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Assessment of the Seismic Provisions of Model Building Codes

Council of American Building Officials
Falls Church, Virginia 22041

United States Department of Commerce
Technology Administration
National Institute of Standards and Technology

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Sponsored by:
Federal Emergency Management Agency
Washington, DC 20472

July 1992
Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899

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prepared by
COUNCIL OF AMERICAN BUILDING OFFICIALS
Falls Church, Virginia
July, 1992

for
Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, Maryland

sponsored by
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EXECUTIVE SUMMARY

Executive Order 12699, signed by the President on Jan. 5, 1990, requires that all Federally owned, leased, assisted, and regulated buildings be designed and constructed in accord with appropriate seismic standards. Each affected agency is required to establish appropriate regulations or programs for implementing the Order. Private sector standards are to be used unless none are adequate for agency use. The Order requires the Interagency Committee on Seismic Safety in Construction (ICSSC) to recommend standards appropriate for implementation of the Order. The ICSSC, in its consensus based document RP 2.1, *Guidelines and Procedures for Implementation of the Executive Order on Seismic Safety of New Construction*, recommended the use of standards and practices which are substantially equivalent to the *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings*. The ICSSC, with funding from the Federal Emergency Management Agency (FEMA), commissioned this study of the seismic provisions of the nation's four major model building codes in order to assess which of the model codes provide the recommended level of seismic safety.

The National Institute of Standards and Technology (NIST), which provides the Chair and Technical Secretariat to the ICSSC, contracted with the Council of American Building Officials (CABO) to perform the necessary comparisons. The four model codes which were compared to the 1988 edition of the NEHRP Recommended Provisions were:

- 1989 CABO One & Two Family Dwelling Code
- 1992 Supplement to the BOCA National Building Code
- 1992 Amendments to the SBCCI Standard Building Code
- 1991 ICBO Uniform Building Code

The seismic requirements of the CABO One & Two Family Dwelling Code were found to be significantly different than those in the NEHRP Recommended Provisions. For buildings which are exempt from the requirements of the NEHRP Recommended Provisions (all dwellings in areas of low seismic hazard and most low-rise wood-frame dwellings in regions of moderate and high seismic hazard) the provisions of the One & Two Family Dwelling Code are adequate. However, for all other dwellings, the comparison showed that the existing CABO provisions were not sufficient to provide substantial equivalence to the NEHRP Recommended Provisions.

Because the BOCA National and SBCCI Standard building codes had adopted the NEHRP Recommended Provisions essentially unchanged into the editions cited above, the comparison was straightforward and the conclusion self-evident: both codes were found to be substantially equivalent.

The ICBO Uniform Building Code has historically been the leader among the model codes in developing improved seismic requirements. However, the requirements in that code are difficult to compare directly to the NEHRP Recommended Provisions because the two documents use significantly different design approaches. The study that was done compared the intent and content of each set of provisions, and examined the results of three case studies. The investigators found that both documents included some sections that were more stringent than the comparable section in the other document. They also compared the stresses under design loads in the three buildings (each assessed for 5 different levels of ground motion) designed for the case studies. Based on the evaluation of similarities and differences in the two documents, and on the results of the case studies, the investigators were able to conclude that both documents provide a similar level of seismic safety, and that the 1991 ICBO Uniform Building Code is substantially equivalent to the 1988 NEHRP Recommended Provisions.

ICSSC Subcommittee 1 (Standards for New and Existing Buildings) reviewed this report in draft form. A panel of reviewers from the private sector was convened to provide additional assessment of the comparisons. Panel members were: Ken Andreason, American Plywood Association; Stanley D. Lindsey, Stanley D. Lindsey & Associates; Gerald H. Jones, City of Kansas City, MO; Roland Sharpe, Consulting Structural Engineer; Mark B. Hogan, Concrete Masonry Association; Alan Porush, Dames & Moore. They concurred with the conclusions of the CABO investigators and supported the findings of this report. NIST technical staff also provided review of the document.

The ICSSC has issued a recommendation to FEMA reaffirming the NEHRP Recommended Provisions as the appropriate level of seismic safety for Federal agency use. The recommendation goes on to identify the 1992 Supplement to the BOCA National Building Code, the 1992 Amendments to the SBCCI Standard Building Code, and the 1991 ICBO Uniform Building Code as providing that level of safety. The recommendation is included in RP 2.1-A, a revised version of the ICSSC implementation guidelines, published as *Guidelines and Procedures for Implementation of the Executive Order on Seismic Safety of New Building Construction*. RP 2.1-A may be obtained from Diana Todd, ICSSC Technical Secretariat, Structures Division, NIST, Bldg. 226, Room B 158, Gaithersburg, MD 20899.

COMPARISON OF

1989 CABO ONE AND TWO FAMILY DWELLING CODE

TO

THE 1988 NEHRP RECOMMENDED PROVISIONS

Prepared By

BOCA INTERNATIONAL

AUGUST, 1991

Revised January, 1992

1988 NEHRP PROVISIONS APPLICABLE
TO
CABO ONE AND TWO FAMILY DWELLING CODE

The scope of the CABO Code is limited to one or two family dwellings and one family townhouses not more than 3 stories in height. The 1988 NEHRP Provisions (Section 1.2) exempt detached, one and two family dwellings located in areas having an effective velocity-related acceleration (A_v) less than 0.15. Thus, detached one and two family dwellings located in areas of the United States east of the Rocky Mountains, except the New Madrid Region, and a major part of the Western United States is exempt by the 1988 NEHRP Provisions.

The 1988 NEHRP Provisions (Section 1.3.1) have reduced requirements for detached one and two family wood frame dwellings, not more than 2 stories or 35 feet in height, which are located in areas where the effective velocity-related acceleration (A_v) is equal to or greater than 0.15. Thus, detached one and two family wood frame dwellings need only comply to the NEHRP requirements for Conventional Light Timber Construction in NEHRP Section 9.7. A detailed comparison of the CABO One and Two Family Dwelling Code to the NEHRP Conventional Light Timber Construction requirements is included in this report.

Detached one and two family wood frame dwellings more than 2 stories or 35 feet in height located in areas where the effective velocity-rated acceleration (A_v) is equal to or greater than 0.15 require an earthquake load structural analysis according to 1988 NEHRP. The CABO Code does not include this requirement.

The 1988 NEHRP Provisions (Section 3.6.1) have minimal requirements for buildings assigned to Seismic Performance Category A, i.e, buildings located in areas having an effective velocity-related acceleration (A_v) less than 0.05. Thus, townhouses located in these areas have minimal requirements according to 1988 NEHRP.

The 1988 NEHRP Provisions require an earthquake load structural analysis for townhouses located in areas having an effective velocity-related acceleration (A_v) greater than 0.05, i.e.,Seismic Performance Category B through E. The CABO code does not include earthquake load structural analysis criteria.

MASONRY CONSTRUCTION

The CABO Code includes construction requirements for masonry walls, veneer and chimneys. A comparison of CABO versus NEHRP requirements are included in this report.

1989 CABO TO 1988 NEHRP COMPARISON

The NEHRP Provisions regarding the seismic risk map, conventional light timber construction and masonry construction are compared with the applicable CABO Code requirements on the following pages.

ITEM DESCRIPTION	NEHRP SECTION #	CABO SECTION #	COMPARISON COMMENTS
Seismic Risk Map	1.4.1	Appendix A, Section R-201.2	The seismic risk map in Appendix A of CABO and Figure 1-4 (the A_v Map) in NEHRP-88 have the same technical basis, i.e., ATC 3-06 Document. The boundary line of Zone 1 on the CABO Map is the 0.05 contour line on the A_v NEHRP Map. The boundary line of Zone 2 on the CABO Map is the 0.10 contour line on the A_v NEHRP Map. The boundary line of Zone 3 on the CABO Map is the 0.20 contour line on the A_v NEHRP Map. The boundary line for Zone 4 on the CABO Map is the 0.40 contour line on the A_v NEHRP Map. The Zone Boundary lines on the CABO Map are in the same location as the contour lines on the NEHRP A_v Map.
Anchor Bolts	9.7.1.1	R-303, Figure R-303, Figure R-402.3b	CABO has the same anchor bolt spacing requirement regardless of site seismicity, i.e., 6 feet on center. NEHRP-88 requires bolt spacing of 4 feet on center where $A_v \geq 0.15$.
Top Wall Plates	9.7.1.2	R-402.3, Figure R-402.3a, R-402.4, Figure R-402.3B	CABO requires double top plate for exterior walls and interior bearing walls with exception or certain conditions (see Referenced Section for details) for all areas. NEHRP-88 double top plates where $A_v \geq 0.15$.
Bottom Wall Plates	9.7.1.3	R-402.3, Figure R-402.3a and Figure R-402.3b	Both NEHRP and CABO require bottom wall plates.

ITEM DESCRIPTION	NEHRP SECTION #	CABO SECTION #	COMPARISON COMMENTS
Wall Sheathing (Bracing)	9.7.2, Tables 9-2 thru 9-4 Section 9.8.3, Table 9-3	R-402.10, Table R-402.10, Table R-402.3a, R-402.3, Table R-402.3b, Table R-402.3c	The requirements in Section 9.7.2 of NEHRP-88 apply to one and two family dwelling where $A_v \geq 0.15$. The wall bracing requirements in Table R-402.10 of CABO are subdivided into regulations for Seismic Zone 0, 1 or 2, and regulations for Seismic Zone 3 and 4. Generally, areas where $A_v \geq 0.15$ in NEHRP-88 are Zones 3 and 4 in CABO. CABO allows the use of 1x4 let-in bracing in Seismic Zones 3 and 4 for One-story dwellings and the top story of multi-level dwellings. NEHRP requires sheathing on all floor levels. Both NEHRP and CABO require sheathing panel widths of 48 inches (minimum). CABO requires more wall sheathing on the lower stories than NEHRP-88. NEHRP-88 requires wall sheathing on "main interior partitions"; and exterior walls. CABO requires wall sheathing on exterior walls and foundation wall panels, (i.e., cripple stud foundation walls). CABO and NEHRP-88 both require 2x4 minimum framing members. The connection of the sheathing to the framing is addressed in NEHRP-88 by Tables 9-2 through 9-4. The connections per CABO are in Table R-402.3a. Nails for Plywood Sheathing are slightly larger in NEHRP.

ITEM DESCRIPTION	NEHRP SECTION #	CABO SECTION #	COMPARISON COMMENTS
Acceptable Types of Wall Sheathing	9.7.3	Table R-402.3a, Table R-402.3b, Table R-402.3c, Section R-402.3, Section R-402.10, Table R-402.10	Per Sections R-402.3 and Table 402.10 of CABO, let-in bracing is allowed top story; NEHRP-88 requires wall sheathing. Where sheathing is required per Table R-402.10 in CABO, it must be either plywood or particleboard according to Section R-402.3. NEHRP-88 allows diagonal boards, plywood, particleboard, fiber board, and gypsum wallboard. The minimum thickness permitted per CABO and NEHRP-88 are the same.
Masonry Walls	Chapter 12	R-404.10, Figures R-404.10a and R-404.10b	CABO requires reinforcement in masonry walls for Seismic Zones 3 and 4. NEHRP requires reinforcement in masonry walls for buildings assigned to Seismic Performance Category C, D and E. Thus, NEHRP is more restrictive than CABO.
Masonry Veneer	Chapter 8, Table 8-2	R-503.4, R-503.4.2, Figure R-503.4	CABO requires horizontal wire reinforcement in seismic zones 3 and 4. NEHRP requires masonry veneer to be designed for earthquake loads for buildings located where the effective velocity-related acceleration (A_v) is equal to or greater than 0.15. Thus, NEHRP is more restrictive than CABO.
Masonry Chimneys	Chapter 12, Table 8-3	R-903.1	CABO requires horizontal and vertical reinforcement in seismic zones 3 and 4. NEHRP requires horizontal and vertical reinforcement for buildings assigned to Seismic Performance Category C, D and E. Thus, NEHRP is more restrictive than CABO.

COMPARISON ANALYSIS

The conventional light timber construction requirements in the CABO Code are comparable with those in the 1988 NEHRP Provisions. The seismic risk map in CABO has the same basis as the 1988 NEHRP risk map, i.e., ATC 3-06. The masonry requirements in the CABO Code are less stringent than those in the 1988 NEHRP Provisions.

FURTHER DEVELOPMENT OF THE NEHRP PROVISIONS

The NEHRP Provisions need further development of the Conventional Light Timber Construction prescriptive requirements for wood framed buildings which are included in the scope of the CABO One and Two Family Dwelling Code; i.e., 1 to 3 story detached one and two family dwellings and townhouses. The prescriptive requirements must be written in mandatory language and be appropriate to the residential construction industry. Since CABO includes masonry construction, further development of prescriptive requirements are needed as well on this topic. The development of construction requirements for the text of the CABO Code would be a very effective program of earthquake mitigation for residential construction, provided the requirements were straight forward and easily understandable to the builder and the code official.

REPORT CONCLUSIONS AND RECOMMENDATIONS

The 1989 CABO One and Two Family Dwelling Code is appropriate for use in meeting the requirements of the Executive Order 12699 "Seismic Safety of Federal and Federally Leased, Assisted, or Regulated New Construction" for residential buildings having the following characteristics:

- Detached one and two family wood frame dwelling, not more than two stories or 35 feet in height.

- Townhouses of wood frame construction, located in areas having an effective velocity related acceleration, (A_v), less than 0.05.

One and Two Family Dwellings and Townhouse construction which does not meet the above criteria are recommended to be designed in accordance with one of the following Model Codes:

- BOCA National Building/1990, with 1992 Accumulative Supplement
- SBCC Standard Building Code/1991, with 1992 Amendments
- ICBO Uniform Building Code/1991

COMPARISON OF

BOCA NATIONAL BUILDING CODE/1990
WITH 1992 ACCUMULATIVE SUPPLEMENT

TO

THE 1988 NEHRP RECOMMENDED PROVISIONS

Prepared By

BOCA INTERNATIONAL

AUGUST, 1991

Revised January, 1992

REPORT INDEX:

A. BOCA NATIONAL BUILDING CODE, HISTORY OF EARTHQUAKE REQUIREMENTS

Earthquake loading requirements for a building design and construction have always been included in the BOCA National Building Code. The first edition of the Code, published in 1950, included requirements which were relatively simplistic in comparison to contemporary provisions. In 1955 the provisions reflected a more meaningful technical content which reflected the technology at that time. In the mid-1970's, BOCA's provisions were revised to conform to that contained in the consensus national standard ANSI A58.1 "Minimum Design Loads for Buildings and Other Structures". In the mid-1980's, BOCA's provisions were comprehensively revised based on the revisions found in the ANSI A58.1-82 standard. The text of the 1990 BOCA National Building Code largely reflects that found in the current national standard ASCE 7-88 (the successor standard to ANSI A58.1).

Several provisions have been adopted by BOCA based on seismic technology developed since the approval of the ASCE 7 standard. For example, the Seismic Zone Map in the 1990 BOCA National Building Code is based on the 1988 edition of the National Earthquake Hazards Reduction Program (NEHRP) Provisions as developed by the Building Seismic Safety Council (BSSC). The effective peak velocity-related acceleration coefficient, A_v, is used to determine the design earthquake loads, based on the 1988 NEHRP Provisions. This results in logical, uniform increases in design loads for sites with increasing seismic risk versus the "Zone" methodology which increases the earthquake design loads by a series of steps between earthquake "Zones".

BOCA has been actively involved with the Building Seismic Safety Council since its inception and has been represented in various committee activities relative to the development of the NEHRP Provisions. These provisions represent the state of the technology in seismic considerations.

B. BOCA/BSSC AD HOC COMMITTEE STUDY

In consideration of the state of the technology of the NEHRP Provisions, an Ad Hoc committee of BOCA code officials and BSSC advisory members was actively engaged in evaluating the 1988 NEHRP provisions for the incorporation into the BOCA National Building Code. The BOCA/BSSC Ad Hoc committee was formed in April, 1989. A detailed review of the entire 1988 NEHRP Provisions resulted in the development and submittal of 1991 Proposed Changes to the BOCA National Building Code. The resulting code changes were recommended for approval by the BOCA National Building Code Changes Committee in April 1991. The final approval of the changes by the BOCA membership occurred at the annual conference in September of 1991. Thus, the seismic provisions in the 1992 BOCA Accumulative Supplement are consistent with the NEHRP Recommended Provisions.

Generally, seismic provisions in the 1992 Accumulative Supplement to the BOCA National Building Code are an editorial revision of the 1988 and 1991 NEHRP Provisions. A considerable effort was made to revise and reformat the text and the tables of the NEHRP Provisions such that the requirements are easily understood and cross referenced. Vague, unenforceable language in the 1988 NEHRP Provisions was revised or deleted. The requirements for each Seismic Performance Category were clearly defined.

As a result of the BOCA/BSSC Ad Hoc committee effort, the 1991 NEHRP Provisions and the ASCE 7 Standard (formerly ANSI A58.1), "Minimum Design Loads for Buildings and Other Structures" are currently being revised such that their format is consistent with the BOCA National Building Code 1992 Accumulative Supplement.

C. COMPARISON OF
BOCA NATIONAL BUILDING CODE/1990
with 1992 ACCUMULATIVE SUPPLEMENT
TO
THE 1988 NEHRP PROVISIONS

The 1988 NEHRP to BOCA and the BOCA to NEHRP cross index provides a section by section comparison of the two documents. Generally, the sections in the 1992 Accumulative Supplement to the BOCA National Building Code are the same as the companion NEHRP sections of the resource document. Where the comparison of the technical content indicated substantive differences, a tabulation of those items is included in Section C3 of this report.

The seismic provisions in the 1992 Accumulative Supplement to the BOCA National Building Code and equivalent to the 1988 NEHRP Recommended Provisions. The seismic provisions in the BOCA 1992 Accumulative Supplement are included in the Appendix.

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1308.8	1.6.2.1
1308.9	1.6.2.8
1308.10	1.6.2.9
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BOCA NATIONAL BUILDING CODE	NEHRP
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1705.4.7.1	9.8.4.2
1705.4.7.1.1	Table 9-1 Note a

BOCA NATIONAL BUILDING CODE	NEHRP
1705.4.7.1.2	Table 9-1 Note c
1705.4.7.1.3	Table 9-1 Note d
1705.4.7.1.4	Not in NEHRP
1705.4.7.2 through 1705.4.7.2.4	Not in NEHRP
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Steel (Chapter 10, NEHRP)

BOCA provisions written for up to date steel reference standards versus the noncurrent standards referenced in NEHRP-88.

1809.1	Appendix to Chapter 10 and 10.9
1809.2	10.2
1809.3	10.3
1809.4	10.4
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1809.4.2	10.4.2
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1809.8	10.8
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1807.2.1	10.2.3

C3. SECTIONS WHICH MERIT COMPARISON COMMENTS

The following sections are not technically the same in the 1992 BOCA Accumulative Supplement to the National Building Code versus the 1988 NEHRP Provisions and thus merit comparison comments. Revisions to the BOCA National Building code are not required for the reasons indicated in the comparison comments.

ITEM	ITEM DESCRIPTION	NEHRP SECTION #	BOCA SECTION #	COMPARISON COMMENTS
Building Change of Use	Application of NEHRP Provisions to Existing Buildings which have a change of use.	1.3.3	1113.1.2	The NEHRP Provisions require existing buildings to comply with the "New Building" seismic requirements when a change of use results in building reclassification to a higher Seismic Hazard Exposure Group, regardless of site seismicity. The BOCA National Building Code has an exception which does not require existing buildings to be upgraded for the new building seismic requirements where the effective peak velocity-related acceleration, coefficient (A_v), is less than 0.15 when the change of use results in a building being reclassified from Seismic Hazard Exposure Group I to Seismic Hazard Exposure Group II. The BOCA exception is included in the 1991 NEHRP Provisions.
Alternative Seismic Risk Maps	NEHRP Alternative Seismic Risk Maps in Appendix to Chapter 1	Appendix to Chapter 1	Not in BOCA National Building Code	NEHRP Appendix to Chapter 1 contains alternative seismic risk maps (Figures 1-5 through 1-8) for trial use and comment. The maps define acceleration and velocity in rock and do not include the effect of soil amplification and attenuations. These "trial" maps, while appropriate for a resource document, (i.e., the NEHRP Provisions) are not appropriate for a model building code.
Symbol definitions	Symbol listing and definitions	2.2	Symbols are defined each time they are included in the text	The symbol listing and definitions in NEHRP are addressed in the BOCA National Building Code by providing a definition of the symbol each time it is used in the text. This is necessary since symbols have different definitions in NEHRP for the design chapters versus the material chapters.

ITEM	ITEM DESCRIPTION	NEHRP SECTION #	BOCA SECTION #	COMPARISON COMMENTS
Soil Structure Interaction	Soil Structure Interaction Detailed Analysis Criteria	Appendix to Chapter 6	Not in BOCA National Building Code	Section 1113.3 of the BOCA National Building Code permits alternative procedures to establish the design seismic forces when approved by the code official. Thus, a soil-structure analysis is generally addressed by the Code. As indicated in the NEHRP Commentary, Section 6A.1, the detailed analysis procedure in NEHRP Appendix to Chapter 6 is one of at least two different approaches of soil-structure interaction analysis. The detailed criteria in NEHRP is not a mandatory requirement. It is resource document information which is not appropriate as a mandatory requirement in the BOCA National Building Code and thus is not be included in the BOCA seismic design requirements.
Architectural, Mechanical and Electrical Components	Threshold for Component Support Requirements	8.1	1113.6	The NEHRP Provision requirements for component supports is more stringent than the design requirements for the building seismic resisting system. Section 8.1 requires that Seismic Hazard Exposure Group III buildings located where A_v is less than 0.05 have component support systems designed for seismic loads in Chapter 8. Section 3.6.1 of NEHRP exempts building assigned to Seismic Performance Category A (i.e., buildings where $A_v < 0.05$) from seismic analysis of the building as a whole. The BOCA Ad Hoc Committee on Earthquake Loads modified the NEHRP requirements of Section 8.1 for the BOCA National Building Code such that components in buildings assigned to low Seismic Performance Categories are exempt, which is consistent with the design requirements for the building as a whole.
Architectural, Mechanical and Electrical Components	Interrelationship of Components	8.1.1	1113.6.3, 1113.6.3.2 and 1113.6.4	The referenced sections in the BOCA National Building Code require architectural, mechanical and electrical components and their supports to be designed for earthquake loads. The NEHRP Commentary (page 168), indicates that secondary effects of falling building components should be left for future development of the NEHRP Provisions.

ITEM	ITEM DESCRIPTION	NEHRP SECTION #	BOCA SECTION #	COMPARISON COMMENTS
Architectural Components	Architectural Components Classifications	Table 8-2	Table 1113.6.3	Table 8-2 of the NEHRP Provisions contain architectural component classifications which are ambiguous and appear to be too refined for an equivalent static force design method. For example, "full-height area separation partitions" have a 50% higher design force requirement than "full-height other partitions". The NEHRP Provisions classify partitions into 9 types; each having different requirements. The description of architectural components is not consistent with the language used in other sections of the BOCA National Building Code. The BOCA Ad Hoc Committee on Earthquake Loads modified the classifications of Table 8-2 to be consistent with code language. Table 8-2 of 1988 NEHRP has been revised in the 1991 NEHRP Provisions.
Mechanical & Electrical Components	Component amplification factor for building height and classifications of Mechanical components	8.3.2 and Table 8-3	1113.6.4, Table 1113.6.4a	The NEHRP Provisions contain a building height amplification factor, (A_x), which result in identical amplifications for components located in the top story of 2 story buildings (i.e., 200%) and those in the top story of a building with additional stories. The BOCA Ad Hoc Committee on Earthquake Loads deleted the building height amplification factor and assigned increased force requirements for components which are essential for life safety by the relative values of the component seismic coefficient (C_c) and the Performance Criteria Factor (P). The height amplification factor, (A_x), has been deleted in the 1991 NEHRP Provisions. Table 8-3 in NEHRP contains requirements for fire suppression piping which is unclear. The Table requires seismic supports for "Fire suppression systems" and exempts "piping distribution systems" for buildings assigned to seismic Hazard Exposure Group I. In addition, Note d of Table exempts "all" piping seismic restraints under certain conditions. The BOCA Ad Hoc Committee on Earthquake Loads modified the requirements for the BOCA National Code to require all fire suppression piping to be designed for seismic loads.

ITEM	ITEM DESCRIPTION	NEHRP SECTION #	BOCA SECTION #	COMPARISON COMMENTS
Utility and Service Interfaces	Shutoff Devices and Utility Connections	8.3.5	Not In BOCA	NEHRP requires shutoff devices for all gas, high-temperature energy and electrical supply for certain buildings where the effective ground acceleration coefficient, A_v is equal to or greater than 0.15. The BOCA Ad Hoc Committee on Earthquake Loads determined that this requirement is not appropriate for the BOCA National Building Code for the following reasons: 1. It is necessary to maintain utility service for Seismic Hazard Exposure Group III buildings such that post earthquake recovery operations are not affected. 2. Manual shut-off devices are commonly installed. 3. An automatic shut-off device does not provide building site safety if the gas piping supply line fails outside of the building. NEHRP requires flexible connections for utilities at the interface of movable portions of the structure. The BOCA Ad Hoc Committee determined that this requirement is not appropriate for the BOCA National Building Code for the following reasons: A flexible connection is not the only means of providing for building movement and the resulting effect on utility lines, pipe failure could occur outside of the building foundation and the NEHRP requirement applies to buildings located in areas of low seismicity which is inappropriate.
Steel LRFD Design	American Institute of Steel Construction Load and Resistance Factor Design Specification of Seismic Provisions for Structural Steel Buildings. (AISC - LRFD seismic provisions)	Appendix to Chapter 10	1809.1, 1809.1.1	The 1988 NEHRP Provisions modify the requirements of the 1986 AISC - LRFD Design Specification. The BOCA National Building Code references the 1990 AISC - LRFD Seismic Provisions which have been developed after the publication of the 1988 NEHRP Provisions. The 1990 AISC - LRFD seismic provisions are the basis for the 1991 NEHRP Provisions. The BOCA National Building Code modifies the AISC - LRFD seismic provisions such that they are consistent with the NEHRP language. This is necessary since the text of the AISC - LRFD seismic provisions were written to correlate with the American Society of Civil Engineers "Minimum Design Loads for Buildings and other Structures", ASCE 7-88.

ITEM	ITEM DESCRIPTION	NEHRP SECTION #	BOCA SECTION #	COMPARISON COMMENTS
Concrete Design	Modifications to ACI 318	11.1.1	1501.1	The 1988 NEHRP Provisions reference ACI 318-83. The BOCA National Building Code references ACI 318-89. Thus, the modifications of ACI 318-89 in the BOCA National Building Code reflect the contents of the updated standard. The ACI-89 standard is the reference for the 1991 NEHRP Provisions.
Design data on contract documents	Required design criteria to be included on the design professionals' plans	Not in NEHRP	1101.6	The BOCA National Building Code requires earthquake design criteria be included on the construction documents which are submitted for a building permit. The earthquake design criteria used for the seismic design of the building is required to meet the requirements of the BOCA National Building Code. The NEHRP Provisions do not include a requirement for earthquake design criteria on the construction documents.
Particleboard Shear Walls	Detailed requirements and allowable shear for particleboard shear walls	Not in NEHRP	1705.4.7.2 through 1705.4.7.2.4	The BOCA National Building Code contains requirements for connection details and allowable shear for particleboard shear walls. The NEHRP Provisions do not contain these requirements. The limitations on the use of the particleboard shear walls is the same in NEHRP and the BOCA National Building Code.
Site-specific response spectra	Spectra requirements for certain buildings in Seismic Performance Category D and E.	Not in NEHRP	1113.1.4	The referenced section in BOCA requires that a site-specific response spectra be used for certain Seismic Performance Category D and E buildings. This requirement is incorporated in the 1991 NEHRP Provisions.
Allowable stresses for wood	Working stress versus factored stress design	9.2	1705.3	BOCA does not increase the allowable stresses for wood seismic design, NEHRP uses increased allowable stresses. Since the seismic loads in BOCA are the same as NEHRP, wood design requirements in BOCA are more stringent than NEHRP.
1991 NEHRP Revisions	Revisions to the 1988 NEHRP Provisions which are included in the 1991 NEHRP Provisions	Not in 1988 NEHRP	Various	The 1992 BOCA Accumulative Supplement includes the revisions to the 1988 NEHRP Provisions which are included in the 1991 NEHRP Provisions.

ITEM	ITEM DESCRIPTION	NEHRP SECTION #	BOCA SECTION #	COMPARISON COMMENTS
Sprinkler pipe bracing	Alternate use of NFiPA 13 standard	8.3.1 and 8.3.2	1113.6.4	The BOCA National Building Code provisions include the alternative use of the standard sprinkler pipe bracing design in accordance with the NFiPA 13 standard. The use of the NFiPA standard for seismic bracing is limited to buildings sited where the effective peak velocity-related acceleration, A_v, is less than 0.20. NEHRP does not include this design alternative. The NFiPA 13 standard is based on an $A_v > 0.20$ and thus is technically justified for low or moderate seismic areas.

C4 REPORT CONCLUSIONS

The following conclusions are a result of the comparison study:

- The seismic provisions in the 1992 Accumulative Supplement to the 1990 BOCA National Building Code are generally an editorial revision of the 1988 and 1991 NEHRP Recommended Provisions.
- The seismic provisions in the 1992 Accumulative Supplement to the 1990 BOCA National Building Code are appropriate for use, without modification, in meeting the requirements of Executive Order 12699, "Seismic Safety of Federal and Federally Leased, Assisted, or Regulated New Construction".

A

Comparison Between

The 1988 NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings

And

The 1991 SBCCI Standard Building Code with 1992 Proposed Amendments

August 16, 1991

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SBCCI EARTHQUAKE LOADS AD HOC COMMITTEE
PROPOSED 1992 CHANGES

In consideration of the state of the technology of the NEHRP Provisions, an SBCCI Earthquake Ad Hoc Committee was formed to evaluate the 1988 NEHRP Provisions for incorporation in the 1992 Revisions of the SBCCI Standard Building Code.

The code change was necessary to update the present code text, which was based on ASCE 7, to the provisions of the NEHRP Provisions. The 1988 NEHRP Provisions were prepared by the Building Seismic Safety Council (BSSC) for the Federal Emergency Management Agency. The SBCCI Earthquake Loads Ad Hoc Committee reviewed the NEHRP Provisions and prepared the code change which reflects the state of the art design criteria for seismic design.

The resulting code change proposals were recommended for approval by the SBCCI Building Code Revisions Committee in July 1991 and later approved by the SBCCI membership.

*Preparer's Comment: When a comment does not appear in the "Comment" column, both NEHRP and SBCCI are considered to be comparable. An * next to the section number designates that the section is found in the 1991 Edition of the Standard Building Code.*

NEHRP/SBCCI COMPARISON

NEHRP		SBCCI
Chapter 1	General Provisions	1206.1
Chapter 2	Definitions and Symbols	1206.2
Chapter 3	Structural Design Requirements	1206.3
Chapter 4	Equivalent Lateral Force Procedure	1206.4
Chapter 5	Modal Analysis Procedure	1206.5
Chapter 6	Soil-Structure Interaction	1206.3
Chapter 7	Foundation Design Requirements	1302.5, 1302.9, 1303.10, 1305.4, 1306.4, 1307.1, 1307.5, 1308.3, 1311.7
Chapter 8	Architectural, Mechanical, and Electrical Components and Systems	1206.6
Chapter 9	Wood	1707, 1710.3, 1710.4, 1711.3, 1712
Chapter 10	Steel	1503.3, 1503.4, 1506.2, 1512
Chapter 11	Reinforced Concrete	1611
Chapter 12	Masonry	1413

NEHRP/SBCCI COMPARISON

CHAPTER 1 - GENERAL PROVISIONS

NEHRP	SBCCI	COMMENT
1.1	N/A	Commentary not appropriate for the Code.
1.2	1206.1.1 1706.1	
N/A	1206.1.2	
1.3	1206.1.1	
1.3.1	1206.1.1	
1.3.2	1206.1.3	
1.3.2.1	1206.1.3	
1.3.2.2	1206.1.3	
1.3.2.3	1206.1.3	
1.3.3	101.5.2* 1206.1.4	
1.3.4	101.5.1*	
1.4	1206.1.8	
1.4.1	1206.1.5	
1.4.1.1	Not in SBCCI	SBC will not use maps 1-1 and 1-2.
1.4.1.2	1206.1.5	
1.4.2	1206.1.6	
1.4.2.1	1206.1.6	
1.4.2.2	1206.1.6	
1.4.2.3	1206.1.6	
1.4.2.4	1206.1.6.1	NEHRP assigns the building to the classification of the SHEG that occupies 15% or more of the building area. SBCCI does not have percentage.
1.4.2.5	1206.1.7	
1.4.2.6	Not in SBCCI	General language, not enforceable.
1.4.3	1206.1.4 1206.1.8	
1.4.4	1206.1.9	
1.5	102.7*	
1.6	1206.15	
1.6.1	Not in SBCCI	SBC will not have specific QA provisions.
1.6.1.1	Not in SBCCI	SBC will not have specific QA provisions.

NEHRP/SBCCI COMPARISON

NEHRP	SBCCI	COMMENT
1.6.1.2	Not in SBCCI	SBC will not have specific QA provisions.
1.6.2	Not in SBCCI	SBC will not specify a special inspector.
1.6.2.1	1206.15.6	
1.6.2.2	1206.15.3	
1.6.2.2.1	1206.15.3	
1.6.2.2.2	1206.15.3	
1.6.2.2.3	1206.15.3	
1.6.2.3	1206.15.3 1303.12*	
1.6.2.4	1206.15.3	
1.6.2.5	1206.15.4	
1.6.2.6	1206.15.1	
1.6.2.6.1	1206.15.1	
1.6.2.6.2	1206.15.2	
1.6.2.7	1206.15.5	
1.6.2.8	1206.15.7	SBCCI requires inspection of only Seismic Performance Category E buildings.
1.6.2.8.1	1206.15.7	
1.6.2.8.2	1206.15.7	
1.6.2.9	1206.15.8 1206.15.8.1	
1.6.3	Not in SBCCI	SBC contains testing provisions through materials standards.
1.6.3.1	Not in SBCCI	Testing required per ACI 318.
1.6.3.2	Not in SBCCI	Testing required per ACI 318.
1.6.3.3	Not in SBCCI	Testing required per ACI 530/ASCE 5.
1.6.3.4	1206.15.1	
1.6.3.4.1	1206.15.1.1	
1.6.3.4.2	1206.15.1.2	
1.6.3.4.3	1206.15.1.3	
1.6.3.5	1206.15.8.2	
1.6.4	Not in SBCCI	
1.6.5	1206.15.8.3	
Appendix to Chapter 1	N/A	Alternate methods covered in 102.7

NEHRP/SBCCI COMPARISON

CHAPTER 2 — DEFINITIONS AND SYMBOLS

NEHRP	SBCCI	COMMENT
2.1	1206.2	SBC will only add those definitions specific to seismic loading.
2.2	N/A	Symbols are defined where they are used.
2.3	N/A	Not appropriate to SBCCI.

NEHRP/SBCCI COMPARISON

CHAPTER 3 — STRUCTURAL DESIGN REQUIREMENTS

NEHRP	SBCCI	COMMENT
3.1	1206.3	
3.2	1206.3.1	
3.2.1	1206.3.1	
3.2.1.1	1206.3.1	
3.2.1.2	1206.3.1	
3.2.1.3	1206.3.1	
3.2.1.4	1206.3.1	
3.2.2	1206.3.1	
3.2.3	1206.3.2	
3.3	1206.3.3 1206.3.3.1	
3.3.1	1206.3.3	
3.3.2	1206.3.3.2	
3.3.2.1	1206.3.3.2.1	
3.3.2.2	1206.3.3.2.2	
3.3.3	1206.3.3.3	
3.3.4	1206.3.3.4	
3.3.4.1	1206.3.3.4.1	NEHRP applies to buildings over 160 feet in height but less than 240 feet. SBCCI does not have a minimum building height.
3.3.4.1.1	1206.3.3.4.1	
3.3.4.1.2	1206.3.3.4.1	
3.3.4.1.3	1206.3.3.4.1	
3.3.4.2	1206.3.3.4.2	
3.3.4.3	1206.3.3.4.3	
3.3.4.4	1206.3.3.4.4	
3.3.5	1206.3 3.5	
3.4	1206.3.4	
3.4.1	1206.3.4.1	
3.4.2	1206.3.4.2	SBCCI exempts 1 and 2 story buildings with irregularity Type 1 and 2.
3.5	1206.3.5	
3.5.1	1206.3.5.1	
3.5.2	1206.3.5.2	

NEHRP/SBCCI COMPARISON

NEHRP	SBCCI	COMMENT
3.5.3	1206.3.5.3	
3.6	1206.3.6	
3.6.1	1206.3.6.1	
3.6.2	1206.3.6.2 1206.3.6.3	
3.6.2.1	1206.3.6.2 1208.1	
3.6.2.2	1206.3.6.2.1	
3.6.2.3	1206.3.6.2.2	
3.6.3	1206.3.6.4	
3.6.3.1	1206.3.6.4	
3.6.3.2	1206.3.6.4	
3.6.4	1206.3.6.4	
3.7	1208.1	
3.7.1	1208.1	
3.7.2	1206.3.6.2.3 1206.3.6.4.1	
3.7.3	1206.3.6.2.4	
3.7.4	1206.3.6.2.5	
3.7.5	1206.3.6.1.1 1206.3.6.4.2	
3.7.6	1206.3.6.1.2	
3.7.7	1206.6.3	
3.7.8	1206.3.6.2.6	
3.7.9	1206.3.6.2.7	
3.7.10	1206.3.6.2.8	
3.7.11	1206.3.6.2.9	
3.7.12	1206.3.6.4.3	
3.8	1206.3.7	

NEHRP/SBCCI COMPARISON

CHAPTER 4 — EQUIVALENT LATERAL FORCE PROCEDURE

NEHRP	SBCCI	COMMENT
4.1	1206.4	
4.2	1206.4.1	SBCCI provides an exception for the floor live load in parking garages.
4.2.1	1206.4.1.1	
4.2.2	1206.4.1.2	
4.2.2.1	1206.4.1.2.1	
4.2.2.2	1206.4.1.2.2	
4.3	1206.4.2	
4.4	1206.4.3	
4.4.1	1206.4.3.1	
4.5	1206.4.4	
4.6	1206.4.5	
4.6.1	1206.4.5.1	
4.6.2	1206.4.5.2	

NEHRP/SBCCI COMPARISON

CHAPTER 5 — MODAL ANALYSIS PROCEDURE

NEHRP	SBCCI	COMMENT
5.1	1206.5.1	
5.2	1206.5.2	
5.3	1206.5.3	
5.4	1206.5.4	
5.5	1206.5.5	
5.6	1206.5.6	
5.7	1206.5.7	
5.8	1206.5.8	
5.9	1206.5.9	
5.10	1206.5.10	
5.11	1206.5.11	

NEHRP/SBCCI COMPARISON

CHAPTER 6 — SOIL-STRUCTURE INTERACTION

NEHRP	SBCCI	COMMENT
Chapter 6	1206.3.2	
Appendix to Chapter 6	N/A	Detailed soil-structure analysis is not appropriate for the Code.

NEHRP/SBCCI COMPARISON

CHAPTER 7 — FOUNDATION DESIGN REQUIREMENTS

NEHRP	SBCCI	COMMENT
7.1	N/A	Commentary not appropriate for the Code.
7.2	1302.4.2	
7.2.1	Not in SBCCI	Similar general statements are found in SBC Ch. 12.
7.2.2	1302.9.2	
7.3	1302.4.2*	
7.4	Not in SBCCI	Understood as a general provision.
7.4.1	1302.2* 1303.1*	
7.4.2	Not in SBCCI	
7.4.3	1302.5.4 1303.10.2.1 1303.10.2.2 1303.10.2.3 1303.10.2.4 1306.4.2 1307.1.4 1307.5.5 1311.7	
7.4.4	1303.10.2.2 1303.10.2.3	
7.4.4.1	1307.1.4	
7.4.4.2	1307.1.4	
7.4.4.3	1306.4.2	
7.4.4.4	1308.2*	
7.4.4.5	1308.3*	
7.5	Not in SBCCI	Understood as a general provision.
7.5.1	1302.4.2* 1303.1* 1302.9.1 1302.9.3	
7.5.2	1302.5.3	
7.5.3	1303.4.2	
7.5.3.1	1307.1.4	
7.5.3.2	1307.5.5	
7.5.3.3	1308.3.6 1308.3.7	

NEHRP/SBCCI COMPARISON

NEHRP	SBCCI	COMMENT
7.5.3.4	1308.3.6 1308.3.7	
7.5.3.5	1305.4	

NEHRP/SBCCI COMPARISON

CHAPTER 8 — ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS AND SYSTEMS

NEHRP	SBCCI	COMMENT
8.1	1206.6	
8.1.1	1201.1.2*	
8.1.2	1206.6.2	
8.1.3	1206.6.3	SBCCI does not classify the Performance Criteria as Superior, Good, or Low. It classifies them as values of 1.5, 1.0, and 0.5 only.
8.2	1206.6.3	
8.2.1	1206.6.3	
8.2.2	1206.6.3	
8.2.3	1206.6.3.1	
8.2.4	1206.6.3.2	
8.2.5	Not in SBCCI	General engineering principle.
8.2.6	1202.3*	
8.3 Table 8-3(b)	1206.6.4 1206.6.1	
8.3.1	1206.6.4	
8.3.2	1206.6.4 1206.6.4.1	
8.3.3	1206.6.4.2	
8.3.4	1206.6.4.3	
8.3.5	Not in SBCCI	
8.3.5.1	Not in SBCCI	
8.3.5.2	Not in SBCCI	
8.4	1206.6.5	
8.4.1	1206.6.5	
8.4.2	Not in SBCCI	
8.4.3	Not in SBCCI	
8.4.4	Not in SBCCI	
8.4.5	Not in SBCCI	
8.4.6	Not in SBCCI	

NEHRP/SBCCI COMPARISON

CHAPTER 9 — WOOD

NEHRP	SBCCI	COMMENT
9.1	1701.2.5*	
9.2	1712.3	
9.3	Not in SBCCI	General provision implied by text.
9.3.1	T. 1707.2.2A	
9.4	Not in SBCCI	General provision implied by text.
9.4.1	Not in SBCCI	General provision implied by text.
9.4.1.1	1712.4.3.1	
9.4.1.2	1712.3.3	
9.5	Not in SBCCI	General provision implied by text.
9.5.1	1712.4.6	
9.5.2	Not in SBCCI	General provision implied by text.
9.5.2.1	1712.4.3	
9.5.2.2	1712.4.8	NEHRP limits its use to one-story buildings or the top story of buildings two stories or more in height.
9.5.2.3	T. 1707.2.2A	
9.5.3	1712.3.1 1712.3.2	
9.6	Not in SBCCI	General provision implied by text.
9.6.1	1712.4.4.2	
9.6.2	1712.4.3.2	
9.6.3	1712.4.2.4 1712.4.4.2	
9.7	Not in SBCCI	General provision implied by text.
9.7.1	Not in SBCCI	General provision implied by text.
9.7.1.1	1706.1	
9.7.1.2	1707.1.5	
9.7.1.3	1707.1.6	
9.7.2	1707.2.2 T. 1707.2.2A	
9.7.3	Not in SBCCI	General provision implied by text.
9.7.3.1	T. 1707.2.2B	
9.7.3.2	T. 1707.2.2B T. 1707.1A*	

NEHRP/SBCCI COMPARISON

NEHRP	SBCCI	COMMENT
9.7.3.3	T. 1707.2.2B	
9.7.3.4	T. 1707.2.2B	
9.7.3.5	T. 1707.2.2B T. 1707.1B*	
9.7.3.6	T. 1707.2.2B	
9.8	1712.1 1712.4	
9.8.1	1712.4.1	
9.8.2	1712.4.4 1712.4.4.1	
9.8.2.1	1712.4.2.1 1712.4.2.2 1712.4.2.3	
9.8.2.2	1712.4.2.5	SBCCI defines torsional irregularity as the lateral stiffness ratio greater than 4 to 1.
9.8.3	1712.4.5	
9.8.3.1	1712.4.5.1 1712.4.5.1.1 1712.4.5.1.2	
9.8.3.2	1712.4.5.2	
9.8.4	1712.4.6	
9.8.4.1	1712.4.6	
9.8.4.2	1712.4.6 1710.3 1710.4	
9.8.5	1707.2.5 1712.4.8	
9.8.6	1206.3.6.1.2	
T. 9-1	T. 1710.2A*	
T. 9-2	T. 1710.2B*	
T. 9-3	1707.2.5 T. 1707.2.5	
T. 9-4	1805.1.1	

NEHRP/SBCCI COMPARISON

CHAPTER 10 — STEEL

NEHRP	SBCCI	COMMENT
10.1	1502*, 1503*, 1504*, 1505*, 1506*	
10.2	1512.2 1512.2.1(1) 1503.4.2	
10.2.1	1512.2.1	
10.2.1.1	1512.2.1(1)	
10.2.1.2	1512.2.1(2)	
10.2.1.3	1512.2.1(3)	
10.2.1.4	1512.2.1(4)	
10.2.1.5	1512.2.1(5)	
10.2.2	1503.3	
10.2.2.1	1503.3	
10.2.2.1.1	1503.3(1)	
10.2.2.1.2	1503.3(2)	
10.2.2.2	1503.3(3)	
10.2.2.3	1503.4.1	NEHRP permits the strength value to be the tested strength values defined as the mean minus two times the standard deviation of at least three tests.
10.2.3	1506.2	
10.3	1512.3	
10.4	1512.4	
10.4.1	1512.4.1	
10.4.2	1512.4.2	
10.5	1512.5	
10.5.1	1512.5.1	
10.5.2	1512.5.2	
10.6	1512.6	
10.6.1	1512.6.1	
10.6.2	1512.6.2	
10.7	1512.7	
10.7.1	1512.7(1)	
10.7.2	1512.7(2)	

NEHRP/SBCCI COMPARISON

NEHRP	SBCCI	COMMENT
10.7.3	1512.7(3)	
10.7.4	1512.7(4)	
10.7.5	1512.7(5)	
10.7.6	1512.7(6)	
10.7.7	1512.7(7)	
10.8	1512.8(3.0)	
10.8.1	1512.8 (3.1-3.4)	
10.8.1.1	1512.8 (3.1)	
10.8.1.2	1512.8 (3.2)	
10.8.1.3	1512.8 (3.3)	
10.8.1.4	1512.8 (3.4)	
10.8.2	1512.8 (3.5)	
10.8.3	1512.8 (3.6)	
10.8.4	1512.8 (3.7)	
10.8.4.1	1512.8 (3.8)	
10.8.4.2	1512.8 (3.9)	
10.8.4.3	1512.8 (3.10)	
10.8.5	1512.8 (3.11)	NEHRP simply requires the bolts to be fully tightened. SBCCI requires the bolts to be tightened per AISC-ASD for slip critical connections.
10.9	1512.9	NEHRP lists 26 different provisions for eccentrically braced frames. SBCCI simply requires the frames which are designed in accordance with the AISC-ASD specification to comply with Section 9 of the AISC-LRFD Seismic Provisions.

Appendix to Chapter 10 - Load and Resistance Factor Design

NEHRP	SBCCI	COMMENT
10A.7	1512.7	
10A.7.1	1512.7(1)	
10A.7.2	1512.7(2)	
10A.7.3	1512.7(3)	
10A.7.4	1512.7(4)	
10A.7.5	1512.7(5)	
10A.7.6	1512.7(6)	
10A.7.7	1512.7(7)	

NEHRP/SBCCI COMPARISON

CHAPTER 11 — REINFORCED CONCRETE

NEHRP	SBCCI	COMMENT
11.1	1611.1	
11.1.1	1611.1.1	
11.1.1.1	1611.1.1(2)	
11.1.1.2	1611.1.1(4)	
11.1.1.3	1611.1.1(5)	
11.1.1.4	1611.1.1(6)	NEHRP also addresses the welding of reinforcing steel.
11.1.1.5	1611.1.1(7)	
11.1.1.6	1611.1.1(8)	
11.1.1.7	1611.1.1(9)	
11.1.1.8	1601.2*	SBC 1601.2 references ACI 318-89, Chapter 21, revised to agree with NEHRP 11.1.1.8, 11.1.1.9, 11.1.1.11, 11.1.1.12, 11.1.1.13 and 11.1.1.15.
11.1.1.9	1601.2*	
11.1.1.10	1611.1.1(10)	
11.1.1.11	1601.2*	
11.1.1.12	1601.2*	
11.1.1.13	1601.2*	
11.1.1.14	1611.1.1(2)	
11.1.1.15	1601.2*	
11.1.1.16	1611.1.1(12)	NEHRP says "intermediate ductility frames." SBCCI says "intermediate moment frames."
11.1.1.17	Not in SBCCI	General statement implied in text.
11.2	1611.2 1611.2.1 1611.2.2	
11.3	1611.3 1611.3.1	
11.4	1611.3 1611.3.2	
11.5	1611.3 1611.3.3	
11.6	1611.4	
11.7	1611.4	
11.8	1611.5	
11.8.1	1611.5.1	

NEHRP/SBCCI COMPARISON

NEHRP	SBCCI	COMMENT
11.8.2	1611.5.2	
11.9	1611.6	
11.9.1	1611.6.1	
11.9.2	1611.6.2	
11.9.3	1611.6.3	

NEHRP/SBCCI COMPARISON

CHAPTER 12 — MASONRY

NEHRP	SBCCI	COMMENT
Chapter 12	1413.1	
12.1	1413.2	
12.1.1	1413.3	
12.2	1413.4	
12.3	1413.5	
12.4	1401*	
12.5	1413.6	
12.6	1413.7	
12.6.1	1413.7	
12.6.1.1	1413.7.1	
12.6.1.2	1413.7.2	
12.6.1.2.1	1413.7.2(1)	
12.6.1.2.2	1413.7.2(2)	
12.6.2	1413.7.3	
12.7	1413.8	
12.7.1	1413.8.1	
12.7.2	1413.8.2	
12.7.2.1	1413.8.2(1)	
12.7.2.2	1413.8.2(2)	
12.8	1413.9	
12.8.1	1413.9.1	
12.8.1.1	1413.9.1.1	
12.8.1.2	1413.9.1.2	
12.8.1.2.1	1413.9.1.2(1)	
12.8.1.2.2	1413.9.1.2(2)	
12.8.1.2.3	1413.9.1.2(3)	

NEHRP/SBCCI COMPARISON

SBCCI PROVISIONS NOT FOUND IN NEHRP

1206.1.2 Required Design Data. Where earthquake loads are applicable, the following design data shall be indicated on the design drawings:

1. The peak velocity related acceleration, A_v, according to 1206.1.5.
2. The peak acceleration, A_a, according to 1206.1.5.
3. The seismic hazard exposure group according to 1206.1.6.
4. The Seismic Performance Category according to 1206.1.8.
5. The soil profile type according to Table 1206.3.1.
6. The basic structural system and seismic resisting system according to Table 1206.3.3.
7. The response modification factor, R, and the deflection amplification factor, C_d, according to Table 1206.3.3.
8. The analysis procedure utilized in accordance with 1206.4 or 1206.5 as applicable.

1206.3.6.3.1 Plan Irregularity. Buildings which have plan structural irregularity Type 5 in Table 1206.3.4.1 shall be analyzed for seismic loads in directions other than the principal axes.

1611.1.1 Modifications to ACI 318. The sections of ACI 318 shall be modified as indicated in items 1 through 12.

1. Modify Section 8.1.2 to read: "Except where load combinations of Standard Building Code 1208 including seismic forces are used, design of nonprestressed reinforced concrete members using Appendix A, Alternate Design Method, is permitted."

3. Add the following definitions to Section 21.1 of ACI 318:

   "Confined region: That portion of a reinforced concrete component in which the concrete is confined by closely spaced special transverse reinforcement restraining the concrete in directions perpendicular to the applied stress."

   "Joint: That portion of a column bounded by the highest and lowest surfaces of the other members framing into it."

   "Special transverse reinforcement: Reinforcement composed of spirals, closed stirrups, or hoops and supplementary cross-ties provided to restrain the concrete and qualify the portion of the component, where used, as a confined region."

11. Modify Section 21.7.1.3 to read: "The design shear force, (V_u), shall be obtained from the lateral load analysis in accordance with the factored loads and combinations of loads specified in 1114.0."

1712.2 Definitions

The following words and terms shall apply to the provisions of this section and have the following meanings:

Blocked diaphragm: A diaphragm in which all sheathing edges not occurring on a framing member are supported on and connected to blocking.

Diaphragm: A horizontal or nearly horizontal system designed to transmit lateral forces to the vertical elements of the seismic resisting system.

Wood shear panel: A wood floor, roof, or wall component sheathed to act as a shear wall or diaphragm.

1711.3 Particleboard Floor and Roof Diaphragm Construction

1711.3.1 The nail size and spacing at diaphragm boundaries and the edges of each sheet of particleboard shall be as shown in Table 1711.2A and shall be designed in accordance with the provisions of this section. Nails of the same size shall be placed along all intermediate framing members at 10 inches on center for floors and 12 inches for roofs.

1711.3.2 Shear capacities for fasteners in framing members of other wood species, shall be calculated by multiplying the shear capacities by 0.82 for Group III species and 0.65 for Group IV species, contained in the NFoPA NDS.

1711.3.3 The orientation of the structural framing and particleboard panels shall comply with Case 1, 2, 3, 4, 5, or 6 in Table 1711.2A.

1711.3.4 When either 2 inch or 2½ inch fastener spacings are used with 2-inch wide framing members in accordance with Table 1711.2A, the framing member adjoining panel edges shall be 3-inch nominal width and nails at panel edges shall be placed in two lines.

1711.3.5 Framing at adjoining panel edges shall be 3-inch nominal or wider and nails shall be staggered where 10d nails having penetration into framing of more than 1 5/8 inches are spaced 3 inches or less on center.

1711.4 Particleboard Shear Wall Construction.

1711.4.1 Nailing. The required nail size and spacing in Table 1711.2B apply to panel edges only. All panel edges shall be backed with 2-inch nominal or wider framing. Sheets are permitted to be installed either horizontally or vertically. For 3/8-inch particleboard sheets installed with the long dimension parallel to studs spaced 24 inches on center, nails shall be spaced at 6 inches on center along intermediate framing members. For all other conditions, nails of the same size shall be spaced at 12 inches on center along intermediate framing members.

1711.4.2 Other Wood Species. Shear capacities for fasteners in framing members of other wood species, shall be calculated by multiplying the shear capacities by 0.82 for Group III species and 0.65 for Group IV species as contained in the NFoPA NDS .

1711.4.3 Framing. Framing shall be 3-inch nominal or wider and the nails shall be staggered where nails are space 2 inches on center or where 10d nails, having a penetration into framing of more than 1 5/8 inches, are used with a 3-inch nail spacing.

1711.4.4 Shear Capacity Increase. The shear capacities for 3/8 inch and 7/16-inch particleboard applied direct to framing with 8d nails, are permitted to be increased to the 1/2-inch particleboard shear capacities of Table 1711.2B when the framing studs are spaced a maximum of 16 inches on center or the particleboard is applied with the long dimension perpendicular to the studs.

1711.4.5 Offset Joints. Where particleboard is applied to both faces of a wall and the nail spacing is less than 6 inches on center on either side, panel joints shall be offset to be placed on different framing members, or framing shall be 3-inch nominal or thicker and nails on each side shall be staggered.

1712.4.7 Particleboard Shear Panels. The design shear capacity of particleboard panels shall be in accordance with 1711.3 for diaphragms and 1711.4 for shear walls.

Shear panels shall be constructed with particleboard sheets not less than 4 ft by 8 ft, except at boundaries and changes in framing. Particleboard panels shall be designed to resist shear only, and chords, collector members, and boundary members shall be designed to transfer the axial forces. Boundary members shall be connected at all corners. Particleboard panels less than 12 inches wide shall be blocked.

1413.3 Modifications to ACI 530/ASCE 5, Appendix A. The sections of Appendix A, ACI 530/ASCE 5 shall be modified as indicated in items 1 through 6.

1. Revise title of Section A.2 to read: "Special Provisions for Seismic Performance Category B."
2. Revise title of Section A.3 to read: "Special Provisions for Seismic Performance Category C".
3. Revise title of Section A.4 to read: "Special Provisions for Seismic Performance Category D and E."
4. Modify Section A.4.1 to read: "All masonry structures assigned to Seismic Performance Category D or E shall be designed and constructed in accordance with the requirements for structures assigned to Seismic Performance Category C and with the following additional requirements."
5. Modify Section A.4.2 to read: "The provisions of Chapters 6 and 9 of ACI 530/ASCE 5 do not apply to structures assigned to Seismic Performance Category D or E."
6. Modify Section A.4.10.1 to read: "The term hook or standard hook used herein for tie anchorage for structures assigned to Seismic Performance Category D or E shall mean a standard 135 degree or 180 degree hook."

Report and Findings

Uniform Building Code Provisions Compared with the NEHRP Provisions

Prepared for
National Institute of Standards and Technology

Prepared by
International Conference of Building Officials

July, 1992

Table of Contents

Executive Summary

Overview and Intent

Executive Order 12699 requires seismic design of federally occupied and assisted projects. The Interagency Committee on Seismic Safety in Construction (ICSSC) in their report RP 2 1 "Guidelines and Procedures for Implementation of the Executive Order on Seismic Safety of New Construction", recommends the use of building codes which are substantially equivalent to the National Earthquake Hazard Reduction Program Recommended Provisions for the Development of Seismic Regulations for New Buildings (NEHRP Provisions) This study was performed by the International Conference of Building Officials for the Council of American Building Officials on behalf of the National Institute of Standards and Technology. The goal of the study is to determine whether a building designed under the *Uniform Building Code* (UBC) would provide a level of safety equivalent to the NEHRP provisions and to note where the provisions of the NEHRP criteria are more restrictive and where the provisions of the *Uniform Building Code* are more restrictive than those in NEHRP.

In addition a "cross-walk" or cross-reference between the two sets of provisions was to be developed.

Several general differences between the UBC/SEAOC approach and the NEHRP approach are:

Ultimate Strength vs. Working Stress Approach: The NEHRP provisions use an ultimate load design approach. The UBC is based on working stress. The NEHRP forces on the building cannot be directly compared to those required by the UBC. Because of this difference in criteria the NEHRP building will have a higher demand/capacity utilization than the UBC building. The UBC designed building will have greater reserve strength under its design load.

Basis for Seismic Load Determination: The UBC design loads are based on the seismic zone, structural system and the building's use (occupancy). This determines the "base shear" design force. Thus as the anticipated level of ground shaking increases, the requirements increase.

As with the UBC, the NEHRP provisions increase the base shear design force as the level of ground shaking increases. However as the need to maintain operations increases, NEHRP uses a different approach utilizing the Seismic Performance category (SPC) The SPC takes into account the seismicity and occupancy.Based on the SPC, different criteria are specified.

Response Factor: Both sets of code provisions contain a response factor. This is commonly called the "R" factor. In the NEHRP provisions the term is R; in the UBC it is R_W. Again these factors cannot be compared even for identical structures, because one modifies Ultimate Strength equations, the other Working Stress equations.

Limitations: The report does not discuss mapping and its impact on seismic design levels.

Methodology

To accomplish the goals of this study the following methodology was used.

Review of Provisions: The individual provisions of both the 1988 NEHRP and the 1991 UBC were compared for technical intent and content. Significant provision sections are shown side by side in the report. A number of flow charts and numerical comparisons are were developed and included in the report.

Case studies: Three case studies of buildings were conducted. These included a single story building of masonry wall and wood roof construction; a three story wood frame apartment building; and a ten story steel frame building.

Findings and Recommendations

The findings of the study are that a building designed under the NEHRP criteria or the UBC provisions would provide the same level of safety and that the two sets of provisions are substantially equal.

I. Introduction

Scope and Intent

Under Executive Order 12699, federally owned, occupied and assisted projects must be designed and constructed using "appropriate seismic design and construction standards". The Interagency Committee on Seismic Safety in Construction (ICSSC) has the responsibility for recommending appropriate seismic design and construction standards. The ICSSC in their report RP 2.1 "Guidelines and Procedures for Implementation of the Executive Order on Seismic Safety of New Construction", recommends the use of building codes which are substantially equivalent to the National Earthquake Hazard Reduction Program Recommended Provisions for the Development of Seismic Regulations for New Buildings (NEHRP Provisions). The National Institute of Standards and Technology, which provides the technical Secretariat to the ICSSC, sponsored this study.

This study was performed by the International Conference of Building Officials (ICBO) for the Council of American Building Officials (CABO). It is intended to determine whether a building designed under the *Uniform Building Code* (UBC) would provide a level of safety equivalent to the NEHRP provisions.

Overview

In the past fifteen years there has been general agreement about the basic level of earthquake forces for which buildings should be designed. Seismic design recommendations developed by the Structural Engineers Association of California (SEAOC) have been the basis for the seismic design provisions in the *Uniform Building Code* for almost thirty years.

Design of various building materials has also evolved. Through research an "ultimate strength" approach has been developed for some building materials. Research is now underway for other materials. This ultimate strength approach is different from the traditional "working stress" approach. In the ultimate strength approach the design is based on factored loads and the strength of the materials with a factor of safety. In the working stress approach the factor of safety is accomplished by factoring down from ultimate strength to an allowable stress. The working stress method frequently results in different factors of safety for different materials and components of a building. The ultimate strength approach is designed to achieve a known and consistent factor of safety.

Building code provisions for seismic design have been based on a working stress approach. Beginning in the mid-1970's, the Applied Technology Council (ATC) began developing new provisions. Very early in the project the decision was made to develop seismic provisions based on an ultimate strength approach. Revisions and updates to the ATC work were undertaken by the Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences (NIBS). This effort was funded by FEMA under the National Earthquake Hazard Reduction Program (NEHRP). The resulting document, officially titled NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings, is commonly called the NEHRP provisions. The design process using NEHRP is shown in Figure A.

The current *Uniform Building Code* seismic provisions are based on those developed by SEAOC. These provisions were completely revised and published in 1988. Some of the approaches of the ATC work have been incorporated. This volunteer effort took almost 10 years of effort and is generally based on the working stress method. The UBC design process is shown in Figure B.

The intent of the NEHRP provisions was to incorporate the most recent research findings and the lessons learned from earthquakes. In addition, since material design provisions are moving towards an ultimate strength approach, the NEHRP provisions are leading the seismic design by using the ultimate strength approach.

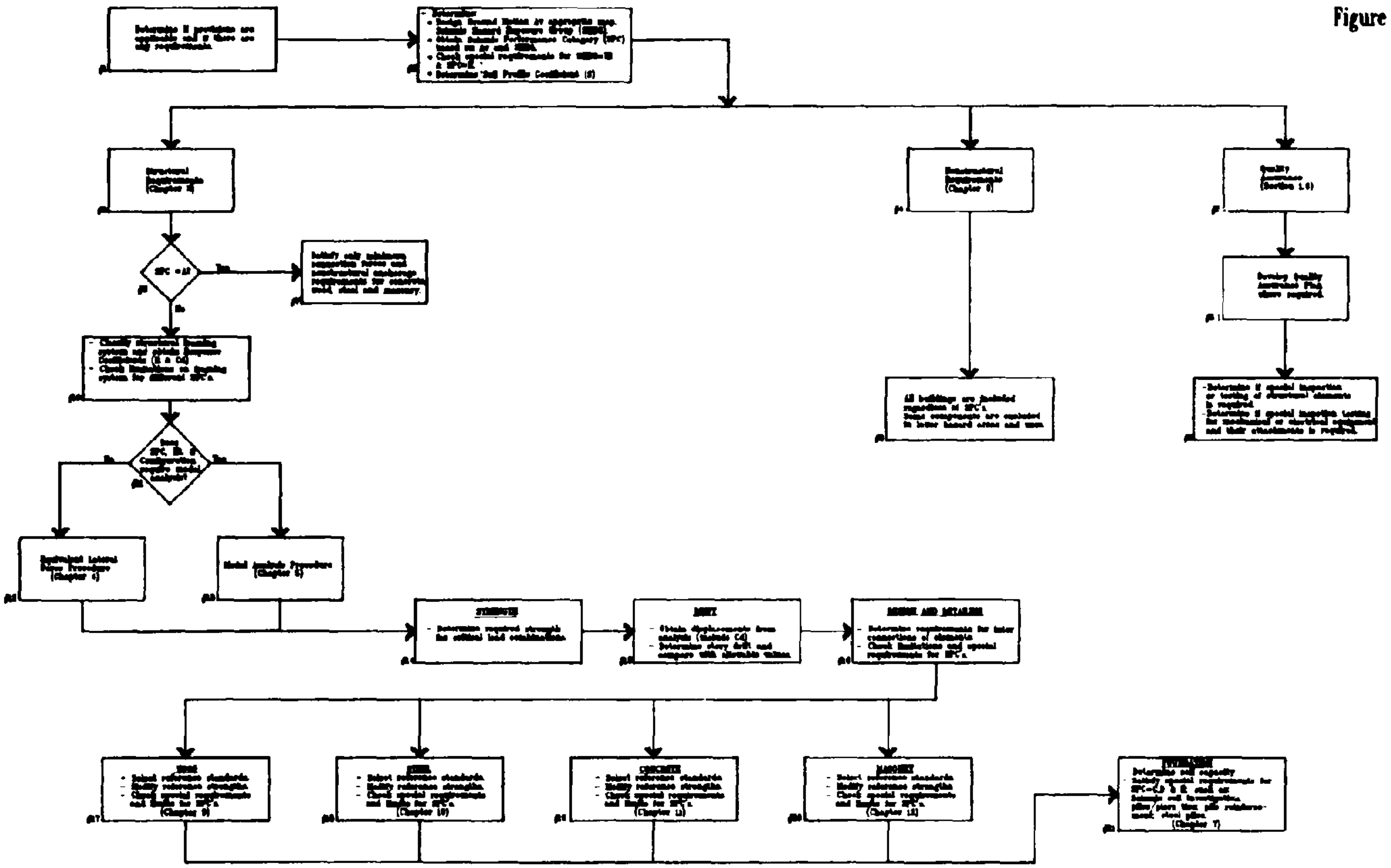
Section VII provides a "cross-walk", a cross reference between the UBC code sections and the NEHRP provisions to assist users in finding similar sections of each document.

Significant Issues

There are several points to be aware of in reviewing the two sets of provisions.

It is important to understand that NEHRP and UBC design loads and stresses cannot be compared by simply looking at the numbers. Since one is based on ultimate strength and the other based on working stress, the results of calculations and analysis are completely different.

Figure A



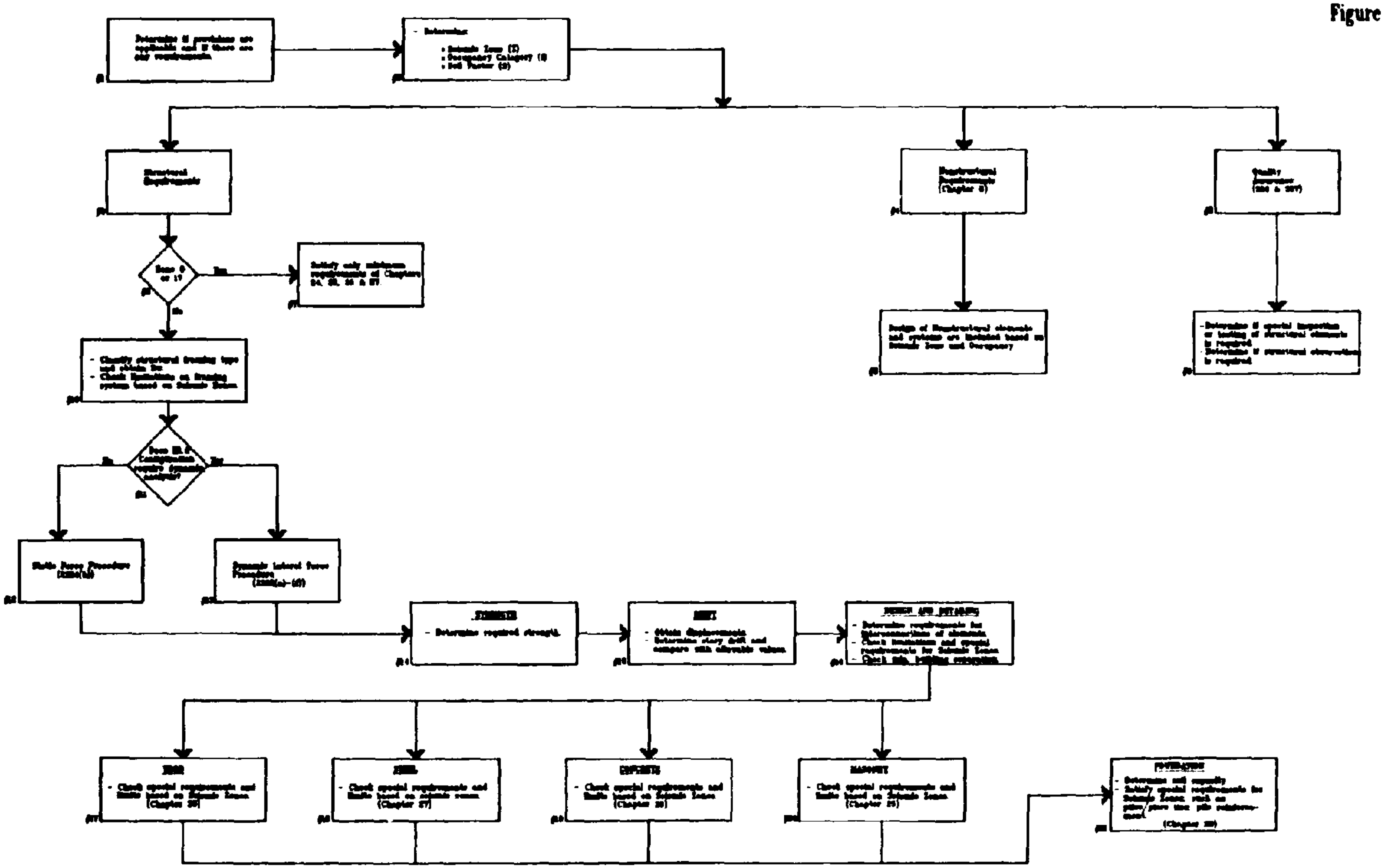
Seismic Design Procedure
1988 NEHRP

Council of American Building Officials

NIST

International Conference of Building Officials

Figure B



Seismic Design Procedure
1991 UBC

Council of American Building Officials

International Conference of Building Officials

Ultimate Strength Design vs. Working Stress Design

The NEHRP provisions use an ultimate load design approach. Ultimate strength design utilizes the total capacity of a building element and factors the load down with a factor of safety. The SEAOC/UBC approach has been to use a working strength approach. In this approach the factor of safety is already included in the allowable material stress. Ultimate strengths, hence factors of safety, may vary based on the specific material. A UBC building would have more "reserve" strength. The NEHRP designed building would have a greater material capacity utilization. Thus any attempt to compare the two sets of provisions based on numerical forces and material stresses is not possible.

Effect of Building Use on Design Approach

The UBC design loads are based on the seismic zone, structural system and the building's use (occupancy). These are used to determine the "base shear" design force. As the anticipated level of ground shaking increases, the base shear requirements increase. Similarly, as the need to be operational in a post-disaster situation increases, the design base shear is increased.

As with the UBC, the NEHRP provisions increase the base shear design force as the level of ground shaking increases. However, as the need to maintain operations increases, NEHRP uses a different approach utilizing the Seismic Performance Category (SPC). The SPC takes into account the seismicity and occupancy. Based on the SPC, different criteria are specified, such as drift limits, detailing requirements, and toughness. Thus the two approaches are quite different.

Response Factor

Both sets of code provisions contain a response factor. This is commonly called the "R" factor. In the NEHRP provisions the term is R; in the UBC it is R_W. Again these factors, since they are based on different design approaches, cannot be compared even for identical structures.

Limitations

The reader should be aware that this report does not include either set of provisions in their entirety and cannot be used as a design document.

Moreover the report does not discuss mapping and its impact on seismic design levels. For example, the UBC places Seattle in Seismic Zone 3 while the NEHRP maps place Seattle in A_V 0.2 which may be considered equivalent to UBC Seismic Zone 2, a seismic zone with lower requirements. As a result a case study of a building to be constructed in Seattle would show significant differences based on the maps. The rationale behind these mapping differences is beyond the scope of this study. Thus the case studies use consistent seismic ground motion rather than being site specific.

II. Methodology

To determine whether an equivalent building would be provided under either set of provisions, the following steps were accomplished.

Review of Provisions

The individual provisions of both the 1988 NEHRP and the 1991 UBC were compared for technical intent and content. Sections of the provisions that provide clarification of consistency between NEHRP and the UBC as well as differences are shown side by side in this report.

To assist in this comparison a number of charts modeling the design process were made. In addition several numerical comparisons were made between the NEHRP and UBC provisions.

Each section where differences occur was reviewed relative to the intent of the change and the effect on building safety.

The sections for the various materials were reviewed but a different approach was taken for comparison. Material requirements are related to the SPC in NEHRP. In the UBC the material requirements are based on Seismic Zone.

A "cross-walk" between the two sets of provisions was developed. This is to permit users of either set of provisions to determine the equivalent section in either NEHRP or the UBC.

Case studies

Several case studies of buildings were conducted. This included a single story building of masonry wall and wood roof construction; a three story wood frame apartment building; and a ten story steel frame building.

The procedure consisted of designing the same building under both the 1988 NEHRP and the 1991 UBC. The intent was only to compare the resulting building. Only the basic structure was designed, no detailing was done.

Designed buildings used the same materials, beam, column and wall sizes. Then the actual stress under the design load was compared with the allowable stress or nominal strength for selected components. This allowed a comparison of the use of materials even though the numbers were different and based on different approaches.

Differences were found in the case study results. A design of a UBC complying structure was undertaken. Comments on the differences in the "UBC" structure is included in each case study.

Engineering Judgment

In evaluating the results of the case studies and comparison of provisions, engineering judgment played an important role. Building loads, including dead loads, may vary somewhat from the design assumptions. As a result material selections may vary somewhat between design engineers. Thus the interpretation of the calculation results was based on the fact that materials and stresses within about ten percent of one another may be considered substantially equivalent.

Findings

Based on this procedure and findings of this report, it was concluded that the two sets of provisions are substantially equivalent.

III. Code Provisions Compared

Introduction

This section examines specific provisions of each document. It is divided into several subsections, one for each of the boxes in Figures A and B, the seismic design process charts. Within each subsection is a side by side comparison of selected provisions as well as observations regarding the effect of differences between the two sets of provisions. For some aspects of the provisions, the subsections also include flow charts which describe the decision process to select required design provisions; comparisons of design values, specific requirements, and tools that will assist the reader in understanding the differences.

Approach

This section compares selected sections of NEHRP and UBC on a side by side basis permitting the reader to compare provisions. The sections selected are intended to show similarity and differences in approach and content. Some sections have been edited to eliminate text and tables that do not add to understanding the intent of this report. Most tables, such as those for "R" are best reviewed in the provisions or code itself.

Not all boxes shown in Figures A and B are detailed here. The figures show the engineering design process and were adapted from the NEHRP documents. These were intended to illustrate the seismic design process for engineers who may not have had such experience. Thus boxes which show ordinary design activities do not have a side by side comparison.

Subjects Covered

This section covers the following topics:

- Applicability of Provisions
- Determination of Design Factors
- Non-structural Requirements
- Quality Assurance
- Site Conditions
- Building Frame Requirements

- Selection of Design Method
- Equivalent Lateral Force Procedure
- Modal Analysis
- Load Combinations
- Drift Limit Comparisons and Building Separation
- Materials Requirements
- Foundations

How the Comparisons Were Made

Each section of the NEHRP provisions was reviewed alongside those of the UBC. They were then compared for intent and approach. In addition the effect of each on the design of the building was evaluated. This was done with the results of the case studies in hand.

After the total comparison was completed, comments, observations and then recommendations were prepared.

Applicability of Provisions

(Ref: Box 1)

1988 NEHRP	1991 UBC	OBSERVATIONS
1.2 and 1.3	**2333**	
1.2 SCOPE These provisions establish requirements for the design and construction of new buildings to resist the effects of earthquake motions. EXCEPTION: The following need not comply with these provisions: 1. Buildings classified for agricultural use and intended only for incidental human occupancy. 2. One-and two-family dwellings that are located in map areas having a value of Av less than 0.15. 3. Special structures including, but not limited to, bridges, transmission towers, industrial towers and equipment, piers and wharves, hydraulic structures, and nuclear reactors. These special structures require special consideration of their response characteristics and environment that is beyond the scope of these provisions	(a) Basis for design. The procedures and limitations for the design of structures shall be determined considering zoning, site characteristics, occupancy, configuration, structural system and height in accordance with this section. The minimum design seismic forces shall be those determined in accordance with the static lateral force procedure of Section 2334 except as modified by Section 2335(e)3. One-and two-family dwellings in Seismic Zone No. 1 need not conform to the provisions of this section.	Figures C and D illustrate the process of determining if a structure is covered by the provisions. One chart is provided for each set of provisions. NEHRP exempts all non-building structures. Thus a bridge or tank on grade must be designed using some other source of design guidance. NEHRP also exempts agricultural buildings and one and two family dwellings in regions equivalent to UBC Seismic Zones 0 and 1. The UBC has exemptions for dwellings in Seismic Zones 0 and 1. In both the UBC and NEHRP, wood frame structures in the lowest seismic zone may conform to conventional framing provisions. The UBC regulates all buildings regulated by NEHRP.

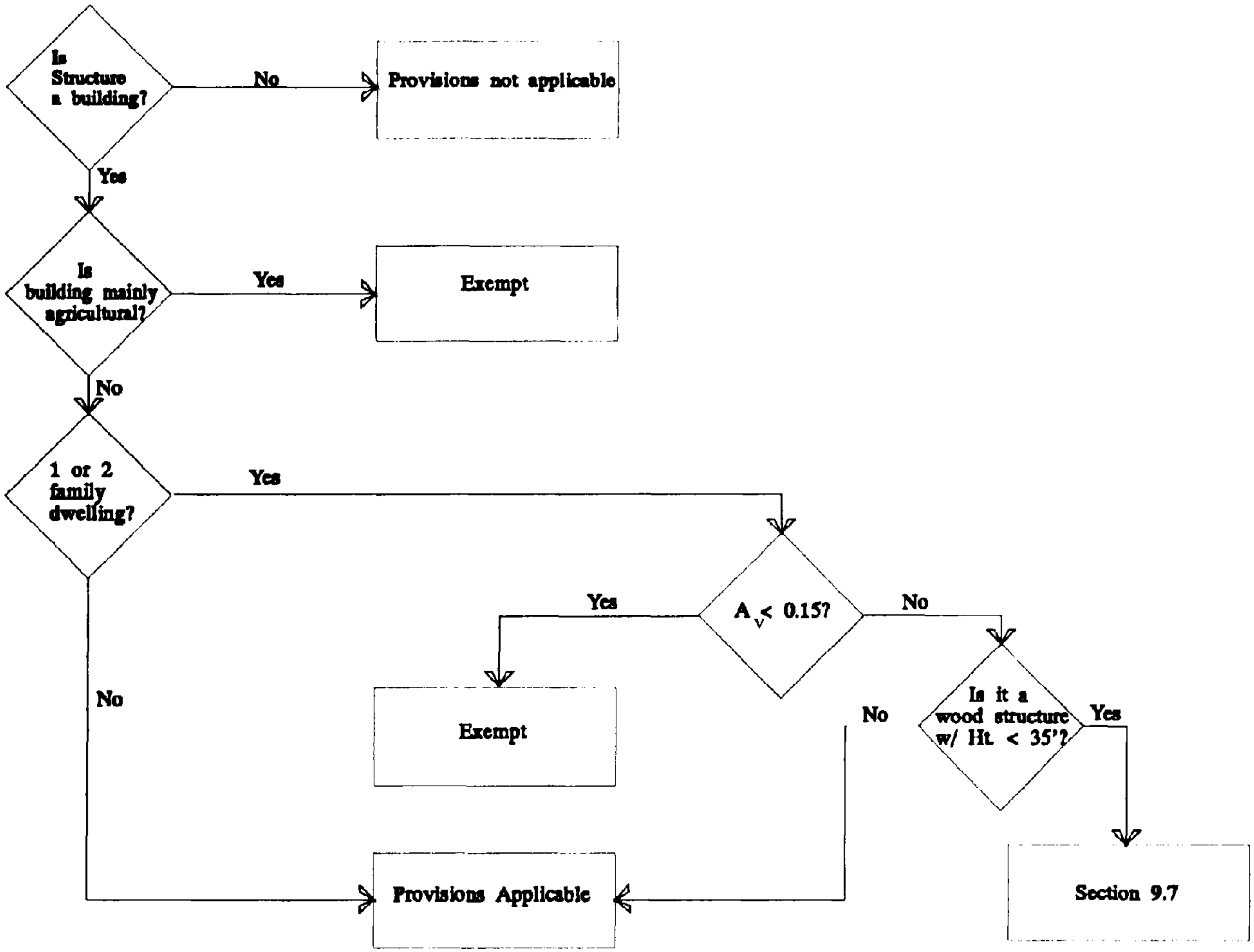
1.3 APPLICATION OF PROVISIONS

New buildings within the scope of these provisions shall be designed and constructed as required by this section. Design documents shall be submitted to determine compliance with these provisions.

1.3.1 New Buildings

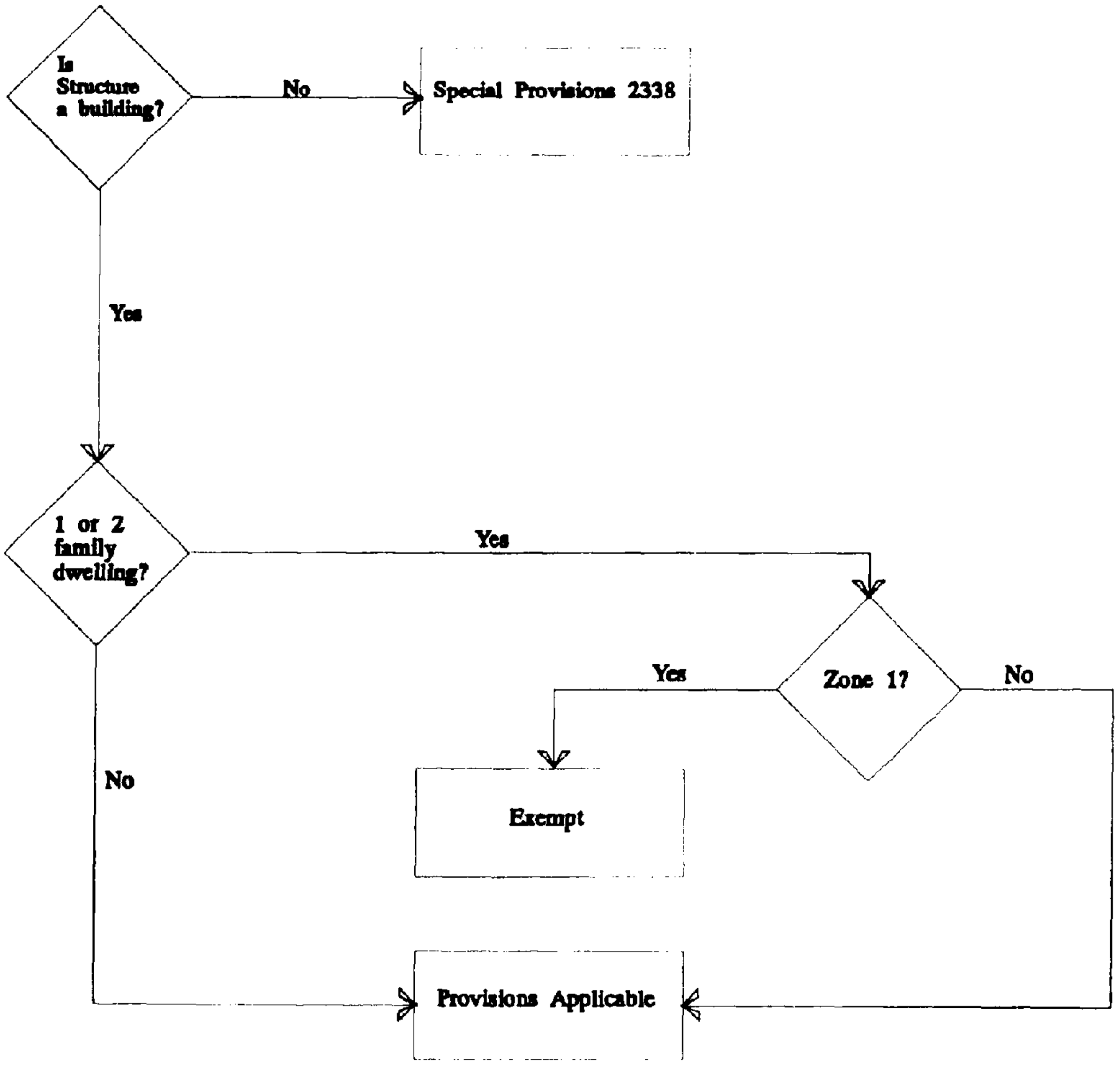
New buildings shall be designed and constructed in accordance with the applicable requirements of Chapters 3 through 12 and shall be subject to the Quality Assurance Requirements of Sec. 1.6. One- and two-story wood frame dwellings not over 35 feet in height located in map areas having a value of Av equal to or greater than 0.15 need only conform to the requirements for Conventional Light Timber Construction set forth in Sec. 9.7.

Although not detailed herein, both NEHRP and UBC require additions to buildings to comply with the provisions.



Applicability of Provisions 1988 NEHRP

Figure C.



Applicability of Provisions 1991 UBC

Figure D.

Determination of Design Factors

(Ref: Box 2)

1988 NEHRP

1.4.1 Design Ground Motions

The design ground motions are defined in terms of Effective Peak Acceleration and Effective Peak Velocity-Related Acceleration, represented by coefficients A_a and A_v, respectively. The coefficients A_a and A_v to be used in the application of these provisions shall be determined in accordance with the following procedure.

1.4.1.1 Determine the appropriate Map Areas for the building site from Figures 1-1 and 1-2 and then determine the values for A_a and A_v from either the value on the figure or Table 1-1.

1.4.1.2 Alternatively, values of Aa and Av may be determined directly from Figures 1-3 and 1-4, respectively; interpolation should be used in reading Figures 1-3 and 1-4.

1991UBC

2333(b)

(b) Seismic Zones. Each site shall be assigned to a seismic zone in accordance with Figure No. 23- 2. Each structure shall be assigned a zone factor, Z, in accordance with Table No. 23-I.

OBSERVATIONS

established. The NEHRP designer determines the building's required Seismic Performance Category (SPC). This is accomplished by determining the design earthquake force (Av) and the SHEG, which is based on occupancy. From this the SPC is determined. From these values the detailed design requirements are determined.

The UBC designer determines the seismic zone and occupancy. These factors are used to find the base shear design loads.

Figure E will assist readers to compare the seismic zone and occupancy requirements the UBC to the SHEG and SPC of NEHRP.

Using this the reader can understand the various terms.

Also included in this section are tables from NEHRP and the UBC used to determine the seismic design coefficients.

1.4.2 Seismic Hazard Exposure Groups

All buildings shall be assigned to one of the following Seismic Hazard Exposures Groups for the purpose of these provisions:

1.4.2.1 Group III

Seismic Hazard Exposure Group III shall be buildings having essential facilities that are necessary for post-earthquake recovery. Also see the requirements for access to and the functionality of essential facilities in Sec. 1.4.2.5 and 1.4.2-6, respectively.

1.4.2.2 Group II

Seismic Hazard Exposure Group II shall be buildings that constitute a substantial public hazard because of occupancy or use.

1.4.2.3 Group I

Seismic Hazard Exposure Group I shall be all other buildings not classified in Group III or II.

1.4.3 Seismic Performance Categories For the purposes of these provisions, all buildings shall be assigned, based on level of the design ground motion coefficient Av and the Seismic Hazard Exposure Group designated, to a Seismic Performance Category in accordance with Table 1-2.

Any method of analysis or type of construction required for a higher Seismic Performance Category may be used for a lower Seismic Performance Category.

2333(d) Occupancy Categories. For purposes of earthquake-resistant design, each structure shall be placed in one of the occupancy categories listed in Table No. 23-K. Table No. 23-L lists importance factors, I, and review requirements for each category.

Both UBC and NEHRP use the same general categories to define occupancy, but they use different numbering systems to identify the groupings.

3.2 SITE EFFECTS

Soil Profile Types and site coefficients, S, are given in this section.

3.2.1 Soil Profile Types

The effects of site conditions on building response shall be established based on the Soil Profile Types defined below.

In locations where the soil properties are not known in sufficient detail to determine the Soil Profile Type or where the profile does not fit any of the four types, Soil Profile S2, Soil Profile S3, or Soil Profile Type S4 shall be used depending on whichever Soil Profile Type results in the higher value of seismic coefficient, Cs, as determined in Sec. 4.2.1.

3.2.2 Site Coefficient

S is a coefficient for the effects of the site conditions on building response and is given in Table 3-1.

3.2.3 Soil-Structure Interaction

The base shear, story shears, overturning moments, and deflections determined in Chapter 4 or Chapter 5 may be modified in accordance with the Appendix to Chapter 6 to account for the effects of soil-structure interaction.

2333 (c)

Site Geology and Soil Characteristics. Soil profile type and site coefficient, S, shall be established in accordance with Table No. 23-J.

Both sets of provisions have similar soils factors. NEHRP requires use of the most restrictive soil factor when there is no soils investigation. The UBC requires a lower factor in this case. The NEHRP provisions could increase the foundation costs for smaller structures.

Seismic Zone and Occupancy Comparison

1991 UBC		OCCUPANCY TYPE		
		IV	III	I, II
	1988 NEHRP	SHEG		
		I	II	III
ZONE	Av	SPC		
3 & 4	0.2 < Av	D	D	E
2B	Av = 0.2	D	D	E
2B	0.15 < Av < 0.20	C	D	D
2A	Av = 0.15	C	D	D
2A	0.10 < Av < 0.15	C	C	C
1	Av = 0.10	C	C	C
1	0.05 <= Av < 0.10	B	B	C
0	Av < 0.05	A	A	A

Figure E. Chart comparing the UBC to NEHRP for seismic zone and occupancy.

TABLE 1-1
Coefficient A_a and A_v

Map Area From Figure 1-1 (A_a) or 1-2 (A_v)	Value of A_a or A_v
7	0.40
6	0.30
5	0.20
4	0.15
3	0.10
2	0.05
1	0.05

NEHRP seismic design coefficients.

TABLE NO. 23-I
SEISMIC ZONE FACTOR Z

ZONE	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

TABLE NO. 23-L—OCCUPANCY REQUIREMENTS

OCCUPANCY CATEGORY[1]	IMPORTANCE FACTOR I	
	Earthquake[2]	Wind
I. Essential facilities	1.25	1.15
II. Hazardous facilities	1.25	1.15
III. Special occupancy structures	1.00	1.00
IV. Standard occupancy structures	1.00	1.00

[1] Occupancy types or functions of structures within each category are listed in Table No. 23-K and structural observation requirements are given in Sections 305, 306 and 307.

[2] For life-safety-related equipment, see Section 2336 (a).

UBC tables for Seismic Zone and Importance Factors.

Nonstructural Requirements

(Ref: Box 4)

1988 NEHRP

8.1 GENERAL REQUIREMENTS

The requirements of this chapter establish minimum design levels for architectural, mechanical, and electrical systems and components recognizing occupancy use, occupant load, need for operational continuity, and the interrelation of structural and architectural, mechanical, and electrical components. All architectural, mechanical, and electrical systems and components in buildings and portions thereof shall be designed and constructed to resist seismic forces determined in accordance with this chapter.

Exceptions:

1. Those systems or components designated in Table 8-2 or 8-3 for performance characteristic level L that are in buildings assigned to Seismic Hazard Exposure Group I which are located in areas with a value of A_v less than 0.15 or that are in buildings assigned to Seismic Hazard Exposure Group II which are located in areas with a a value of A_v less than 0.05 are not subject to the provisions of this chapter.

2. Elevator systems that are in buildings assigned to Seismic Hazard Exposure Group I which are located in areas with a value of A_v less than 0.15 or that are in buildings assigned to Seismic Hazard Exposure Group II and are located in areas with a value of A_v less than 0.05 are not subject to the provisions of this chapter.

1991UBC

2336

(a) General. Parts and portions of structures and their attachments, permanent nonstructural components and their attachments, and the attachments for permanent equipment supported by a structure shall be designed to resist the total design seismic forces prescribed in Section 2336 (b).

Attachments shall include anchorages and required bracing. Friction resulting from gravity loads shall not be considered to provide resistance to seismic forces.When the structural failure of the lateral force-resisting systems of nonrigid equipment would cause a life hazard, such systems shall be designed to resist the seismic forces prescribed in Section 2336 (b).

EXCEPTION: Equipment weighing less than 400 pounds, furniture or temporary or movable equipment.

When allowable design stresses and other acceptance criteria are not contained in or referenced by this code or the U.B.C. Standards, such criteria shall be obtained from approved national standards.

OBSERVATIONS

Both UBC and NEHRP have requirements for design of non-structural components and elements.

NEHRP provisions are very specific in listing the requirements by component. NEHRP considers survivability and defines performance based on Superior (S), Good (G) and Low (L) requirements. This rating determines the Performance Characteristics Level (P) factor, a design load modifier. As can be seen in Table 8-1 at the end of this section the P factor increases the design load on the component. Tables 8-2 and 8-3 illustrate the detail of the regulations.

The UBC accomplishes this through the "I" factor and specific provisions in various parts of the code some shown herein. The references to UBC Chapters 18 and 19 are provisions requiring post earthquake performance of safety systems in high-rise buildings.

Figures F and G compare the computed values for various building elements and occupancies. Although direct comparison is not possible, relative comparison of design factors for various elements illuminates several differences between the NEHRP and the UBC. Despite these differences, rigorous compliance with the UBC will provide for adequate design of all elements required by NEHRP.

Seismic Hazard Exposure Groups are determined in Sec. 1.4. Mixed Occupancy requirements are provided in that section.

The seismic force on any component shall be applied at the center of gravity of the component and shall be assumed to act in any horizontal direction. For vertical forces on mechanical and electrical components, see Table 8-3.

8.2 ARCHITECTURAL

8.2.1 General

Systems or components listed in Table 8-2 and their attachments shall be designed and detailed in accordance with the requirements of this chapter. The designs or criteria for systems or components shall be included as part of the design documents.

8.2.2 Forces

Architectural systems and components and their attachments shall be designed to resist seismic forces determined as follows:

$$F_p = A_v C_c P W_c, \qquad (8\text{-}1)$$

where

F_p = the seismic force applied to a component of a building or equipment at its center of gravity,

A_v = the seismic coefficient representing the Effective Peak Velocity-Related Acceleration as determined in Sec. 1.4,

C_c = the seismic coefficient for components of architectural systems as given in Table 8-2 (dimensionless),

(b) *Design for Total Lateral Force.* The total design lateral seismic force, Fp, shall be determined from the following formula:

$$F_p = ZIC_pW_p \qquad (36\text{-}1)$$

The values of Z and I shall be the values used for the building.

EXCEPTIONS:-1. For anchorage of machinery and equipment required for life-safety systems, the value of I shall be taken as 1.5.

2. For the design of tanks and vessels containing sufficient quantities of highly toxic or explosive substances to be hazardous to the safety of the general public if released, the value of I shall be taken as 1.5.8.2.2 Forces

3. The value of I for panel connectors for panels in Section 2337 (b) 4 C shall be 1.0 for the entire connector.

The coefficient Cp is for elements and components and for rigid and rigidly supported equipment. Rigid or rigidly supported equipment is defined as having a fundamental period less than or equal to 0.06 second. Nonrigid or flexibly supported equipment is defined as a system having a fundamental period, including the equipment, greater than 0.06 second.

P = Performance criteria factor as given in Table 8-1 (dimensionless), and

W_c = the weight of a component of a building or equipment.

The force, F_p, shall be applied independently vertically, longitudinally, and laterally in combination with the static load of the element.
EXCEPTIONS: When positive and negative wind loads exceed F_p for nonbearing exterior walls, these loads shall govern the design. Similarly, when the Code horizontal loads exceed F_p for interior partitions, these loads shall govern the design.

8.3 MECHANICAL AND ELECTRICAL DESIGN REQUIREMENTS

8.3.1 General

Systems or components listed in Table 8-3 and their attachments shall be designed and detailed in accordance with the requirements of this chapter. The designs or criteria for systems or components shall be included as part of the Design Documents.

An analysis of a component supporting mechanism based on established principles of structural dynamics may be performed to justify reducing the forces determined in Sec. 8.3.2.

Combined states of stress, such as tension and shear in anchor bolts, shall be investigated in accordance with established principles of mechanics.

The lateral forces calculated for nonrigid or flexibly supported equipment supported by a structure and located above grade shall be determined considering the dynamic properties of both the equipment and the structure which supports it, but the value shall not be less than that listed in Table No. 23-P. In the absence of an analysis or empirical data, the value of Cp for nonrigid or flexibly supported equipment located above grade on a structure shall be taken as twice the value listed in Table No. 23-P, but need not exceed 2.0.

EXCEPTION: Piping, ducting and conduit systems which are constructed of ductile materials and connections may use the values of Cp from Table No. 23-P.

The value of Cp for elements, components and equipment laterally self-supported at or below ground level may be two thirds of the value set forth in Table No. 23-P. However, the design lateral forces for an element or component or piece of equipment shall not be less than would be obtained by treating the item as an independent structure and using the provisions of Section 2338.

The design lateral forces determined using Formula (36-1) shall be distributed in proportion to the mass distribution of the element or component.

Forces determined using Formula (36-1) shall be used to design members and connections which transfer these forces to the seismic-resisting systems.

For applicable forces in connectors for exterior panels and diaphragms, refer to Section 2337 (b) 4 and 9.

Forces shall be applied in the horizontal directions, which result in the most critical loadings for design.

(c) Specifying Lateral Forces. Design specifications for equipment shall either specify the design lateral forces prescribed herein or reference these provisions.

1807(c)1B, 1807(k), 1907.

Seismic Force Comparison of Structural Elements and Nonstructural Components

TOPIC	1988 NEHRP (For SHEG I)	1991UBC
Bearing Wall (Zone 4)	0.4 Wc	0.3 Wp
Bearing Wall Connections (Zone 4)	0.4 Wc or 400 plf (Concrete or Masonry)	0.3 Wp or 200 plf
Bearing Wall Connections (Zone 2A)	0.15 Wc or 150 plf (Concrete or Masonry)	0.11 Wp or 200 plf
Nonbearing Wall (Zone 4)	0.54 Wc	0.3 Wp
Parapet (Zone 4)	0.4 Wc (bearing wall)	0.8 Wp
	0.54 Wc (nonbearing wall)	
Wall Attachment (Appendage)	1.8 Wc	0.8 Wp
Veneer Anchor	0.6 Wc	2 Wp

Observations:

Direct comparison between coefficients is not possible because of the ultimate/working stress issue. But comparison of the ratio of coefficients for various elements provides insight for the reader.

Figure F. Seismic loads on various building elements and components.

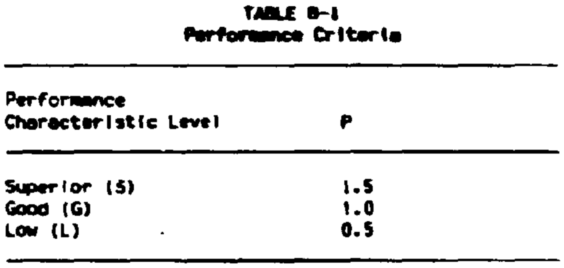


TABLE 8-1

Performance Criteria

Performance Characteristic Level	P
Superior (S)	1.5
Good (G)	1.0
Low (L)	0.5

Table 8-1 from NEHRP. Performance Criteria.

TABLE 8-3
Seismic Coefficient (C_c) and Performance Characteristic Levels Required for Mechanical and Electrical Components (see Table 8-1 for S, G, and L Designations)

Mechanical/Electrical Components[a]	C_c Factor	Seismic Hazard Exposure Group Required Performance Characteristic Levels		
		III	II	I
Emergency electrical systems (code required) Fire and smoke detection system (code required) Fire suppression systems (code required) Life safety system components	2.00	S	S	S
Elevator machinery and controller anchorage	1.25	S	G	G
Boilers, furnaces, incinerators, water heaters, and other equipment using combustible energy sources or high-temperature energy sources, chimneys, flues, smokestacks and vents Communication systems Electrical bus ducts and primary cable systems Electrical motor control centers, motor control devices, switchgear, transformers, and unit substations Reciprocating or rotating equipment Tanks, heat exchangers, and pressure vessels Utility and service interfaces	2.00	S	G	L
Machinery (manufacturing and process)	0.67	S	G	L
Lighting fixtures	0.67[c]	S	G	L
Ducts and piping distribution systems				
Resiliently supported	2.00	S	G	NR
Rigidly supported	0.67[d]	S	G	NR
Electrical panelboards and dimmers	0.67	S	G	NR
Conveyor systems (nonpersonnel)	0.67	S	NR	NR

NR = not required.

Table 8-2 from NEHRP. Architectural component design.

TABLE 8-3
Seismic Coefficient (C_c) and Performance Characteristic Levels Required for Mechanical and Electrical Components (see Table 8-1 for S, G, and L Designations)

Mechanical/Electrical Components[a]	C_c Factor	Seismic Hazard Exposure Group Required Performance Characteristic Levels		
		III	II	I
Emergency electrical systems (code required)	2.00	S	S	S
Fire and smoke detection system (code required)				
Fire suppression systems (code required)				
Life safety system components				
Elevator machinery and controller anchorage	1.25	S	G	G
Boilers, furnaces, incinerators, water heaters, and other equipment using combustible energy sources or high-temperature energy sources, chimneys, flues, smokestacks and vents	2.00	S	G	L
Communication systems				
Electrical bus ducts and primary cable systems				
Electrical motor control centers, motor control devices, switchgear, transformers, and unit substations				
Reciprocating or rotating equipment				
Tanks, heat exchangers, and pressure vessels				
Utility and service interfaces				
Machinery (manufacturing and process)	0.67	S	G	L
Lighting fixtures	0.67[c]	S	G	L
Ducts and piping distribution systems				
Resiliently supported	2.00	S	G	NR
Rigidly supported	0.67[d]	S	G	NR
Electrical panelboards and dimmers	0.67	S	G	NR
Conveyor systems (nonpersonnel)	0.67	S	NR	NR

NR = not required.

Table 8-3 from NEHRP. Mechanical and electrical component design.

Seismic Force Comparison

Nonstructural Components*	1988 NEHRP		1991 UBC	
	SHEG = I	SHEG = III	Occupancy = IV	Occupancy = I
Ext. Nonbearing Wall	0.54 Wc	0.54 Wc	0.3 Wp	0.375 Wp
Parapet Nonbearing Wall	0.54 Wc	0.54 Wc	0.8 Wp	1.0 Wp
Veneer Attachment	0.6 Wc	1.2 Wc	2.0 Wp	2.0 Wp
Lighting Fixture	0.133 Wc	0.4 Wc	0.3 Wp	0.375 Wp
Tank	0.4 Wc	1.2 Wc	0.3 Wp	.375 Wp
Life Safety Equipment	1.2 Wc	1.2 Wc	0.45 Wp	0.45 Wp
* All categories are for Zone 4.				

Figure G. Seismic Force Comparison

Quality Assurance

(Ref: Box 5)

1988 NEHRP	1991UBC	OBSERVATIONS
1.6.1 Quality Assurance Plan A Quality Assurance Plan shall be submitted to the Regulatory Agency for the following: 1. Buildings assigned to Category E for the Designated Seismic Systems. 2. Buildings assigned to Categories C and D for the Structural Seismic Resisting Systems. 3. All other buildings determined by the Regulatory Agency.		NEHRP requires a Quality Assurance Plan for SPC E and certain designated structural systems in categories C and D. No such plan is required by the UBC. NEHRP also requires special inspection of non-structural components. The UBC does not contain similar requirements. NEHRP allows for self-certification by component manufacturers for certain systems which may reduce the amount of inspections. The UBC requires continuous inspection by special inspectors; NEHRP permits periodic inspections in some cases. The UBC requires halving the allowable stresses if continuous inspection is not provided. NEHRP has no such requirement. The UBC has a requirement for structural observation by an inspector reporting directly to the engineer. NEHRP has no such requirement. The UBC contains stricter requirements for major masonry structures. NEHRP includes additional requirements for a Quality Assurance Plan. NEHRP also contains requirements for inspection of architectural and mechanical and electrical components.

1.6.2 - Special Inspection

	306 Special Inspection	All structural building components are inspected under each set of provisions. The UBC permits half stress masonry design. This eliminates the need for special inspection and may be more restrictive than NEHRP. The NEHRP provisions for non-structural inspection are more restrictive than those in the UBC.
1.6.2.1 Piles	306(a)11 Piles	
1.6.2.2 Reinforcing Steel	306(a)4 Reinforcing Steel	
1.6.2.3 Concrete Placement	306(a)1 Concrete	
	306(a)3 Concrete Frames (Zones 3 & 4)	
1.6.2.4 Prestressed Concrete	306(a)1 and 4 Prestressed Concrete	
1.6.2.5 Masonry (SPC = D and E)	306(a)7 Masonry	
1.6.2.2.2 Reinforced Masonry Shear Walls		
1.6.2.6.1 Welding	306(a)5 Welding	
1.6.2.6.2 High Strength Bolts	306(a)6 High Strength Bolts	
1.6.2.7 Structural Wood	306 (a) 14	
1.6.2.8 Architectural Panels and Veneers	None	
1.6.2.9 Mechanical and Electrical Components	None	

1.6.3 Special Testing

1.6.3.3 Masonry	2405 (c) Masonry
1.6.3.4 Steel and Welding	2710(k) Steel and Welding
1.6.3.5 Mechanical and Electrical Equipment	
	307 Structural Observation

Site and Building Framing Considerations

(Ref: Box 10)

3.3 FRAMING SYSTEMS

1988 NEHRP

As shown in Table 3-2, four types of general framing systems (Bearing Wall, Building Frame, Moment Resisting Frame, and Dual) are recognized for purposes of these provisions. Each type is subdivided by the types of vertical element used to resist lateral seismic forces. For a dual system, a Moment Frame must be provided that is capable of resisting at least 25 percent of the prescribed seismic forces. The total seismic force resistance is provided by the combination of the Moment Frame and the complementary seismic resisting elements in proportion to their rigidities. Special framing requirements are given in Sec. 3.6 and in Chapters 9 through 12 for buildings assigned to the various Seismic Performance Categories.

3.3.1 Classification of Framing Systems

Each building or portion thereof shall be classified as one of the four general framing system types of Table 3-2. The response modification factor, R, and the deflection amplification factor, Cd, are given in Table 3-2 and are used in determining the base shear and the design story drift. Inverted pendulum-type structures associated with buildings are included in Table 3-2.

2. See Sec.3.3 and 3.6 and Chapters 9 through 12 for special requirements for buildings assigned to various Seismic Performance Categories.

1991UBC

2333 (f)

Structural Systems. 1. General. Structural systems shall be classified as one of the types listed in Table No. 23-O and defined in this subsection.

2. Bearing wall system. A structural system without a complete vertical load-carrying frame. Bearing walls or bracing systems provide support for all or most gravity loads. Resistance to lateral load is provided by shear walls or braced frames.

3. Building frame system. A structural system with an essentially complete frame providing support for gravity loads. Resistance to lateral load is provided by shear walls or braced frames.

4. Moment-resisting frame system. A structural system with an essentially complete frame provides support for gravity loads. Moment-resisting frames provide resistance to lateral load primarily by flexural action of members.

OBSERVATIONS

The numerical value of the R factor in NEHRP and the R_w in the UBC are not directly comparable. Figure H illustrates some qualitative differences of factors for different framing types.

The differences in R factors between the two sets of provisions may be viewed as differences in engineering judgment and shading of the construction types rather than significant differences in the needs and approach to different construction types.

Limitations on the height of concrete and steel frames are shown in Figures I and J.

3.4 BUILDING CONFIGURATION

For purposes of seismic design, buildings shall be classified as regular or irregular as specified in this section. Both plan and vertical configuration of a building shall be considered when determining whether a building is to be classified as regular or irregular.	2333(e) Configuration Requirements. 1. General. Each structure shall be designated as being structurally regular or irregular.2. Regular structures. Regular structures have no significant physical discontinunities in plan or vertical configuration or in their lateral force-resisting systems such as the irregular features described below.	The descriptions of irregular structures are the same in both the UBC and NEHRP.
All structures having irregular features as described in Table 3-3 or Table 3-4 shall be designed to meet the additional requirements of those sections referenced in the tables.	3. Irregular structures. A. Irregular structures have significant physical discontinuities in configuration or in their lateral force-resisting systems. Irregular features include, but are not limited to, those described in Tables Nos. 23-M and 23-N. Structures in Seismic Zone No. 1 and in Occupancy Category IV in Seismic Zone No. 2 need be evaluated only for vertical irregularities of Type E (Table No. 23-M) and horizontal irregularities of Type A (Table No. 23-N). B. Structures having one or more of the features listed in Table No. 23-M shall be designated as if having a vertical irregularity. C. Structures having one or more of the features listed in Table No. 23-N shall be designated as having a plan irregularity. EXCEPTION: Where no story drift ratio under design lateral forces is greater than 1.3 times the story drift ratio of the story above the structure may be deemed to not have the structural irregularities of Type A or B in Table No. 23-M. The story drift ratio for the top two stories need not be considered. The story drifts for this determination may be calculated neglecting torsional effects.	

Representative "R" Factor Differences

FRAMING SYSTEM	1988 NEHRP	1991UBC
Light-framed w/ shear panels	One value for R	Two values for R (3-story all plywood & all others)
Concentric Braced Frame	One value for R	Three values for R (steel, concrete, heavy timber)
Unreinforced Masonry	Included	Prescriptive provisions
Light steel-framed walls with tension bracing	No such category	Included
Reinforced Concrete & Reinforced Masonry	Different R's	Same R's
Dual system - Special Moment-Resisting Frame with Eccentric Braced Frame	Steel and Concrete	Steel only
Dual system with wood shear panel	Included	No such category
Inverted Pendulum	Included	No such category

Figure H. Representative "R" Factors.

Steel: Limitations on Framing Systems

FRAMING SYSTEM	1988 NEHRP	1991UBC
Ordinary Moment-Resisting Frame	SPC = D 1 or 2 Stories	Zone 3 and 4 Ht.<160 feet
	SPC = E 1 Story	
Eccentric Braced Frame	SPC = D Ht. <160 feet	Zone 3 and 4 Ht. <240 feet
	SPC = E Ht. <100 feet	
Concentric Braced Frame	SPC = D Ht. <160 feet	Zone 3 and 4 Ht. <160 feet
	SPC = E Ht. <100 feet Allowed only as part of a Dual System	

Note that NEHRP SPC and UBC Zone are not directly comparable.

Figure I. Comparison of permitted uses of steel frames for NEHRP and the UBC.

Concrete: Limitations on Framing Systems

FRAMING SYSTEM	1988 NEHRP	1991UBC
Ordinary Moment-Resisting Frame	Not allowed in SPC = C, D and E	Not allowed in Zones 2, 3 and 4
Intermediate Moment-Resisting Frame	Not allowed in SPC = D and E	Not allowed in Zones 3 and 4
Shear Wall	SPC = D Ht. <160 feet SPC = E Ht. <100 feet	Zones 3 and 4: (a) Bearing wall Ht. <160 feet (b) Frame system Ht. <240 feet
Braced frame/ Bracing carries gravity load	No limitation	Not allowed in Zones 3 and 4
Dual System	No limitation	Special Moment-Resisting Frame and concentrically braced frame not allowed in Zones 3 and 4

Note that NEHRP SPC and UBC Zone are not directly comparable.

Figure J. Comparison of limitations for concrete frames for NEHRP and the UBC

Selection of Design Method

(Ref: Box 11)

1988 NEHRP

3.5 ANALYSIS PROCEDURES

This section prescribes the minimum analysis procedure to be followed. An alternate generally accepted procedure, including the use of an approved site specific spectrum, if desired, may be used in lieu of the minimum applicable procedure. The limitations upon the base shear stated in Chapter 5 apply to any such analysis.

3.5.1 Seismic Performance Category A

Regular or irregular buildings assigned to Category A need not be analyzed for seismic forces for the building as a whole. The provisions of Sec. 3.6 shall apply to the components indicated therein.

3.5.2 Seismic Performance Categories B and C

Regular or irregular buildings assigned to Category B or C shall be, as a minimum, analyzed in accordance with the procedures in Chapter 4.

3.5.3 Seismic Performance Categories D and E

Buildings assigned to Categories D and E shall, as a minimum, be analyzed in accordance with the following procedures:

1. When designated as regular	Chapter 4
2. When designated as irregular and having height not over 5 stories or 65 feet	Chapter 4

1991UBC

2333(h)

(h) Selection of Lateral Force Procedure.

1. General. Any structure may be, and certain structures defined below shall be, designed using the dynamic lateral force procedures of Section 2335.

2. Static. The static lateral force procedure of Section 2334 may be used for the following structures:

A. All structures, regular or irregular, in Seismic Zone No. 1 and in Occupancy Category IV in Seismic Zone No. 2.

B. Regular structures under 240 feet in height with lateral force resistance provided by systems listed in Table No. 23-O except where Section 2333 (h) 3 D applies.

C. Irregular structures not more than five stories or 65 feet in height.

D. Structures having a flexible upper portion supported on a rigid lower portion where both portions of the structure considered separately can be classified as being regular, the average story stiffness of the lower portion is at least 10 times the average story stiffness of the upper portion and the period of the entire structure is not greater than 1.1 times the period of the upper portion considered as a separate structure fixed at the base.

OBSERVATIONS

These sections describe when use of the NEHRP Equivalent Lateral Force (ELF) or the UBC static analysis is permitted.

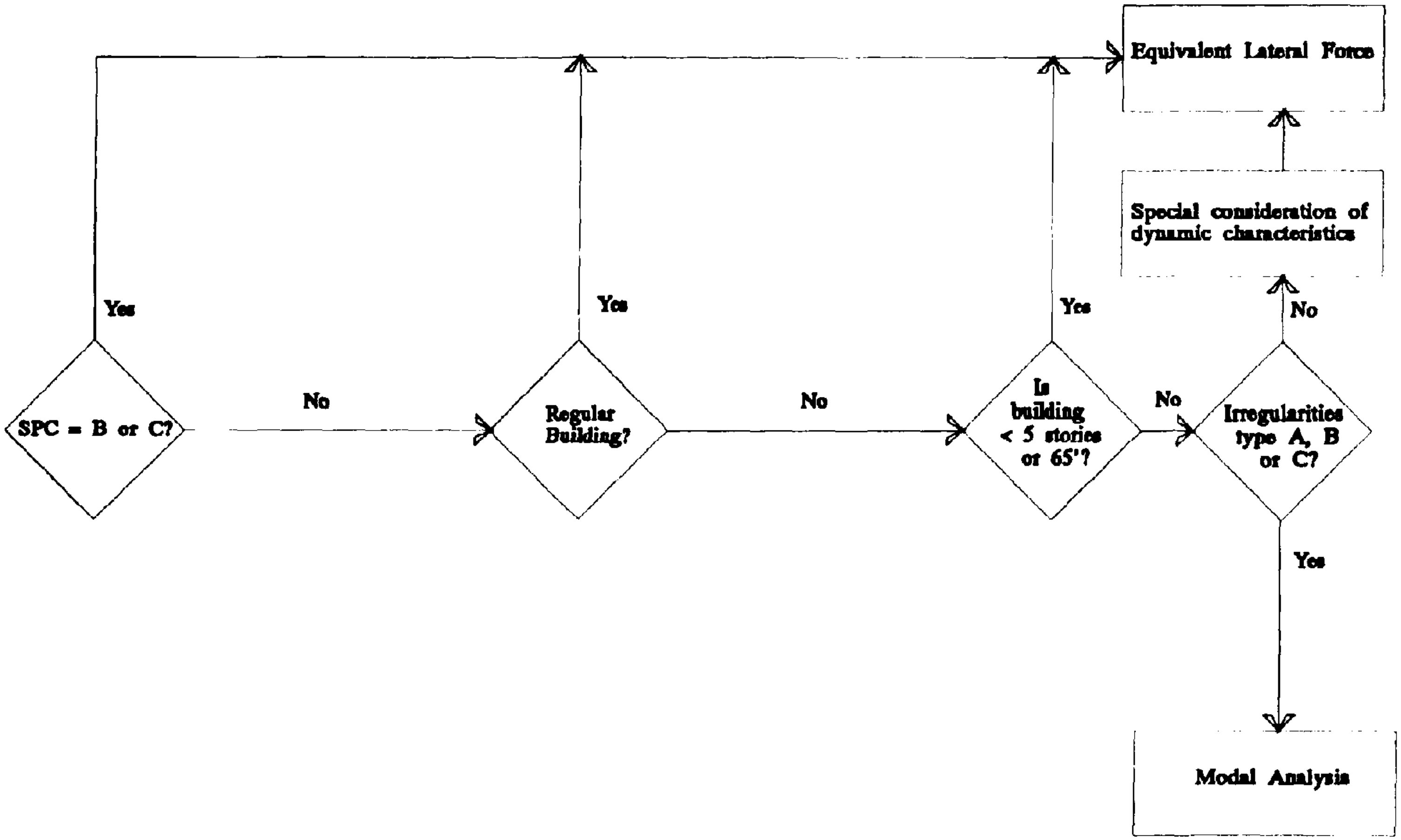
A comparison of decision process and requirements is shown in the Figures K and L.

NEHRP has more restrictive requirements for SPC E buildings than the UBC does for comparable Zone 4 Occupancy I and II structures.

The UBC requires a dynamic analysis for all structures with height greater than 240 feet. NEHRP does not have such a requirement.

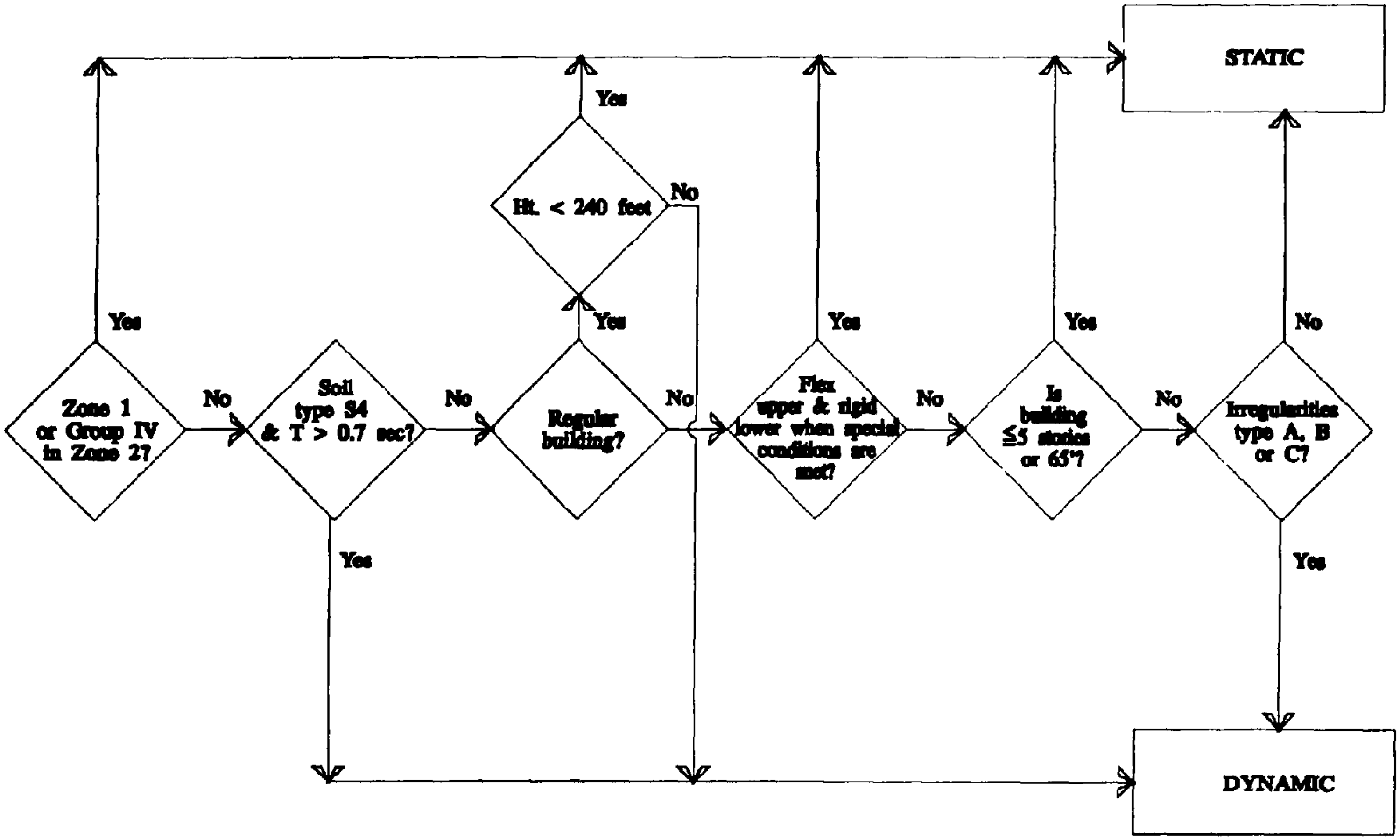
The UBC is more restricive in limiting use of a static approach.

3.When designated as Irregular and having height over 5 stories or 65 feet	Special consideration of dynamic characteristics shall be given	3. Dynamic. The dynamic lateral force procedure of Section 2335 shall be used for all other structures, including the following:
Such buildings having irregularities of Types A, B, or C in Table 3-4	Chapter 5	A. Structures 240 feet or more in height except as permitted by Section 2333 (b) 2 A.
All buildings designated as irregular shall satisfy the requirements referenced in Tables 3-3 and 3-4.		B. Structures having a stiffness, weight or geometric vertical irregularity of Type A, B or C as defined in Table No. 23-M or structures having irregular features not described in Table No. 23-M or 23-N except as permitted by Section 2334 (c) 2.
		C. Structures over five stories or 65 feet in height in Seismic Zones Nos. 3 and 4 not having the same structural system throughout their height except as permitted by Section 2334 (c) 2.
		D. Structures, regular or irregular, located on Soil Profile Type S4 which have a period greater than 0.7 second. The analysis shall include the effects of the soils at the site and shall conform to Section 2335 (b) 4.



Selection of Design Method 1988 NEHRP

Figure K.



Selection of Design Method 1991 UBC

Figure L.

Equivalent Lateral Force Procedure

(Ref: Box 12)

1988 NEHRP

Chapter 4

4.2 SEISMIC BASE SHEAR

The seismic base shear, V, in a given direction, shall be determined from the following:

$V = C_s W,$ (4-1)

where

C_s = the seismic design coefficient determined in accordance with Sec. 4.2.1, and

W = the total dead load and applicable portions of other loads listed below:

1. In storage and warehouse occupancies, a minimum of 25 percent of the floor live load shall be applicable.

2. Where an allowance for partition load is included in the floor load design, the actual partition weight or a minimum weight of 10 psf of floor area, whichever is greater, shall be applicable.

3. Total operating weight of permanent equipment.

4. The effective snow load as defined in Sec. 2.1.

The value of C_s shall be determined in accordance with Eq. 4-2, 4-3, or 4-3a as appropriate.

1991UBC

2334 (a) and (b)

(a) General. Structures shall be designed for *seismic forces coming from any horizontal direction.*

The design seismic forces may be assumed to act nonconcurrently in the direction of each principal axis of the structure, except as required by Section 2337 (a).

Seismic dead load, W, is the total dead load and applicable portions of other loads listed below.

1. In storage and warehouse occupancies, a minimum of 25 percent of the floor live load shall be applicable.

2. Where a partition load is used in the floor design, a load of not less than 10 pounds per square foot (psf) shall be included.

3. Where the snow load is greater than 30 psf, the snow load shall be included. Where considerations of siting, configuration and load duration warrant, the snow load may be reduced up to 75 percent when approved by the building official.

4. Total weight of permanent equipment shall be included.

OBSERVATIONS

The NEHRP and the UBC formulas for determining base shear have similar factors.

Each uses the "R" type factor as part of the equation. The "S" soil factor is also used here. However since different numbers are used, the results of each formula cannot be compared.

The factor W, weight, is determined in a similar manner.

In the case studies, part V of this report, equivalent buildings using the appropriate R factor were designed. From the case studies, the differences between design approaches can be vieved.

Differences are discussed in the case study section of the report. The reader will observe that the case studies show the stress, or material utilization, is within engineering judgement of being equivalent.

4.2.1 Calculation of Seismic Coefficient

When the fundamental period of the building is computed, the seismic design coefficient, C_s, shall be determined from the following:

$$C_s = 1.2\ A_v S/RT^{2/3} \qquad (4\text{-}2)$$

where

A_v = the coefficient representing Effective Peak Velocity-Related Acceleration from Sec. 1.4.1,

S = the coefficient for the soil profile characteristics of the site given in Table 3-1,

R = the response modification factor given in Table 3-2, and

T = the fundamental period of the building determined in Sec. 4.2.2.

C_s need not be taken greater than the value given by Eq. 4-3 or 4-3a.

The soil-structure interaction reduction, when determined in accordance with the Appendix to Chapter 6, may be used.

For the design of a building where the period is not calculated, the value of Cs shall be determined from the following:

$$C_s = 2.5\ A_a/R \qquad (4\text{-}3)$$

where

A_a = the seismic coefficient representing the Effective Peak Acceleration as determined in Sec. 1.4.1.

(b) Static Force Procedure. 1. Design base shear. The total design base shear in a given direction shall be determined from the following formula:

$$V=(ZIC)W/R_w \qquad (34\text{-}1)$$

The value of C need not exceed 2.75 and may be used for any structure without regard to soil type or structure period.

Except for those provisions where code-prescribed forces are scaled up by 3 ($R_w/8$) the minimum value of the ratio C/R_w shall be 0.075.

2. Structure period. The value of T shall be determined from one of the following methods:

A. METHOD A: For all buildings, the value T may be approximated from the following formula:

$$T = C_1\ (h_n)^{3/4} \quad \text{Equation (34-3)}$$

WHERE:

C_t=0.035 for steel moment-resisting frames.

C_t=0.030 for reinforced concrete moment-resisting frames and eccentrically braced frames.

C_t=0.020 for all other buildings.

EXCEPTION: For Soil Profile Type S3 or Soil Profile Type S4 in areas where $A_a = 0.30$, C_s shall be determined from the following:

$$C_s = 2\ A_a/R. \qquad (4\text{-}3a)$$

4.2.2 Period Determination

For use in Eq. 4-2, the fundamental period of the building, T, In the direction under consideration, may be established using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis. The period so determined shall not exceed C_aT_a where C_a is given In Table 4-1.

Alternatively, the value of T may be taken equal to the approximate fundamental period of the building, T_a, determined in accordance with Eq. 4-4 or 4-5 as appropriate.

Alternatively, the value of C_t for structures with concrete or masonry shear walls may be taken as $0.1/\ A_c$

The value of A_c shall be determined from the following formula:

$$A_c = \Sigma A_e\ [0.2 + (D_e/h_n)^2] \qquad (34\text{-}4)$$

The value of D_e/h_n used in formula (34-4) shall not exceed 0.9.

B. METHOD B: The fundamental period T may be calculated using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis. This requirement may be satisfied by using the following formula:

$$T = 2\Pi \sqrt{\left(\sum_{i=1}^{n} w_i\delta_i^2\right) \div \left(g\sum_{i=1}^{n} f_i\delta_i\right)} \qquad (34\text{-}5)$$

4.3

4.3 VERTICAL DISTRIBUTION OF SEISMIC FORCES

The lateral force, Fx, induced at any level, shall be determined from the following:

$$F_x = C_{vx} V, \qquad (4\text{-}6)$$

where

$$C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k} \qquad (4\text{-}6a)$$

w_i and w_x = the portion of W located at or assigned to level i or x;

h_i and h_x = the height above the base to level i or x; and

k = an exponent related to the building period as follows:

For buildings having a period of 0.5 seconds or less, k=1.

For buildings having a period of 2.5 seconds or more, k=2.

For buildings having a period between 0.5 and 2.5 seconds, k may be taken as 2 or may be determined by linear interpolation between 1 and 2.

2334(d)

(d) Vertical Distribution of Force. The total force shall be distributed over the height of the structure in conformance with Formulas (34-6), (34-7) and (34-8) in the absence of a more rigorous procedure.

The concentrated force F_t, at the top, which is in addition to F_n, shall be determined from the formula:

$$F_t = 0.07TV \qquad (34\text{-}7)$$

The value of T used for the purpose of calculating F_t may be the period that corresponds with the design base shear as computed using Formula (34-1). F_t need not exceed 0.25V and may be considered as zero where T is 0.7 seconds or less. The remaining portion of the base shear shall be distributed over the height of the structure, including Level n, according to the following formula:

$$F_x = \frac{(V - F_t)\, w_x h_x}{\sum_{i=1}^{n} w_i h_i} \qquad (34\text{-}8)$$

At each level designated as x, the force F_x shall be applied over the area of the building in accordance with the mass distribution at that level. Stresses in each structural element shall be calculated as the effect of forces F_x and F_t applied at the appropriate levels above the base.

Both sets of provisions have requirements for load distribution over the height of the structure.

The NEHRP vertical shear distribution places more lateral force in the upper stories of buildings with a period in excess of 2.5 seconds. NEHRP also contains a provision permitting the designer to interpolate a distribution factor for buildings between 0.5<T<2.5.

For buildings with a period of 0.7 seconds or more, the UBC designed buildings will have greater force at the roof, the f_t factor.

Thus each set of provisions distribute the lateral forces in a triangular pattern. The specific additional load at the top of the structure may be slightly more under the UBC. For buildings with a T=0.7 seconds the added load is the same with either design method.

Either set of provisions will produce a building that will provide equivalent life safety.

4.4

4.4 HORIZONTAL SHEAR DISTRIBUTION

The seismic design story shear in any story, V_x, shall be determined from the following:

$$V_x = \sum_{i=x}^{n} F_i \qquad (4\text{-}7)$$

The shear, V_x, shall be distributed to the various vertical elements of the seismic resisting system in the story under consideration with due consideration given to the relative stiffnesses of the vertical resisting elements and the diaphragm.

2334(e)

(e) Horizontal Distribution of Shear. The design story shear, V_x, in any story is the sum of the forces F_t and F_x above that story. V_x shall be distributed to the various elements of the vertical lateral force-resisting system in proportion to their rigidities, considering the rigidity of the diaphragm. See Section 2337 (b) 4 for rigid elements that are not intended to be part of the lateral force-resisting systems.

To account for the uncertainties in locations of loads, the mass at each level shall be assumed to be displaced from the calculated center of mass in each direction a distance equal to five percent of the building dimension at that level perpendicular to the direction of the force under consideration. The effect of this displacement on the story shear distribution shall be considered.

The UBC requires design for 5 percent accidental torsion under the horizontal shear distribution section. NEHRP has a similar provision under the torsion section.

4.4.1 Torsion

The design shall provide for the torsional moment M_t resulting from the location of the building masses plus the torsional moments M_{ta} caused by assumed displacement of the mass each way from its actual location by a distance equal to 5 percent of the dimension of the building perpendicular to the direction of the applied forces.

For Categories C, D, and E buildings where torsional irregularity exists, as defined in Table 3-4, the effects shall be accounted for by increasing the accidental torsion at each level by an amplification factor, A_x, determined from the following:

$$Ax = (d_{max}/1.2d_{avg})^2 \qquad (4\text{-}8)$$

where

d_{max} = the maximum displacement at level x, and

d_{avg} = the average of the displacements at the extreme points of the structure at level x.

The value of Ax need not exceed 3.0.

The more severe loading for each element shall be considered for design.

2334(f)

(f) Horizontal Torsional Moments. Provision shall be made for the increased shears resulting from horizontal torsion where diaphragms are not flexible. Diaphragms shall be considered flexible for purposes of this paragraph when the maximum lateral deformation of the diaphragm is more than two times the average story drift of the associated story. This may be determined by comparing the computed midpoint in-plane deflection of the diaphragm under lateral load with the story drift of adjoining vertical resisting elements under equivalent tributary lateral load.

The torsional design moment at a given story shall be the moment resulting from eccentricities between applied design lateral forces at levels above that story and the vertical resisting elements in that story plus an accidental torsion. .

The accidental torsional moment shall be determined by assuming the mass is displaced as required by Section 2334 (e)

Where torsional irregularity exists, as defined in Table No. 23-N, the effects shall be accounted for by increasing the accidental torsion at each level by an amplification factor, A_x, determined from the following formula:

$$A_x + [\delta\frac{\max}{1.2\delta avg}]^2 \qquad (34\text{-}9)$$

The UBC exempts flexible diaphragms from the horizontal torsion moment requirements, NEHRP does not. This possible change is currently being discussed in the SEAOC Seismology committee.

4.5 OVERTURNING

Every building shall be designed to resist overturning effects caused by the seismic forces determined in Sec. 4.3. At any story, the increment of overturning moment in the story under consideration shall be distributed to the various vertical resisting elements in the same proportion as the distribution of the horizontal shears to those elements.

The overturning moments shall be determined from the following:

$$M_x = \kappa \sum_{i=x}^{n} F_i (h_i - h_x) \qquad (4\text{-}9)$$

where

k = 1.0 for the top 10 stories,

k = 0.8 for the 20th story from the top and below, and

k = a value between 1.0 and 0.8 determined by a straight line interpolation for stories between the 20th and 10th stories below the top

The foundations of buildings, except inverted pendulum structures, may be designed for the foundation overturning design moment, M_f, at the foundation-soil interface determined using Eq. 4-9 with k = 0.75 for all building heights.

1. General. Every structure shall be designed to resist the overturning effects caused by earthquake forces specified in Section 2334 (d). At any level, the overturning moments to be resisted shall be determined using those seismic forces (F_t and F_x) which act on levels above the level under consideration. At any level, the incremental changes of the design overturning moment shall be distributed to the various resisting elements in the manner prescribed in Section 2334 (e). Overturning effects on every element shall be carried down to the foundation. See Section 2337 for combining gravity and seismic forces.

2. Seismic Zones Nos. 3 and 4. In Seismic Zones Nos. 3 and 4, where a lateral load-resisting element is discontinuous, such as for vertical irregularity Type D in Table No. 23-M or plan irregularity Type D in Table No. 23-N, columns supporting such elements shall have the strength to resist the axial force resulting from the following load combinations, in addition to all other applicable load combinations:

A. The axial forces in such columns need not exceed the capacity of other elements of the structure to transfer such loads to the column.

B. Such columns shall be capable of carrying the above described axial forces without exceeding the axial load strength of the column. For designs using working stress methods this capacity may be determined using an allowable stress increase of 1.7.

C. Such columns shall meet the following detailing or member limitations:

NEHRP varies the percentage of dead load assumed capable of resisting overturning based on the value of A_v. (See SEc. 3.7.1, Combination of Load Effects) The UBC in Sec 2337(a) permits use of 85% of the dead load to resist overturning.

Chapter 26, Section 2625 (e), for concrete, and Chapter 27, Section 2710 (e), for steel in structures in Seismic Zones Nos. 3 and 4.

Chapter 26, Section 2625 (k), for concrete, Chapter 27, and U.B.C. Standard No. 27-15, special provisions for developing plastic hinges at ultimate loading, for steel in structures in Seismic Zone No. 2.

3. At foundation. See Section 2910 (d) for overturning moments to be resisted at the foundation soil interface.

Modal Analysis

(Ref: Box 13)

1988 NEHRP	1991 UBC	OBSERVATION
Chapter 5	2335	Both NEHRP and the UBC require a dynamic analysis except in the case where a ELF or static approach is permitted. The NEHRP procedure, not repeated here, is modeled after the traditional static approach. It is simpler than the UBC. The UBC takes a more rigorous approach for dynamic analysis. Buildings using either approach should meet the intent of both NEHRP and the UBC.

Load Combinations

(Ref: Box 14)

1988 NEHRP	1991UBC	OBSERVATIONS
3.7.1 and 3.7.2	**2303(f) and 2337(a)**	
3.7.1 Combination of Load Effects The effects on the building and its components due to gravity loads and seismic forces shall be combined in accordance with Eq. 3-1 or, as applicable, Eq. 3-2 or 3-2a. Combination of load effects $= (1.1 + 0.5 A_v) Q_D + 1.0 Q_L + 1.0 Q_S +/- 1.0 Q_E$ (3-1) Combination of load effects $= (0.9 - 0.5 A_v) Q_D +/- 1.0 Q_E$ (3-2) For partial penetration welded steel column splices or for unreinforced masonry and other brittle materials, systems, and connections: Combination of load effects= $(0.7 - 0.5 A_v) Q_D +/- 1.0 Q_E$ (3-2a) The term 0.5 A_v may be neglected where A_v is equal to 0.05.	(f) Load Combinations. Every building component shall be provided with strength adequate to resist the most critical effect resulting from the following combination of loads (floor live load shall not be included where its inclusion results in lower stresses in the member under investigation): Dead plus floor live plus wind (or seismic). Dead plus floor live plus snow plus seismic.	NEHRP uses factors that vary with A_v when combining loads whereas UBC does not.

3.7.2 Orthogonal Effects

In buildings assigned to Category B or C, the design seismic forces may be applied separately in each of two orthogonal directions. In buildings assigned to Category D or E, the critical load effect due to direction of application of seismic forces on the building may be assumed to be satisfied if components and their foundations are designed for the following combination of prescribed loads: 100 percent of the forces for one direction plus 30 percent of the forces for the perpendicular direction. The combination requiring the maximum component strength shall be used.

EXCEPTION: Diaphragms and components of the seismic resisting system utilized in only one of the two orthogonal directions need not be designed for the combined effects.

Sec 2337(a).

The requirement that orthogonal effects be considered may be satisfied by designing such elements for 100 percent of the prescribed seismic forces in one direction plus 30 percent of the prescribed forces in the perpendicular direction. The combination requiring the greater component strength shall be used for design. Alternatively, the effects of the two orthogonal directions may be combined on a square root of the sum of the squares (SRSS) basis. When the SRSS method of combining directional effects is used, each term computed shall be assigned the sign that will result in the most conservative result.

The two sets of provisions are similar in intent and results.

Drift Limit and Building Separations

(Ref: Box 15)

1988 NEHRP	1991UBC	OBSERVATIONS
3.8	**2334(h)**	
3.8 DEFLECTION AND DRIFT LIMITS All portions of the building shall be designed and constructed to act as an integral unit in resisting seismic forces unless separated structurally by a distance sufficient to avoid damaging contact under total deflection, dx (as determined in Sec. 4.6.1), or modified deflection, dx (as determined in Sec. 6A.2.3), corresponding to the seismic design forces. The design story drift, "delta", as determined in Sec. 4.6 or 5.8, shall not exceed the allowable story drift "delta-a" as obtained from Table 3-5 for any story. For structures with significant torsional deflections, the effect of maximum drift, including torsional effects, shall be considered for stability and damage control.	(h) Story Drift Limitation. 1. Defined. Story drift is the displacement of one level relative to the level above or below due to the design lateral forces. Calculated drift shall include translational and torsional deflections. 2. Calculated. Calculated story drift shall not exceed $0.04/R_w$ or 0.005 times the story height for structures having a fundamental period of less than 0.7 seconds. For structures having a fundamental period of 0.7 seconds or greater, the calculated story drift shall not exceed 0.03/Rw or 0.004 times the story height. These drift limits may be exceeded when it is demonstrated that greater drift can be tolerated by both structural elements and nonstructural elements that could affect life safety. 3. Deriving forces. The design lateral forces used to determine the calculated drift may be derived from a value of C based on the period determined from Formula (34-5) neglecting the lower bound ratio for C/Rw of 0.075 of Section 2334 (b) 1 and the 80 percent limitation of Section 2334 (b) 2 B.	The NEHRP provisions have a drift limit based on the total expected deflection under an ultimate- level load. The UBC drift limits are based on elastic deflection only using a working-stress level load. The NEHRP criteria differs based on the SHEG which reflects the character of the occupancy. The UBC increases the base shear for certain occupancies. An example is SHEG = III in NEHRP compared to the I=1.5 factor in the UBC. The two sets of provisions use different approaches to limiting drift. They are not numerically comparable. The NEHRP story drift criteria is shown on the next page. A comparison of numeric drift limits under both sets of provisions for selected buildings is shown Figure M. These are qualitive only. Since the basic design loads and stress levels differ, they do not provide a comparison or that would lead one to conclude that the provisions differ dramatically.

2337(b)11 Building Separation

11. Building separations. All structures shall be separated from adjoining structures. Separations shall allow for $3(R_w/8)$ times the displacement due to seismic forces.

EXCEPTION: Smaller separations may be permitted when justified by rational analyses based on maximum expected ground motions. As a minimum, building separations shall not be less than (Rw/8) or = 1 times the sum of displacements due to code-specified seismic forces.

NEHRP is silent on required building separations. The UBC provisions provide specific requirements for designers.

Drift Limit Comparison

Note: Because NEHRP uses ultimate level load, whereas the UBC uses a working stress level load, values are not quantitavely comparable. They may provide the reader with a qualitative comparison of the two criteria.

Structural System	1988 NEHRP		1991 UBC
	SHEG = I	SHEG = III	(T < 0.7 Sec.)
Light-Framed with Plywood	(Cd = 4)		
(4 stories or less)	0.005 h	0.0025 h	(Rw = 8) 0.005 h
Masonry Shear Wall	(Cd = 3)		
Bearing Wall			
<= 4 stories	0.0067 h	0.0033 h	(Rw = 6) 0.005 h
> 4 stories	0.0050 h	0.0033 h	0.004 h*
Concrete Shear Wall	(Cd = 5)		
=< 4 stories	0.004 h	0.002 h	(Rw = 8) 0.005 h
> 4 stories	0.003 h	0.002 h	0.0038 h*
SMRF	(Cd = 5.5)		
<= 4 stories	0.0036 h	0.0018 h	(Rw = 12) 0.0033 h
> 4 stories	0.0027 h	0.0018 h	0.0025 h*
Concrete SMRF and Shear Wall	(Cd = 6.5)		
<= 4 stories	0.0031 h	0.0015 h	(Rw =12) 0.0033 h
> 4 stories	0.0023 h	0.0015 h	0.0025 h*
			*T>0.7 Sec

Figure M. Drift Limits.

Materials Requirements

(Ref: Boxes 17-20)

Material	1988 NEHRP	1991 UBC
Wood	Chapter 9	Chapter 25
Steel	Chapter 10	Chapter 27
Concrete	Chapter 11	Chapter 26
Masonry	Chapter 12	Chapter 24

Note:

The details of each material section are not reproduced in this report. Selected sections of NEHRP are included in Section IV, Structural Materials Comparison.

Foundations

(Ref: Box 21)

1988 NEHRP	1991UBC	OBSERVATIONS
Chapter 7		
7.3 SPC = A and B	**Chapter 29**	NEHRP and the UBC are consistent in the requirements for pile and caisson ties.
7.4 SPC = C	2908(b)	
7.4.3	b) Interconnection. Individual pile caps and caissons of every structure subjected to seismic forces shall be interconnected by ties. Such ties shall be capable of resisting, in tension or compression, a minimum horizontal force equal to 10 percent of the larger column vertical load.	
7.4.3 Foundation Ties "SPC = C"		
Individual pile caps, drilled piers, or caissons shall be interconnected by ties. All ties shall be capable of carrying, in tension or compression, a force equal to Av/4 of the larger pile cap or column load unless it can be demonstrated that equivalent restraint can be provided by reinforced concrete beams within slabs on grade or reinforced concrete slabs on grade or confinement by competent rock, hard cohesive soils, very dense granular soils, or other approved means.	2909 and 2910	
7.4.4		
7.5.2		NEHRP requirements for foundation ties for spread footings for SPC = D & E are more restrictive than the UBC.
7.5.2 Foundation Ties "SPC = D & E"		
Individual spread footings, unless founded directly on rock, as defined in Sec. 3.2.1.1, shall be interconnected by ties. Ties shall conform to Sec. 7.4.3.		

IV. Structural Materials Comparison

Introduction

NEHRP and the UBC contain specific provisions for the conventional construction materials. The specific chapter references were shown in the side by side comparisons on page 53 of the report and in Boxes 17 to 20 in Figures A and B.

The task of comparing the materials requirements between the two documents was not always an easy one. NEHRP is based on the ultimate strength design concept while the UBC is primarily based on working stress. However, both documents are based on the same national reference standards for wood, steel and concrete. Specific sections are then amended and further restricted. The major difference in the adoption of design standards is that NEHRP adopts the masonry provisions of the ACI-ASCE standard, the UBC does not.

The NEHRP provisions are structured in a manner that includes increasingly stringent detailing, materials and construction requirements linked to the Structural Performance Category (SPC).

The UBC uses a different approach. The design base shear is based on a multitude of factors including seismic zone and occupancy. Material and detailing requirements are based on the seismic zone with the most stringent requirements in Seismic Zones 3 and 4.

The comparison methodology is outlined below.

The first step taken to make the materials comparisons was to prepare the "crosswalk" between the two documents. These pages are essentially an index referencing each itemized section in one document to the corresponding section(s) in the other.

This task laid the foundation for the detailed compare-and-contrast work.

For wood structure requirements, both documents reference the 1986 National Design Specification. The general construction requirements are similar but are arranged differently within each document. The UBC breaks down the requirements by categories, and any further restrictions for higher seismic zones are included in subsections. For example, Section 2513 covers shear walls and diaphragms while Section 2513(e) spells out additional requirements for Seismic

Zones 3 and 4. NEHRP outlines the requirements according to Seismic Performance Category, adding more restrictions for each subsequent SPC. As a result, many items in NEHRP were found to correspond to parts of several sections in the UBC.

The masonry comparison was made directly between the UBC and ACI-ASCE 530 with NEHRP's modifications. NEHRP proves to be more restrictive with regard to stack bond construction requirements. The UBC prohibits several materials in vertical or lateral load-resisting systems. NEHRP permits most of these materials, but prohibits structural clay wall tile which is permitted by the UBC.

The concrete design provisions of the two documents lend themselves to be compared more readily than the other material provisions. NEHRP adopts ACI 318-83 and then modifies it to meet the requirements of the latest edition of ACI 318. The UBC incorporates many provisions of ACI 318-89 directly; portions of the Code which differ substantively from ACI are printed italicized. As a result, the UBC is more restrictive at nearly all of the italicized sections. NEHRP contains some more restrictive requirements for prestressed concrete construction.

For steel design both documents utilize the AISC design standards. Steel was the most difficult material to directly compare; working stress and ultimate stress are not readily comparable. NEHRP contains some concentrically braced frame items not addressed in the UBC. The UBC contains several aspects of special moment resisting frame requirements not covered in NEHRP.

The following pages illustrate the differences between the two documents. The first part of each materials section shows NEHRP Provisions thought to affect the design and be more stringent than the UBC. The second part lists sections in the UBC for each material that are either more restrictive than or not addressed in the NEHRP Provisions. The reader is referred to the crosswalk index for the corresponding UBC and NEHRP sections. Following each material section, a brief summary of design differences is presented.

Wood

NEHRP Chapter 9 and UBC Chapter 25 contain references and criteria for wood frame buildings. The NEHRP sections shown here describe the requirements for different SPC categories that are more restrictive than the corresponding UBC requirements. There are only two items for which the UBC is more restrictive than NEHRP. A comparison of the NEHRP and UBC wood standards is shown in Figure N at the end of the wood section. A comparison of each set of provisions is shown in Figure O. While these criteria are shown side by side, the reader should keep in mind that the SPC and Seismic Zones are not the same and thus the requirements are not directly comparable.

The following NEHRP Provisions are more restrictive than the corresponding UBC provisions:

9.3 SEISMIC PERFORMANCE CATEGORIES A AND B

Buildings assigned to Category A or B may be constructed using any of the materials and procedures permitted in the reference documents and this chapter except as limited in this section.

9.3.1 Bracing Requirements

All wood frame buildings three stories in height shall have solid sheathing of one of the materials specified in Sec. 9.7.3 applied for the full height over not less than 25 percent of the length of each exterior wall in the first story.

9.4 SEISMIC PERFORMANCE CATEGORY C

Buildings assigned to Category C shall conform to all of the requirements for Categories A and B and to the additional requirements of this section.

9.4.1 Detailing Requirements

The construction shall comply with the requirements given below.

9.4.1.1 Anchorage of Concrete or Masonry Walls

The diaphragm sheathing shall not be used for providing ties and splices required in Sec. 3.7.5 and 3.7.6.

9.5 SEISMIC PERFORMANCE CATEGORY D

Buildings assigned to Category D shall conform to all the requirements for Category C and to the additional requirements and limitations of this section.

9.5.2 Framing Systems

The limitations on framing systems that may be used in Category D are given below.

9.5.2.2 Shear Walls

The use of walls sheathed with gypsum sheathing, particle board, gypsum wall board, or wire lath and cement plaster as shear walls for resisting seismic forces shall be limited to one-story buildings or the top story of buildings two stories or more in height. Fiberboard sheathed shear walls shall not be used as part of the seismic force resisting system.

9.5.2.3 Conventional Light Frame Construction

Buildings over one story in height of conventional light frame construction shall have solid sheathing of one of the materials specified in Sec. 9.7.3.1 or 9.7.3.2 applied for the full height over at least 40 percent of the length of the building at each exterior wall of the stories below the top story.

9.5.3 Detailing Requirements

Special details for Category D construction are given below.

Common wire nails driven parallel to the grain of the wood shall not be used to resist loads greater than 50 percent of working stress values permitted in Ref. 9.1 for normal duration of loading for nails driven perpendicular to the grain.

Connections using multiple nails driven perpendicular to the grain and used to resist loads in withdrawal shall use the capacity reduction factors given for lag screws and wood screws.

9.6 SEISMIC PERFORMANCE CATEGORY E

Buildings assigned to Category E construction shall conform to all of the requirements for Category D and to the additional requirements and limitations of this section.

9.6.1 Material Limitations

Walls sheathed with gypsum sheathing, particle board, gypsum wall board, fiberboard, or wire lath and cement plaster shall not be used as part of the seismic resisting system.

9.6.2 Framing Systems

Unblocked plywood diaphragms shall not be used as part of the seismic resisting system.

9.6.3 Diaphragm Limitations

Plywood used for shear panels that are a part of the seismic resisting system shall be applied directly to the framing members, except that plywood may be used as a diaphragm when nailed over solid lumber planking or laminated decks. The allowable working stress shear for vertical plywood shear walls used to resist horizontal forces in buildings with masonry or reinforced concrete walls shall be one-half of the allowable values set forth in Table 9-2.

9.7 CONVENTIONAL LIGHT TIMBER CONSTRUCTION

Wood frame buildings that require no engineering analysis of the seismic loading effects, in accordance with Sec. 1.3.1, shall be subject to the design regulations enforced by the Regulatory Agency for general wood frame and light frame construction except as modified by the provisions of this section.

9.7.1 Wall Framing and Connections

The following wall framing and connection details shall apply as a minimum.

9.7.2 Wall Sheathing Requirements

All exterior walls and main interior partitions shall be effectively and thoroughly braced by one of the types of sheathing described in Sec. 9.7.3 at each end of the wall or partition, or as near thereto as possible, and at not over 25- foot intervals between the ends. To be considered effective as bracing, the sheathing shall be at least 48 inches in width covering three 16-inch stud spaces or two 24-inch stud spaces. All vertical joints of panel sheathing shall occur over studs and all horizontal joints shall occur over blocking at least equal in size to the studs. All framing in connection with sheathing used for bracing shall be not less than 2 inch nominal thickness.

Minimum nailing shall be as given in Tables 9-1 through 9-4. Nailing for diagonal boards shall be as specified in Sec. 9.8.3. Minimum nailing for particle board shall be the same as given for fiberboard in Table 9-3.

9.7.3.5 Particleboard

Particleboard exterior sheathing panels Type 2-M-1 grade, or better, not less than 3/8 inch thick on studs spaced not over 16 inches on center.

The following NEHRP provision is not addressed in the UBC:

9.4 SEISMIC PERFORMANCE CATEGORY C

9.4.1.2 Lag Screws

Washers shall be provided under the heads of lag screws that would otherwise bear on wood.

The following UBC sections are more restrictive than the comparable NEHRP provisions:

2510(c) Nails and Spikes, safe lateral strength

The UBC limits a nail driven parallel to grain to 2/3 of allowable lateral load for a nail driven perpendicular to grain. NEHRP imposes a 50% limit, but only for SPC D and E. The result is that the UBC is more restrictive in the low seismic zones, 0 - 2A (0 - 2B for Occupancy IV), and NEHRP is more restrictive in the higher seismic zones.

2513(a) General

In masonry or concrete buildings, the UBC does not permit wood diaphragms to resist torsion. NEHRP allows rotation (torsion) for one- and two-story buildings in Seismic Performance Categories D and E and in all other buildings.

While some NEHRP provisions appear to be more restrictive than the UBC, the itemized provisions are detailing requirements and engineering judgments regarding damage limitations. For all practical purposes the same building will result from design by either document.

Wood Standards Comparison

1988 NEHRP	1991 UBC
NDS (1986)	National Design Spec. (1986)
PS20-70	PS 20-70 (ref. UBC Std. 25-1)
ASTM D245 (1986)	ASTM D 245 (1986)(ref. UBC Std. 25-1)
ASTM D255 (1981)	ASTM D 255 (1981)(ref.UBC Std. 25-1)
PS 1-83	PS 1-83 (ref.UBC Std. 25-9)
ANSI A208.1	ANSI A208.1 (ref. UBC Std. 25-25)
APWA C1, C2,C3, C4, C9, C14, C23, C24, C28 & M4 (ref UBC 2501 (a) 3A)	AWPA C1 (1987)C2 (1987) C3 (1987)C9 (1985) & C29 (1982)
ASTM D1760-86a	
ANSI/AITC A190.1(1983)	ANSI/AITC A190.1 (1983) (ref. UBC 2501 (a) 2A)
AITC 117 (1987)	AITC 117 (1987)(ref. UBC 2501 (a) 2B)
ANSI O5.1 (1987)	ANSI 05.1 (1987)(ref. UBC 2501 (a) 4B)
ASTM D25 (1986)	ASTM D25 (1986) (ref. UBC 2501 (a) 4C)

Figure N. Wood standards.

	1988 NEHRP								1991 UBC							
	A & B		C		D		E		Zone 0		Zone 1		Zone 2		Zone 3 & 4	
	Req'd	not allowed	Req'd	not allowed	Req'd	not allowed	Req'd	not allowed	Req'd	not allowed	Req'd	not allowed	Req'd	not allowed	Req'd	not allowed
Solid shtg. on 1st floor of 3 story bldg.* (9.3.1) (9.5.2.3)	X		X		X		X		X		X		X		X	
Use of shtg. as tie (9.4.1)				X		X		X							X	
Washer for lag screw (9.4.1.2)			X		X		X									
Exterior type plywood (9.5.1)					X		X								X	
Wood diaphragm resisting torsion in masonry or concrete bldg. > 2 stories (9.5.2.1)						X		X		X		X		X		X
Use of non-plywood wall shtg. in stories below top stories of multi-storie bldg. (9.5.2.2)						X		X								
Stress reduction for nail parallel to grain (9.5.3)					X		X		X		X		X		X	
Use of non-plywood wall shtg. (9.6.1)								X								
Blocked plywood diaphragm (9.6.2)							X									
Stress reduction for plywood in shear wall in masonry or reinforced concrete (9.6.3)							X									

* For SPC = A, B & C - 25% of length of walls
For SPC = D - 40% of length of walls
For Zone 0, 1 & 2 - 25% of walls
For Zone 3 & 4 - 40% of length of walls

Note that the SPC and Seismic Zones are not directly comparable.

Figure O. Wood requirements.

Steel

Chapter 10 in NEHRP and Chapter 27 in the UBC reference the nationally accepted standards for steel construction. NEHRP has additional provisions for various types of braced frames. In this section the NEHRP provisions are performance based. The UBC provisions tend to be prescriptive. An example is the requirements for a "link beam" for which NEHRP specifies an ultimate yield stress. The UBC calls for specific ASTM steel types for the link beam. When the yield stresses of the UBC specified steels are compared to the NEHRP performance criteria, the two sets of provisions are the same. There are many detail requirements in NEHRP for braced frames which are more restrictive than the UBC. These detailing requirements will not result in substantially improved life safety with NEHRP over the UBC.

The standards listed below are the NEHRP reference documents for steel. These are also the basis of the UBC. Enforcement of these requirements is in the UBC and the UBC Standards.

Ref. 10.1 The American Institute of Steel Construction (AISC) Specifications (Parts 1 and 2) for the Design, Fabrication and Erection of Structural Steel for Buildings, November 1, 1978, Including Supplement No. 1, Effective March 11, 1986 (guideline standard in section 2701(a)1B of the UBC)

Ref. 10.2 Specification for the Design of Cold-formed Steel Structural Members, American Iron and Steel Institute (AISI), August 10, 1986 (UBC Standard 27-9)

Ref. 10.3 The Specifications for the Design of Cold-formed Stainless Steel Structural Members, AISI, 1974 Edition (UBC Standard 27-10)

Ref. 10.4 Standard Specification, Load Tables and Weight Tables for Steel Joists and Joist Girders, Steel Joist Institute, 1986 Edition (UBC Standard 27-4)

Ref. 10.5 The Criteria for Structural Applications for Steel Cables for Buildings, AISI, 1973 Edition (UBC Standard 27-12)

Ref. 10.6 Load and Resistance Factor Design Specification for Structural Steel Buildings, American Institute of Steel Construction, September 1, 1986 (UBC Standard 27-14)

The following NEHRP provisions are more restrictive than the corresponding UBC provisions:

10.8 CONCENTRICALLY BRACED FRAME REQUIREMENTS

10.8.4 Bracing Member Connections

In Seismic Performance Categories D and E, connections shall be designed to develop the full tensile yield capacity of the member.

10.8.4.1 Net Area

In bolted brace connections, the ratio of the minimum effective net section area to the gross section area shall not be less than 1.2 times the ratio of the material minimum yield strength to the minimum tensile strength.

10.8.4.2 Stitches

For a brace that will buckle out-of-plane, the first stitch on each side of the midlength of a built-up member shall be designed to transmit a force equal to 50 percent of the yield capacity of one element to the adjacent element. Bolted stitches shall not be placed at the midlength of a brace member.

10.8.4.3 Gusset Plates

The end gusset plates shall be designed to carry the full axial load and end moment capacities of the bracing member for in-plane buckling. For out-of-plane buckling, the gusset plate shall have a clear end length of two times the gusset plate thickness and shall be able to carry the full compression capacity of the brace member without local buckling of the gusset plate. The bolts or welds shall be designed to transmit the brace forces along the centroids of the brace elements. The length should be sufficient to avoid tearing failure.

10.9 ECCENTRICALLY BRACED FRAME REQUIREMENTS

10.9.1 Link beams shall satisfy compact section requirements of Ref. 10.6, Sec. B5 and Table C-B5.1 for seismic applications. The nominal yield strength of steel used for link beams shall not exceed Fy = 50 ksi.

The following UBC sections are more restrictive than the corresponding NEHRP provisions:

2710 STEEL STRUCTURES RESISTING FORCES INDUCED BY EARTHQUAKE MOTIONS IN SEISMIC ZONES NOS. 3 AND 4

2710(g)4 Continuity plates

To determine the need for girder tension flange continuity plates, the UBC uses the equation $P_{bf} = 1.8(bt_f)F_{yb}$ while NEHRP does not include the 1.8 factor.

2710(h)4B and 5 K Bracing

The UBC allows K-bracing in Zones 1 and 2 if bracing members are designed for 1.5 times the prescribed forces, and in 2-story buildings in all zones if the braces have the strength to resist $3(R_w/8)$ times the code equivalent static forces; NEHRP does not allow K- bracing in SPC D or E.

2710(i)3 EBF link beam rotation

The UBC drift limitations are more strict than NEHRP's: 0.06 radians vs. 0.08 rads respectively for link segments having clear lengths of 1.6 M_s/V_s or less; 0.015 rads vs. 0.02 radians for link segments having clear lengths of 2.6 M_s/V_s or greater.

No equivalent NEHRP sections could be found for the following UBC sections:

2710(g)3 Flange width-thickness ratio

The UBC requires that the flange width-thickness ratio not exceed 52/(square root of Fy).

2710(g)5 SMRF Strength ratio

At any moment frame joint, the ratio of the column strength to the sum of the beam strengths should be less than one.

2710(g)7 Girder-column joint restraint

The UBC requires that the flanges of columns be laterally supported only at the level of the girder top flange, if the columns remain elastic, or at the levels of the girder top and bottom flanges if the column does not remain elastic. Columns without the required lateral support transverse to a joint should assume a pin ended connection for the purpose of unsupported height.

2710(g)8 Beam bracing

The UBC requires that both flanges of beams be braced.

2710(g)9 Changes in beam flange area

The UBC does not allow abrupt changes in beam flange area within possible plastic hinge regions of special moment-resisting frames.

2710(g)10 Moment frame drift calculations

The UBC requires that moment frame drift calculations include bending and shear contributions from the clear girder and column spans, column axial deformation and the rotation and distortion of the panel zone, with some exceptions.

2710(h)2A Braced Frame Requirements, Slenderness of bracing members

In Seismic Zones 3 and 4, the UBC limits l/r ratio to 720/(sqrt Fy), except for one- and two- story buildings if braces can resist 3(R_w/8) times code forces.

Note that all of the above-outlined UBC items are from Section 2710. This section of the code applies only to Seismic Zones 3 and 4 while Section 2711 pertains to Seismic Zones 1 and 2. No UBC requirement is more restrictive than its NEHRP counterpart for Seismic Zones 1 and 2.

Several requirements from both documents have been discussed in the preceding paragraphs. As can be seen most are detailing requirements and do not represent any significant difference in life safety.

Concrete

Chapter 11 of NEHRP references ACI 318-83 for concrete design. Chapter 26 of the UBC references ACI 318-89. The concrete chapter in NEHRP is organized differently than the other materials chapters. Only specific amendments and addenda to certain paragraphs of the ACI 318 text are listed. NEHRP's modifications to the 1983 edition of ACI 318 include the changes made in the updated ACI edition. However, the UBC includes some additional requirements not covered in either ACI 318 or in NEHRP, and is therefore more restrictive. Only NEHRP provisions for prestressed concrete design are more restrictive than those in the UBC. The NEHRP reference standard is listed below.

> Ref. 11.1 Building Code Requirements for Reinforced Concrete, American Concrete Institute, ACI 318-83, including Appendix A (ACI 318-89 for the UBC)

The following NEHRP provisions are more restrictive than the corresponding UBC provisions:

> 11.1.1.4 Modify Sec. A.2.5.1 to read as follows:
>
> "Reinforcement resisting earthquake-induced flexural and axial forces in frame members and in wall boundary members shall comply with ASTM A706 except as modified herein. ASTM A615 Grades 40 and 60 ... not less than 1.25. [Post-tensioning tendons may be used in flexural members of frames provided the average prestress f_{pc}, calculated for an area equal to the member's shortest cross-sectional dimension multiplied by the perpendicular dimension, does not exceed 350 psi.]"
>
> Note: Bracketed section is not in the UBC.
>
> Add the following to the end of Sec. A.2.5.1:
>
> "When reinforcing steel is to be welded, the steel shall comply with ASTM A706. This requirement may be satisfied by the use of steel complying with ASTM A615 provided that this steel meets the carbon equivalent requirements and chemical limits for ASTM A706 steel."
>
> 11.1.1.5 Insert the following new Sec. A.3.2.3 and change the existing Sec. A.3.2.3 and A.3.2.4 to A. 3.2.4 and A.3.2.5, respectively:

"For members in which prestressing tendons are used together with ASTM A706 or with A615 (Grades 40 or 60) reinforcement to resist earthquake-induced forces, prestressing tendons shall not provide more than one quarter of the strength for both positive moments and negative moments at the joint face. Anchorages for tendons must be demonstrated to perform satisfactorily for seismic loadings. Test assemblies shall withstand, without failure, a minimum of 50 cycles of loading ranging between 40 and 85 percent of the minimum specified strength of the tendon. Tendons shall extend through exterior joints and be anchored at the exterior face of the joint or beyond."

The following UBC sections contain requirements more restrictive than NEHRP:

2607(k)3B Ties - Lateral Reinforcement for Compression Members

The UBC agrees with ACI (NEHRP) for Seismic Zones 0 and 1. In Seismic Zones 2 through 4, however, the UBC requires that lateral ties be placed at top and bottom of the column for a distance that is the greater of one-sixth the clear height or the maximum column dimension, but not less than 18". Tie spacing should not be greater than 8 bar diameters, 24 tie diameters, or one-half the least column dimension.

Seismic Zones 3 and 4 only:

2625(c)4 Load Factors

The UBC modifies the load combination equations for Seismic Zones 3 and 4 over those of lower zones by increasing dead load and live load by extra factors of 1.4 and 1.1 respectively.

2625(c)5B Concrete in Members Resisting Earthquake-Induced Forces

Both documents state that f'c for lightweight concrete shall not exceed 4000 psi, unless experimental evidence demonstrates a higher value may be used. The UBC is slightly more conservative with the extra requirement that in no case may the compressive strength of lightweight concrete exceed 6000 psi.

2625(c)6 Reinforcement in Members Resisting Earthquake-Induced Forces

The UBC specifically calls for low alloy A706 reinforcement. It also prohibits welding of stirrups, ties, inserts, etc. to longitudinal bars.

2625(e)3B Longitudinal Reinforcement - Frame Members Subject to Bending Plus Axial Load

The UBC specifically calls for Class A tension splices of longitudinal bars with transverse reinforcement over the length of the splice.

2625(e)4A(i) Transverse Reinforcement - Frame Members Subject to Bending Plus Axial Load

The UBC factor for the volumetric ratio of spiral or hoop reinforcement is 0.12, while for NEHRP it is 0.09.

2625(g)3 Joints of frames, shear strength

The UBC differentiates between joints confined on four faces and joints confined on three faces or 2 opposite faces, and reduces the allowable strength factor from 20 to 15 respectively. The strength factor for cases other than those mentioned above is 12. NEHRP doesn't make a distinction based on the number of confined faces. The factor for the confined condition is 20, while the factor for all other conditions is 15. "Confined" is defined in both documents as a joint with members framing into all vertical faces, and at least three-quarters of each face of the joint is covered by the framing member. The effect is that the UBC reduces the allowable shear strength of joints confined on three sides or two opposite sides, and it also reduces the strength of unconfined joints.

The following UBC sections contain requirements not addressed in NEHRP (Seismic Zones 3 and 4 only):

2625(e)4A(v) Transverse Reinforcement - Frame Members Subject to Bending Plus Axial Load

The UBC adds a minimum nonseismic reinforcement requirement for any column that extends more than 4" beyond the confined core.

2625(e)4A(vi) Transverse Reinforcement - Frame Members Subject to Bending Plus Axial Load

When the point of contraflexure is not within the middle one-half of the member clear height, the UBC requires transverse reinforcement over the full height of the column.

2625(e)4G Transverse Reinforcement - Frame Members Subject to Bending Plus Axial Load

The UBC requires spiral or hoop reinforcement at a maximum of 6 bar diameters or 6" when transverse reinforcement as specified in Sections 2625(e)4A-C is not provided.

2625(f)2D Shear Wall Reinforcement

The UBC has extra requirements: splices in horizontal reinforcement shall be staggered; splices in 2 curtains where used shall not occur at the same location.

2625(f)5 Coupling Beams

The UBC requires special shear reinforcement for horizontal members with small span-to-effective-depth ratios and high factored shear forces and which interconnect shear walls.

2625(f)8 Minimum Thickness of Diaphragms

The UBC requires diaphragms to be at least 2 inches thick, and topping slabs over precast floor and roof elements must be at least 2 1/2 inches thick.

2625(f)9 Wall Piers

The UBC defines specific transverse reinforcement requirements for piers not designed as part of a special moment-resisting frame. These transverse reinforcement requirements do not differ substantially from the shear wall requirements.
2625(g)1D Joints of frames, general requirements

Where longitudinal beam reinforcing bars extend through a joint, the UBC requires that the column depth in the direction of loading be equal to or greater than 20 times the diameter of the largest longitudinal bar.

The UBC contains many requirements more restrictive than or not required in NEHRP. Nearly all of these apply to the higher seismic zones. The items are detailing provisions and have no significant effect on the life safety of the resulting structure.

Masonry

NEHRP Chapter 12 adopts ACI-ASCE 530 as its standard for masonry design. It then struggles with the conversion from Seismic Zones to SPCs for which there is no direct relationship. NEHRP makes simplifying assumptions by equating Zones 0 and 1 to SPCs A and B; Zone 2 to SPC B; and Zones 3 and 4 to SPCs D and E. With this modification, the masonry chapter becomes less restrictive than the remainder of NEHRP. For example, if a building is Occupancy Type IV with Av = 0.2, Figure E on page 16 shows that the equivalent UBC Seismic Zone is 2B and the SPC is D. With the changes in the masonry chapter, NEHRP classifies the building as SPC C.

Despite the simplified conversions from Seismic Zones to SPCs, the UBC and NEHRP should result in comparable building designs. An example, and perhaps the only "difference," is in regard to steel spacing and minimum steel in other than running bond. This is actually an area of committee judgment rather than one shown by research or other investigation to substantially affect life safety.

The following NEHRP Provisions are more restrictive than the corresponding UBC provisions:

> 12.7.1 Construction Requirements for Masonry Laid in Other than Running Bond
>
> The maximum spacing of horizontal reinforcement shall not exceed 24 inches.
>
> 12.8.1.1 Reinforced Hollow Unit Masonry
>
> Structural reinforced hollow unit masonry shall conform to the following requirement: Vertical reinforcement shall be securely held in position at tops, bottoms, splices, and at intervals not exceeding 112 bar diameters. Horizontal wall reinforcement shall be securely tied to the vertical reinforcement or held in place during grouting by equivalent means.
>
> 12.8.1.2 Stacked Bond Construction
>
> All stacked bond construction shall conform to the following requirements:
>
> 12.8.1.2.1 The minimum ratio of horizontal reinforcement shall be 0.0015 for nonstructural masonry and 0.0025 for structural masonry. The maximum spacing of horizontal rein-

forcing shall not exceed 24 inches for nonstructural masonry or 16 inches for structural masonry.

12.8.1.2.2 Reinforced hollow unit construction that is part of the seismic resisting system shall be grouted solid, shall use double open end (H block) units so that all head joints are made solid, and shall use bond beam units to facilitate the flow of grout.

12.8.1.2.3 Other reinforced hollow unit construction used structurally, but not part of the seismic resisting system, shall be grouted solid and all head joints shall be made solid by the use of open end units.

The following UBC sections are more restrictive than analogous NEHRP provisions:

2407(h)3A and 4A Special Provisions for Seismic Zones, Materials

UBC Seismic Zone No. 2 prohibits the use of the following materials as part of the vertical or lateral load-resisting system: Type O mortar, masonry cement, plastic cement, nonload bearing masonry units and glass block. Seismic Zones 3 and 4 further eliminate Type N mortar. NEHRP allows the use of these materials, except that in SPC D and E, Type N mortar and masonry cement are prohibited by reference to ACI-530. Therefore, the UBC is more restrictive with some materials. NEHRP SPC C prohibits only structural clay wall tile, which is allowed in the UBC.

2407(h)4E(i) Minimum Dimension, Bearing Walls

Both documents have the same requirements, except for one extra condition in ACI 530: "Nominal 4-inch thick load-bearing reinforced hollow clay unit masonry walls with a maximum unsupported height or length to thickness of 27 are permitted to be used . . ." (emphasis added). The UBC does not limit the h/t ratio for 4-inch bearing walls in this section, but any reinforced "walls with an h'/t ratio larger than 30 shall be based on forces and moments determined from analysis of the structure" (Section 2409(b)2).

As evidenced by the few minor differences between NEHRP and the UBC, the masonry designs for seismic loads are very similar. A design under either of the two documents will result in essentially the same building. The differences between the two sets of requirements seem to be based on committee judgment and are insignificant relative to life safety.

V. Summary Results of Case Studies

Case Study Description

In order to better understand the differences between the NEHRP provisions and the UBC, three case studies of building design were undertaken. The goal was to conduct a trial design using the different structural materials. The buildings selected were:

- A one story building of masonry wall construction with a wood roof.
- A three story wood frame apartment building
- A ten story steel frame office or apartment building

The following sections describe the three case study buildings. NEHRP study buildings used in the trial design program were selected for the case studies. Each building was designed for several seismic zones using the 1988 NEHRP provisions. Then the same building was designed for the same seismic zones using the UBC. After each case study a comparison of the stresses in selected building elements or members was made. By comparing stress levels, or utilization, of building elements one can compare the loads imposed by each design approach.

As noted earlier the case studies used buildings from the NEHRP trial design program. However, since the trial designs were intended to illustrate typical building examples in a region, using the same building configuration in several seismic zones resulted in a building that may not be built in another seismic zone.

An additional case study of a twenty story steel moment resisting frame with concrete shear walls as well as a concrete frame was started. The UBC required a dynamic analysis; NEHRP permitted an ELF (static) approach. Since this would result in totally different approaches with significant assumptions that could make the results meaningless, the case study was terminated. It does serve as an example of the UBC's more restrictive requirement of requiring a dynamic approach for highrise buildings.

For each case study this section contains a summary of results and comparisons for different seismic zones. Typically the case study summaries show the stresses resulting from a NEHRP design and the equivalent UBC design. The actual stresses were divided by the allowable stresses so that the percentage of stress utilization becomes a basis for comparing the base shear of each method. Where a building was significantly overstressed using the NEHRP trial design building, an independent design, using different materials such as thicker plywood, was undertaken to obtain an idea of the differences in the actual buildings.

The results of the independent design can be seen in the case study summaries. One can compare the actual differences in shear walls and diaphragm nailing and materials in the three story building. The ten story steel frame shows the difference of member sizes for selected beams and columns.

No design was done on a SPC category "E." In the Case Study I this SPC would have required only a blocked diaphragm under NEHRP. Under the UBC, which would have required a greater base shear and would have a much higher stress in the diaphragm possibly requiring a different nailing pattern or thicker plywood.

Case Study Observations

Case Study I

Case Study I, the case study of the one story masonry structure, indicates that design in any seismic zone will result in approximately the same structure using either the UBC or NEHRP. The UBC is slightly more conservative in the higher seismic zones but essentially the same building results from either design approach.

The UBC specifies an R_w factor for masonry structures without distinguishing between reinforced or unreinforced. Thus the case study used a value for reinforced masonry which resulted in a difference in the calculated stresses for the building in Seismic Zone 1. A redesign, using the R_w of 2 suggested by some engineers, resulted in a building that was the same as the NEHRP design. An unreinforced masonry building designed for Zone 1 under the UBC would follow the prescriptive provisions for walls and anchorage. No calculations would be required for wall bending and diaphragm deflection.

Case Study II

Case Study II is a three story wood frame apartment building. The same configuration of diaphragms and shear walls was used to compare the demand/capacity ratio for material utilization.

The findings were that in Seismic Zones 2B, 3 and 4 the UBC was more restrictive than NEHRP. Specific differences in the higher seismic zones include:

Closer nail spacing in the plywood diaphragms at the upper floors of the building.

Heavier (thicker) plywood would be required at the 1st and 2nd floor in Seismic Zone 4.

The nailing in the shear walls is greater in these zones.

Some shearwalls required heavier plywood.

A trial building was designed under the UBC to see the differences. The result was that additional shear walls were required on the lower floors in higher seismic zones. As noted the floor diaphragms had to be heavier and have closer nailing. There was no way to make the NEHRP building work in Seismic Zone 4 as configured in the trial design. (The trial design was for Seismic Zone 2B.)

The NEHRP designed building showed no difference in Seismic Zone 1 and 2A. In each case the same building would work for both NEHRP and the UBC. The demand/capacity requirement was generally higher for the UBC designed building. Even in Seismic Zone 2B the findings were that only the shear walls at the lower levels had to be heavier.

Case Study III

Case Study III was for a ten story steel frame building. The NEHRP design from the trial designs provided a starting point. A new design with the same configuration was done using the UBC. Typically the results were that the UBC members were smaller and lighter at the lower stories when compared to the NEHRP design. Upper story members were close to those in the NEHRP design. Members shown were to be similar to those used in the trial design rather than the most efficient to try to obtain some comparison of the designs. The story drifts are shown but may not be comparable The UBC allowable drift is under working stress allowable loads while the NEHRP drift is under ultimate-strength loads.

The demand/capacity ratio for the NEHRP building was higher than the UBC designed building. This relates to the ultimate strength/working strength approaches. The UBC designed building had greater reserve capacity.

Case Study I

Single Story Warehouse with Masonry Walls and Wood Roof - Building "M-1"

Building Description:

This case study is taken from the Guide to Application of the NEHRP Recommended Provisions, July 1987 edition, page 207. The building is a one-story rectangular warehouse, 100 feet by 200 feet in plan. The masonry walls are 24 feet high on all sides with the wood roof structure sloping slightly higher towards the center of the building for drainage.

The gravity load resisting system begins with straight sheathing over 2 x 12 joists spanning 20 feet between glued-laminated beams. The glued-laminated beams are 24 in. deep and span five bays of 40 feet each. The diaphragm system is supported by 2000 psi concrete masonry unit walls 10 in. thick and intermediate steel columns. The floor is a slab on grade with conventional spread footings. The lateral load resisting system consists of the exterior shear walls, which take the load transferred by the flexible diaphragm to the foundation. The long walls (side walls) are solid (no openings), and the short walls have several large door openings each. There are no interior walls for seismic resistance. The design assumes full inspection of the masonry.

Approach:

The comparison approach taken for Case Study I is as follows:

The building used for the study was taken from the Guide example.

The building was analyzed in each of the five seismic zones according to the UBC requirements (1, 2A, 2B, 3, and 4) as well as in the five corresponding NEHRP seismic map areas (3, 4, 5, 6, and 7). The loads on the building were then determined.

The stresses within the major building elements were then computed. Items compared include total base shear, diaphragm shear, shear and bending stresses in the masonry, and story drift.

The load demand was then compared to the resistance capacity (allowable stress) for each of the five zones.

The ratio of the demand/capacity for UBC and NEHRP was then compared.

The demand/capacity can be compared using the % Stress of Allow(able) column for each zone.

A factored value was then computed for each material. The material factor was derived from the manner that the NEHRP values were derived. The "phi" is included in the NEHRP provisions.

Findings:

The findings were that essentially the same building would result from a design under either set of provisions. Note that in Seismic Zones 1 and 2A, the building need not be designed, but need only meet certain prescriptive criteria in the Code. The building designed for the case study meets the prescriptive criteria and is therefore essentially the same building.

Case Study I

Summary of Results NEHRP Map Area 7 UBC Zone 4
Seismic Hazard Exposure Group I
Seismic Performance Category D

ITEM	1988 N.E.H.R.P.			1991 UBC	
	Value	% Stress of Allow.	Factored Value*	Value	% Stress of Allow.
TOTAL BASE SHEAR (KIPS)	242			155	
DIAPHRAGM SHEAR (PLF)					
Actual	1100	89%	647	704	96%
Allowable	1241			730	
MASONRY WALL STRESSES					
Actual In-Plane Shear (psi)	18	23%	9	11.73	23%
Allow. Shear Stress (psi)	78			52	
Actual Bending Stress (psi)	234	13%	88	172	20%
Allow. Bending Stress (psi)	1756			878	
ACTUAL PERPENDICULAR LOAD (PLF)	400		200	223	
TOTAL DEFLECTION (IN)					
Actual	7.36	100%		1.73	100%
Allowable	6			1.44	

*Factored NEHRP Value is the actual value divided by the product of a material factor and a phi factor. The material factor = 2 for wood; 2.5 for masonry.
The phi factor = 0.85 for diaphragm shear; 0.6 for masonry shear; and 0.8 for masonry flexural compression.
An additional seismic load factor of 1.33 must also be included for the masonry stress values.

Case Study I

Summary of Results NEHRP Map Area 6 UBC Zone 3
Seismic Hazard Exposure Group I
Seismic Performance Category D

ITEM	1988 N.E.H.R.P.			1991 UBC	
	Value	% Stress of Allow.	Factored Value*	Value	% Stress of Allow.
TOTAL BASE SHEAR (KIPS)	181			116	
DIAPHRAGM SHEAR (PLF)					
Actual	825	76%	485	528	83%
Allowable	1088			640	
MASONRY WALL STRESSES					
Actual In-Plane Shear (psi)	13.72	18%	7	8.78	17%
Allow. Shear Stress (psi)	78			52	
Actual Bending Stress (psi)	198	11%	74	129	15%
Allow. Bending Stress (psi)	1756			878	
ACTUAL PERPENDICULAR LOAD (PLF)	300		150	200	
TOTAL DEFLECTION (IN)					
Actual	5.9	98%		1.44	100%
Allowable	6			1.44	

*Factored NEHRP Value is the actual value divided by the product of a material factor and a phi factor. The material factor = 2 for wood; 2.5 for masonry.
The phi factor = 0.85 for diaphragm shear; 0.6 for masonry shear; and 0.8 for masonry flexural compression.
An additional seismic load factor of 1.33 must also be included for the masonry stress values.

Case Study I

Summary of Results NEHRP Map Area 5 UBC Zone 2B
Seismic Hazard Exposure Group I
Seismic Performance Category D

ITEM	1988 N.E.H.R.P.			1991 UBC	
	Value	% Stress of Allow.	Factored Value*	Value	% Stress of Allow.
TOTAL BASE SHEAR (KIPS)	121			77.6	
DIAPHRAGM SHEAR (PLF)					
Actual	548	76%	322	352	83%
Allowable	722			425	
MASONRY WALL STRESSES					
Actual In-Plane Shear (psi)	9.17	12%	5	5.87	11%
Allow. Shear Stress (psi)	78			52	
Actual Bending Stress (psi)	140	8%	53	126	14%
Allow. Bending Stress (psi)	1756			878	
ACTUAL PERPENDICULAR LOAD (PLF)	200		100	200	
TOTAL DEFLECTION (IN)					
Actual	4.4	73%		1.09	76%
Allowable	6			1.44	

*Factored NEHRP Value is the actual value divided by the product of a material factor and a phi factor. The material factor = 2 for wood; 2.5 for masonry.
The phi factor = 0.85 for diaphragm shear; 0.6 for masonry shear; and 0.8 for masonry flexural compression.
An additional seismic load factor of 1.33 must also be included for the masonry stress values.

Case Study I

Summary of Results NEHRP Map Area 4 UBC Zone 2A
Seismic Hazard Exposure Group I
Seismic Performance Category C

ITEM	1988 N.E.H.R.P.			1991 UBC	
	Value	% Stress of Allow.	Factored Value*	Value	% Stress of Allow.
TOTAL BASE SHEAR (KIPS)	90.6			58.2	
DIAPHRAGM SHEAR (PLF)					
Actual	411	76%	242	264	83%
Allowable	544			320	
MASONRY WALL STRESSES					
Actual In-Plane Shear (psi)	6.86	9%	3	4.41	8%
Allow. Shear Stress (psi)	78			52	
Actual Bending Stress (psi)	89	5%	33	95	11%
Allow. Bending Stress (psi)	1756			878	
ACTUAL PERPENDICULAR LOAD (PLF)	150		75	200	
TOTAL DEFLECTION (IN)					
Actual	3.24	54%		0.82	57%
Allowable	6			1.44	

*Factored NEHRP Value is the actual value divided by the product of a material factor and a phi factor. The material factor = 2 for wood; 2.5 for masonry.
The phi factor = 0.85 for diaphragm shear; 0.6 for masonry shear; and 0.8 for masonry flexural compression.
An additional seismic load factor of 1.33 must also be included for the masonry stress values.

Case Study I

Summary of Results NEHRP Map Area 3 UBC Zone 1
Seismic Hazard Exposure Group I
Seismic Performance Category C

ITEM	1988 N.E.H.R.P.			1991 UBC	
	Value	% Stress of Allow.	Factored Value*	Value	% Stress of Allow.
TOTAL BASE SHEAR (KIPS)	169			29.1	
DIAPHRAGM SHEAR (PLF)					
Actual	700	64%	412	132	21%
Allowable	1088			640	
MASONRY WALL STRESSES					
Actual In-Plane Shear (psi)	16	24%	8	2.75	6%
Allow. Shear Stress (psi)	67.8			45.22	
Actual Bending Stress (psi)	32.3	49%	12	24	72%
Allow. Bending Stress (psi)	66.5			33.25	
ACTUAL PERPENDICULAR LOAD (PLF)	100		50	200	
TOTAL DEFLECTION (IN)					
Actual	2.33	39%		0.53	37%
Allowable	6			1.44	

*Factored NEHRP Value is the actual value divided by the product of a material factor and a phi factor. The material factor = 2 for wood; 2.5 for masonry.
The phi factor = 0.85 for diaphragm shear; 0.6 for masonry shear; and 0.8 for masonry flexural compression.
An additional seismic load factor of 1.33 must also be included for the masonry stress values.

Case Study II

Three Story Wood Frame Building - Building "W-1"

Building Description:

This case study is based on building "W-1" used in the "Guide to Applications of the NEHRP Recommended Provisions" . This 3-story residential wood frame building is 148 feet x 56 feet in plan. The total building height is 28 feet, with a 9 foot typical story to story height.

The gravity load resisting system for the building consists of plywood sheathing on wood floor joists and roof rafters supported on wood stud bearing walls and wood post and beam lines. The lateral load resisting system consists of plywood diaphragms and plywood shear walls.

Approach:

The comparison approach taken for Case Study II is as follows:

The building used for the study was taken from the Guide example.

The building was analyzed in each of the five seismic zones according to the UBC requirements (1, 2A, 2B, 3, and 4) as well as in the five corresponding NEHRP seismic map areas (3, 4, 5, 6, and 7). The loads on the building were then determined. Because the building was originally designed for the Seattle area, it did not "work" in some of the zones. In these cases the building was redesigned under the NEHRP provisions and a new equivalent UBC design done. Typically all building elements were held consistent and the plywood nailing placed closer to obtain the required higher allowable stress. Only where it was not possible to design the building using the same material thickness as in the Guide example was the plywood thickness changed.

The stresses within the lateral force resisting elements were then computed. Items compared include diaphragm shear and shear walls in both the longitudinal and transverse directions.

The load demand was then compared to the resistance capacity (allowable stress) for each of the five zones.

The ratio of the demand/capacity for UBC and NEHRP was then compared.

The demand/capacity can be compared using the % Stress of Allow(able) column for each set of calculations.

Findings:

The findings were that in Seismic Zones 2B, 3 and 4 the UBC was more restrictive than NEHRP for the low rise wood shear wall building.

Specific differences in the higher seismic zones include:

Closer nail spacing in the plywood diaphragms at the upper floors of the building.

Heavier (thicker) plywood would be required at the second and third floor diaphragms in Seismic Zone 4.

The nailing in the shear walls is greater in these zones.

Some shearwalls required heavier plywood.

A trial building was designed under the UBC to see the differences. The result was that additional shear wall strength was required on the lower floors in higher seismic zones. As noted the floor diaphragms had to be heavier and have closer nailing. The NEHRP building could not be made to work in Seismic Zone 4 as configured in the trial design. (The trial design was for Seismic Zone 2B.)

The NEHRP designed building showed no difference in Seismic Zone 1 and 2A. In each case the same building would work for both NEHRP and the UBC. The demand/capacity requirement was generally higher for the UBC designed building. Even in Seismic Zone 2B the findings were that only the shear walls at the lower levels had to be heavier.

Case Study II

Summary of Results and Comparison for N.E.H.R.P. Map Area 3 and U.B.C. Seismic Zone 1

SHEG = 1

SPC = C

		NEHRP				UBC			
		Material	Allowable (plf)	Actual (plf)	% Stress of Allow	Material	Allowable (plf)	Actual (plf)	% Stress of Allow
Diaphragms	Roof	Use : 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Boundary Nailing @ 6" O C Edge Nailing and @ 12" O C Field Nailing	315	111	35%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Boundary Nailing @ 6" O C Edge Nailing and @ 12" O C Field Nailing	186	69	37%
	3rd Fl	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Boundary Nailing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	460	133	29%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Boundary Nailing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	270	84	31%
	2nd Fl	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Boundary Nailing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	460	133	29%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Boundary Nailing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	270	65	24%
Shear Walls Transverse	3rd Fl	Use : 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	374	124	33%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	220	76	34%
	2nd Fl	Use . 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	374	253	68%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	220	154	70%
	Gr Fl	Use : 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	374	318	85%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	220	184	84%
Longitudinal	3rd Fl	Use : 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	374	103	27%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	220	64	29%
	2nd Fl	Use : 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	374	209	56%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	220	129	59%
	Gr Fl	Use : 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	374	262	70%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	220	162	74%

Case Study II
Summary of Results and Comparison for N.E.H.R.P. Map Area 4 and U.B.C. Seismic Zone 2A
SHEG = 1
SPC = C

		N.E.H.R.P.				U.B.C.			
		Material	Allowable (plf)	Actual (plf)	% Stress of Allow	Material	Allowable (plf)	Actual (plf)	% Stress of Allow
Diaphragms	Roof	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	310	167	53%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	185	135	73%
	3rd Fl.	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 10" O.C. Field Nailing	458	199	43%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 10" C.C. Field Nailing	270	168	62%
	2nd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 10" O.C. Field Nailing	458	199	43%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 10" O.C. Field Nailing	270	131	49%
Shear Walls Transverse	3rd Fl.	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	442	187	42%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	220	152	69%
	2nd Fl.	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Edge Nailing and @ 12" O.C. Field Nailing	442	380	86%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Edge Nailing and @ 12" O.C. Field Nailing	380	308	81%
	Gr. Fl.	Use 1/2" CDX or Structural II plywood, blocked, with 10d nails @ 4" O.C. Edge Nailing and @ 12" O.C. Field Nailing	627	477	76%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 3" O.C. Edge Nailing and @ 12" O.C. Field Nailing	480	377	79%
Longitudinal	3rd Fl.	Use : 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	374	154	41%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	220	127	58%
	2nd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 10d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	374	314	84%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	260	259	100%
	Gr. Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	442	384	87%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Edge Nailing and @ 12" O.C. Field Nailing	380	325	85%

Case Study II
Summary of Results and Comparison for N.E.H.R.P. Map Area 5 and U.B.C. Seismic Zone 2B
SHEG = 1
SPC = D

		N.E.H.R.P.				U.B.C.			
		Material	Allowable (plf)	Actual (plf)	% Stress of Allow	Material	Allowable (plf)	Actual (plf)	% Stress of Allow
Diaphragms	Roof	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	316	222	71%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	186	160	86%
	3rd Fl.	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 10" O.C. Field Nailing	450	266	59%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 10" O.C. Field Nailing	270	224	83%
	2nd Fl.	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 10" O.C. Field Nailing	450	266	59%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Boundary Nailing @ 6" O.C. Edge Nailing and @ 10" O.C. Field Nailing	270	174	66%
Shear Walls Transverse	3rd Fl.	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	374	249	67%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	220	202	92%
	2nd Fl.	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Edge Nailing and @ 12" O.C. Field Nailing	544	507	93%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 3" O.C. Edge Nailing and @ 12" O.C. Field Nailing	480	412	86%
	Gr. Fl.	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Edge Nailing and @ 12" O.C. Field Nailing	646	636	98%	Use 1/2" CDX or Structural II plywood, blocked, with 10d nails @ 3" O.C. Edge Nailing and @ 12" O.C. Field Nailing	600	516	86%
Longitudinal	3rd Fl.	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	374	208	56%	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	220	170	77%
	2nd Fl.	Use 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Edge Nailing and @ 12" O.C. Field Nailing	544	419	77%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Edge Nailing and @ 12" O.C. Field Nailing	380	346	91%
	Gr. Fl.	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Edge Nailing and @ 12" O.C. Field Nailing	646	525	81%	Use 1/2" CDX or Structural II plywood, blocked, with 10d nails @ 4" O.C. Edge Nailing and @ 12" O.C. Field Nailing	460	433	94%

Case Study II

Summary of Results and Comparison for N.E.H.R.P. Map Area 6 and U.B.C. Seismic Zone 3

SHEG = 1

SPC = D

		N.E.H.R.P.				U.B.C.			
		Material	Allowable (plf)	Actual (plf)	% Stress of Allow	Material	Allowable (plf)	Actual (plf)	% Stress of Allow
Diaphragms	Roof	Use : 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Boundary Nailing @ 6" O C Edge Nailing and @ 12" O C Field Nailing	408	333	82%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Boundary Nailing @ 6" O C Edge Nailing and @ 12" O C Field Nailing	270	270	100%
	3rd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Boundary Nailing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	450	390	87%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O C Boundary Nailing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	360	336	93%
	2nd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C. Boundary Nailing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	450	390	87%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Boundary Nailing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	270	262	97%
Shear Walls Transverse	3rd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O C Edge Nailing and @ 12" O.C Field Nailing	442	373	84%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O C Edge Nailing and @ 12" O C Field Nailing	380	303	80%
	2nd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 10d nails @ 4" O.C Edge Nailing and @ 12" O.C. Field Nailing	782	760	97%	Use 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 3" O C Edge Nailing into 3x Framing and @ 12" O C Field Nailing	665	617	93%
	Gr. Fl.	Use 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 3" O.C Edge Nailing into 3x framing and @ 12" O.C. Field Nailing	1131	953	84%	Use 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 2" O C Edge Nailing into 3x Framing and @ 12" O C Field Nailing	870	775	89%
Longitudinal	3rd Fl.	Use : 3/8" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C Edge Nailing and @ 12" O C Field Nailing	374	308	82%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	260	254	98%
	2nd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O C Edge Nailing and @ 12" O C. Field Nailing	648	629	97%	Use 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 3" O C Edge Nailing into 3x Framing and @ 12" O C Field Nailing	665	518	78%
	Gr. Fl.	Use 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 4" O C Edge Nailing and @ 12" O.C Field Nailing	867	787	91%	Use 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 3" O C Edge Nailing into 3x Framing and @ 12" O C Field Nailing	665	650	98%

Case Study II
Summary of Results and Comparison for N.E.H.R.P. Map Area 7 and U.B.C. Seismic Zone 4
SHEG = 1
SPC = D

		N.E.H.R.P.				U.B.C.			
		Material	Allowable (plf)	Actual (plf)	% Stress of Allow.	Material	Allowable (plf)	Actual (plf)	% Stress of Allow.
Diaphragms	Roof	Use : 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C Boundary Nailing @ 6" O.C Edge Nailing and @ 12" O.C Field Nailing	459	444	97%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O C Boundary Nailing @ 6" O C Edge Nailing and @ 12" O C Field Nailing	380	380	100%
	3rd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C Boundary Nailing @ 6" O.C Edge Nailing and @ 10" O C Field Nailing	612	532	87%	Use 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 2-1/2" O C Boundary Nailing into 3x Framing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	640	447	70%
	2nd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O.C. Boundary Nailing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	612	532	87%	Use 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 4" O C Boundary Nailing @ 6" O C Edge Nailing and @ 10" O C Field Nailing	386	348	91%
Shear Walls: Transverse:	3rd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 10d nails @ 6" O C Edge Nailing and @ 12" O C Field Nailing	527	496	94%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 3" O C Edge Nailing and @ 12" O C Field Nailing	480	404	84%
	2nd Fl.	Use 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 3" O.C. Edge Nailing into 3x framing and @ 12" O.C Field Nailing	1131	1013	90%	Use 5/8" CDX or Structural I plywood, blocked, with 8d nails @ 2" O C Edge Nailing into 3x Framing and @ 12" O C Field Nailing	870	823	95%
	Gr. Fl.	Use : 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 2" O.C. Edge Nailing into 3x framing and @ 12" O C Field Nailing	1479	1271	86%	Use. 5/1" CDX or Structural II plywood, blocked, with 10d nails @ 2" O C Edge Nailing into 3x Framing and @ 12" O C Field Nailing	870	1033*	119%
Longitudinal:	3rd Fl.	Use : 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 6" O.C. Edge Nailing and @ 12" O.C. Field Nailing	442	411	93%	Use 1/2" CDX or Structural II plywood, blocked, with 8d nails @ 4" O C Edge Nailing and @ 12" O C Field Nailing	380	339	89%
	2nd Fl.	Use . 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 4" O.C. Edge Nailing and @ 12" O C Field Nailing	867	837	97%	Use 5/8" CDX or Structural I plywood, blocked, with 8d nails @ 2" O C Edge Nailing into 3x Framing and @ 12" O C Field Nailing	870	681	78%
	Gr. Fl.	Use : 5/8" CDX or Structural II plywood, blocked, with 10d nails @ 3" O.C. Edge Nailing into 3x framing and @ 12" O C Field Nailing	1131	1050	93%	Use 5/8" CDX or Structural I plywood, blocked, with 8d nails @ 2" O C Edge Nailing into 3x Framing and @ 12" O C Field Nailing	870	868	100%

* Requires additional shear walls

Case Study III

Ten Story Steel Frame Building - Building "LA27"

Building Description:

This case study is based on building "LA27" used in the trial designs for the BSSC program. It is 125 feet x 180 feet in plan with 25 foot by 30 foot bays. The building is 10 stories in height. The first story height is 22 feet 6 inches. The remaining stories have a 13 feet 6 inches story to story height. The total building height is 144 feet.

The gravity load resisting system for the building consists of metal deck with standard weight concrete floors and roof supported on steel beams, girders, and columns. The lateral load resisting system consists of ductile moment resisting frames at the perimeter of the building. The lateral forces are transferred to the frame by the floor which is designed as a rigid diaphragm.

A 20 story building was first considered for this case study. Its total height is 270 feet, which exceeded the 240 feet height limit for the use of the equivalent static approach set forth in the 1991 UBC.

Approach:

The comparison approach taken for Case Study III is as follows:

The building used for the study was taken from the Guide example. To allow for adequate comparison, the same member depths determined in the original NEHRP case study were used throughout this analysis. Also the same building mass and site soil characteristics used in the NEHRP Guide case study were used for this case study.

The building was designed for two seismic zones according to the UBC requirements (2B and 4) as well as for two corresponding NEHRP seismic map areas (5 and 7). The loads on the building were then determined.

The stresses in typical frame members were then computed. Items compared include the combined stress in the steel columns and beams and story drifts.

The load demand was then compared to the resistance capacity (allowable stress) for each of the designs.

The ratio of the demand/capacity for UBC and NEHRP was then compared.

The demand/capacity can be compared using the % Stress of Allow(able) column for each zone.

Findings

The findings were that buildings designed under the NEHRP procedures generally had heavier members apparently relating to the drift limitations but possibly to the ultimate strength approach. The UBC members were smaller and lighter at the lower stories when compared to the NEHRP design. Upper story members were close to those in the NEHRP design.

The NEHRP buildings have a higher demand/capacity ratio on the materials than the UBC buildings. This is probably because the NEHRP building is an ultimate load demand. The UBC building has additional reserve strength, or toughness, since they are designed under a working stress level loads.

CASE STUDY III
MEMBER SIZES COMPARISON

	ZONE 4 - AREA 7		ZONE 2B - AREA 5	
MEMBER	91 UBC	88 NEHRP	91 UBC	88 NEHRP
COL 1	W33X241	BUW37X415	W33X221	W33X221
COL 2	W30X211	W36X210	W27X178	W27X178
COL 3	W30X211	W36X210	W27X161	W27X178
COL 4	W30X191	W36X194	W27X146	W27X161
COL 5	W30X173	W36X194	W27X146	W27X161
COL 6	W27X178	W36X170	W27X102	W27X161
COL 7	W27X178	W36X170	W27X94	W27X114
COL 8	W27X161	W36X135	W27X84	W27X94
COL 9	W27X102	W36X135	W24X76	W27X94
COL 10	W27X84	W36X135	W24X62	W27X84
BM 1	W36X230	W36X300	W33X152	W30X173
BM 2	W33X201	W36X260	W27X178	W30X173
BM 3	W33X201	W36X245	W27X161	W27X178
BM 4	W33X201	W36X210	W27X146	W27X161
BM 5	W30X191	W36X194	W27X114	W27X161
BM 6	W30X173	W36X194	W27X102	W27X146
BM 7	W27X178	W33X130	W27X102	W27X114
BM 8	W27X178	W33X130	W27X94	W27X102
BM 9	W27X102	W30X90	W21X62	W24X94
BM 10	W24X68	W27X84	W21X57	W24X84

CASE STUDY III

SUMMARY OF RESULTS - UBC ZONE 4, NEHRP MAP AREA 7

COMBINED STRESS RATIO (UNITY CHECK) COMPARISON

	1991 UBC			1988 NEHRP		
	ACT.	ALL.	RATIO (%)	ACT.	ALL.	RATIO (%)
COL 5 - 1st STORY	0.664	1.33	49.9%	1.006	1.7	59.2%
COL 11 - 2nd STORY	0.698	1.33	52.5%	1.051	1.7	61.8%
COL 35 - 6th STORY	0.571	1.33	42.9%	0.880	1.7	51.8%
COL 59 - 10th STOR	0.215	1.33	16.2%	0.222	1.7	13.1%
BM 65 - 2nd FLOOR	0.509	1.33	38.3%	0.684	1.7	40.2%
BM 90 - 7th FLOOR	0.509	1.33	38.3%	0.706	1.7	41.5%
BM 110 - ROOF	0.345	1.33	25.9%	0.331	1.7	19.5%

STORY DRIFT COMPARISON

	1991 UBC			1988 NEHRP		
LEVEL	ACT.d (in.)	ALL.d (in.)	RATIO (%)	DELTA	ALL.DELTA	RATIO (%)
Roof	0.216	0.405	53.3%	1.375	2.43	56.6%
10th floor	0.269	0.405	66.4%	1.953	2.43	80.4%
9th floor	0.305	0.405	75.3%	2.409	2.43	99.1%
8th floor	0.290	0.405	71.6%	2.371	2.43	97.6%
7th floor	0.284	0.405	70.1%	2.338	2.43	96.2%
6th floor	0.286	0.405	70.6%	2.349	2.43	96.7%
5th floor	0.282	0.405	69.6%	2.299	2.43	94.6%
4th floor	0.266	0.405	65.7%	2.140	2.43	88.1%
3rd floor	0.264	0.405	65.2%	2.101	2.43	86.5%
2nd floor	0.334	0.675	49.5%	2.635	4.05	65.1%

CASE STUDY III
SUMMARY OF RESULTS - UBC ZONE 2B, NEHRP MAP AREA 5

COMBINED STRESS RATIO (UNITY CHECK) COMPARISON

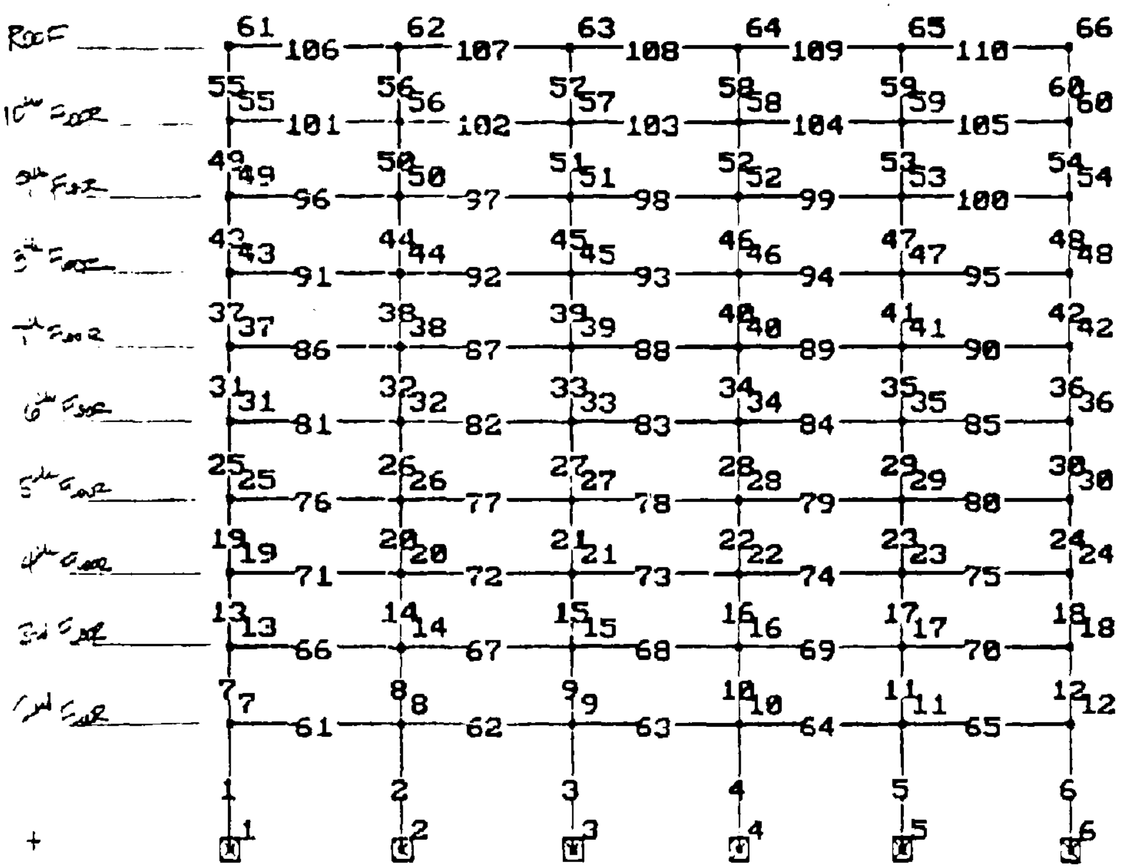
	1991 UBC			1988 NEHRP		
	ACT.	ALL.	RATIO (%)	ACT.	ALL.	RATIO (%)
COL 5 - 1st STORY	0.227	1.33	17.1%	0.641	1.7	37.7%
COL 11 - 2nd STORY	0.237	1.33	17.8%	0.718	1.7	42.2%
COL 35 - 6th STORY	0.207	1.33	15.6%	0.577	1.7	33.9%
COL 59 - 10th STOR	0.09	1.33	6.8%	0.133	1.7	7.8%
BM 65 - 2nd FLOOR	0.241	1.33	18.1%	0.356	1.7	20.9%
BM 90 - 7th FLOOR	0.212	1.33	15.9%	0.400	1.7	23.5%
BM 110 - ROOF	0.127	1.33	9.5%	0.223	1.7	13.1%

STORY DRIFT COMPARISON

	1991 UBC			1988 NEHRP		
LEVEL	ACT.d (in.)	ALL.d (in.)	RATIO (%)	DELTA	ALL.DELTA	RATIO (%)
Roof	0.105	0.405	25.9%	0.671	2.43	27.6%
10th floor	0.133	0.405	32.8%	0.974	2.43	40.1%
9th floor	0.151	0.405	37.3%	1.205	2.43	49.6%
8th floor	0.144	0.405	35.6%	1.183	2.43	48.7%
7th floor	0.140	0.405	34.6%	1.166	2.43	48.0%
6th floor	0.142	0.405	35.1%	1.172	2.43	48.2%
5th floor	0.140	0.405	34.6%	1.150	2.43	47.3%
4th floor	0.132	0.405	32.6%	1.067	2.43	43.9%
3rd floor	0.131	0.405	32.3%	1.051	2.43	43.2%
2nd floor	0.166	0.675	24.6%	1.320	4.05	32.6%

BLDG LA-27

TRANSVERSE FRAME NODE & ELEMENT NUMBERS



VI. Findings

Findings Related to Design and Inspection Criteria

Based on the side by side comparison of the NEHRP provisions and the UBC the following summary points were noted:

- NEHRP has approximately the same inspection requirements as the UBC for building elements. The UBC requires structural observation for major buildings and essential and hazardous occupancies; NEHRP does not.
- NEHRP requires more inspection on non-structural items such as mechanical and electrical components. NEHRP has the non-structural requirements structured in a very detailed manner. Most of the same components are regulated by the UBC and the general design requirements are in Chapter 23. Additional criteria are also found in chapters relating to type of construction.
- Both UBC and NEHRP use the same occupancies relative to exposure. In NEHRP the categories are referred to as Seismic Hazard Exposure Groups (SHEG). In the UBC the Occupancy Categories are used to select the Importance Factor (I). NEHRP uses the SHEG to determine the Seismic Performance Category which establishes the design and detailing requirements. In the UBC the I factor controls the base shear requirements.
- For buildings where damage reduction is desirable, or where continued functionality is necessary, NEHRP controls damage by tightening drift controls based on the SHEG. The UBC addresses this issue by increasing the design base shear and requiring structural observation but allowing the same drift as any other structure.
- For structures without a geotechnical investigation the soil coefficient NEHRP requires the assumption of the worst type of soil condition whereas the UBC uses a more probable minimum soil factor.
- The R factor in NEHRP and the R_w in the UBC are not comparable. NEHRP has a number of additional structural types defined and R values given. This is to try to cover all possible building types. The UBC would permit the building official to accept a different Rw value if there was substantiating documentation. The descriptions of irregular structures are the same in each document.

- NEHRP has additional detailed requirements for the various construction materials including wood, steel, masonry and prestressed concrete that are more restrictive than the detailing requirements in the UBC. There are some provisions in the UBC that are more restrictive than those in the NEHRP provisions.
- Spread footing requirements are greater in NEHRP for SPC D and E structures than for equivalent structures in UBC.

Findings Related to the Case Studies

The findings of the case studies were as follows:

- For design of a single story masonry building the same structure would result using either document.
- For a low rise wood frame shear wall building, the UBC design resulted in thicker plywood shear walls and diaphragms and closer nailing in the higher seismic zones. In the lower zones the same building would be obtained using either document.
- For the ten story steel structure, the UBC design resulted in smaller structural members than the NEHRP designed building. The NEHRP design had a greater load/capacity utilization of the steel frames.

Conclusion

The findings of this study indicate that a building constructed under the Uniform Building Code would provide a similar level of safety to the same building designed under the NEHRP provisions. The NEHRP provisions and the UBC are substantially equivalent.

VII. Cross Reference Between NEHRP and the UBC

The following pages provide the reader a resource with which to locate equivalent sections between the two sets of provisions. This cross-walk is provided as a reference from either document.

UBC to NEHRP

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1991 UNIFORM BUILDING CODE TO 1988 NEHRP

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10.7	2710(g) and 2711(e)
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10.8.1.2	2710(h)2C
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10.8.3	2710(h)
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10.8.4.1	2710(h)3B and 2711(f)3B
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11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

The seismic provisions of four major model building codes are compared to the 1988 edition of the **NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings**. The 1992 BOCA National, 1992 SBCCI Standard, and 1991 ICBO Uniform Building Codes are found to be substantially equivalent to the **NEHRP Recommended Provisions**. The CABO 1 & 2 Family Dwelling Code is found to be not equivalent. Crosswalks indicate comparable NEHRP section numbers for each of the compared codes.

This report was prepared to assist the Interagency Committee on Seismic Safety in Construction (ICSSC) and Federal agencies in identifying codes appropriate for use in implementing Executive Order 12699, "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction". The ICSSC recommends the use of codes and standards that are substantially equivalent to the **NEHRP Recommended Provisions**.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

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