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Comparison of the Seismic Provisions of Model Building Codes and Standards to the 1991 NEHRP Recommended Provisions

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Executive Summary

The Interagency Committee on Seismic Safety in Construction (ICSSC) recommends 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) for new federal construction.

The intent of this study is to review the seismic provisions of the current editions the BOCA National, SBCCI Standard and the ICBO Uniform Codes to determine whether the codes provide an equivalent level of safety to that contained in the 1991 Edition of the NEHRP Provisions. In addition the provisions of the CABO One and Two Family Dwelling Code and ASCE 7-93 are be reviewed.

The NEHRP Provisions have been adopted in code format by the 1993 BOCA and 1994 Standard Building Codes and ASCE 7-93. The Uniform Building Code adopts the seismic provisions developed by the Structural Engineers' Association of California (SEAOC). The CABO code is a prescriptive code that has requirements for seismic safety.

The ICSSC previously commissioned a study comparing the model and CABO codes to the 1988 NEHRP Provisions. The findings of that study were that a design under any of the three model codes provided equivalent safety to that anticipated under the 1988 NEHRP Provisions. The CABO code provided equivalent safety for wood frame buildings up to 2 stories or 35 feet in height.

This study reviewed the changes from the 1988 NEHRP Provisions to the 1991 NEHRP Provisions and compared them to the current editions of the model codes. In addition ASCE 7-93 was reviewed since its seismic provisions are based on the 1991 NEHRP Provisions.

The study found that the provisions adopted by the 1993 BOCA and the 1994 Standard Building Codes and ASCE 7-93 are virtually identical to those in the 1991 NEHRP Provisions. The study also determined that the provisions of the 1994 Uniform Building Code provided a level of safety substantially equivalent to that intended by the 1991 NEHRP Provisions. The 1992 CABO One and Two Family Dwelling Code was found equivalent only for light wood frame buildings of 2 stories or 35 feet in height maximum in the highest seismic zones and all wood frame buildings in the lower seismic zones.

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I. Introduction

Scope and Intent

Executive Order 12699 established the requirements for seismic design standards for new federally owned, leased, assisted and regulated building projects. The Interagency Committee on Seismic Safety in Construction (ICSSC) recommends use of building codes which are substantially equivalent to/or exceed the National Earthquake Hazard Reduction Program Recommended Provisions for the Development of Seismic Regulations for New Buildings (NEHRP Provisions) for purposes of implementing EO 12699.

Background

In 1992, the Council of American Building Officials (CABO) conducted a study to review the seismic provisions of the current editions of the model codes. The study was to determine whether the use of these codes resulted in buildings that were substantially equivalent to the intent of the 1988 edition of the NEHRP Provisions. Included in this study were the:

1989 CABO One and 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

At that time BOCA and SBCCI had adopted provisions based on the 1988 NEHRP Provisions and some of the adopted, but not published, 1991 NEHRP Provisions. Since codes are typically published every three years the adopted provisions were included in the supplements of the codes.

The approach used in the CABO study was a review of the adopted provisions of BOCA and SBCCI to determine whether they were equivalent to the 1988 NEHRP Provisions. The findings were that the BOCA National and SBCCI Standard Building codes had adopted the NEHRP Provisions essentially unchanged into the editions cited above. Both codes were found to be substantially equivalent to the NEHRP Provisions.

The review of the UBC required a more rigorous approach. The UBC seismic provisions are based on the seismic design provisions developed by the Structural Engineers Association of California (SEAOC). These provisions are different from the NEHRP Provisions in that they use an allowable stress approach whereas NEHRP Provisions uses an ultimate strength

(strength) design approach. The study of the UBC included a side by side comparison of provisions and a series of design case studies.

The side by side comparison concluded that the contents of the UBC and the NEHRP Provisions included the same engineering design approach. Each contained equivalent geotechnical, foundation, materials and quality control requirements. The design case studies found that the buildings designed under the UBC provided the same level of safety as the buildings designed under the NEHRP Provisions. The details of the review are discussed under the UBC later in this report.

The seismic requirements of the CABO code were found to be significantly different from those in the NEHRP Provisions. Some buildings are exempt from the requirements of the NEHRP Provisions, but are covered by provisions of the CABO code. However, for all other dwellings, the comparison showed that the existing CABO provisions were not sufficient to provide substantial equivalence to the NEHRP Provisions. The CABO code could be used only for all dwellings in areas of low seismic hazard and most low-rise wood frame dwellings in regions of moderate and high seismic hazard and result in a level of seismic safety significantly equivalent to the NEHRP Provisions.

ASCE 7-93 was not reviewed in the previous study.

The overall findings of the 1992 report were that BOCA, SBCCI and UBC provided an equivalent level of safety to the 1988 NEHRP Provisions. The CABO code could be used under limited conditions to provide a similar level of safety.

Intent of This Study

Since the earlier CABO report, the NEHRP Provisions have been updated and the 1991 NEHRP Provisions published. This study is intended to review the current editions of the model codes, and other applicable national standards, to determine whether they provide a substantially equivalent level of safety to the 1991 NEHRP Provisions.

The codes reviewed for this study are:

1993 BOCA/National Building Code

1994 Standard Building Code

1994 Uniform Building Code

ASCE 7-93 "Minimum Design Loads for Buildings and Other Structures"

1992 CABO One and Two Family Dwelling Code

The NEHRP Provisions have been modified to code format and adopted by the BOCA and Standard Building Codes. The Uniform Building Code adopts the seismic provisions developed by the Structural Engineers' Association of California (SEAOC). The CABO Code is a prescriptive code, not a design document. In addition, the American Society of Civil Engineers has published ASCE 7-93 Minimum Design Loads for Buildings and Other Structures which includes seismic provisions based on the 1991 NEHRP Provisions.

The format for presentation is as follows:

Specific provisions and sections that are common to all codes were reviewed in a side by side format that notes the comparable sections or tables. Significant differences, with their implications, are described and discussed. The complete side by side comparison is not included herein.

Where the provisions of the 1991 NEHRP Provisions have been changed from the 1988 NEHRP Provisions, the changes are shown. These are shown in italics so the reader can compare them. Differences with the codes are described and the implications of the differences noted.

A "crosswalk" between the provisions of the three model codes and ASCE 7-93 is provided in the Appendix.

A section providing a tabular presentation of the standards for construction materials adopted by the model codes and the 1991 NEHRP Provisions is included in the materials section of this study. In addition, there are comparisons for foundations and quality assurance.

II. Methodology

The following describes the general approach to this review.

Review Changes to the 1991 NEHRP Provisions - Each change included in the 1991 NEHRP Provisions was reviewed. The changes that would affect the design of a building or scope of coverage were noted for use in the report.

Review Current Edition of the Model Codes - The current edition was defined as noted in the introduction. The provisions of each of the three model codes were reviewed. The code changes from the previous editions were identified. In the case of BOCA and SBCCI, the NEHRP Provisions were initially added in each code's annual supplement. The current edition is the first in which the entire NEHRP Provisions were published. Thus for all practical purposes all the provisions are new in these model codes.

In addition the CABO 1 and 2 Family Dwelling Code was reviewed as part of the model code review.

ASCE 7-93 standard was reviewed in a manner similar to the model codes.

Compare Engineering Design Provisions - Revisions and new provisions in the 1991 NEHRP Provisions, were reviewed in their entirety and compared with the reviewed documents. The provisions were compared side-by-side with the provisions in the model codes and ASCE 7. Where differences occurred, a determination was made whether they were editorial, modifications for code language or a substantive change. The complete side by side comparison is not included herein. Only significant changes are shown. For reference, the changes in the NEHRP Provisions are shown in italics so the reader can quickly compare the provisions.

Compare Material Design Standards, Foundation Design Requirements and Quality Assurance Provisions in Each Code - The materials design criteria and standards adopted for design are compared in a tabular form. Similar tables are provided for foundation design requirements and the quality control provisions and special testing requirements.

Summary and Conclusions - The observations were considered and the findings and conclusions are summarized in a chapter.

III. Comparison of the Codes

Overview

This section begins with several resources to assist the reader. The first is a series of definitions of terms used in the NEHRP Provisions that are used throughout the comparison. The second is a table of the Seismic Performance Categories (SPC). The intent is to permit the user to understand the requirements of the NEHRP Provisions.

Following this overview is a section summarizing the individual model code provisions. The significant findings of the earlier CABO study are noted for the individual model codes. The Appendix includes a crosswalk table that includes a section-by-section reference between the 1991 NEHRP Provisions, the three model codes and ASCE 7-93. Within the Appendix there is a second table that serves as an index to tables in the several codes, ASCE 7 and the NEHRP Provisions. These are intended to assist the user in finding the equivalent section in any of the documents.

These are followed by a tabular comparison of referenced materials standards. Next is a side by side section listing of the foundation requirements. The model code format is to have the foundation sections separate, similar to the materials sections. Last is the quality control provisions, again shown in a comparison table.

Terms and Definitions

The following terms are used by the NEHRP Provisions and throughout this report.

SHEG - Seismic Hazard Exposure Group. This is a classification assigned to a building based on its occupancy or character of use. There are three groups, I, II and III. Group III is associated with uses requiring the highest level of protection.

SPC - Seismic Performance Category. This is a measure of the degree of protection provided for the public and building occupants against the potential hazards resulting from the effects of earthquakes motions on buildings. Categories range from A through E, with E being the highest level of design performance.

A_V - Effective peak velocity related acceleration. This is the anticipated ground movement in a specific region or site.

A. Tables and Matrices

Figure 1 shows the applicability of the NEHRP Provisions. This can be used to understand the structures regulated by these provisions. The process of determining the design procedures is shown in Figure 2.

Table 1, below, from NEHRP illustrates the SHEG, SPC and A_V in tabular form. Table 2 shows the various requirements based on the SPC of the building. The SPC becomes more restrictive from SPC Categories A through E. Thus the requirements increase as a building's occupancy group and regional seismicity becomes greater.

Tables A-1 and A-2 in the Appendix provide a crosswalk between the various codes. They may be used for comparing the requirements or for finding similar provisions in the several codes.

Earthquake Design Maps

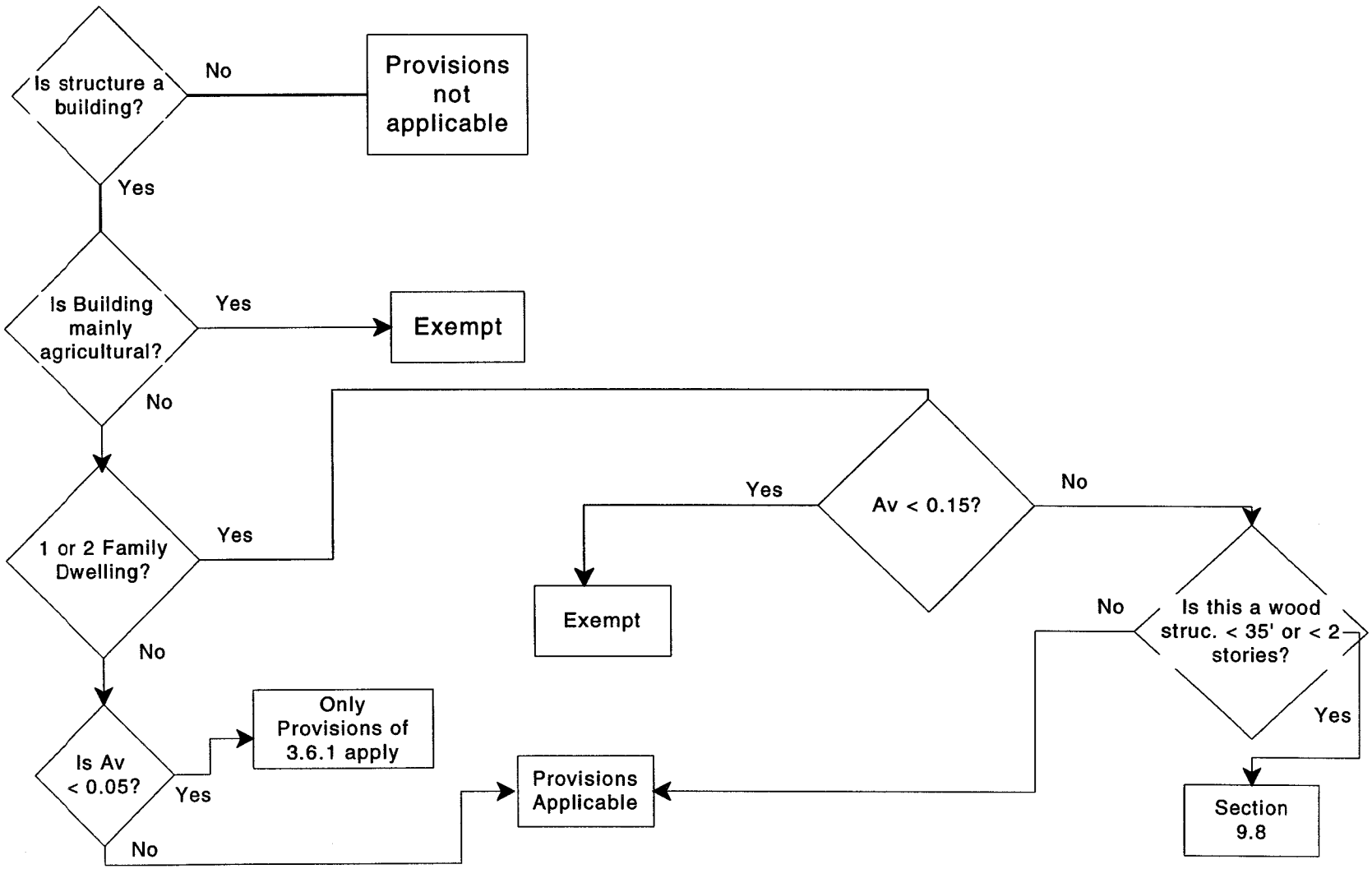
Each model code and the 1991 NEHRP Provisions adopt maps of the United States that indicate the anticipated acceleration (A_V) or Seismic Zone based on acceleration. In different codes the maps may be taken from different sources. In reviewing the maps the A_V maps in BOCA and SBCCI are based on the NEHRP maps and are substantially equivalent. The Seismic Zone maps in the UBC typically have acceleration values equal to or greater than those in NEHRP.

ASCE 7-93 adopts the NEHRP maps. Minor differences occur but the maps are more restrictive than the NEHRP maps.

The CABO One and Two Family Code adopts the Seismic Zone concept and uses a map similar to that in the UBC.

Table 1 - Seismic Performance Category

Value of A_V	Seismic Hazard Exposure Group		
	I	II	III
$A_V < 0.05$	A	A	A
$0.05 \leq A_V < 0.10$	B	B	C
$0.10 \leq A_V < 0.15$	C	C	C
$0.15 \leq A_V < 0.20$	C	C	D



1991 NEHRP/Model Building Codes Comparison Project

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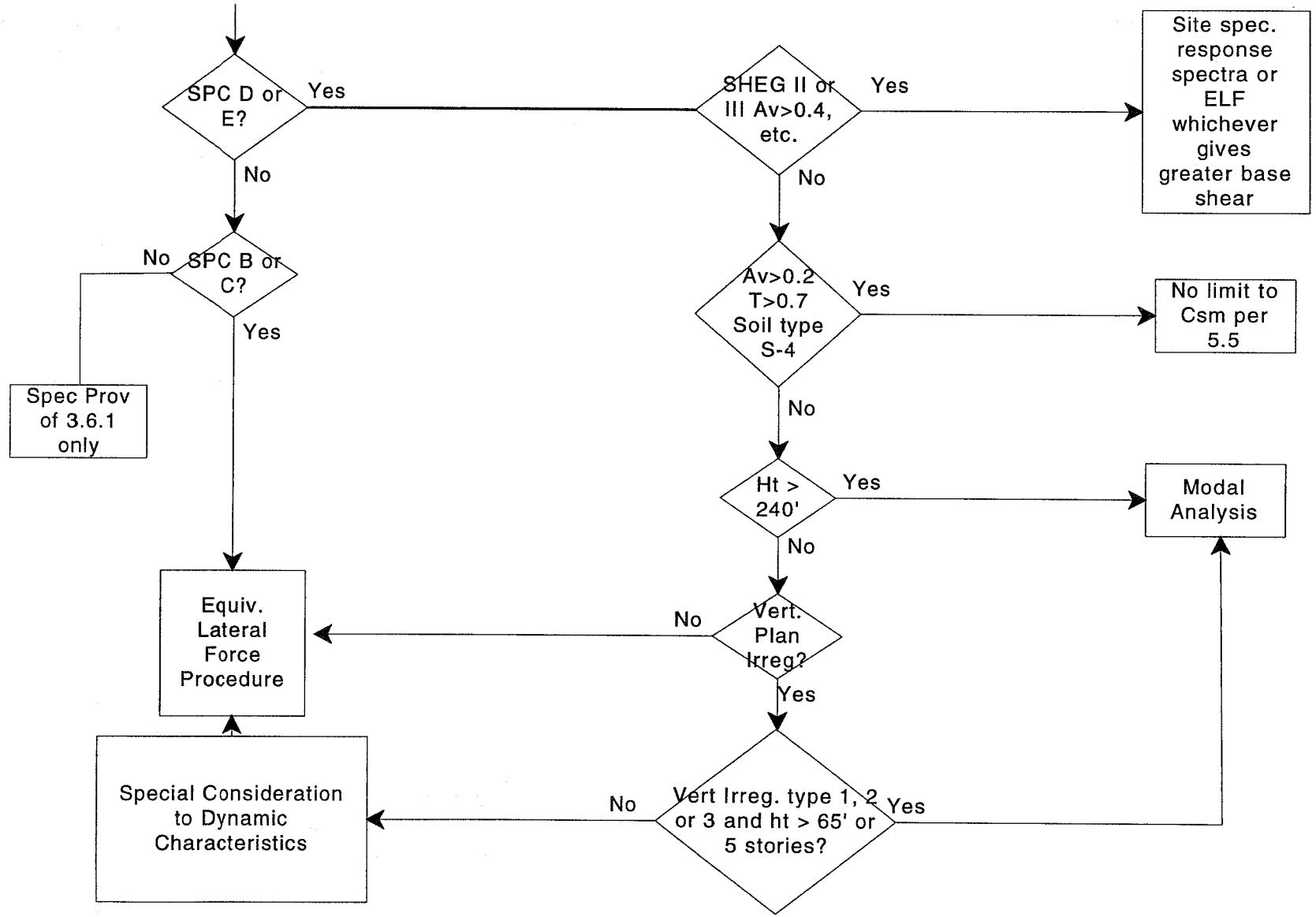
Figure 1



1991 NEHRP/Model Building Codes Comparison Project

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Figure 2

Table 2 - Design Considerations for Seismic Performance Category					
CRITERIA	**A**	**B**	**C**	**D**	**E**
Strength of Building Elements Connections	✓	✓	✓	✓	✓
Anchorage of Concrete or Masonry Walls	✓	✓	✓	✓	✓
Anchorage of Non-Structural Systems	✓	✓	✓	✓	✓
Component Load Effects		✓	✓	✓	✓
Reinforcement at Openings		✓	✓	✓	✓
Height Limitations for Buildings with Weak Stories		✓	✓	✓	✓
Non-Redundant Systems		✓	✓	✓	✓
Collector Elements		✓	✓	✓	✓
Design of Diaphragms		✓	✓	✓	✓
Bearing Walls and Anchorage		✓	✓	✓	✓
Inverted Pendulum-Type Structures		✓	✓	✓	✓
Non-parallel Lateral Force Resisting Systems			✓	✓	✓
Orthogonal Load Effects				✓	✓
Diaphragm Connections for Buildings with Plan Irregularities or Vertical Offset				✓	✓
Vertical Seismic Forces				✓	✓

The NEHRP requirements increase as a function of the SPC Category of a structure. This table illustrates the increasing requirements as a basis of the SPC.

B. 1993 BOCA/National Building Code

The 1993 BOCA National Building Code is the first edition to completely print the adopted NEHRP Provisions. Previously the provisions were included in the 1992 Supplement to the code. Basically BOCA took the NEHRP "model" Provisions and converted them to code language. Commentary or tentative provisions were not included.

The 1992 CABO report noted the following differences between the 1992 Supplement and the 1988 NEHRP Recommended Provisions:

> Components including architectural, mechanical and electrical - Components in buildings in low SPC categories were made exempt in the BOCA code. (The basis for this is that the building as a whole was exempt.) BOCA also modified and simplified the requirements for some mechanical, electrical and architectural components. NEHRP has a very detailed breakdown of partition types for example. Design of sprinkler pipe bracing is referenced to NFiPA 13 as the design standard by BOCA.
>
> Adopted standards - BOCA has adopted later industry standards than NEHRP leading to possible minor design differences.
>
> Materials - BOCA permits particleboard shear walls, not included in NEHRP.
>
> Updates - BOCA already adopted some provisions of the 1991 NEHRP Provisions before they were published.

The report concluded that the BOCA seismic provisions were basically an editorial revision of the 1988 and 1991 NEHRP Recommended Provisions and that the provisions were appropriate to use to meet the intent of the NEHRP Provisions.

Observations in this study

The following differences were noted in the review of the seismic design provisions of the 1993 BOCA building code.

NEHRP Section 1.4.2.5 Group III Function - NEHRP has a requirement for designated seismic systems to be, so far as practical, functional during and after an earthquake. BOCA does not have this requirement. The NEHRP provision may be difficult to enforce in a model code. There is no safety issue with this not being included in BOCA.

BOCA has adopted higher R values for IMF and OMF concrete frames. The result of this is that the structures are designed for a lower base shear

1994 NEHRP has reportedly revised its R values and BOCA and NEHRP will be the same in the future. This difference is not shown in the code text but is in the tables. Based on the pending change to the NEHRP Provisions there is no safety implication of this difference.

Section 3.8 of NEHRP defines the Deflection and Drift Limits. BOCA, Section 1612.3.7 allows greater drift than NEHRP. This is compared in the conclusions chapter of this report. Drift limits are a damage control measure and do not affect safety.

For architectural components, BOCA has simplified the partition bracing requirements of NEHRP. There is no safety issue with this change.

BOCA has reduced the design SPF for some architectural, mechanical and electrical components and elevators in some SPC categories. These are shown in the tables in Chapter 4, Conclusions. These changes appear to be judgment changes on risk and do not affect safety.

On the following pages is a partial side by side comparison of selected provisions of the 1993 BOCA and 1991 NEHRP Provisions. These are to provide a sense of how BOCA compares to NEHRP but do not illustrate all the provisions or all the differences. Selected differences between the NEHRP Provisions and BOCA are shown in the side by side comparison.

Essentially the 1993 BOCA code technical seismic provisions and 1991 NEHRP Provisions are substantially equivalent.

1993 BOCA National Building Code	1991 NEHRP Provisions	Comments
SECTION 1612.0 EARTHQUAKE LOADS **1612.1 General**: Every building and structure shall be designed and constructed to resist the effects of earthquake motions determined in accordance with this section. Additions and changes of occupancy to existing buildings and structures shall be designed and constructed to resist the effects of earthquake motions determined in accordance with this section. Special structures, including but not limited to vehicular bridges, transmission towers, industrial towers and equipment, piers and wharves, and hydraulic structures shall be designed for earthquake loads utilizing in approved, substantiated analysis. **Exceptions** 1. Detached one- and two-family dwellings that are located in seismic map areas having an effective peak velocity-related acceleration (A_V) value less than 0.15, in accordance with Section 1612.1.3, are exempt from the requirements of this section. 2. Agricultural storage buildings which are intended only for incidental human occupancy are exempt from the requirements of this section, 3. Buildings or structures located where the seismic coefficient representing the effective peak velocity-related acceleration (A_V) is less than 0.05, are only required to comply with Section 1612.3.6.1. 4. The seismic force-resisting system of wood frame buildings that conform to the provisions of Section 2305.8 and are constructed in accordance with Section 2305.0 and Section 1612.3.6.1 are not required to be analyzed as specified in Sections 1612.3 through 1612.5.	CHAPTER 1 GENERAL PROVISIONS *1.2 SCOPE: Every building, and portion thereof, shall be designed by these provisions. Additions to existing buildings also shall be designed and constructed to resist the effects of earthquake motions determined as prescribed by these provisions. Existing buildings and alterations and repairs to existing buildings need only comply with these provisions when required by Sec. 1.3.1 through 1.3.3.* EXCEPTIONS: 1. Detached one- and two-family dwellings that are located in seismic map areas having an effective peak velocity-related acceleration (Av) value less than 0.15 are exempt from the requirements of these provisions. 2. Agricultural storage buildings that are intended only for incidental human occupancy are exempt from the requirements of these provisions. *3. Buildings located in seismic map areas having an effective peak velocity-related acceleration (Av) value less than 0.05 shall only be required to comply with Sec. 3.6.1.* Special structures including, but not limited to, bridges, transmission towers, industrial towers and equipment, piers and wharves, hydraulic structures, and nuclear reactors require special consideration of their response characteristics and environment that is beyond the scope of these provisions.	The BOCA seismic provisions mirror the NEHRP provisions in a general way. The technical provisions of the BOCA seismic provisions are equivalent to the NEHRP. In sections that relate to other adopted standards or code chapters, and in sections on applicability, BOCA follows a code format rather than the model provisions approach of NEHRP. Throughout this side by side comparison of BOCA to NEHRP, few comments are offered since the two documents are similar. The same structure would result from using either for design. In this section the applicability of the provisions are presented in the BOCA code writing format but contain the same requirements for buildings.

1612.1.1 Additions to existing buildings: An addition that is structurally independent from an existing building shall be designed and constructed in accordance with the seismic requirements for new buildings. An addition that is not structurally independent from an existing building shall be designed and constructed such that the entire building conforms to the seismic requirements for new buildings unless the following three provisions are complied with:

1. The addition complies with the seismic requirements for new buildings;

2. The addition shall not increase the seismic forces in any structural element of the existing building by more than 5 percent unless the increased forces on the element are still in compliance with these provisions; and

3. The addition shall not decrease the seismic resistance of any structural element of the existing building below that required for new buildings.

1612.1.2 Change of occupancy: Where a change of occupancy results in an existing building being reclassified to a higher Seismic Hazard Exposure Group, the building shall conform to the seismic requirements for new buildings.

Exception: Upgrading the building for the seismic requirements of this section is not required for buildings located in seismic map areas having an effective peak velocity-related acceleration (A_v) value of less than 0.15 where the change of occupancy results in a building being reclassified from Seismic Hazard Exposure Group I to Seismic Hazard Exposure Group II.

1.3.2 ADDITIONS TO EXISTING BUILDINGS: Additions shall be made to existing buildings only as follows:

1.3.2.1: An addition that is structurally independent from an existing building shall be designed and constructed in accordance with the seismic requirements here in.

1.3.2.2: An addition that is not structurally independent from an existing building shall be designed and constructed such that the entire building conforms to the seismic force resistance requirements for new buildings unless the following three conditions are complied with:*

1. The addition shall comply with the requirements for new buildings, and

2. The addition shall not increase the seismic forces in any structural element of the existing building by more than 5 percent unless the capacity of the element subject to the increased forces is still in compliance with these provisions, and

3. The addition shall not decrease the seismic resistance of any structural element of the existing building unless the reduced seismic resistance of the element is equal to or greater than that required for new buildings.

1.3.3 CHANGE OF USE: When a change of use results in a building being reclassified to a higher Seismic Hazard Exposure Group, the building shall conform to the seismic requirements for new construction.

EXCEPTION: When a change of use results in a building being reclassified from Seismic Hazard Exposure Group I to Seismic Hazard Exposure Group II, compliance with these provisions is not required if the building is located in a seismic map area having an effective peak velocity-related acceleration (Av) value of less than 0.15.

1993 BOCA National Building Code	1991 NEHRP Provisions	Comments
1612.6.3.2 Architectural component deformation: Architectural components shall be designed for the design story drift of the structural seismic-resisting system determined in accordance with Sections 1612.4.5.1 or in accordance with Sections 1612.5.6 and 1612.5.8. Architectural components shall be designed for vertical deflection due to joint rotation of cantilever structural members. Exception: Architectural components having a performance criteria factor of 0.5 shall be designed for 50 percent of the design story drift.	CHAPTER 8 ARCHITECTURAL COMPONENT DEFORMATION	Differences in the requirements for architectural components between NEHRP and BOCA are shown in the tables in the Conclusions chapter.
	8.2.5 OUT-OF-PLANE BENDING: Transverse or out-of-plane bending of deformation of a component or system that is subjected to forces as determined in Eq. 8-1 shall not exceed the deflection capability of the component or system.	
1612.6.3.3 Ceilings: Provision shall be made for the lateral support and interaction of other architectural, mechanical and electrical systems or components incorporated into the ceiling which impose seismic forces into the ceiling system.	*8.2.6 CEILINGS: Provisions shall be made for the lateral support and/or interaction of other architectural, mechanical, and electrical systems or components that may be incorporated into the ceiling and may impose seismic forces into the ceiling system.*	
1612.6.4.2 Component attachment: Systems, components and the means of their attachment shall be designed to accommodate relative seismic displacements between points of support. Displacements at points of support shall be determined in accordance with Section 1612.4.5 or 1612.5.8. Relative lateral	8.3.4 COMPONENT ATTACHMENT: Component supporting mechanisms shall be designed for the forces determined in Sec. 8.3.2 and in conformance with Chapters 9, 10, 11, or 12 for the materials comprising the means of attachment.	

displacements at points of support shall be determined considering the difference in elevation between the supports and considering full out-of-phase displacements across portions of the building that are capable of moving in a differential manner such as at seismic and expansion joints. Anchor bolts shall be designed for combined shear and tension. Restraining devices shall be provided to limit the horizontal and vertical motions, to prevent component resonance and to prevail overturning.

Systems, components, and the means of their attachment shall be designed to accommodate relative seismic displacements between points of support. Displacements at points of support shall be determined in accordance with Eq. 4-10. Relative lateral displacements at points of support shall be determined considering the difference in elevation between the supports and considering full out-of-phase displacements across portions of buildings that may move in a differential manner such as at seismic and expansion joints.

C. 1994 Standard Building Code - SBCCI

The 1994 Standard Building Code is the first edition to completely print the adopted NEHRP Provisions. Previously the provisions were included in the 1992 Amendments to the SBCCI code. Basically SBCCI took the NEHRP "model" Provisions and converted them to code language. Commentary or tentative provisions were not included.

Review of the 1992 report by CABO found no significant differences between the 1988 NEHRP Provisions and the 1992 Amendments to the SBCCI.

Observations in this study

The following differences were noted in the review of the seismic design provisions of the 1994 SBCCI Standard Building Code.

NEHRP Section 1.4.2.5 Group III Function - NEHRP has a requirement for designated seismic systems to be, so far a practical, functional during and after an earthquake. SBCCI does not have this requirement. This would apply to structures in with greater Av and SPC Categories D and E. The NEHRP provision may be difficult to enforce. There is no safety issue with this not being included in SBCCI.

SBCCI has adopted higher R values for IMF and OMF concrete frames. The result of this is that the structures are designed for a lower base shear than under NEHRP. This is less restrictive than the 1991 NEHRP. The 1994 NEHRP has reportedly revised its R values and SBCCI and NEHRP will be the same in the future. This difference is not shown in the code text but is in the tables. There is no safety implication of this difference.

Section 3.8 of NEHRP defines the Deflection and Drift Limits. SBCCI allows greater drift than NEHRP. This is compared in the conclusions chapter of this report. Drift limits are a damage control measure and do not affect safety.

For architectural components, SBCCI has simplified the partition bracing requirements of NEHRP. There is no safety issue with this change.

SBCCI has reduced the design coefficient for selected architectural, mechanical and electrical components and elevators in some SPC categories. These are shown in the tables in Chapter 4, Conclusions. These changes appear to be judgment changes on risk and do not affect safety.

On the following pages is a partial side by side comparison of selected provisions of the 1993 SBCCI and 1991 NEHRP provisions. These are to pro-

vide a sense of how SBCCI compares to NEHRP but do not illustrate all the provisions or all the differences. Selected differences between NEHRP and SBCCI are shown in the side by side comparison.

The 1994 SBCCI code's technical seismic provisions and 1991 NEHRP Provisions are substantially equivalent.

1994 Standard Building Code	1991 NEHRP Provisions	Comments
1607 EARTHQUAKE LOADS **1607.1.General** **1607.1.1 Scope.** Every building and structure, and portion thereof, shall be designed and constructed to resist the effects of earthquake motions determined in accordance with 1607. Additions and change of occupancy to existing buildings and structures shall be designed and constructed to resist the effects of earthquake motions determined in accordance with 1607. Special structures, including but not limited to vehicular bridges transmission towers, industrial towers and equipment, piers and wharves, and hydraulic structures shall be designed for earthquake loads using a properly substantiated analysis. EXCEPTIONS: 1. Buildings of detached one and two family dwellings (Group R3) that are located in seismic map areas having an effective peak velocity - related acceleration value, Av, according to 1607.1.5, less than 0.15 are exempt from the requirements of 1607. 2. Agricultural storage buildings which are intended only for incidental human occupancy are exempt from the requirements of 1607. 3. Buildings or structures located where the seismic coefficient representing the effective peak velocity-related acceleration, Av, is less than 0.05 need only comply with 1607.3.6.1. 4. Buildings of detached one and two family dwellings (Group R3) with a building height not more than 35 feet (10.7m) or two stories, which have seismic load-resisting systems which are entirely of wood frame construction in accordance with the requirements of Chapter 23, and are lo-	CHAPTER 1 GENERAL PROVISIONS *1.2 SCOPE: Every building, and portion thereof, shall be designed by these provisions. Additions to existing buildings also shall be designed and constructed to resist the effects of earthquake motions determined as prescribed by these provisions. Existing buildings and alterations and repairs to existing buildings need only comply with these provisions when required by Sec. 1.3.1. through 1.3.3.* EXCEPTIONS: 1. Detached one- and two-family dwellings that are located in seismic map areas having an effective peak velocity-related acceleration (Av) value less than 0.15 are exempt from the requirements of these provisions. 2. Agricultural storage buildings that are intended only for incidental human occupancy are exempt from the requirements of these provisions. *3. Buildings located in seismic map areas having an effective peak velocity-related acceleration (Av) value less than 0.05 shall only be required to comply with Sec. 3.6.1.* Special structures including, but not limited to, bridges, transmission towers, industrial towers and equipment, piers and wharves, hydraulic structures, and nuclear reactors require special consideration of their response characteristics and environment that is beyond the scope of these provisions.	The SBCCI seismic provisions mirror the NEHRP Provisions and are substantially equivalent to the 1991 NEHRP Provisions. The SBCCI converted NEHRP into a code very well and the side by side comparison illustrates that either document would result in equivalent design loads on a structure.

1994 Standard Building Code	1991 NEHRP Provisions	Comments
cated in seismic map areas having an effective peak velocity-related acceleration, Av, equal to or greater than 0.15, need only comply with 1607.3.6.1. 5. Buildings assigned to Seismic Performance Category B, according to 1607.1.5 and 1607.1.8, which have seismic load-resisting systems which are entirely of light frame wood construction in accordance with the provisions of Chapter 23, need only comply with 1607.3.6.1.		
1607.1.3 Additions to Existing Buildings. An addition which is structurally independent from an existing building shall be designed and constructed in accordance with the seismic requirements for new buildings. An addition which is not structurally independent from an existing building shall be designed and constructed such that the entire building conforms to the seismic requirements for new buildings unless the following three provisions are complied with: 1. The addition complies with the seismic requirements for new buildings. 2. The addition shall not increase the seismic forces in any structural element of the existing building by more than 5% unless the increased forces on the element are still in compliance with these provisions. 3. The addition shall not decrease the seismic resistance of any structural element of the existing building below that required for new buildings.	1.3.2 ADDITIONS TO EXISTING BUILDINGS: Additions shall be made to existing buildings only as follows: *1.3.2.1: An addition that is structurally independent from an existing building shall be designed and constructed in accordance with the seismic requirements herein.* *1.3.2.2:* An addition that is not structurally independent from an existing building shall be designed and constructed such that the entire building conforms to the seismic force resistance requirements for new buildings unless the following three conditions are complied with:* *1. The addition shall comply with the requirements for new buildings, and* *2. The addition shall not increase the seismic forces in any structural element of the existing building by more than 5 percent unless the capacity of the element subject to the increased forces is still in compliance with these provisions, and* *3. The addition shall not decrease the seismic resistance of any structural element of the existing building unless the reduced seismic resistance of the element is equal to or greater than that required for new buildings.*	SBCCI exempts light frame wood construction in SPC B. Prescriptive provisions in SBCCI will result in a building providing equivalent life safety to one designed under the NEHRP Provisions.

1994 Standard Building Code	1991 NEHRP Provisions	Comments
1607.3 Structural Design Requirements 1607.3.3.5 Seismic Performance Category E. The framing systems of building assigned to Category E shall conform to the requirements of 1607.3.3.4 for Category D and to the additional requirements and limitations of this section. The building height limitation in 1607.3.3.4.1 is reduced to 160 ft (48.8 m) for buildings assigned to Seismic Performance Category E.	CHAPTER 3 STRUCTURAL DESIGN REQUIREMENTS 3.3.5 SEISMIC PERFORMANCE CATEGORY E: The framing systems of buildings assigned to Category E shall conform to the requirements of Sec. 3.3.4 for Category D and to the additional requirements and limitations of this section. The height limitation of Sec. 3.3.4.1 shall be reduced from 160 feet and 100 feet and, for braced frame or shear wall systems, the maximum height shall be reduced from 240 feet to 160 feet.	

1994 Standard Building Code	1991 NEHRP Provisions	Comments
1607.6 Architectural, Mechanical and Electrical Components and Systems	CHAPTER 8	
All components and systems in buildings shall be designed and constructed to resist seismic forces determined in accordance with this section.	8.1 GENERAL: This chapter establishes minimum design levels for architectural, mechanical, and electrical systems and components recognizing occupancy use, occupant load, and need for operational continuity.	
EXCEPTIONS: 1. Architectural components in buildings assigned to Seismic Performance Category A are exempt from the requirements of this section.	All architectural, mechanical, and electrical systems and components and systems in building shall be designed and constructed to resists seismic forces determined in accordance with this chapter.	Exceptions for architectural components, mechanical and electrical equipment and elevators are different. The tables in the Conclusions chapter illustrate the differences. The structures designed will be equivalent to the NEHRP Provisions for safety.
2. Mechanical and electrical components and systems in buildings assigned to Seismic Performance Category A or B are exempt from the requirements of this section.	EXCEPTION: The following components and systems are exempt from the requirements of this chapter:	
3. Architectural, mechanical and electrical components and systems in buildings assigned to Seismic Performance Category B or C, are in Seismic Hazard Exposure Group I buildings, and have a Performance Criteria Factor of 0.5, are exempt from the requirements of this section.	1. Those systems or components assigned a performance criteria factor of 0.5 in Table 8.2.2 or 8.3.2a in Seismic Hazard Exposure Group I buildings located in areas with a value of Av less than 0.15 or in Seismic Hazard Exposure Group II buildings located in areas with a value of Av less than 0.05.	
4. Elevator components and systems in buildings assigned to Seismic Performance Category A or B are exempt from the requirements of this section. Elevator components and systems in buildings assigned to Seismic Performance Category C, and are in Seismic Hazard Exposure Group I buildings, are exempt from the requirements of this section.	2. Elevator systems in Seismic Hazard Exposure Group I buildings located in areas with a value of Av less than 0.15 or in Seismic Hazard Exposure Group II buildings located in areas with a value of Av less than 0.05.	
1607.6.3.3 Ceilings. Provision shall be made for the lateral support and interaction of other architectural, mechanical and electrical systems or components incorporated into the ceiling which impose seismic forces into the ceiling system.		

D. 1994 Uniform Building Code - ICBO

Background

The 1992 CABO report included an in-depth review of the 1991 Uniform Building Code (UBC). The report reviewed the code provisions and contained several case studies to determine the differences, if any, from buildings designed under the 1988 NEHRP Provisions.

The UBC seismic provisions are based on those developed by the Structural Engineers Association of California (SEAOC). These provisions use the traditional working stress approach whereas the NEHRP Provisions use a strength design approach. The two are not numerically comparable in a side by side review. However a review can determine whether the same design issues and approaches are used. The following is a list of design issues contained in NEHRP. These were compared with the similar provisions within the UBC in the CABO Study.

Applicability of Provisions

Determination of:

- Appropriate Ground Motion (Seismic Zone or Av)
- Occupancy Requirements (SHEG and SPC)
- Soil Factors

Structural Requirements (based on Av or Seismic Zone)

Classification of Structural Framing System

Determination of R factor

Determine whether a Modal Analysis or or Equivalent Lateral Force Procedure is to be used

Determine the Strength of Elements required - Load Combinations

Determine that Drift is within limits

Check Detailing Requirements.

Design by specific materials requirements

Design Foundation

Design Nonstructural elements

Determine Quality Assurance Requirements

The study found that the UBC contained each of the above requirements within the code. A series of design case studies was completed using the requirements of each set of provisions. In each case study equivalent accel-

eration values were used. The findings were that buildings designed under either set of provisions provided substantially equivalent levels of safety.

The report noted the following differences between the 1991 UBC and the 1988 NEHRP Recommended Provisions:

Quality Control - Both UBC and NEHRP have requirements for inspection. NEHRP requires a Quality Assurance Program to be developed for SPC D and E structures. UBC does not. The UBC has additional requirements for structural observation not included in the NEHRP Provisions.

Non-structural Components - NEHRP requires more inspection of nonstructural items such as electrical and mechanical components. Both sets of provisions regulate the same items, the NEHRP Provisions in a much more detailed manner.

Drift Limit - The UBC permits greater drift limits than those required under the NEHRP Provisions. In buildings where damage reduction or continued functionality is necessary, NEHRP imposes reduced drift limits. The UBC deals with the importance factor by imposing a greater base shear for these structures. This increases the design loads on the building. Under the UBC, the drift limits are the same regardless of occupancy.

Geotechnical Requirements - NEHRP requires the designer to assume the worst type of soil condition without a geotechnical investigation. UBC uses a more probable minimum soil factor.

Spread Footing Ties - NEHRP requires crossties between spread footings of SPC D and E buildings. The UBC does not.

R Factors - The R factor in NEHRP and the Rw in UBC are not comparable. NEHRP has values for structural types not contained in UBC. The description of irregular structures is the same in each document.

Detailing Requirements - NEHRP has additional detailed requirements for various construction materials, wood, steel, masonry and prestressed concrete, that are more restrictive than the UBC. There are provisions in the UBC that are more restrictive than NEHRP for concrete.

Shear Distribution into Resisting Elements - The UBC permits distribution of loads to walls by tributary areas in buildings with flexible diaphragms. NEHRP requires the loads to be distributed by wall rigidity regardless of diaphragm type.

The report concluded that a building constructed under either set of provisions would provide an equivalent level of safety and that the provisions

are substantially equivalent. The chart below compares Seismic Zones to Av.

Seismic Zone and Occupancy Comparison

1994 UBC		Table 16-K		
		IV	III	II, I
	1991 NEHRP		SHEG	
Seismic Zone	Av	I	II	III
			SPC	
4, 3	0.2 < Av	D	D	E
2B	0.15 < Av< 0.20	C	D	D
2A	0.10 < Av < 0.15	C	C	C
1	0.05 < Av < 0.1	B	B	C
0	Av < 0.05	A	A	A

Current Work

This study reviewed changes to the 1994 UBC and compared them to the 1991 NEHRP Provisions. There were no major changes to the 1994 UBC from the 1991 UBC, only minor, detail design requirement changes. These, however, brought the UBC closer to the 1991 NEHRP in some ways. These details cannot readily be compared to NEHRP without design examples. Since the original study found the codes to substantially equivalent and because the recent changes are minor, there are no additional safety implications.

Example changes that bring the UBC closer to NEHRP are:

The requirement that shear from flexible diaphragms must now be distributed into shear resisting elements as a function of the their stiffness. This was identified as a difference in the 1992 CABO report.

Additional lateral force resisting systems have been added to the Rw tables in the UBC, including types included in the NEHRP Provisions

The UBC has also added provisions for structural wood panel shear walls, similar to those in the NEHRP Provisions.

The UBC uses Seismic Zones to define the design ground motion in an area. The accelerations specified in the UBC maps were equal to or greater than those required in the NEHRP Provisions. A comparison of Seismic Zones to Av areas was shown on the previous page.

A partial side by side comparison of the 1994 UBC to the 1991 NEHRP follows this page. The intent is to illustrate that the UBC provisions contain similar engineering requirements to those in the NEHRP Provisions.

The 1994 UBC technical seismic provisions and 1991 NEHRP Provisions result in buildings of equivalent safety.

1994 Uniform Building Code	1991 NEHRP Provisions	Comments
SECTION 1627 — CRITERIA SELECTION	1.2 SCOPE	Several representative provisions of the UBC are included here to illustrate that the UBC and NEHRP are very similar in structure and design requirements.
1627.1 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 1628 except as modified by Section 1629.5.3. One– and two–family dwellings in Seismic Zone 1 need not conform to the provisions of this section.	1.3 APPLICATION OF PROVISIONS	The UBC has exemptions for dwellings in Seismic Zones 0 and 1. Both documents permit the use of conventional framing provisions to be used for buildings in the lowest seismic zones.
1627.2 Seismic Zones. Each site shall be assigned to a seismic zone in accordance with Figure 16–2. Each structure shall be assigned a zone factor, Z, in accordance with Table 16–I.	1.4.1 SEISMIC GROUND ACCELERATION MAPS	The UBC regulates all buildings regulated by NEHRP. Each code requires additions to be designed for seismic forces.
1627.3 Site Geology and Soil Characteristics. Soil profile type and site coefficient, S, shall be established in accordance with Table 16–J.	3.2 SITE COEFFICIENT	The UBC uses Seismic Zones and NEHRP uses Effective Peak Acceleration and Effective Peak Velocity Related Acceleration. These are represented by Aa and Av.
1627.4 Occupancy Categories. For purposes of earthquake–resistant design, each structure shall be placed in one of the occupancy categories listed in Table 16–K. Table 16–K lists importance factors, I, and review requirements for each category.	1.4.2 SEISMIC HAZARD EXPOSURE GROUP	Each of these methods provide the engineer with the base shear design loads.
1627.6 Structural Systems.		Designers using either of the provisions must consider the soil characteristics.
1627.6.1 General. Structural systems shall be classified as one of the types listed in Table 16–N and defined in this subsection.		Both the UBC and NEHRP use the same general occupancy categories. Each uses a different numbering system to identify groups. The attached chart compares Seismic Zones and Occupancies between the documents. Both the UBC and NEHRP use a response modification factor "R" to define the various structural types. These are not numerically comparable. Similar requirements are included based on materials, frame type and height limitations.

1994 Uniform Building Code	1991 NEHRP Provisions	Comments
1627.8 Selection of Lateral–force Procedure. **1627.8.1 General.** Any structure may be, and certain structures defined below shall be, designed using the dynamic lateral–force procedures of Section 1629.	3.5 ANALYSIS PROCEDURES	These sections include the requirements and limitations of the two lateral force design procedures. The UBC is more restrictive in limiting the use of a static approach and is more conservative than NEHRP.

1994 Uniform Building Code	1991 NEHRP Provisions	Comments
SECTION 1628 — MINIMUM DESIGN LATERAL FORCES AND RELATED EFFECTS	CHAPTER 4	Both NEHRP and the UBC formulas to determine base shear have similar factors. This includes the seismic response factor "R", the soil factor "S", and the building weight. Because one design use the strength approach and the other a working stress approach there is no simple method of comparing them. They do however result a building with the same level of safety. The 1992 CABO study detailed the comparison of design.
1628.1 General. Structures shall be designed for seismic forces coming from any horizontal direction.	EQUIVALENT LATERAL FORCE PROCEDURE	
The design seismic forces may be assumed to act noncurrently in the direction of each principal axis of the structure, except as required by Section 1631.1.	4.1 GENERAL	
Seismic dead load, W, is the total dead load and applicable portions of other loads listed below.	4.2 SEISMIC BASE SHEAR: The seismic base shear (V) in a given direction shall be determined in accordance with the following equation:	
1. In storage and warehouse occupancies, a minimum of 25 percent of the floor live load shall be applicable.	$V = C_s W$	
2. Where a partition load is used in the floor design, a load of not less than 10 pounds per square foot (psf) (0.48 kN/m2) shall be included.	where:	
3. Design snow loads of 30 pounds per square foot (psf) (1.44 kN/m2) or less need not be included. Where design snow loads exceed 30 psf (1.44 kN/m2) the design snow load shall be included, but may be reduced up to 75 percent where consideration of siting, configuration and load duration warrant when approved by the building official.	Cs = the seismic design coefficient determined in accordance with Sec. 4.2.1 and	
4. Total weight of permanent equipment shall be included.	W = the total load and applicable portions of other loads listed below:	
The value of C need not exceed 2.75 and may be used for any structure without regard to soil type or structure period.	1. In areas used for storage, a minimum of 25 percent of the floor live load shall be applicable. Floor live load in public garages and open parking structures is not applicable.	
Except for those provisions where code–prescribed forces are scaled up by 3 (Rw/8) the minimum value of the ratio C/Rw shall be 0.075.	2. Where an allowance for partition load is included in the floor load design, the actual partition weight or a minimum weight of 10 pounds per square foot of floor area, whichever is greater, shall be applicable.	
	3. Total operating weight of permanent equipment.	
	4. In areas where the design snow load is less than 30 pounds per square foot, the load factor on Qs is permitted to be taken as zero. In areas where the design snow load is greater than 30 pounds per square foot and where siting and load duration conditions warrant and when approved by the regulatory agency, the load factor on Qs is permitted to be reduced to not less than 0.2.	
	The value of Cs shall be determined in accordance with Eq. 4-2, 4-3, or 4-3a as appropriate.	

1994 Uniform Building Code	1991 NEHRP Provisions	Comments
DYNAMIC LATERAL FORCE PROCEDURES **1629.1 General.** Dynamic analyses procedures, when used, shall conform to the criteria established in this section. The analysis shall be based on an appropriate ground motion representation and shall be performed using accepted principles of dynamics. Structures which are designed in accordance with this section shall comply with all other applicable requirements of these provisions.	CHAPTER 5 MODAL ANALYSIS PROCEDURE (The NEHRP procedure being similar to the UBC's is not reproduced here. Only the general chapter number is presented.)	Both the UBC and NEHRP require a dynamic analysis except in a case where an ELF or static approach is permitted. The NEHRP procedure is modeled after the traditional static approach. It is simpler than the UBC. Buildings using either approach will provide an equivalent level of safety.

1994 Uniform Building Code	1991 NEHRP Provisions	Comments
SECTION 1630 — LATERAL FORCE ON ELEMENTS OF STRUCTURES, NONSTRUCTURAL COMPONENTS AND EQUIPMENT SUPPORTED BY STRUCTURES	CHAPTER 8	Both the UBC and NEHRP have requirements for the design of non-structural components and elements.
1630.1 General. Elements 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 1630.2. Attachments for floor or roof mounted equipment weighing less than 400 pounds (181 kg), and furniture need not be designed.	ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS AND SYSTEMS.	The NEHRP approach is to provide a very specific listing of requirements by component. The provisions consider survivability and defines performance based on Superior (S), Good (G) and Low (L) requirements.
Attachments shall include anchorages and required bracing. Friction resulting from gravity loads shall not be considered to provide resistance to seismic forces.		The UBC uses the importance factor (I) to define those components requiring a greater degree of survivability.
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 1630.2.		Some seismic design requirements for components are located in different chapters in the UBC making them less easy for a designer to find. The NEHRP requirements are all in one location.
When allowable design stresses and other acceptance criteria are not contained in or referenced by this code, such criteria shall be obtained from approved national standards.		
1630.2 Design for Total Lateral Force. The total design lateral seismic force, Fp, shall be determined from the following formula:		
$F_p = Z I_p C_p W_p$		
The values of Z and Ip shall be the values used for the structure from Tables 16–I and 16–K.		

E. ASCE 7-93 Minimum Design Loads for Buildings and Other Structures

ASCE 7-93 is a standard developed by the American Society of Civil Engineers. It has undergone a consensus process approved by the American National Standards Institute (ANSI). The standard includes loads for buildings including vertical and wind as well as seismic forces. Before responsibility for maintaining this standard was taken over by ASCE, it was called ANSI A 58.1.

ASCE 7-93 adopts the NEHRP Provisions in standard format similar to a code. While there may be minor differences, use of ASCE 7-93 and its Appendix will result in a structure that is substantially equivalent to one designed under the 1991 NEHRP Provisions.

ASCE 7-93 takes a very good approach to the load factor equations. The body of the standard clearly defines the load factors to be used for the allowable stress method and those that are to be used for strength design. Then the seismic provisions clearly spell out the revised formulas to be used with seismic design.

Specifically the following summarizes our observations:

The Appendix must be adopted for ASCE 7-93 to be substantially equivalent to the 1991 NEHRP Provisions.

The masonry chapter still maintains some of the confusion in ACI/ASCE 530 in converting from seismic zones to SPC design requirements.

Because of the way the materials sections and load combinations are organized, ASCE 7-93 may be more user friendly as a design document than the NEHRP Provisions. Examples include the organization of load combination factors discussed above.

The wood section has clearer provisions for designing in either allowable stress or strength design methods.

Observations in This Study

The following differences were noted in the review of the seismic design provisions of the ASCE 7-93 Standard.

There is no requirement for ties between spread footings in SPC D and E buildings in ASCE 7-93. Such a provision is contained in the NEHRP Provisions. A similar situation occurs in the UBC. This is an engineering judgement issue and does not affect safety.

NEHRP Section 1.4.2.5 Group III Function - NEHRP has a requirement for designated seismic systems to be, so far a practical, functional during and after an earthquake. ASCE 7-93 does not have this requirement. The NEHRP provision may be difficult to enforce. There is no safety issue with this not being included in ASCE 7-93.

ASCE 7-93 has adopted higher R values for IMF and OMF concrete frames. The result of this is that the structures are designed for a lower base shear than under NEHRP. This is less restrictive than the 1991 NEHRP. The 1994 NEHRP has reportedly revised its R values and ASCE 7-93 and NEHRP will be the same in the future. Since the 1994 NEHRP will have the same values, there is no safety implication of this difference.

Section 3.8 of NEHRP defines the Deflection and Drift Limits. ASCE 7-93 allows greater drift than NEHRP. Drift limits are a damage control measure and do not affect safety. Drift limits are shown in Table 11.

For architectural components, ASCE 7-93 has simplified the partition bracing requirements of NEHRP. There is no safety issue with this change.

ASCE 7-93 has reduced the design PCF for some architectural, mechanical and electrical components and elevators in some SPC categories. These are shown in the tables in Chapter 4, Conclusions. These changes appear to be judgment changes on risk and do not affect safety.

On the following pages is a partial side by side comparison of selected provisions of the 1993 ASCE 7-93 and 1991 NEHRP provisions. These are to provide a sense of how ASCE 7-93 compares to NEHRP but do not illustrate all the provisions or all the differences. Selected differences between NEHRP and ASCE 7-93 are shown in the side by side comparison.

ASCE 7-93	1991 NEHRP Provisions	Comments
9. Earthquake Loads		
9.1 General Provisions		
9.1.1 Purpose. Section 9 presents criteria for the design and construction of buildings and similar structures subject to earthquake ground motions. The specified earthquake loads are based upon post-elastic energy dissipation in the structure, and because of this fact, the provisions for design, detailing, and construction shall be satisfied even for structures and members for which load combinations that do not contain the earthquake effect indicate larger demands than combinations including earthquake.	CHAPTER 1 GENERAL PROVISIONS 1.1 PURPOSE *1.2 SCOPE: Every building, and portion thereof, shall be designed by these provisions. Additions to existing buildings also shall be designed and constructed to resist the effects of earthquake motions determined as prescribed by these provisions. Existing buildings and alterations and repairs to existing buildings need only comply with these provisions when required by Sec. 1.3.1 through 1.3.3.*	The following sections contain selected text from the ASCE 7-93 seismic design provisions. These provisions are word for word based on the 1991 NEHRP Provisions and are equal to NEHRP. ASCE 7-93 contains an Appendix with modifications to national material design standards. For proper use of ASCE 7-93, the Appendix must be also used.
9.1.2 Scope. Every building, and portion thereof, shall be designed and constructed to resist the effects of earthquake motions as prescribed by these provisions. Additions to existing buildings also shall be designed and constructed to resist the effects of earthquake motions as prescribed by these provisions. Existing buildings and alterations to existing buildings need only comply with these provisions when required by Secs. 9.1.3.1 through 9.1.3.3. Exceptions: 1 . Buildings located where the effective peak velocity-related acceleration (Av) value read from Map 9-2 is less than 0.05 shall only be required to comply with Sec. 9.3.6.1. 2. Detached one- and two-family dwellings that are located in seismic map areas having an effective peak velocity-related acceleration (Av) value less than 0.15 are exempt from the requirements of these provisions. 3. Agricultural storage buildings that are intended only for incidental human occupancy are exempt from the requirements of these provisions.	EXCEPTIONS: 1. Detached one- and two-family dwellings that are located in seismic map areas having an effective peak velocity-related acceleration (Av) value less than 0.15 are exempt from the requirements of these provisions. 2. Agricultural storage buildings that are intended only for incidental human occupancy are exempt from the requirements of these provisions. *3. Buildings located in seismic map areas having an effective peak velocity-related acceleration (Av) value less than 0.05 shall only be required to comply with Sec. 3.6.1.* Special structures including, but not limited to, bridges, transmission towers, industrial towers and equipment, piers and wharves, hydraulic structures, and nuclear reactors require special consideration of their response characteristics and environment that is beyond the scope of these provisions.	The applicability of ASCE 7-93 is the same as the 1991 NEHRP Provisions.

ASCE 7-93	1991 NEHRP Provisions	Comments
Other structures including, but not limited to, bridges, transmission towers, industrial towers and equipment, piers and wharves, hydraulic structures, and nuclear reactors require special consideration of their response characteristics and environment that is beyond the scope of these provisions.		
.1.6 Quality Assurance. The performance required of buildings in Seismic Performance Categories C, D, or E requires that special attention be paid to quality assurance during construction. Refer to A.9.1.6 for supplementary provisions.	1.6 QUALITY ASSURANCE	ASCE 7-93 has the complete Section in Appendix A. The Appendix must be adopted for ASCE to be equal to NEHRP.

ASCE 7-93	1991 NEHRP Provisions	Comments
9.7 Foundation Design Requirements **9.7.1 General.** Sec. 9.7 sets requirements for loads that foundations must resist and for investigations to establish critical geotechnical parameters.	CHAPTER 7 FOUNDATION DESIGN REQUIREMENTS 7.1 GENERAL. This chapter includes only those foundation requirements that are specifically related to seismic resistant construction. It assumes compliance with all other basic requirements. These requirements include, but are not limited to, provisions for the extent of the foundation investigation, fills to be present or to be placed in the building area, slope stability, subsurface drainage, and settlement control. Also included are pile requirements and capacities and bearing and lateral soil pressure recommendations.	The foundation provisions in ASCE 7-93 are the same as in NEHRP. Certain sections are in the Appendix rather than the body of the provisions
9.7.5 Foundation Requirements for Seismic Performance Categories D and E. Foundations for buildings assigned to Categories D and E shall conform to all of the requirements for Category C construction and to the additional requirements of this section.	7.5 SEISMIC PERFORMANCE CATEGORIES D AND E	ASCE does not contain the provision for continuous ties between spread footing that are in NEHRP. This is an engineering judgment issue and has no safety implications.
9.8 Architectural, Mechanical, And Electrical Components And Systems **9.8.1 General.** Sec. 9.8 establishes minimum design levels for architectural, mechanical, and electrical systems and components recognizing occupancy use, occupant load, and need for operational continuity. All architectural, mechanical, and electrical systems and components and systems in buildings shall be designed and constructed to resist seismic forces determined in accordance with this Section. Exceptions:	CHAPTER 8 ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS AND SYSTEMS 8.1 GENERAL: This chapter establishes minimum design levels for architectural, mechanical, and electrical systems and components recognizing occupancy use, occupant load, and need for operational continuity. All architectural, mechanical, and electrical systems and components and systems in building shall be designed and constructed to resist seismic forces determined in accordance with this chapter.	Requirements for non-structural components are the same as in NEHRP. ASCE has simplified the charts in a manner similar to BOCA and SBCCI. The differences are typically exemptions to sesimci design loads. These differences are shown in the tables 11, 12, and 13 in Chapter IV, Conclusions and Findings.

F. 1992 CABO One and Two Family Dwelling Code

General

The CABO One and Two Family Dwelling Code (CABO) is a prescriptive document intended for primary use with conventional light frame construction.

The CABO code does permit its use for townhouses of not more than three stories in height. A townhouse is a multi-family building, with the number of units limited by the fire rating of the building, division wall construction and allowable area of construction.

Background

In the 1992 study the CABO code was found to be substantially equivalent to the 1988 NEHRP Provisions for detached buildings of conventional light framing that are not more than 2 stories or 35 feet in height in areas where the $Av \geq 0.15$. The NEHRP Provisions require detached dwellings greater than 2 stories or 35 feet to be designed for earthquake forces. In areas where the $Av < 0.15$, detached one and two family dwellings of 3 stories or less are exempt from the NEHRP Provisions.

Townhouses, which are multi-family structures, are required by the NEHRP Provisions to be designed when the $Av > 0.05$. Thus if the CABO code was used for this type of structure, typically SPC B,C, and D, it would not be significantly equivalent to the level of seismic safety in the 1988 NEHRP Provisions.

Specifically the study noted the following:

> Maps were different in CABO and in the 1988 NEHRP Provisions.
>
> CABO permitted let-in braces for walls of one story dwellings and the top story of multi-family dwellings. NEHRP would require solid sheathing as the lateral force resisting element.
>
> The NEHRP Provisions require reinforcing steel in masonry buildings in SPC C,D and E whereas CABO required it only in Seismic Zones 3 and 4.

Current Study

The current study found no changes to the 1991 NEHRP Provisions or the 1992 CABO code that would change the findings of the previous report. The CABO code meets the intent of the 1991 NEHRP Provisions

for buildings not more than two stories or 35 feet in height of conventional light frame construction.

A townhouse is a multi-family dwelling under the NEHRP Provisions and the use of the 1992 CABO code for this type of occupancy for buildings requiring design would not be considered equivalent. Thus the townhouse provisions could only be considered in areas where the $Av < 0.05$.

Specifically the following summarizes our findings of the differences between the 1991 NEHRP Provisions and the 1992 CABO code:

> The 1991 NEHRP Provisions contains requirements for "bracing walls" which act as crosswalls. These are limited to 25 feet on center with an exception to 35 feet. CABO has no similar provision. However, the type of buildings constructed under the CABO code will probably never be of the size where the rooms are more than the NEHRP limitation.
>
> The CABO and NEHRP Provisions wall sheathing requirements are equivalent. CABO does permit the use of let-in braces in some cases, which is less than what NEHRP requires.
>
> Both CABO and NEHRP Provisions contain equivalent provisions for wall framing details such as top and bottom plates.
>
> CABO requires a continuous foundation. Although the requirement for a continuous footing is not specific in the NEHRP Provisions, it may be implicit since it assumes a designed building.
>
> The CABO code is inadequate for masonry connections. CABO permits connections with crossgrain bending, specifically prohibited in the NEHRP Provisions. Ledger bolt spacing may be less than that required by calculation in NEHRP. NEHRP Provisions requires connection strength to be a minimum of 1000 Av, which will require closer anchor bolt spacing than that shown in the prescriptive sketches in the CABO code.

Figure 3 on the following page summarizes the process in the 1991 NEHRP Provisions for determining the applicability of provisions for 1 and 2 family dwellings. Figure 4 summarizes the CABO code applicability and the prescriptive provisions included therein.

The tables following these charts compare the CABO and the 1991 NEHRP Provisions for masonry and conventional light wood frame dwelling construction.

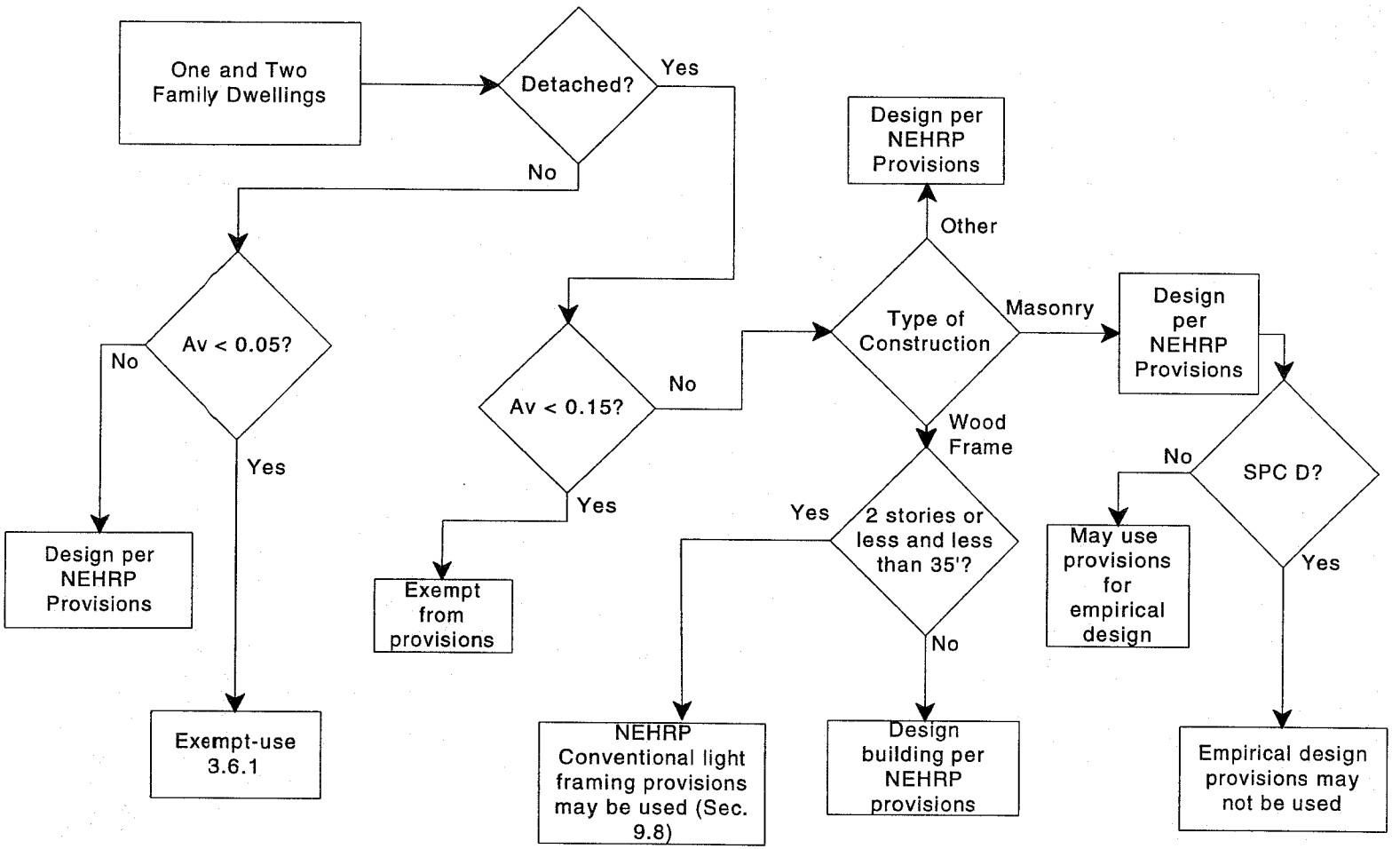
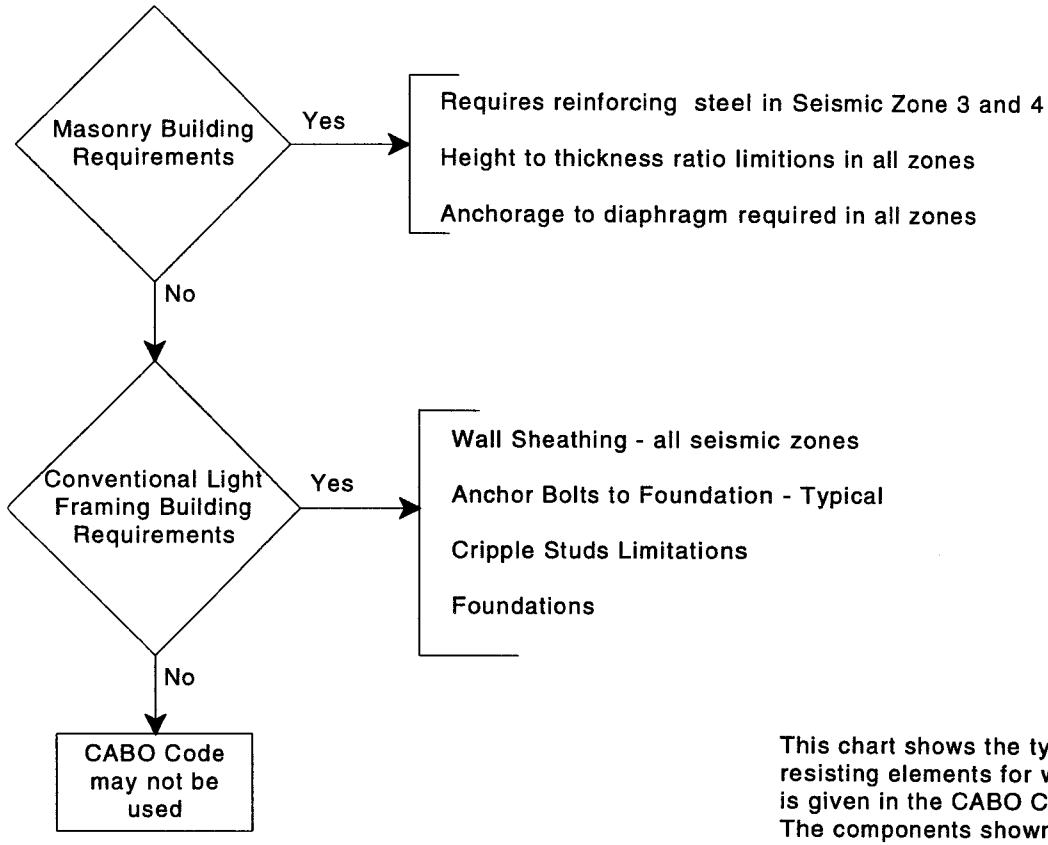


Figure 3 - NEHRP Applicability of Provisions for Dwellings



This chart shows the typical lateral resisting elements for which design guidance is given in the CABO Code.
The components shown are analogous to those required by the NEHRP Provisions

Figure 4 - CABO Requirements Applicable to Lateral Force Resistance for Detached One and Two Family Dwellings

Table 3 - CABO Masonry Review		
CABO Section No.	**NEHRP Section No.**	**Discussion**
R 404.10	ACI/ASCE 530 Appendix A	Reinforcing steel - CABO uses ACI/ASCE 530 as its basis for the provisions. Both CABO and ACI/ASCE 530 call for reinforcing steel only in buildings in Seismic Zones 3 and 4. NEHRP requires reinforcing steel in SPC C, D and E buildings. An SPC C building could be located in Seismic Zone 2. Thus CABO is therefore less conservative than NEHRP.
R 404.7 and ACI/ASCE 530	ACI/ASCE 530 9.5.1	Height to thickness ratio - Height to thickness ratios for masonry walls are based on ACI/ASCE 530 in both NEHRP and CABO. They are the same in each.
R 404.9	9.9.2.2	Wall anchorage - CABO contains standard details drawings for the connection between a masonry wall and the ledger and diaphragm. NEHRP prohibits the use of toe nailing and crossgrain bending in such connections. The details in CABO show crossgrain bending. The masonry wall provisions are therefore less conservative in CABO.

Table 3 Continued - CABO Conventional Light Wood Framing		
CABO Section No.	**NEHRP Section No.**	**Discussion**
NONE	9.8.1.1	Crosswall Spacing - NEHRP has a criteria for the maximum spacing of "bracing walls." These are walls normal to the wall being considered. The maximum spacing is 25 feet with 35 feet being permitted in SPC-B. CABO has no such provision and is thus less conservative than NEHRP.
R 402.10	9.8.3	Wall Sheathing - Each code has requirements for solid sheathing of walls. CABO divides requirements by Seismic Zone with special provisions in Zones 3 and 4. CABO will also allow the use of let-in bracing in Seismic Zones 3 and 4 and the top story of multi-story buildings, NEHRP requires wood sheathing.
R 303	9.8.2.1	Anchor Bolts to Foundation - CABO requires anchor bolts at 6 feet on center. NEHRP requires anchors at 6 feet o.c.
R 402.3 and 402.4	9.8.2.2	Top Plates - CABO requires double top plates for exterior walls and interior bearing walls, with some exceptions. NEHRP-91 requires double top plates where Av ≤ 0.15. The two codes are equal for all practical purposes.
R402.3	9.8.2.3	Bottom Plates - Both CABO and NEHRP require bottom plates for walls.
R402.9	9.8.1.2	Cripple Wall Bracing - Both CABO and NEHRP require cripple stud walls to be braced.
R303 and R304		Foundations - Both CABO and NEHRP require continuous foundations under exterior walls.

G. Materials Criteria and Reference Standards Comparison

Model codes adopt the national standards developed by industry and other groups for specific construction materials. Depending on specific code needs, these may be modified. The code will either publish the entire material design document with changes or only the revised sections. In the case of seismic design, the model codes, ASCE 7, and NEHRP Provisions have adopted these nationally recognized design documents and have made modifications to them. This section discusses each of the standard construction materials, contains a table identifying the adopted standards by model code and ASCE 7 and provides comments on the implication of changes.

Wood at this time remains an allowable stress design procedure. Each code modifies the wood criteria to achieve a strength design approach.

Wood Design

The wood and masonry sections are the least consistent nationally. The 1991 NEHRP Provisions differs substantially from BOCA and SBCCI; the model codes are more conservative. ASCE 7 is similar to BOCA and SBCCI in its wood provisions

Wood design in all the codes and the NEHRP Provisions adopt the National Design Specifications (NDS) developed and maintained by the National Forest Products Association (NFoPA). Table 3 shows the adopted provisions and the edition specified in the model codes and NEHRP Provisions.

Differences may occur where the NEHRP Provisions adopts the 1986 Edition of the NDS and BOCA adopts the 1991 Edition of the NDS. SBCCI and UBC adopt the 1986 Edition. The implication of this is that the 1991 NDS is more restrictive in the bolt values. This will have an effect on seismic design where drag or collector members are utilized. Use of the 1991 Edition of the NDS is more conservative than the NEHRP Provisions.

The other issue related to wood design occurs in the load combinations. NEHRP uses a ϕ factor to adjust allowable ultimate loads. BOCA and SBC do not use this approach and are, in effect, more conservative.

Wall bracing requirements in BOCA differ from those of the NEHRP Provisions for conventional light framing. NEHRP Provisions places a limit of 1 story or 20 feet in height for SPC - C buildings. BOCA allows 2 story or 30 feet in height for SPC - C buildings. This section has varying wall bracing requirements based on SPC and Av. Buildings designed under BOCA may have greater story drift than a building designed under the 1991 NEHRP Provisions. The significance of this is the potential for greater property damage. It does not reduce safety and is considered significantly equivalent to the 1991 NEHRP Provisions.

The UBC too has provisions for conventional framed structures. In Seismic Zones 0, 1, 2 and 3 the requirements for crosswalls and bracing are significantly equivalent to the 1991 NEHRP Provisions.

Table 4 - Reference Documents - Wood							
Standard	**Doc. NUMBER**	**YEAR**	**NEHRP**	**BOCA**	**SBCCI**	UBC	**ASCE**
National Design Specifications for Stress Grade Lumber & Fastenings	NFoPA T901	1986	✓	1991	✓	✓	✓
Softwood Plywood - Constr. & Industrial	PS 1-83	1983	✓		✓	✓	✓
Wood Particleboard	ANSI A 208.1	1989	✓	✓	✓	✓	✓
Pressure Preservation - All Timber	AWPA C1	1988	✓	1992	1990	✓	
Pressure Treatment of Timber	ASTM D1760-86a	1986	✓				
Structural Glue Laminated Timber	ANSI/AITC A 190.1	1983	✓	1992	✓	✓	
Design & Man. Softwood Glu-Lam	AITC 117	1989	✓	1987	1987/88	✓	✓
Wood Poles	ANSI 05.1	1988	✓			✓	✓
Round Timber Piles	ASTM D25	1988	✓	1991	✓	✓	
Gypsum Wallboard	ASTM C36-84	1984	✓	1992	1985		✓
Fiberboard Nail-Base Sheathing	ASTM D2277-87	1987	✓				✓
Plywood Design Specifications	APA	1986	✓		✓		✓
Diaphragms	APA	1987	✓				✓
Structural Use Panels	APA PRP 108	1988	✓				✓
Design Caps. of APA Structural Use Panels	APA N375	1988	✓				✓

Steel Design

Steel design is all based on the Specification for Structural Steel Buildings developed by the American Institute of Steel Construction, Inc. All the model codes, ASCE 7, and NEHRP adopt the AISC specifications. NEHRP makes a few modifications to AISC. Differences between NEHRP and the model codes are not considered to have any design implications and the provisions are equivalent.

Several other standards,none of which have a seismic design implication, are referenced in the NEHRP Provisions.

Table 5 includes a summary of the adopted steel design specifications and year by code.

Table 5 - Reference Documents - Steel					
	NEHRP	**BOCA**	**SBCCI**	**UBC**	**ASCE**
AISC LRFD 1986 w. 1989 supplement	✓	✓	✓1993	✓	✓
AISC ASD 1989	✓	✓	✓	✓	✓
AISI 1986 w. 1989 addendum	✓	✓	✓	✓	✓
ANSI/ASCE-8 - 1990	✓	✓	✓	✓	✓
STEEL JOISTS & JOIST GIRDERS (SJI) 1990	✓	1992	1992	1985	✓
STEEL CABLES AISI 1973	✓	✓	✓	✓	✓
SEISMIC PROVISIONS FOR STRUCTURAL STEEL BUILDINGS AISC 92		✓		✓	✓
AISI (LRFD) - 91		✓	1990	✓	✓

Concrete Design

Concrete design is based on the Recommended Provisions for Concrete Design (ACI 318) developed by the American Concrete Institute (ACI).

Each model code, ASCE 7, and the NEHRP Provisions adopt these provisions with changes. The UBC makes extensive revisions to the detailing provisions of ACI and is generally more restrictive than the NEHRP Provisions. The NEHRP Provisions have minor changes to ACI relative to detailing. Both BOCA and SBCCI have the same modifications to ACI as the 1991 NEHRP Provisions. ASCE 7 makes similar changes to the concrete requirements.

The reference concrete specifications are shown in Table 6.

Table 6 - Reference Documents - Reinforced Concrete					
	NEHRP	BOCA	SBCCI	UBC	ASCE
American Concrete Institute, ACI 318-89, excluding Appendix A	✓	✓	✓	✓	✓

Masonry Design

Masonry design provisions have never been standardized or consistent. The ACI/ASCE 530-88 Building Code Requirements for Masonry Structures is the first national model developed by a consensus process.

The ACI/ASCE 530 provisions have been adopted by NEHRP, BOCA and SBC and ASCE 7. ACI/ASCE 530 retains seismic zones. The 1991 NEHRP includes a chart converting seismic zones to SPC categories. This same chart is adopted by BOCA, SBCCI and ASCE 7. The table below, from NEHRP, illustrates how ACI/ASCE 530 is converted from Seismic Zones to SPC categories.

BOCA modifies the empirical provisions of ACI/ASCE 530 in a manner that is more restrictive than NEHRP.

The UBC has its own chapter for masonry. The UBC contains provisions for strength design of masonry. This is included as an appendix in NEHRP. There are minor differences between NEHRP and the UBC. NEHRP has more restrictive detailing and closer spacing requirements for running bond and stacked masonry. The UBC has more detailed requirements for masonry structures in Seismic Zones 3 and 4. There are no safety implications from these differences.

The masonry provisions of all the reviewed documents are considered equivalent to NEHRP. Table 7 notes which codes adopt ACI/ASCE 530 and the edition.

Seismic Zones and Replacement Seismic Performance Categories

Seismic Zone	Seismic Performance Category
0 and 1	A and B
2	C
3 and 4	D and E

Table 7 - Reference Documents - Masonry					
	NEHRP	BOCA	SBCCI	UBC	ASCE
ACI 530-88/ASCE 5-88, including Appendix A, Special Provisions for Seismic Design and Specifications for Masonry Structures, ACI 530.1-88/ASCE 6-88	✓	✓	✓		1992✓

H. Foundation Requirements Comparison

Foundation design requirements are contained in different chapters of the building codes than the structural design chapter. Each code has specific provisions for various foundations including spread footings and piles. Seismic design and detailing provisions are found in these chapters.

The 1991 NEHRP Provisions contain a number of detail modifications to foundation design for seismic requirements. The foundation design provisions of BOCA and SBC are the same as the 1991 NEHRP Provisions.

NEHRP requires a soils investigation for SPC C, D and E. Both BOCA and SBC require an investigation for SPC D and E only. Since the requirement is to use the most restrictive soil type if there is no geotechnical investigation, the implication is that BOCA and SBCCI are more conservative than NEHRP.

The SBC contains a lesser requirement for concrete pile reinforcing steel ties. NEHRP requires 1/2 inch diameter ties in piles greater than 20 inches in diameter. In SPC, 3/8 inch minimum ties may be used for these piles. This applies to SPC D and E. NEHRP permits the 3/8 inch ties in piles less than 20 inches in diameter. This tends to be an engineering judgment and is not a significant difference between NEHRP and SBCCI.

ASCE 7-93 is similar to BOCA and SBCCI in its foundation requirements.

The 1994 UBC is consistent with NEHRP for pile and caisson foundations and interconnecting ties.

All codes require horizontal crossties at the top of pile footing and caps. These are for pile stability. NEHRP requires interconnecting ties for spread footings in SPC categories D and E. The UBC does not require foundation ties for spread footings in similar occupancies and building types. This is an engineering judgment on the need for such ties. The implication is that the UBC is less conservative than NEHRP. There are no safety implications due to this difference.

Table 8 provides a crosswalk between the various codes and may be used for comparison purposes.

Table 8 - Foundations

FOUNDATION TYPE	NEHRP	BOCA	SBCCI	UBC	ASCE
PILES and SPC Groups					
Pile Ties - C,D, & E	7.4.3	1816.11.2	1805.4.3	1807.2	9.7.4.3
Pile Bending - D&E	7.5.3	1816.3	1805.10.2	1809.5.1 (3& 4)	9.7.5.3
Steel - (Pile Cap Connection)					
D&E	7.5.3.5	1818.3	1807.4		A.9.7.5.3.5
Concrete Filled Steel Pipe					
C, D & E	7.4.4.3	1819.3	1808.4.2		A.9.7.4.4.1
Drilled (Uncased) Concrete Piles, Piers & Caissons					
C	7.4.4.1	1820.1.2.1	1809.1.4		A.9.7.4.4
D&E	7.5.3.1	1820.1.2.1	1809.1.4	1809.5.2.2 (3 & 4)	A.9.7.5.3.2
Precast Reinforced Concrete					
Reinf.C, D & E	7.4.4.4	1821.1	1810.2.1 & 1809.1.4	1808.4.2 & 1809.5.2.2	A.9.7.4.4.2
Ties D & E	7.5.3.3	1816.11.2	1810.2.1 & 1809.1.4		A.9.7.5.3.2
Metal Cased Concrete					
C	7.4.4.2	1820.1.2.1 & 1820.5.4.1	1809.1.4		A.9.7.4.4.2
D & E	7.5.3.2	1820.1.2.1 & 1820.5.4.1	1809.1.4		A.9.7.5.3.2
Precast/ Prestressed Concrete					
Ties C, D & E	7.4.4.5		1809.1.4	1808.5.2	A.9.7.4.4.5
Reinf D & E	7.5.3.4	1821.3.6	1810.3.7	1809.5.2.3(3 & 4)	A.9.7.5.3.4

Table 8 Cont... - Foundations					
FOUNDATION TYPE	**NEHRP**	**BOCA**	**SBCCI**	**UBC**	**ASCE**
CONCRETE PILE CAPS					
C, D & E	7.4.4	1816.11.1 & 1820.3	1805.10.2		A.9.7.4.4
SPREAD FOOTING TIES					
D & E	7.5.2	1802.2.1	1804.5.3		
POLE-TYPE STRUCTURES					
C, D & E	7.4.2		1804.9.2	1806.7	9.7.4.2
INVESTIGATION					
C	7.4.1			1804	9.7.4.1
D & E	7.5.1	1802.1.1	1804.9.1		9.7.5.1

I. Quality Assurance Provisions

Construction quality control for structures other than dwellings typically involves field inspection by a special inspector. This inspector will observe reinforcing steel in place, concrete placement, field welding, installation of high strength bolts and construction of masonry utilizing higher stresses. Typically there are no inspection requirements for non-structural components.

The NEHRP Provisions include very detailed requirements for construction quality control. Included are requirements for both structural components and non-structural components. There are many subcategories for some non-structural components such as partitions. The NEHRP Provisions also have a special requirement for a quality assurance program for SPC categories D and E. In general the NEHRP Provisions are more restrictive than the traditional building code in quality control requirements.

There are no significant changes to the model codes, except for the UBC as discussed below, in the inspection requirements.

The model codes all codes require independent, or special, inspection of selected structural components and building types. All structural inspection in the model codes is equivalent to the NEHRP Provisions. BOCA and SBC have less inspection requirements for nonstructural components than the NEHRP Provisions. There is no specific safety implication of this.

The UBC has similar requirements to the NEHRP Provisions for quality control of structural elements. UBC has additional requirements for "structural observation" in the 1994 edition. The UBC has no specific inspection requirements for nonstructural components.

ASCE 7-93 contains quality assurance requirements similar to those in the NEHRP Provisions.

The NEHRP Provisions, beginning in the 1991 Edition, permit "periodic inspection." This is less conservative than required in the 1988 NEHRP Provisions.

Table 9 is a side by side comparison of quality control provisions. The table indicates what each code requires and whether continuous or periodic inspection. Table 10 shows the requirements for special testing of materials.

Table 9 - Quality Assurance - Special Inspection

Inspection Item	NEHRP	BOCA	SBCCI	UBC	ASCE	NOTES
STRUCTURAL						
FOUNDATIONS: Piles And Caissons	1.6.2.1	1705.8 and 1705.9	1708.7	1701.5 No. 11	A.9.1.6.2.1	
	●	●	●	●		
REINFORCING STEEL						
R/C SMRF	1.6.2.2.1	1705.4.2	1708.4	1701.5 No. 3	A.9.1.6.2.2.1	BOCA - General
	o	●	●	●	Daily	
R/C OMRF and shear walls	1.6.2.2.2	1705.4.2	1708.4		A.9.1.6.2.2	ASCE for IMF not OMF
	o	●	●		o	
Welding	1.6.2.2.3	1705.4.2	1708.4	1701.5 No. 5	A.9.1.6.2.2.3	
	●	●	●	●	●	
STRUCTURAL CONCRETE						
Drilled Piers, Caissons, R/C Frames, Shear Walls	1.6.2.3	1705.4.4	1708.4	1701.5 No. 1 and 3	A.9.1.6.2.3	SBCC - Frames and Shear Walls
	o	●	●	●	o	

● Designates Continuous Inspection

o Designates Perodic Inspection

Table 9 Cont... - Quality Assurance - Special Inspection						
Inspection Item	**NEHRP**	**BOCA**	**SBCCI**	**UBC**	**ASCE**	**NOTES**
Prestressed Concrete	1.6.2.4	1705.4	1708.4	1701.5 No. 1 & 4	A.9.1.6.2.4	
Steel Placing	O	1705.4.2 ●	●	●	O	SBC - In SMRFs, OMRFs and shear walls
Concrete	●	1705.4.4 ●		●	●	
Stressing and Grouting	●	1705.4.5 1705.4.5.1 ●	●	●	●	
STRUCTURAL MASONRY	1.6.2.5	1705.5	1708.5	1701.5 No. 7	A.9.1.6.2.5	
During mortar, reinf. placing and laying	O	●	●	●	O	SBCC Location and installation of reinforcing in reinforced masonry shear walls.
Prior to grouting	O			●	●	
During reinf. welding, grouting, consolidation and reconsolidation	●	●	●	●	●	

● Designates Continuous Inspection

O Designates Perodic Inspection

Table 9 Cont... - Quality Assurance - Special Inspection						
Inspection Item	**NEHRP**	**BOCA**	**SBCCI**	UBC	**ASCE**	**NOTES**
STRUCTURAL STEEL	1.6.2.6	1705.3	1708.2	1701.5 No. 5		
Welding	1.6.2.6.1 ●	1705.3.3.2 .1 ●	1708.2.1 ●	●	A.9.1.6.2.6 .1 ●	
Single pass fillet or resistance weld w/ qualified welder	1.6.2.6.1 exception o		1708.2.1 o	o	A.9.1.6.2.6 .1 Exception o	
Connections						
High Strength Bolts	1.6.2.6.2 o	1705.3.3.1 ●	1708.3 o	1701.5 No. 6 o	A.9.1.6.2.6 .2 o	
STRUCTURAL WOOD	1.6.2.7	1705.6	1708.6		A.9.1.6.2.7	
Gluing	●	●	●		●	
Nailing, bolting, etc.	o	●	●		o	

● Designates Continuous Inspection

o Designates Perodic Inspection

Table 9 Cont... - Quality Assurance - Special Inspection						
Inspection Item	**NEHRP**	**BOCA**	**SBCCI**	**UBC**	**ASCE**	**NOTES**
NON-STRUCTURAL						
ARCHITECTURAL	1.6.2.8	1705.10	1708.8		A.9.1.6.2.8	NEHRP for PCF = 1 OR 1.5. BOCA & SBC for SPC "E"
Erection/ fastening of exterior and interior architectural panels	1.6.2.8.1 o	1705.10 ●	1708.8 ●		A.9.1.6.2.8 .1 o	
Adhesion or anchorage of veneers	1.6.2.8.2 o	1705.10 ●	1708.8 ●		A.9.1.6.2.8 .2 o	
MECHANICAL/ELECTRICAL Motors, Rotating Machinery, Tanks, etc.	1.6.2.9 o	1705.11.1 ●	1708.9 ●		A.9.1.6.2.9	PCF= 1 or 1.5

● Designates Continuous Inspection

o Designates Perodic Inspection

Table 10 - Special Testing					
TESTING ITEM	**NEHRP**	**BOCA**	**SBCCI**	**UBC**	**ASCE**
STRUCTURAL					
REINF. AND PRESTRESSING STEEL					
Reinf. for SMRF's, boundary members of shear walls.	1.6.3.1.1		1708.4 also OMRF's		A.9.1.6.3.1.1
Prestressing steel	1.6.3.1.2				A.9.1.6.3.1.2
STRUCTURAL CONCRETE	1.6.3.2	1705.4	1905	1905.6	A.9.1.6.3.2
STRUCTURAL MASONRY	1.6.3.3	1705.5	2104	2102.2	A.9.1.6.3.3
STRUCTURAL STEEL					
Welded connections for SMRF and EBF	1.6.3.4.1	1705.3.3.2.1	1708.2.1	1703	A.9.1.6.3.4.1
Full penetration welds in joints and splices	1.6.3.4.1		1708.2.2	1703 - No. 1	A.9.1.6.3.4.1
Partial penetration welds in column splices	1.6.3.4.2	1705.3.3.2.2	1708.2.2	1703 - No. 2	A.9.1.6.3.4.2
Base metal > 1.5" thick	1.6.3.4.3	1705.3.3.2.3	1708.2.3	1703 - No. 3	A.9.1.6.3.4.3
NON-STRUCTURAL					
MECHANICAL AND ELECTRICAL EQUIPMENT	1.6.3.5	1705.11.2			A.9.1.6.3.5
REPORTING AND COMPLIANCE	1.6.4		105		A.9.1.6.4.
APPROVED MANUFACTURER CERTIFICATION	1.6.5	1705.11.3	1708.9.3		A.9.1.6.5

IV. Summary and Conclusions

General

The 1993 BOCA and 1994 Standard Building Codes each adopt the NEHRP Provisions in a building code format. While there are minor differences, their use will result in a structure that has seismic design and seismic safety equivalent to one designed under the 1991 NEHRP Provisions.

The Uniform Building Code remains a working stress document and is not directly comparable to the NEHRP Provisions. However the findings of the previous study, described earlier in this report, found that design under the UBC will provide a structure of equivalent safety to the NEHRP Provisions. Changes from the 1991 version to 1994 version of the Uniform Building Code incorporate additional provisions similar to those in the NEHRP Provisions.

None of the model building codes contain a requirement for a quality assurance program as the NEHRP Provisions does for SHEG III structures. However each has detailed inspection requirements for structural construction based on the materials types.

One factor in evaluating equivalence in the model codes is that each is continuously being updated. This report is essentially a snapshot but the target is moving. In the 1993 BOCA and SBCCI, there are different R values for certain concrete frame building types. These revised R factors are reportedly a change to the 1994 NEHRP Provisions. Similar comments apply to the adoption of industry design standards for the various materials.

ASCE 7-93 adopts the 1991 NEHRP Provisions. The minor changes are described below.

The CABO Code is prescriptive. It is substantially equivalent to the NEHRP Provisions only for a certain buildings of conventional light wood framing with additional limitations based on height and A_v.

The following summarizes our observations:

BOCA National Building Code

1993 BOCA/National Building Code (BOCA) - The BOCA seismic provisions are almost word for word the 1991 NEHRP Provisions. The organization within the code has the same numbering flow as the NEHRP Provisions, permitting quick reference. The specific differences are:

Load Combinations - BOCA has a somewhat different approach to the load combination requirements. BOCA has a working stress approach to load combination for wood and a strength design approach for other materials. The NEHRP Provisions use a strength design approach for all materials.

Story Drift - BOCA permits a greater story drift for SHEG Group I, II and III in buildings 4 stories or less without brittle finishes and in SHEG I buildings. A comparison of story drift limitations is shown in Table 11.

Architectural and Mechanical Components - Some architectural components not regulated by the NEHRP Provisions are included in BOCA. The subtle differences in the NEHRP Provisions for partitions are not included in BOCA. There are also minor differences in SHEG I buildings with greater requirements in BOCA. Differences in design values for architectural components, mechanical and electrical equipment and elevators are shown in Tables 12, 13 and 14.

R Values - BOCA contains a R and C_d factor for plain concrete shear wall structures that is not contained in the NEHRP Provisions. It also has a higher R for ordinary and intermediate concrete frames. This results in a lower base shear than the NEHRP Provisions.

SBCCI Standard Building Code

1994 Standard Building Code (SBCCI) - The SBCCI seismic provisions are the same as the 1991 NEHRP Provisions. The organization within the code has a numbering flow close to the NEHRP Provisions. The specific differences are:

Load Combinations - SBCCI has a working stress approach to load combinations for wood and a strength design approach for other materials. The NEHRP Provisions use a strength design approach for all materials.

Modal Analysis - One sentence giving an alternate computation for dynamic analysis is not included in SBCCI.

Architectural and Mechanical Components - Some architectural components not regulated by the NEHRP Provisions are included in SBCCI. The subtle differences in the NEHRP Provisions for partitions are not included in SBCCI. There are also minor differences in SHEG I buildings with greater requirements in SBCCI. Differences in design values for architectural components, mechanical and electrical equipment and elevators are shown in Tables 12, 13 and 14.

R Values - SBCCI has higher R and C_d values for intermediate and ordinary reinforced concrete frames. The NEHRP Provisions are 4

and SBCCI 5 for intermediate; the NEHRP Provisions are 2 and SBCCI is 3 for ordinary concrete frames. This will result in a lower base shear than the NEHRP Provisions.

Story Drift - SBCCI permits a greater story drift for SHEG Group I, II and III in buildings 4 stories or less without brittle finishes and in SHEG I buildings. (These are the same as the BOCA provisions.) A comparison of story drift limitations is shown in Table 11.

ICBO Uniform Building Code

1994 Uniform Building Code (UBC) - The UBC adopts the seismic provisions developed by the Structural Engineers Association of California (SEAOC). The approach is a working stress design rather than the strength design approach taken by the NEHRP Provisions. Thus the two are not readily comparable. Within the engineering design provisions there are equivalent sections illustrating that the technical approach is the same. Within materials the same reference standards are used for concrete, wood and steel. There are additional provisions for seismic design of concrete structures. The UBC has its own chapter on masonry. Changes to the 1994 UBC include picking up provisions in the NEHRP Provisions. An example is the torsion design requirements for flexible diaphragms now added to the UBC.

ASCE 7-93

The ASCE 7-93 adopts the NEHRP Provisions in standard format similar to a code. While there may be minor differences, use of ASCE 7-93 and Appendices will result in a structure that is the equivalent to one designed under the 1991 NEHRP Provisions.

ASCE 7-93 takes a very good approach to the load factor equations. The body of the standard clearly defines the load factors to be used for the allowable stress method and those that are to be used for strength design. Then the seismic provisions clearly spell out the revised formulas to be used with seismic design.

Specifically the following summarizes our observations:

There is no requirement for ties between spread footings in SPC D and E buildings in ASCE 7-93. Such a provision is contained in the NEHRP Provisions.

Because of the way the materials sections and load combinations are organized, ASCE 7-93 may be more accessible as a design document than the NEHRP Provisions. Examples include the organization of load combination factors discussed above.

The provisions in the wood section are clearer than those in the NEHRP Provisions for designing in either allowable stress or strength design methods.

Drift limits are different and shown in Table 11.

Nonstructural exemptions are shown in Tables 12, 13 and 14.

CABO One and Two Family Dwelling Code

The CABO One and Two Family Dwelling Code is a prescriptive document intended for primary use with conventional light frame construction. The code does permit its use for townhouses of not more than three stories in height.

A townhouse is a multi-family building, with the number of units limited by the fire rating of the building, division wall construction and allowable area of construction. A townhouse is considered a multi-family dwelling under the NEHRP Provisions and the use of the 1992 CABO Code for this type of occupancy for buildings requiring design would not be considered equivalent. Thus the townhouse provisions could only be considered in areas where $A_V < 0.05$.

The CABO Code meets the intent of the 1991 NEHRP Provisions for wood frame dwellings not more than two stories in height or 35 feet. It does not result in an equivalent seismic safety for masonry.

Specifically the following summarizes our observations:

The CABO masonry wall connections are not equivalent to the NEHRP Provisions and other model code provisions on connections. The CABO illustrated connection permits crossgrain bending. The ledger bolt spacing may be less than that required by calculation in the NEHRP Provisions.

The CABO Code is inadequate for masonry connections. The NEHRP Provisions requires connections strength to be a minimum of 1000 A_V, which will require anchor bolt spacing at less than that shown in the prescriptive sketches in the CABO code.

For light-framed wood construction, the 1991 NEHRP Provisions contains requirements for "bracing walls" which act as crosswalls . These are limited to 25 feet maximum on center with an exception to 35 feet. CABO has no similar provision. However, the type of buildings constructed under the CABO Code will probably rarely be of the size where the rooms are larger than the NEHRP limitation. Therefore there is very little practical effect of this difference in housing construction.

The CABO and the NEHRP Provisions wall sheathing requirements are equivalent. CABO does permit the use of let-in braces in some cases, which is not permitted under the NEHRP Provisions.

Both CABO and the NEHRP Provisions contain equivalent provisions for wall framing details such as top and bottom plates.

Conclusions

Building codes are dynamic documents. Each is constantly changing and being updated to incorporate the latest research findings, standards and methodologies. Each model code leapfrogs the NEHRP Provisions. This is illustrated by the adoption into the model code of provisions proposed for the next edition of the NEHRP Provisions. Trying to compare any two documents requires judgment based on this knowledge, not just a simple side by side reading of the provisions.

Based on the findings in this study, buildings constructed under the 1993 BOCA or 1994 SBCCI would result in a building providing the same level of safety as the same building designed under the 1991 NEHRP Provisions. A building designed under the 1994 UBC would provide a substantially equivalent level of seismic safety to a building designed under the 1991 NEHRP Provisions.

The conclusion of this study is that the current editions of the three model codes are substantially equivalent to the 1991 NEHRP Provisions.

Based on the findings in this study, buildings constructed under ASCE 7-93 and its Appendix would result in a building providing the same level of safety as the same building designed under the 1991 NEHRP Provisions. The conclusion of this study is that the ASCE 7-93 is substantially equivalent to the 1991 NEHRP Provisions.

Based on the findings in this study, conventional light frame dwellings of two stories or 35 feet in height maximum, constructed under the 1992 CABO One and Two Family Dwelling Code provide the same level of seismic safety as those designed using the 1991 NEHRP Provisions. Townhouses of wood frame construction in areas where the $A_V < 0.05$ will provide a level of safety equivalent to the 1991 NEHRP Provisions. Townhouses where the $A_V \geq 0.05$ will not meet the level of safety prescribed by the NEHRP Provisions.

Dwellings of masonry designed using the CABO 1 and 2 Family Dwelling Code will not provide a similar level of seismic safety except where $A_V < 0.05$.

The following tables illustrate differences among the several design provisions. Tables included are:

Table 11 - Allowable Story Drift comparison

Table 12 - Exemptions - Architectural Components and Systems

Table 13 - Exemptions - Mechanical and Electrical

Table 14 - Exemptions - Elevators

SPC's shown as bold are elements that are exempt in the specific code or standard, but which are required to be designed by the 1991 NEHRP Provisions.

Table 11 - Allowable Story Drift				
Building Type	CODE	SHEG		
		I	II	III
Single-story steel buildings without equipment attached to the structural resisting system and without brittle finishes	NEHRP	No Limit	0.02hsx	0.015hsx
	BOCA	No Limit	0.02hsx	0.015hsx
	SBC	No Limit	0.02hsx	0.015hsx
	ASCE	No Limit	0.02hsx	0.015hsx
Buildings 4 stories or less in height without brittle finishes	NEHRP	0.020 hsx	0.015 hsx	0.010hsx
	BOCA	**0.025** hsx	**0.020** hsx	**0.015** hsx
	SBC	**0.025** hsx	**0.020** hsx	**0.015** hsx
	ASCE	**0.025** hsx	**0.020** hsx	**0.015** hsx
All other buildings	NEHRP	0.015 hsx	0.015 hsx	0.010hsx
	BOCA	**0.020** hsx	0.015 hsx	0.010hsx
	SBC	**0.020** hsx	0.015 hsx	0.010hsx
	ASCE	**0.020** hsx	0.015 hsx	0.010hsx

Table 12 - Exemptions - Architectural Components and Systems				
Value of A_V	CODE	SHEG		
		I	II	III
Av<0.05	NEHRP	A*	A*	
	BOCA	**A**	**A**	**A**
	SBC	**A**	**A**	**A**
	ASCE	**A**	**A**	**A**
0.05≤A_V<.0.10	NEHRP	B*		
	BOCA	B*		
	SBC	B*		
	ASCE	B*		
0.10≤A_V< 0.15	NEHRP	C*		
	BOCA	C*		
	SBC	C*		
	ASCE	C*		
0.15≤A_V< 0.20	NEHRP	C*		
	BOCA	C*		
	SBC	C*		
	ASCE	C*		

* Components w/PCF = 0.50

SPC's shown as bold are exempt in the specific code or standard when compared to the 1991 NEHRP Provisions.

Table 13 - Exemptions - Mechanical and Electrical				
Value of A_V	CODE	SHEG		
		I	II	III
Av<0.05	NEHRP	A*	A*	
	BOCA	**A**	**A**	**A**
	SBC	**A**	**A**	**A**
	ASCE	**A**	**A**	**A**
0.05≤A_V< 0.10	NEHRP	B*		
	BOCA	**B**	**B**	
	SBC	**B**	**B**	
	ASCE	**B**	**B**	
0.10≤A_V<0.15	NEHRP	C*		
	BOCA	C*		
	SBC	C*		
	ASCE	C*		
0.15≤A_V<0.2	NEHRP			
	BOCA	**C***		
	SBC	**C***		
	ASCE	**C***		

Components w/ PCF = 0.50

SPC's shown as bold are exempt in the specific code or standard when compared to the 1991 NEHRP Provisions.

Table 14 - Exemptions - Elevators

Value of A_V	CODE	SHEG		
		I	II	III
Av<0.05	NEHRP	A	A	
	BOCA	**A**	**A**	**A**
	SBC	**A**	**A**	**A**
	ASCE	**A**	**A**	**A**
0.05≤A_V<0.10	NEHRP	B		
	BOCA	**B**	**B**	
	SBC	**B**	**B**	
	ASCE	**B**	**B**	
0.10≤A_V< 0.15	NEHRP	C		
	BOCA	C		
	SBC	C		
	ASCE	C		
0.15≤A_V< 0.20	NEHRP			
	BOCA	**C**		
	SBC	**C**		
	ASCE	**C**		

SPC's shown as bold are exempt in the specific code or standard when compared to the 1991 NEHRP Provisions.

Appendices

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 1 - GENERAL PROVISIONS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
PURPOSE	1.1				9.1.1
SCOPE	1.2	1612.1	1607.1.1		9.1.2
APPLICATIONS OF PROVISIONS	1.3			1627.1	9.1.3
NEW BUILDINGS	1.3.1				9.1.3.1
ADDITIONS TO EXISTING BUILDINGS	1.3.2	1612.1.1	1607.1.3		9.1.3.2
CHANGE OF USE	1.3.3	1612.1.2	1607.1.4		9.1.3.3
SEISMIC PERFORMANCE	1.4				9.1.4
SEISMIC GROUND ACCELERATION MAPS	1.4.1	1612.1.3	1607.1.5	1627.2	9.1.4.1
SEISMIC HAZARD EXPOSURE GROUPS	1.4.2	1612.1.5	1607.1.6	1627.4	9.1.4.2
Group III	1.4.2.1	Table 1612.1.5	Table 1607.1.6	Table 16-K	9.1.4.2.1
Group II	1.4.2.2	Table 1612.1.5	Table 1607.1.6	Table 16-K	9.1.4.2.2
Group I	1.4.2.3	Table 1612.1.5	Table 1607.1.6	Table 16-K	9.1.4.2.3

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 1 - GENERAL PROVISIONS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
Multiple Use	1.4.2.4	1612.1.5.1	1607.1.6.1.1		9.1.4.2.4
Group III Building Protected Access	1.4.2.5	1612.1.6	1607.1.7		9.1.4.2.5
Group IIIFunction	1.4.2.6				9.1.4.2.6
SEISMIC PERFORMANCE CATEGORY	1.4.3	1612.1.7	1607.1.8		9.1.4.3
SITE LIMITATION FOR SEISMIC PERFORMANCE CATEGORY E	1.4.4	1612.1.8	1607.1.9		9.1.4.4
ALTERNATE MATERIALS AND METHODS OF CONSTRUCTION	1.5				9.1.5
QUALITY ASSURANCE	1.6	1705	1708		9.1.6
QUALITY ASSURANCE PLAN	1.6.1				
SPECIAL INSPECTION	1.6.2	1705	1708	1701	
SPECIAL TESTING	1.6.3	1705	1708, 1905 & 2104	1703	

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 1 - GENERAL PROVISIONS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
REPORTING AND COMPLIANCE PROCEDURES	1.6.4		105		
APPROVED MANUFACTURER'S CERTIFICATION	1.6.5		1708.9.3		

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 2 DEFINITIONS AND SYMBOLS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
DEFINITIONS	2.1	1612.2	1607.2	1625	9.2.1
SYMBOLS	2.2			1626	9.2.2

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 3 STRUCTURAL DESIGN REQUIREMENTS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
DESIGN BASIS	3.1	1612.3	1607.3		9.3.1
SITE COEFFICIENT	3.2	1612.3.1	1607.3.1	1627.3	9.3.2
STRUCTURAL FRAMING SYSTEMS	3.3	1612.3.3	1607.3.3	1627.6	9.3.3
DUAL SYSTEM	3.3.1	1612.3.3.1	1607.3.3.1	1627.6.5	9.3.3.1
COMBINATIONS OF FRAMING SYSTEMS	3.3.2	1612.3.3.2	1607.3.3.2	1628.3	9.3.3.2
Combination Framing Detailing Requirements	3.3.2.2	1612.3.3.2.2	1607.3.3.2.2		9.3.3.2.2
SEISMIC PERFORMANCE CATEGORIES A, B, AND C	3.3.3	1612.3.3.3	1607.3.3.3		9.3.3.3
SEISMIC PERFORMANCE CATEGORY D	3.3.4	1612.3.3.4	1607.3.3.4		9.3.3.4
Limited Building Height	3.3.4.1	1612.3.3.4.1	1607.3.3.4.1	1627.7	9.3.3.4.1
Interaction Effects	3.3.4.2	1612.3.3.4.2	1607.3.3.4.2		9.3.3.4.2

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 3 STRUCTURAL DESIGN REQUIREMENTS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
Deformational Compatibilityy	3.3.4.3	1612.3.3.4.3	1607.3.3.4.3		9.3.3.4.3
Special Moment Frames	3.3.4.4	1612.3.3.4.4	1607.3.3.4.4		9.3.3.4.4
SEISMIC PERFORMANCE CATEGORY E	3.3.5	1612.3.3.5	1607.3.3.5		9.3.3.5
BUILDING CONFIGURATION	3.4	1612.3.4	1607.3.4	1627.5	9.3.4
PLAN IRREGULARITY	3.4.1	1612.3.4.1	1607.3.4.1	1627.5.1	9.3.4.1
VERTICAL IRREGULARITY	3.4.2	1612.3.4.2	1607.3.4.2	1627.5.2	9.3.4.2
ANALYSIS PROCEDURES	3.5	1612.3.5	1607.3.5	1627.8	9.3.5
SEISMIC PERFORMANCE CATEGORY A	3.5.1	1612.3.5.1	1607.3.5.1		9.3.5.1
SEISMIC PERFORMANCE CATEGORIES B AND C	3.5.2	1612.3.5.2	1607.3.5.2		9.3.5.2
SEISMIC PERFORMANCE CATEGORIES D AND E	3.5.3	1612.3.5.3	1607.3.5.3		9.3.5.3

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 3 STRUCTURAL DESIGN REQUIREMENTS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
DESIGN, DETAILING REQUIREMENTS, AND STRUCTURAL COMPONENT LOAD	3.6	1612.3.6	1607.3.6	1631	9.3.6
SEISMIC PERFORMANCE CATEGORY A	3.6.1	1612.3.6.1	1607.3.6.1		9.3.6.1
Connections	3.6.1.1	1612.3.6.1.1	1607.3.6.1.1		9.3.6.1.1
Anchorage of Concrete or Masonry Walls	3.6.1.2	1612.3.6.1	1607.3.6.1.2	1631.2.8	9.3.6.1.2
Anchorage of Nonstructural Systems	3.6.1.3				
SEISMIC PERFORMANCE CATEGORY B	3.6.2	1612.3.6.2	1607.3.6.2		9.3.6.2
Component Load Effects	3.6.2.1		1607.3.6.2.1		9.3.6.2.1
Openings	3.6.2.2	1612.3.6.2.2	1607.3.6.2.2		9.3.6.2.2
Orthogonal Effects	3.6.2.3	1612.3.6.2.3	1607.3.6.2.3		9.3.6.2.3
Discontinuities in Vertical System	3.6.2.4	1612.3.6.2.4	1607.3.6.2.4		9.3.6.2.4

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 3 STRUCTURAL DESIGN REQUIREMENTS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
Nonredundant Systems	3.6.2.5	1612.3.6.2.5	1607.3.6.2.5		9.3.6.2.5
Collector Elements	3.6.2.6	1612.3.6.2.6	1607.3.6.2.6	1631.2.6	9.3.6.2.6
Diaphragms	3.6.2.7	1612.3.6.2.7	1607.3.6.2.7	1631.2.9	9.3.6.2.7
Bearing Walls	3.6.2.8	1612.3.6.2.8	1607.3.6.2.8		9.3.6.2.8
Inverted Pendulum-Type Structures	3.6.2.9	1612.3.6.2.9	1607.3.6.2.9		9.3.6.2.9
SEISMIC PERFORMANCE CATEGORY C	3.6.3	1612.3.6.3	1607.3.6.3		9.3.6.3
Plan Irregularity	3.6.3.1	1612.3.6.3.1	1607.3.6.3.1		9.3.6.3.1
SEISMIC PERFORMANCE CATEGORY D AND E	3.6.4	1612.3.6.4	1607.3.6.4		9.3.6.4
Orthogonal Load Effects	3.6.4.1	1612.3.6.4.1	1607.3.6.4.1		9.3.6.4.1
Plan or Vertical Irregularities	3.6.4.2	1612.3.6.4.2	1607.3.6.4.2		9.3.6.4.2
Vertical Seismic Forces	3.6.4.3	1612.3.6.4.3	1607.3.6.4.3	1628.10	9.3.6.4.3
COMBINATIONS OF LOAD EFFECTS					

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 3 STRUCTURAL DESIGN REQUIREMENTS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
COMBINATION OF LOAD EFFECTS	3.7	1616.0	1609		9.3.7

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 4 EQUIVALENT LATERAL FORCE PROCEDURE					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
GENERAL	4.1	1612.4	1607.4	1628.1	9.4.1
SEISMIC BASE SHEAR	4.2	1612.4.1	1607.4.1	1628.2.1	9.4.2
CALCULATIONS OF SEISMIC COEFFICIENT	4.2.1	1612.4.1.1	1607.4.1.1	1628.2.1	9.4.2.1
PERIOD DETERMINATION	4.2.2	1612.4.1.2	1607.4.1.2	1628.2.2	9.4.2.2
Approximate Fundamental Period for Concrete and Steel Moment Resisting Frame Buildings	4.2.2.1	1612.4.1.2.1	1607.4.1.2.1	1628.2.2	9.4.2.2.1
VERTICAL DISTRIBUTION OF SEISMIC FORCES	4.3	1612.4.2	1607.4.2	1628.4	9.4.3
HORIZONTAL SHEAR DISTRIBUTION	4.4	1612.4.3	1607.4.3	1628.5	9.4.4
TORSION	4.4.1	1612.4.3.1	1607.4.3.1	1628.6	9.4.4
OVERTURNING	4.5	1612.4.4	1607.4.4	1628.7	9.4.5
DRIFT DETERMINATION AND P-DELTA EFFECTS	4.6	1612.4.5	1607.4.5		9.4.6

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 4 EQUIVALENT LATERAL FORCE PROCEDURE					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
STORY DRIFT DETERMINATION	4.6.1	1612.4.5.1	1607.4.5.1	1628.8	9.4.6.1
P-DELTA EFFECTS	4.6.2	1612.4.5.2	1607.4.5.2	1628.9	9.4.6.2

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 5 MODAL ANALYSIS PROCEDURE					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
GENERAL	5.1	1612.5.1	1607.5.1		9.5.1
MODELING	5.2	1612.5.2	1607.5.2		9.5.2
MODES	5.3	1612.5.3	1607.5.3		9.5.3
PERIODS	5.4	1612.5.4	1607.5.4		9.5.4
MODAL BASE SHEAR	5.5	1612.5.5	1607.5.5		9.5.5
MODAL FORCES, DEFLECTIONS, AND DRIFTS	5.6	1612.5.6	1607.5.6		9.5.6
MODAL STORY SHEARS AND MOMENTS	5.7	1612.5.7	1607.5.7		9.5.7
DESIGN VALUES	5.8	1612.5.8	1607.5.8		9.5.8
HORIZONTAL SHEAR DISTRIBUTION	5.9	1612.5.9	1607.5.9		9.5.9
FOUNDATION OVERTURNING	5.10	1612.5.10	1607.5.10		9.5.10
P-DELTA EFFECTS	5.11	1612.5.11	1607.5.11		9.5.11

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 7 FOUNDATION DESIGN REQUIREMENTS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
GENERAL	7.1	1801.1			9.7.1
STRENGTH OF COMPONENTS AND FOUNDATIONS	7.2				9.7.3.1
STRUCTURAL MATERIALS	7.2.1				
SOIL CAPACITIES	7.2.2				9.7.3.2
SEISMIC PERFORMANCE CATEGORIES A AND B	7.3				9.7.2 & 9.7.3
SEISMIC PERFORMANCE CATEGORY C	7.4				9.7.4
INVESTIGATION	7.4.1			1804	9.7.4.1
POLE-TYPE STRUCTURES	7.4.2		1804.9.2	1806.7	9.7.4.2
FOUNDATION TIES	7.4.3	1816.11.2	1805.4.3	1807.2	9.7.4.3
SPECIAL PILE REQUIREMENTS	7.4.4	1816.11.1&1820.3	1805.10.2		9.7.4.4 & A9.7.4.4
Uncased Concrete Piles	7.4.4.1	1820.1.2.1	1809.1.4		A9.7.4.4.1
Metal-Cased Concrete Piles	7.4.4.2	1820.1.2.1 & 1820.5.4.1	1809.1.4		A9.7.4.4.2

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 7 - FOUNDATION DESIGN REQUIREMENTS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
Concrete-Filled Pipe	7.4.4.3	1819.3	1808.4.2		A9.7.4.4.3
Precast Concrete Piles	7.4.4.4	1821.1	1810.2.1 & 1809.1.4	1808.4.2 & 1809.5.2.2	A9.7.4.4.4
Precast-Prestressed Piles	7.4.4.5		1809.1.4	1808.5.2	A9.7.4.4.5
SEISMIC PERFORMANCE CATEGORIES D AND E	7.5				9.7.5
INVESTIGATION	7.5.1	1802.1.1	1804.9.1		9.7.5.1
FOUNDATION TIES	7.5.2	1802.2.1	1804.5.3		
SPECIAL PILE REQUIREMENTS	7.5.3	1816.6	1805.10.2	1809.5.1(3&4)	9.7.5.3 & A9.7.5.3
Uncased Concrete Piles	7.5.3.1	1820.1.2.1	1809.1.4	1809.5.2.2(3&4)	A9.7.5.3.1
Metal-Cased Concrete Piles	7.5.3.2	1820.1.2.1 & 1820.5.4.1	1809.1.4		A9.7.5.3.2
Precast Concrete Piles	7.5.3.3	1816.11.2	1810.2.1 & 1809.1.4		A9.7.5.3.3
Precast-Prestressed Piles	7.5.3.4	1821.3.6	1810.3.7	1809.5.2.3(3&4)	A9.7.5.3.4
Steel Piles	7.5.3.5	1818.3	1807.4		A9.7.5.3.5

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 8 ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS AND SYSTEMS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
GENERAL	8.1	1612.6	1607.6		9.8.1
COMPONENT FORCE APPLICATION	8.1.1	1612.6.1	1607.6.1		9.8.1.1
COMPONENT FORCE TRANSFER	8.1.2	1612.6.2	1607.6.2		9.8.1.2
ARCHITECTURAL COMPONENT DESIGN	8.2	1612.6.3	1607.6.3		9.8.2
GENERAL	8.2.1	1612.6	1607.6		9.8.2.1
FORCES	8.2.2	1612.6.3	1607.6.3		9.8.2.2
EXTERIOR WALL PANEL CONNECTIONS	8.2.3	1612.6.3.1	1607.6.3.1		9.8.2.3
ARCHITECTURAL COMPONENT DEFORMATION	8.2.4	1612.6.3.2	1607.6.3.2		9.8.2.4
OUT-OF-PLANE BENDING	8.2.5				9.8.2.5
CEILINGS	8.2.6	1612.6.3.3	1607.6.3.3		9.8.2.6

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 8 ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS AND SYSTEMS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
MECHANICAL AND ELECTRICAL COMPONENT DESIGN	8.3	1612.6.4	1607.6.4		9.8.3
GENERAL	8.3.1				9.8.3.1
FORCES	8.3.2	1612.6.4	1607.6.4		9.8.3.2
COMPONENT PERIOD	8.3.3	1612.6.4.1	1607.6.4.1		9.8.3.3
COMPONENT ATTACHMENT	8.3.4	1612.6.4.2	1607.6.4.2		9.8.3.4
COMPONENT CERTIFICATION	8.3.5	1612.6.4.3	1607.6.4.3		9.8.3.5
UTILITY AND SERVICE INTERFACES	8.3.6				9.8.3.6
Shutoff Devices	8.3.6.1				9.8.3.6.1
Utility Connections	8.3.6.2				9.8.3.6.2
SITE-SPECIFIC CONSIDERATIONS	8.3.7				9.8.3.7
ELEVATOR DESIGN REQUIREMENTS	8.4	1612.6.5	1607.6.5		9.8.4

Table A-1 Crosswalk Between Design Provisions					
1991 NEHRP Chapter 8 ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS AND SYSTEMS					
SECTION TITLE	**NEHRP**	**BOCA**	**SBCCI**	**ICBO**	**ASCE**
REFERENCE DOCUMENT	8.4.1				9.8.4.1
ELEVATORS AND HOISTWAY STRUCTURAL SYSTEM	8.4.2				9.8.4.2
ELEVATOR MACHINERY AND CONTROLLER ANCHORAGE(S)	8.4.3				9.8.4.3
SEISMIC CONTROLS	8.4.4				9.8.4.4
RETAINER PLATES	8.4.5				9.8.4.5
DEFLECTION CRITERIA	8.4.6				9.8.4.6

Table A-2 - Matrix Of Table Numbers

TABLE DESCRIPTION	NEHRP	BOCA	SBC	UBC	ASCE
Coefficient A_a & A_v	1.4.1.1	Fig. 1612.1.3(1) Fig. 1612.1.3(2)	Maps Fig. 1607.1.5 A+B	Fig. 16-2 & Table 16-I	9.4-1
Seismic Hazard Exposure Group	1.4.2	1612.1.5	1607.1.6	16-K	9.1.4.2
Seismic Performance Category	1.4.3	1612.1.7	1607.1.8	N/A	9.1-1
Site Coefficient	3.2	1612.3.1	1607.3.1	16-J	9.3-1
Structural Systems	3.3	1612.3.3	1607.3.3	16-N	9.3-2
Plan Structural Irregularity	3.4.1	1612.3.4	1607.3.4.1	16-M	9.3-3
Vertical Structural Irregularity	3.4.2	1612.3.4.2	1607.3.4.2	16-L	9.3-4
Analysis Procedures for SPC D & E	3.5.3	1612.3.5.3	1607.3.5.3	1627.8	9.3-5
Allowable Story Drifts	3.8	1612.3.7	1607.3.7	1628.8	9.3-6
Coefficient for Upper Limit on Calculated Period	4.2.2	1612.4.1.2	1607.4.1.2		9.4-1
Architectural (C_c) & (P)	8.2.2	1612.6.3	1607.6.3	16-O & 16-P	9.8-1
Mechanical & Electrical (C_c) & (P)	8.3.2a	1612.6.4(1)	1607.6.4a	16-O & 16-P	9.8-2
Attachment Amplification Factor	8.3.2b	1612.6.4(2)	1607.6.4b		9.8-3

This table provides a "crosswalk" of the equivalent table or section numbers in the several codes and standards.

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