Perspectives on SRP Enhancements for Review of Seismic and Civil Structural Design of New Reactors

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2013 NRC Regulatory Information Conference
March 12 - 14, 2013

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Overview

- Seismic and structural design challenges during licensing reviews
- Technical issues resulting from seismic/structural design challenges
- Development of proposed enhancements to SRP 3.7 & 3.8
- Examples of enhancements
- Conclusions

Seismic and Structural Design Challenges During Licensing Reviews

- Design certification (DC) - Conservatively defined certified seismic design response spectra (CSDRS)
- Typically consider wide range of site characteristics
- Consider hard rock high frequency (HRHF) characteristics
- Issues identified with the use of SASSI computer code
- Consideration of the effects of concrete cracking
- Implementation of regulatory guidance for certain aspects of seismic analysis and design

Technical Issues Resulting from Seismic/Structural Design Challenges

- Conservatively defined CSDRS with consideration of a wide range of site profiles, lead to large seismic loads
- Uncertainties lead to conservative estimates of capacities
- Large seismic loads and conservative capacities lead to difficulties in design analyses:
  - Uplift in soil structure interaction (SSI) analysis
  - Demonstrating stability of structures
  - Nonlinear seismic analysis
  - Seismic soil pressure on foundations
- For HRHF, uncertainties exist associated with analytical predictions of the effects of incoherency
- Technical issues associated with use of SASSI

Technical Issues Resulting from Seismic/Structural Design Challenges (Cont'd)

- Acceptable methods for considering effects of concrete cracking on stiffness and damping
- Implementation of regulatory guidance
  - Interaction of non-category I structures with category I SSCs
  - Artificial time-history development
  - Differential settlement and construction sequence
  - Site parameters and adequacy of generic site profiles
  - Seismic qualification of spent fuel racks and fuel assemblies

Development of Proposed Enhancements to SRP 3.7 & 3.8

- NRC defined 11 important seismic/structural issues
- Developed enhancements to existing SRP 3.7 & 3.8 criteria
- Proposed enhancements are based on:
  - Research studies
  - Past precedence
  - Industry guidance and practice
  - Rational and conservative engineering principles
- Interaction and feedback with industry
- Benefits of SRP Enhancements
  - Provide improved clarity, quantitative and qualitative criteria
  - Facilitate effective and efficient review of designs

Example 1 - Seismic Stability Evaluation of Structures

- Underlying issue: with higher seismic loads and bounding soil properties - more difficult to demonstrate factors of safety (FOS)
- Existing criteria: geared towards statically applied forces; conservative method
- Proposed enhancements:
  - Clarify the need to use consistent lateral displacement criteria (friction resistance and partial/full passive pressure)
  - Need to consider all sliding surfaces
  - If linear time history analysis - capacity to demand calculated at each time step
  - If nonlinear time history - increase input motion by 1.1; guidance in 3.7.1 II expanded for development of time histories for use in nonlinear analyses
  - Acceptance criteria - no or minimal sliding, no overturning

Example 1 - Seismic Stability Evaluation of Structures (Cont'd)

- Technical Rationale:
  - Use of time history method is - more accurate, accounts for phasing (V vs H), can reduce conservatism
  - Depending on magnitude of displacement - static vs dynamic friction and partial vs full passive pressure of soil
  - Using the lowest coefficient of friction among potential sliding interfaces is required
  - For nonlinear analysis important criteria - number of time histories, development of time histories, enveloping of results
  - No or minimal sliding, no overturning (separate uplift criteria proposed in 3.7.2)
- Facilitates review:
  - By providing criteria for implementing pseudo-static and time history analysis methods

Example 2 – Cracking Effects on Seismic Analysis of Concrete Structures

- Underlying issue: proper representation of cracking effects on stiffness in mathematical models
- Existing criteria: only provides generic guidance on the need to consider effects of cracking on stiffness
- Proposed enhancements:
  - For cracked concrete members can use stiffness reduction factors
  - For generation of in-structure response spectra (ISRS):
    - For generic design, where design basis ISRS represent envelop of in-structure responses obtained from multiple analyses considering range of expected site soil conditions associated with CSDRS - can use cracked concrete properties and SSE damping in RG 1.61, Rev. 1
    - For CSDRS associated with a single site condition such as HRHF spectra - can use uncracked concrete properties with OBE damping in RG 1.16, Rev. 1
    - For existing structures or site-specific designs - perform seismic analysis based on best estimates of stiffness properties, then iterate (cracked/uncracked) based on the resulting state of stress

Example 2 - Cracking Effects on Seismic Analysis of Concrete Structures (Cont'd)

- **Technical Rationale:**
  - Use of stiffness reduction factors - Use of these factors account for stiffness reductions due to cracking and they have been used in several industry standards
  - Design based on envelop of responses from multiple analyses considering range of expected site soil conditions associated with CSDRS - Consistent with guidance provided in RG 1.61, Rev. 1, and is considered acceptable because enveloping the responses from multiple SSI analyses for a range of soil conditions is considered to be conservative
  - Existing structures or site-specific designs - iterating stiffnesses corresponding to cracked and uncracked, based on resulting state of stress, is considered to be an accurate method
- **Facilitates review:**
  - By clarifying when cracking effects need to be considered and providing acceptable methods for representing cracking effects

Example 3 – Artificial Time History Development

- **Underlying issue:**
  - (1) response of structures can be sensitive to the seed used in generating artificial time histories
  - (2) existing guidance for spectral matching and power spectrum density (PSD) may not be sufficient in certain cases
- **Existing criteria:**
  - (1) SRP guidance for selection of seed is lacking
  - (2) SRP 3.7.1 II, Option 1 - Single Set of Time Histories, Approach 2 - use spectral matching <u>or</u> PSD
- **Proposed enhancements:**
  - When seed time histories from real earthquake records are used, response spectra of seed should be similar in shape to target spectra
  - The 5% damped spectrum of artificial motion shall not exceed target spectrum by more than 30% <u>and</u> PSD of accelerogram should not to have significant gaps in energy

Example 3 - Artificial Time History Development (Cont'd)

- **Technical Rationale:**
  - (1) Seed selection - When seed recorded time histories are selected based on a reasonable comparison of the spectral shape, good spectral matching can be achieved - magnitude of seed motion can be increased/decreased rather than adjusting magnitudes at certain frequencies
  - (2) SRP 3.7.1, Option 1, Approach 2, spectral matching/PSD - demonstrating both criteria are met ensures that no overprediction of response spectrum occurs and no significant energy gap at any frequency
- **Facilitates review:**
  - (1) Provides guidance for selection of seed to aid in spectral matching
  - (2) Enhances criteria for SRP 3.7.1 II, Option 1 - Single Set of Time Histories, Approach 2 - to ensure spectral matching and demonstrate adequate energy throughout frequency range

Conclusions

- Seismic and structural design challenges arose during licensing reviews
- 11 Technical issues identified from seismic/structural design challenges
- Proposed enhancements to SRP 3.7 & 3.8 developed to address 11 technical issues
- Provided examples of enhancements