

Draft

NEI New Plant Seismic Issues Task Force  
Meeting with the NRC  
Santa Ana, CA  
October 24-25, 2006

Conference Report

Purpose: To continue the dialogue between NEI and NRC to reach a common understanding as a basis for resolving seismic issues related to future nuclear power plants. See the agenda attached to the NRC meeting notice (Attachment 1).

Attendees: See Attachment 2

Summary:

Andy Murphy (NRC) opened the meeting by welcoming all and discussing the scope of the agenda for the two days. The participants introduced themselves. The NRC desire was to have RAIs on the S2.1 A and B reports addressed as part of the presentation materials and the discussions.

The point was made that this meeting is very important for utilities to file their COLs. The timeline for making plant siting decisions is getting critically short, and if a common and satisfactory understanding is not reached shortly, plants may not be able to be sited on rock.

Greg Hardy (ARES) discussed the meeting logistics for both days. Because of some late arrivals, the meeting presentations started with the structural response area but then shifted to the ground motion area and back again to the structural response area. This report contains the discussion summaries in order of topic, not chronologically.

**GROUND MOTION PORTION OF THE MEETING**

Dr. Norm Abrahamson presented (Attachment 3) information on the responses to the RAIs on his report. He noted that the report sent to the NRC should be published by EPRI soon. Also he referred to a March 2002 report that is proprietary to EPRI. This report has not yet been released by EPRI for the NRC. Dr. Abrahamson also referred to a non-published report, which has already been transmitted to the NRC. Highlights of his presentation included:

- Even though some of the NRC questions mix up the ground motion and response effects, they would all be answered.
- He explained the array depths noting that for some arrays there are multiple sensors at varying depths that are at separate layers. An Array plot is in the EPRI report 1014101. He stated that for some arrays, old mining tunnels were used so the existence of the tunnel needed to be considered.
- Dr. Abrahamson explained how the energy is distributed and how the coherency between adjacent records at depth developed. He demonstrated that wave scattering

BAB

- is the same for a single earthquake at a single site as it is for multiple earthquakes (distance to epicenter and magnitude) at multiple sites (rock and soil).
- Coherency is an empirically driven assessment.
  - It was noted that positive plane-wave coherency residual is non-conservative; negative is overly conservative. Combining all the data from 10 to 20 meters depth suggests a small under prediction of about 0.1.
  - NRC participants and their consultants struggled with several issues related primarily to rock sites including:
    - Professor Zerva indicated that people have built models in the past and found higher coherency in the rock sites relative to soil sites. She stated that she would be more convinced if the analysis dealt with one event at a time and one direction at a time. Dr. Abrahamson demonstrated that making conclusions based on such an approach would be misleading. Trends should not be over interpreted.
    - Carl Costantino stated that he believed that the phase shifts should be different at different sites. Dr. Abrahamson provided data to justify that the phases should be the same for close points at the same depth for separate sites.
    - EPRI array has a bump in the 20-50 Hz area and the question was posed whether all rock sites have that similar bump.
    - Professor Veletsos questioned the physical reasoning for rock site coherency being the same as soil site coherency. He questioned the coherency Norm used for rock sites at high frequencies.
    - Farhang Ostadan noted that Paul Summerville had a paper that declared coherency to be lower in rock.
    - It was suggested that the analysis should be done separately for the P and the S waves. Dr. Abrahamson stated that P waves have not been analyzed and the results would not be valuable for the structural response.
    - Mean and median based models were addressed. The mean based model was used and the difference is not significant. Professor Veletsos stated that there is a large scatter in the data. He was uncomfortable with this large scatter and was not convinced the median was appropriate due to this large scatter. Dr. Kennedy concurred with Dr. Abrahamson that the use of the median was appropriate. Similar scatter exists in the seismic hazard area for determining the attenuation relationship and that the median is similarly utilized. Dr. Abrahamson stated that the bulk of the scatter is randomness and a smaller part is from an event term.
  - **Hard Rock Data**
    - Some NRC members and NRC consultants were concerned with the lack of hard rock data and the feeling that maybe the coherency would increase for hard rock. There is a considerable amount of Pinion Flats data (although it is just one site). It is the only real hard rock data that exists and the data has not been plotted for the plane wave coherency. The data is not usable as it exists; it needs to be corrected for lag coherency and polarity before analysis for plane coherency can be evaluated. The polarity correction is from instrument signals being crossed (the report for Pinion Flats documents the changing of

the signals by the operators). The data will be aligned to the P wave and will then be plotted.

- Effect of Site Condition on Coherency
  - There were various comments relative to the degree to which we believe the statement in the report that the coherency function is not correlated to the site shear wave velocity.
  - Dr. Kennedy stated that if there is a difference in the mean of shear wave velocity, then this needs to be incorporated in some way. He also suggested that it may be beneficial for Dr. Abrahamson to separate his data into several bins based on the site properties in order to address these questions. Dr. Abrahamson suggested that he could separate the results (residuals) based on some appropriate soil and rock categories.
  - There is no systematic magnitude dependence in the coherency function. The 3-7 Hz coherency function is less valuable than the 6-12 Hz. The later frequency range is less coherent.
  - The average surface frequency content shows low amplitudes less than 20 Hz; consequently, the equations were fit up to 20 Hz, but the data was carried on.
  - Goutam Bagchi asked about the effect of deep soil sites and how to convolve to the surface. How far do the borings need to go to justify the convolution? This was not related to the coherency question but will be important in the new regulations and guidance documents.
  - Dr. Zerva asked the question of whether the plane wave coherency was what the industry wanted to be using going forward or whether the industry wanted to consider the effects on both the P waves and the S waves and use the lagged coherency. The SSI analysis considers a vertically propagating shear wave. Dr. Johnson offered that his understanding was that the motion from the recordings had been separated into two parts and that wave passage effects were studied as a sensitivity study early within the EPRI project. These wave passage analyses utilized the complex coherency function within Dr. Abrahamson's report. Subsequent analyses within this project have all assumed infinite wave passage and ignored the wave passage effects (conservative assumption) since the wave passage effects were shown to reduce the coherency.
  - Dr. Kennedy summarized the project overall philosophy that we are trying to achieve a median response. Dr. Abrahamson recommended the use of his plane wave coherency function as being appropriate in achieving that median response for these structural response analyses. Action to talk with Norm to address this question. ARES took the action to set up a call with Drs. Abrahamson, Johnson, Costantino, Zerva and Kennedy to explore this question in more detail.
- The issues identified during this portion of the meeting included:
  - Coherence at depth and in rock vs. soil
  - Vs dependence
  - Correlation with peak FAS
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#### Action Items

- Greg Hardy took an action item to have a near-term conference call between Dr. Abrahamson and Professor Zerva regarding issues with the coherency methods in connection with P and S. Others may be invited to attend the call if available.
- The following three immediate action items for Dr. Abrahamson are to be provided to the NRC by the close of business on November 27, 2006. With this material being delivered to the NRC on time, it is expected that NRC and industry can reach a consensus agreement by the end of the next meeting, which is tentatively scheduled for a half-day of December 20, 2006 and either a half-day or a whole day on December 21, 2006 in the San Francisco Bay Area.
  - Discuss the magnitude dependence at higher frequency 15-20 Hz.
  - Provide to the NRC Data set, time set, residuals in a spreadsheet.
  - Provide information to understand the EPRI "bump" plot by redoing to the usable frequencies on the spectra.
- Dr. Abrahamson will write a separate document to address these previous three action items. It will likely be characterized as an appendix to the EPRI report 1014101 not a revision of to it.
- Other action items based on this portion of the meeting included Dr Abrahamson needs to:
  - Separate out the two EPRI events and show what is above 30 Hz.
  - Plot residuals by array.
  - Plot the results of other coherency models.
  - Provide more information on why phase sift for two sites would not be different.
  - Discuss if the coherency function drops off after the peak in the Fourier amplitude.
- An action item for EPRI is to release the EPRI proprietary report released referred to by Dr. Abrahamson.
- The following suggestions were made during this portion of the meeting:
  - It would be helpful if both CLASSI/SASSI codes were availability for the NRC contractors would be advantageous; however, there are commercial and proprietary issue that must be solved, and it is unlikely that they will be solved in the near-term.
  - It would be helpful of a guideline was prepared on how to do a site specific study if the generic spectra are not applicable.
  - The industry needs to get a firm agreement from the NRC that SSASI can be used.
  - The question of how deep is deep needs to be addressed in the Regulatory Guide.

#### **STRUCTURAL RESPONSE PORTION OF THE MEETING**

Greg Hardy provided an introduction to the ARES presentation (Attachment 4) which addressed the structural response RAIs. Highlights of his presentation included:

- The engineering subtasks of the S2.1 task were identified including defining the cases to be analyzed, developing the ground motion input, deriving the approach to include coherency function, conducting parametric studies, benchmarking the computed incoherency, conducting SSI analyses, investigating a simplified approach, and providing documentation of the work.
- The S2.1 report consists of two separate reports. The Structural Response report (EPRI Report 1013504), developed by ARES Corporation, was designated "a," and Ground Motion report developed by Dr. Abrahamson (EPRI report 1014101), was designated as "b").
- Greg suggested that if typos are found, please let him know because the final publishing by EPRI will take some time.

Steve Short and Jim Johnson provided a team presentation of the technical details of Attachment 3. Highlights of this presentation included:

- The response spectrum for rock sites was discussed. The spectra presented are typical as those for the COL applicants for rock sites; thus, any rock site with any significant seismicity will have the issues identified in these example spectra. The larger the peak of the motion the higher the reduction provided by incoherency. It was recognized that the engineering results can not be any better than the incoherency function used.
- Consensus was that if the coherency function changes with depth, that the coherency would be changed at all elevations. This might introduce a slight conservatism but the data may not be sufficient to differentiate the coherency with depth. Some discussion will occur before the decision is finalized. The NEI/EPRI team will review in the near term and make a recommendation. Dr. Costantino would also like to think through the process in the near future.
- The response spectra for soil sites were also discussed. There was little discussion of these spectra. Dr. Kennedy stated that these spectra would be representative of soil sites with significant seismicity, excluding Texas, Florida, and Mississippi.
- Relative to the embedment study in Appendix E, Dr. Zerva noted that since the process is a linear one between the surface and the embedded cases, it is not appropriate to make conclusions on the separation between the embedment effects and the incoherency effects. Dr. Johnson noted that there is a difference in the incoherency based on the inclusion of the vertical cylinder of nodes for the embedded case. The transfer functions (Page E 14 and E 15) are not the same and that is demonstrated by the figures in the report.
- Dr. Veletsos had several questions on whether the effects shown in Figures 4-9 and 4-10 were really only incoherence effects or whether they included SSI effects also. Dr. Veletsos has requested that ARES provide additional information regarding the structural model. The main frequencies, mode shapes, eigenvectors, and participation factors would be beneficial to him to understand the responses presented throughout the report.
- Dr. Veletsos indicated he would be sending written comments and requests on this

EPRI report #1013504; however, Andy Murphy stated that these comments could be treated as Staff comments and not RAIs.

- Dr. Zerva indicated that the simplified approach presented within the report was appropriate in concept but that more research into a variety of structures and ground motion might be required (as has been indicated within the report) before it could be utilized on a generic basis.
- The studies within Chapter 5 have been done with three independent time histories simultaneously. Some ESP submittals have been required to go back and change the phasing on one horizontal direction to understand the difference that results. Dr. Kennedy noted that there is no requirement within the Standard Review Plan or ASCE 4 to do anything further than the simultaneous application of independent time histories. The NRC will consider this issue which was noted to be a more generic issue that exists for any response (with or without the incoherence effects).
- Dr. Veletsos offered that the "approximate deterministic" approach he had helped develop in the past was valid for the evaluation of incoherence. Dr. Johnson noted that this same approach was used in CLASSI and has been described as one method of incorporating the "direct" approach. Based on this understanding, Dr. Veletsos is comfortable with this methodology. It was noted that this original paper by Dr. Veletsos should be referenced in the EPRI report.
- Dr. Veletsos offered an explanation as to the reasons for the reductions that have been noted in the evaluations. The SSI evaluation will decrease the frequency of the combined system and will increase the damping.
- The reactor stick model structure was discussed. Jim Johnson explained that considering incoherent input motion creates torsional motion for the building response. Coherent motion does not develop torsional motion. This torsional motion drove the analysis to be more realistic. This is really a three dimensional problem. For the high frequency inputs, it is important to include soil structure interaction.
- The technical approach is similar to that used in the 1980's with the exception of the incoherency function. They developed a simplified, empirically based method for rock sites, high frequency input, and example structures with multiple significant frequencies. The discussion centered on the analyses done by CLASSI and SASSI. The industry believes that use of both codes and obtaining the same results indicate that a simplified approach is viable. The NRC would like to see two codes based on different theoretical assumptions and gaining the same results.
- He showed the reductions of the horizontal and torsional spectral acceleration on the foundation produced by the wave passage.
- Dr. Veletsos raised the question regarding developing the spectra without consideration of mass.
- CLASSI can not analyze embedded or flexible foundations. These must be analyzed with SASSI.

#### Action Items:

1. Project team to review the implications of a change in the coherency function with depth (see Dr. Abrahamson action item from previous day). Come back with a recommendation on how to address a potential variation in the coherency function

with depth.

2. Greg Hardy will set up a conference call with appropriate group of people noted above relative to the issue of the correct coherency function to be used in the evaluations in order to ensure we obtain a median response.
3. Change wording to state that the coherency function was assumed to be independent of depth.
4. Recommendation is to produce the free field ground motion, SSI coherent and SSI incoherent Fourier Spectra for figures such as 5-80 and 5-81. This will help demonstrate the effects of SSI (coherent or incoherent) on the seismic response of foundations and structures. This task was in response to several questions posed by an NRC consultant on separating the results of the incoherency responses.
5. ARES was requested to develop additional information on the main structural model results (frequencies, mode shapes, eigenfunctions and participation factors up to about 30 Hz) in order for the NRC consultants to fully understand the responses.
6. ARES to discuss with EPRI a path generating documentation and a version of CLASSI (can be kept proprietary) with incoherency to the NRC for specific use in reviews on this project.
7. Reference Dr. Veletsos earlier study on incoherency that describes the "approximate deterministic" approach within the ARES incoherency response report.
8. Discuss and resolve the issue of whether both versions of SASSI and CLASSI get the increase in the low frequency region due to the rotations. A meeting was recommended between Bechtel and ARES needs to address this issue and come up with a resolution. There should be a problem that is done consistently with all codes. The resolution will be communicated to the NRC.
9. Dr. Costantino has scheduled a discussion with Bechtel of SASSI details relative to the input motion PSD preservation and on load vectors.
10. Add material in Chapter 4 to address the translation and rotation combination.
11. Assuming that a change to the coherency function with depth is decided upon, develop new foundation and structure responses to demonstrate the effects of the changes.
12. Industry requested to participate in an effort to generate an NRC/Industry consensus on elements of the seismic qualification process that have not been finalized, e.g.:
  - a. Convolution for deep soil sites
  - b. Site profile properties uncertainty usage for SSI analyses
  - c. Minimum seismic design levels