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Preliminary Design Criteria for Functional Recovery of Buildings

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ABSTRACT

Improving post-earthquake reoccupancy and functional recovery of buildings is a topic of broad interest for community resilience advocates, earthquake risk mitigation professionals, building design practitioners, code and standard developers, and building owners. This paper describes the ongoing work of the Functional Recovery Task Committee of the Building Seismic Safety Council's NEHRP Provisions Update Committee (PUC), which aims to propose design criteria for functional recovery for the design of new buildings for the *2026 NEHRP Recommended Seismic Provisions for New Buildings and Other Structures*. This paper defines the goals and scope of the Task Committee. It then summarizes ongoing work progress, including: developing key terms, defining functional recovery categories and associated performance goals, developing prescriptive provisions, and investigating appropriate hazard levels for functional recovery design.

Keywords: functional recovery, seismic performance objectives, resilient design

INTRODUCTION

The concept of functional recovery has been advanced in recent years to mobilize building design and mitigation decisions that reduce the long-term effects of earthquake-induced building (or infrastructure) damage, enhancing community resilience. The interest in this concept is motivated by increasing recognition that the design of buildings to life safety standards may not be sufficient to ensure thriving and prosperous communities after an earthquake. Functional recovery has been defined as "a post-earthquake performance state in which a building or lifeline infrastructure system is maintained, or restored, to safely and adequately support basic intended functions associated with pre-earthquake use or occupancy of a building, or the pre-earthquake service level of a lifeline infrastructure system" [1]. The focus herein is on functional recovery of buildings.

In the US, there are significant ongoing efforts to explore design criteria and related provisions for improving functional recovery in new building design for potential incorporation in the *National Earthquake Hazards Reduction Program (NEHRP) Recommended Seismic Provisions for New Buildings and Other Structures*. FEMA contracts with the Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences (NIBS) to develop the *NEHRP Recommended Seismic Provisions*. This document is a primary technical resource for the seismic design provisions of the professional design standard for new buildings: *ASCE/SEI 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. In response to a broad community interest and need for improving functional recovery for buildings, FEMA requested BSSC and the Provisions Update Committee (PUC) to explore development of functional recovery code resources for the 2026 *NEHRP Recommended Seismic Provisions*. A functional recovery planning committee was first formed, which held open discussions with stakeholders and potential users, reviewed available technical information, data and research, and recommended to form a Functional Recovery Task Committee. In view of limited capacity of a voluntary committee, complexity of communitywide functional recovery and ongoing research in the area, the Task Committee is to focus on functional recovery for new building design, collaborate with broad community effort for improving functional recovery, and support consensus evaluation of its proposed code resources.

The authors lead the Functional Recovery Task Committee. The Task Committee is charged with developing technical proposals and other resources related to the design of new buildings to meet post-earthquake functional recovery performance objectives within the context of the *2026 NEHRP Recommended Seismic Provisions*. These technical proposals and other

resources will serve as source material for proposals for possible adoption and use in other codes and standards for new buildings. The Task Committee membership includes those with a depth of expertise in the subject matter and a breadth of experience across the industry stakeholder groups, including practicing engineers, researchers, architects, owners, planners, business continuity experts, and public policy advocates.

This extended abstract and the associated presentation describe the ongoing work of the Functional Recovery Task Committee to define terms, create and assign functional recovery categories for building occupancies and services, develop prescriptive provisions for each category, and identify the hazard level(s) applicable to these objectives. In addition, it highlights the key ideas proposed for implementation in provisions for the design of functional recovery for new buildings, showing how probabilistic assessments of functional recovery for individual buildings and broad stakeholder input have and will be used to develop and support the key ideas.

FUNCTIONAL RECOVERY TASK COMMITTEE

The Functional Recovery Task Committee is charged with developing technical proposals and other resources needed to establish criteria for the design of new buildings to meet post-earthquake functional recovery performance objectives for the *2026 NEHRP Recommended Seismic Provisions*. These efforts aim to set the stage to propose seismic building code provisions established based on buildings' seismic performance impacts across the community to ultimately support community resilience.

As such, the goals of the Task Committee are to:

1. Transition the philosophy and language of seismic code provisions to address functional recovery time, in addition to life safety;

2. Standardize what is meant by functional recovery and functional recovery time; and

3. Develop "1st-generation" language for seismic code provisions, including seismic design provisions that improve recovery time compared to current provisions and initial recommendations for recovery priorities.

To the extent possible, these efforts will also develop strategies and seismic code provisions to achieve specific seismic performance targets directly tied to community needs and priorities, not just improved performance. The present scope addresses new building structures, attending primarily to those aspects of the building design that are within the purview of a design team. Externalities, or conditions independent of damage to the building that affects the ability of a building to function, e.g., lack of utility service provisions, while very important for community resilience and building function, are outside the scope of this effort.

To achieve these goals, the Functional Recovery Task Committee has five subcommittees, the activities of which are described in detail below. These subcommittees are defining key terms and concepts related to functional recovery, elaborating functional recovery categories and performance metrics, drafting functional recovery time targets for various building occupancies and services, proposing prescriptive provisions for each functional recovery category, and exploring the hazard level(s) applicable to functional recovery objectives. There is necessarily considerable coordination between the subcommittees.

The expected deliverables from the Functional Recovery Task Committee include proposed provisions for a stand-alone chapter or appendix for the *2026 NEHRP Recommended Seismic Provisions* Parts 1 and 2 that address "Design for Functional Recovery". This Task Committee's aim is for the chapter to be submitted for consideration during the next development cycle for the ASCE/SEI 7 standard and is envisioned to include draft provisions and commentary. The Task Committee will likely also produce resource papers with additional content, context, commentary, or perspective for Part 3 of *the 2026 NEHRP Recommended Seismic Provisions*.

Work on the *2026 NEHRP Recommended Seismic Provisions* is ongoing, with completion expected in 2025. The final content of the proposals and the intended location for placement within the *2026 NEHRP Recommended Seismic Provisions* will depend on the technical and policy deliberations of the Task Committee as well as the PUC. All proposals will be balloted through the PUC/BSSC consensus review and approval process, and any concepts discussed herein are subject to change depending on further development of proposals and deliberations during balloting.

The Task Committee is relying on, rather than duplicating, several significant preceding efforts. These include FEMA P-2090 / NIST SP-1254 *Recommended Options for Improving the Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time* [1], and "Recommendation C1 – Address Functional Recovery and Enhanced Resilience in Model Code Framework" from FEMA P-2191 A Step Forward: Recommendations for Improving Seismic Code Development, Content, and Education [2]. The Task Committee is also employing a methodology for assessing the seismic performance of buildings in terms of functional recovery time funded by FEMA through the ATC 138 project. The ATC 138 methodology grew out of a functional recovery assessment methodology funded by NIST and described in Cook et al. [3].

Definitions of Key Terms

Writing design provisions for functional recovery requires agreement on the definitions of new terms that will eventually guide the provision's review, adoption, and implementation. Therefore, a significant effort is underway to develop working definitions of key terms. These terms include, among others, *functional recovery*, *recovery time*, and *impeding factor*. In these definitions, recovery time is distinguished from repair time in its inclusion of other actions that may need to precede repairs, e.g., arranging a contractor, as well as the time needed to conduct the repairs. This effort will also elaborate 'basic intended function' for various building occupancy types and what types of temporary repairs and other actions may be appropriate to achieve functional recovery more quickly.

Functional Recovery Categories

The provisions being developed are built around a concept of Functional Recovery Categories, tentatively labeled A, B, C, etc. These Functional Recovery Categories were introduced in FEMA P-2090 / NIST SP-1254 [1] to identify groups of occupancies or services with similar recovery time objectives. The idea of the Functional Recovery Categories is that buildings would be categorized based on the occupancy and services they provide. The list of occupancies and services is similar to those in the *International Building Code*. However, these occupancies and services will likely be grouped differently to ensure that occupancies and services with similar function requirements and importance for community resilience will be grouped together. It is likely that five or fewer Functional Recovery Categories will be defined.

Each Functional Recovery Category will be associated with a functional recovery performance goal. Work is ongoing to determine how to define these performance goals. These goals may be expressed in terms of a recovery time. If time is selected, other considerations address how precise these goals can and should be to support their use in design provisions. Options being considered are both qualitative and quantitative, with quantitative options also considering a range to reflect the large uncertainties associated with future performance. Other options include descriptions of damage that impair function, rather than focusing on time.

Functional Recovery Objectives for Various Building Occupancies and Services

The Task Committee is also drafting functional recovery time objectives for the aforementioned occupancies and services, incorporating input from a broad group of stakeholders. This effort focuses on identifying those building occupancies and services whose functional performance is most essential to the wider community in the immediate, near-term, short-term, medium-term, and long-term after the earthquake. In other words, the critical question in this part of the effort is: What functional recovery time is needed for various occupancies and services, based on when a community would need that occupancy or service to be available? How long can the community reasonably accommodate that occupancy or service being unavailable?

Initially, this effort was built from public workshops held for the FEMA P-2090 / NIST SP-1254 [1] and described in [4]. It is also leveraging additional work conducted by NIST and others on acceptable functional recovery times. The subcommittee, which has a membership that leverages diverse expertise beyond engineering, has developed a list of building occupancies and services whose consideration is essential. They have also developed working definitions of the key time frames of interest, considering near-term, for example, as the first week after the earthquake (0-7 days). Ongoing work involves soliciting and resolving judgment from subcommittee members and others on draft target recovery times.

Eventually, it is envisioned that these target times will be used to group the various building occupancies and services into Functional Recovery Categories, and to define the target performance statements associated with each category.

Prescriptive Design Requirements

A central part of the work is the development of design provisions for structures to meet the functional recovery time objective associated with each Functional Recovery Category. This effort considers the many possible levers in seismic design codes that influence how buildings are designed and perform, including: seismic design values, importance factors, drift limits, limitations on structural system selection, prohibited horizontal or vertical structural irregularities, design requirements for nonstructural components and systems, and other analysis and design requirements. Quality Assurance/Quality Control (QA/QC) provisions are also being considered. This effort will also explore how the Functional Recovery Categories align with the current Risk Categories, especially Risk Category IV, which implies a high level of post-earthquake functionality.

This subcommittee is conducting a large number of component-level and building-level analyses that will inform these prescriptive provisions. At the component level, the team aims to explore the probability of observing damage to key components that influence recovery time. This analysis can inform tangible design interventions that reduce the probability of damage that could trigger function loss. These design interventions could include, for example, drift limits, capacity enhancements through revised detailing, stricter QA/QC, or design to hasten recovery (e.g., strategies that facilitate rapid

inspection). While drift limits may adequately address drift-sensitive components, acceleration systems components may require additional design or detailing requirements.

The selection of the components for study is based on building-level analyses that have identified systems that influence function, e.g., heating, ventilation, and air conditioning systems (HVAC), and the critical components within those systems. For example, in some recent studies, engineers have found that the exterior enclosure systems have a high probability of impacting function in some types of buildings. Accordingly, components in this system will be examined. The significance of the component impact on function, measured by system-level or building-level recovery times, influences the targeted probability of damage that could trigger function loss. Finally, building-level analysis, based on the adopted functional recovery assessment methodology from ATC 138, will examine whether the prescriptive design requirements meet the targeted recovery times.

Work is ongoing to determine the design interventions that adequately reduce component damage probabilities associated with loss of function, and the influence of those on building-level targeted recovery times. Although the focus is currently on conventional structures, the team recognizes that appropriate treatment of the potential performance benefits of damped and base isolated structures will be important to address in our work. We intend to address non-building structures as the Task Committee work progresses, but in a more limited scope than for building structures.

Hazard Definition

An additional area of ongoing work is exploring the appropriate hazard level(s) applicable to functional recovery performance objectives and design. The key concern is identifying a design hazard that supports the performance goals and target design times for functional recovery. Practicality issues, i.e., how the selected hazard level fits within current design practices, are also being addressed.

The current design basis earthquake is a seismic effect related to two-thirds of the risk-targeted maximum considered earthquake (MCE_R). The MCE_R is developed from a risk-targeted approach, i.e., the values are determined to target uniform probability of collapse across the US. This risk-targeted approach to determine the MCE_R values combines a generic building collapse fragility curve with site seismic hazard estimates.

We are currently exploring risk-targeted design values for functional recovery. The rationale for using risk-targeted values in this context is that it is consistent with the life-safety objectives that motivated the existing MCE_R, enables consideration of the hazard characteristics at many return periods, and facilitates communication with stakeholders and comparisons with other societal risks.

Two key pieces of information are needed to determine risk-targeted functional recovery ground motions. The first is a risk objective or target. For life safety, this target is expressed as 1% probability (or risk) of collapse in 50 years. For functional recovery, this would take the form of some (to be determined, TBD) percentage in 50 years risk of losing some level of functionality or exceeding some selected functional recovery time. The choice of the specific functional recovery performance target will depend on the societal needs for rapid recovery of that building occupancy or service; performance targets are envisioned to differ by Functional Recovery Category. The second piece of information needed is the characterization of functional recovery fragility curves, which define the probability of not reaching the functional recovery objective (as a function of ground motion intensity). This generalized functional recovery fragility will likely be determined by exercising the ATC 138 functional recovery assessment methodology for a range of building types to determine the expected level of performance across various ground motion intensities, based on the proposed prescriptive design provisions associated with each Functional Recovery Category.

CONCLUSIONS AND NEXT STEPS

Work is ongoing to propose potential provisions for design of new buildings to achieve functional recovery after an earthquake. All the efforts described herein will be considered through the Building Seismic Safety Council's Provisions Update Committee for a consensus review and balloting process and are, therefore, subject to change.

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REFERENCES

References should be cited in the text in square brackets (e.g., [1], [2-4]), numbered according to the order in which they appear in the text. Only list references that are referred in the text. A complete reference should provide enough information to find the article.

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