NRC Standards Forum II

Session 2: Commercial Standards – Needs and Priorities

Applying Commercial Codes/Standards to Safety-Significant Structures

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Background

- *From the standpoint of structural design requirements, classifications such as safety-related, II/I, non-safety related, and on-site radioactive waste storage are well-understood for ALWRs and SMRs.*
- *Even for ALWRs and SMRs, the structural design requirements can sometimes become somewhat ambiguous when the structure supports/houses equipment related to defense-in-depth features*
- *In contrast, non-water reactors (i.e., Advanced Reactors and Microreactors) operate at much higher temperatures, but do not require protection from accident pressure; they also contain many fail-safe features that result in reduced need for a safety-related classification.*
- *Structural classification for fuel production and waste processing facilities can also be challenging.*
- *Unless II/I considerations apply, all these facilities contain some non-safety related structures that can be designed using commercial codes.*

The Structural Design Conundrum for Safety-Significant Structures

For ease of reference, structures that are neither outright safety-related nor non-safety related are hereby referred to as safety-significant structures.

- *This group includes structures with some sort of II/I significance as well as other acronyms such as NSRST (non-safety related with regulatory treatment), AQ (augmented quality), etc.*
- *Structures that pose II/I risk can be designed to respond inelastically, albeit for the same performance goal (risk target) as that for the most significant proximate SSC.*
- *For other safety-significant structures, selection of appropriate risk target and limit state (performance level) is generally not as straightforward (ANS 2.26 may be used as a guide).*
- *Even after selection of risk target and limit state, for seismic & structural design, the designer has to decide whether to use nuclear set of standards or commercial codes/standards - the industry prefers the latter!*

Challenges associated with Use of Commercial Codes/Standards

- *Two choices exist:*
  1. *Comply with the nuclear set of standards (i.e., DOE 1020, ASCE 4, ASCE 43, ACI 349, and AISC N690) or*
  2. *Commercial set of codes and standards (i.e., IBC, ASCE 7, ACI 318, AISC 360, and AISC 341)*
- *A decision to use nuclear set of standards is onerous because it requires compliance with the NQA requirements for the engineering, procurement, and construction effort.*
- *The use of commercial codes is not straightforward because they are based a higher annual failure risk and cater to only Life Safety and Collapse Prevention performance levels.*
- *Also, the QA program for commercial codes does not reflect the need for any heightened regime based on radiological consequence.*
- *This implies that the analysis/design and QA requirements in the commercial codes need to be modified to suit safety-significant applications! Topics warranting adjustment include:*
  1. *Design loads based on the required risk targets*
  2. *Confidence levels that may correspond to the target performance level*
  3. *Response modification factors based on the required performance level*
  4. *Analysis methods and deformation acceptance criteria for additional performance levels*
  5. *Graded QA program based on risk targets and/or performance levels*

Why adjustments will be needed if commercial codes/standards are used?

- *Three additional Performance Levels could be included based on vendor's choice & preference:*
  - *(i) Essentially Elastic, (ii) Operational, and (iii) Immediate Occupancy*

- *Additional Risk targets, other than 2E-4, need to be included (e.g., 1E-5, 5E-5, 1E-4)*

- *ASCE 7 provides the risk-targeted seismic design spectrum for 2E-4 risk level by considering 90% confidence level in the design and 0.60 as the logstandard deviation for seismic capacity*
  - *Alternate process for generating seismic design spectra may be needed for lower risk levels using higher confidence levels and lower logstandard deviation values for other risk and/or performance levels*

- *For non-seismic natural hazard loads, the ASCE 7/Building based design results in Essentially Elastic performance level at the postulated design load event*
  - *ASCE 7 does indicate annual failure risk for these loads at Life Safety and Collapse Prevention performance levels, it does not do so for other performance levels (i.e., Essentially Elastic, Operational, and Immediate Occupancy levels)*

Why adjustments will be needed if commercial codes/standards are used?

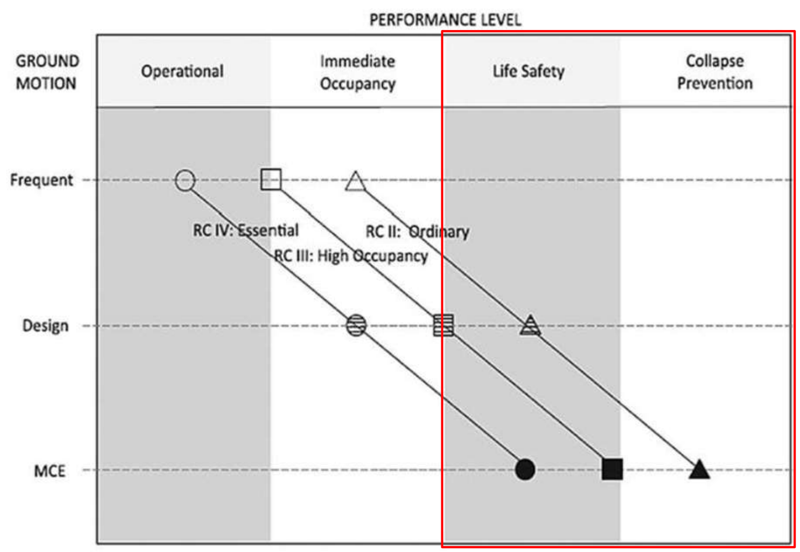


Figure C11.5-1. Expected performance as related to risk category and level of ground motion.

Table 1.3-2. Target Reliability (Conditional Probability of Failure) for Structural Stability Caused by Earthquake.

Risk Category	Conditional Probability of Failure Caused by the MCE_R Shaking Hazard (%)
I and II	10
III	5
IV	2.5

Note: As seen from the above table, for Risk Category I & II structures, there is 10% CPF against the Collapse Prevention performance level at MCE_R shaking level. However, for Risk Category IV structures, the 10% CPF corresponds to the Life Safety performance level at MCE_R shaking level… No CPF or reliability information is provided for other performance levels.

Why adjustments will be needed if commercial codes/standards are used?

Table 1.3-1. Target Reliability (Annual Probability of Failure, P_F) and Associated Reliability Indices (β) for Load Conditions That Do Not Include Earthquake, Tsunami, or Extraordinary Events.

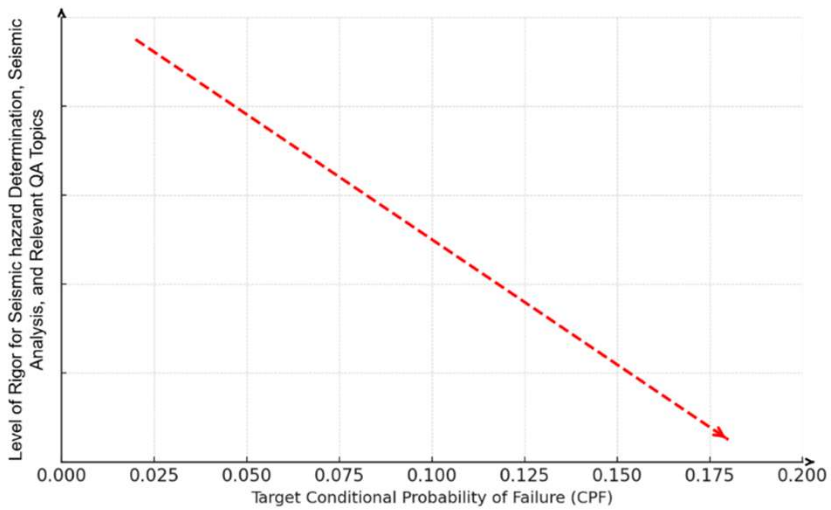
Basis	Risk Category I	Risk Category II	Risk Category III	Risk Category IV
Failure that is not sudden and does not lead to widespread progression of damage	$P_F = 1.25 \times 10^{-4}$ per year $\beta = 2.5$	$P_F = 3.0 \times 10^{-5}$ per year $\beta = 3.0$	$P_F = 1.25 \times 10^{-5}$ per year $\beta = 3.25$	$P_F = 5.0 \times 10^{-6}$ per year $\beta = 3.5$
Failure that is either sudden or leads to widespread progression of damage	$P_F = 3.0 \times 10^{-5}$ per year $\beta = 3.0$	$P_F = 5.0 \times 10^{-6}$ per year $\beta = 3.5$	$P_F = 2.0 \times 10^{-6}$ per year $\beta = 3.75$	$P_F = 7.0 \times 10^{-7}$ per year $\beta = 4.0$
Failure that is sudden and results in widespread progression of damage	$P_F = 5.0 \times 10^{-6}$ per year $\beta = 3.5$	$P_F = 7.0 \times 10^{-7}$ per year $\beta = 4.0$	$P_F = 2.5 \times 10^{-7}$ per year $\beta = 4.25$	$P_F = 1.0 \times 10^{-7}$ per year $\beta = 4.5$

- The implied performance levels under the "Basis" column heading correspond to either "life safety" (highlighted in green for the first row), somewhat controlled "collapse" (highlighted in yellow for the second row), or sudden collapse (highlighted in red for the third row).
- ASCE 7-22 does not provide risk values corresponding to enhanced performance levels such as essentially elastic, operational, and immediate occupancy

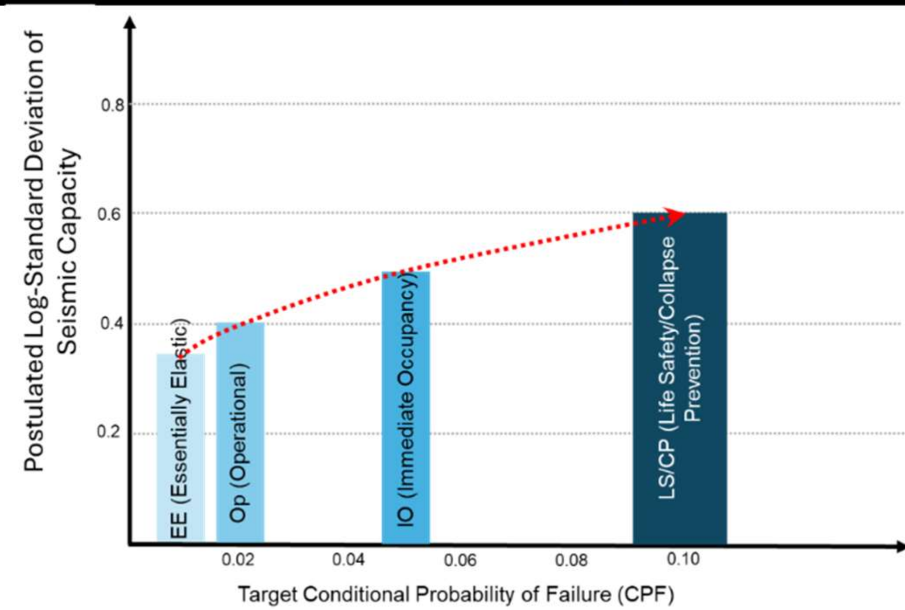
A Graded Approach based on Use of Design Basis Designations (DBDs)

- *Design of safety-significant structures could be performed using a set of DBDs that cover the range of target risk levels and performance levels (this will result in a similar matrix for SDBs in ASCE 43)*
- *Because of the difference in design philosophies, DBDs could be categorized into those associated with seismic loads and those that include other applicable natural hazard loads (like NDCs in DOE 1020)*
- *For seismic design, DBD-based conditional probabilities of failure could be specified to reflect the confidence levels in design and construction process*
- *DBD-specific (graded) engineering and QA requirements could be specified in recognition of the risk level and performance level*

A Graded Approach based on Use of Design Basis Designations (DBDs)

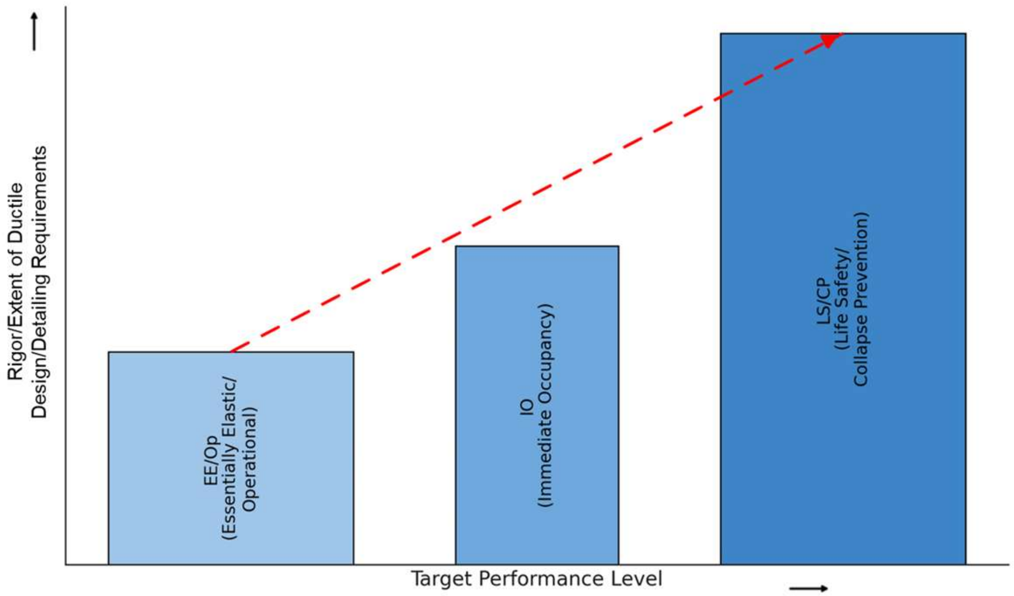


Representative Correlation between CPF and Engineering Rigor for Seismic Design



Representative Correlation between CPF and Performance Level dependent Seismic Capacity Logstandard Deviation

A Graded Approach based on Use of Design Basis Designations (DBDs)



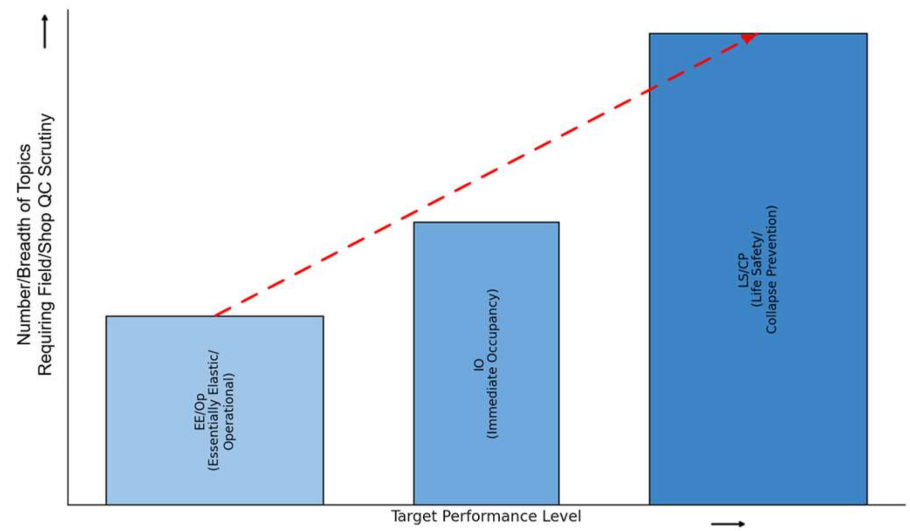


Illustration of impact of performance levels on ductile detailing and relevant QC scrutiny

EXPECTED BENEFITS

1. *Seismic/structural design and construction requirements, including QA requirements, could be untethered from those in the nuclear standards.*

2. *The proposed approach will be graded/non-binary, whereby the dichotomy represented by the commercial and nuclear standards will be avoided.*

3. *The proposed Seismic/structural design and construction approach, including the QA requirements, will be more sophisticated than the limited choices presented in the commercial codes/standards – this makes more logical sense and could be appealing to stakeholders.*

PATH FORWARD

- *Socialization with various SMR, AR, and MR vendors as well as nuclear fuel producers and DOE nuclear enterprise to establish range of risk targets and performance levels*

- *Socialization with regulators, material code/standard committees, and fabricators/erectors/constructors to develop DBD-based design and QA approaches*