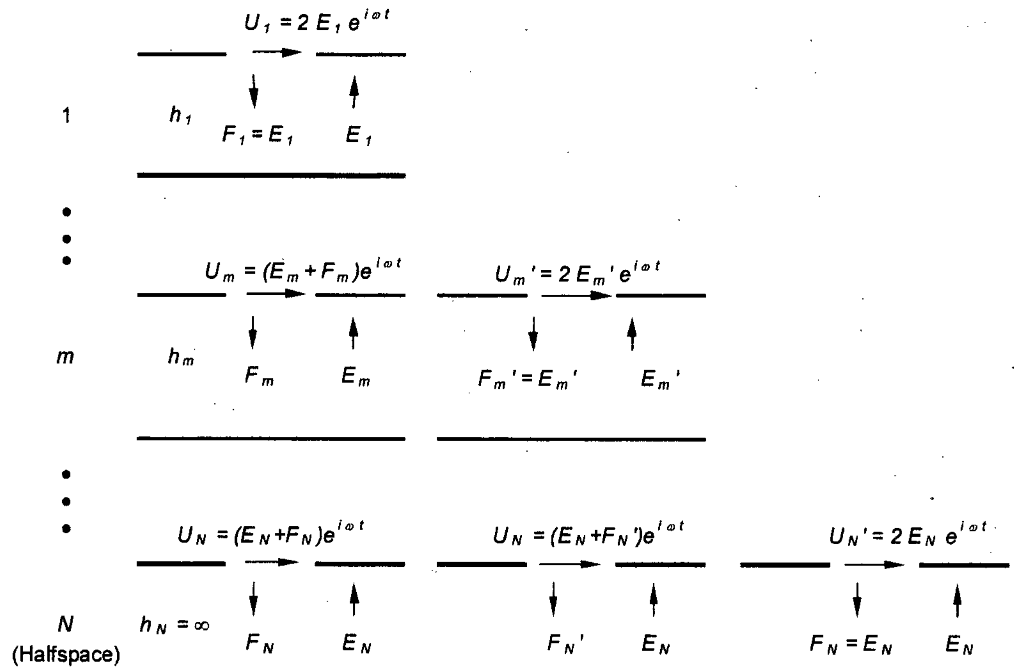


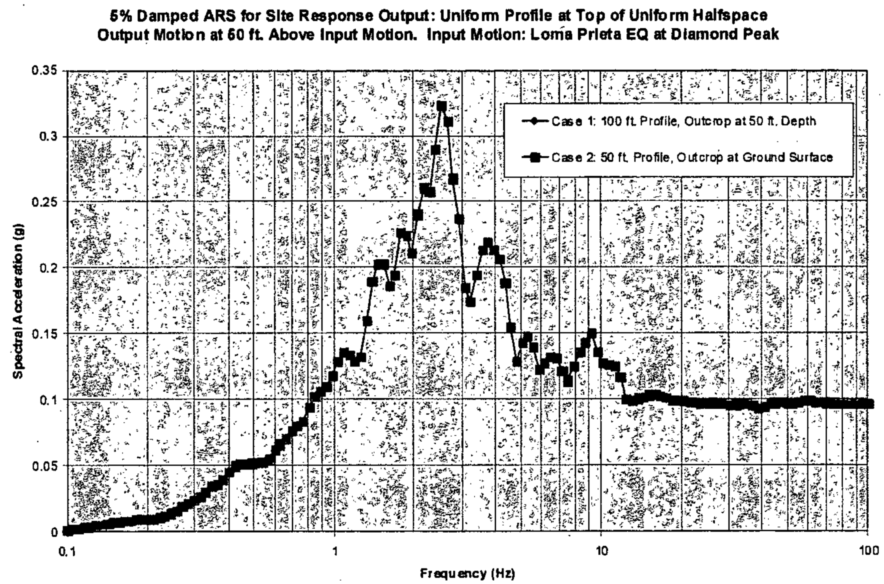
Figure 2 One-Dimensional Layered System with Outcropping Layers

EXAMPLE

- Case 1-100 ft. soil profile at top of a uniform halfspace with the same properties as the soil column, input motion is specified at 100 ft. outcrop, output ARS at 50 ft. outcrop.
- Case 2 is a 50 ft. soil profile at top of a uniform halfspace with the same properties as the soil column, input motion is specified at 50 ft. outcrop, output ARS at ground surface outcrop.
- Case 3 is a 100 ft. soil profile at top of a hard rock with Vs=10000 ft/s, input motion is specified at 100 ft depth as outcrop, output ARS at 50 ft. depth.
- Case 4 is a 50 ft. soil profile at top of a rigid rock with Vs=10000 ft/s, input motion is specified at 50 ft. outcrop, output ARS at ground surface outcrop.

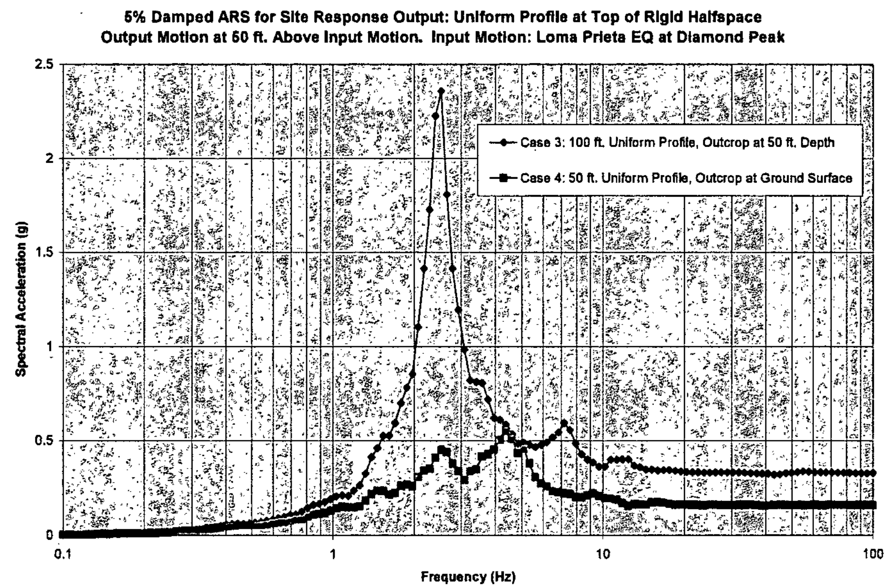
EXAMPLE-Cases 1 and 2

- Uniform Soil Profile (Halspace with no layering contrast)
- For a uniform Soil Profile with 100 ft thickness, response at 50 ft depth as outcrop is the same as running the 50 ft soil column (the upper 50 ft removed) and computing the response at the top of the soil column



EXAMPLE-Cases 3 and 4

- Layered site (100 ft of 1000 ft/sec over hard rock) with input motion specified as outcrop motion at the rock level
- Response motion at 50 ft depth as outcrop is different from the surface motion of 50-ft column (upper 50 ft removed) using the same input motion at the rock level as outcrop



Observation

- The notion that the SHAKE outcrop motion at a certain depth is the same as the surface motion of the same depth with the top soil removed is valid only for the uniform soil profile with no reflection from base

- For all real soil profiles (not uniform), the SHAKE outcrop motion at certain depth is different from the surface motion with top layers removed.

- If response motion is computed at surface with top layers removed, this response motion can not be used directly as input in the same profile with top layers added

- SHAKE outcrop response motion for any soil layer can be used as input outcrop motion in the same layer resulting in consistent and identical results

GMRS

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

- Currently GMRS is computed at the top of a competent soil layer with top layers removed
- The calculation includes PSHA analysis to get rock motion, soil column characterization and randomization of the data, convolution of de-aggregated HF and LF rock spectra, development of UHS at the GMRS horizon, and applying design factors to obtain design response spectra

GMRS-ISSUES

1. Removing the top layers is appealing since it seems to protect the GMRS from any changes that may take place in the soil profile above GMRS horizon during COLA. GMRS can never be free of the soil layers above it:
   - The initial velocity measured at the site has the effect of soil layers above on GMRS horizon on layers below
   - The nonlinear soil curves should include the effect of overburden
2. The site condition that defines the GMRS with top layers removed is not a realistic site condition and it never exists at the plant site
3. In spite of including the effect of overburden pressure on soil properties, the soil nonlinearity calculated as part of GMRS computation is an approximation of the nonlinearity since it does not have the effect of soil frequency of the soil layers above it

GMRS-ISSUES

4. GMRS with the above definition can not be used directly in the subsequent soil column that includes the top layers. It would require de-convolution to uniform halfspace in a separate de-convolution analysis and yet again convolved in a subsequent convolution analysis with the full soil column
5. GMRS is a broad band spectrum with high frequency controlled by stiffer soil profiles and low frequency by the softer soil profiles. De-convolution of a broad band spectrum is problematic and amounts to unrealistic motion, unconservative at some frequencies and overly excessive at other frequencies
6. GMRS is a design spectra and not UHS, de-convolution of GMRS and subsequent convolution does not yield the performance-based design motion at the horizon of interest

GMRS

It is suggested that GMRS to be computed as outcrop motion with soil layers above included. The soil layers above may be in-situ soil layers or backfill if it is an extended backfill. GMRS is not used for structural analysis, only FIRS is used. This approach maintains the effect of overburden from soil layers above and properly considers the effect of the soil column frequency above the GMRS horizon on GMRS. In addition this approach reduces the need to generate and randomize two soil columns, one for GMRS and one for FIRS

FIRS

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

FIRS use for SSI

- Any rigorous SSI model consists of two parts: the structural/foundation model and the free-field soil model
- The free field soil model must be consistent with the soil profile used to generate FIRS
- For SSI analysis including embedment, soil layers within the embedment depth of the SSI model should be included in the soil column analysis
- For SSI analysis with no embedment, the soil column model for FIRS should terminate at the base of the SSI model with no soil layers above it
- The input motion in SSI analysis is defined in the free-field model as control motion at control point
- Using consistent FIRS soil column and FIRS motion for free-field SSI model ensures application of performance-based motion for structural analysis

FIRS

The use of FIRS are as follows:

1. Comparison with CSDRS to evaluate applicability of the design to the site

   For this purpose FIRS should be computed compatible with use of CSDRS in SSI analysis.

   - For SSI analysis with no embedment, FIRS should be computed as a free surface motion (no soil layer above) at the foundation level.
   - For SSI analysis with embedment, FIRS should be computed as outcrop free-field motion including the soil layers above

   For standard designs that are based on CSDRS at the ground surface level and included embedment in the SSI analysis, the CSDRS-consistent motion in the free-field at the foundation level should be obtained from the generic profiles and compared with the site specific outcrop FIRS that includes the soil layer above the FIRS horizon

FIRS

2. Performing site specific SSI analysis

For this purpose FIRS should be computed compatible with its application for SSI analysis.

- For SSI analysis with no embedment, FIRS should be computed as a free surface motion (no soil layer above) at the foundation level
- For SSI analysis with embedment, FIRS should be computed as outcrop free-field motion including the soil layers above
- The soil profiles for SSI analysis should be obtained from the set of same profiles used for generation of FIRS to obtain upper, mean and lower bound profiles

FIRS

3. Checking with minimum 10% requirement

- All standard designs are designed for RG 1.60 scaled to 0.30g as a minimum and this is not an issue
- For other class I structures not covered by DCD, the requirement must be met
- For this evaluation, the FIRS again should be consistent with its application for SSI (with either embedment or no embedment). It is suggested that the site specific FIRS consistent with its application to be compared with the minimum requirement

FIRS

Methodology for Computation of FIRS

- Once the application of the FIRS is determined and the decision on modeling of the top soil layers is made, the soil profile and the soil data will be randomized compatible with the method used for GMRS and soil column analysis will be performed using rock motion as input to obtain UHS and DRS at the FIRS horizon
- This approach provides performance-based motion for structural analysis
- The three soil profiles needed for SSI can be obtained from the strain-compatible soil properties generated from the FIRS computation
- This approach ensures consistent motion in site response and SSI analysis

Example of GMRS/FIRS

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)

Example of GMRS/FIRS

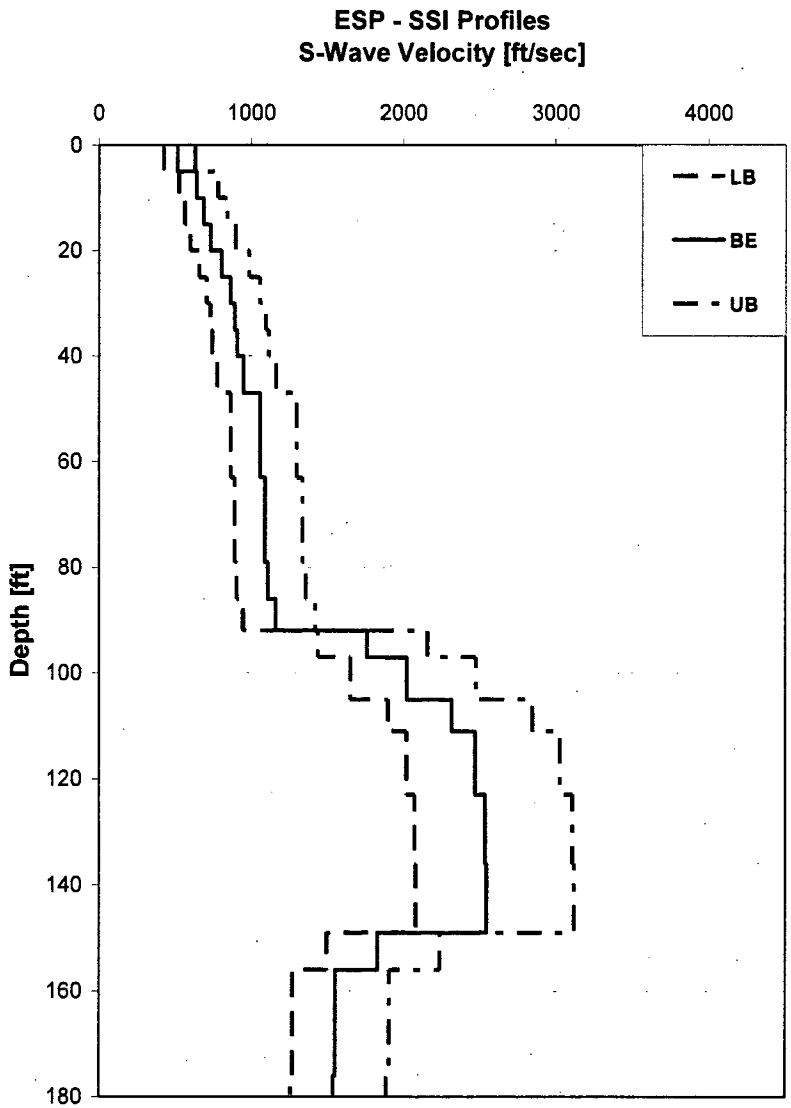
Soil Amplification

- 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

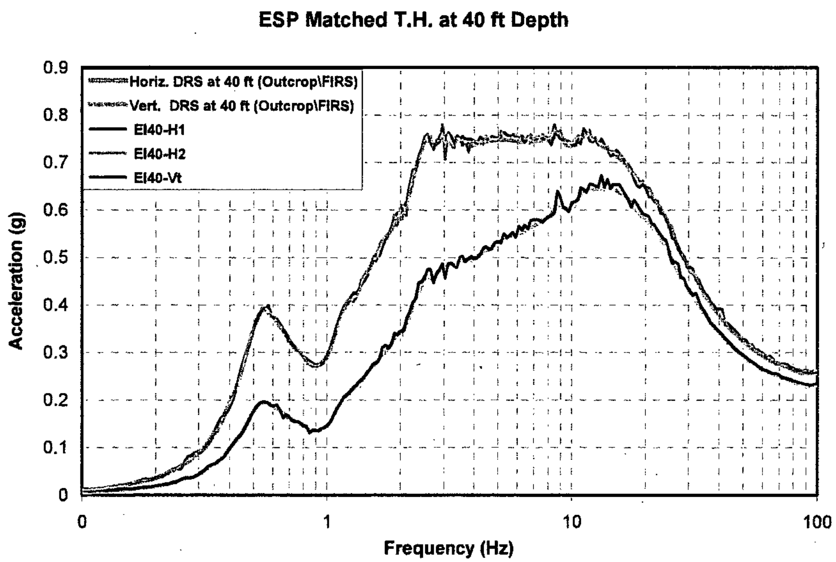
Design Spectra

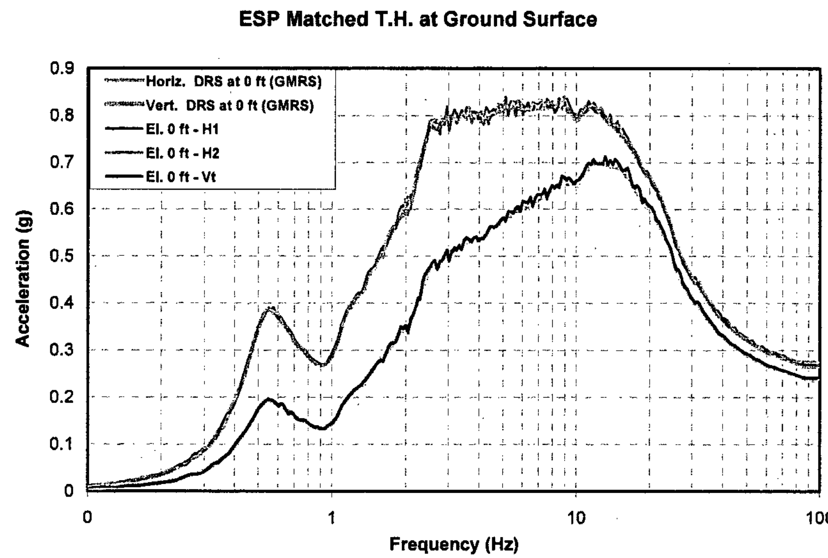
- The log-mean (median) of 60 soil amplification functions were used to develop soil uniform hazard spectra
- The design factors were applied to the uniform hazard spectra to obtain design spectra
- Vertical design spectra was obtained using V/H ratio
- The design spectra at the ground surface is labeled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

Example of GMRS/FIRS

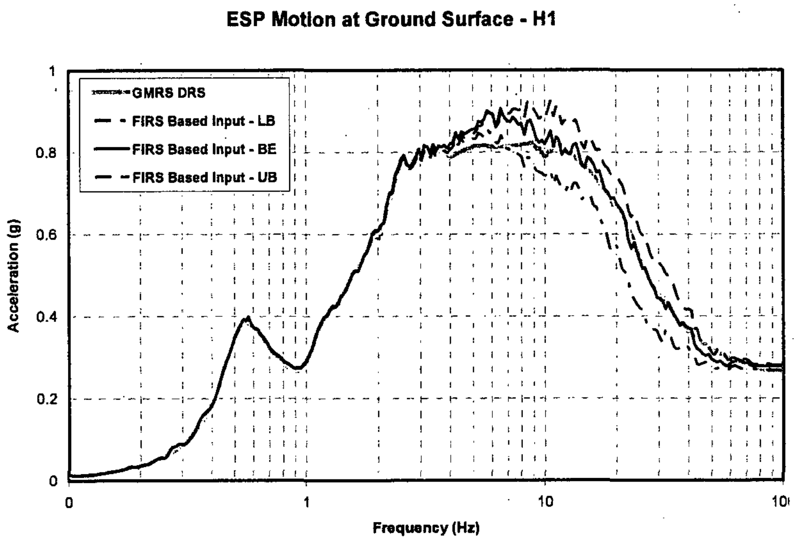


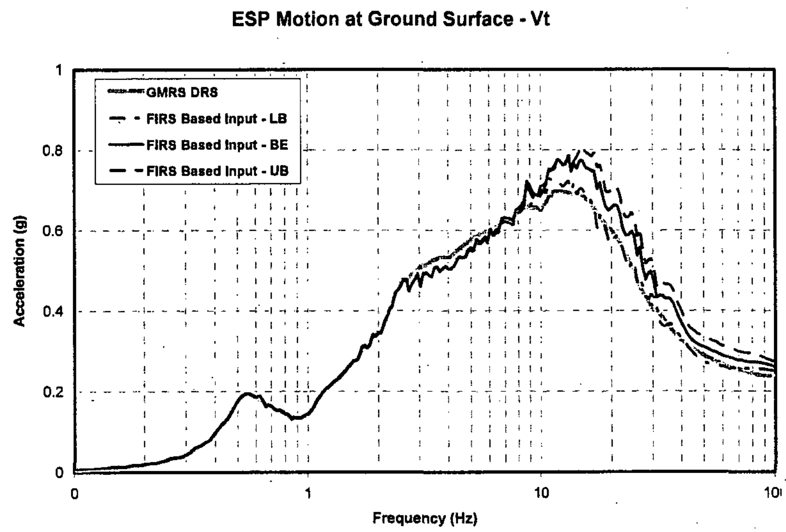
Example of GMRS/FIRS





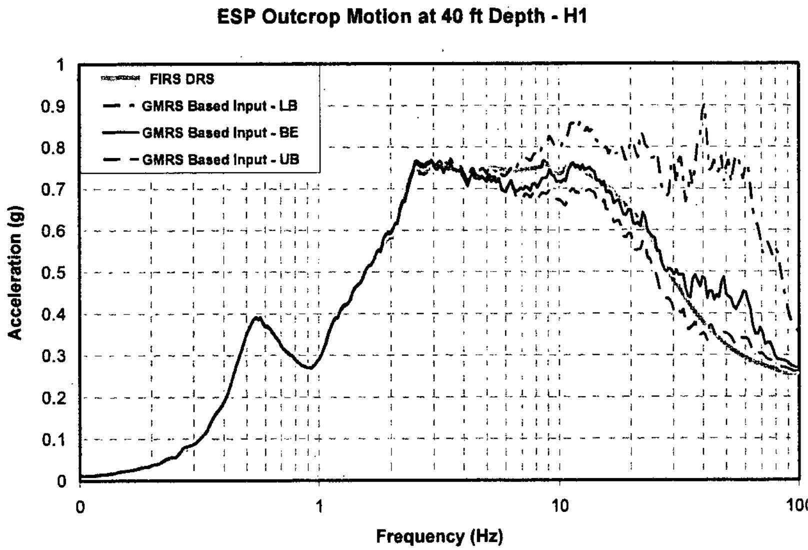
Example of GMRS/FIRS

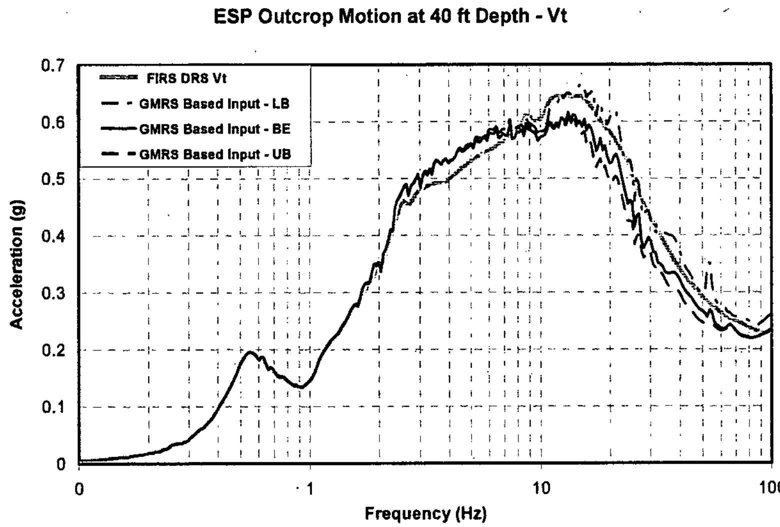




Green lines designate response motion at ground surface using FIRS-based time histories as input

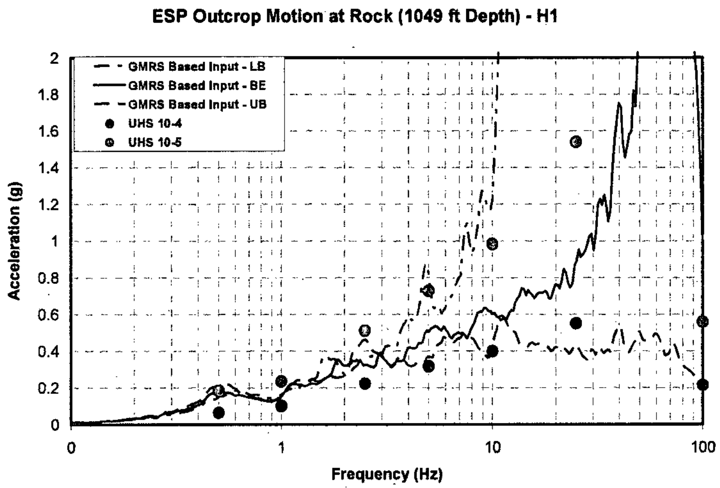
Example of GMRS/FIRS

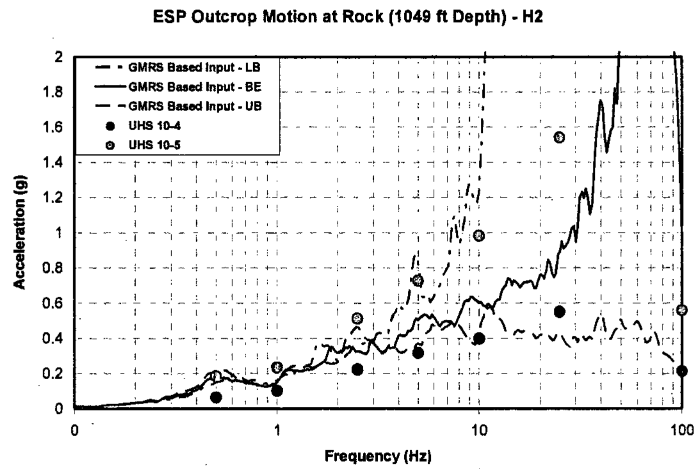




Purple lines designate response motion at 40 ft depth using GMRS time histories as input

Example of GMRS/FIRS





Purple lines designate response motion at 1049 ft depth using GMRS time histories as input

Example of GMRS/FIRS

OBSERVATION

- De-convolution of site specific smooth spectra results in unrealistic motion even at shallow depths. De-convolved motion can be lower or higher than the performance-based motion at foundation level of the structure
- De-convolved response motion is no longer a performance-based motion

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Ground Motion Considerations

Developing GMRS, FIRS, and SSI Input Motion

by

Clifford G. Munson, PhD
U.S. Nuclear Regulatory Commission

September 25, 2008

Scope of Presentation

- SSE and Siting Regulations
- Current Regulatory Guidance
- Fundamental Issues

SSE Requirements

- 10 CFR 50, Appendix S
  - SSE “must be characterized by free-field ground motion response spectra at the free ground surface.”
  - Horizontal component of SSE in free-field at foundation level “must be an appropriate response spectrum with a peak ground acceleration of at least 0.1g.”

Siting Criteria

- 10 CFR 100.23
  - Geological, seismological, and engineering characteristics of a site and its environs must be investigated in sufficient scope and detail to arrive at estimates of SSE
  - SSE for the site is characterized by both horizontal and vertical response spectra at the free ground surface

Ground Motion Definitions – CSDRS (RG 1.208)

- Certified Seismic Design Response
  - Site-independent seismic design response spectra that have been approved under Subpart B of 10 CFR Part 52 as the seismic design response spectra for an approved certified standard design nuclear power plant. The input or control location for the CSDRS is specified in the certified standard design.

Ground Motion Definitions – GMRS (RG 1.208)

- Ground Motion Response Spectra
  - 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

Ground Motion Definitions – GMRS (cont.)

- When GMRS are determined as free-field outcrop motions on the uppermost in-situ competent material, only the effects of the materials below this elevation are included in the site-response analysis (RG 1.208)
- If non-competent material is present, any excavation and/or backfilling should not alter the development or location of the GMRS (SRP 3.7.1)

Ground Motion Definitions – FIRS (SRP 3.7.1)

- Foundation Input Response Spectra
  - When the site-specific GMRS and CSDRS are calculated 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.

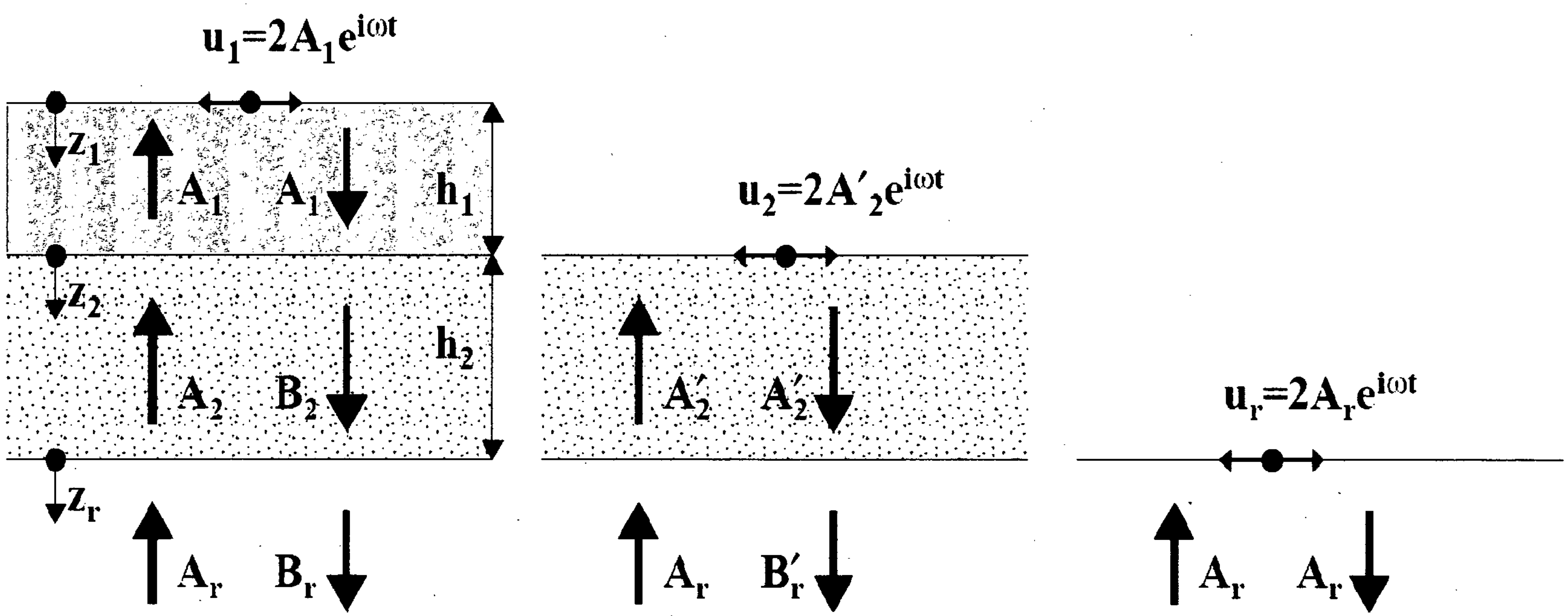
Ground Motion Definitions – FIRS (cont.)

- Further guidance related to FIRS (SRP 3.7.1)
  - Only the effects of materials below the base elevation of the seismic Category I structure are included in the site response analysis

Fundamental Issues – Developing GMRS

- Use of "SHAKE outcrop" rather than "geological outcrop" does not result in free surface motion
- Effect of weight of soil column above outcrop elevation needs to be included to ensure the correct overburden stress effects on the strain calculation

Outcropping Motion - GMRS



a) Two layer model b) Layer 2 outcrop c) Halfspace outcrop

Fundamental Issues – Deriving FIRS from GMRS

- Whenever motions are computed at a given elevation, all soil layers below must be included
- Any transfer of ground motion from one elevation to another elevation needs to consider the entire soil column down to the effective uniform halfspace

Fundamental Issues – Deriving FIRS from GMRS

- Transfer of GMRS to individual foundation elevations should be consistent with the same process of randomization of soil properties and the site profile that was used to establish the GMRS
- Only the effects of materials below the base elevation of the seismic Category I structure are included in the site response analysis for FIRS

Fundamental Issues – Developing SSI Input Motion

- Transfer of FIRS or GMRS to SSI input motion must consider entire soil column
- Cannot simply convolve FIRS or GMRS up to ground surface considering the soil column above the foundation level alone
- Linear SASSI SSI analysis conducted without performing above step correctly results in an unconservative estimate of seismic demands

Ground Motion Considerations

THANK YOU