U.S. Regulatory Lessons Learned from New Nuclear Power Plant Applications on Evaluating Soil-Structure Interaction

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October 6-8 2010
• Objective
  – Review Pertinent Regulations & Review Guidance
  – Discuss recent lessons learned from NRC review of new power plants
• Regulations
  – SSI must be considered in evaluating effects of seismic ground motion on NPP SSCs important to safety
  – NRC regulations provide framework for this process
  – GDC - 2 in Appendix A to 10 CFR Part 50 - Design bases for natural phenomena such as earthquake
  – 10 CFR 100.23 - Establishment of SSE (siting criteria)
  – Appendix S to 10 CFR Part 50 – Earthquake Engineering Criteria (Minimum SSE)
  – 10 CFR 52 – ESP, DC, and COL

• Review Guidance
  – Standard Review Plan (NUREG 0800)
  – Regulatory Guides
  – ISGs (1 & 17)
• CSDRS, GMRS, and SSE

  – Certified Seismic Design Response Spectra (CSDRS)
  – Free field ground motion response spectra (GMRS)
  – RG 1.60 or similar spectra normalized to 0.3g PGA used in the standard design as the proposed CSDRS
  – Site-specific GMRS developed in accordance with RG 1.208 is used to establish site-specific Safe shutdown earthquake (SSE)
  – SSE must meet the minimum requirement of Appendix S to 10 CFR part 50
  – CEUS sites have high frequency ground motion which can exceed standard plant CSDRS
  – COL applicants have to demonstrate standard plant design is acceptable at the proposed site.
• Developing FIRS
  – Some plant designs have seismic Category I buildings with foundations at different elevations
  – FIRS must be developed in a consistent manner
  – ISG-17 provides guidance
  – Check FIRS for Appendix S to 10 CFR Part 50 criteria (smooth, broad band response spectrum with PGA greater than 0.1g in horizontal direction)
  – Compare GMRS/FIRS to standard design CSDRS
    • If exceedance, site-specific evaluation should be performed
Lessons Learned (Cont’d)

• Soil Modeling
  – Consider embedment, layering, water table, etc
  – Element size for transmitting HF ground motion
  – ISG-1 provides guidance
  – Sensitivity studies to understand important parameters

• Structural Model
  – Capable of transmitting frequency of interest including HF ground motion as appropriate
  – Capable of adequately capturing out-of-plane response of floors and walls
• Structural Damping
  – Accounts for energy dissipation
  – RG 1.61 provides guidance
  – OBE level damping for generating ISRS is conservative
  – SSE level damping for ISRS generation should be justified

• Soil-Structure Interaction
  – Many COL applications require SSI analysis for site-specific reconciliation
  – Structure to Structure Interaction effect of adjacent structures on seismic loads (including buried structures) and dynamic soil pressure (SSSI)
Lessons Learned (Cont’d)

• **Backfill Considerations**
  – Fill can affect structural response
  – Backfill properties should be verified once backfill is placed
  – Properties should be consistent with expected strain levels along with expected lower and upper bound values

• **Soil Separation**
  – Uplift and soil separation should be considered
  – Can affect bearing pressure calculations
• **Incoherency Effects**
  
  – DC and COL applicants now incorporating incoherency functions
  
  – ISG 1 provides guidance and accepted incoherency functions
  
  – Low frequency (<10 Hz) ISRS reductions should be minimal
  
  – High frequency (>10 Hz) ISRS reductions greater than 50% should be carefully reviewed
  
  – Potential effects of increasing other responses (overturning, torsional) should be considered
• Conclusion
  – Regulations provide requirements for seismic design
  – SRP, Regulatory guides, and ISGs provide implementing guidance
  – Alternative approaches are reviewed on a case by case basis
### Acronyms

- **CEUS**  Central and Eastern United States
- **COL**  Combined Operating License
- **CSDRS**  Certified Seismic Design Response Spectra
- **DC**  Design Certification
- **ESP**  Early Site Permit
- **FIRS**  Foundation Input Response Spectra
- **GDC**  General Design Criteria
- **GMRS**  Ground Motion Response Spectra
- **ISG**  Interim Staff Guidance
- **ISRS**  In-structure Response Spectra
- **NPP**  Nuclear Power Plant
- **OBE**  Operating Basis Earthquake
- **PGA**  Peak Ground Acceleration
- **RG**  Regulatory Guide
- **SRP**  Standard Review Plan
- **SSC**  Structures, Systems, Component
- **SSE**  Safe-Shutdown Earthquake
- **SSI**  Soil-Structure Interaction
- **SSSI**  Structure-Soil-Structure Interaction
Helpful References


