Progress Report on the Technical Development of the 2014 NEHRP Recommended Seismic Provisions

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SUMMARY
The 2014 *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures* (NEHRP Provisions) will represent the ninth edition of the national consensus publication that serves as the state-of-the-art resource document for US seismic codes and standards. The NEHRP Provisions are developed by the Building Seismic Safety Council (BSSC) through a five-year project sponsored by the Federal Emergency Management Agency (FEMA). The Provisions are developed for the BSSC by its Provisions Update Committee (PUC). In this update cycle, the PUC is supported by eleven Issue Teams, which develop technical concepts in the form of either seismic provisions with commentary or resource papers. The author serves as Chair of the PUC and presents this work as part of BSSC's commitment to ongoing outreach to the engineering community. This paper summarizes the framework for the 2014 NEHRP Provisions and the concepts currently under development by the Issue Teams.

1. INTRODUCTION

The National Earthquake Hazards Reduction Program (NEHRP) was created in 1979 to provide a framework to reduce the risk of earthquakes. The *NEHRP Recommended Provisions for New Buildings and Other Structures* (NEHRP Provisions) serve as a national resource for design professionals and the US standards and code-development community. In general, the NEHRP Provisions are viewed as a vehicle for the introduction of seismic concepts that will later be developed into code language by standards development organizations, most notably by the American Society of Civil Engineers Structural Engineering Institute (ASCE/SEI). The 2014 edition of the NEHRP Provisions is being developed by the Building Seismic Safety Council (BSSC) through a five-year contract sponsored by the Federal Emergency Management Agency (FEMA). The NEHRP Provisions are developed for the BSSC by its Provisions Update Committee (PUC) and most of the technical development work of the PUC is done through Issue Teams, which bring forth technical proposals covering a range of seismic topics.

During the development of the 2009 NEHRP Provisions (BSSC, 2009) a collaborative effort was established between the PUC and the seismic subcommittee of ASCE/SEI 7, which developed the seismic provisions for the national consensus design loads standard, ASCE/SEI 7-05, *Minimum Design Loads for Buildings and Other Structures* (ASCE, 2005). This resulted in the adoption of ASCE/SEI 7-05 by reference in the 2009 NEHRP Provisions. This collaboration continues in the current cycle and the 2014 NEHRP Provisions will adopt by reference the seismic requirements of ASCE/SEI 7-10 (ASCE, 2010).

As initiated in the 2009 edition, the NEHRP Provisions are presented in three parts. Part 1 will include consensus-approved modifications to ASCE/SEI 7-10. Part 2 will provide commentary, also consistent with ASCE/SEI 7-10 and Part 3 will provide resource papers covering material intended to stimulate discussion from the engineering community on new seismic design concepts. BSSC policies and procedures require that material developed for the Provisions, whether by Issue Teams or by the

PUC itself, go through balloting by the PUC, then following approval by the BSSC Board of Direction, though balloting by the 62 BSSC member organizations.

In the following sections the major efforts underway by the Issue Teams are described briefly. At the time of the writing of this paper all of the work of the Issue Teams is in the developmental stage, prior to PUC balloting, so this is intended to serve as information related to the general direction of the 2014 Provisions and to solicit comments.

2. INCORPORATION OF FEMA P695 AND P795

FEMA P695 – *Quantification of Building Seismic Performance Factors* (ATC, 2009) is a methodology to quantify the seismic performance factors for code-defined structural systems and to verify the adequacy of proposed new systems. FEMA P795 – *Component Equivalency Method* (ATC, 2011) is a component-based methodology for verifying equivalency of components, connections and sub-assemblies proposed for substitution into an established structural system. Since their publication, P695 and P795 have been generally accepted as the most appropriate approach to assigning seismic design coefficients to new systems and for qualifying new components. However, the NEHRP Provisions have not incorporated these methodologies or other analytical approaches for justifying seismic design coefficients for alternative systems or for establishment of equivalency of new components. Code language providing specific targets for collapse probabilities conditioned on the occurrence of MCE_R (risk targeted maximum considered earthquake) ground shaking is being considered, along with analysis and testing requirements. Similarly specific performance and analysis/testing language related to component substitution is being considered. This issue team is chaired by Ronald Hamburger.

3. EVALUATION AND QUANTIFICATION OF SEISMIC PERFORMANCE OBJECTIVES

This issue team is examining the seismic performance that is inherent in our current provisions and considering modifications to design procedures to improve our ability to achieve desired performance across all risk categories. Among the issues being considered are: how does seismic risk in general compare with other natural hazards; how do collapse risk and other performance levels vary among structural systems, risk categories and seismic design categories; and how does seismic risk vary with seismic hazard. Of interest for Risk Category IV (critical) buildings is the intensity at which building function is lost. Changes being considered include establishment of seismic design coefficients for collapse, functional design and economic design; and ground motion maps for very rare, rare and frequent events. This team is chaired by James Harris.

The work described above is being carried out in close coordination with a team chaired by John Hooper that is studying system exclusions, height limits and Seismic Design Categories. This team is evaluating the rationale behind the current SDC boundaries and the possibility of reducing the number of categories from the current four to either two or three. It is also reviewing the current system exclusions and system height limits given in the Seismic Design Coefficients (R-factor) table.

The efforts of these two teams are being supported by two ongoing Applied Technology Council (ATC) projects. First, input is provided from work on the National Institute of Standards and Technology (NIST) funded project, *ACT-84 – Tentative Framework for Development of Advanced Seismic Design Criteria for New Buildings – 100 % Draft* (ATC, 2012), Charles Kircher, Project Director. In addition, the Applied Technology Council (ATC) was recently awarded a FEMA contract to benchmark building code (structural and nonstructural) performance on various building types using established FEMA methodologies, including *FEMA P-695 – Quantification of Building Seismic Performance Factors* (ATC, 2009), Charles Kircher - Project Technical Director, for collapse prevention and *FEMA P-58 – Seismic Performance Assessment of Buildings – 100% Draft* (ATC, 2012), Ronald Hamburger - Project Technical Director, for all other performance levels. This project, tentatively titled *ATC 63-2 - Development of Seismic Performance and Methodology Calibration*, Ronald Hamburger - Project Technical Director, is being carried out on a schedule that will allow it to provide valuable input into this issue team.

4. SEISMIC ANCHORAGE TO CONCRETE

This issue team is studying seismic anchorage to concrete and issues related to the application of *ACI 318-11 Building Code Requirements for Structural Concrete* (ACI, 2011) Appendix D. The issue team supports the technical basis for the Appendix D provisions, but is interested in a better understanding of its seismic application, potential opportunities for simplification and potential exceptions where it can be assured that strength and ductility demands are satisfied through yielding elsewhere within the seismic load path. Considerations include anchorage detailing to assure sufficient anchor stretch length and development of hinging elsewhere in the connection. The establishment of nominal anchor strength based on 5 percent fractile test strength is being considered in view of system over-strengths and redundancies that in some seismic applications cases may suggest consideration of less conservatism. This issue team is chaired by Kevin Moore.

5. RESPONSE HISTORY ANALYSIS

The issue team, chaired by Curt Haselton, is undertaking a complete review and revision of the Seismic Response History Analysis requirements given in Chapter 16 of ASCE/SEI 7-10. The PUC judged that the current requirements lack specificity in many areas, leading to inconsistencies in interpretation. The team contains the following task groups:

General Requirements: How performance goals will be either implicitly demonstrated through predictable stable response under MCER ground motion or explicitly through fulfillment of performance goals related to collapse probability and possibly other performance levels, as a function of Risk Category.

Ground Motion Selection and Scaling: Definition of the target spectrum (or spectra) using either the ASCE/SEI 7-10 Chapter 11 mapped or site specific ground motion values or through one or more site specific scenario spectra covering MCER ground motion at appropriate (significant) periods of vibration of the building. Consideration is given to specifying earthquake events that capture frequency content at appropriate magnitude and distance, including where appropriate, requirements to address multiple earthquakes having distinct characteristics. Use of a maximum direction spectrum is considered along with the period range for scaling. Consideration is given to use of simulated records (similar to current provisions) where appropriate records are not available. Provisions for use of spectral matching are being considered, along with guidance and limitations. Orientation (fault-normal and fault-parallel) of ground motions for sites within 5 km of controlling faults is addressed, as is the lack of specificity of orientation at other sites. Consideration is given for input ground motion at subterranean levels and for soil-foundation-structure interaction.

Modeling, Analysis and Acceptance Criteria: System modeling considerations include the use of two-dimensional and three-dimensional modeling (including where to allow 2-D models), when to require application of vertical ground motions, how to address non-participating elements and gravity loads, as well as diaphragm modeling, requirements for force controlled elements and guidance on soil-structure interaction. Analysis and acceptance criteria considerations include use of average vs. maximum criteria, treatment of outlier ground motions resulting analytically in collapse, treatment of gravity element collapse and consideration of residual drift.

6. SELF CENTERING ROCKING SYSTEMS

Current code provisions do not address the response of lateral force resisting systems to rocking behavior, although this type of behavior does occur in certain buildings that are subject to seismic forces in excess of design lateral forces. Such behavior, if controlled in such a way as to protect structural and nonstructural elements form damaging displacements, may result in favorable non-linear performance. Furthermore it is possible to incorporate self-centering/rocking behavior into a structural system through configuration and detailing of the lateral force resisting system resulting in controlled yielding of specially designed elements. If such systems are to become more commonly utilized in seismic design it is necessary to develop appropriate analysis and design requirements, as these are not currently addressed in building codes.

The goal of this team is to propose seismic design requirements for rocking behavior in buildings, including implementation of innovative systems that achieve self-centering response through rocking. Design limit states may include onset of rocking (initiation of structural damage), safety (onset of significant deterioration) at MCE, and preservation of self-centering. Design requirements may include elastic analysis and design and nonlinear analysis and design. Systems including self-centering braced frames and concrete shear walls are considered candidates for this type of controlled behavior. This issue team is chaired by Greg Deierlein.

7. DIAPHRAGM ISSUES

The issue team is evaluating the behavior and performance of cast-in-place concrete, precast concrete (with or without topping), metal and wood diaphragms. Considerations include material-specific issues, redistribution of vertical and horizontal forces (through diaphragms) within the structural system and behavior of buildings in which the diaphragm controls or significantly contributes to modal response. It is felt that common analysis and design practices may not always recognize these issues and that code provisions, particularly the equivalent lateral force procedure, do not offer sufficient direction.

Our code provisions have traditionally defined system ductility in terms of the vertical lateral force resisting system, with more than 80 systems defined in the table of seismic design coefficients. Many large footprint low-rise buildings have significant mass participation in the diaphragm, but design forces are prescribed only on the basis of the vertical lateral force resisting system. This may result in an underestimate of demands in some elements and overestimation in others. A consideration is whether diaphragms should be designed to perform elastically, as is currently implied by the provisions, or whether it would be appropriate and beneficial in some cases to recognize nonlinear diaphragm response. Additionally in taller buildings higher mode effects may result in increased diaphragm demands, not recognized in common rigid diaphragm modeling assumptions. This issue team is chaired by S.K. Ghosh.

8. LIQUEFACTION AND OTHER SITE CONSIDERATIONS

The Provisions require that buildings be assessed for potential consequences of liquefaction and soil strength loss, including but not limited to, estimation of total and differential settlement, lateral soil movement, lateral loads on foundations, reduction of foundation soil bearing capacity, reduction of axial and lateral soil reaction on piles and floatation of buried structures. These effects are to be analyzed on the basis of peak ground accelerations, earthquake magnitudes and source characteristics associated with MCE_G peak ground accelerations, where MCE_G represents the Maximum Considered Earthquake geometric mean ground motion. Evaluating liquefaction for MCE ground motions is intended to minimize risk of collapse for the rare MCE ground motion, rather than at the building design level, which assumes a certain level of reserve building structural capacity. This Issue Team will consider more closely the geotechnical effects of the expected ground failure and its implications related to building damage and performance.

The Provisions utilize site amplification coefficients F_a and F_v that scale the mapped spectral values S_S and S_1 to obtain acceleration response parameters for sites with classification other than Site Class B. These coefficients were originally developed in the 1990's based primarily on the 1989 Loma Prieta Earthquake and are being re-evaluated by this Issue team based on recorded data from more recent earthquakes and nonlinearity of site response. This work is based on studies underway at the Pacific Earthquake Engineering Research Center. This Issue Team is chaired by C.B. Crouse.

9. FOUNDATION SOIL-STRUCTURE INTERFACE

Traditional geotechnical engineering practice provides foundation requirements based on allowable stresses. Commonly, allowable soil stresses for dead loads are arbitrarily increased by one-third for load combinations that include seismic forces. This practice is overly conservative and not consistent with the design basis of the NEHRP Provisions or ASCE/SEI 7 since it is not based on expected soil strength or the dynamic properties of site soils. This Issue Team is developing proposed modifications to foundation design requirements that address horizontal load effects (considering inelastic demands based on response modifications factors), nominal strengths, resistance factors and acceptance criteria. Additional work by this team may involve the further development of concepts contained in a 2009 NEHRP Provisions Part 3 Resource Paper, which considered controlling behavior and load-deformation modeling of the system consisting of the structure, its anchorage to the foundation, the foundation itself and the soil. This Issue Team is chaired by Martin Johnson.

10. LEARNING FROM RECENT EARTHQUAKES

Recent major earthquakes in developed countries, particularly those in Chile (2010), New Zealand (2011) and Japan (2011), provide an opportunity to judge the adequacy of the NEHRP Provisions from the standpoint of actual building performance. This Issue Team, chaired by William Holmes, will collect research from organizations that have published relevant reports and from engineers who have direct reconnaissance experience following these events. This will be presented in a NEHRP Provisions Part 3 report.

11. DESIGN MAPPING TASK FORCE

The 2009 NEHRP Provisions introduced new seismic design maps based on seismic hazard maps issued in 2008 by the U.S. Geological Survey (USGS) along with significant design-related adjustments, including use of risk-targeted ground motions, use of maximum direction ground motions, and use of near-source 84^{th} percentile ground motions. In this update cycle changes of this magnitude are not being proposed. It is expected that mapping changes will involve the following:

-Prepare supplemental design values from USGS hazard values and compare with design maps
-Prepare serviceability level design maps analogous to MCE_R maps
-Consider improvements to T_L (long period) maps
-Update the design maps for American Samoa and Guam
-Reshape the MCR_R design spectrum with additional (up to 7) spectral periods
-Address S_S values greater than 3g
-Support other Issues Teams, particularly the team related to Evaluation and Quantification of Seismic Performance Objectives

The Design Mapping Task Force is chaired by Nico Luco.

12. CONCLUDING REMARKS

The 2014 NEHRP Provisions is intended to serve as a nationally applicable resource document including Part 1 charging language based on and modifying ASCE/SEI 7-10, Part 2 detailed commentary also consistent with ASCE/SEI 7-10, and Part 3 introducing of new technologies. This paper provides an overview of the work that is underway related to the Provisions update project and is intended to contribute to the FEMA goal of outreach to the engineering community.

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