RIC 2006
Session W4F
Current Seismic Issues & Associated Research
March 8, 2006

Performance-Goal Based Approach for Establishing the SSE Design Response Spectrum for Future Nuclear Power Plants

Robert P. Kennedy

RPK Structural Mechanics Consulting
28625 Mountain Meadow Road, Escondido, CA 92026
(760)751-3510 • (760) 751-3537 (Fax)
email: bob@rpkstruct.com

Purpose of Talk

- Outline a Practical Approach for Establishing a Performance-Goal Based SSE Design Response Spectrum
- Stimulate Interest in Further Development of Performance-Goal Based Seismic Design Criteria

Issues Which Must Be Addressed In Order to Develop a Performance-Goal Based SSE Design Response Spectrum

1. What Target Annual Probability of Seismic Induced Unacceptable Performance is Acceptable?
   - Policy Maker Decision
   - Can Be Based on Existing Precedence
2. What Minimum Seismic Margin is Achieved by Seismic Design Criteria??
   - A Question of How Much Deterministic Conservatism Exists in Design Criteria
3. Given the Decisions Made Under Issues 1 and 2, How Should the SSE Design Response Spectrum be Defined?

Step #1: Establish Target Performance Goal
(Ingredient of Risk Informed Seismic Design)

Performance Goals

- Both Qualitative and Quantitative Performance Goals Should Be Established

Qualitative Goals

- What Constitutes Acceptable Performance?
- Example: Avoidance of Seismic-Induced Core Damage (SCD)

Quantitative Goal

- What is a Target Acceptable Mean Annual Frequency P_{FT} of Seismic Induced Core Damage (SCDF)
- Example: SCDF $P_{FT} \leq$ Mean $5x10^{-6}$/yr

Step # 2: Establish Acceptable Seismic Margin Goals

- Typically Seismic Margin Has been Defined in Terms of High-Confidence-Low-Probability-of-Failure (HCLPF) Capacity

- HCLPF Approximately Corresponds to 1% Conditional Probability of Unacceptable Performance Level on Composite (Mean) Fragility Curve

- An Acceptable HCLPF Capacity is Typically Established at Some Factor Greater than the Seismic Design Response Spectrum (DRS)

- Example: For ALWR Designs NRC Staff Established (SECY-93-087)

  F_P = (HCLPF/DRS) ≥ 1.67 for Seismic Core Damage

- **Step #3:** Establish Seismic Hazard Exceedance Frequency H at Which Uniform Hazard Response Spectrum UHRS Is To Be Defined

$H = R_P * P_{FT}$

R_P = Probability Ratio

Preferably: $2 \leq R_P \leq 20$

- Example:

Selected: $R_P = 10$

Result: H = Mean 5×10^{-5}/yr for P_{FT} = Mean 5×10^{-6}/yr

- Selection of R_P is Fairly Arbitrary Since Accounted for in Step #4

STEP #4: Define Design-Basis Earthquake Response Spectrum (DRS)

DRS = DF ∗ UHRS

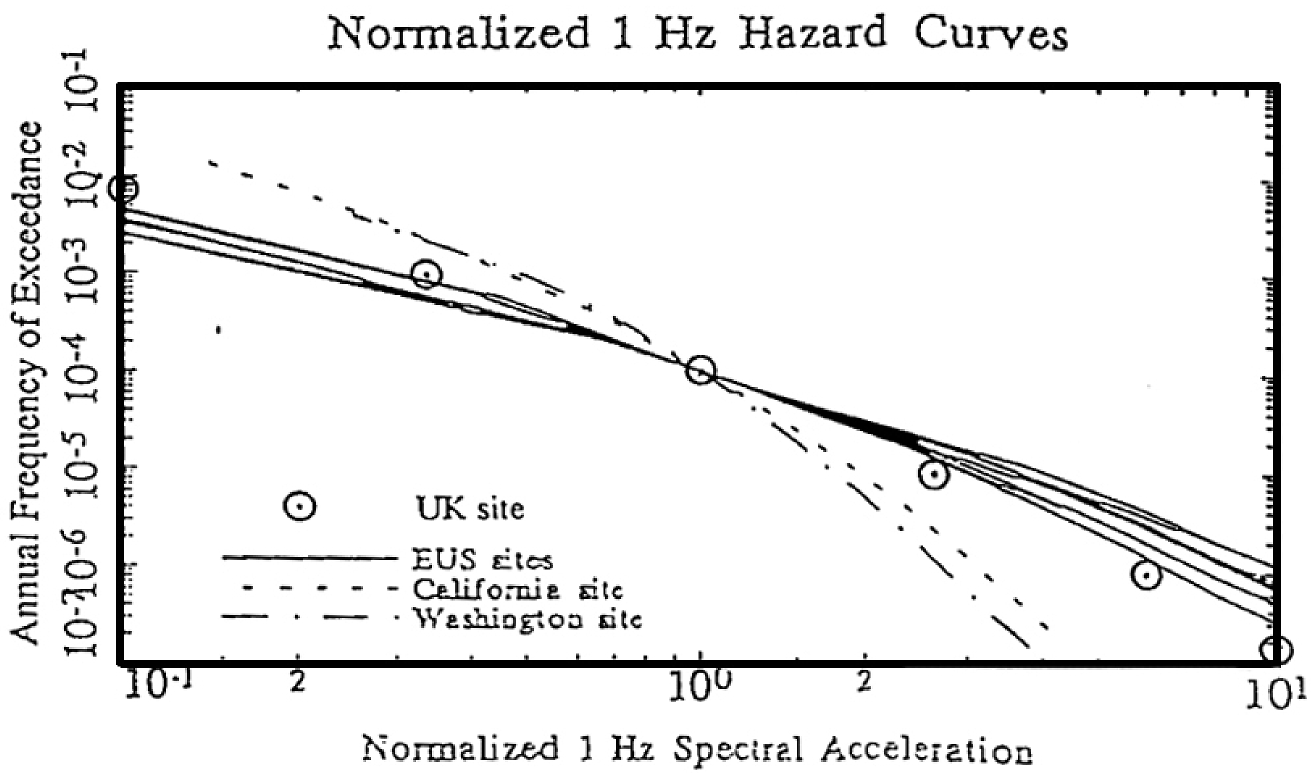
DF = Design Factor

DF Function of:

- Probability Ratio R_P Defined in Step #3
- Seismic Margin Factor F_P Defined in Step #2
- Hazard Curve Slope Ratio A_R

A_R = Ratio of Ground Motions Corresponding to Ten-Fold Reduction in Exceedance Frequency

Seismic Hazard Curves Normalized By the Spectral Acceleration Value Corresponding to a 10^{-4} Annual Probability



STEP #4 (cont.):

Example:

For $R_P = (H/P_{FT}) = 10.0$

$F_P = 1.67$

$DF = \text{Maximum}\ (DF_1, DF_2)$

$DF_1 = 0.241 + 0.225\ A_R \geq 0.60$

$DF_2 = 0.375\ A_R^{0.9}$

For H_D = Mean $5x10^{-5}$

Calif. Site: A_R = 1.5 to 2.25

EUS Site: A_R = 2.25 to 4.0

Design Factors DF For Various Seismic Hazard Slope Factors A_R

A_R	DF
1.5	0.60
1.75	0.64
2	0.70
2.25	0.78
2.5	0.86
2.75	0.93
3	1.01
3.25	1.08
3.5	1.16
3.75	1.23

A_R	DF
4	1.31
4.25	1.38
4.5	1.45
4.75	1.52
5	1.60

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