Updated Seismic Fragility Guide Highlights

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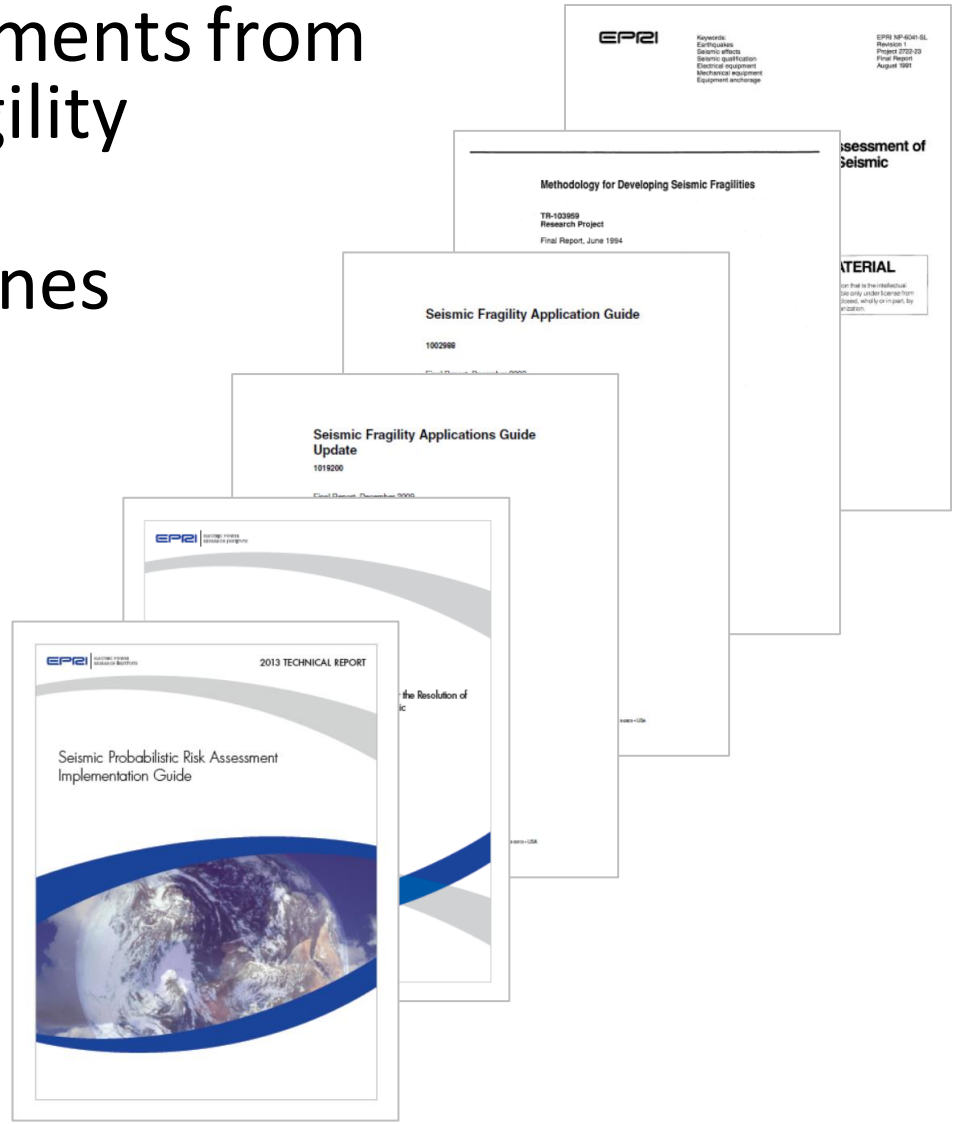
October 22, 2020

Updated Fragility Guide

- A collection of EPRI seismic fragility documents from the past 25 years have been used for fragility analysis
- Developed a single document that combines past fragility knowledge and key new developments
  - Updated methods and data
  - Consolidated the guidance
  - Includes updated insights
- Incorporated review comments from:
  - EPRI Structural Reliability & Integrity Technical Advisory Committee
  - Dr. Bob Kennedy



Updated Fragility Guide Table of Contents

Updated Fragility Guide Appendices

Walkdown

- A. English to SI Unit Conversion
- B. Walkdown Criteria: General Guidance
- C. Walkdown Criteria: Basis for Seismic Capacity Guidelines for Structures, Equipment, and Subsystems
- D. Walkdown Criteria: Sampling Guidelines

Fragility Methods

- E. Fragility Methods: Background on Recommendations for Hook Anchors and Deeply Embedded Anchors
- F. Fragility Methods: Influence of Small Concrete Cracks on Expansion Anchors
- G. Fragility Methods: Comparison of ASCE/SEI 43 Design Criteria and CDFM Criteria for Low Ductility Failure Modes
- H. Fragility Methods: Issues Concerning the Inclusion of Response Spectral Peak and Valley Variability in Development of Fragility and HCLPF Capacity Estimates
- I. Fragility Methods: Horizontal Direction Peak Response Variability
- J. Fragility Methods: Development of Test-Based Fragility Parameters
- K. Fragility Methods: Treatment of Small-Small Loss of Coolant Accidents in Fragility Analysis

Response

- L. Response Analysis: Refinement of In-Cabinet Amplification Factors
- M. Response Analysis: Benchmark Studies to Verify an Approximate Method for Spectra Scaling
- N. Response Analysis: Development of In-Structure Response Spectra for Seismic Margin or Seismic PRA Evaluation by Scaling

Examples

- O. Example: Fragility Analysis of a Reinforced Concrete Shear Wall
- P. Example: Cylindrical Concrete Wall CDFM Capacity
- Q. Example: CDFM Analysis of Lightly Reinforced Non-Load Bearing Masonry Walls
- R. Example: Comparison of ASCE/SEI 43-05/Barda and Gulec/Whittaker Strengths for an Example Low-Rise Shear Wall
- S. Example: Fragility and CDFM Analysis of a Metal Flat-Bottom Vertical Liquid Storage Tank
- T. Example: Heat Exchanger Fragility by Separation of Variables and Hybrid Approaches
- U. Example: Fragility for Service Water Pump
- V. Example: Expansion Anchor Fragility by Separation of Variables and Hybrid Approaches
- W. Example: CDFM Evaluation for Fillet Weld Anchorage
- X. Example: Fragility Analysis for Equipment Qualified by Testing
- Y. Example: Fragilities Derived from Experience Data

Capacity

Equipment Seismic Capacities Based on Earthquake Experience Data

- Updated capacities based on work presented in EPRI 3002011627
- An additional 8 classes of seismic capacities are documented in EPRI 3002013017 (*Completed after the Fragility Guide*)
- Capacities increased by up to 47% vs. previous experience-based capacities

Equipment Classes in Fragility Guide	Additional Classes in EPRI 3002013017
Control Panels	Air Compressors
Engine Generators	Air-Operated Valves
Fans	Battery Racks
Horizontal Pumps	Distribution Panels
Inverters and Battery Chargers	Instrument Racks
Medium Voltage Switchgear	Low Voltage Switchgear
Motor Control Centers	Transformers
Motor Operated-Valves	Vertical Pumps

Material Properties – Reviews of Existing Data

- Concrete
  - Quantitative guidance provided to account for increase in concrete strength due to aging (adopted from NEI 07-13 & based on data)
  - Recommendation provided for ratio of median 28-day strength to minimum design 28-day strength when plant-specific test data not available
- Steel
  - Minimum specified and median ultimate strength of ASTM A307 bolts are updated to 60 ksi and 66 ksi, respectively (NUREG/CR-5270; previously 58 & 64 ksi)
  - Median yield strengths of 48 ksi and 66 ksi for Grade 40 and Grade 66 rebar, respectively (Mirza and MacGregor review of test data)

Updated Strength Equations

- Shear friction failure of concrete shear walls
  - Previous guidance of checking diagonal shear strength against $7\sqrt{f'_{cm}}$ to preclude shear friction failure is now considered inappropriate
  - Updated guidance is to follow the ACI 318 shear friction provisions
- Anchorage to concrete
  - General recommendation is to follow the Concrete Capacity Design (CCD) Method as formulated in ACI for concrete breakout failure modes
  - An alternative median equation for deeply embedded (7.5 in. < h_{ef} < 45 in.) headed anchors is specified, based on work documented in EPRI 3002008099
  - For pullout failure of L-bolts and J-bolts, median equations developed in EPRI 3002008099 are recommended
- Various strength equations recommended for diagonal shear failure of concrete walls, depending on aspect ratio, boundary elements, etc.

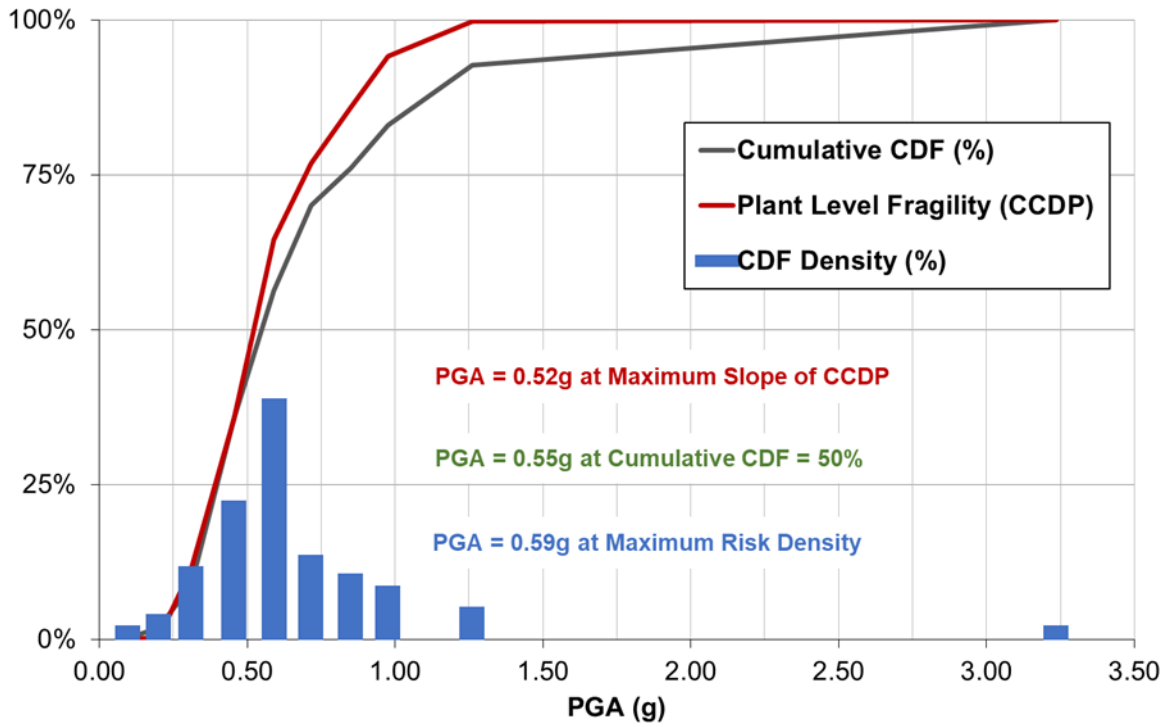
ASCE Inelastic Energy Absorption Factors

- Inelastic deformation limits provide guidance that was lacking in previous fragility guides
  - ASCE 43-05 drift and rotation limits are recommended, with guidance on which Limit State(s) are appropriate for SOV and CDFM evaluations
- Recommendation provided for obtaining median F_μ from conservatively biased ASCE 43-05 values

Demand

Definition of Reference Earthquake

- The hazard level (e.g., 1E-4, 1E-5 etc.) that dominates the seismic risk, which can be approximated using one or more of the following:
  - The level at which the cumulative risk (SCDF or SLERF) reaches 50% of the total
  - The level where the risk density is maximized, defined as the risk contribution normalized to the width of the hazard bin
  - The level at which the slope of the plant-level fragility curve is maximized



High-Frequency Seismic Demand Guidance

- Relays and Contactors
  - EPRI High-Frequency Test Program (EPRI 3002002997 and 3002004396) justifies extending the low-frequency test capacities of relays and contactors into the high frequency range (up to 40 Hz)
- High-frequency inelastic effects on anchorage systems
  - EPRI 3002010665 presents a method to quantify the effect of inelastic anchor deformations on equipment response at high-frequencies
  - Significant reductions in seismic demands at high frequencies can occur even at small ductility levels (such as those associated with brittle anchorage failure modes), due to very low displacement demands on the equipment

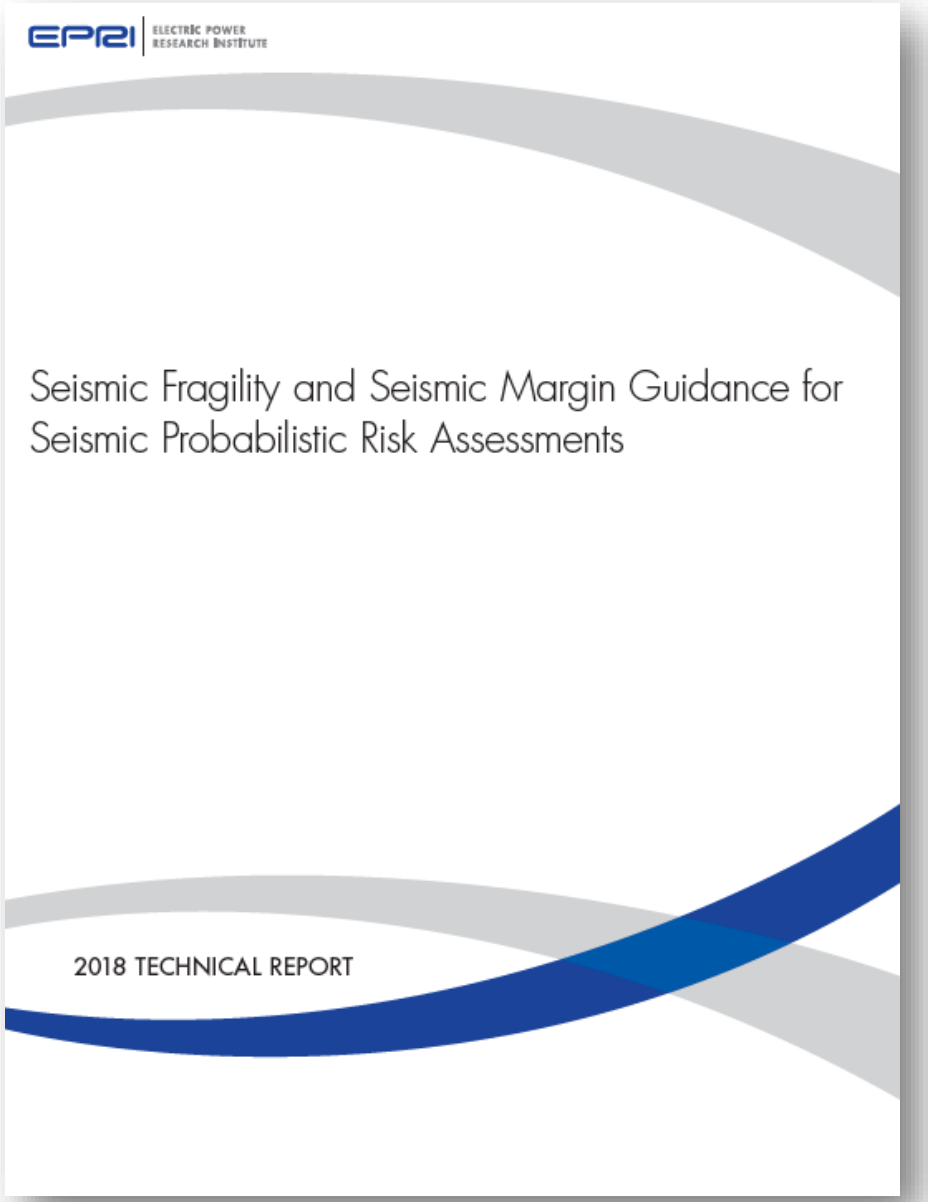
Structure and Equipment Damping

- Median and 84th percentile damping values recommended for various structure and equipment types.
- Largely from ASCE 4-16.
- Clarity on damping to be used in Conservative Deterministic Failure Margin calculations.
- Structure damping function of damage state represented in response analysis.
  - Response Levels from ASCE 4-16.

Structure Type
Welded and friction-bolted steel structures
Bearing-bolted steel structures
Reinforced concrete structures

Equipment Type
Electrical cabinets, mechanical equipment (including horizontal tanks and heat exchangers)
Massive, low stressed components
Instrument racks
Metal flat bottom tanks (impulsive mode)
Piping
Cable trays
Ducting Welded Companion angle Pocket lock

Questions



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