Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.V)

8-1-7

CURRENT CHANGES AND FUTURE TRENDS IN U.S. SEISMIC CODE PROVISIONS

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SUMMARY

This paper presents an overview of new seismic design provisions contained in the 1988 Edition of the Uniform Building Code (UBC). This is the building code used in most areas of the western United States. First, a brief historical background and a description of U.S. seismic code design philosophy are provided. Then key changes incorporated into the new UBC are outlined. Finally, probable future trends in U.S. code seismic design provisions are briefly outlined.

INTRODUCTION

The Uniform Building Code (UBC) is published by the International Conference of Building Officials (ICBO), and is a "model code" which is adopted by most local governmental jurisdictions (cities and counties) in the western half of the United States. These areas include those parts of the United States which have the greatest potential for future seismic activity.

This paper presents an overview of the major changes that have been incorporated into the seismic provisions of the 1988 Edition of the UBC (Ref. 1), and projects some probable trends for future provisions. The New 1988 UBC Seismic Provisions were developed and submitted to ICBO by the Structural Engineers Association of California (SEAOC), and are actually an adaptation of the 1988 edition of the SEAOC publication "Recommended Lateral Force Requirements and Tentative Commentary" (Ref. 2). This latter document, rewritten over the past eight years from previous editions by SEAOC's Seismology Committee is commonly known as the "Blue Book". This paper is an extension of one presented at the SEAOC Annual Convention in October 1987 (Ref. 3).

HISTORY AND PERSPECTIVE

Before proceeding into a description of the new UBC provisions, a short history of U.S. seismic codes and a brief cataloguing of organizations and the roles they have been playing in recent code writing activity will be helpful.

Seismic provisions have existed in California building codes since 1925, and particularly since the 1933 Long Beach earthquake. Since the first edition of the SEAOC "Blue Book" in 1959, U.S. seismic code writing has been principally the domain of the SEAOC Seismology Committee. At least until 1971, this was almost by default. SEAOC developed seismic provisions and submitted them to ICBO for inclusion in the Uniform Building Code. An informal client relationship was forged between ICBO and SEAOC, and persists to this day.

On February 9, 1971, the San Fernando earthquake struck Los Angeles. The injuries and deaths in that earthquake were primarily caused by the collapse of unreinforced masonry buildings which predated code seismic provisions. However, there was major damage to many buildings which were, at least nominally, deemed to be in compliance with the seismic requirements of building codes then in force. In response to the effects of the San Fernando earthquake, other groups, some with U.S. federal government funding, began to study seismic code provisions. The primary groups and their documents are as follows:

1. Applied Technology Council (ATC) published ATC 3-06, Tentative Provisions for the Development of Seismic Regulations for Buildings (Ref. 4).

2. The Building Seismic Safety Council (BSSC) published the NEHRP Provisions (Ref. 5; 6).

3. The American National Standards Institute (ANSI) published A58.1-1982 Building Code Requirements for Minimum Design Loads in Buildings and Other Structures (Ref. 7) which includes seismic design forces for buildings.

4. The American Concrete Institute as part of ACI 318-83, Building Code Requirements for Reinforced Concrete, included Appendix A, which addressed seismic detailing of concrete structures (Ref. 8).

5. The American Institute of Steel Construction (AISC) is currently developing a document, now in draft form, which will be part of their design specification, and which will provide seismic detailing provisions for steel structures.

The ANSI document, patterned after an earlier edition of the UBC, treats seismic loads only without addressing seismic detailing. The ACI appendix and the draft AISC seismic provisions are the reverse. They provide detailing provisions for concrete and steel structures, respectively, but rely on other documents for describing design seismic forces.

The ATC 3-06 document (Ref. 4) can now be said to have been superceded by the NEHRP provisions (Refs. 5; 6). With BSSC work funded by the Federal Emergency Management Agency (FEMA), the NEHRP provisions are intended to be a "source" document -- one which local code writing bodies can use for preparing seismic code provisions specifically adapted to the local area.

In a real sense all the other documents listed above served as "source" documents for the new SEAOC "Blue Book" and the 1988 UBC provisions. In this perspective, the confusing array of proposed code seismic provisions has not been a drawback, but their selective inclusion is a strength of the new UBC.

CODE PHILOSOPHY

The primary objective of the seismic design provisions in U.S. Building Codes is to protect life safety, which ultimately means to prevent structural collapse. Both past and current code seismic provisions are based on the assumption that inelastic (post-yield) action will permit properly designed structures to absorb the energy inparted by the largest earthquakes and avoid collapse. This assumption is primarily based on empirical observation. Although theoretical analyses and laboratory research may corroborate or explain this assumption, it is still largely based on observations of building response in past earthquakes. It has often been observed that structures with certain characteristics will tend to resist strong ground shaking without collapse. The structural characteristics which seismic resistant buildings have been observed to possess include the following:

1. A complete "load path" that carries seismic inertia forces from all structural and nonstructural elements to the vertical lateral force resisting system, and then to the foundation.

2. Minimum levels of strength and stiffness, smoothly increasing from top to bottom of a structure and evenly distributed in plan. This distribution is such that the seismic demand-strength ratio is everywhere approximately constant.

3. A detailing of the elements of the lateral force resisting system such that they exhibit ductile behavior -- they sustain large cyclic inelastic deformations and do not fail locally by either instability or brittle fracture.

The first two characteristics in the above list can be obtained by properly proportioning a structure's lateral force resisting system. The third characteristic can be obtained if individual elements are detailed so as to promote ductile behavior. UBC seismic design provisions can be conveniently divided into the same two categories -- provisions for proportioning structures (force provisions) and detailing provisions.

UBC FORCE PROVISIONS

Key changes contained in the 1988 UBC seismic force provisions relative to those contained in the 1985 edition are as follows:

Base Shear Equation The design lateral force (base shear) equation in the new 1988 UBC is in a format similar to that proposed in ATC3-06 (Ref. 4) and in the NEHRP provisions (Refs. 5; 6). One difference is that at least for the present, the seismic design forces are set at a working stress rather than at a yield level. Even though the format of the equation has changed, the values of the parameters have been set so that the differences in total base shear between the 1985 and 1988 codes will, for most structures, be small.

Fig. 1 shows a side by side comparison of base shear equations from the 1985 and 1988 editions of the UBC. A key conceptual difference is that although their product has been deemed to be about right, the individual parameters in the 1985 code base shear equation individually had no rational basis. In the new format, a product of semi-rational parameters in the numerator, which can be said to represent the elastic base shear of a uniform multi-storied structure, is divided by a single empirical denominator. This divisor reduces the semi-rational numerator to consensus values of design base shear.

The following summarize a few of the key attributes of the various parameters in the new base shear equation.

1. The parameter Z represents effective peak ground acceleration that can be expected for an event having a 475-year recurrence interval. The value is obtained from a zone map, which although similar to that contained in ATC3/NEHRP, has only four zones. The resulting map was modified both for technical and political reasons.

2. The parameter S represents the amplification effects of softer soils. There are two key changes from previous editions of the UBC. First, soil Type S4 was added. This is to cover the large amplifications that can occur on soft clay deposits, such as the Mexico City lake bed. Second, the "site period" concept has been removed. This was done in the belief that the process by which predominant ground motion frequencies are produced is very complex. Therefore, this process cannot, for all sites, be adequately or reliably represented by a single equation based on a simplified model of local soil conditions.

3. The parameter C, without the S factor, represents a structure's elastic dynamic response or structural amplification of ground motion expressed as a base shear. It is a function of first mode natural period (T) taken to the 2/3 power as suggested by ATC 3-06 and the NEHRP provisions.

4. The parameter R_W is the factor which accounts for total energy absorbtion in the structure including inelastic action. Appearing in the demoninator, it reduces the elastic response of a structure (the numerator) to the emperically predetermined working level design base shear. Based on past earthquake experience, the R_W values have been judgmentally set by the SEAOC seismology committee for various structural systems and materials.

It was mentioned above that the zone map was modified for political reasons from the one originally constructed by seismologists. This should not be surprising. When adopted by a governmental jurisdiction, a building code is first a legal document, and only secondarily is it an engineering document.

Structural Irregularity Another change in the new UBC's seismic force provisions is the attempt to deal with the greater vulnerability of irregular structures. The objective was to deal with such structures in a manner which is quantitative and enforceable by building officials. The UBC design procedures presume a uniform distribution of mass (both in plan and vertically), a regular or gradually varying distribution of stiffness with height and a uniform distribution of stiffness in plan. Such a structure is presumed to have an essentially linear first mode shape which is primarily translational with minimal torsional coupling. Structures proportioned using this linear distribution are assumed to have the desired constancy of demand-strength ratio.

Previous code editions were vague on when departures from these assumptions were sufficient to make the code procedure inapplicable, and on what was to be done if the procedures were in fact found to be inapplicable.

Using the ATC3/NEHRP commentary concepts for irregular structural configurations, the SEAOC seismology committee attempted to quantify the limits for regular structures. Since neither comprehensive analytical studies nor physical test data was available, these limits were set primarily by judgment.

The 1988 UBC provides additional requirements that must be met for various structural irregularities. For some irregularities, such as excessive plan eccentricities, there are "penalty functions" that increase the required accidental torsion that must be considered. Some, such as excessively weak lower stories are prohibited. Other irregular configurations such as the vertical "soft" and "heavy" stories require that dynamic analysis procedures be used to determine the vertical distribution of the code base shear.

The requirements for performing a dynamic analysis are defined. These involve performing a elastic response spectrum analysis, and then scaling the results so that the base shear is greater than or equal to the code minimum.

A comment is needed on the use of elastic analysis procedures when a primary assumption of the UBC seismic provisions is that inelastic action will occur in large earthquakes. The code procedure, including its design force distribution, is empirical and approximate. The code formula is a reasonable first approximation for force distribution for a fairly narrow class of regular structures. When a structural configuration is outside these bounds, an alternate first approximation is sought -- one which will better provide the desired constant demand-strength ratio. Thus, although inelastic behavior is anticipated, elastic dynamic procedures are viewed as a better first approximation for force distribution for certain types of irregular structures.

CHANGES TO DETAILING PROVISIONS

In the new 1988 UBC detailing provisions are provided for all basic building materials and for all commonly used types of structures. For wood masonry and concrete, the 1988 changes consisted of a series of additions and exceptions to current code provisions. However, for steel, a comprehensive new set of detailing requirements were developed and incorporated. All structural systems are covered, including "ordinary" moment frames, "special" moment frames (formerly "ductile" moment frames) and concentric braced frames. Also included is a newly described system -- eccentric braced frames. The changes and additions to the steel detailing provisions, although perhaps the most fundamental set of changes incorporated in the 1988 UBC, are too extensive to describe here.

FUTURE TRENDS

The new SEAOC "Blue Book" and the 1988 UBC represents significant progress in U.S. building code provisions for seismic resistant design. However, many questions remain unanswered. Some questions which will be answered by more research and more data from future earthquakes include the following:

1. Development of a rationally consistent basis for determining R_W (for yield level design -- R) factors that can be applied to all materials.

2. Verification of the appropriate limits for structural regularity, i.e., bounds beyond which more detailed procedures must be employed or more stringent requirements imposed.

3. Verification of and extension of a host of detailing provisions, particularly for steel structures. For example, research data is still needed on panel zone yielding and "strong-beam, weak-column" systems in moment frames. Provisions for concentric braced frames must be more definitively separated into distinct categories such as the following:

   a) moment frames where bracing is provided only for drift control;
   b) dual systems; and
   c) pure vertical truss systems.

Other more fundamental trends in future U.S. building code seismic provisions, will probably include the following:

1. A change from seismic zone maps to contour maps for determining design seismic forces. Hopefully, use of contours will reduce the influence of politics in the determination of the seismic map. In addition, look for detailing provisions to be tied not only to the expected ground motion at the site for a 475-year recurrent earthquake, but also to be a function of the intensity expected from a "maximum credible" earthquake. Such an approach would better address the needs of those areas where large earthquakes, although infrequent, can still occur.

2. As "strength-type" design provisions are developed for all materials, the seismic design forces will be reset to a "yield", rather than a "working stress" level. For a loading which envisions post-yield excursions, it would certainly be philosophically preferable if a yield-level approach were used.

CONCLUSIONS

The new seismic resistant design procedures contained in the 1988 UBC are significant steps. However, much remains to be done to more reliably protect the life safety of building occupants in large earthquakes.

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1985 UBC	1988 UBC
$V = ZIKCSW$	$V = \frac{ZIC}{R_w} W$
$Z = 1, 3/4, 3/8, 3/16$	$Z = 0.4, 0.3, 0.2, 0.075$
$I = 1, 1.25, 1.5$	$I = 1.0, 1.25$
$C = \frac{1}{15\sqrt{T}}$	$C = \frac{1.25\ S}{T^{2/3}}$
a) $S = S_1, S_2, S_3$ or b) $S = 1.0 + \frac{T}{T_s} - 0.5\left[\frac{T}{T_s}\right]^2 ; \frac{T}{T_s} \leq 1.0$ $S = 1.2 + 0.6\frac{T}{T_s} - 0.3\left[\frac{T}{T_s}\right]^2 ; \frac{T}{T_s} \leq 1.0$	$S = S_1, S_2, S_3, S_4$
$C \leq 0.12$ $C * S \leq 0.14$	$C \leq 2.75$
	$C/R_w > 0.075$
$0.67 \leq K \leq 1.33$ $K \approx R_w/8$	$4 \leq R_w \leq 12$

FIGURE 1

UBC LATERAL FORCE EQUATIONS