Incorporation of Risk-Informed Performance-Based (RIPB) Framework in Seismic Design

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Outline of the Presentation

- Project scope and objectives
- Approach
- Brief review of key assumptions and principles of ASCE 43 and 4 approach
- Brief overview of LMP approach
- Discussion of process for integrating seismic design in the RIPB framework
- Discussion of approaches to demonstrate feasibility and validity of the process
- Preliminary insights
- Summary
- Next Steps

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Project Scope and Objectives

- From an NRC White Paper: (Near-term goals):

Aligning with the LMP approach

Developing strategies linking ASCE seismic performance goals to LMP risk-informed SSC categorization

Evaluating the adequacy of ASCE criteria in meeting target performance goals.

Developing a plan for the future activities including consideration of processes to take full advantage of the LMP categorizations.

Future potential (some collaborative) activities:

Illustrate the effectiveness and efficiency of the RIPB process

Demonstrate how ASCE 43 design complements the LMP categorization through physical design problems

Expand near-term developments to take full advantage

Work with stakeholders to achieve consensus on the approach and going forward

Approach

- Reviewed selected regulations and guidance, ASCE 43, 4, and 1, and LMP documents
- Formulated a stylized seven-step design process that incorporates the LMP concepts with the ASCE 43 design approach
- Several implementation issues were assessed, and initial insights were developed
- Site -specific ground motions from nine sites were assessed to understand the benefits of the ASCE 43 design approach
- A series of simple calculations were performed to support the development of the process to demonstrate feasibility
- Developed detailed plans for potential future activities extending simple problems and making a progressive use of SPRAs

Brief Review of ASCE 43

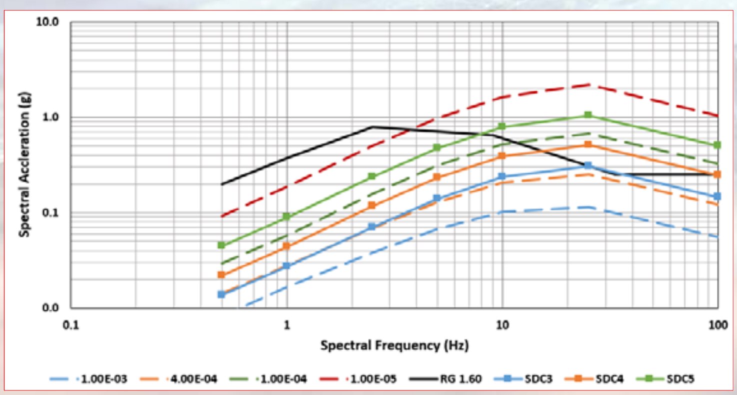
- The acceptable performance level (the target performance goal) is achieved by selecting the return period of the DBE shaking for a given seismic design category (SDC)
- Limit state (LS) defines the required performance in terms of the limiting acceptable condition of the SSC.
- The limit state (or the design performance) is adjusted based on the ultimate safety function and risk significance of the component.
- This approach allows to control conservatisms and safety margins in accordance with the risk significance of SSCs permitting more balanced design

Review of ASCE 43, SDC and LS categories

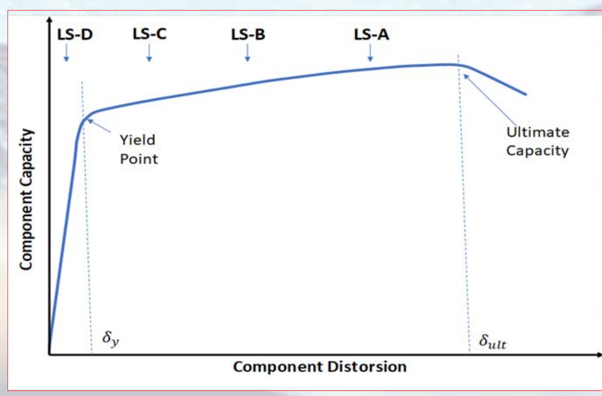
ASCE 43 Seismic Design Provision

Seismic Design Category	Target Performance Goal/Year
SDC3	1×10^{-4}
SDC4	4×10^{-5}
SDC5	10^{-5}

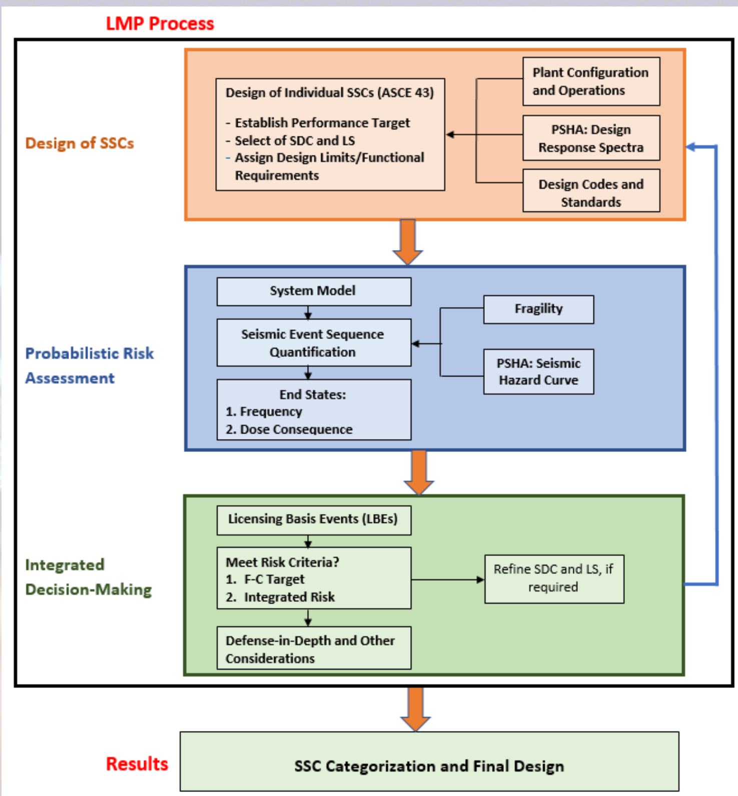
DRS for three SDC categories and four UHRS for Site A and RG-1.60 spectrum

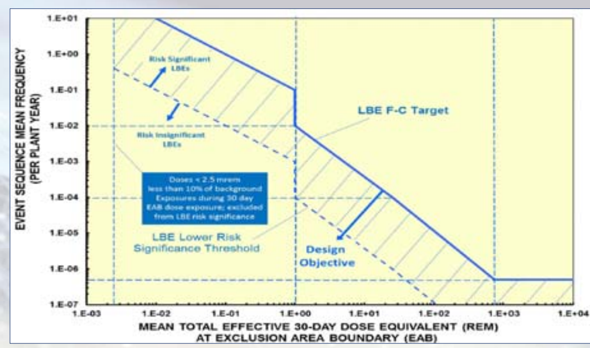


Typical load-deformation curves and Limit States



Proposed LMP-ASCE 43 Seismic Design Process





Frequency-Consequence Target

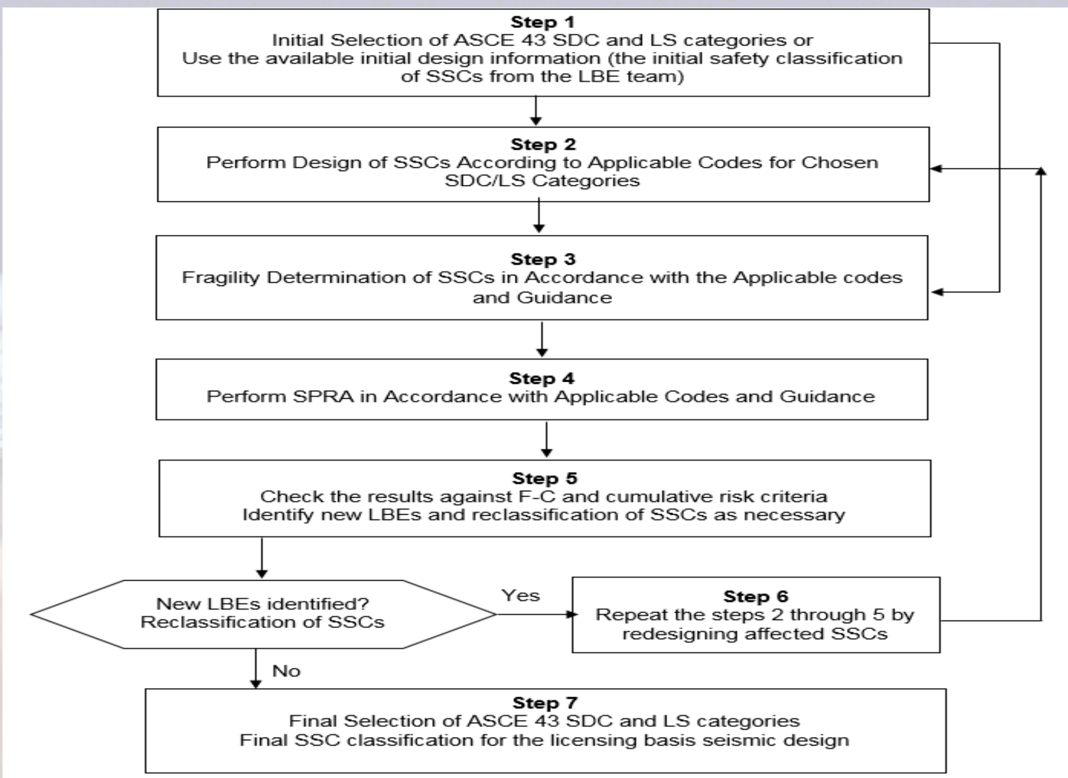
Guiding Principles
Development of the Seven-Step Process

- Integrate within the broader RIPB framework;
- Build on existing RIPB approaches in structural/seismic engineering;
- Recognize that the design process itself is still basically the familiar "deterministic" process;
- Utilize existing codes and standards to the maximum extent feasible;
- Useable with any regulatory framework (e.g., Part 52 and Part 50); and
- Identify and suggest updates to the regulatory framework and guidance as necessary.

Overview of the Process

- *In using the ASCE 43 SDCs and LSs graded approach, it's clear that the performance goals for different SSCs cannot be derived from the F-C plot.*
- *There are a multitude of SSCs in various event sequences, and hence there is no unique solution.*
- *Therefore, one potential approach is to use predetermined SSC categories and performance goals and then rely on the PRA to demonstrate how close the resulting F-C pairs are to the target and how the design meets the F-C and cumulative risk metrics.*
- *This is an inherently iterative process that could also lead to identification of additional LBEs and the reclassifications of SSCs.*
- *The risk target can be achieved by re-designating the safety classification, selectively hardening/relaxing the design, introducing redundancy, improving random failure rates, or improving human-error probabilities, or some combination.*

Seven Step Process



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Reductions in Ground Motion Levels for Various SDC Categories

Site	Ratio of PGA Values		Ratio of Spectral Accelerations at 5 Hz.	
	SSDRS4 /SSDRS5	SSDRS3/ SSDRS5	SSDRS4 /SSDRS5	SSDRS3/ SSDRS5
A	0.49	0.29	0.50	0.30
B	0.48	0.30	0.50	0.30
C	0.67	0.49	0.65	0.46
D	0.56	0.37	0.57	0.37
E	0.57	0.39	0.60	0.42
F	0.50	0.30	0.45	0.26
G	0.52	0.32	0.51	0.31
H	0.55	0.38	0.58	0.40
I	0.58	0.40	0.60	0.42

SDC-4/SDC-5 average ratios for peak ground acceleration and 5 Hz spectral accelerations are close to 0.55, and SDC-3/SDC-5 average ratios are close to 0.35.

Reductions in Seismic Demands for Alternate Limit States

Reinforced concrete shear walls, in-plane.	Ratio of reduction of forces for different limit states compared to LS-D		
Shear controlled walls Aspect Ratio: height/length, <2.0	LS-A/LS-D	LS-B/LS-D	LS-C/LS-D
	0.50	0.57	0.67

Reductions in Seismic Demand for a Shear Wall due to Inelastic Energy Absorption Factor

Three Approaches to Demonstrate Feasibility

- <u>Approach 1</u>: In this approach, a simple structural element is designed using selected combinations of SDC and LS categories and using the ASCE 43 and 4 codes, and the same element is also designed using the conventional past approach. Fragilities are developed for each case and compared and are then used to compute failure probabilities.
- <u>Approach 2</u>: In this approach, generic fragility calculations are performed for selected combinations of SDC and LS categories using the assumptions outlined in the ASCE 43 and 4 codes with respect to performance goals.
- <u>Approach 3 (Future Activity)</u>: This approach explores the progressive use of SPRAs to evaluate risk impacts of the proposed process, to get better understanding of the implementation issues, to develop detailed ground rules, to understand the efforts involved, and to provide guidance on the key managerial and technical decisions.

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Preliminary Insights

- No inherent technical impediments to our RIPB approach
- Our analysis shows that selecting a different Seismic Design Category (SDC) (e.g., SDC-4 instead of SDC-5) provides RIPB benefits and is more easily implemented.
  - Implementation involves regulatory and managerial considerations, in addition to changes in some technical design guidance
  - Could result in multiple design ground motions for a site and a facility
- Selecting a different Limit State (LS) (e.g., LS-C instead of LS-D) is also feasible but may yield smaller (but not unsubstantial) RIPB benefits. Could be useful option in certain situations.
  - Implementation may be somewhat more complex and may require some modifications of existing guidance, but these modifications are not necessary in short-term
  - Could affect operations and post-earthquake restart actions in addition to design
- Need to consider broader regulatory and operational perspectives for successful implementation
  - Current guidance may have to be re-evaluated in the long-term to assess how to implement these changes to maintain a consistent RIPB framework
  - Need to complete pilot studies to demonstrate feasibility and validity in order to fully develop our process

Summary

- An initial seven-step process has been developed
- No inherent impediment to implement the RIPB framework for the seismic design
- Demonstration through examples is vital to refine the process and give implementation guidance
- Reports will provide the technical basis needed to develop a regulatory guide for the RIPB framework
- Stakeholder interactions are crucial for broader acceptance and developing additional collaborative activities.

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Next Steps

- Prepare for stakeholder workshop
- Hold stakeholder workshop - Spring 2020
- Continue development of plans for future activities based on NRC feedback

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Acronyms

ASCE	American Society of Civil Engineers
DRS	Design Response Spectrum
F-C	Frequency vs Consequence
LBE	Licensing Basis Events
LMP	Licensing Modernization Project
LS	Limit States
LS-A/LS-B/LS-C/LS-D	Limit States A/B/C or D
PSHA	Probabilistic Seismic Hazard Analysis
RIPB	Risk-Informed Performance-Based
RG 1.60	Regulatory Guide 1.60
SDC	Seismic Design Criteria
SPRA	Seismic Probabilistic Risk Assessment
SSC	Structures, Systems, and Components
SSDRS	Site-Specific Design Response Spectra
SSDRS3/4/5	SSDRS for SDC-3/4/ or 5
UHRS	Uniform Hazard Response Spectra