
Northbrook, Illinois

A report to:

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

February 2001
ACKNOWLEDGEMENT

Project Participants

S.K. Ghosh Associates Inc.
  S.K. Ghosh
  Susan Dowty
  Madhu Khuntia
  Kihak Lee

Building and Fire Research Laboratory, NIST:
  H.S. Lew
  Stephen A. Cauffman
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1.0 EXECUTIVE SUMMARY

Executive Order 12699, *Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction*, requires that all new federally owned, leased, assisted, and other regulated buildings be designed and constructed in accordance with the appropriate seismic standards. The Interagency Committee on Seismic Safety in Construction (ICSSC) has recommended the use of building codes which are substantially equivalent to the 1997 *National Earthquake Hazards Reduction Program Provisions for the Development of Seismic Regulations for New Buildings* (NEHRP Provisions).

The objective of this study is to determine whether or not the seismic and material design provisions of the *Uniform Building Code* (UBC) 2000 edition are substantially equivalent to, or exceed, the 1997 NEHRP Provisions.


The seismic design provisions of the 1997 *Uniform Building Code* are based on Appendix C of the 1996 edition of the *Recommended Lateral Force Requirements* published by the Structural Engineers Association of California (SEAOC Blue Book). It also includes many of the features of the 1994 NEHRP Provisions. The earthquake regulations of the 1997 NEHRP Provisions are substantially different from the corresponding requirements of the 1994 Provisions. Partly as a result of this and partly because the 1997 UBC did not include some important features of the 1994 NEHRP Provisions, the seismic and material design requirements of the 1997 UBC were found to be not equivalent to those of the 1997 NEHRP Provisions.
2.0 INTRODUCTION

Executive Order 12699, *Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction*, requires that all new federally owned, leased, assisted, and other regulated buildings be designed and constructed in accordance with the appropriate seismic standards. The Interagency Committee on Seismic Safety in Construction (ICSSC) has recommended the use of building codes, which are substantially equivalent to the 1997 *National Earthquake Hazards Reduction Program Provisions for the Development of Seismic Regulations for New Buildings* (NEHRP Provisions).

The objective of this study is to determine whether or not the seismic and material design provisions of the *Uniform Building Code* (UBC) 1997 edition are substantially equivalent to, or exceed, the 1997 NEHRP Provisions.


Comparisons between the 1997 NEHRP Provisions and the UBC are made on the basis of seismic provisions, material design provisions, foundation design requirements, quality assurance provisions, and non-structural element design requirements. In the comparisons, the UBC is judged equivalent if its provisions are equivalent to, or more stringent than, the corresponding requirements in the 1997 Provisions. The UBC is judged not equivalent if the requirements of the 1997 NEHRP Provisions are more stringent than the requirements in the model code.

In certain instances NEHRP includes provisions that the UBC does not. When a model code or standard does not have specific provisions regarding criteria, elements or systems, the design is left to the discretion of the designer. Depending on the judgment of the designer, the design may or may not be equivalent to NEHRP. Therefore, when the UBC is silent on certain issues, equivalency may not be judged.

One item of overriding importance for the purposes of this comparison must be noted at the outset. In the *Uniform Building Code*, the seismic zone in which a structure is located determines permissible structural systems, including the level of detailing required for structural
members and joints that are part of the lateral-force-resisting system and for the structural components that are not. It also determines applicable limitations on height of a structural system and structural irregularity, the type of lateral analysis that must be performed as the basis of design, as well as nonstructural component requirements. Seismic zones are regions in which seismic ground motion, corresponding to a certain probability of occurrence, is within certain ranges. The United States is divided into Seismic Zones 0 through 4, with 0 indicating the weakest earthquake ground motion, and 4 indicating the strongest.

The 1997 NEHRP Provisions uses Seismic Design Categories (SDC) as the determinant of seismic design and detailing requirements. The SDC is a function of the location’s seismicity, building occupancy and soil type.

Although the 1997 USC “seismic zone” only considers the seismicity of a location (whereas the 1997 NEHRP “Seismic Design Category” takes into account the building occupancy and soil type as well as seismicity), an equivalency between “seismic zone” and “Seismic Design Category” was assumed for this comparison study. The following table identifies which seismic zones were assumed equivalent for Seismic Design Categories A-F:

<table>
<thead>
<tr>
<th>NEHRP SDC</th>
<th>Assumed Equivalent Seismic Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B</td>
<td>0, 1</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
</tr>
<tr>
<td>D, E, F</td>
<td>3, 4</td>
</tr>
</tbody>
</table>
3.0 1997 NEHRP PROVISIONS

3.1 Overview of NEHRP Provisions

The Federal Emergency Management Agency (FEMA) has contracted the Building Seismic Safety Council (BSSC) to develop the National Earthquake Hazards Reduction Program (NEHRP) Provisions for new buildings. One of the primary goals of the program is to reduce or mitigate losses from earthquakes. *The NEHRP Recommended Provisions for Seismic Regulations for New Buildings* are recommended provisions that have increasingly been adopted in recent times by model codes and standards. The first edition of the NEHRP Provisions was dated 1985. The document is updated on a 3- year cycle. The 1997 edition of the NEHRP provisions is the fourth update of the document.

The NEHRP Provisions present a strength-based approach to design that represents the state of knowledge of seismic design. The seismic design provisions incorporate current research and knowledge from previous earthquakes. Seismicity maps are used to assess the seismic hazard at a particular site. Forces and seismic design requirements are increased with increasing seismic hazard. In the 1997 edition of the NEHRP Provisions, the seismic design category (SDC) of a structure, which is based on occupancy as well as on soil-modified seismic risk at the site of a structure, determines the level of detailing and design requirements. The seismic design category is used to obtain higher levels of performance; however, it does not influence the force level which is increased for structures in higher occupancy categories through an importance factor. In the design base shear equation, a factor $R$ which accounts for system response and inelastic deformability, reduces the strength that would have been needed for elastic response to the design earthquake to a design level. Detailing requirements that are formulated to provide a commensurate amount of inelastic deformability are given in the materials chapters. The design base shear varies with $1/T$, where $T$ is the elastic fundamental period of the structure.

3.2 Overview of Major Changes from NEHRP 1994 to 1997

The earthquake regulations of the 1997 NEHRP Provisions are substantially different from the corresponding requirements of the 1994 Provisions. The biggest change is the completely new set of ground motion maps and resulting design ground motion parameters which are now $S_{DS}$ and $S_{D1}$, rather than the $C_a$ and $C_V$ of the 1994 Provisions and $A_a$ and $A_V$ of earlier Provisions. $S_{DS}$ and $S_{D1}$ are 5%-damped design spectral response accelerations at short periods and 1 sec. period, respectively. $S_{DS}$ and $S_{D1}$ are two-thirds of $S_{MS}$ and $S_{M1}$ which are soil-modified (Maximum Considered Earthquake) spectral response accelerations at 0.2 sec. and 1 sec. period, respectively. $S_{MS}$ and $S_{M1}$ are obtained by multiplying mapped MCE spectral response accelerations $S_5$ (at 0.2 sec. period) and $S_1$ (at 1 sec. period), respectively, by $F_a$, the acceleration-related soil factor and $F_v$, the velocity-related soil factor, respectively. The maximum considered earthquake is the 2500- year return period earthquake (2% probability of exceedance in 50 years) in most of the country, except that in coastal California, it is the largest (deterministic) earthquake that can be generated by the known seismic sources. The design earthquake of the 1997 NEHRP provisions is two-thirds of the MCE, whereas the design earthquake of the 1994
NEHRP Provisions has an average return period of 475 years (10% probability of exceedance in 50 years). The two-thirds is the reciprocal of 1.5 which is agreed to be the “seismic margin” built into structures designed by the 1994 and older editions of the NEHRP Provisions. In other words, a structure designed by the 1994 or older editions of the NEHRP Provisions is believed to have a low likelihood of collapse under an earthquake that is one and one-half times as large as the design earthquake of those documents. The redefinition of the design earthquake in the 1997 NEHRP Provisions is intended to provide a uniform level of safety across the country against collapse in the Maximum Considered Earthquake. This was not the case before because the MCE is only 50% larger than the design earthquake of the 1994 NEHRP Provisions in coastal California, while it can be four or five times as large as the design earthquake of the 1994 Provisions in the Eastern United States. \( A_a \) and \( A_v \) of the 1994 NEHRP Provisions indicated the effective peak acceleration and the effective peak velocity-related acceleration of the ground corresponding to the design earthquake of the 1994 Provisions on Type \( S_B \) soil or soft rock. The mapped MCE spectral response accelerations \( S_1 \) and \( S_2 \) of the 1997 NEHRP Provisions are also mapped on Type \( S_B \) soil. The soil classification and the associated site coefficients first introduced in the 1994 NEHRP Provisions have been retained unchanged in the 1997 Provisions.

The second most important difference between the 1994 and the 1997 editions of the NEHRP Provisions is the replacement of the Seismic Performance Category (SPC) with the Seismic Design Category (SDC). In the 1994 and older editions of the NEHRP Provisions, restrictions on building height and structural irregularity, choice of analysis procedures that form the basis of seismic design, as well as the level of detailing required for a structure were all governed by the Seismic Performance Category. The SPC was a function of occupancy (called Seismic Hazard Exposure Group in the 1994 and older NEHRP editions) and of the seismic risk at the site of the structure in the form of \( A_v \), the effective peak velocity-related acceleration coefficient. In the 1997 NEHRP Provisions, the level of detailing and the other restrictions are all governed by the Seismic Design Category, which combines occupancy (called Seismic Use Group in the 1997 NEHRP Provisions) with the soil-modified seismic risk at the site of the structure, in the form of the design spectral response accelerations \( S_{DS} \) and \( S_{D1} \). The 1997 NEHRP Provisions for the first time has made detailing as well as the other restrictions a function of the soil characteristics at the site of a structure. This is a major departure from current seismic design practice – a departure that has far-reaching financial and other consequences. The basis for categorizing structures into SDC E was also changed between 1994 and 1997 and a new SDC F was added. In 1994, Category E consisted of Group III structures (essential facilities) in regions anticipated to experience strong ground motion (\( A_v > 0.2 \)). In 1997, Category E consists of Seismic Use Group I and II structures (standard-occupancy structures and assembly buildings) located within a few kilometers of major active faults as indicated by the maximum considered earthquake spectral response maps (\( S_1 \geq 0.75g \)). Category F includes Seismic Use Group III structures (essential facilities) located within a few kilometers of major active faults. Most buildings assigned to Category E in the 1994 Provisions are assigned to Category D in the 1997 Provisions.

The third most important difference between the 1994 and 1997 editions of the NEHRP provisions is the introduction of the Importance Factor, \( I \). An I-factor was not included in ATC 3, the predecessor document to the NEHRP Provisions, or in any of the NEHRP Provisions through its 1994 edition. ATC 3 and NEHRP opted instead for tighter drift limits and higher levels of detailing for structures in higher occupancy categories. An Occupancy Importance
Factor – 1.5 and 1.25 for Seismic Use Group III or II structures, respectively – has been brought into the 1997 NEHRP Provisions, increasing the design force level for higher occupancy categories. This is in addition to the requirements of tighter drift limits and higher levels of detailing for higher occupancy categories.

One notable change from the 1994 to the 1997 NEHRP Provisions is the proliferation of structural systems in Table 5.2.2 of the latest edition. The reason is a policy decision made with respect to the 1997 Provisions. It was decided that each basic-seismic-force-resisting system defined in Table 5.2.2 would have its own unique set of detailing requirements and commensurate R- and C_{drt} values assigned to it. This eliminated having the same name, R- and C_{drt} values assigned to two completely different seismic-force-resisting-systems. A case in point illustrating this scenario is the bearing wall system with concrete shear walls. In the 1994 Provisions, the bearing wall system with concrete shear walls was assigned R- and C_{drt}-values of 4.5 and 4, respectively. These values did not change from the high to the low Seismic Performance Categories. In SPC D and E, the shear walls required special detailing, while in SPC A, B, and C, ordinary detailing was all that was needed. Thus, in effect, two different seismic force-resisting systems with different levels of inelastic deformability went under the same name and were assigned the same R- and C_{drt} values. Thus, four different types of concrete shear walls have been defined: ordinary plain concrete, detailed plain concrete, ordinary reinforced concrete, and special reinforced concrete. This obviously adds to the total number of structural systems defined in the table.

There is an associated change to Table 5.2.2 that should be noted as well. In the 1994 Provisions, overstrength was recognized for the design of a limited number of elements such as columns supporting discontinued lateral-force-resisting elements, and was approximated by the factor 2R/5. In the 1997 Provisions, a separate tabulated \( \Omega_0 \) factor replaces the arbitrary 2R/5 value. The \( \Omega_0 \) factors are intended to be approximate, upper-bound estimates of the probable overstrength inherent in the typical lateral-force-resisting systems of common structures.

Finally, the nonbuilding structures requirements which were in 1994 Section 2.6, appear as 1997 Chapter 14 and the requirements have been significantly expanded and modified to reflect the new design procedures for the 1997 Provisions. An appendix is included to provide the user with considerable extra guidance concerning nonbuilding structures for which no formal standards exist.
4.0 1997 UNIFORM BUILDING CODE

4.1 Overview of 1997 UBC

The Uniform Building Code (UBC) is published by the International Conference of Building Officials (ICBO), Whittier, California. ICBO is one of three model code groups in the country, the other two being the Building Officials and Code Administrators International (BOCA), Country Club Hills, Illinois, publishers of The BOCA National Building Code (BOCA/NBC), and the Southern Building Code Congress International (SBCCI), publishers of the Standard Building Code (SBC). The seismic design provisions of the UBC are, and have long been based on the Recommended Lateral Force Requirements of the Structural Engineers Association of California (referred to as the SEAOC Blue book). The seismic design requirements of the other two model codes, on the other hand, have in recent times been based on the NEHRP Provisions.

The Uniform Building Code, unlike the other two model codes, is a three-volume set, consisting of:

Vol. 1 – Administrative, Fire Safety and Field Inspection Provisions,

Vol. 2 – Structural Engineering Design Provisions,

Vol. 3 – Material, Testing and Installation Standards.

In 1994, the so-called common code format was introduced to the Uniform Building Code, making chapter numbering uniform in all three model codes (for instance, structural design requirements are in Chapter 16 in all three codes).

In 1997, the UBC switched in size from 6-1/2 in. x 9 in. pages to 8-1/2 in. x 11 in. pages.

More importantly, the 1997 UBC expanded the adoption of standards by reference, whereas prior codes typically adopted standards by incorporation. Three categories of standards are listed in Chapter 35, Vol. I:

UBC Standards – The Uniform Building Code (or UBC) standards referred to in various parts of the code and listed in Part II of Chapter 35 are declared to be part of the code.

Adopted Standards – The standards referred to in various parts of the code and listed in Part III of Chapter 35 are declared to be part of the code.

Recognized Standards - The standards listed in Part IV of Chapter 35 are recognized standards. Compliance with these recognized standards constitutes prima facie evidence of compliance with the standard of duty established for recognized standards. The standard of duty is that the design, construction and quality of materials for buildings and structures be reasonably safe for life, limb, health, property and public welfare.
4.2 Seismic Design Provisions of 1997 UBC

Changes in seismic design provisions from the 1994 to the 1997 UBC are many and far-reaching in their impact. Part of the reasons for these changes was to incorporate the following lessons learned from the 1994 Northridge and the 1995 Kobe earthquakes:

- Need to consider near-source effects
- Underestimation of damage to members of non-lateral-force-resisting systems
- Need for more redundancy in lateral-force-resisting systems
- Need for improved anchorage between concrete/masonry walls and horizontal diaphragms
- Need for reinforcement in continuous footings and stemwalls in conventional light-frame buildings
- Need for improved anchorage for in-plane shear (sill anchorage) in light wood-frame buildings

The primary reason for significant changes from the 1994 to the 1997 UBC, however, was the realization that the national trend in seismic design has been toward use of the NEHRP Provisions. SEAOC, the proponent of the majority of the code changes approved for the 1997 UBC seismic provisions, made the following strategic planning statement: “Because a unified national building code based on existing codes will be a reality by the year 2000, it is in the best interest of ICBO’s membership and user community to make the UBC and NEHRP Provisions as similar as possible in the 1997 UBC.” The 1997 UBC seismic changes were designed to provide a smooth transition from the 1994 UBC to the 2000 International Building Code, the seismic provisions of which were to be based on the 1997 NEHRP Provisions. This was done by incorporating many of the features of the 1994 NEHRP Provisions (the 1997 NEHRP Provisions were not available until later).

The following are the major changes from the 1994 to the 1997 edition of the Uniform Building Code:

1. Strength-level, rather than service-level earthquake design forces are given, which obviously involves changes in the design load combinations as well.

2. Earthquake effect considered in design includes the effect resulting from the vertical component of the earthquake ground motion.

3. A redundancy factor is incorporated into the design load combinations, which increases the design forces for less redundant structures.

4. An overstrength factor, $\Omega_0$, distinct from the response modification factor, $R$, is introduced, and is incorporated into special design load combinations (applicable, for instance, to axial forces in columns supporting discontinued shearwalls). The factors are listed for each structural system in Table 16-N.
5. There is an acceleration-dependent near-fault factor and a velocity-dependent near-fault factor introduced for Zone 4 structures located within 10 km (6.2 miles) and 15 km (9.3 miles), respectively, of known active faults, which increase the seismic design force for near-fault structures.

6. Soil classifications are expanded from a four-tier ($S_1$ through $S_4$) to a six-tier ($S_A$ through $S_F$) scheme. Instead of one site factor, there are an acceleration-dependent site factor and a velocity-dependent site factor. Both depend not only on the soil classification as before, but also on seismic risk at the location of the structure (as represented by the seismic zone factor, $Z$).

7. The seismic design force varies in inverse proportion to the fundamental period of the structure, $T$, rather than $T^{2/3}$.

8. Instead of one minimum on the design base shear, there are two minima. The second minimum is in consideration of large displacement pulses in near-fault ground motion, which were observed in the 1994 Northridge earthquake.

9. When certain structural elements are designated not to be part of the designated lateral-force-resisting system, they are required to retain their full gravity-load-carrying capacity as they deform together with the lateral-force-resisting system all the way up to the design earthquake intensity. This deformation compatibility requirement is revised in 1997 UBC in view of observations from the 1994 Northridge earthquake.

10. The limitations on inter-story seismic drift are updated.

11. The dynamic analysis provisions are expanded.

12. A simplified static lateral-forced procedure is introduced for the design of: (a) Buildings of any occupancy (including single-family dwellings) not more than three stories in height excluding basements, that use light-frame construction, and (b) Other buildings not more than two stories in height excluding basements.

13. Increased strength of anchorage is required for out-of-plane connections of concrete and masonry walls to flexible diaphragms.

14. Structural observation is required for structures in Seismic Zone 4 with near-source factor $N_a > 1.0$.

15. Nondestructive testing is required for welded fully restrained connections between primary members of ordinary moment frames of steel in Seismic Zones 3 and 4.

16. Minimum 5/8 in. diameter anchor bolts are required for wood foundation plates in Seismic Zone 4.

17. Horizontal reinforcement is required in continuous footings and stemwalls in Seismic Zones 3 and 4.
18. Detailing requirements for structural members that are not part of the lateral-force-resisting system are made significantly more stringent. This change may be looked upon as part of the revised deformation compatibility requirement mentioned above.

19. Significant new restrictions on welded and mechanical splices of reinforcing bars are introduced. In Seismic Zones 2, 3 and 4, within an anticipated plastic hinge region or within a joint: (a) welded splices on billet steel A615 or low-alloy A706 reinforcement shall not be allowed, and (b) only such mechanical connections shall be allowed as are able to develop in tension the lesser of 95 percent of the ultimate tensile strength or 160 percent of the specified yield strength of the spliced reinforcing bars.

20. The Zone 3 and 4 shearwall design provisions that departed from ACI 318 requirements and were first introduced in the 1994 UBC are refined and simplified in many ways.

21. In a very significant development, provisions for seismic design of precast concrete structures in Seismic Zones 3 and 4 are included for the very first time.

22. A number of design standards/specifications are adopted by reference in the steel chapter, thereby dramatically reducing the length of the chapter.

23. ASTM A913 Grade 50 and 65 steels are added to the list of structural steels permitted for lateral-force-resisting systems.

24. The emergency code change approved in response to fractures in beam-column connections of steel moment frames during the 1994 Northridge earthquake is retained in the 1997 UBC. “Connection configurations utilizing welds or high-strength bolts shall demonstrate, by approved cyclic test results or calculations, ability to sustain inelastic rotation and develop strength criteria...considering effect of steel overstrength and strain hardening.”

25. A number of design standards/specifications are adopted by reference in the wood chapter, thereby significantly reducing the length of the chapter.


27. Provisions concerning non-building structures are significantly enhanced.
5.0 COMPARISON OF 1997 UBC TO 1997 NEHRP

Detailed chapter-by-chapter and side-by-side comparisons of the 1997 NEHRP Provisions and the seismic and material design requirements of the 1997 UBC are provided in Table 1. These are summarized below, and some overall conclusions are drawn based on the comparisons.

5.1 Chapter 1: General Provisions

The UBC provisions concerning additions to existing buildings and alterations to existing buildings are somewhat less restrictive than those of the 1997 NEHRP Provisions. The occupancy importance factors of the UBC are less than those of the 1997 NEHRP Provisions for Seismic Use Group II and III buildings. The UBC is equivalent to or more restrictive than the NEHRP Provisions in all other areas covered by Chapter 1.

5.2 Chapter 2: Glossary and Notations

This chapter is considered equivalent between the 1997 UBC and the 1997 NEHRP Provisions.

5.3 Chapter 3: Quality Assurance

The 1997 NEHRP Provisions require that a quality assurance plan be submitted to the authority having jurisdiction, gives the details of that plan, and lays down contractor responsibilities for the same. These provisions are not part of the 1997 UBC, making it less stringent. The special inspection provisions can be or are slightly less stringent in the UBC for piers, piles, caissons, and for reinforcing steel. The 1997 NEHRP Provisions include special inspection provisions for structural wood, cold-formed steel framing, architectural components, and mechanical and electrical components, which are not part of the 1997 UBC, making it less stringent. The 1997 NEHRP Provisions have testing requirements for reinforcing and prestressing steel, structural concrete, structural masonry, and mechanical and electrical components that are not included in the 1997 UBC. This also makes the UBC less stringent.

5.4 Chapter 4: Ground Motion

The 1997 NEHRP Provisions require that all structures be assigned to a Seismic Design Category, based on their Seismic Use Group and the design spectral response acceleration coefficients, $S_{DS}$ and $S_{D1}$, which are soil-modified. The 1997 UBC simply requires that each site be assigned to a seismic zone. These are obviously not equivalent. The 1997 NEHRP Provisions also contain siting restrictions for structures assigned to Seismic Design Categories E and F, which are not in the 1997 UBC, making it less stringent.

5.5 Chapter 5: Structural Design Criteria
1. The wind and snow loads set forth in ASCE 7-95 and adopted by reference in the 1997 NEHRP provisions are more current and state-of-the-art than the 1997 UBC provisions. The UBC wind loads are based on fastest-mile wind speeds dating back to 1988, whereas the ASCE 7-95 wind loads are based on three-second gust wind speeds, which reflect current data. This makes the UBC non-equivalent.

2. One notable feature of the 1997 NEHRP Provisions is the proliferation of structural systems in Table 5.2.2. For example, in the 1994 Provisions, the bearing wall system with concrete shear walls was assigned R- and $C_d$- values of 4.5 and 4, respectively. These values did not change from the high to the low Seismic Performance Categories. In SPC D and E, the shear walls required special detailing, while in SPC A, B, and C, ordinary detailing was all that was needed. Thus, in effect, two different seismic-force-resisting systems with different levels of inelastic deformability went under the same name and were assigned the same R- and $C_d$- values. For the 1997 NEHRP Provisions it was decided that each basic seismic-force-resisting system defined in Table 5.2.2 would have its own unique set of detailing requirements and commensurate R- and $C_d$- values assigned to it. Thus, four different types of concrete shear walls have been defined: ordinary plain concrete, detailed plain concrete, ordinary reinforced concrete, and special reinforced concrete. This obviously adds to the total number of structural systems defined in the table. R- and $\Omega_0$- values for the same structural system are often different between Table 5.2.2 of the 1997 NEHRP Provisions and Table 16-N of the 1997 UBC. $C_d$, of course, is not used in the UBC. System limitations are based on Seismic Design Categories in NEHRP, and on Seismic Zones in the UBC. All of this makes the two documents non-equivalent.

3. UBC has no structure height and structural system limitations below Seismic Zone 3; the NEHRP Provisions contain such limitations for structures assigned to Seismic Design Categories B and C. NEHRP has shorter height limits in SDC E than in SDC D and even shorter height limits in SDC F. UBC has the same height limits in Zones 3 and 4. UBC is less restrictive in this regard.

4. With respect to plan and vertical irregularities, the UBC is slightly less stringent because it does not include the extreme torsional irregularity and the extreme soft story irregularity.

5. With respect to redundancy, the UBC is less stringent because: (a) it does not use variable floor areas along the height of the building, (b) it takes $\rho$ as the highest floor-level $\rho$-value over the lower two-thirds of the building height, while NEHRP considers the entire building height, and (c) for special moment frames in SDC E or F, $\rho$ is restricted to 1.1 by NEHRP, but only to 1.25 by the UBC.

6. UBC is at times somewhat less stringent in its treatment of structures with certain types of structural irregularities.

7. UBC is less stringent with respect to the consideration of vertical earthquake ground motion in special seismic load combinations.

8. NEHRP allows $T$ (rationally computed elastic fundamental period) to be a larger multiple of $T_a$ in lower seismic areas, but restricts it to a lower multiple of $T_a$ (approximate elastic fundamental period) in the highest seismic areas. This makes the UBC somewhat less stringent in high seismic areas.

9. UBC is less stringent with respect to the dynamic amplification of torsion in structures of SDC C, D, E, and F, where Type 1 torsional irregularity exists.
10. Disregard of minimum base shear given by Eq. (30-6) in drift computations makes the UBC less stringent with respect to drift control for tall buildings.
11. UBC is less stringent in its considerations of P-Delta effects.

5.6 Chapter 6: Architectural, Mechanical and Electrical Components Design Requirements

The UBC is less stringent with respect to:

1. Component anchorage,
2. Construction documents,
3. Design of architectural components for seismic relative displacements,
4. Out-of-plane bending of architectural components,
5. Design of suspended ceilings,
6. Design of access floors,
7. Design of partitions, and
8. Mechanical and electrical component design.

5.7 Chapter 7: Foundation Design Requirements

UBC foundation design requirements are related to Seismic Zones, while those of the NEHRP Provisions are related to Seismic Design Categories. There is a lack of equivalency here. The UBC is less stringent with respect to geotechnical investigation in Seismic Zone 2. The UBC is less stringent concerning pile to pile cap connections in buildings assigned to SDC C and higher. The UBC is also less stringent with respect to ties between spread footings founded on Site Class E and F soils.

5.8 Chapter 8: Steel Structure Design Requirements

The UBC references the same standards as the NEHRP Provisions; however, in two cases, the UBC referenced standard is an older edition. The major reference for seismic provisions is an older edition (1992, rather than 1997). Similarly, the specification adopted for design of cold-formed steel structural members is also an older edition (1991, rather than 1996). This makes the UBC non-equivalent. UBC steel design requirements are tied to Seismic Zones, while those of the NEHRP Provisions are tied to Seismic Design Categories. There is a lack of equivalency here as well. The UBC is less stringent with respect to light framed cold-formed steel wall systems in lower seismic zones. This is true of general wall provisions as well as of provisions concerning: (a) boundary members, (b) connections, (c) braced bay members, (d) diagonal braces, and (e) shear walls. The provisions concerning steel cables are equivalent, with the exception of a NEHRP modification to the referenced standard.

5.9 Chapter 9: Concrete Structural Design Requirements

Where prestressing tendons are to be permitted in flexural members, the NEHRP Provisions contain a requirement concerning anchorages for tendons that is not in the UBC, making it less stringent. NEHRP encourages steel failure rather than concrete failure to govern the strength of
anchors; this requirement is not in the UBC, making it less stringent. Design tensile strength of an anchor based on concrete failure is less conservative in the UBC than in the NEHRP Provisions. The classification of moment frames and shear walls is not the same in the NEHRP Provisions and the UBC. The NEHRP Provisions classify structural systems based on the level of detailing. The UBC simply indicates which provisions of ACI 318 Chapter 21 are applicable to various structural systems in various seismic zones. NEHRP also imposes detailing requirements on ordinary moment frames that are additional to those of ACI 318-95. These are not included in the 1997 UBC, making it less stringent. NEHRP requires all moment frames forming part of the seismic-force-resisting system of buildings assigned to SDC B and founded on Site Class E or F soils to be intermediate or special moment frames. The UBC contains no corresponding requirement, making it less stringent. NEHRP indicates which structural systems are permitted in the various Seismic Design Categories; structural systems of lower inelastic deformability are excluded in the higher Seismic Design Categories. The UBC simply indicates which provisions of ACI 318 Chapter 21 are applicable to various structural systems in various seismic zones. For columns supporting reactions from discontinuous stiff members such as walls, the UBC is less stringent with respect to detailing requirements as well as the consideration of vertical earthquake ground motion in special seismic load combinations.

5.10 Chapter 10: Steel & Concrete Design Requirements

These requirements do no exist in the UBC. Thus, equivalency cannot be judged.

5.11 Chapter 11: Masonry Structure Design Requirements

1. NEHRP adopts ACI 530-95 and ACI 530.1-95 by reference; the UBC does not, making the two documents non-equivalent.
2. UBC masonry design requirements are tied to Seismic Zones, while those of the NEHRP Provisions are tied to Seismic Design Categories. There is a lack of equivalency here.
3. The UBC is non-equivalent with respect to compliance with the specified \( f_m \).
4. The UBC has working stress design for masonry, while NEHRP does not. This makes the two documents non-uniform.
5. Empirical design is allowed for lateral-force-resisting systems in Seismic Zone 1 of the UBC, while it is not allowed for buildings assigned to NEHRP Seismic Design Category B, making the UBC less stringent.
6. The UBC maximum spacing of reinforcement in a Seismic Zone 3 & 4 shear wall is less restrictive than the NEHRP maximum spacing of reinforcement in a special reinforced masonry shear wall.
7. Where masonry is laid in stack bond in a building assigned to SDC D or higher, NEHRP specifies a maximum horizontal reinforcement spacing of 24 in. A similar spacing limitation does not exist in the UBC for stack bond masonry in Seismic Zones 3 & 4, making it less restrictive.
8. Concrete abutting structural masonry is required to be roughened to a full amplitude of 1/16 in. by the UBC in Seismic Zones 3, 4. The required amplitude is 1/8 in. in the NEHRP Provisions for buildings assigned to Seismic Design Category D and higher.
9. Reinforcement requirements for stack bond masonry are increased from SDC D to SDC E, F in the NEHRP provisions. UBC has the same reinforcement requirements across Zones 3 and 4, making it less stringent.

10. The UBC is less restrictive with respect to the size of reinforcement in reinforced masonry construction.

11. NEHRP prohibits bundling of reinforcing bars in masonry construction. UBC is silent on the topic.

12. The UBC does not contain the following NEHRP requirements: (a) the minimum grout thickness between reinforcing bars and masonry units shall be $\frac{1}{4}$ in. for fine grout and $\frac{1}{2}$ in. for coarse grout, (b) Longitudinal wires of joint reinforcement shall be fully embedded in mortar or grout with a minimum cover of $\frac{1}{2}$ in. when exposed to earth or weather and $\frac{3}{8}$ in. when not exposed to earth or weather, (c) wall ties, anchors and inserts, except anchor bolts not exposed to the weather or moisture, shall be protected from corrosion.

13. NEHRP prohibits the use of lap splices in plastic hinge zones. UBC contains no such prohibition.

14. The stress block assumed for masonry in compression in designs for flexure and axial loads is more liberal in the UBC than in the NEHRP Provisions.

15. NEHRP requires that the design shear strength, $\phi V_n$, shall exceed the shear corresponding to the development of 1.25 times the nominal flexural strength of the member, except that the nominal shear strength need not exceed 2.5 times $V_u$. The UBC does not contain a corresponding provision, making it less stringent.

16. NEHRP requires that the nominal moment strength at any section along a member shall not be less than one-half the higher moment strength provided at the two ends of the member in a special moment frame of masonry. In the UBC, the corresponding number is one-quarter, making it less restrictive.

17. NEHRP requires that the clear span of a wall frame beam be not less than four times its depth. In the UBC, the corresponding ratio is two, making it less restrictive.

18. Maximum vertical reinforcement in wall frame columns is more restrictive in NEHRP than in the UBC.

5.12 Chapter 12: Wood Structural Design Requirements

1. The UBC can be less restrictive with respect to the horizontal distribution of shear to lateral-force-resisting elements.

2. The UBC can be less restrictive with respect to detailing of shear wall and diaphragm boundary elements.

3. The UBC requires smaller plate washers than the NEHRP Provisions for shear wall anchorage; and these are only required in Seismic Zones 3 and 4.

4. The UBC panel sheathing size requirement for diaphragms and shear walls apply only in Seismic Zones 3 and 4, making the UBC less restrictive in this regard.

5. The UBC allows a 4:1 aspect ratio for both blocked and unblocked wood structural panel diaphragms, whereas the NEHRP limits the aspect ratio to 3:1 for such unblocked diaphragms, thus making the NEHRP Provisions more restrictive in this regard. Under certain conditions depending upon seismic zone, the UBC allows a higher aspect ratio for shear walls than the NEHRP Provisions.
6. The UBC allows the use of particleboard and fiberboard for shear walls, while the NEHRP Provisions do not allow such usage, making the UBC less restrictive in this regard.
7. For double diagonally sheathed lumber diaphragms, the allowable aspect ratio is less restrictive in the UBC.
8. The UBC is less restrictive as to structures for which conventional light frame construction is allowed.
9. For braced walls of particleboard in conventional light-frame construction, no attachment is specified in the UBC, whereas NEHRP does specify minimum attachment. Another difference is that the UBC requires 7 in. o/c fastener spacing for gypsum board sheathing whereas the NEHRP Provisions require the same size fasteners to be spaced at 4 in. o/c.
10. The UBC is not equivalent to NEHRP with respect to foundations supporting braced wall panels in conventional light-frame construction.
11. NEHRP requires structures assigned to Seismic Design Categories E and F to conform to all of the requirements for engineered construction and to the additional requirements of Section 12.8. The UBC does not contain any such restriction, making it less conservative.

5.13 Chapter 13: Seismically Isolated Structures Design Requirements

NEHRP requires all portions of a structure, including the structure above the isolation system, to be assigned a Seismic Use Group. The UBC specifies that the importance factor, I, for a seismic-isolated building be taken as 1.0 regardless of occupancy category. This makes the UBC non-equivalent.

5.14 Chapter 14: Nonbuilding Structure Design Requirements

The UBC is generally less stringent with respect to the design of steel storage racks.

5.15 Conclusions Regarding 1997 UBC

The seismic and material design requirements of the 1997 UBC were found to be not equivalent to those of the 1997 NEHRP Provisions in a number of important respects (as detailed above):

1. The 1997 NEHRP Provisions require all structures to be assigned to a Seismic Design Category, based on their Seismic Use Group or occupancy and the soil-modified seismic risk at the site of the structure. The 1997 UBC simply requires that each site be assigned to a Seismic Zone. The foundation, concrete, masonry, steel and wood design requirements of the UBC are tied to Seismic Zones, while those of the NEHRP Provisions are tied to Seismic Design Categories.
2. A policy decision was made with respect to the 1997 NEHRP Provisions. It was decided that each basic seismic-force-resisting system defined in Table 5.2.2 would have its own unique set of detailing requirements and commensurate R- and C\textsubscript{d}- values assigned to it. This eliminated having the same name, R- and C\textsubscript{d}- values assigned to two completely different seismic-force-resisting systems, as is the case with the 1997 UBC. This
obviously adds to the total number of structural systems formally recognized by the 1997 NEHRP Provisions. $R$- and $\Omega_o$-values for the same structural system are often different between Table 5.2.2 of the 1997 NEHRP provisions and Table 16-N of the 1997 UBC. $C_d$, of course, is not used in the UBC. System limitations are based on Seismic Design Categories in NEHRP, and on Seismic Zones in the UBC.

3. The occupancy importance factors of the UBC are less than those of the 1997 NEHRP Provisions for Seismic Use Group II and III buildings (high-occupancy buildings and essential facilities).

4. UBC has no structure height and structural system limitations below Seismic Zone 3; the NEHRP Provisions contain such limitations for structures assigned to Seismic Design Categories B and C. NEHRP has shorter height limits in SDC E than in SDC D and even shorter height limits in SDC F. UBC has the same height limits in Zones 3 and 4.

5. With respect to redundancy: (a) the UBC, unlike NEHRP, does not use variable floor areas along the height of the building, (b) the UBC takes $\rho$ as the highest floor-level $\rho$-value over the lower two-thirds of the building height, while NEHRP considers the entire building height, and (c) for special moment frames in SDC E or F, $\rho$ is restricted to 1.1 by NEHRP, but only to 1.25 by the UBC.

6. NEHRP restricts rationally computed elastic fundamental period ($T$) to a lower multiple of the approximate fundamental period ($T_a$) in regions of high seismicity.

7. UBC disregards the minimum base shear given by Eq. (30-6) in drift computations, thereby making drift control requirements less stringent for tall buildings.

8. The 1997 NEHRP Provisions require that a quality assurance plan be submitted to the authority having jurisdiction, gives the details of that plan, and lays down contractor responsibilities for the same. The UBC does not have such provisions. The special inspection and testing requirements of the NEHRP Provisions are also more onerous than those of the UBC.

9. The NEHRP Provisions are much more comprehensive and onerous with respect to design requirements for architectural, mechanical and electrical components.

10. The UBC is less stringent than NEHRP with respect to: (a) geotechnical investigation in Seismic Zone 2, (b) pile to pile cap connections in buildings assigned to SDC C and higher, and (c) ties between spread footings founded on Site Class E and F soils.

11. The UBC references the same steel standards as the NEHRP Provisions; however, in two cases, the UBC referenced standards are older editions.

12. The classification of concrete moment frames and shear walls is not the same in the NEHRP Provisions and the UBC. The NEHRP Provisions classify structural systems based on the level of detailing. The Provisions indicate which structural systems are permitted in the various Seismic Design Categories; structural systems of lower inelastic deformability are excluded in the higher SDC’s. The UBC simply indicates which provisions of ACI 318 Chapter 21 are applicable to various structural systems in various Seismic Zones.

13. NEHRP adopts ACI 530-95 and 530.1-95 by reference for masonry design and construction. The UBC does not.

14. The UBC has working stress design for masonry, while NEHRP does not.

15. Concerning wood structural design: (a) The UBC can be less restrictive with respect to the horizontal distribution of shear to lateral-force-resisting elements, (b) The UBC allows a 4:1 aspect ratio for both blocked and unblocked wood structural panel diaphragms, whereas the NEHRP limits the aspect ratio to 3:1 for such unblocked
diaphragms, (c) Under certain conditions depending upon Seismic Zone, the UBC allows a higher aspect ratio for shear walls than the NEHRP Provisions, (d) The UBC allows the use of particleboard and fiberboard for shear walls, while the NEHRP Provisions do not allow such usage, (e) The UBC is less restrictive as to structures for which conventional light frame construction is allowed.

16. The UBC is generally less stringent with respect to the design of steel storage racks.

In view of the above, it is concluded that the seismic and material design requirements of the 1997 UBC are not equivalent to those of the 1997 NEHRP Provisions.
6.0 CONCLUSIONS

In this report, the 1997 NEHRP Provisions are compared to the seismic and material design requirements of the *Uniform Building Code* 1997 edition.

The seismic design provisions of the 1997 *Uniform Building Code* are based on Appendix C of the 1996 edition of the *Recommended Lateral Force Requirements* published by the Structural Engineers Association of California (SEAOC Blue Book). It also includes many of the features of the 1994 NEHRP Provisions. The earthquake regulations of the 1997 NEHRP Provisions are substantially different from the corresponding requirements of the 1994 Provisions. Partly as a result of this and partly because the 1997 UBC did not include some important features of the 1994 NEHRP Provisions, the seismic and material design requirements of the 1997 UBC were found to be not equivalent to those of the 1997 NEHRP Provisions. Detailed chapter-by-chapter and side-by-side comparisons of the 1997 NEHRP Provisions and the seismic and material design requirements of the 1997 UBC are provided in this report, and form the basis of the conclusion just stated.
REFERENCES