U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Observations on the Southern Company Draft Base Isolation Guidelines Report

Thomas Weaver, Weijun Wang, and Jose Pires
Office of Nuclear Regulatory Research, Nuclear Regulatory Commission

July 24, 2024
Advanced Reactors Stakeholders Meeting

Draft Report:
Guidelines for Implementing Seismic Base Isolation in Advanced Nuclear Reactors, Southern Company, Document Number SC-SND8932-001 Rev A, May 2024

Overview

- Draft Report Purpose and Scope:
  - *Document and provide the technical justification for a process to select, analyze, design, and deploy a passive isolation system beneath an advanced reactor building that meets applicable regulatory requirements*
  - The guidelines are limited to the isolation system design and do not address design of SSCs supported by base isolators and viscous dampers
- To be submitted to NRC as topical report for formal review and issuance of a safety evaluation report.
- Staff observations provided for consideration in developing a final draft.

Endorsement Request (Section 1.2)

- Section 1.5
  - The role of seismic isolation solutions in defense-in-depth
- Section 3.2 – 3.7
  - Earthquake shaking definitions, performance expectations, and other requirements
- Section 5
  - Performance-based design of a seismic isolation system
- Section 6
  - Qualification, prototype, and production testing
- Section 7
  - Specifications for the supply of isolators and viscous damping devices
- Section 8
  - Commercial grade dedication of seismic isolators and dampers
- Appendix D
  - Achieving a performance target for a seismic isolator

Endorsement Request (Section 1.2) and Seismic Isolation Checklist (Section 1.3)

- Item 7 in Section 1.2 includes requirements for design of structures, systems and components above the seismic isolation interface
  - Confirm that the requirement for the SSCs above the seismic isolation interface is only the one pertaining to their seismic design category (SDC) vis-à-vis the SDC for the isolation system (Section 3.7.4)
- Section 1.3 states that the seismic isolation checklist does not apply to structures, systems and components above the isolation plane
  - The last paragraph of Section 1.3 provides a guideline for the analysis and design of the SSCs above the isolation plane including referring to standards for the assignment of seismic design categories
    - Confirm that if this is outside the scope of the report guidelines for which endorsement is requested

Role of Isolator Solutions in Defense-in-Depth (Section 1.5)

- Key Attribute of Defense in Depth
  - Multiple independent and redundant layers of defense so that no single layer, no matter how robust, is exclusively relied upon
- Draft Guidance: “seismic isolation supports the objective of defense-in-depth…”
  - Reduces earthquake demands
  - Seismic isolation augments the approach to achieve defense-in-depth
  - The rules for implementing seismic isolation systems satisfy criteria for implementation of defense in depth
- Needs clarification of what specific endorsement is requested
  - E.g., if the endorsement is for a process to assess the isolation system contribution, what are the specific steps for that assessment?

Earthquake Shaking Definitions, Performance Expectations, and Other Requirements (Section 3)

- Additional technical information and discussion on the following is recommended:
  - Is the use of a scale factor SF = 0.5 to calculate the DB spectral from the TPG spectra a simplification for the examples shown or a guideline? (Section 3.2)
  - Details on how to evaluate the isolators and viscous dampers so that they do not suffer damage under wind loads (Section 3.4.1.4 and 3.4.1.1) including wind-borne missiles (Section 3.4.1.1)
  - Power spectral density (PSD) requirements for spectrally matched input motions (Sections 3.5, 3.7 and 5.2.2 for example)
  - Can the recommended use of 11 sets of ground motion be compared with the use of 30 sets of ground motions used in the example of Section 5? (Section 3.5)
  - Discussion to support comments in the report on the significance of soil-structure-interaction for base-isolated advanced reactor buildings and equipment (e.g., Section 3.6.1; Appendix D 2.2) (e.g., contrasting with ASCE 4-16 provisions in Section 12.3)

Earthquake Shaking Definitions, Performance Expectations, and Other Requirements (Section 3)

- Additional technical information and discussion on the following is recommended:
  - Is D_{50} established from a fragility analysis alone or fragility analysis in combination with the seismic hazard and a target MAFE? (Section 3.7.2 and Section 3.3)
  - What is the intent of the sentence in Section 3.7.2 stating a dynamic analysis of a 3D finite element model of the isolated building shall be performed for DB and TPG shaking?
    - For the calculation of D_{50} only the lumped building reactive mass above the basemat is used in Section 5.2.2
      - Is a verification of D_{50} expected after the building design is more detailed?
    - Is it for the calculation of axial forces on the isolators?
  - Why is ACI 318-19 proposed for the design of the isolators' pedestals? (Section 3.7.3)
  - Justification for use of precast concrete pedestals (Section 3.7.5)

Performance Expectations (Section 3.3)

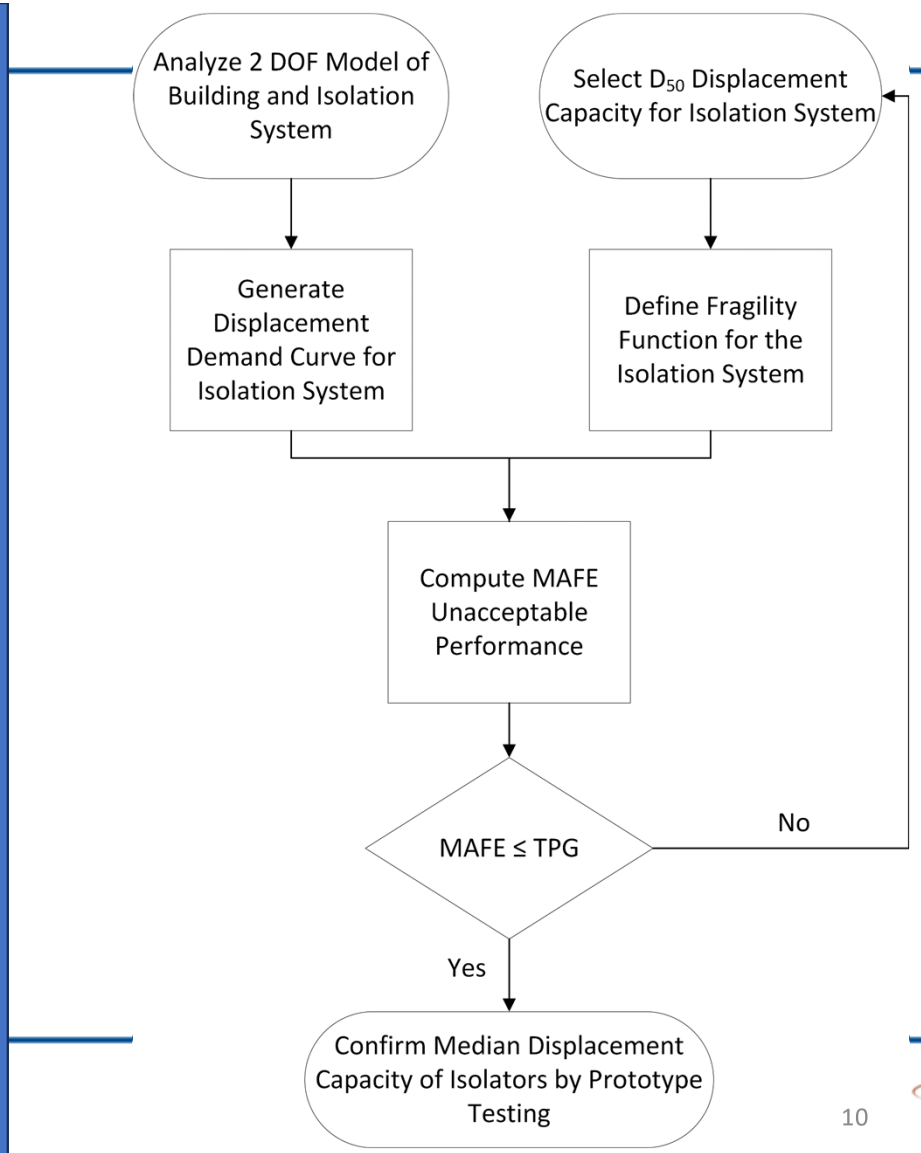
	Design Basis Shaking	At Target Performance Goal
Use	Production testing of isolators and dampers	Prototype testing of isolators and dampers
Isolator and Damper Displacement	Mean maximum	D_{50} from fragility analysis
Damper Velocity	Mean maximum	Mean maximum from TPG shaking
Acceptance Criteria	Production testing of each isolator for mean maximum horizontal displacements and corresponding axial force	Prototype testing of three isolators of each type and size for D_{50} displacement and TPG axial force
	Production testing of each damper for mean maximum displacement and corresponding maximum velocity	Prototype testing of three dampers of each type and size for D_{50} displacement and TPG velocity
	No damage to isolators	Isolator damage is acceptable but load-carrying capacity for gravity loading is maintained
	No damage to dampers	No damage to dampers

From Table 3.1 in the Draft Report

Performance Expectations (Section 3.3)

- Consider adding discussion on how and why performance expectations vary from ASCE 4 Table 12-1.
- Expand on meaning and clarification of terms in table,
  - Mean maximum displacements (DB) and their use
  - TPG axial force (TPG)
  - TPG velocity (TPG)
  - E.g., terms denoting response demands, viscous dampers demands and terms referring to isolators' capacities

Performance Based Design (Section 5)



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Performance-Based Design of a Seismic Isolation System (Section 5, Appendix D)

- Separation between guidelines and example calculations
  - Listing of guidelines and then their illustration with the examples
  - For example, can the guideline for establishing D_{50} be written as the median fragility displacement capacity corresponding to a MAFE equal to the TPG MAFE?
- Define the building reactive mass at the level of the basemat (Section 5.2.2)
- Comparison of the proposed fragility analysis Section 5.2.3) and displacement hazard approach (Section 5.2.4) with the traditional approach where the original hazard curve is convolved with a fragility curve which is a function of spectral acceleration in the hazard curve.
- Is the approach in Section 5 one way to determine D_{50} for the target MAFE and other approaches are acceptable provided prototype testing per Section 6 confirms D_{50}?
  - E.g., traditional fragility analysis approach and convolution of fragility analysis with the original hazard curve
  - How would the logarithmic standard deviations for fragility analysis change with different approaches such as the traditional fragility analysis methodology?
  - How would the median fragility change?

Qualification, Prototype, and Production Test (Section 6)

- Qualification Tests: Demonstrate basic performance characteristics independent of project application for qualification of vendors/isolators/dampers
- Prototype Tests: Performed on limited number of devices to confirm the isolators D_{50} capacity and the dampers requirements
- Production Tests: Performed on all devices at the DB seismic loads

Qualification, Prototype, and Production Test (Section 6)

- Approach for qualification tests is comprehensive with detailed information and uses parameters in the performance expectation table (Table 3.1)
- Identify and justify how the testing protocols were derived from ASCE 4-16 (Chapter 12), ASCE 43-19 (Chapter 9) and ASCE 7-22 (Chapters 17 an 18)
  - What was used or not from each code and what has been added and why
  - Justification and sources for the acceptance criteria, especially the deviations from the target values (e.g., force-displacement relations, stiffness)
- Testing protocols are per isolator and damping types to address different behaviors
  - Feasibility of expressing protocols in terms of behavior and response characteristics of isolators and dampers rather than type
- Qualification testing: can exemptions for qualification testing be related to specification and performance requirements rather than through a list of specific vendors?
- Is there an intent to also validate the isolators and dampers mathematical models using the testing results (Section 3.6.3 models)?

Specifications for the Supply of Isolators and Viscous Damping Devices (Section 7)

- Draft specifications for supply of 2D isolators and 1D fluid viscous dampers.
- 3D isolation systems are not addressed
- Gamma and Neutron radiation resistance are not addressed
- Clarify that the Section 7 specification are not related for technical plant specifications in Appendix E
- Part II.4 Design Calculations
  - The only seismic demands considered are D_{50}
  - Axial loads at TPG shaking
    - Is this the shaking characterized by the uniform hazard spectra at the TPG MAFE?
- Are any design calculations at the DB shaking needed?
- Why is the AISC 360 chosen for the mounting plates as opposed to the AISC N690?
- Level of detail recommended for the SSCs above the isolation interface to calculate the demands in the load combinations?

Commercial Grade Dedication of Seismic Isolators and Dampers (Section 8)

- Section 8 provides a template for the technical evaluation tasks required by 10CFR21 and 10CFR50 Appendix B and follows the process in Section 4 of EPRI TR-102260 (Plant engineering: guideline for the acceptance of commercial-grade items in nuclear safety-related applications)
  - Identify deviations from RG 1.164
  - Recognizes that the entirety of the supplier CGD is out of scope for Section 8
- Address if CGD of isolators is anticipated for most designs
  - Section 8 would be reviewed by staff specialized in CGD regulations, guidance and processes

Other Items

- Appendix E – Considerations for ITAAC
  - Endorsement of Appendix E is not requested and observations on Appendix E are outside of the scope of these observations including the assertion in Section E.3 that a seismic isolation system and associated components need not be explicitly addressed in a plant's Technical Specifications

Summary

- Guidance document is limited to isolation system design and does not address design of structures, systems, and components supported by base isolators and viscous dampers
- Additional technical justification and discussion is recommended for some sections of the report to facilitate a safety evaluation review

Acronyms

ACI: American Concrete Institute

AISC: American Institute of Steel Construction

ASCE: American Society of Civil Engineers

CFR: Code of Federal Regulations

CGD: Commercial Grade Dedication

DB: Design Basis

D_{50}: Median displacement from fragility curve

ITAAC: Inspections, tests, analyses, and acceptance criteria

MAFE: Mean annual frequency of exceedance

PSD: Power spectral density

RG: Regulatory Guide

TPG: Target performance goal, frequency of unacceptable performance

SSC: Structures, Systems, or Components

SDC: Seismic design category

SF: Scale factor applied to the TPG hazard curve to develop the design response spectrum