Seismology and Structural Standards Committee

Seismology Committee Position Statement

April 2005

Seismic Design Factors and Coefficients in Seismic-Force Resisting Systems

Scope:

This document presents the position of the SEAONC Seismology and Structural Standards Committee on the development and use of seismic design factors. This statement is the product of the Committee's opposition to an effort by the International Code Council to allow the independent development of seismic design factors by manufacturers of seismic force resisting system elements (ICC-ES AC 215). Terms used are as defined in the 2003 Edition of *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures,* 1997 *Uniform Building Code* and the 2000 *International Building Code*.

Position Statement:

For all Seismic Force Resisting Systems, especially those that are undefined, the following statement applies:

1. The current set of seismic design factors found in codes and national standards are based on a measured combination of research and engineering judgment, considering system ductility and energy dissipation with respect to other systems. The tabulation is made internally consistent in a manner that requires the deliberation and consensus of a group of design professionals that objectively consider the comparative ranking of the subject system. At present, this responsibility belongs to the technical subcommittees of the Building Seismic Safety Council (BSSC) and follows the process outlined below.

   As a recent example of the BSSC process, the Buckling Restrained Braced Frame (BRBF) system was proposed for the assignment of seismic design factors. The proponents of BRBF, AISC and SEAOC, proposed design values to the AISC committee charged with developing seismic provisions, TC 9. This committee evaluated the proposal and made necessary adjustments based on the analyses and data submitted. The BSSC technical subcommittee for steel, TS-6, reviewed the AISC proposed BRBF system and proposed seismic design factors. Subsequently, TS-6 submitted the proposed values to the BSSC, TS-2 technical subcommittee (which is responsible for the assignment of seismic design values) for consideration. The BRBF system will be assigned seismic design values with the publication of the 2003 Edition of *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*. Upon publication of the 2003 NEHRP, codes such as ASCE-7 and IBC can incorporate the recommended provisions as part of their consensus balloting process. This process provides many opportunities for the inclusion of detailed technical support, engineering judgment and correlation with established seismic design factors prior to the assignment of seismic design factors for a new system.

2. The development of seismic design values without relating performance to detailing requirements may presume an inappropriate tradeoff between strength and ductility, especially at the low end of the R value scale. Although this may be true for some types of structures, permitting low ductility systems without other restrictions (height limits, etc.) or detailing requirements (such as additional ties in boundary members, confinement, etc.) is not consistent with accepted structural performance. Furthermore, current research shows that the equal-displacement rule (the assumption that the global drift ratio is insensitive to inelasticity) is not appropriate for structures with short periods. While this inadequacy may not be properly addressed with current or future seismic design factors, detailing requirements must be considered to establish system performance.

Assignment of R factors greater than 8.5 should not be permitted in context of the current codes, regardless of the results of any given qualification procedure. This limitation was applied to the BRBF system for the proposed seismic design factors considered by BSSC. High R values may also adversely affect building performance in moderate earthquakes.

3. Current code establishes system overstrength based on system strength (R factor), which is dependent on both the system strength (detailing) and the material strength (yield strength). The NEHRP Commentary states that the material overstrength for shear wall systems may be as low as one, but the system overstrength defined in Table 5.2.2 is typically 2-1/2. While the use of an overstrength factor based only on material overstrength is appropriate for establishing R factors, it is not appropriate for the broader use of the overstrength factor, which is to provide maximum probable forces for the design of elements, the failure of which, could lead to catastrophic collapse.

4. For establishing expected behavior of seismic force resisting elements, it is very important to have correlation between component test loading history and design ground motion. Cyclic loading poses inherent difficulties when applied to the testing of systems. When testing components, pseudo dynamic protocols are usually followed, but critical parameters related to testing protocols are not provided in the proposed criteria. The range of specimen testing should fully cover the intended use of this material as a part of a structure (system). We suggest that the minimum number of specimens be two for any configuration (shape factor, reinforcement pattern, reinforcement quantity, axial load and external reinforcement, etc.). Relationships between the component and system response parameters also need to be established.

Symbols and Abbreviations:

R Numerical coefficient representative of the inherent overstrength and global ductility capacity of lateral force resisting systems (UBC); Response Modification Coefficient (IBC)

Ω_0 Seismic Force Amplification Factor (UBC); System Overstrength Factor (IBC)

C_d Deflection Amplification Factor (IBC)

BSSC Building Seismic Safety Council

TC Technical Committee (AISC)

TS Technical Subcommittee (BSSC)

Commentary:

The building industry, specifically the structural engineering profession, has long been lacking a codified, traceable, rational and robust method for determining system R, Ω_0 and C_d factors. One must consider the relationship between seismic design factors and all other building codes provisions. The seismic code development process has been evolving in the US for more than 70 years. While some of the assumptions and values established in the codes may not be perceived as rational or scientific, the entire code has been in support of certain design assumptions and parameters to more simply identify and confirm expected seismic behavior and structural performance based on post-earthquake observations. One of the main challenges associated with the assignment of seismic design factors is the basic premise of current building codes.

Current building codes allow the use of simplified, monotonic, static, linear elastic analysis procedures to represent very complicated building behavior when subjected to earthquake ground motions.

The structural engineering profession is well aware of the inelastic behavior, increased damping, soil structure interaction and period lengthening that occurs in a building subjected to strong ground shaking. However, there are no comprehensive analytical tools available that allow for the accurate consideration of such behavior, especially when limited to simplified, monotonic, static, linear elastic analyses. Because of certain limitations present at the development of each new code edition, engineering judgment was utilized to develop a set of equations and factors that yield building designs consistent with the performance objective of the code. These equations and factors were correlated to past experience and observations following earthquakes. Development of seismic design factors is only one part of this process.

Over the years, structural design code sections (outside of Chapter 16 of the UBC and IBC) have been modified, augmented and refined to require component and system design that will result in building behavior that is more consistent with observed building performance in earthquakes. The changes occurring outside of Chapter 16 have rarely included the modification of system seismic design factors. In fact, most changes outside of Chapter 16 have been made in an effort to address perceived shortcomings in the system seismic design factors.

In addition to ensuring controlled levels of damage under a design level earthquake, the performance basis of the IBC and 1997 UBC is to provide a low probability of collapse under the maximum considered earthquake demands. The intensity of maximum considered earthquake shaking is 150% of that represented by the design spectrum. Some undefined systems may be capable of performing adequately for design level shaking, but may degrade and deteriorate rapidly for ground motion with greater intensity. It is imperative that any protocol for qualifying new structural systems addresses not only the performance under design ground shaking but also under maximum considered ground shaking.

In regards to the development of seismic design factors, one might reflect on previous efforts to understand and better quantify this issue. ATC-19 *Structural Response Modification Factors* examined the issue at hand with a focus on the following:

- *Historical Perspective*: The relationship between K factors introduced in 1959 by SEAOC, R factors introduced in 1978 in the ATC-3-06 report, and R_w factors introduced in 1988 by ICBO is established, and the shortcomings of seismic design using R factors are enumerated.
- *Use of R Factors*: U.S. response modification factors for buildings are compared with those for U.S. bridges and with those for common framing types in the seismic codes of Europe, Mexico, and Japan. Conclusions are drawn about the likely behavior of buildings meeting current code requirements in the United States during severe earthquake shaking.
- *Components of R*: A new formulation for R is proposed that expresses R as the product of three factors: R_S, a period-dependent strength factor, R , a period-dependent ductility factor, and R_R, a redundancy factor. Methods for estimating these three components are discussed.

Some of the recommendations presented in ATC-19 were incorporated into the UBC between 1991 and 1997 and the 2000 IBC. However, derivations of R factors and development of other seismic design factors were not addressed outside of the code development process. Commencing with the *1991 NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings (FEMA 222)* and continuing through to the *2000 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures (FEMA 368)*, the code development process has utilized the Building Seismic Safety Council (BSSC) via these FEMA documents as a "model code" for the publication of recommended changes related to seismic design and analysis of structures.

Based on the historic context provided above, any procedure should first be "calibrated" by establishing roughly similar results for new systems as compared to existing systems. As stated earlier, this area of code development has been in control of the BSSC through its recommendations to NEHRP. SEAONC has severe reservations about the independent, individual establishment of seismic design values without the checks and balances of committee review and consensus.

References:

*1991 NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings (*FEMA 222*),* NIBS 1991*.*

1997 *Uniform Building Code,* ICBO 1997.

2000 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures Part 1 –Provisions (FEMA 368), NIBS 2001.

2000 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures Part 2 –Commentary (FEMA 369), NIBS 2001.

2000 *International Building Code,* International Code Council, 2000.

ATC-3-06 *Tentative Provisions for the Development of Seismic Regulations for Buildings,* Applied Technology Council, 1978

ATC-19 *Structural Response Modification Factors,* Applied Technology Council, 1996.

Recommend Lateral Force Requirements and Commentary (SEAOC Blue Book), SEAOC, 1999.

Authorship:

This recommendation represents the official position of the Seismology Committee. It may differ from the policies and interpretations of some building authorities. Engineers are cautioned to ascertain such policies and interpretations in advance of design.

The document was approved by the Seismology Committee March 2005.

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