SIMPLIFICATION OF SEISMIC CODE PROVISIONS

A WHITE PAPER

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Introduction

Over the past several decades, the seismic design procedures and provisions in the U.S. national model codes and standards have continuously been refined and been made more comprehensive to cover more building types and sizes, to be efficient for design of buildings located in regions with a wide range of seismicity, to accommodate an ever-expanding state-of-the-art, and to incorporate lessons learned from damaging earthquakes. As a result, the design provisions have grown in number and complexity. In addition, national standards such as ASCE/SEI 7 [1] reference extensive material standards for various material design details, which also contribute to the complexity of the design process.

Some engineers and building officials have articulated their concern that the current code provisions are difficult for them to understand and to correctly implement, particularly for simple and small buildings that are expected to be designed quickly and efficiently [2], [3], [4]. These concerns are particularly troublesome if lack of understanding or short-cuts lead to incomplete or incorrect designs of buildings that will perform poorly in strong ground shaking or, on the other hand, of buildings that are unreasonably over-designed as a compromise to avoid complex code requirements. Although training is available in various forms for correct use of seismic design provisions, only a minority of engineers take advantage of these opportunities. Automation has also been suggested as a partial solution, but in the U.S. many engineers are wary of such applications due to potential misuse on the wide variety of materials and configurations used in building construction here. In recognition of this dilemma, exploration of the development of simplified design procedures was encouraged by FEMA and a modest start was contained in the 2003 NEHRP Recommended Seismic Provisions (NEHRP Provisions) [5] covering simple short and stiff structures. Subsequently, the national load standard, ASCE/SEI 7-05 [1] incorporated similar simplified design provisions in Section 12.14. The initial development effort was the result of a more comprehensive planning study previously completed during the development of the 2000 NEHRP Provisions [6]. The 2000 study concluded that simplification and improved understanding of the code procedures could be accomplished in several ways, including editing and clarifying the current provisions, reducing prescription and emphasizing performance-based design, reducing complexity by increasing conservatism, or developing structure-specific provisions parallel to the main design standard that might not even follow the current general procedures but would yield equivalent performance.

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The issues, interests, and viewpoints related to simplification of seismic design are multiple. They include the public need for provision of adequate seismic safety, highly variable designer interest and motivation (particularly in regions of infrequent seismic activity), the economic interests of various material industries, the inherent complexity of the design process due to variation of design ground motion by geographic area and site soil conditions, the nonlinear dynamic response of structures to shaking, and the rich variety of building systems and styles used in the United States. The very process of building code development encourages consideration of additional aspects and nuances of structural seismic response, which tends to continually add provisions, and seldom eliminates or simplifies the procedures. Some are concerned that seismic code changes are occurring faster than they can be absorbed, that added complexity may not assure safer buildings, and that the costs to design professionals and owners are excessive. Although many different approaches have already been proposed or explored in various attempts to meet the largely dispersed interests in simpler and more efficient seismic design methods, it is widely recognized that there is no practical overall simplification to the seismic design procedures as a whole. The only existing simplified design procedures in ASCE/SEI 7 (Section 12.14) were developed in 2003 as a conservative sub-set of the existing standard design requirements, applicable only to a narrow type of low rise buildings, primarily because there was concern about proving code equivalency for design provisions that used completely different procedures (e.g. displacement based design).

Since then, the recently developed procedures for qualifying new structural systems for incorporation in the building code as described in *Quantification of Building Seismic Performance Factors*, FEMA P-695 [7], also can be used to demonstrate equivalency with code objectives for alternative design methodologies with less prescription or that are not based on traditional force-based design concepts. This capability was not available during the development cycles of the 2000 or 2003 NEHRP Provisions, when the initial simplified design procedures were studied.

It also must be noted that a considerable portion of perceived complexity in overall seismic code provisions stems from the material-specific detailing requirements needed to provide the ductility and toughness assumed in the main body of the code. These detailing requirements are typically provided by expert committees organized and sponsored by various groups that promulgate material-specific design standards. There has been little effort to simplify these provisions, other than industry sponsored handbooks and tables intended to clarify requirements and pre-calculate parameters.

**New Studies Began in 2009**

Beginning in 2009, FEMA, through the National Institute of Building Sciences’ Building Seismic Safety Council (BSSC), initiated new studies of seismic code simplifications, intended to be more comprehensive than previous studies. The study was intended primarily to generate simplifications to the 2015 NEHRP provisions (the Simplified Seismic Design Procedures Project), but also to test the viability of various methods of simplification, including use of stand-alone provisions for individual building types and use of FEMA P-695 to prove equivalency. The study included review input on the subject received by FEMA since 2000, articles and
papers discussing simplified design, new input from various regions of the country obtained by the project team, and consideration of various guidelines currently available to assist engineers with seismic design.

Various options for simplification were identified. In general, the project focused on simplification of provisions in the main body of the code contained in the NEHRP Provisions, particularly considering the capabilities of FEMA P-695. Obvious opportunities to simplify, or eliminate, material-specific detailing requirements were also considered. The background study, identification of options, and final recommendations were documented in a report, called the Framework Report [8], available on the BSSC Portal.

**Framework Report**

The Framework Report described many options for simplification of seismic design provisions. Complete overhaul of the U.S seismic design provisions, suggested by some, was not an option because 1) such a massive effort is completely beyond the scope of this project, and 2) it is not clear that such an effort would result in simplification considering that the state of the art of seismic design is inherently complicated and the code must cover many building types. Similarly, a major editorial rewrite to improve clarity was not an option, primarily because just such an effort was completed for the 2003 NEHRP Provisions [5]. Therefore, realistic options that were identified were generally focused on narrowly defined buildings types or groups of buildings with similar seismic characteristics that could potentially be designed for more specific—and simpler—requirements than the base code. The very large number of structural materials and systems used in the U.S., coupled with somewhat unlimited configurations, results in a variation in building stock covered by the seismic code that is perhaps the largest in the world. This variation somewhat limits the applicability of simplifications with a narrow focus. The primary options included in the Framework Report are discussed below.

**Further Simplification of ASCE/SEI 7-10, Section 12.14**

ASCE/SEI 7-10 includes Section 12.14, Simplified Alternative Structural Design Criteria for Simple Bearing Wall or Building Frame Systems, which is the result of previous developmental work by the BSSC. This section allowed a simplified version of the equivalent static force analysis for seismic load effects along with a somewhat simpler statement of required strengths for selected components. It is applicable to buildings up to three stories tall of regular configuration so long as the seismic-force-resisting system (SFRS) is composed of bearing walls or braced frames. One of the premises is that such buildings do not require the computation of lateral drift, which is a substantial simplification.

The section is useful for qualified buildings with flexible diaphragms, but it was widely criticized as not being particularly useful for qualified buildings with rigid diaphragms. The reason is that a check for sensitivity to horizontal torsion is required for such buildings (Equations 12.14-2A and 12.14-2B, ASCE/SEI 7-05). The check itself required computation of the stiffness of each vertical element of the seismic force resisting system, and it was algebraically complex, essentially negating other simplifications of the procedure.
Suggestions were made for simplifying this portion of Section 12.14 and, given the investment of effort to date in development plus the generally favorable acceptance of the remainder of the section, an attempt to overcome this shortcoming appeared to be justified.

**Development of Stand-alone Design Provisions for Low and Moderate Seismic Regions (Seismic Design Category B and C)**

The concept of reducing complexity and increasing clarity using stand-alone and targeted design provisions for buildings with certain characteristics has been suggested before, but never tested.

Developing stand-alone seismic design requirements for Seismic Design Category (SDC) B and C buildings was an option for consideration. SDCs B and C represent low-to-moderate seismic hazard areas that cover a large portion of the United States and stand-alone provisions would be useful to many structural engineers. However, the seismic design requirements for SDC B and C differ on many key seismic design issues. Physical separation of the provisions would make them easier to follow; however, simplification would probably imply identifying commonality in requirements. This would result in an increase in the design requirements for SDC B, reductions in requirements for SDC C, or would demand development of completely new provisions. These options appeared to present difficult issues that would require extensive analysis in accordance with FEMA P-695, to resolve.

**Development of Stand-alone Design Provisions for Low Seismic Regions (for Seismic Design Category B)**

This option consisted of development of specific seismic design requirements for SDC B buildings. These requirements could be developed in a stand-alone document or as a special section of the current seismic design standards. For either approach, only the seismic design requirements for SDC B would be included in the stand-alone document or special section, and should be expected to be much shorter than provisions that must cover all regions of seismicity. This option could be pursued by editorial and/or technical changes to the seismic design requirements of ASCE/SEI 7-10.

**Development of Stand-alone Design Provisions for Buildings with Rigid Walls and Flexible Diaphragms**

Single-story buildings with rigid walls and flexible diaphragms (RWFD buildings) are common throughout the United States and are often used for warehouse buildings and “big box” retail stores. These buildings have stiff walls constructed of reinforced concrete or masonry, or braced frames of structural steel, and relatively flexible diaphragms of bare metal deck or wood structural panels. For typical large footprint RWFD buildings, deformation and cyclic behavior of the flexible diaphragm dominates the response to earthquake ground motions. Seismic provisions of building codes used in the United States, including those of ASCE/SEI 7-10, are developed based on seismic response dominated by deformation of the vertical elements of the seismic-force-resisting system. Engineers involved in building code development have long
suspected that the standard code model for seismic provisions does not fit well for design of RWFD buildings.

The committee that studied code simplification for the 2000 NEHRP Provisions Update Committee considered developing stand-alone seismic provisions for RWFD building that would focus on the diaphragm’s response. Simplification/clarification could occur because the design engineer would only have to refer to the stand-alone provisions; in addition, stand-alone provisions could more easily use a response model different than the primary code (diaphragm rather than vertical elements). But separate design provisions were not fully developed at that time, primarily because a procedure for establishing equivalent performance to that intended by the base code was not available. This hurdle has been overcome with the availability of FEMA P-695.

Development of Stand-alone Design Provisions for Wood-frame Buildings

The vast majority of building construction in the United States utilizes light framing of wood – bearing, closure, and partition walls of repetitive studs supporting floors and roofs framed with repetitive joists or trusses. The walls, floors, and roofs act as shear panels with the wood structural panels and gypsum wallboard providing the strength and stiffness for the shear panel action. This structure type is so common for single family residences that simplified, prescriptive rules have been available in codes for decades that can be used without engineering design. In addition, the American Wood Council has developed the *Wood Frame Construction Manual* to address design and construction issues for this building type. However, there are still many such buildings that are designed directly from code provisions.

The shear panel systems develop substantial ductility, mostly through inelastic action in and around the panel connectors. The fact that there are many components in the system means that there are many boundaries across which forces must be transferred, and design and detailing of these load paths causes the bulk of design time and complexity. Providing details for transfer of force across the many boundaries within the typical light-frame structure is a painstaking and time-consuming task.

The availability of a stand-alone set of seismic provisions limited to wood light-framed structures would be convenient for designers, but would probably not be substantially simpler than the base code, and will not reduce the complexities from providing load paths. Furthermore, proposed changes to the base code to achieve further simplifications using FEMA P-695 methodology [7] would require a very extensive set of archetypical designs because there are so many actual configurations of wood frame structural systems exist.

Use of the Ratio of Bearing Walls to Floor Area as a Primary Design Requirement

Rules allocating the amount and location of walls for seismic design in a concrete bearing wall building would be established using the FEMA P-695 methodology and would be determined independently for each SDC. The specific limitation on wall location would be determined consistent with the occupancy of the building. For instance, the wall locations for a residential
structure would be different from those for an office building. The archetype design space would need to be selected based on building occupancy and the resulting rules for wall placement consistent with the analysis results.

Rules-of-thumb consistent with this approach have been used in Chile, where mid- to high-rise residential structures consist almost exclusively of concrete bearing wall systems. Given the wall layout mandated by the various occupancy types, the large amount of variation in U.S. building configuration, and the amount of wall that would likely result (two to three times greater that is currently used in the U.S.), this option is not recommended for further investigation.

**Reduce Material Detailing Requirements (to Achieve Ductility) with Use of Lower $R$ Factors**

The detailing requirements for systems with high $R$ factors generally involve design checks to avoid brittle limit states (e.g., tensile fracture of structural steel or compressive crushing of concrete) and to avoid focusing the inelastic demand in a small portion of the system (e.g., the “strong-column, weak-beam” rule for special moment frames). Many of these detailing rules are rooted in the concept of “capacity design,” in which the structure is constrained by design to perform in certain desirable manners. These detailing requirements can be very time consuming in engineering practice.

The NEHRP Provisions and ASCE/SEI 7-10 are written to exclude the most brittle systems, generally those with the lower $R$ factors, from use on the higher seismic design categories, generally in locations with the potential for very large seismic ground motions. In some cases, the restrictions apply primarily to tall structures whereas in others, the restrictions apply to all heights. Suggestions to relax these restrictions by requiring higher loading (smaller $R$ factors) have been made in the past. Since the design procedures include a reduction in the MCE ground motion as a part of the basic equation for an equivalent design force, even an $R$ of 1.0 implies acceptable structural performance beyond the design loading assumptions. Some individuals cognizant of this fact suggest a value of $R$ equal to 2/3 as a safe alternative. Given that the ground motions to be considered exhibit a significant variability in key parameters and that the capacity of a structure is not known with certainty, a probabilistic approach is probably needed when considering these marginal cases. The methodology of FEMA P-695 would provide guidance in this regard, but the amount of work required to perform these analyses systematically for a wide category of structural systems would be overwhelming. Therefore, this option was not selected for consideration in this study.

**Options Studied**

In 2010, the Project Management Committee, in consultation with a Project Review Committee and FEMA, selected three options for study and development based on somewhat limited resources, the most needs subject areas, and potential benefits. The results of these studies are described below.

**Further Simplification of ASCE/SEI 7-10, Section 12.14**
The primary goal for this simplification is to eliminate the complex torsional check for qualifying buildings with rigid diaphragms that was described as part of the Framework Report. Considering that using flexible diaphragm assumptions is a desirable design simplification, studies were undertaken to determine what conditions would require rigid diaphragm assumptions for the sub group of buildings that qualified for Section 12.14. General use of flexible diaphragm assumptions in Section 12.14 for all diaphragms would not only eliminate the need for the torsional check, but also introduce additional simplification. Extensive FEMA P-695 analyses were run on small structures with a variety of wall/brace layouts to determine under what conditions the results of design would diverge using assumptions for both flexible and rigid diaphragms. The FEMA P-695 methodology yields an index related to probability of collapse and as long as the index for designs using flexible diaphragm assumptions was equal or better than design using rigid diaphragm assumptions, flexible diaphragm assumptions were acceptable.

It was found that design in which the seismic forces are apportioned to the vertical lateral force resisting elements as if the diaphragm was flexible was acceptable under the following conditions:

- For structures with two lines of resistance in a given direction, the distance between the two lines is at least 50% of the length of the diaphragm perpendicular to the lines;
- For structures with more than two lines of resistance in a given direction, the distance between the two most extreme lines or resistance is at least 60% of the length of the diaphragm perpendicular to the lines;
- Where two or more lines of resistance are closer together than one-half the horizontal length of the longer of the two walls or braced frames, the lines can be replaced by a single line at the centroid of the group for the initial distribution of forces and to distribute the resulting force to the members of the group based on their relative stiffness.

The conditions outlined above are relatively easy to achieve in the structures that qualify for design under Section 12.14, so in most cases, flexible diaphragm assumptions can be used and simplifying Section 12.14 considerably.

**Development of Stand-alone Design Provisions for Low Seismic Regions (for Seismic Design Category B)**

Seismic Design Category B (SDC B) structures are located in regions of very low seismicity where:

- Maximum considered ground motion spectral accelerations, as modified for local soil conditions are:

  \[0.167 \leq S_{DS} < 0.33\]  where \(S_{DS}\) is the design spectral response acceleration for short periods, and
  \[0.067 \leq S_{D1} < 0.133\]  where \(S_{D1}\) is the design spectral response acceleration for a period of 1.0 sec.

SDC B structures include all buildings in these areas except Risk Category IV (essential
occupancies). The area covered by the SDC B design criteria applies to much of the densely populated east so a very large number of buildings in the U.S. are covered by the SDC B design criteria. Seismic design provisions for these buildings are minimal but design engineers must still use all 80 pages of the seismic design provisions in ASCE /SEI 7 [1], even though most provisions are not applicable.

In this study, several concepts were used to minimize the provisions needed to design a SDC B building:

- **Editorial Deletions:** All the provisions that do not apply to SDC B buildings are simply removed. For example there are 9 pages of provisions in ASCE/SEI 7 covering nonstructural components, but only parapets and exit stairs are specified for protection in SDC B. The necessary provisions could thus be covered in about one third of a page.

- **Judgmental Deletions:** Since these provisions are to be specified as an option to the use of the full code, regulations that very rarely are used can be eliminated. If these regulations are needed for an unusual building, the design engineer can resort to design by the full code. For example, there are many structural systems listed in the so-called “R-factor table”, (officially titled, “Design Coefficients and Factors for Seismic Force-Resisting Systems”) that are never, or rarely, used in SDC B. These are primarily archaic systems (e.g. Plain concrete shear walls) and high ductility systems (e.g. Special moment frames of concrete or steel), neither of which, according to several engineers familiar with SDC B design, are used. This reduces the table of 83 systems to 36.

- **Technical Simplifications:** The availability of FEMA P695 allows determination of equivalency for technical changes. For example, the use of accidental torsion is not required unless the building has an Extreme Torsional Irregularity.

This study resulted in acceptance of a proposal to add a stand-alone chapter in the 2015 NEHRP Provisions [10] for design of SDC B buildings. The simplified chapter consists of only 35 pages as an alternate to the full seismic provisions spread over 11 chapters comprising 87 pages. An engineer designing a SDC B building will only need to refer to this chapter and the associated material standards previously discussed.

To test the merit of the concept and the efficiency of the technical changes, trial designs were commissioned to three engineering companies practicing in SDC B regions. The buildings used in the trial designs had been previously designed using the full code provisions. The structures incorporated the following seismic systems:

1. a three-story steel moment frame (R=3);
2. a four-story, light framed wood shear wall (R=6.5);
3. a four-story ordinary reinforced concrete wall (R=4);
4. a six-story steel braced frame (R=3).

The results of the trial design study are summarized as follows:

- The resulting designs do not differ significantly from the original designs previously completed using the full code.
- The stand-alone format is viewed very favorably. Trial design engineers suggested that
such a format would both prevent omissions of requirements and prevent confusion from mixing requirements from different Seismic Design Categories. The design engineers uniformly reported that they would use such provisions if they were code approved.

- Most of the engineers suggested additional judgmental deletions on the basis that they are seldom used—provisions for spectral analysis, foundation modeling, and two stage analyses.
- The attempted simplification to eliminate accidental torsion is not seen favorably. The analytical tests needed to eliminate the inclusion of accidental torsion were seen to be equal or in some cases more time consuming than the original provision.

This particular test of the concept of stand-alone provisions for specific building types or groups of buildings was found to be successful and useful. However, to be incorporated into building codes commonly used in the U.S., the chapter must be adopted into ASCE-SEI 7 [1]. Such a change proposal was made in 2014 and rejected, due to 1) arguments that simplification of the seismic code was not needed at all, and 2) that parallel methods of design, represented by a stand-alone chapter, created unwarranted ongoing risks of inconsistent updating and a potential double standard. This result was disappointing but the stand-alone chapter is available in the 2015 NEHRP Provisions as well in the final report, Report on the 2015 NEHRP Chapter 24 Stand-Alone Seismic Design Requirement for SDC B Buildings, [15]. However, it will be necessary for engineers who want to use this chapter to obtain approval from local building departments as to its equivalency and acceptability.

Development of Stand-alone Design Provisions for Buildings with Rigid Walls and Flexible Diaphragms (RWFD)

This study, in addition to developing improved design provisions for this building type, was also a test of the concept that design provisions narrowly directed at a single building type could be simpler and provide designs that would more consistently meet expected performance standards. The seismic response of this type of structure is practically all in the displacement of the large and relatively flexible diaphragms. However, the standardized design methods used in current seismic codes for all buildings assume primary response occurs in deformation of the vertically oriented lateral force resisting elements (i.e. the moment frames, braced frames, or shear walls). A design approach for this building type that was more technically correct and that could be shown to meet accepted code performance had been sought for some time. Such an approach would also meet some, if not all, of the code simplification goals by eliminating confusion and creating more consistent designs. The benefits of a “stand-alone” format in this situation were not initially anticipated.

As part of the study, testing data for wood and steel diaphragms were collected. A highly detailed nonlinear model of a one story prototype RWFD building was developed at University of Buffalo to improve understanding of response characteristics and to enable application of FEMA P-695 methods to demonstrate full code equivalency of proposed design provisions. The prototype building was 200’ x 400’ in plan, had perimeter concrete “tilt-up” walls, and was modeled with both wood and steel diaphragms. From this base building, P-695 archetypes were developed with aspect ratios of 1:1, 2:1, and 1:2, and spans of 100’, 200’ and 400.
Insights into the seismic response of this structural type are:

- Wood diaphragms are considerably stiffer than steel and the two are probably not interchangeable in design provisions (as assumed in current seismic provisions).
- Acceptable ductility levels of these diaphragms often do not justify the Response Modification Coefficient, R, currently assigned to this system. Steel diaphragms using some connection methods have low ductile capacity, reinforcing the notion that a single R factor for this building type, regardless of the specifics of construction, is not justified.
- Current diaphragm design methods incorporate a linear reduction of shear stress from the supporting exterior walls to the center of the building. Connector type and spacing is typically “zoned” to envelop the demand. P-695 analysis of typical designs indicates that inelasticity is limited to the high shear zone near the walls; if the adjacent zones more near the center of the building are weakened, inelasticity is spread out over a larger area and collapse probability, as measured by P-695, decreases.
- The lateral displacement of diaphragms in typical use, and in conformance with current design standards, can often be in the 12”-18” range near the center of the building creating a significant rotation at the important diaphragm-wall connection. Structural connections for both shear and out-of-plane tension are currently not designed for this rotation, and it is not specifically required to estimate this diaphragm deformation. Requirements to estimate this deformation should be required and connection details should be shown to be capable of accommodating the resulting rotation.
- The historical weakness of wall to diaphragm ties was briefly studied. In general, the current design force level was found to be adequate and collapse simulation in the P-695 studies was the result of side-sway (P-delta) collapse due to large diaphragm displacements. However, higher force levels were noted for diaphragms with short (100’) spans, for diaphragms expected to stay elastic for large loadings, and near corners. These special cases are not directly related to this study and should be pursued by code-writers separately.
- Procedures for considering wall to diaphragm connections for the combined loading of out of plane (tension/compression) and in-plane (shear) forces are not included in the code for either wood or metal diaphragms. Detailing of this connection varies by material and by region. When the connections for these two forces are not separate, the combined loading could be critical on the diaphragm.

The results of this study will be included in Part 3 of the 2015 NEHRP Provisions [10]. Part 3 contains code change proposals and associated studies that are judged to require further study prior to implementation. The recommendations include:

- A formula for determining the fundamental period of these building considering the primary response is in the diaphragm;
- A design procedure that changes the traditional straight line reduction of shear demands as a function of distance from the lateral force resisting elements. The strength of certain interior portions of the diaphragm is reduced relative to the perimeter to spread inelastic behavior over more of the diaphragm. Designs using this philosophy were shown to have reduced P-695 collapse probabilities.
- The change in fundamental period and the reduction of diaphragm design strengths is
easily accommodated by the existing equivalent lateral force procedures in current seismic codes and therefore the development of a “stand-alone” set of provisions for these buildings is not justified.

- The inelastic capacity of steel deck diaphragms based on currently available fasteners and completed testing is not adequate for the purposes of the proposed new design procedure; at this time the new procedure is recommended for wood diaphragms only. Additional testing may qualify certain steel deck diaphragm and fastener combinations before these recommendations are considered for adoption into the building code.

This study produced a far greater understanding of the seismic response of RWFD buildings, and will probably result in future code changes. However, as noted above, changes to reflect an improved design method can probably be made within the context of current code procedures, reducing or eliminating the potential simplification of a stand-alone set of provisions. It was also noted during a meeting between the Project Management Committee and a Project Review Panel, which included several big box store representatives, that if a stand-alone design procedure was developed for RWFD buildings, industry would probably expect complete detailing guidance for such issues of collectors and wall-to diaphragm connections for combined directions of loading as well as tolerance for very large diaphragm drifts. These detailing issues are traditionally not covered by code and are the purview of design engineers and contractors. Future efforts of code simplification/clarification using stand-alone provisions should consider the level of design detail appropriate to be included in the stand-alone provisions.

In addition to the project description in Part 3 of the 2015 NEHRP Provisions, a final project report is available from BSSC [16] and the design process is described in the FEMA report, *Seismic Design of Rigid Wall-Flexible Diaphragm Buildings: a Proposed Alternate Procedure* [17].

Although FEMA P-695 was originally intended as a procedure to allow code approval of seismic systems using new materials and/or configurations, the RWFD study has confirmed that the procedure is equally useful for testing alternate design rules or analytical methods for existing systems.

**Conclusions from the Simplified Seismic Design Provisions Project (2009-2015)**

The project was intended to provide recommended simplification to the 2015 NEHRP Provisions as well as test certain simplification techniques for viability in the future.

All three initiatives studied resulted in changes to the 2015 NEHRP Provisions: 1) ASCE/SEI 7, Section 12.14 will be changed to allow the assumption of flexible diaphragm in most cases, eliminating the need for an excess-torsion check. 2) The 2015 NEHRP Provisions will include a stand-alone chapter for buildings of Seismic Design Category B; unfortunately, this change will not be carried forward into ASCE/SEI 7-13) The 2015 NEHRP Provision will include a description of the study on RWFD buildings and a proposed new design procedure in Part 3; it is expected that the proposal will be taken up as a code change in the next cycle (2015-2020).
The procedures of FEMA P-695 were very useful for measuring changes in expected performance when introducing simplifying code changes. However, the procedures require extensive nonlinear modeling and calculation time, particularly when applied to situations that could affect a wide variety of structures.

Tests of the technique of using stand-alone design procedures for well defined structural types, or groups of buildings had mixed results. Stand-alone provisions for SDC B buildings simplified and clarified design of those buildings and were popular with engineers who performed trial designs. However, as previously noted, the committees of ASCE/SEI 7 did not accept the stand-alone chapter. To obtain the full benefits of stand-alone seismic design provisions, particularly if the provisions differ from the full code, a process must be developed to obtain an approval for use of the provisions acceptable to local building departments.

The focus of FEMA’s simplification efforts has been on the seismic loading and analysis procedure—material that is covered in the NEHRP Provisions and ASCE/SEI-7. It was previously noted that much of the perceived complexity, demand on design resources, and design and construction misinterpretation or errors associated with seismic design provisions stems from material specific design rules or detailing of load path that are not specifically covered in these documents. The importance of this issue was demonstrated in the Project Review Panel meeting for the RWFD initiative. A “design guidance” document was prepared to define and explain the proposed new design approach. The majority of participants suggested the document was inadequate because specific detailing guidance was not included on such issues as wall-diaphragm connections, cross building ties, and collector design—none of which were addressed by the proposed new analytical approach.

Other Efforts to Simplify Seismic Design Procedures

During the ASCE/SEI 7-16 code development cycle (2013-2015), several attempts were made for code simplification. The first was somewhat similar in concept to the stand-alone seismic provisions for SDC B, described earlier. The proposal was to break the ASCE standard into two volumes, one containing the more straightforward existing procedures covering most structures, and the second containing more complex procedures. Most engineers would seldom, if ever, consult the second document and the procedures most commonly used (in the first volume) could be more streamlined and less confusing. This proposal was intended to cover all design procedures, not just for seismic. Although there was favorable discussion, the proposal failed to achieve consensus support of the committee because members feared the extra work associated with producing two volumes and keeping them consistent [18]. These reasons are not unlike the arguments used against the stand-alone provisions for SDC B.

The second initiative within the ASCE/SEI 7-16 committee came from a special subcommittee, Task Committee TC-2S, charged with investigation of simplification of the seismic design procedures. That committee drafted a proposal for a simplified alternate procedure that would keep structures elastic during expected seismic events (using a force reduction factor, R, of 1.0). If structures had no inelastic demand during earthquakes, many code requirements, most of
which are focused on providing adequate inelastic performance, could be eliminated, including
detailing requirement contained in material standards. The total alternate provision was only 5
pages in length [19]. Due to code development protocols previously agreed to by ASCE and
BSSC, this proposal was sent to the Provisions Update Committee. The PUC rejected the
proposal because it had not been justified using the FEMA P-695 procedures, which had been
previously set as a standard for consideration of such proposals. However, the proposal was then
revised to be limited to Seismic Design Categories B and C and passed the ASCE 7 Seismic
Subcommittee in that form. Its final disposition is unknown at the time of this writing.

The Future of Simplified Seismic Design Provisions

Overall simplification of the seismic provisions was not studied in the project. Instead, as
knowledge about the hazard and structural response increases, code-writers have tended to add
options and nuances, essentially increasing complexity. Current analytical studies of
performance and performance based design in general are also tending to demand more detailed
consideration of system response. Based on ASCE/SEI 41 [14], substituting displacement based
design for force based design will not reduce complexity and might increase it. Efforts have
already been made to reorganize and edit the seismic provisions to improve logic and clarity.
Therefore, it presently appears that no overall simplification of seismic design provisions is
possible.

However, the availability of FEMA P-695 presents opportunities to simplify portions of the
seismic provisions, or seismic provisions as applied to certain building types. For example, the
studies of SDC B buildings found that the accidental torsion provisions may not be needed in
many cases. Consideration of accidental torsion adds considerably to the calculations necessary
for seismic design. A more thorough study of this provision may be justified for all SDCs.

The concept of stand-alone provisions for certain buildings or groups of buildings remains a
possibility for future development. However, the aversion of ASCE 7 to adopt such provisions
must be overcome. A parallel adoption process to prove equivalency to the full code is a
possibility, either locally or nationally (perhaps through the International Code Council’s
Evaluation Service). If such an approval procedure could be identified, other stand-alone design
provisions could be considered, perhaps starting with the most common building type in the
U.S., light frame construction.

The study of SDC B buildings as well as the proposal to split ASCE/SEI 7 into two volumes was
revealing. Recent discussions within Issue Team 7 (IT 07) of the Provisions Update Committee
included the possibility of combining SDC B and C into one. If that is done in the future and a
new set of provisions developed for the combined B and C, a complete separation of the
provisions into three groups could be considered: one very simple set for what is now SDC A; a
slightly more complete set for the combined B and C; and a “full” set for what is now D and
above. Based on the studies of SDC B, it is believed that the intermediate provisions could be
greatly simplified over the full set. Presenting each set of requirements separately would further
clarify and reduce confusion and errors.
Considering the complexity of some material design standards, and the popularity in low seismic zones of the R=3 steel buildings (requiring little no detailing rules), an elastic design option for would apparently be widely used for many structures. Although such a proposal was rejected by the PUC, P-695 studies of one or several structural systems would develop the data needed for the technical provisions. These studies may show that force reduction factors less than 1.0 are needed for brittle structures, but this requirement will probably not reduce use of this alternate.

It is recommended that any future initiative for code simplification, including those discussed above, be thoroughly vetted through the BSSC Provisions Update Committee before any significant development work is completed, including the need for specific equivalency studies (e.g. FEMA P-695).

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