PMSTPCOL PEmails

From: Wunder, George
Sent: Thursday, February 17, 2011 5:08 PM
To: STPCOL
Subject: FW: Poisson's ratio
Attachments: Confirmatory Analysis of Poisson's Ratio.doc

From: Head, Scott [mailto:smhead@STPEGS.COM]
Sent: Thursday, February 17, 2011 4:35 PM
To: Tonacci, Mark; Wunder, George; Tai, Tom
Subject: FW: Poisson's ratio

Mark

Here is our White Paper on Poisson's Ratio.

Thanks

Scott

Hearing Identifier: SouthTexas34Public_EX
Email Number: 2611

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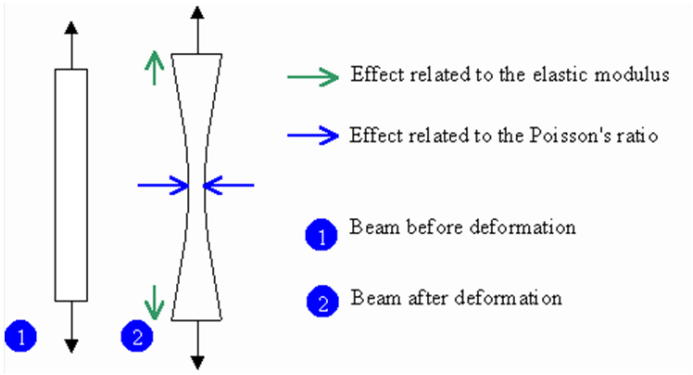
Proposed Confirmatory Calculation Concerning Poisson's Ratio
Used in the Seismic Soil-Structure Interaction Analyses

The NRC staff has stated that it will perform a confirmatory analysis to verify acceptability of the design basis STP SSI analysis results for the Ultimate Heat Sink/Reactor Service Water Pump House to gain additional assurance and confidence that the SSI analysis results are not adversely affected by the use of a high Poisson's ratio. NINA believes that this is unnecessary and will delay completion of the SER.

- <u>Background on Poisson's ratio</u>

  Material strains are often idealized as being linearly proportional to the applied stresses. For instance, if you pull on a strip of material, the amount it stretches is linearly proportional to the force of the pull: pull with 10 pounds, and it stretches x inches; pull with 20 pounds and it stretches 2x inches. The constant ratio between the applied stress and the elongation is known as the elastic modulus (or Young's modulus, E). However, when you pull this strip it will not only elongate in the direction of pull, but will also contract in the directions perpendicular to the pull. This contraction is known as Poisson's effect, and the ratio of the contraction to the elongation is known as Poisson's ratio ν (nu). For "well behaved" materials,[1] E and ν are all that is required to completely define the material's response to applied loads. The figure below illustrates the elastic modulus and Poisson's ratio.



  A special case occurs when Poisson's ratio is ν = 0.5. Materials with ν = 0.5 are called *incompressible* because the volume of contraction precisely matches the volume of elongation (total volume does not change). Some materials, such as natural rubber and water, are very nearly incompressible, and these materials are more difficult to analyze because the standard formulations of the equations of mechanics break down when ν = 0.5. It is the assumption that some soil layers below the top of the groundwater table will be saturated and nearly incompressible that has led to this discussion of the proper value of Poisson's ratio to be used when evaluating soil structure interaction (SSI).

  For common construction materials, E and ν are tabulated. For instance, for steel E is 30,000,000 pounds per square inch and ν is 0.3. For soils, E and ν must be determined by testing, and will vary by soil layer. The COLA describes soil testing at the site of STP 3

[11] In engineering jargon, these would be linear-elastic, homogeneous, isotropic materials.

& 4 and the calculation of ν based on measured shear wave and compression wave velocities: "Overall, average Poisson's ratio was approximately 0.47 at depths below the groundwater level."

- Use of Poisson's ratio in the Seismic Soil- Structure Interaction (SSI)Analyses

  SRP 3.7.2 does not have a requirement regarding the cut-off value for Poisson's ratio below the water table. It requires three sets of soil properties to be used in the SSI analyses to cover the variability in soil properties. This requirement was met by performing the SSI analyses for three soil properties.

  The equations of mechanics used in SSI are not formulated to handle ν = 0.5. For instance, the compression wave velocity V_P is related to shear wave velocity V_S and Poisson's ratio ν by the following equation:

$$V_P = V_S \sqrt{\frac{2-2\nu}{1-2\nu}}$$

  For very low values of shear wave velocity in saturated soils under water, Poisson's ratio will approach 0.5. A problem with the equation above becomes apparent: as ν goes to 0.5 and the denominator approaches zero, V_P grows without bound and the equations of motion become ill conditioned, potentially producing results that are meaningless. To avoid this problem, Poisson's ratio is customarily capped at some value close enough to 0.5 to retain accuracy, but not so close that numerical instabilities make the solution unreliable. Precisely how high to cap Poisson's ratio is a matter of engineering judgment. Based on common industry practice, STP 3 & 4 soil testing data, and to be consistent with the SSI analysis of the DCD, Sargent and Lundy and Bechtel judged that 0.48 was an appropriate cap.

- NRC Review Status

  In RAI 3.07.01-25 (issued June 21, 2010), the staff requested an analysis be conducted with a higher Poisson's ratio cap to test whether the 0.48 cap was too low. In a meeting with NRC staff in August, this RAI was further discussed. We provided the results of an NRC-sponsored study from the Lotung SSI Experiment (Reference: Mok, C. M. Chang, C.-Y., and Legaspi, D. E. (1998) "Site Response Analyses of Vertical Excitation," Geotechnical Earthquake Engineering and Soil Dynamics III, Geotechnical Special Publication No 75, Proceedings of a Specialty Conference, Vol. 1, pp. 739-753, University of Washington, Seattle Washington, August 3-6, 1998). Based on a comparison of the measured responses during earthquakes and benchmarking analytical responses, the paper recommends the use of decreased P-wave velocities for site response analysis of vertical excitation, especially in the upper soil layers. We believe this supports the use of a 0.48 cap for Poisson's ratio, although this cap limits the compression wave velocities in the upper soil layers to less than 5000 ft/sec (the velocity in water). However, Staff maintained that it was necessary that one SSI analysis be repeated with Poisson's ratio capped at 0.495, and we agreed to run one analysis with the value proposed by the Staff to assess its effect.

The results of this analysis were presented to the Staff during the audit performed in October, 2010. The conclusion of the analysis was that for the most part changing Poisson's ratio had very little effect on calculated responses for the governing upper bound soil case, but some vertical responses increased to some extent, especially for the lower bound soil case. Based on this result, STPNOC agreed to re-run the other analyses of site-specific Category I structures using the 0.495 cap, and to revise the design loads to envelope the results.

Even though capping ν at 0.495 versus 0.48 may yield minor differences in the analysis results, the Lotung Study and the data collected at the STP 3&4 site discussed above show that the 0.495 results do not necessarily represent the soil below the water table more accurately than those using 0.48. There are approximations and judgments inherent in all seismic analyses, and by doing our analyses for the best estimate, upper bound and lower bound soil properties we have reasonably considered the inherent uncertainties as required by SRP 3.7.2. Nevertheless, we agreed to reanalyze the other site-specific Category I structures using a 0.495 cap for Poisson's ratio. These additional analyses have been completed and, where 0.495 yielded higher response, the design loads of the structures have been increased to envelope the results.

During the October audit, the Staff asked us to review the analysis results to assess if the use of 0.495 for Poisson's ratio had resulted in any numerical instability. We re-reviewed all of our analysis results in that context, and reported in the November 2010 response to RAI 03.07.01-25 that we did not find any evidence of numerical instability. Despite this response, the Staff has advised that it intends to conduct a confirmatory analysis and has requested additional information for use as inputs to this analysis.

- <u>NINA's Position</u>

  In an effort to be completely responsive to the Staff, we have completed a number of complex analyses beyond those we considered necessary and increased some design loads, even though we believe that the associated Staff concerns were somewhat academic and had no safety implications. In our opinion, issues associated with capping Poisson's ratio should be considered resolved without any further analyses.

  <u>Conclusion</u>

  The two analyses already completed, with Poisson's ratio capped at 0.48 and 0.495, have demonstrated the adequacy of the structural design. An additional NRC analysis to confirm the results of the analysis using 0.495 as the cap is not justified.

  <u>Schedule Impact</u>

  The impact depends on how long it takes for the NRC Staff to conduct its confirmatory analysis, and whether the allocation of Staff resources to the analysis affects the schedule for writing the SER.