UBC-IBC Structural

(1997-2000)

Comparison

&

Cross Reference

UBC-IBC Structural Comparison and Cross Reference
(1997-2000)

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Preface

In 1994, the common code format was introduced to the *Uniform Building Code* (UBC), preparing for the consolidation of the three model building codes (BOCA's *National Building Code*, ICBO's *Uniform Building Code* and SBCCI's *Standard Building Code*) into a single model building code. After years of drafting and over four public hearings, this consolidation has been realized in the publication of the *2000 International Building Code* (IBC).

Each existing model building code was considered as primary source documents for the IBC. As in any code development cycle, the current code forms the basis for the new edition. This is no different with the evolution from the 1997 UBC to the 2000 IBC. The purpose of this document is to provide an analysis comparing the 1997 UBC with the 2000 IBC.

The intent of this publication is to provide useful information to assist the code user in the transition from the structural provisions of the 1997 UBC to the 2000 IBC. The first part of this book provides a comparative analysis between the two codes. The second part is a cross reference directory.

Comparative Analysis

Similar to past "analyses of revision" published by ICBO, the comparative analysis is arranged in sequence based on the new edition. The 2000 IBC sections, tables and figures are listed sequentially for the structural provisions with an analysis of comparison to the 1997 UBC. This will provide a concise report that may be used to transition from the 1997 UBC to the 2000 IBC, facilitating in the adoption of the new code. This comparative analysis may also be used as a plan checking and field inspection aid to ensure a better understanding of the latest revisions to the building code.

If commentary on a particular section is not provided, a difference between codes may or may not exist. This document is not intended to identify every difference in the text or requirements. Analyses of the provisions is provided with details supplied on many sections, especially those reflecting a greater change.

Cross Reference Directory

While the common code formatting effort in 1994 generally aligned the format of the Uniform and International Codes, provisions are not necessarily aligned section by section. The cross reference directory is designed to assist the code user familiar with the structural portions of the 1997 UBC and transition them to the 2000 IBC.

The directory is divided into two parts. The first part, the 1997 UBC to 2000 IBC tables, assists code users in locating new 2000 IBC section numbers for similar provisions found in the 1997 UBC. The second part, the 2000 IBC to 1997 UBC tables, assists code users in locating source sections of the 1997 UBC for similar provisions found in the 2000 IBC.

Cross reference tables are arranged in sequence based on the first code. The 1997 UBC to 2000 IBC table sequentially lists sections, tables and figures from the 1997 UBC and their counterpart in the 2000 IBC. Similarly, the 2000 IBC to 1997 UBC table sequentially lists sections, tables and figures from the 2000 IBC and the corresponding location in the 1997 UBC.

Cross reference tables are intended to guide code users between the 1997 UBC and 2000 IBC. It does not necessarily indicate that the text or requirements of the cross referenced sections will be identical. Differences in the provisions between these two editions are discussed in the Comparative Analysis.

A reference indicating that a section is new or does not have a corresponding section does not necessarily mean that there are no applicable regulations in the cross referenced code. Such a reference only indicates that the section does not have a close match in the referenced code edition.

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Structural

Chapter 16 of the IBC Structural Design

Introduction

Chapter 16 of the 2000 *International Building Code* (IBC) is different in many significant ways from Chapter 16 of the 1997 *Uniform Building Code* (UBC). Chapter 16 of the IBC primarily addresses design requirements for the following types of loads: dead, live, wind, snow, rain, soil, flood and earthquake. The IBC Structural Subcommittee used the UBC, the other two model codes (References. 1, 20, ASCE 7 Standard *Minimum Design Loads for Buildings and Other Structures* (Reference 3) and the 1997 NEHRP Provisions (Reference 4) when determining what the basis for these loads should be in the IBC.

One significant difference between the IBC and the UBC Chapter 16 is that the IBC relies on adopting portions of ASCE 7 for wind, snow, rain and flood loads whereas the UBC includes these requirements in the code itself. Some benefits of this new approach are the following:

1. The length of the code is reduced.
2. Technical provisions which are adopted by reference are revised through the ASCE consensus process.
3. Code users having access to a copy of ASCE 7 can benefit from the useful accompanying commentary.

The wind and snow loads set forth in ASCE 7 and adopted by reference in the IBC are much more current and state-of-the-art than the 97 UBC provisions. The UBC wind loads are based on fastest mile wind speeds dating back to 1988, whereas the IBC wind loads are based on three-second gust wind speeds which reflect current data.

Another significant difference between the IBC and the UBC is in the seismic provisions. Formulation of the IBC seismic provisions generated considerable debate because the other two model codes are based on FEMA's NEHRP *Recommended Provisions for the Development of Seismic Regulations for New Buildings* (Reference 4), whereas the Uniform Building Code has been based on SEAOC's *Recommended Lateral Force Requirements* (commonly referred to as the "Blue Book," Reference 5). In 1996, the IBC Structural Subcommittee agreed in concept for the IBC to be based on the 1997 edition of the NEHRP Provisions which was still under development after the last edition of the UBC (1997) had been published. This allowed further coordination between the 1997 UBC and the 2000 IBC. A Code Resource Development Committee (CRDC), funded by FEMA, was formed under the direction of the Building Seismic Safety Council (BSSC) to develop seismic code provisions based on the 1997 edition of the NEHRP Provisions, for incorporation into the 2000 IBC. This effort was successful and the CRDC submittal was accepted by the IBC Structural Subcommittee for inclusion in the IBC.

1603 Construction Documents

This section details the items to be shown on construction documents. Most of it is not found in the 1997 UBC.

Construction documents are defined in IBC Section 202.3. The information required to be provided on construction documents is typically found to be useful if additions or alterations are made to a structure at a later date. The exception to IBC Section 1603.1 simplifies the structural design information required for buildings constructed in conformance with the conventional light-frame construction provisions of IBC Section 2308.

IBC Sections 1603.1.8 and 1603.2 through 1603.4 go beyond items to be shown on construction documents. IBC Section 1603.3, Live loads posted, is similar to 1997 UBC Section 1607.3.5. The requirements, however, are somewhat different.

1604 General Design Requirements

This section is comparable to, but not the same as, the 1997 UBC Section 1605—Design.

1604.1 General. Requires buildings and other structures and all portions thereof to be designed and constructed in accordance with certain methods is similar to UBC Section 1605.1, except that Empirical Design is not specifically mentioned in the UBC, and conventional construction is mentioned in an exception.

1604.2 Strength. Most of this section is reproduced from ASCE 7-98 and is not found, at least in the same form, in the 1997 UBC.

1604.3 Serviceability. The general statement is adopted with modification from ASCE 7-98. The detailed IBC Sections 1604.3.1 through 1604.3.6 are developed from and closely follow the requirements of the 1996 BOCA/NBC. The comparable 1997 UBC section is 1613 and UBC Table 16-D is the counterpart of IBC Table 1604.3. The IBC table is clearly more comprehensive.

ASCE 7-98 requires structural systems and members to be designed to provide adequate stiffness "to limit deflection, lateral drift, vibration, or any other deformations that adversely affect the intended use and performance of buildings and other structures." The IBC has chosen to restrict itself to deflections and lateral drift only, due to the following enforceability issues:

1. The code has no objectively defined a standard for structural vibration. Acceptable limits are frequently subjective and highly dependent on the specific requirements of occupants of a building. This information is not necessarily available to the building official.

2. It is impossible for the code official to anticipate everything that can "adversely affect the intended use and performance" of a building.

1604.4 Analysis. The first two paragraphs are not in the 1997 UBC. The third paragraph is a reproduction of UBC Section 1605.2 Rationality. The fourth paragraph is reproduced from Section 1605.2.1 Distribution of horizontal shear. The final paragraph is transcribed from UBC Section 1605.2.2 Stability against overturning.

1604.5 Importance Factors. This section and Table 1604.5 make a combined presentation of snow load, wind load and seismic load importance factors. The comparable UBC table is Table 16-K. However, important differences should be noted as follows:

1. UBC Table 16-K does not include snow load importance factors.
2. The occupancy categories are quite different in the two tables. The UBC occupancy categories 1 and 2; 3; and 4 and 5 are comparable to IBC occupancy categories III, II, and I, respectively. IBC occupancy category IV is not defined in the UBC; although in some respects it may be comparable to UBC occupancy category 5.
3. The UBC uses two seismic importance factors: IE for buildings and other structures, and Ip for portions thereof. The IBC uses the same seismic importance factor IE for structures as well as structural components. It uses an importance factor Ip, given in Section 1621 but not listed in Table 1604.5, for architectural, electrical and mechanical components only.
4. The UBC importance factor I is 1.25 for essential as well as hazardous facilities, whereas the importance factor for parts and portions, Ip, is 1.5 for these occupancies. Both factors are 1.0 for other occupancies. The IBC seismic importance factor IE is 1.5 for essential facilities (including hazardous facilities), 1.25 for assembly buildings and 1.0 for other occupancies.
5. For IBC Occupancy Category IV, low-hazard buildings, the wind importance factor IW is 0.87, a value adopted from ASCE 7-98 that is different from the value of 1.00 assigned to Occupancy Category 5 buildings (miscellaneous structures) in the UBC. In hurricane-prone regions with basic wind speeds V exceeding 100 mph, IW is changed from 0.87 to 0.77 through footnote b to IBC Table 1604.5.

1604.8 Anchorage. Basically the same as UBC Section 1605.2.3. There are important differences, however. The following post-Northridge UBC requirement, applicable in Seismic Zones 3 and 4, is placed not in this section, but in IBC Section 1620.2.1. "Diaphragm to wall anchorage using embedded straps shall have the straps attached to or hooked around the reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel." IBC Section 1620.2.1 is applicable in Seismic Design Categories C, D, E, and F. Also, IBC Section 1604.8.2 requires anchorage (between concrete and masonry walls and elements providing lateral support) to provide a positive direct connection capable of resisting a minimum horizontal force of 200 pounds per linear foot substituted for E. Section 1605.2.3 of the UBC refers to IBC Section 1611.4 which specifies a minimum horizontal force of 280 pounds per linear foot of wall, substituted for E.

1605 Load Combinations

1605.1 General. Introduces strength design or LRFD load combinations of Sections 1605.2, the ASD load combinations of Section 1605.3, and the special seismic load combinations of Section 1605.4.

1605.2 Load combinations using strength design or load and resistance factor design. The basic strength design load combinations of the 2000 IBC are adapted from those of the 1997 UBC, which in turn were adapted from the strength design load combinations of ASCE 7-95 (Reference 3). Between the Final Draft and the First Edition of the IBC, the strength design load combinations were made consistent with those of ASCE 7-98.

In ASCE 7-98, the wind load provisions which have been adopted into the 2000 IBC, wind directionality is explicitly accounted for in the calculation of the wind loads, while previously it was a component of the wind load factor. A new factor, K_d, has been introduced, which varies depending upon the type of structure. Thus it became necessary to increase the load factor for wind from 1.3 to 1.6.

Exception 1 to Section 1605.2.1 provides that in the design of reinforced concrete structures where the load combinations do not include seismic forces, the factored load combinations of ACI 318 Section 9.2 continue to be used, rather than the IBC load combinations. Since W in the ACI 318 load combinations predate explicit consideration of directionality effects, Exception 1 provides that for concrete structures designed using the design wind forces of ASCE 7-98, W shall be divided by the directionality factor K_d. For concrete structures designed using IBC Section 1609.6 (Simplified Provisions for Low Rise Buildings), W shall be divided by a directionality factor of 0.85.

Exception 1 is also the source of a hidden difference between the strength design load combinations of the 2000 IBC and those of the 1997 UBC. IBC Section 1908.1.2 requires the use of the strength design load combinations of ASCE 7-98, as adopted into IBC Section 1605.2, rather than the strength design load combinations of ACI 318-99, in the seismic design of reinforced concrete structures. This requirement is the same as in the 1997 UBC. However, the 1997 UBC requires the design loads given by the seismic strength design load combinations of ASCE 7-95 to be amplified by a factor of 1.1. The Working, the First and the Final Drafts of the IBC contained a corresponding requirement that the reduced strength reduction factors of Appendix C of ACI 318, rather than those of Chapter 9, be used in conjunction with the seismic strength design load combinations of ASCE 7-95. This requirement has been deleted from the 2000 IBC for reasons outlined in References 6 and 7.

1605.3 Load combinations using allowable stress design. The IBC contains two alternative sets of ASD load combinations originally adopted from the 1997 UBC. The 1997 UBC in turn adapted the "basic" ASD load combinations from ASCE 7-95 and the "alternate basic" ASD load combinations from the 1994 UBC. The two sets of ASD load combinations of the 2000 IBC and the 1997 UBC are based on different philosophies and were not specifically intended to be equivalent to each other.

Between the Final Draft and the First Edition of the IBC, the basic ASD load combinations were made consistent with those of ASCE 7-98.

For the basic ASD load combinations, the IBC specifically states that increases in allowable stresses "specified in the appropriate materials section of this code or referenced standard" shall not be used with the basic ASD load combinations, except that a duration of load increase shall be permitted in accordance with Chapter 23. On the other hand, when using the alternate basic load combinations that include wind or seismic loads, allowable stresses are permitted to be increased or load combinations reduced, "where permitted by the material section of this code or referenced standard." The 1997 UBC is very specific in this regard. UBC Section 2316.2 permits the load duration factor to be used with the basic load combinations. When using the alternate basic load combinations, the one-third increase in allowable stresses is not permitted to be used concurrently with the load duration factor.

1605.4 Special seismic load combinations. IBC Section 1620.1.6 requires the collector elements of diaphragms and IBC Section 1620.1.9 requires elements supporting discontinuous walls or frames to be designed by the special seismic load combinations of IBC Section 1605.4. When the definition of maximum earthquake effect, E_m, is incorporated from IBC Section 1617.1.2, Formulas 16-19 and 16-20 become:

$$(1.2 + 0.2S_{DS})D + f_1L + \Omega_0 Q_E \qquad (16\text{-}19)$$

and

$$(0.9 - 0.2S_{DS})D + \Omega_0 Q_E \qquad (16\text{-}20)$$

where Ω_0 is the system overstrength factor given in Table 1617.6 and varies between 2 and 3.

UBC Sections 1630.8.2.1 and 1633.2.6 require elements supporting discontinuous systems and collector elements of diaphragms to be designed by the special load combinations of UBC Section 1612.4. Although this is also in the IBC, the definition of E_m in the 1997 UBC is quite different from that in the IBC. In UBC Section 1630.1.1, E_m is defined as being equal to $\Omega_0 E_h$. Thus, the special load combinations of Section 1612.4 become:

$$1.2D + f_1L + \Omega_0 E_h \qquad (12\text{-}17)$$

$$0.9D \pm \Omega_0 E_h \qquad (12\text{-}18)$$

The E_h of the 1997 UBC and the Q_E of the 2000 IBC represent the effects of horizontal seismic forces and are identical terms. The significant difference between the UBC and the IBC special load combinations is that there is no consideration of vertical earthquake ground motion in the UBC combinations.

1605.5 Heliports and helistops. These provisions are adopted, with significant modifications, from Section 1611.10 of the 1997 UBC. The following are the differences between the IBC and the UBC, specifically with respect to items 1 through 3 of IBC Section 1605.5.

1. The UBC does not include the snow load, S, in Item 1.
2. The UBC requires consideration of a single concentrated impact load, L, covering 1 sq. ft. ($0.093m^2$) of area, having a magnitude equal to 0.75 times the fully loaded weight of the helicopter if it is

equipped with hydraulic-type shock absorbers, or 1.5 times the fully loaded weight of the helicopter if it is equipped with a rigid or skid-type landing gear.

3. The UBC specifically indicates that the required live load may be reduced, as permitted by that code.

1606 Dead Loads

This section is adopted without modification from ASCE 7-98. The 1997 UBC addresses dead loads under Section 1606. UBC Section 1606.2, Partition Loads represents an important difference between the IBC, ASCE 7 (Reference 3), and the BOCA/NBC (Reference 1) which treat those loads as live loads (see IBC Section 1607.5), and the UBC and the SBC (Reference 2) which treat partition loads as dead loads.

1607 Live Loads

Most of the IBC provisions concerning live loads are adopted from ASCE 7-98, with relatively few drawn from the 1996 BOCA/NBC (Reference 1) or the 1997 UBC. The provisions, in general, are quite different from those of the 1997 UBC.

1607.3 Uniform live loads, and 1607.4 Concentrated loads. Both sections refer to Table 1607.1, which is the core of Section 1607. The IBC Structural Subcommittee opted to use the ASCE 7 live load table rather than attempt to compare, revise and merge the three model code tables. The 1997 UBC Table 16-A plays the same role and is comparable to IBC Table 1607.1; however, it is quite different in scope and substance. A partial comparison of IBC Table 1607.1 and UBC Table 16-A is presented in Table 1 of this document. A counterpart to UBC Table 16-B is not found in the IBC. Some of the items in UBC Table 16-B are included in IBC Table 1607.1, and some other items are covered in Section 1607.7 of the IBC.

Table 1: Partial Comparison of IBC Table 1607.1 and UBC Table 16-A.

Occupancy/Use	IBC	UBC
Exterior balconies	100	60*
Exterior decks	**	40*
Balcony for 1 & 2 family dwellings ≤ 100 sq. ft.	60	
Office Buildings		
Lobbies/1st floor corridors	100	100
Offices	50	50
Corridors above 1st floor	80	100
Residential (1 & 2 family dwellings)		40
Uninhabitable attics		10
without storage	10	
with storage	20	
Habitable attics and sleeping areas	30	40
All other areas	40	40

* For residential occupancies including private dwellings, apartments and hotel guest rooms.

** Same as occupancy served.

1607.5 Partition loads. The minimum requirement of 20 psf for partition load is adopted from Section 1606.2 of the 1997 UBC which treats partition loads as part of dead loads, as noted earlier.

1607.6 Truck and bus garages. Identical to Section 1606.2.1 of the BOCA/NBC. Table 1607.6 reproduces the lane loading requirements from AASHTO's Bridge Specifications (Reference 8).

The 1997 UBC does not specifically provide for truck and bus garage loads; it addresses vehicular loads only under Section 1607.3.3.

1607.7 Loads on handrails, guards, grab bars and vehicle barriers. The entire section is essentially adopted from ASCE 7-98, except that Section 1607.7.1.3 Stress increase is not part of ASCE 7-98.

1607.7.1 Handrails and guards. The IBC adds a second exception that is not found in ASCE 7-98, which allows a lesser design load in certain occupancies. These are the same occupancies listed in IBC Section 1003.2.12.2, which are allowed to have larger openings in the guard. The UBC has no load requirement unless a guard is in a location serving 50 occupants. Therefore the second exception, while stricter than the UBC, is reasonable.

The Commentary to ASCE 7-98 points out that loads expected to occur on handrail and guardrail systems are highly dependent on the use and occupancy of the protected area. It further points out that when extreme loads can be anticipated, such as long straight runs of guardrail systems against which crowds can surge, appropriate increases in loading need to be considered.

1607.7.2 Grab Bars. It is noted in the Commentary to ASCE 7-98 that when grab bars are provided for use by persons with physical disabilities, the design is governed by CABO/ANSI A117.1 Accessible and Usable Buildings and Facilities (Reference 9).

1607.8 Impact loads. These provisions are also adopted from ASCE 7-98 and are not part of the UBC.

1607.9 Reduction in live loads. The live load reduction provisions of IBC Section 1607.9.1 are based on ASCE 7-98, while the alternate floor live load reduction provisions of IBC Section 1607.9.2 are those of Section 1607.5 of the 1997 UBC. The alternate floor live load reduction provisions of UBC Section 1607.6, on the other hand, are from ASCE 7-95.

The alternate floor live load reduction provisions of Section 1607.9.2 or the reduction of live load provisions of Section 1607.5 of the 1997 UBC, based on tributary floor area, represent the "original" live load reduction provisions in older editions of ANSI A58.1 (predecessor to ASCE 7) and in all three model codes.

The concept of, and method for, determining member live load reductions as a function of a loaded member's influence area, AI, was first introduced into ANSI A58.1 in 1982 (Reference 3). The influence area-based live load reduction formula of ANSI A58.1-82, ASCE 7-88, ASCE 7-93 and ASCE 7-95 is used in the alternate floor live load reduction provisions of UBC Section 1607.6.

In ASCE 7-98, the influence area has now been defined as a function of the tributary area, AT. The factor KLL is the ratio of the influence area (AI) of a member to its tributary area (AT), and is used to better define the influence area of a member as a function of its tributary area.

Although ASCE 7-95, UBC 1997 (alternate floor live load reduction) and the Final Draft of the 2000 IBC contained the same live load reduction formula based on an influence area, there was an important variation from document to document. The ASCE 7 standard has historically taken a position of prohibiting live load reduction for one-way slabs, supposedly due to a lack of redundancy inherent in the design and construction of one-way slabs. The 1997 UBC, however, defines AI as being equal to the product of the span and the full flange width for a precast T- beam, thereby expressly permitting live load reduction for certain one-way slab systems. According to the Final Draft of the IBC, for members supporting cantilevered construction, for a one-way slab and a precast T-beam, the influence area is the same as the tributary area. ASCE 7-98 provisions, as adopted into the 2000 IBC, do not really allow live load reduction for one-way slabs. It is important to note that live load reduction for one-way slabs is permitted under the alternate floor live load reduction provisions of Section 1607.9.2.

1607.11 Roof loads. The lead paragraph is adopted from the 1996 BOCA/NBC, and IBC Section 1607.11.1 from the 1997 UBC. Sections 1607.11.2.1 and 1607.11.2.2 of the IBC are reproduced from ASCE 7-98. IBC Sections 1607.11.2.3 through 1607.11.2.5 are adopted from the 1996 BOCA/NBC. Roof live loads are treated under Section 1607.4 of the 1997 UBC. The provisions are quite different from those of the IBC.

1607.12 Crane loads. The provisions of this section are adopted from ASCE 7-98. The 1997 UBC does not contain comparable provisions.

1607.13 Interior walls and partitions. These provisions are adopted from the 1996 BOCA/NBC. The 1997 UBC does not include comparable requirements.

1608 Snow Loads

The snow load provisions are adopted from ASCE 7-98, with only a few modifications.

UBC Section 1614 on snow loads leaves the determination of snow loads to the building official. IBC Section 1608 addresses the determination of snow loads completely differently. The alternative snow load design procedure of Appendix Chapter 16 Division I of the 1997 UBC is much closer to IBC Section 1608. The Appendix Chapter 16 Division I of the 1997 UBC is almost a direct reproduction of Chapter 7 of ASCE 7-93, which was the latest edition of the ASCE 7 standard available at the time the 1997 UBC was finalized. There were significant changes in Chapter 7 from ASCE 7-93 to ASCE 7-95 and then a few additional less substantive changes from ASCE 7-95 to ASCE 7-98. In view of these changes, even Appendix Chapter 16 Division I of the 1997 UBC is significantly different from Section 1608 of the 2000 IBC.

1609 Wind Loads

The basis for the 1997 UBC wind provisions dates back to ANSI A58.1-1988. The basis for the 2000 IBC wind provisions is ASCE 7-98. Section 6 of ASCE 7-98 is to be used for the determination of wind loads, with three exceptions allowed for building structures.

IBC Section 1609.6 contains a simplified procedure for determining wind loads that is consistent with the provisions of ASCE 7-98. The procedure contains limitations on its own applicability.

Subject to the limitations given in Section 1609.1.1.1, the SBCCI SSTD 10-99 *Standard for Hurricane Resistant Residential Construction* (Reference 10) may be used for applicable Group R2 and R3 buildings. SSTD 10 is a standard that was originally developed in 1990 to provide prescriptive provisions for wind resistant design and construction of one- and two-story residential buildings of wood-framed construction, and one-, two- and three-story residential buildings of concrete and masonry construction sited in high wind regions. See also the analysis to Section 1714.5 for window and door requirements.

Subject to the limitations of Section 1609.1.1.1, the AFPA Wood Frame Construction Manual for One- and Two-Family Dwellings, High Wind Edition, (Reference 11) may be used. This manual gives prescriptive requirements for the design and construction of one- and two-family dwellings of wood-framed construction.

The most significant change between the wind provisions of the 1997 UBC, based on ASCE 7-88, and those of 2000 IBC, based on ASCE 7-98, is the use of 3-second gust wind speed, rather than the fastest-mile wind speed, as the basis of the basic wind speed used in design. This change necessitated revision of terrain and height factors, gust-effect factors and pressure coefficients for components and cladding. Additional significant changes and additions are as follows:

1. Provisions have been added for wind speed-up over isolated hills and escarpments (topographical effect).
2. New provisions have been added for full and partial loading on main wind-force resisting systems of buildings with a mean roof height greater than 60 ft (torsional loading effect).
3. An alternative procedure has been added for determining external loads on main wind-force resisting systems of low-rise buildings.
4. Internal pressure coefficients have been increased for partially enclosed buildings located in hurricane-prone regions.
5. Pressure coefficients for components and cladding have been added for hipped, stepped, multispan and sawtooth roofs.
6. Velocity pressure exposure coefficients have been revised to be compatible with 3-second gust wind speeds.
7. Gust effect factor procedures have been unified for flexible and non-flexible buildings and structures. A new procedure has been provided for calculating a gust effect factor.
8. Pressures for components and cladding of buildings with a mean roof height less than 60 ft have been reduced for buildings sited in Exposure B.
9. Wind directionality is now explicitly accounted for in the calculation of the wind loads; it is no longer just a component of the wind load factor. A new factor, K_d, has been introduced, which varies depending upon the type of structure.

1610 Soil Lateral Load

This section reproduces part of Chapter 5, Soil and Hydrostatic Pressure and Flood Loads of ASCE 7-98. IBC Table 1610.1 giving soil lateral loads, however, is different from the corresponding ASCE 7-98 Table 5-1. The values set forth in the IBC are closer to (although not exactly the same all the way as) the corresponding values used in the BOCA/NBC (Reference 1) and the SBC (Reference 2). The issue of variance with the national standard was debated by the IBC Structural Subcommittee who at the Final Public Hearing reaffirmed their decision to use values that have been used in other model codes.

The 1997 UBC does not address soil lateral load except under Section 1611.2 Other Loads. That section simply states in very general terms that “Buildings and other structures and portions thereof shall be designed to resist all loads due to…lateral soil pressure, H,…”

1610.2 Retaining walls. Both codes require retaining walls to be designed to resist sliding by at least 1.5 times the lateral force and overturning by at least 1.5 times the overturning moment using allowable stress design loads.

1611 Rain Loads

This section reproduces Chapter 8 Rain Loads of ASCE 7-98, except that Section 8.2 on Roof Drainage is not included. Each portion of a roof is required to be designed to sustain the load of rainwater that will accumulate on it if the primary drainage system for that portion is blocked, plus the uniform load caused by water that rises above the inlet of the secondary drainage system at its design flow.

Rain loads are not addressed in the 1997 UBC or in the other two model codes. The IBC requirement to design roofs for rain load represents a change in design practice.

1612 Flood Loads

Through the Final Draft of the 2000 IBC, Section 1612.1 simply stated that the design and construction of structural systems and components which resisted flood loads had to conform to the requirements of Section 5.3 of ASCE 7-98. This changed significantly between the Final Draft and the First Edition of the IBC.

The American Society of Civil Engineers (ASCE) and the Federal Emergency Management Agency (FEMA) proposed modifications to the IBC Final Draft, which were accepted for the First Edition, for the purpose of ensuring that the building sciences provisions of the IBC and the manner in which they are administered is consistent with the National Flood Insurance Program (NFIP). Much of this is accomplished through adoption by reference of ASCE 24-98 Flood Resistant Design and Construction Standard. The provisions of ASCE 24-98 represents the culmination of over four years of work by dozens of experts in flood resistant design and construction from all facets of the land development and regulations community. FEMA was in full support of this effort and provided both financial and technical assistance in this endeavor.

The 1997 UBC has a Section 1611.9 on Flood-resistant Construction. It simply refers the user to Appendix Chapter 31 Division I (UBC Volume 1) for flood resistant construction requirements, where specifically adopted.

1613–1623 Seismic Design Requirements—Overview

The earthquake regulations of Sections 1613 through 1623, based on the 1997 NEHRP Provisions, are substantially different from the corresponding provisions of the 1997 UBC. For further information regarding the application of the IBC seismic provisions, one should refer to the 1997 NEHRP Provisions Part 2—Commentary. The Provisions, the Commentary and an accompanying set of 32 maps are available free of charge from the FEMA Publication Distribution facility at 1-800-480-2520.

The biggest change from the 1997 UBC to the 2000 IBC is in the design ground motion parameters which are now S_{DS} and S_{D1}, rather than Z. S_{DS} and S_{D1} are five-percent-damped design spectral response accelerations at short periods and 1-second period respectively. S_{DS} determines the upper-bound design base shear (the "flat-top" of the design spectrum) used in seismic design (see Fig. 1615.1.4 and Section 1617.4). S_{D1} defines the descending branch or the period-dependent part of the design spectrum (see Fig. 1615.1.4 and Section 1617.4). The seismic zone map of the UBC has been replaced by contour maps giving two quantities from which S_{DS} and S_{D1} are derived. The mapped quantities are the maximum considered earthquake spectral response accelerations S_S (at short periods) and S_1 (at 1-second period).

The maximum considered earthquake (MCE) is the 2500-year return period earthquake (two-percent 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 IBC is two-thirds of the MCE, whereas the design earthquake of the 1997 UBC has an approximate return period of 475 years (ten-percent 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 UBC or older editions of the NEHRP provisions. In other words a structure designed by the UBC or older editions of the NEHRP provisions is believed to have a low likelihood of collapse from 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 IBC 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 percent larger than the design earthquake of the UBC in coastal California, while it can be four or five times as large as the design earthquake of the UBC in the Eastern United States. In the 1997 UBC Z indicates effective peak ground acceleration (more exactly, the larger of effective peak acceleration or effective peak velocity-related acceleration) expected within a seismic zone corresponding to the design earthquake of the UBC on Type S_B soil or soft rock. The mapped MCE spectral response accelerations S_S and S_1 of the 2000 IBC are also mapped on Type S_B soil.

S_{DS} and S_{D1} are two-thirds of S_{MS} and S_{M1} which are the soil modified MCE spectral response accelerations at short period and 1-second period, respectively. S_{MS} is obtained by multiplying the mapped MCE spectral response acceleration S_S (at short periods) by F_a, the acceleration-related soil factor. S_{M1} is similarly obtained by multiplying the mapped MCE spectral response acceleration S_1 (at 1-second period) by F_V, the velocity-related soil factor. F_a and F_v are analogous to C_a/Z and C_v/Z of the 1997 UBC, respectively.

Because the 2000 IBC and the 1997 UBC have both adopted the soil classification and the associated site coefficients first introduced in the 1994 NEHRP Provisions, a correlation of ground motion parameters between the two codes is possible. If S_{DS} of the 2000 IBC is equal to 2.5 C_a and S_{D1} of the 2000 IBC is equal to C_v for a particular location, then the soil-modified seismicity for that site has not changed from the 1997 UBC to the 2000 IBC. Table 2 shows a comparison of soil-modified seismicity (for Site Class D) by the 1997 UBC and the 2000 IBC for a number of locations.

Table 2: Comparison of Soil-Modified Seismicity by the 1997 UBC and the 2000 IBC for Site Class D

	UBC			IBC	
Site	**Zone**	**$2.5C_a$**	**C_v**	**S_{DS}**	**S_{D1}**
West Los Angeles[1]	4	1.3	0.64	1.37	0.54
Downtown San Francisco (4th & Market)	4	1	0.45	1	0.43
U.C. Berkley Memorial Stadium[2]	4	1.5	0.8	1.33	0.62
Denver	1	0.2	0.08	0.17	0.04
Sacramento	3	0.75	0.3	0.4	0.17
St. Paul	0	0	0	0.07	0.01
Seattle	3	0.75	0.3	1	0.4
Portland	3	0.75	0.3	0.8	0.26
Houston	0	0	0	0.07	0.03

1. On Type B Newport-Inglewood Fault
2. On Type A Hayward Fault

The 1997 edition of the UBC for the first time introduced two near-source factors: acceleration-related N_a and velocity-related N_v, the purpose of which is to increase the soil-modified ground motion parameters C_a and C_v when there are active faults capable of generating large-magnitude earthquakes within 15 km or 9 miles of a Seismic Zone 4 site. These factors became necessary in view of the artificial truncation of Z-values to 0.4 in UBC Seismic Zone 4. These near-source factors are not found in the 2000 IBC because the artificial truncation of ground motion is not a feature of that code. Both S_S and S_1 attain high values in the vicinity of seismic sources that are judged capable of generating large earthquakes.

The 2000 IBC maps for S_S and S_1 are based on USGS probabilistic maps. Both the probabilistic and the MCE Ground Motion maps are on the USGS web site at http://geohazards.cr.usgs.gov/eq. The address http://geohazards.cr.usgs.gov/eq/html/nehrp.shtml will take the user directly to the NEHRP maps.

Two CDs are also available. One is for the USGS probabilistic maps and one for the NEHRP design maps. The design CD and a Users Manual was prepared by USGS in cooperation with BSSC and FEMA. Along with the map values, the user can also view a design spectrum for a site specified by latitude-longitude or ZIP code. Soil factors, other than the default value, may be included in the calculations using NEHRP site coefficients or as specified by the designer. Additionally, all 32 maps of the NEHRP map package, the IBC maps, and the IRC map are included on the CD.

One difference really stands out when the seismic design provisions of the 2000 IBC are compared with those of the 1997 UBC. In the UBC, 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 particular structure are all governed by the seismic zone in which a structure is located. In the 2000 IBC, all are governed by the seismic design category which combines the occupancy (seismic use group) with the soil modified seismic risk at the site of the structure.

The 1997 NEHRP Provisions, the basis for the 2000 IBC seismic provisions, for the first time made the detailing as well as the other restrictions dependent on the soil characteristics at the site of a structure. This is a major departure from current seismic design practice - a departure that has significant design implications. Table 3 shows a comparison of 1997 UBC seismic zones and seismic design categories of the 2000 IBC for a number of locations across the country.

Table 3: Comparison of 1997 UBC Seismic Zones and Seismic Design Categories of the 2000 IBC

Location	UBC	IBC				
	Seismic	Site Class				
	Zone	A	B	C	D	E
West Los Angeles	4	E	E	E	E	*
San Francisco	4	D	D	D	D	*
Berkley	4	E	E	E	E	*
Denver	1	A	B	B	B	C
Sacramento	3	C	C	D	D	D
St. Paul	0	A	A	A	A	B
Seattle	3	D	D	D	D	*
Portland	3	D	D	D	D	*
Houston	0	A	A	A	B	C
Washington D.C.	1	A	A	A	B	C
Chicago	0	A	A	A	B	C
Baltimore	1	A	A	A	B	C
Boston	2A	B	B	B	C	D
New York	2A	B	B	B	C	D
Cincinnati	1	A	A	B	C	D
Philadelphia	2A	B	B	B	C	C
Richmond	1	A	B	B	B	C
Birmingham	1	B	B	C	C	D
Atlanta	2A	A	B	B	C	D
Orlando	0	A	A	A	B	B
Little Rock	1	B	B	C	D	D
New Orleans	0	A	A	A	B	B
Nashville	1	B	B	C	D	D
Charlotte	2A	B	B	C	D	D
Charleston	2A	D	D	D	D	D

* Site-specific geotechnical information and dynamic site response analysis required.

Finally, the IBC Section 1622 on nonbuilding structures seismic design requirements, based on the 1997 NEHRP Provisions, is much more extensive and detailed than the corresponding 1997 UBC Section 1634 on nonbuilding structures. IBC Section 1622 represents a major expansion of the guidance available in the building codes concerning the seismic design of nonbuilding structures.

1613 Earthquake Loads Definitions

This section is comparable to UBC Section 1627—Definitions; however, the terms defined and the definitions are not necessarily the same. Also, in the IBC some of the terms relating to earthquake provisions have been defined in Section 1602.

The 1997 UBC contains a separate Section 1628 on symbols and notations used in the earthquake design provisions. The 2000 IBC defines symbols and notations as they occur in the text. The IBC Structural Subcommittee thought it was more user-friendly to have symbols and notations defined following the formula in which they are used, rather than requiring the reader to refer back to the beginning of a chapter.

1614 Earthquake Loads—General

After having stated that every structure and portion thereof shall as a minimum be designed and constructed to resist the effects of earthquake motions and assigned a Seismic Design Category (SDC) in accordance with Section 1616.3, the IBC proceeds to permit a number of important exemptions:

1. Structures in Seismic Design Category A need only comply with Section 1616.4 (minimum lateral force design and complete load path).
2. Detached Group R-3 (one- and two-family) dwellings in Seismic Design Categories A, B, and C are exempt from all seismic design requirements.
3. The seismic force resisting system of wood frame buildings that conform to the provisions of Section 2308 (conventional light frame construction) need not be analyzed as required by Section 1616.1.
4. Agricultural storage structures intended only for incidental human occupancy are exempt from all seismic design requirements.
5. Structures located where $S_S \leq 0.15g$ and $S_1 \leq 0.04g$ need only comply with Section 1616.4.
6. Structures located where $S_{DS} \leq 0.167g$ and $S_{D1} \leq 0.067g$ need only comply with Section 1616.4.

Since $S_{DS} = (2/3)\ F_a S_S$ and $S_{D1} = (2/3)\ F_v S_1$ (Section 1615.1.3), Item 6 can be rewritten as follows:

> Structures where $S_S \leq 0.25g/F_a$ and $S_1 \leq 0.1g/F_v$ need only comply with Section 1616.4.

Thus, for F_a and F_v values exceeding 1.5, Exemption 5 supersedes Exemption 6. Item 6 provides additional exemptions at stiffer soil sites and/or high seismicity areas to those provided by Item 5.

The 1997 UBC Section 1626.2, Minimum Seismic Design, basically paraphrases the first paragraph of IBC Section 1614. The only exemption from seismic design requirements in the UBC is found in Section

1629.1, Basis for Design. The last sentence of that section reads: "One- and two-family dwellings in Seismic Zone 1 need not conform to the provisions of this section." UBC Section 2320, Conventional Light-Frame Construction Design Provisions, however, provides other implicit exemptions for structures that qualify under that section.

1614.1.1 Addition to existing buildings. Design and construction requirements that apply to a new structure also apply to an addition that is structurally independent from an existing structure.

An addition that is not structurally independent from an existing structure must be designed and constructed such that the entire structure conforms to the seismic force resistance requirements for new structures unless the two conditions given in this section are met.

The 1997 UBC addresses additions under Section 3403, Volume 1 with performance-based language.

1614.2 Change of occupancy. As long as a change of occupancy does not result in a higher Seismic Use Group (SUG) classification, there is no additional requirement. However, when a structure gets reclassified into a higher SUG as the result of a change in occupancy, the structure must conform to the seismic requirements for a new structure.

An important exception to the above requirement is provided. Specific detailing requirements applicable to a new structure need not be met if an equivalent level of performance and seismic safety contemplated for a new structure can be demonstrated.

1614.3 Alterations. Compliance with Sections 1613 through 1622 can be waived for an existing structure being altered only if the four given conditions are met.

The UBC addresses alterations under Section 3403, Volume 1.

1614.5 Seismic and wind. Substantially the same as UBC Section 1626.3, Seismic and Wind Design. A structure and components thereof must be designed to resist the effects of wind as well as earthquakes, assumed not to occur simultaneously. If a structure is in UBC Seismic Zones 2, 3, or 4, or in an IBC Seismic Design Category higher than B, the special seismic detailing requirements of the materials chapters must be complied with, irrespective of how high the wind effects may be in comparison to the earthquake effects.

1615 Earthquake Loads—Site Ground Motion

Two procedures are provided for the determination of ground motion accelerations, represented by response spectra and coefficients derived from these spectra: the general procedure of Section 1615.1 or the site-specific procedure of Section 1615.2. The site-specific procedure is required to be used for structures on Site Class F (see Section 1615.1.1)

1615.1 General procedure for determining maximum considered earthquake and design spectral response accelerations. The mapped maximum considered earthquake spectral response acceleration at short periods (S_S) and at 1-second period (S_1) for a particular site are to be determined from Figures 1615(1) through 1615(10). Where a site is between contours, straight line interpolation or the value of the higher contour may be used. Figure 1615 is adapted from the Maximum Considered Earthquake Ground Motion Maps 1 through 24 of the 1997 NEHRP Provisions (Reference 4). See Commentary Appendix A to the 1997 NEHRP Provisions.

The seismic zone map of the 1997 UBC dates back to the 1988 edition of the *Uniform Building Code.* In drawing the zone boundaries, both acceleration and velocity-related maps were consulted, and, if they disagreed, the one indicating the higher zone prevailed. The design base shear equation was modified so that the values of Z would correspond to the estimated values of effective peak acceleration.

Given the wide range in return periods for maximum-magnitude earthquakes in different parts of the United States (100 years in parts of California to 100,000 years or more in several other locations), the 1997 NEHRP Provisions focused on defining maximum considered earthquake ground motions for use in design. These ground motions may be determined in different manners depending on the seismicity of an individual region; however, they are uniformly defined as "the maximum level of earthquake ground shaking that is considered as reasonable to design buildings to resist." This definition facilitates the development of a design approach that provides approximately uniform protection against collapse throughout the United States.

The NEHRP 1997 seismic design provisions are based on the assessment that if a building experiences a level of ground motion 1.5 times the design level of the 1994 and prior NEHRP Provisions, the building should have a low likelihood of collapse. Although, quantification of this margin is dependent on the type of structure, detailing requirements, etc. The 1.5 factor was felt to be a conservative judgment.

Given that the maximum earthquake for many seismic faults in coastal California is fairly well known, a decision was made to develop a procedure that would use the best estimate of ground motion from maximum magnitude earthquakes on seismic faults with higher probabilities of occurrence. For the purpose of the 1997 NEHRP Provisions, these earthquakes are defined as "deterministic earthquakes." Following this approach and recognizing the inherent margin of 1.5 contained in the NEHRP Provisions, it was determined that the level of seismic safety achieved in coastal California would be approximately equivalent to that associated with a 2 to 5 percent probability of exceedance in 50 years in areas outside of coastal California. Accordingly, the ground motion corresponding to a 2 percent probability of exceedance in 50 years was selected as the maximum considered earthquake ground motion for use in design where the deterministic earthquake approach discussed above is not used.

1615.1.1 Site class definitions. The site class definitions of Table 1615.1.1 date back to the 1994 NEHRP Provisions (Reference 4) in which extensive modifications were made to the consideration of site effects. The 1994 NEHRP classification was adopted and incorporated into Table 16-J of the 1997 UBC. Table 1615.1.1 of the IBC is identical to Table 16-J of the 1997 UBC, except that a footnote has been incorporated into the table itself.

1615.1.2 Site coefficients and adjusted maximum considered earthquake spectral response acceleration parameters. Table 1615.1.2(1) indicates how the mapped spectral response acceleration at short periods for site class B (S_S) is to be modified for other site classes for the purposes of seismic design. Table 1615.1.2(1) accomplishes the same task for the mapped spectral response acceleration at 1-second period for site class B (S_1). The coefficients F_a and F_v of the IBC are analogous to C_a/Z and C_v/Z, respectively, of the 1997 UBC (Tables 16-Q, 16-R). The UBC Seismic Zone 4 values include the near-source factors N_a and N_v that are not part of the 2000 IBC. The factors are determined by the closest distance from a site to known seismic sources that are capable of generating large-magnitude earthquakes.

It should be noted that the 2000 IBC requires site-specific geotechnical investigation and dynamic site response analysis for Soil Profile Type E in areas having $S_S \geq 1.25$g or $S_1 \geq 0.5$g. The 1997 UBC does not require such investigation or analyses for Soil Profile Type E in Seismic Zone 4.

The soil-modified mapped (MCE) spectral acceleration at short periods, F_aS_S, is denoted by S_{MS}. Similarly, the soil-modified mapped MCE spectral acceleration at 1-second period, F_vS_s, is denoted by S_{M1}.

1615.1.3 Design spectral response acceleration. Five-percent-damped design spectral response accelerations at short periods, S_{DS}, and at 1-second period, S_{D1}, are equal to (⅔) S_{MS} and (⅔) S_{M1}, respectively. In other words, the design ground motion is $1/1.5$ or ⅔ times the soil- modified maximum considered earthquake ground motion. This is in recognition of the inherent margin contained in the NEHRP Provisions that would make collapse unlikely under 1.5 times the design-level ground motion.

1615.1.4 General procedure response spectrum. Provides a general method for obtaining a five-percent-damped response spectrum from the site design acceleration response parameters S_{DS} and S_{D1}. This spectrum is based on that proposed by Newmark and Hall (Reference 13), and consists of a series of three curves representing in the short period range, a region of constant spectral response acceleration; in the long period range, a region of constant spectral response velocity; and in the very long period range, a region of constant spectral response displacement. Response acceleration at any period in the short period range is equal to the design spectral response accelera - tion at short periods, S_{DS}:

$$S_a = S_{DS}$$

The spectral response acceleration at any point in the constant velocity range can be obtained from the relationship:

$$S_a = S_{D1}/T$$

The constant displacement domain of the response spectrum is not included in the generalized response spectrum because relatively few structures have a period long enough to fall into this range.

The "ramp" building up to the "flat top" of the design spectrum is defined by specifying (1) that the spectral response acceleration at zero period is equal to 40% of the spectral response acceleration corresponding to the "flat top", SDS, and (2) that the period T_0 at which the "ramp" ends is 20% of the period, T_s, at which the constant acceleration and the constant velocity portions of the spectra meet. That period,

$$T_s=S_{D1}/S_{DS}$$

is solely a function of the seismicity and the soil characteristics at the site of the structure. It also serves as the dividing line between short- and long-period structures.

The general procedure design response spectrum of IBC Section 1615.1.4 becomes identical to the design response spectrum of Fig. 16-3 and Section 1631.2 (1) of the 1997 UBC if the following conversion is made:

$$S_{DS}=2.5C_a$$
$$S_{D1}=C_v$$

1615.1.5 Site classifications for seismic design. The definitions of average soil properties of IBC Section 1615.1.5 and the "Steps for Classifying a Site" of IBC Section 1615.1.5.1 first appeared in the 1994 NEHRP Provisions. The material was adopted virtually unmodified into UBC Section 1636 – Site Categorization Procedure.

1615.2 Site-specific procedure for determining ground motion accelerations. Gives rules governing site-specific procedures for determining the maximum considered earthquake ground motion response spectrum, site-specific design ground motion and design spectral response coefficients. The subject is treated under UBC Section 1631.2 (2). The IBC rules, adopted without modification from the 1997 NEHRP Provisions, are more specific and elaborate.

1616 Earthquake Loads—Criteria Selection

This section, comparable to UBC Section 1629—Criteria Selection, in its generally applicable portion, requires each structure to be assigned to a seismic design category which is not used in the UBC. This item is discussed further under IBC Section 1616.6.3.

1616.1 Structural design criteria. This section is comparable to UBC Section 1629.1, Basis for Design. Although contents are not necessarily the same, both sets of criteria address adequate strength, stiffness, and energy dissipation capacity to withstand the design earthquake ground motions within the prescribed deformation limits.

1616.2 Seismic use groups and occupancy importance factors. The IBC defines occupancy categories in Table 1604.5 and seismic use groups in this section. The 1997 UBC defines occupancy categories in Section 1629.2 and Table 16-K. The three are correlated in Table 4:

Table 4: IBC Occupancy Categories and Seismic Use Groups versus UBC Occupancy Categories

2000 IBC Occupancy Category	2000 IBC Seismic Category	1997 UBC Occupancy Category	General Description
I	I	4	Standard-occupancy building
II	II	3	Assembly building
III	III	1, 2	Essential or hazardous facility
IV	I	5	Low-hazard facility

Section 1616.2.4 of the IBC discusses assignment of seismic use group to structures occupied for two or more occupancies.

The IBC assigns seismic importance factors, I_E, to the various seismic use groups in Table 1604.5. The 1997 UBC assigns seismic importance factors to the various occupancy categories in Table 16-K. See analysis to Section 1604.5 for further discussion on importance factors.

1616.3 Determination of seismic design category. The IBC uses Seismic Design Categories (SDC) to determine permissible structural systems, limitations on height and irregularity, the type of lateral force analysis that must be performed, the level of detailing for structural members and joints that are part of the lateral-force-resisting system and for the components that are not. The 1997 UBC, as in the prior editions of the Code, utilizes the Seismic Zone (Section 1629.4.1, Figure 16-2, Table 16-I) in which a structure is located for all these purposes. The Seismic Design Category is a function of occupancy (called Seismic Use Group in the IBC and the 1997 NEHRP Provisions) and of *soil-modified* seismic risk at the site of the structure in the form of the design spectral response acceleration at short periods, S_{DS}, and the design spectral response acceleration at 1-second period, S_{D1}. For a structure, the Seismic Design Category needs to be determined twice—first as a function of S_{DS} by Table 1616.3-1 and a second time as a function of S_{D1} by 1616.3-2; the more severe category governs. For the purposes of detailing as well as the other restrictions, the UBC Seismic Zones and the corresponding IBC Seismic Design Categories shown in Table 5 may be considered to be approximately equivalent:

Table 5: Approximate Equivalency between UBC Seismic Zones and IBC Seismic Design Categories

1997 UBC Seismic Zone	0,1	2A, 2B	3, 4
2000 IBC Seismic Design Category	A, B	C	D, E, F

1616.4 Design requirements for Seismic Design Category A. Seismic Design Category A structures are those in all occupancy categories located where $S_{DS} < 0.167g$ and $S_{D1} < 0.067g$. The IBC has conveniently placed all of the requirements for Seismic Design Category A structures in Section 1616.4. Seismic Design Category A structures are required to be provided with a complete lateral-force-resisting system designed to resist a minimum lateral force given in IBC Section 1616.4.1, which is simply 1 percent of the weight of the structure. No corresponding provision exists in the 1997 UBC. Section 1616.4.2 Connections requires all parts of a structure between separation joints to be interconnected and requires connections to be capable of transmitting the seismic force induced by the parts being connected. The 1997 UBC has a similar, but not identical, provision in Section 1633.2.5 Ties and Continuity. IBC Section 1616.4.3 requires a minimum of anchorage between concrete and masonry walls and elements providing lateral support as per IBC Section 1604.8.2 which is similar to, but not the same, as UBC Section 1605.2.3.

It should be noted that UBC Section 1629.1 exempts one- and two-family dwellings in Seismic Zone 1 from seismic design requirements.

1616.5 Building configuration. This section, which is very similar to UBC Section 1629.5, classifies structures as regular or irregular, creates six categories of plan irregularities and six categories of vertical irregularities, and prescribes requirements (by citing section numbers) that each irregular structure must conform with. Tables 1616.5.1 (Plan Structural Irregularities) and 1616.5.2 (Vertical Structural Irregularities) correspond to UBC Tables 16-M and 16-L respectively. There are some detailed differences between the two sets of tables. For instance, the IBC has created additional categories of extreme torsional irregularity and "Stiffness Irregularity—Extreme Soft Story."

1616.6 Analysis procedures. This section and UBC Section 1629.8 address the selection of analysis procedure as the basis of design. The requirements are laid out differently—by the Seismic Design Category in the IBC and by the analysis procedure in the UBC. Also, the IBC criteria are in terms of Seismic Use Group, Seismic Design Category and the ground motion parameter S_{D1}, while the UBC requirements are in terms of Seismic Zones and Occupancy Categories. In spite of these obvious differences, the requirements are similar.

1617 Earthquake Loads—Minimum Design Lateral Force and Related Effects

1617.1 Seismic Load Effect E and E_m. Defines the earthquake effect E (Table 6) as the sum of two parts: (1) the effect of the horizontal earthquake ground motion, which is the same as the effect of the design earthquake forces, Q_E, amplified by the redundancy factor, ρ, and (2) the effect of the vertical earthquake ground motion, which is to be taken equal to $0.2S_{DS}D$. The 1997 UBC defines the earthquake effect E as the sum of the same two parts in UBC Section 1630.1.1, where Formula (30-1) has E_h in place of Q_E and E_v in place of $0.2S_{DS}D$. The E_v of the 1997 UBC is equal to $0.5C_aID$. This term is similar, but not equivalent to, the $0.2S_{DS}D$ of the IBC, as has been discussed in References 6 and 7. The 1997 UBC consideration of vertical earthquake effect is more severe than that of the 2000 IBC, in the sense of potentially resulting in more conservative designs.

1617.1.2 Maximum seismic load effect, E_m. Defines the maximum earthquake effect E_m (Table 6) also as the sum of two parts: (1) the effect of the horizontal earthquake ground motion, which is the same as the effect of the design earthquake forces, Q_E, amplified by the overstrength factor, W_0 (Table 1617.6), and (2) the effect of the vertical earthquake ground motion, to be taken equal to $0.2S_{DS}D$. The 1997 UBC defines the maximum earthquake effect E_m by Formula (30-2) in Section 1630.1.1. The UBC definition does not include the effect of the vertical earthquake ground motion. This makes the 1997 UBC less conservative when it comes to the special load combinations and other applications that require the use of E_m.

Table 6: Earthquake Effect *E* and Maximum Earthquake Effect E_m of 2000 IBC and 1997 UBC

2000 IBC	1997 UBC
$E = \rho Q_E \pm 0.2S_{DS}D$	$E = \rho E_h + E_V$ $= \rho E_h \pm 0.5C_aID$
$E_m = \Omega_0 Q_E \pm 0.2S_{DS}D$	$E_m = \Omega_0 E_h$

1617.2 Redundancy. A redundancy factor, ρ, was first defined in the 1997 UBC Section 1630.1.1 and then adopted into the 1997 NEHRP Provisions and the IBC. The 1997 UBC specifically states: when calculating drift, or when a structure is located in Seismic Zone 0, 1, or 2, ρ shall be taken equal to 1. Likewise, per IBC Section 1617.2.1, for structures assigned to Seismic Design Category A, B, or C, the value of the redundancy coefficient ρ is 1.0. Per IBC Section 1617.4.6.1, when calculating drift, the redundancy coefficient *r* shall be taken as 1.0.

There are two differences between the 1997 UBC formulation and the IBC formulation of the ρ factor. The UBC uses a fixed area A_B, the ground floor area of the structure. The IBC uses a variable area A_i which is defined as the floor area of the diaphragm level immediately above the story. Secondly, the UBC defines r_{max} as the largest of the element-to-story shear ratios, r_i, occurring over the lower two-thirds of the building height. The IBC defines ρ as the largest of the values of ρ_i over the entire height of a structure. In both formulations, ρ is for a given direction of an entire building. Also, in both formulations, ρ shall not be taken less than 1.0 and need not be greater than 1.5.

There is a third difference between the 1997 UBC and the 2000 IBC concerning redundancy. The UBC requires that for special moment-resisting frames, except when used in dual systems, ρ shall not exceed 1.25. The IBC requires that for structures with seismic force resisting systems comprised solely of special moment frames, the said system shall be configured such that the value of ρ does not exceed 1.25 for structures assigned to Seismic Design Category D and does not exceed 1.1 for structures assigned to Seismic Design Category E or F which will result in more frames being required in structures designed using the IBC.

1617.3 Deflection and drift limits. (and Section 1617.4.6.1 Story drift determination) Both the IBC and the 1997 UBC place limits on interstory drift. In the 1997 UBC (Section 1630.9) it is based on Δ_M, the Maximum Inelastic Response Displacement; in the IBC, it is based on δ_x which is equivalent to Δ_M. In the 1997 UBC, Δ_M is obtained by applying a multiplier of 0.7R on Δ_S, the determination of which is precisely specified in UBC Section 1630.9.1. In the IBC, δ_x is obtained by applying a multiplier of Cd/I, rather than $0.7R$, on δ_{xe} which is analogous to Δ_S. δ_{xe} is determined the same way as Δ_S, using the specified earthquake forces of the IBC. However, the specific modeling guidelines of UBC Section 1630.1.2 are not included in the IBC. Secondly, the IBC requires torsional deflections to be included only for structures assigned to Seismic Design Category C, D, E or F that have plan irregularity Type 1a or 1b (torsional or extreme torsional irregularity).

The 2000 IBC limits on story drift, as given in Table 1617.3, depend upon the seismic use group, and become tighter for higher use groups. The limits also depend on the type of structure. In the 1997 UBC, the drift limits are not dependent on occupancy, which is already effectively considered because Δ_S is higher for structures in higher occupancy categories with an I of 1.25 assigned to them, and because the multiplier of $0.7R$ is independent of I. The UBC drift limits (Section 1630.10) are dependent only on the period of the structure, drift limits being tighter for structures having periods greater than or equal to 0.7 seconds, although some exceptions to general rules are made.

It is not easy to make a generalized statement as to whether the IBC or the UBC drift limitations are the more conservative. For standard-occupancy buildings, the requirements are likely to be quite comparable for periods not exceeding 0.7 seconds; the UBC requirement is more stringent for periods exceeding 0.7 seconds For assembly buildings, the IBC requirement is likely to be more stringent for periods less than or equal to 0.7 seconds; the requirements are likely to be comparable for longer-period buildings. For essential facilities, the IBC requirements are likely to be more stringent irrespective of structural period.

1617.4 Equivalent lateral force procedure for seismic design of buildings. The design base shear formulas of the IBC and the 1997 UBC are written in the same format in Table 7:

Table 7: Design Base Shear Formulas of the 2000 IBC and the 1997 UBC

2000 IBC	1997 UBC
$V/W = S_{D1}/(R/I_E)T$	$V/W = Cv/(R/I)T$
$\leq S_{DS}/(R/I_E)$	$\leq 2.5C_a/(R/I)$
$\geq 0.044 S_{DS} I_E$	$> 0.11 C_a I$
$> 0.5S_1/(R/I_E)$, Seismic Design Category E, F or where $S_1 \geq 0.6$g	$> 0.8ZN_v/(R/I)$, Seismic Zone 4

It can be seen that the two sets of expressions are equivalent if the following conversions are made: $S_{D1} = C_v$, $S_{DS} = 2.5C_a$, and S_1 (spectral response acceleration at 1-second period in the Maximum Considered Earthquake) = $1.5ZN_v$ (ZN_v is long-period spectral response acceleration in the Design Basis Earthquake). There are obvious differences in the applicability of the lower-bound expressions that depend on R.

Approximate period determination per Section 1617.4.2.1 of the IBC is the same as that per Method A, Section 1630.2.2 of the 1997 UBC, with two exceptions. First, for structures with concrete or masonry shear walls, the 1997 UBC gives an alternative to the period coefficient of 0.02, which is not included in the IBC. Second, the IBC gives an alternative formula for the determination of approximate fundamental period of concrete and steel moment resisting frame buildings not exceeding 12 stories in height and having a minimum story height of 10 ft. This formula is not included in the 1997 UBC.

Rational period computation is also the same in the IBC Section 1617.4.2 and the 1997 UBC (Method B, Section 1630.2.2), except that the UBC specifically includes one particular rational computation procedure, as given by Formula (30-10), which is not included in the IBC.

The limits on rationally computed period are different in the two codes. The IBC limits the rationally computed period to be no larger than C_u times the approximate period. The factor C_u given in Table 1617.4.2, depends on S_{D1} at the site of a structure, and varies between 1.2 in areas of high seismicity and 1.7 in areas of low seismicity. The 1997 UBC limits rational period to be no larger than 1.4 times the approximate period in Seismic Zones 1, 2, and 3, and no larger than 1.3 times the approximate period in Seismic Zone 4.

The vertical distribution of seismic forces of IBC Section 1617.4.3 is different from that of UBC Section 1630.5. The IBC prescribes a linear distribution and a parabolic distribution, for structures with $T \leq 0.5$ seconds and $T \geq 2.5$ seconds, respectively, varying from a zero value at the base to a maximum value at the top. For intermediate periods, one may use a linear interpolation between a linear and a parabolic distribution, or a parabolic distribution which is more conservative. The UBC uses a linear distribution, with zero value at the base, for structures with $T \leq 0.7$ seconds For longer-period structures, a portion of the design base shear ($0.07TV \leq 0.25V$) is concentrated at the top, with the remainder of the design base shear being distributed linearly as for short-period structures. The linear distribution considers fundamental mode response and assumes the fundamental mode shape to be linear. The concentrated force at the top is an allowance made for higher mode effects. The parabolic distribution of the IBC also shifts more forces towards the top, thereby increasing overturning effects.

The IBC distribution and the UBC distribution typically result in similar, if not identical, designs, if a linear interpolation between a linear and a parabolic distribution is adopted for the IBC design. If the IBC design is based on a parabolic distribution for intermediate-period structures (0.5 seconds < T < 2.5 seconds), then it is likely to be more conservative than the corresponding UBC design.

Horizontal distribution of story shear (sum of lateral forces acting at floor levels above a particular story) is prescribed in Section 1617.4.4 of the IBC and Sections 1630.6 and 1630.7 of the 1997 UBC. Both codes define flexible diaphragms the same way—the IBC in Section 1602.1 under definitions, and the UBC in Section 1630.6. The IBC prescribes a distribution of story shear based on the relative lateral stiffness of the vertical resisting elements for rigid diaphragms, and based on areas of diaphragm tributary to the various vertical resisting elements for flexible diaphragms. The UBC prescribes only the former distribution, but requires the user to "consider the rigidity of the diaphragm." In other words, it is not specific about the horizontal shear distribution in the case of non-rigid diaphragms. Both codes have the same torsion design provisions for non-flexible diaphragm situations. The torsion to be included in design is the actual torsion plus accidental torsion. The same accidental torsion is required to be included by both documents. Both require the accidental torsion to be amplified by the same factor for torsionally irregular buildings. However, the IBC requires the amplification for structures assigned to Seismic Design Category C, D, E or F only.

IBC Section 1617.4.5 allows a reduction in overturning moments that are statically consistent with the design story shears for taller buildings. The 1997 NEHRP Commentary (Section 5.3.6) provides an elaborate background on this reduction, which is not allowed by the UBC.

P-delta effects are addressed in IBC Section 1617.4.6.2 and in UBC Section 1630.1.3. Both documents allow P-delta effects to be disregarded as long as the secondary to primary moment ratio does not exceed 10 percent. According to the UBC, the ratio may be evaluated for any story as the product of the total dead, floor live and snow load above the story times the seismic drift in that story, divided by the product of the seismic shear in that story times the height of that story. The IBC gives an expression, Equation 16-47, for this ratio. The IBC, unlike the UBC, constrains this ratio to be within an upper limit. The IBC also gives a specific procedure for considering P-delta effects, the UBC does not. Finally, the UBC has an additional drift-based criterion for neglect of P-delta effects that is not included in the IBC.

1617.5 Simplified analysis procedure for seismic design of buildings. A similar simplified procedure is given in UBC Section 1630.2.3. Limitations on the use of the respective procedures are given in the IBC Section 1616.6 and the UBC Section 1629.8.2. The limitations are virtually identical, since IBC Seismic Use Group I is equivalent to UBC Occupancy Categories 4 and 5. The simplified design base shear Equation 16-49 of the IBC and Formula (30-11) of the 1997 UBC are the same, if one uses the conversion: S_{DS}=2.5C_a. The uniform distribution of the design base shear along the height is also the same in the two codes. Both allow the design story drift, where needed, to be taken as one-percent of the story height. There are some differences, however, between the IBC and the UBC provisions. The UBC requires the use of a default soil profile S_E, rather than the usual S_D, in the simplified procedure; the IBC does not. The UBC allows the near-source factor N_a to be taken as no larger than 1.3 if irregularities of certain types do not exist in a structure; the IBC, of course, does not use near-source factors. The UBC specifically lists certain code sections that are not applicable when the simplified procedure is used (the redundancy factor r, however, is not allowed to be taken equal to unity without computations justifying that value); the IBC does not give such a specific list. Finally, the UBC gives a modified Formula (33-1) for diaphragm design forces when the simplified procedure is used; the IBC does not give a similar modification of the corresponding IBC Equation 16-65.

1617.6 Seismic-force-resisting systems. This section requires that the seismic-force-resisting system of a structure be of one of the types listed in Table 1617.6. The corresponding 1997 UBC section is 1629.6 and table number is 16-N. There are some obvious differences between the two tables: (1) The UBC table does not list C_d values because C_d is not used in the UBC, (2) The IBC table gives height limits by the seismic design category, while the UBC table specifies the limits by the seismic zone, (3) The IBC table has a column of detailing reference sections, that is not in the UBC.

It should be noted that identical structural systems in the two tables often have slightly different R and C_d values. The item of most importance, however, is the proliferation of structural systems in the IBC table. The reason is a policy decision made with respect to the 1997 NEHRP Provisions which forms the basis of the seismic design requirements of the IBC. In the 1997 UBC, the bearing wall system with concrete shear walls has been assigned R and Ω_O values of 4.5 and 2.8, respectively. These values do not change from the high to the low seismic zones. In Seismic Zones 3 and 4, the shear walls require special detailing, while in Seismic Zones 1 and 2, ordinary detailing is all that is needed. Thus, in effect, two different seismic-force-resisting systems with different levels of inelastic deformability go under the same name and are assigned the same R and Ω_O values. This situation needed improvement. For the 1997 NEHRP Provisions it was decided that each basic seismic-force-resisting system defined in Table 1617.6 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.

The cantilevered column system category of the UBC is included in IBC Table 1617.6 as one of a number of types of inverted pendulum systems. Also, in the IBC, the shearwall-frame interactive system of concrete is included under "Dual Systems with Intermediate Frames." In the UBC Table 16-N it forms its own category.

IBC Sections 1617.6.1 through 1617.6.3 give rules about combinations of structural systems, as does the UBC Section 1630.4. There are basically three rules. (1) Vertical combination: When different structural systems are combined along the height of a building, the value of R used in the design of any story shall be less than or equal to the value of R used in the given direction for the story above. Also, the value of Ω_O used in the design of any story shall be more than or equal to the value of Ω_O used in the given direction for the story above. (2) Combinations along the same axis: For other than dual systems and shear wall-frame interactive systems (which are restricted to seismic zones no higher than 1 in the UBC and seismic design categories no higher than B in the IBC), where a combination of different structural systems is utilized to resist lateral forces in the same direction, the value of R used for design in that direction shall not be greater than the least value for any of the systems utilized in that same direction. The IBC does provide a sensible exception to this rule, not included in the UBC. For light frame, flexible diaphragm buildings, of Seismic Use Group I and two stories or less in height, resisting elements are permitted to be designed using the least value of R for the different structural systems found on each independent line of resistance. The value of R for design of diaphragms in such structures shall not be greater than the least value of any of the systems utilized in that same direction. (3) Combinations along different axes: The UBC rule simply states that in Seismic Zones 3 and 4 where a structure has a bearing wall system in only one direction, the value of R used for design in the orthogonal direction shall not be greater than that used for the bearing wall system. The IBC has a more general requirement. In Seismic Design Category D, E or F, if a system with $R < 5$ is used as part of the seismic-force-resisting system in any direction of a structure, the lower such value shall be used for the entire structure.

The IBC specifically states in Section 1617.6.3.2 that the detailing required by the higher R-value shall be used for structural components common to systems having different R-values. This explicit statement is not in the UBC.

IBC Section 1617.6.4 gives system limitations for Seismic Design Categories D, E, and F. Section 1617.6.4.1 relaxes height limits for buildings that have steel braced frames or concrete cast-in-place shear walls, provided certain conditions are met. The requirements are taken from the 1997 NEHRP Provisions, with one restriction made more stringent. The 1997 UBC does not contain a similar provision. The only relaxation of height limit allowed by UBC Section 1629.7 is that regular structures may exceed the specified height limits by no more than 50 percent for unoccupied structures that are not accessible to the general public.

IBC Section 1617.6.4.3 gives very important deformation compatibility requirements for structural framing elements and connections not required by design to be part of the lateral-force-resisting system. Similar requirements are given in UBC Section 1633.2.4. The UBC requirements are somewhat more comprehensive than those of the IBC. The UBC specifically requires P-delta effects to be included in the story drift under which deformation compatibility is to be maintained. The UBC also imposes a minimum of 0.0025 times the story height on this story drift. The UBC specifically requires that for concrete and masonry elements that are part of the lateral-force-resisting system, the assumed flexural and shear stiffness properties shall not exceed one-half of the gross section properties unless rational cracked-section analysis is performed. Additional deformations that may result from foundation flexibility and diaphragm deflections are also required to be considered.

1618 Dynamic Analysis Procedure for the Seismic Design of Buildings

This section, comparable to UBC Section 1631 Dynamic Analysis Procedures recognizes the following dynamic analysis procedures: Modal Response Spectra Analysis, Linear Time-History Analysis and Nonlinear Time-History Analysis.

IBC Section 1618.1 on modeling and Section 1618.2 on modes are very similar in content with UBC Sections 1631.3 and 1631.5.2, respectively. IBC Section 1618.1 includes items from UBC Section 1630.1.2 Modeling requirements. IBC Sections 1618.4 Modal base shear, 1618.5 Modal forces, deflections, and drifts, and 1618.6, Modal story shears and moments basically spell out the details of what is intended by UBC Sections 1631.4.1 and 1631.5.1. IBC Section 1618.7 on design values combines the requirements of UBC Sections 1631.5.3 Combining Modes and 1631.5.4 Reduction of Elastic Response Parameters for Design. The scaling provisions of IBC Section 1618.7 and UBC Section 1631.5.4 are different.

IBC Section 1618.8 Horizontal shear distribution refers to IBC Section 1617.4.4 which is part of the static procedure, except that amplification of torsion per Section 1617.4.4.3 is not required for that portion of the torsion included in the modal analysis model. IBC Section 1618.9 P-Delta effects similarly refers to Section 1617.4.6.2 which is part of the static procedure. IBC Sections 1617.4.4 and 1617.4.6.1 are similar in content with UBC Sections 1630.6 and 1630.1.3 respectively.

IBC Section 1618.10 on time-history analysis is very similar to UBC Section 1631.6 on time-history analysis.

1619 Earthquake Loads—Soil-Structure Interaction Effects

This section refers to Section 9.2.5 of ASCE 7-98 (Reference 3) which adopted its requirements from the 1994 NEHRP Provisions. The requirements remain unchanged in Section 5.5 of the 1997 NEHRP Provisions. Detailed background to the requirements is available in the 1997 NEHRP Provisions Part 2—Commentary.

1620 Earthquake Loads—Design, Detailing Requirements and Structural Component Load Effects

This section gives systematically organized requirements for the design and detailing of the components of the seismic force resisting systems. As mentioned earlier, there are no requirements for structures assigned to Seismic Design Category A, because they have been exempt from seismic design requirements. From Seismic Design Category B onwards, the requirements are "cascading" in the sense that requirements for Seismic Design Category B also apply to Seismic Design Categories C, D, E, and F structures. The comparable UBC section is 1633, although this section is not systematically organized in the same way.

1620.1 Structural component design and detailing. This section gives requirements applicable to structures assigned to seismic design categories higher than A.

1620.1.3 Discontinuities in vertical system. This section restricts the height of a structure with vertical irregularity Type 5 to a maximum of 2 stories or 30 ft when the weak story has a calculated strength of less than 65 percent of the story above. The UBC has the same requirement under Section 1629.9.1. The UBC waives this restriction when the weak story is capable of resisting a total lateral seismic force of Ω_O times the design force prescribed in the static procedure. The IBC includes a similar exemption, in which the force multiplier used is 0.75 C_d rather than Ω_O.

1620.1.4 Connections. This section and the corresponding UBC Section 1633.2.5 require all parts of a structure (except at separation joints) to be interconnected and require the connections to be capable of transmitting the seismic force induced by the parts being connected. As a minimum, any smaller portion of the building is tied to the remainder of the building with elements that are capable of resisting a minimum force equal to a multiplier times the weight of the smaller portion. In UBC Section 1633.2.5, the multiplier is $0.5C_aI$. In IBC Section 1620.1.4, the multiplier is the larger of $0.133S_{DS}$ or 0.05.

In addition, the sections cited from both codes require that a positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder or truss. This force shall not be less than $0.5C_aI$ times the dead plus live load reaction in the UBC, or less than five percent of the dead plus live load reaction in the IBC.

1620.1.5 Diaphragms. The corresponding UBC Section is 1633.2.9. The first part of the section is on permissible deflection in the plane of the diaphragm, and is essentially the same as in the UBC. The second part requires a floor or roof diaphragm to be designed for a force $F_p = 0.2I_ES_{DS}\, w_p + V_{px}$ where wp is the weight of the diaphragm and other elements of the structure attached thereto. When the diaphragm is required to transfer design seismic forces from the vertical resisting elements above the diaphragm to other vertical resisting elements below the diaphragm due to offset in the placement of the elements or to changes in stiffness in the vertical elements, those forces are V_{px}. The 1997 UBC gives diaphragm design forces by Formula (33-1) which is the equivalent of IBC Equation 16-65 which is invoked only for structures assigned to Seismic Design Category D and above. UBC Section 1633.2.9 specifically adds the force described as V_{px} above to the diaphragm design force given by Formula (33-1).

1620.1.6 Collector elements. This section requires collector elements, splices and their connections to resisting elements to have the design strength to resist the special load combinations of Section 1605.4. UBC Section 1633.2.6 contains essentially the same requirement in addition to the requirement that collector elements, splices, etc. be designed to resist the forces given by Formula (33-1) which is equivalent to the IBC Equation 16-65, and which in the IBC is not invoked until a structure is in Seismic Design Category D. As an exception, the IBC allows collector elements, splices and connections to resisting elements to only have the strength to resist the basic strength design or ASD load combinations (basic as well as alternate basic) in structures or portions of structures braced entirely by light frame shear walls. UBC Section 1633.2.6 includes a similar exception that states that the above items need only be designed to resist forces in accordance with Formula (33-1).

1620.1.7 Bearing walls and shear walls. This section requires bearing walls and shear walls and their anchorages to be designed for an out-of-plane force that is the larger of $0.1\ w_w$ or $0.40I_ES_{DS}\ w_w$, whichever is larger, where w_w is the weight of the wall. This particular requirement is not part of the 1997 UBC, although UBC Section 1633.2.4.2 contains a parallel requirement concerning exterior nonbearing, nonshear wall panels or elements that are attached to or enclose the exterior of a building.

Concrete and masonry walls are required to be anchored to the roof and floors and members providing lateral support, with anchorage providing a direct connection between the wall and the supporting construction capable of resisting the greater of the forces: (1) $0.40 I_E S_{DS}\ w_w$ or (2) $400 S_{DS}\ I_E$ pounds per linear foot of wall. UBC Section 1633.2.8 requires the anchorage force to be the larger of: (1) that given by the UBC strength design or ASD load combinations using the greater of the wind or earthquake loads required by Chapter 16 or a minimum horizontal force of 280 pounds per linear foot of wall substituted for E, as specified in Section 1611.4, or (2) forces specified in Section 1632.2. The two sets of requirements are not necessarily equivalent. Walls must be designed to resist bending between anchors where the anchor spacing exceeds 4 ft. This requirement is in UBC Section 1605.2.3.

1620.1.8 Inverted pendulum-type structures. This design provision for columns or piers supporting inverted pendulum type structures is not part of the 1997 UBC.

1620.1.9 Elements supporting discontinuous walls or frames. This section is identical to UBC Section 1630.8.2.1.

1620.1.10 Direction of seismic load. While it is required that the direction of application of seismic forces be such as to produce the most critical load effect in each component, the requirement is deemed to be satisfied if the design seismic forces are applied separately and independently along each of two principal plan axes.

1620.2 Seismic Design Category C. This section gives additional design requirements for structures assigned to Seismic Design Categories higher than B.

1620.2.1 Anchorage of concrete or masonry walls. The anchorage force that was discussed earlier under Section 1620.1.7 for Seismic Design Category B, is now increased for nonflexible diaphragms to that given by Equation 16-68, subject to a (non-mandatory) maximum given by Equation 16-68 and a (mandatory) minimum given by Equation 16-69. Equation 16-67 is equivalent to UBC Formula (32-2), with $S_{DS} = 2.5C_a$, except that the IBC uses a constant of 2 with the z/h ratio, whereas the UBC uses a constant of 3 with the same ratio which in the UBC is h_x/h_r. It should be noted that the R_p values are different between the IBC and the UBC to somewhat compensate for the above difference. The UBC upper and lower bounds, as given by Formula (32-3) are the same as those given by Equations 16-68 and 16-69. For flexible diaphragms, the anchorage force is increased to $1.2 S_{DS} I_E w_w$. UBC Section 1633.2.8.1 requires that for flexible diaphragms, elements of the wall anchorage system be designed for forces given by Formulas (32-1) or (32-2) and (32-3), with $R_p = 3.0$ and $a_p = 1.5$. In the UBC, however, this requirement is applicable only in Seismic Zones 3 and 4 (comparable to Seismic Design Categories D, E, and F). Additionally, in Seismic Zone 4, the value of F_p used for the design of the elements of the wall anchorage system is required to be not less than 420 pounds per linear foot of wall substituted for E. The user is referred to UBC Section 1611.4 for minimum design forces in other seismic zones. UBC Section 1633.2.8.1 gives a number of other requirements for out-of-plane wall anchorage to flexible diaphragms in Seismic Zones 3 and 4 that are not part of the IBC.

IBC Section 1620.2.1 also contains detailed requirements concerning: (1) continuous ties or struts between diaphragm chords, (2) wood diaphragms, (3) metal deck diaphragms, and (4) diaphragm to wall anchorage using embedded straps. The first, the second and the fourth requirements are found in UBC Sections 1633.2.9(4), 1633.2.9(5), and 1633.2.8, respectively.

1620.2.2 Direction of seismic load. For structures having non-parallel lateral-force-resisting systems (irregularity Type 5, Table 1616.5.1), the requirement that the critical direction of seismic forces (or the so-called orthogonal effects) be considered (IBC Section 1620.1.10) may be satisfied by designing structural elements for 100 percent of the effects of the prescribed design seismic forces in one direction plus 30 percent of the effects of the prescribed design seismic forces in the orthogonal direction. The combination requiring the greater component strength must be used in design. Alternatively, the effects in the two orthogonal directions are permitted to be combined on a square root of the sum of the squares (SRSS) basis. The same requirement is in the UBC Section 1633.1. The UBC requirement is applicable in Seismic Zones 2, 3 and 4 to a broader segment of structures and structural elements. Sections 1620.1.10, 1620.2.2 and 1620.3.5 clearly show that the IBC gradually increases the requirements based on Seismic Design Category rather than providing an across-the-board requirement for Seismic Zones 2, 3 and 4.

1620.3 Seismic Design Category D. This section gives additional seismic design requirements for structures assigned to Seismic Design Categories higher than C.

1620.3.1 Plan or vertical irregularities. For buildings having torsional irregularity, extreme torsional irregularity, re-entrant corners, diaphragm discontinuity, out-of-plane offsets of the vertical lateral-force-resisting elements (irregularity Type 1a, 1b, 2, 3, or 4, IBC Table 1616.5.1) or in-plane discontinuity in vertical lateral-force-resisting elements (irregularity Type 4, IBC Table 1616.5.2), the design forces determined from the simplified static procedure of IBC Section 1617.5.1 shall be increased 25 percent for connections of diaphragms to vertical elements and to collectors, and for connections of collectors to the vertical elements. It should be noted that this is, in addition to the severe requirement of IBC Section 1620.3.4, discussed below. This is a 1997 NEHRP Provision requirement that is not part of the 1997 UBC.

1620.3.2 Vertical seismic forces. Horizontal cantilever and horizontal prestressed components are required to be designed to resist the vertical component of earthquake ground motion. This requirement is a carry-over from UBC editions prior to 1994, which required only such components to be designed considering the vertical component of earthquake ground motion. Now, of course, the consideration of vertical earthquake ground motion is a design requirement for all elements of the structure. IBC Section 1620.3.2 states that the specific requirements concerning horizontal prestressed components shall be considered satisfied if two conditions are met. The first condition is that E be taken equal to $\rho Q_E = 0.2S_{DS}D$, as given by Equation 16-29. This is also a general requirement that applies to all structural elements. The second condition, which is the only one specific to horizontal cantilever and horizontal prestressed components requires that such components be designed to resist, in addition to the applicable load combinations of Section 1605, a minimum net upward force of 0.2 times the dead load.

The UBC section corresponding to the IBC section being discussed is 1630.11. The UBC requirement applies in Seismic Zones 3 and 4 only, and the detailed requirements are somewhat different. Horizontal cantilever components are required to be designed for a net upward force of $0.7C_aIW_p$. Horizontal prestressed components are required to be designed using no more than 50 percent of the dead load for gravity load, alone or in combination with the lateral force effects.

1620.3.3 Diaphragms. This section first gives essentially the same deflection limitations as given earlier in IBC Section 1620.1.5 for Seismic Design Category C. It then presents Equation 16-65 for diaphragm design forces, which is essentially identical to UBC Formula (33-1). It has been noted earlier that the UBC formula is applicable across all seismic zones. The IBC formula, however, is applicable only to Seismic Design Category D, E or F structures. The (non-mandatory) upper-bound and the (mandatory) lower-bound values of F_p are $0.3S_{DS}I_Ew_{px}$ and $0.15S_{DS}I_Ew_{px}$, which are equivalent to $0.75C_aI_Ew_{px}$ and $0.375C_aI_Ew_{px}$, respectively, in UBC terminology, taking $S_{DS} = 2.5C_a$. The upper and lower-bound values in the 1997 UBC are $1.0C_aI_Ew_{px}$ and $0.5C_aI_Ew_{px}$, respectively. So both UBC limits are higher.

The V_{px} term of Section 1620.1.5 is to be added to the diaphragm design force given by Equation 16-65, as in the UBC.

1620.3.4 Collector elements. This section requires, as does IBC Section 1620.1.6 applicable to Seismic Design Categories B and higher, that collector elements, splices and their connections to resisting elements shall have the design strength to resist the special load combinations of Section 1605.4. In addition, collector elements, splices and their connections to resisting elements shall be designed to resist the forces given by Equation 16-65 which is equivalent, as has been noted, to UBC Formula (33-1). As an exception, the IBC allows collector elements, splices and connections to resisting elements to only have the strength to resist the forces given by Equation 16-65 in structures or portions of structures braced entirely by light frame shear walls. This exception is similar to, but not the same as, the corresponding exception in IBC Section 1620.1.6. The requirements of IBC Section 1620.3.4 are identical to those of UBC Section 1633.2.9, except that the UBC section applies across all seismic zones, while the IBC section is applicable to only Seismic Design Category D, E or F structures. Also, as noted earlier, the upper- and lower-bound limits on the diaphragm design forces as given by IBC Equation 16-65 or the UBC Formula (33-1) are somewhat different.

1620.3.5 Direction of seismic load. Section 1620.1.10 allows that for Seismic Design Category B structures, the requirement that the critical direction of seismic forces (or the so-called orthogonal effects) be considered may be deemed satisfied if the design seismic forces are applied separately and independently along each of two principal plan axes. For structures assigned to Seismic Design Category C and higher and having non-parallel lateral-force-resisting systems, IBC Section 1620.2.2 indicates that this independent orthogonal procedure is not sufficient. As a minimum, the orthogonal combination procedure of that section must be implemented. IBC Section 1620.3.5 mandates the orthogonal combination procedure as a minimum for all structures assigned to Seismic Design Category D and higher. This requirement is more severe than that of UBC Section 1633.1 where the orthogonal combination procedure is mandated only for certain structures and structural elements in Zones 2, 3 and 4.

1620.3.6 Building separations. This section giving the minimum separation between adjacent buildings on the same property, and minimum setback distance from the property line when a structure adjoins a property line not common to a public way, is the same as UBC Section 1633.2.11. The exceptions included in the two sections are also the same.

1620.4 Seismic Design Categories E and F. This section gives additional seismic design requirements for structures assigned to seismic design categories higher than D.

1620.4.1 Plan or vertical irregularities. Structures having extreme torsional irregularity (irregularity Type 1b, Table 1616.5.1), stiffness irregularity - extreme soft story or discontinuity in capacity - weak story (irregularity Type 1b or 5, Table 1616.5.2) are simply not permitted in Seismic Design Categories E and F. This is a severe restriction that is not part of the 1997 UBC. Seismic Design Categories E and F include structures located in areas with $S_1 \geq 0.75g$. The 1997 UBC does not have a separate category for these structures.

1621 Architectural, Mechanical and Electrical Component Seismic Design Requirements

This section, adopted from Chapter 6 of the 1997 NEHRP Provisions, is much more extensive than the corresponding UBC Section 1632, Lateral Force on Elements of Structures, Nonstructural Components and Equipment Supported by Structures. The IBC requirements stretch over thirteen pages of the code, whereas the UBC requirements occupy no more than three-quarters of a page. The two extensive IBC Sections 1621.2, Architectural Component Design and 1621.3 Mechanical and Electrical Component Design simply do not have corresponding requirements in the 1997 UBC. The *Uniform Building Code* has been lacking in this area of nonstructural components, and building officials will no doubt be welcoming these much needed provisions now included in the 2000 IBC.

IBC Sections 1621.1.1 Applicability to components and 1621.1.2 Applicability to supported nonbuilding structures are much more explicit than UBC Section 1632.1, General, which does address applicability. IBC Sections 1621.1.3 Component force transfer and 1621.1.4 Seismic forces have basically the same content as UBC Section 1632.2. IBC Equation 16-67 and UBC Formula (32-2) differ only in one respect if the conversion $S_{DS} = 2.5C_a$ is kept in mind, which would make $0.4S_{DS} = C_a$. The IBC uses a constant 2 with z/h, whereas the UBC uses a constant 3 with the corresponding term h_x/h_r. However, the R_p values are different between the IBC and the UBC to somewhat compensate for this difference. The upper and lower bound values of IBC Equations 16-68 and 16-69 are identical to the corresponding values in UBC Formula (32-2), with the $S_{DS} = 2.5C_a$ conversion. The UBC explicitly states that the upper-bound value of the component design force may be used unless more detailed calculations are made using Formula (32-2). The IBC does not format its provisions the same way. IBC Section 1621.1.5 Seismic relative displacements is clearer and more explicit than the corresponding UBC Section 1621.4. IBC Section 1621.1.6 Component importance factor is covered by Table 16-K of the 1997 UBC. IBC Sections 1621.1.7 Component anchorage, and 1621.1.8 Quality assurance, special inspection and testing do not have corresponding requirements in UBC. Section 1632.5 Alternative designs of the UBC does not have corresponding provisions in the IBC.

1622 Nonbuilding Structures Seismic Design Requirements

IBC Section 1622 is essentially identical to Chapter 14 of the 1997 NEHRP Provisions. Building structures, vehicular and railroad bridges, nuclear power plants, and dams are excluded from the scope of the nonbuilding structure requirements. The excluded structures are covered either by other sections of the IBC or by other well established design criteria.

Chapter 14 of the 1997 NEHRP Provisions, in a real sense, did not exist previously. It represents a major expansion of Section 2.7 of the 1994 NEHRP Provisions, the requirements of which were also modified to reflect the new design procedures of the 1997 NEHRP Provisions.

Building codes traditionally have been perceived as minimum standards of care for the design of nonbuilding structures and building code compliance of these structures is required by building officials in many jurisdictions. However, requirements in the industry standards are often at odds with building code requirements. In some cases, the industry standards need to be altered, while in other cases the building codes need to be modified. Design professionals are not always aware of the numerous accepted standards within an industry or if the accepted standards are adequate. The requirements of the 1997 NEHRP Provisions for nonbuilding structures attempt to bridge the gap between building codes and existing industry standards.

One of the goals through the process of development of Chapter 14 of the 1997 NEHRP Provisions was to review and list appropriate industry standards to serve as a resource. Such a list is included in an appendix to Chapter 14 of the 1997 NEHRP Provisions. The appendix, however, has not been incorporated into the IBC.

The *Uniform Building Code* added a section on nonbuilding structures for the first time in its 1988 edition. This section, which has remained essentially unchanged in the 1994 and 1997 editions of the UBC, formed the basis of Section 2.7 of the 1994 NEHRP Provisions. Thus, a comparison between IBC Section 1622 and UBC Section 1634 is really in essence a comparison between Chapter 14 of the 1997 NEHRP Provisions and Section 2.7 of the 1994 NEHRP Provisions.

The 1997 UBC Section 1634 covers: (1) nonbuildings structures that have structural systems similar to those in buildings and are therefore building-like, (2) rigid nonbuilding structures, (3) grade-supported tanks, and (4) all other nonbuilding structures in a blanket manner. IBC Section 1622.1.1 Nonbuilding structures supported by other structures is similar to, but is more detailed than UBC Sections 1634.1.6 Interaction Effects. UBC Section 1632 contains provisions similar to, but less detailed than those in IBC Section 1622.1.2 Architectural, mechanical and electrical components. IBC Sections 1622.2.1 Weight, 1622.2.2 Fundamental period, 1622.2.3 Drift limits, and 1622.2.5 Minimum seismic forces are equivalent to the 1997 UBC Sections 1634.1.3, 1634.1.4, 1634.1.5, and 1634.2, respectively, although the drift limits are numerically different in the two documents. The IBC addresses rigid nonbuilding structures in Section 1622.2.6. The requirements are essentially identical to those of the 1997 UBC Section 1634.3 (with the conversion, $S_{DS} = 2.5C_a$). The 1997 UBC Sections 1630.10 and 1633.2.11 have provisions similar to those in the IBC Section 1622.2.7 Deflection limits and structure separation. IBC Section 1622 has a Section 1622.3 on Nonbuilding structures similar to buildings, under which specific guidance is provided for: Pipe racks (Section 1622.3.3), Steel storage racks (Section 1622.3.4), Electrical power-generating facilities (Section 1622.3.5), Structural towers for tanks and vessels (Section 1622.3.6), and Piers and wharves (Section 1622.3.7). The IBC Section 1622 also has a Section 1622.4 on Nonbuilding structures not similar to buildings, under which specific guidance is provided for: Earth-retaining structures (Section 1622.4.2), Tanks and vessels (Section 1622.4.3—separate provision for above-grade storage tanks and at-grade storage tanks), Telecommunication Towers (Section 1622.4.4), Stacks and chimneys (Section 1622.4.5), Amusement structures (Section 1622.4.6), Special hydraulic structures (Section 1622.4.7), Buried structures (Section 1622.4.8), and Inverted pendulums (Section 1622.4.9). As noted above, the UBC has specific requirements only for grade-supported storage tanks.

1623 Seismically Isolated Structures

Background. In late 1989, the SEAOC Seismology Committee adopted an "Appendix to Chapter 2" of the SEAOC Blue Book (Reference 5) entitled, *"General Requirements for the Design and Construction of Seismic-Isolated Structures."* These requirements were adopted as an appendix to the 1991 UBC. The isolation appendix of the UBC has been updated on an annual basis since that time and the most current version of these regulations may be found in the 1997 UBC Appendix Chapter 16, Division IV.

During development of the 1994 NEHRP Provisions, it was decided to use the then-latest version (1993 approved changes) of the SEAOC/UBC provisions as a basis for the development of the requirements included in the Provisions. The only significant changes involved an appropriate conversion to strength design and making the requirements applicable on a national basis. For the 1997 NEHRP Provisions, it was decided to incorporate the 1997 UBC provisions. Since the 1997 UBC is based on strength design, Appendix Chapter 16 Division IV of the 1997 UBC and Chapter 13 of the 1997 NEHRP Provisions are almost identical, except for seismic criteria. The seismic criteria of the 1997 NEHRP Provisions are based on the new national earthquake maps and the associated ground motion parameters.

General Comparison of 2000 IBC and 1997 UBC Provisions

IBC Section 1623 is equivalent to the 1997 NEHRP Provisions Chapter 13, except for one minor item. The IBC is slightly less stringent in its requirement concerning sequences and cycles for required tests of isolation systems. Thus, Section 1623 of the 2000 IBC and Appendix Chapter 16, Division IV of the 1997 UBC differ primarily in the seismic criteria. The two sets of provisions become essentially equivalent, except for a number of details that are different, if the following conversions are made:

1. Site with $S_1 \leq 0.60g$ of the IBC should be considered equivalent to sites located at least 10 km from all active faults of the 1997 UBC.
2. S_{M1} of the IBC should be considered equivalent to $C_{VM} = M_M Z N_V$ of the 1997 UBC.
3. S_{D1} of the IBC should be considered equivalent to $C_{VD} = C_V$ as given by Table 16-K of the 1997 UBC.

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Chapter 17 of the IBC
Structural Tests and Special Inspections

Introduction

The purpose of the requirements of Chapter 17 is to ensure proper construction through special inspection, testing, structural observation and quality assurance. Chapter 17 of the 2000 *International Building Code* (IBC) is primarily based on Chapter 17 of the *BOCA National Building Code.* Although Chapter 17 of the IBC contains provisions similar to the 1997 *Uniform Building Code* (UBC), the IBC requirements are much broader in scope. This is apparent by the fact that UBC Chapter 17 consists of only 3 pages whereas IBC Chapter 17 is 19 pages in length. Many provisions that are only implied in the UBC are more explicitly described in Chapter 17 of the IBC.

One of the most significant differences between the UBC and IBC provisions are the quality assurance plans contained in Chapter 17 of the IBC. The quality assurance plan for seismic requirements, which is outlined in section 1705 of the IBC, is based on the *National Earthquake Hazard Reduction Program Recommended Provisions for Seismic Regulations for New Buildings* (NEHRP), 1997 Edition (Reference 1). In addition, Section 1706 of the IBC includes quality assurance plan for wind requirements. The underlying purpose of the quality assurance plan is to address the fact that post earthquake and high wind damage reports always indicate that many cases of severe damage and collapse could have been prevented by better construction practices through improved quality assurance.

Chapter 17 is divided into 14 sections as follows:

1701 General
1702 Definitions
1703 Approvals
1704 Special Inspections
1705 Quality Assurance for Seismic Resistance
1706 Quality Assurance for Wind Requirements
1707 Special Inspections for Seismic Resistance
1708 Structural Testing for Seismic Resistance
1709 Structural Observations
1710 Design Strengths of Materials
1711 Alternative Test Procedure
1712 Test Safe Load
1713 In-Situ Load Tests
1714 Preconstruction Load Tests
1715 Material and Test Standards

1701 General

The general section includes the scope of the chapter and contains two sub-sections that deal with the types of materials of construction. New materials, equipment, appliances or systems not specifically covered by the code must be qualified by testing to determine their quality and limitations of use. Used materials are permitted provided they meet the same requirements for new materials.

1702 Definitions

Unlike the UBC, Chapter 17 of the IBC has a specific section that contains definitions of significant terms used in the chapter. Some of the terms defined in the IBC are implicitly defined in the UBC, but do not appear as a specific definition as in the IBC. Having specifically defined terminology rather than having implied meanings by context helps code users because it minimizes ambiguity.

1703 Approvals

One important requirement that is necessary to ensure that proper construction materials are used in the construction process is the submittal of substantiating data to the building official. In the UBC this has traditionally been accomplished through the administrative provisions, and in the 1997 UBC are contained in Section 106.3.2 Submittal of documents. In the IBC, the requirements are included in Section 1703 which covers the general requirements related to obtaining approval of the proposed construction.

It is the intent of all building codes that construction methods, materials and equipment be approved and conform to the minimum standards of the code. Where materials must be tested to demonstrate their conformance, test procedures are required to meet approved standards and test reports must be submitted to the building official. Although similar requirements are covered in the administrative provisions of the UBC, the comparable provisions in the IBC are more detailed and broader in scope. The section requires that all materials, appliances, equipment and construction systems that have been deemed to meet the requirements of the code be approved in writing, and that the record of approval be kept on file with the building official. Such approvals are to include any conditions of approval as well as any applicable limitations of use.

The section requires that test reports by an approved agency be provided to the building official to demonstrate that proposed construction materials comply with applicable code requirements. In addition, the section also indicates that where labeling is required, the materials and assemblies are to be labeled by an approved agency. The term, "approved agency," is defined in the beginning of Section 1702 as an established and recognized agency regularly engaged in providing testing or inspection services and provides sufficient information demonstrating that it meets applicable requirements established by the building official.

The approved agency is required to make periodic in plant inspections of the materials or products to verify that conformance with applicable standards is maintained. The approved agency is required to be competent and objective, have the proper equipment and have sufficiently experienced personnel to properly conduct and evaluate test procedures and test results.

Products and materials that are required to be labeled must be done so by an approved agency, based on representative sample testing in accordance with applicable standards. The labels need to clearly identify the manufacturer, model or serial number, definitive product description and performance characteristics, as well as identify the approved agency responsible for testing and labeling.

Section 1703.6 permits the use of heretofore existing construction materials which conformed to previous code requirements provided that their continued use is not detrimental to the health and safety of the public.

Where prefabricated assemblies are used and the components of the assembly are not visible at the time of inspection, the code requires a description of the components and details of the assembly so that the building official can determine that the assembly conforms to the applicable requirements of the code. The section also stipulates that the costs of tests and test reports be borne by the permit applicant.

In general, Section 1703 offers much more detailed requirements than the UBC in regards to the type and scope of information that must be provided to the building official in order to ensure code compliance.

Section 1704 Special Inspections

One of the oldest means of providing quality assurance during the construction process is through what is referred to as special inspections. The purpose of special inspections is to ensure proper fabrication, installation and placement of specific components that require special knowledge or expertise. In addition, special inspectors are responsible for verifying that the specified construction materials are being used in the construction project. Both the knowledge and duties of the special inspector differs from that of the jurisdiction building inspector in that their expertise is more narrow in scope and very specialized. (Reference 5). Hence the term, "special inspection" is defined in the IBC as, "Inspection as herein required of the materials, installation, fabrication, erection or placement of components and connections requiring special expertise to ensure compliance with approved construction documents and referenced standards." Thus, the significant characteristic that distinguishes the special inspector from the building department inspector is special knowledge and expertise.

Two key aspects of special inspection are that these inspections are in addition to those performed by the jurisdiction building inspector, and the special inspector is to be employed by the owner or the design professional. The latter requirement is intended to minimize potential conflicts of interest that could occur if the inspector worked for the contractor, and to ensure that special inspections are not provided at the financial expense of the jurisdiction.

As remarkable as it may seem, the concept of special inspection dates back to the 1927 Edition of the UBC under the designation of Special Engineering Supervision. The special inspection provisions as we know them today first appeared in the 1943 UBC under the designation of Registered Inspectors. The requirements in the 1943 UBC contained the essential ingredients of modern special inspection provisions which are: the specific types of work requiring inspection are specified; the inspector must be thoroughly qualified; these inspections are in addition to those performed by the jurisdiction building inspector; and the inspector is to be employed by the owner or the design professional, not the contractor.

Although similar, the special inspection requirements of the IBC are more extensive than those of the 1997 UBC. The IBC gives more detailed information as to what each type of inspection entails, and identifies whether the inspection is periodic or continuous. An improved feature of the IBC is that this detailed information is provided in tabular form for steel (Table 1704.3), concrete (Table 1704.4) and masonry (Tables 1704.5.1 and 1704.5.2). It is important to clearly distinguish between periodic and continuous inspection as defined in Section 1702.

Section 1704.1 outlines the general requirements for special inspection, which are essentially the same as the UBC. These general requirements are reiterated as follows:

1. The owner or registered design professional must employ the special inspector.
2. The types of work requiring special inspection are specified.
3. The special inspector shall be qualified and demonstrate his or her qualifications to the building official for the specific type of inspection involved.
4. The inspections are in addition to those required by the jurisdiction specified in Section 109.

It is important to also distinguish that a special inspector acts in an inspection and reporting capacity, and is not empowered with the same authority as the building department inspector in regards to issuing notices and orders or authorizing construction progress.

Similar to the UBC, the IBC includes certain exceptions for work that do not require special inspection:

1. Minor work when approved by the building official.
2. Construction that is not required to be designed by a registered professional.
3. Unless otherwise required by the building official, special inspection is not required for Group R, Division 3, occupancies and Group U occupancies accessory to residential occupancies that are constructed in accordance with the *International Residential Code*.

Similar to the special inspection program of UBC Section 106.3.5, IBC Section 1704.1 requires the permit applicant to submit a statement prepared by the registered design professional that itemizes all of the materials and work requiring special inspection. The statement must identify the individuals, firms or approved agencies that are responsible for performing special inspections.

The special inspector is required to keep accurate records of inspections performed, and furnish periodic inspection reports to the building official and the registered design professional. Any observed discrepancies are to be brought to the attention of the contractor for correction. If not corrected, discrepancies shall be reported to the building official and the registered design professional prior to completion of the particular phase of work involved. A final report is to be filed with the building official and registered design professional.

Where fabrication of structural members and assemblies is done in a fabricator's shop, special inspection of the fabrication process is required, unless the fabricator is approved in accordance with Section 1704.2.2. The special inspector must verify that the fabricator maintains the proper fabrication and quality control procedures to maintain workmanship and conform to approved construction documents and applicable standards.

Special inspection is not required when fabrication takes place on the premises of a fabrication facility that is registered and has been specifically approved to perform such work without special inspection. Approval to fabricate without special inspection must be based on a review of the written procedural and quality control manuals as well as periodic auditing of the fabrication process by an approved special inspection agency. A certificate of compliance must be provided to the building official that states that fabrication work was done in accordance with the approved construction documents.

Although the scope of items that require special inspection are similar to the 1997 UBC, the IBC requires special inspection for a broader range of items. Special inspection is required for certain aspects of structural steel construction, concrete construction, masonry construction, wood construction, soils, pile foundations, pier foundations, wall panels and veneers, sprayed fire-resistant materials, exterior insulation and finish systems (EIFS), and smoke control systems. Special inspection for seismic resistance is a separate, special category with detailed provisions covered in Section 1707. Special inspection is also required for unusual cases or special conditions that use either alternative materials or construction methods in the opinion of the building official.

A significant difference between the UBC and IBC is the requirement in Section 1704.3.2 for special inspectors to review the structural details and perform inspections to verify compliance with the approved construction documents. This section requires the inspector to verify bracing, stiffening, member location and proper joint construction at each connection. Although implied in the UBC, it is not clearly stated as in the IBC.

Another significant difference between the UBC and the IBC relates to special inspection for masonry construction. When using the allowable stress design procedure, the UBC has historically not required special inspection for structures that were designed using one-half allowable stresses. For structures designed using full allowable stresses, the UBC requires special inspection. The approach taken in the IBC is that masonry designs are based on full allowable stresses, and minimum levels of special inspection are required for all engineered masonry structures. However, special inspection is not required for empirically designed masonry structures in non-essential structures. See also the analysis to Section 2105.

1705 Quality Assurance for Seismic Resistance

The quality assurance plan outlined in Section 1705, which only applies to seismic requirements, did not originate from the model codes, but was derived from the 1997 NEHRP (Reference 1). The seismic design provisions of the IBC, which are primarily based on the 1997 NEHRP, rely heavily on the concept of quality control to ensure adequate performance of the seismic force resisting system during earthquake events. Post-earthquake studies indicate that a substantial number of earthquake related structural failures can be traced to poor quality control during the construction process. This fact forms the basis for the IBC quality assurance plan for structures located in areas of higher seismic risk.

The quality assurance plan applies to the seismic-force-resisting system, the designated seismic system, and certain mechanical and electrical equipment depending on the seismic design category assigned to the building. The seismic-force resisting system consists of the structural system that is designed to provide resistance to seismic forces. The designated seismic system consists of those architectural, mechanical and electrical systems that have a component importance factor (*Ip*) greater than one. These terms are defined in Section 1613.

A quality assurance plan for the seismic system is required for the following:

1. The seismic-force-resisting systems in structures in Seismic Design Category C, D, E, or F.
2. The designated seismic systems in structures in Seismic Design Category D, E, or F.
3. The following additional systems in structures in Seismic Design Category C:
   - HVAC ductwork and anchorage of ductwork containing hazardous materials.
   - Piping systems and mechanical units containing flammable, combustible or highly toxic materials.
   - Anchorage of electrical equipment used in emergency and stand-by power systems.

4. The following systems in structures in Seismic Design Category D:
   - HVAC ductwork and anchorage of ductwork containing hazardous materials.
   - Piping systems and mechanical units containing flammable, combustible or highly toxic materials.
   - Anchorage of electrical equipment used in emergency and stand-by power systems.
   - Exterior wall panels and their anchorages.
   - Suspended ceiling systems and their anchorages.
   - Access floor systems and their anchorages.
   - Steel storage racks and their anchorages where the importance factor, *Ip*, is 1.5.

5. The following systems in structures in Seismic Design Category E or F:
   - HVAC ductwork and anchorage of ductwork containing hazardous materials.

- Piping systems and mechanical units containing flammable, combustible or highly toxic materials.
- Anchorage of electrical equipment used in emergency and stand-by power systems.
- Exterior wall panels and their anchorages.
- Suspended ceiling systems and their anchorages.
- Access floor systems and their anchorages.
- Steel storage racks and their anchorages where the importance factor, *Ip*, is 1.5.
- Electrical equipment.

There are some specific exceptions where the quality assurance plan is not required. A quality assurance plan is not required for structures designed and constructed in accordance with the conventional construction provisions of Section 2308. In addition, a quality assurance plan is not required for structures in Seismic Use Group I that do not have plan or vertical irregularities and conform to other of the following conditions:

1. Structures of light frame wood or cold-formed light gauge steel construction where the short period design spectral response acceleration, S_{DS}, does not exceed 0.5g and the height of the structure does not exceed 35 feet.
2. Structures of reinforced concrete or reinforced masonry where the short period design spectral response acceleration, S_{DS}, does not exceed 0.5g and the height of the structure does not exceed 25 feet.
3. The structure is a detached one- or two-family dwelling not exceeding two stories in height.

The quality assurance plan must be prepared by a registered design professional and shall identify the following items:

1. The designated seismic systems and the seismic-force-resisting systems that are subject to the plan as prescribed by Section 1705.
2. Special inspections and testing required by Sections 1704 and 1708 or other provisions of the code including applicable referenced standards.
3. Type and frequency of testing required.
4. Type and frequency of special inspections required.
5. Required frequency and distribution of testing and special inspection reports.
6. Structural observations to be performed.
7. Required frequency and distribution of structural observation reports.

Each contractor responsible for constructing the seismic-force-resisting systems, the designated seismic systems, or the components listed in the quality assurance plan shall prepare and submit a statement of responsibility to the building official. The statement shall acknowledge awareness of the special requirements of the quality assurance plan, acknowledge that proper control will be exercised to achieve conformance with the approved construction documents, describe procedures used by the contractor for exercising control, and identify and describe the qualifications of the personnel within their organization responsible for implementing the plan.

1706 Quality Assurance for Wind Requirements

Statistics indicate that high wind events cause more fatalities and property damage than any other type of natural disaster, including earthquakes. Similar to earthquake losses, studies indicate that a significant number of structural failures resulting from high wind loading can be traced to poor quality control during the construction process. The requirement for providing a quality assurance plan for buildings subjected to high wind is intended to reduce damage and losses associated with high wind events.

The quality assurance plan for wind requirements applies to structures in wind exposure categories A and B where the designated 3-second-gust basic wind speed is 120 mph or higher, or in wind exposure categories C and D where the designated 3-second-gust basic wind speed is 110 mph or higher. However, a quality assurance plan is not required for buildings constructed in accordance with the *International Residential Code* (Reference 6) or the conventional construction provisions of Section 2308 of the IBC provided the items listed in Section 1706.1.2 are inspected by a qualified individual approved by the building official.

When a quality assurance plan is required, it is required to address the following items:

1. Roof cladding and roof framing connections.
2. Wall connections to roof and floor diaphragms and framing.
3. Roof and floor diaphragm systems including collectors, drag members, and diaphragm boundary elements.
4. Vertical elements of the lateral force resisting system such as braced frames, moment frames and shear walls.
5. Wind-force-resisting system connections to the foundation.
6. Fabrication and installation of components and assemblies required to comply with the impact resistance requirements in Section 1609.1.4, unless such items have an approved label indicating compliance with the impact requirements.

The quality assurance plan must be prepared by a registered design professional unless the subject building is not required to be designed by a registered design professional, in which case the quality assurance plan may be prepared by a qualified person approved by the building official. The plan is to clearly identify the following items:

1. The main wind-force-resisting system and components that are subject to the quality assurance plan.
2. Any special inspection and specific testing to be provided as required by Section 1704 or any applicable referenced standards.
3. The type and frequency of testing required.
4. The frequency and proper distribution of special inspection and testing reports.
5. Any structural observations required.
6. The frequency and proper distribution of structural observation reports.

Each contractor responsible for constructing the wind-force-resisting systems or wind-resisting component listed in the quality assurance plan shall prepare and submit a statement of responsibility to the building official and building owner prior to commencement of work on the system or component. The statement of responsibility shall acknowledge awareness of the special requirements of the quality assurance plan, acknowledge that proper control will be exercised to achieve conformance with the approved construction documents, describe procedures to be used by the contractor for exercising control, and provide the qualifications of the personnel within their organization responsible for implementing the plan.

1707 Special Inspection for Seismic Resistance

Special inspection is required for the seismic-force-resisting system, the designated seismic system, and certain architectural, mechanical and electrical equipment, depending on the particular seismic design category assigned to the building. The "seismic-force-resisting system" consists of the structural system that is designed to provide seismic force resistance. The "designated seismic system" consists of those architectural, mechanical and electrical systems that have a component importance factor (I_p) greater than one. See definitions in Section 1613.

Special inspection is required for the following:

1. The seismic-force-resisting systems in structures assigned to Seismic Design Category C, D, E, or F.
2. The designated seismic systems in structures assigned to Seismic Design Category D, E, or F.
3. Architectural, mechanical and electrical components in structures assigned to Seismic Design Category C, D, E or F that are required by Sections 1707.6 and 1707.7.

For various types of construction, Sections 1707.3 through 1707.8 describe those specific items that require continuous special inspection as opposed to those that only require periodic special inspection.

1708 Structural Testing for Seismic Resistance

Section 1708 first sets forth the minimum testing requirements for masonry. Empirically designed masonry and glass block provisions, which were taken from ACI 530-99/ASCE 5-99/TMS 402-99 (Reference 6), are covered by Sections 2109 and 2110. Testing requirements for masonry and glass unit construction are broken down into two categories: empirically designed masonry and engineered masonry. Engineered masonry using the working stress design method is outlined in Section 2107, and the strength design procedure is in Section 2108.

Empirically designed masonry and glass unit construction in nonessential facilities must comply with the Level 1 quality assurance requirements described in Table 1708.1.1. Empirically designed masonry in essential facilities and engineered masonry in nonessential facilities must comply with the Level 2 quality assurance requirements described in Table 1708.1.2. Engineered masonry construction in essential facilities is required to comply with the Level 3 quality assurance requirements described in Table 1708.1.4. These tables clearly itemize the type of inspection task, the frequency (continuous or periodic) and provide a reference to the applicable code section or standard.

Depending on the Seismic Design Category of a particular structure, specific testing is required by Section 1708.2 for the seismic-force-resisting systems, designated seismic systems, and architectural, mechanical or electrical components. For structures in Seismic Design Category C, D, E, or F, testing is required for seismic-force-resisting systems. For structures in Seismic Design Category D, E, or F, testing is also required for the designated seismic systems. For structures in Seismic Design Category C, D, E, or F, testing is also required for those architectural, mechanical and electrical components and their mounting and anchorage systems that are also included in the designated seismic system.

The specific structural tests required are as follows:

1. Mill test reports for reinforcing steel used in reinforced concrete intermediate frames, special moment frames, and boundary elements in special reinforced concrete and special masonry shear walls.
2. Where ASTM A615 is used to resist flexural and axial forces from seismic loads in special moment frames and shear wall boundary elements for structures in Seismic Design Category D, E, or F, the testing in accordance with ACI 318 is required.
3. Where ASTM A615 reinforcing is welded, chemical property testing is required to determine weldability in conformance with AWS D1.4.
4. Structural steel testing shall be accordance with the *Seismic Provisions for Structural Steel Buildings* (Reference 4). The acceptance criteria for nondestructive testing shall be as required in AWS D1.1 as specified by the registered design professional.
5. Where base metal thickness exceeds 1.5 inches and is subject to through-thickness weld shrinkage strains, ultrasonic testing is required and discontinuities must be accepted or rejected on the basis of ASTM A435 or ASTM A898 Level 1 Criteria.

The manufacturer of mechanical and electrical equipment and components that are a part of the designated seismic system (as defined in Section 1613.1), are required to test or otherwise analyze the components and their mounting or anchorage systems. They are also required to submit a certificate of compliance to the registered design professional and the building official. The registered design professional is required to review and accept the certificate of compliance, and the building official is required to review and approve it. The special inspector is required to examine the mechanical and electrical equipment and components, and verify that their installation and anchorage systems comply with the approved documents.

Seismically isolated structures are required to be tested in accordance with Section 1623.8, which prescribes detailed testing procedures and protocols.

1709 Structural Observations

In addition to special inspection, the concept of structural observation first appeared in the 1988 UBC, and applied to buildings located in areas of high seismic risk. The structural observation provisions of the IBC are patterned after the UBC. The purpose of structural observation is to ensure that the structural system that provides lateral force resistance is constructed in general conformance with the construction documents. Since the design professional is most familiar with the principal elements of the seismic force resisting systems in a structure, he or she is the most appropriate individual to perform structural observation.

Structural observation is required for structures in Seismic Design Category D, E, or F when the structure is in Seismic Use Group II or III or has a height exceeding 75 feet above the base. In addition, structures greater than two stories in height that are in Seismic Design Category E and Seismic Use Group I require structural observation. (Note: Structures in Seismic Design Category F are those that are classified in Seismic Use Group III and have high spectral accelerations. See Section 1616.3).

Structural observation is also required where the 3-second-gust basic wind speed exceeds 110 mph as determined from Figure 1609, and the structure is in Category II or III (per Table 1604.5) or exceeds 75 feet in height.

Deficiencies noted during the structural observation process are to be reported to the owner and the building official. At the conclusion of the project, a written statement is to be submitted to the building official. The statement is required to state that site visits were made as well as report any deficiencies that were not resolved.

Structural observation can also be required at the discretion of either the registered design professional or the building official. This provision allows for either the designer or the building official to require structural observation for unusual conditions or alternate methods or materials of construction.

Alternative Methods and Materials. The UBC provisions that govern the use of alternate construction methods and materials are included in the administrative chapter and are very general in nature. Similarly, the IBC also includes general requirements in the administrative chapter. These general provisions apply to all methods and materials, both nonstructural and structural. In contrast to the UBC, the IBC also includes more extensive and specific provisions in Chapter 17 that regulate approval, test procedures and reporting requirements for use of alternate design methods or construction materials. The provisions are intended to apply to those methods or materials that are not covered by either the code or those standards that are referenced within the code.

1710 Design Strengths of Materials

In the absence of applicable standards, the design strengths or permissible stresses of any structural material must conform to the specifications and design methods that are consistent with principles of accepted engineering practice. Materials that are not specifically covered by the code or the standards referenced in the code must have their design strengths or permissible stresses established by the testing requirements prescribed by Section 1711.

1711 Alternative Test Procedure

In the absence of approved standards for materials or assemblies, the building official shall require tests and investigations by approved agencies to determine their quality and proper manner of use as prescribed by Section 104.11. The costs for such tests and investigations shall be borne by the permit applicant, not the jurisdiction.

1712 Test Safe Load

In addition to the general requirements contained in the administrative chapter, the IBC includes specific requirements for testing where the proposed construction is incapable of being designed by approved engineering methods or where design methods do not comply with applicable standards. In this case, the proposed construction shall be subjected to the tests and investigations prescribed by Section 1714.

1713 In-Situ Load Tests

When there is reasonable doubt as to the stability or structural integrity of a completed building, structure or portion thereof, an engineering assessment based on either structural analysis or in-place testing is required. If such a building or structure is found to be inadequate, modifications shall be made to ensure the structural adequacy or the deficient construction shall be removed. Structural components shall be tested in accordance with appropriate material standards listed in Chapter 35. In the absence of such standards, test procedures shall be developed by a registered design professional that reasonably simulate the anticipated loads on the completed structure when subjected to normal use.

1714 Preconstruction Load Tests

When the physical properties of materials or the methods of construction are not capable of being designed by approved engineering methods or which do not comply with applicable standards listed in Chapter 35, their structural adequacy shall be predetermined. Where load test procedures or acceptance criteria are included in applicable design standards listed in Chapter 35, such standards shall be followed. Where load test procedures or acceptance criteria are not included in applicable design standards listed in Chapter 35, structural components and assemblies shall be tested in accordance with the in-situ load test procedure prescribed in Section 1713.

The 1997 UBC did not address the issue of design and testing of window or door assemblies. IBC Section 1714.5 requires all exterior window and door assemblies be tested for wind load resistance in accordance with ASTM E330. Although not explicitly stated in the section regarding aluminum, vinyl or wood windows and glass doors (Section 1714.5.1), it is required in the referenced standard AAMA/NWWDA/101/I.S.2. This testing requirement applies only to "assemblies," meaning that site-built windows need not be tested, provided they are designed in accordance with Chapter 24 of the IBC.

Note that AAMA/NWWDA/101/I.S.2 was accepted as a nationally recognized performance-based standard by the IBC Structural Subcommittee, although its title states that it is "voluntary" in nature. This standard has been submitted for approval as an ANSI standard. This standard contains many other requirements not directly related to structural performance (e.g., air and water resistance and forced entry resistance), which are needed for satisfactory long-term performance of the products. Other optional provisions for condensation resistance, thermal transmittance, and acoustical performance are also contained in the standard. Although the standard is being adopted by reference, the intent is that these other provisions would remain optional.

1714.5.1 Aluminum, vinyl and wood exterior windows and glass doors. Requires all aluminum, vinyl or wood windows and glass doors to be labeled in accordance with AAMA/NWWDA/101/I.S.2. Although some jurisdictions are requiring labeling of window assemblies for energy code purposes, this may still be a major change in acceptance criteria for windows since there may be manufacturers of these assemblies who are not currently getting their products labeled for this standard. In addition, some care will need to be exercised by the building official in verifying that the assemblies are labeled for the correct design loads. For example, the standard assigns a "performance class" and "performance grade" to assemblies according to their use (residential, light commercial, etc.) The performance grades assign design loads to each class (15 pounds per square foot for residential, 25 pounds per square foot for light commercial, and so on). However, since the design wind loads in Chapter 16 do not depend on the use of the building, the design loads for a particular area of the country may exceed those prescribed for the performance grade in the standard. In other words, installing a "residential" grade window in a single-family residence may not meet the code in many areas of the country, since the design wind load could easily be greater than 15 pounds per square foot.

Section 1714.5.1 also exempts these assemblies from the specific requirements of Sections 2403.2 and 2403.3 (determining glazing thicknesses and allowable loads) since they are tested as a whole assembly. All other types of windows and doors, including site-built windows, must be designed using applied and allowable loads from Chapters 16 and 24, respectively (Section 1713.5.2).

Section 1715. Material and Test Standards. Section 1714 sets forth testing requirements for joist hangers and concrete and clay roof tiles.

References

1. Building Seismic Safety Council, *NEHRP (National Earthquake Hazards Reduction Program) Recommended Provisions for the Development of Seismic Regulations for New Buildings (and Other Structures)*, Washington, D. C., 1997.
2. Building Officials and Code Administrators International, *The BOCA National Building Code,* Country Club Hills, IL, 1996.
3. Southern Building Code Congress International, *Standard Building Code,* Birmingham, AL, 1997.
4. American Institute of Steel Construction, INC., *Seismic Provisions for Structural Steel Buildings,* One East Wacker Drive, Suite 3100, Chicago, IL, 1997.
5. Robert E. O'Bannon, "The Meaning of Special Inspection", *Building Standards,* International Conference of Building Officials, July-August, 1982.
6. American Concrete Institute/Structural Engineering Institute of the American Society of Civil Engineers/The Masonry Society, *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 5-99/ TMS 402-99), Farmington Hills, MI, 1999.
7. International Code Council, INK, *International Residential Code,* Falls Church, VA, 1998.

Chapter 18 of the IBC
Soils and Foundations

Introduction

This chapter has been reorganized in order to consolidate similar requirements into the same sections. For instance, all the requirements for where a soils investigation is required have been placed in Section 1802.2, and grading requirements that formerly appeared in Chapter 33 in the 1997 UBC now appear in this chapter. Chapter 18 in the 2000 IBC also contains considerably more detailed requirements than the 1997 UBC. The increased detail is important, as it gives more guidance to designers and building officials as to what is acceptable, particularly in the area of deep foundation designs (Sections 1807 through 1811).

Other substantial differences from the 1997 UBC include:

- Table 1804.2 contains increased values for allowable soil bearing pressures.
- There is now a set of prescriptive designs for foundation walls that are contained in Tables 1805.5(1) through 1805.5(4).
- New definitions are introduced for pile and pier foundation systems in Section 1807.
- Provisions for anchor bolts and minimum foundation reinforcement in higher seismic regions that appeared in Chapter 18 in the 1997 UBC have been moved in the 2000 IBC to Chapters 23 and 19, respectively.

However, users of the code who are comfortable with the UBC will also find many provisions in this chapter that are virtually unchanged from the 1997 UBC provisions, including:

- Allowable lateral bearing and sliding resistance pressures (IBC Table 1804.2, UBC Table 18-I-A).
- Provisions for footings on or adjacent to slopes (IBC Section 1805.3, UBC Section 1806.5).
- Prescriptive requirements for footings supporting walls of light frame construction (IBC Table 1805.4.2, UBC Table 18-I-C)
- Designs employing lateral bearing (IBC Section 1805.7, UBC Section 1806.8)

In general, the drafting committee for this chapter tried to maintain any requirement that appeared in any one of the model codes, and to coordinate the seismic requirements with the NEHRP Provisions. Thus, unless otherwise indicated in the analysis, the provisions that are new to users of the UBC appeared in at least one of the other model codes, and new seismic requirements were recommended by the Code Resource Development Committee (CRDC).

The following analysis of this chapter is not intended to be a comprehensive point-by-point comparison of the 2000 IBC to the 1997 UBC, but summarizes the contents of the general sections and highlights some of the of differences from the UBC.

1801 General

This section sets the scope and lays out general requirements for the design of foundations.

1801.2.1 Foundation design for seismic overturning. This section was added to clarify that where strength design loads are used to size the foundations, the seismic overturning moment can be reduced. This was done in recognition of the fact that the seismic loads in Chapter 16 are based on strength design, not allowable stress design.

1802 Foundation and Soils Investigations

The reorganization of this section consolidates all the conditions for which a soils investigation is required into Section 1802.2, and for the most part, consolidates what information is required to be included in a soils report into Section 1802.6.

1802.2 Where required. The intent of the exception to this section is to allow the building official some flexibility in requiring a soils report, where the soil conditions of a site are already known from other soil reports. The language is discretionary, allowing the building official to exercise judgement as to whether or not the existing data is satisfactory.

1802.2.3 Groundwater table. The revision of this section may result in significant changes in standard foundation construction. In order to avoid requiring a soils report to demonstrate that the groundwater is more than 5 feet below the bottom of floors below grade, the floor and walls below grade must be waterproofed in accordance with Section 1806.3.

1802.2.6 Seismic Design Category C. Whereas the 1997 UBC only required seismic-related soils investigations for Seismic Zones 3 and 4, this section requires an evaluation of the potential for liquefaction, slope instability, and surface rupturing starting in Seismic Design Category C (roughly corresponding to Zone 2). This reflects a concern by the CRDC that significant ground motion can occur even in moderate seismic areas.

1802.2.7 Seismic Design Category D, E or F. The soils investigation must evaluate additional potential geotechnical hazards in Seismic Design Categories D through F, including additional loads on basement and retaining walls due to earthquake motions.

1803 Excavation, Grading and Fill

Some of the requirements in this section relating to excavations, grading, and placement of fill materials were contained in Chapter 33 of the 1997 UBC.

1803.3 Site grading. While it is recognized that there is a need to drain surface water away from foundations, there is some disagreement over how much slope is required to accomplish this. The 1997 UBC required the top of foundations to be 12 inches plus 2 percent above the point of drain line discharge (Section 1806.5.5). Depending on soil and climate conditions, a 2-percent slope may be adequate and is allowed by the exception to this section. However, as a result of committee and membership actions in 1999, the general rule is that the ground must be graded so that there is a one unit vertical in 20 units horizontal (approximately 5 percent) slope away from the foundation, which is consistent with the provisions in one of the other model codes.

1804 Allowable Load-bearing Values of Soils

This section specifies the soil load bearing values that can be assumed in design, along with the allowable lateral bearing and lateral sliding values. One improvement in format is to move many of the provisions that were in footnotes in Table 18-I-A in the 1997 UBC into the code text of the 2000 IBC.

The presumptive load bearing values of soils generated a lot of discussion among the committee and at public hearings. The model codes take different approaches to obtain the values in the table, and so, they vary widely. It was ultimately decided to take a simpler approach than is used in the UBC, and use a single given value for allowable soil bearing, which is not modified for depth or width of footings. However, the increase in the values in IBC Table 1804.2 over the UBC allowable values does not make up the total difference for the increases that were allowed in the UBC for additional footing width or depth. This is because it was believed that the initially proposed values were too high, particularly for the clay-type soils (Item 5 in IBC Table 1804.2). Although the tabular values are allowed to be increased for wind or seismic load combinations, the result is that footings previously designed using the UBC soil bearing values will most likely be larger under the 2000 IBC provisions.

1805 Footings and Foundations

Contains the design requirements for footings and foundations, including minimum footing size and depth, setback distance from slopes, prescriptive foundation wall designs, designs employing lateral bearing (pole designs), and design for expansive soils.

1805.4.1.1 Design loads. Defines which loads must be accounted for, and clearly allows the use of reduced live loads in the design of foundations. The 1997 UBC was silent on the issue, which led to some confusion as to what was required.

1805.4.2.2 Footing seismic ties. Requires interconnection of individual spread footings in buildings in Seismic Design Categories D through F if the footings are placed on Site Class E or F soils. This is similar to the UBC requirement to tie individual pile caps together. The intent is to minimize differential settlement and spreading of the footings and to allow for localized differences in soil properties by ensuring that the foundation acts as a single unit under earthquake loads.

1805.5. Foundation wall drainage. Provides prescriptive designs for foundation walls constructed of masonry or concrete. The walls must be laterally supported at the top and the bottom, and meet the criteria in the tables. Although these tables have been in use in other areas of the country, there have been questions raised as to whether or not they are adequate for seismic design.

1805.5.6 Pier and curtain wall foundations. This all new "pier and curtain wall foundation" system may not be familiar to many users of the UBC, but it is commonly found in the eastern United States. The specific design provisions included in the 2000 IBC are based on language from one of the other model codes. This system is not a deep foundation system, but another type of foundation wall system (see IBC Section 1805.5). In order to better understand this new system, the term "pilasters" may be substituted for the term "piers" when applying this section.

In addition to the limitations specified in the code, it is recommended that the unbalanced backfill be limited to 2 feet for solid masonry, and 1 foot for hollow masonry. This limitation appears in the corresponding section of the *International Residential Code.*

Figure R404.1.5(1) of the *International Residential Code* illustrates an example of typical construction. Note that many of the items shown in the figures are not explicitly required by the code. In particular, the straps at the top and bottom of the pilasters and the plates connecting the sill plate to the rim joists. However, a design should include components corresponding to those in the figures in order to provide complete load path continuity.

1805.6 Foundation plate of sill bolting. The requirements for bolting of foundation sill plates have been moved to the chapter on wood construction, IBC Chapter 23 (see Sections 2308.6, 2308.12.8, and 2308.12.9). This was done to clarify that the prescriptive anchor bolt provisions only apply to conventional wood construction. Anchor bolts must be engineered where conventional construction is not used.

1805.8 Design for expansive soils. Addresses the requirements for design of foundations in areas with expansive soils. Two new sections have been added to allow the expansive soil to be removed or stabilized in lieu of providing special foundation designs. These alternatives provide some flexibility in dealing with expansive soils.

1805.9 Seismic requirements. The requirements for minimum reinforcement in foundations in Seismic Design Categories C through F have been moved to Section 1910.4.4, which contains the requirements for plain concrete. This should reduce confusion as to whether these are considered plain concrete or reinforced concrete.

1806 Dampproofing and Water proofing

Contains detailed requirements for waterproofing and dampproofing foundations, to prevent penetration of water or moisture from the ground into the building. Waterproofing is required for those sites where there is a high water table and an engineered drainage system is not provided. Otherwise, dampproofing is required for floors and walls below grade. Note that occupancy groups other than residential or institutional need not provide waterproofing or dampproofing, where it can be shown that omission of dampproofing "is not detrimental to the building or occupancy". This allows design flexibility where moisture intrusion is not deemed to be a problem. These issues were only generally addressed in the body of the 1997 UBC (see Sections 1402.4 and 1804.7) with no details on how to construct the waterproofing or dampproofing. However, requirements that are very similar to those in the 2000 IBC were contained in Appendix Chapter 18 of the UBC.

1806.4 Subsoil drainage system. This section requires subsoil drainage systems for buildings in the form of footing drains and a drainage mat below slabs-on-ground. These drains are deemed to be adequate to keep the moisture level in the soil low enough to use the lateral soil loads specified in Table 1610.1 to design foundation walls, without additional hydrostatic loads. The 1997 UBC contained similar provisions in Appendix Chapter 18, Section 1825.

1807 Pier and Pile Foundations
1808 Driven Pile Foundations
1809 Cast-in-place Concrete Pile Foundations
1810 Composite Piles
1811 Pier Foundations

These re-formatted sections cover the requirements for all deep foundation systems (piles and piers). New definitions have been added to clarify the terms used in Section 1807, which also contains all the requirements that are common for all types of piles and piers. Sections 1808, 1809, and 1810 cover the more specific requirements for driven piles, cast-in-place piles, and composite piles, respectively. Section 1811 covers the requirements that are specific to pier foundations. For the most part, the requirements in these sections are based on the Board for Coordination of the Model Codes (BCMC) report on Pile Foundation Systems published in July, 1979, as adopted by the other model codes. The exception is the seismic requirements, which are based on the 1997 NEHRP provisions. The provisions in the 2000 IBC cover more deep foundation types and are more detailed than the requirements in the UBC. Required material properties (e.g., allowable concrete or steel stresses) were also added to types of piles where none were specified in any of the model codes, and some requirements were modified as compared to the UBC or other model codes. The intent was to coordinate all the material property requirements, not just the new ones, in order to eliminate conflicts or inconsistencies.

1807.1 Definitions. One major change from the 1997 UBC was to add new definitions for piles and piers, and to standardize the definitions of other terms that are inconsistently used by the design, enforcement, and scientific communities. As defined in the IBC, piles are relatively slender (long in comparison to their cross-sectional dimension), whereas piers are relatively stocky (short in comparison to their cross-sectional dimension). The definitions were derived by balancing the definitions found in the following references with existing code language already in use.

1807.2.4 Stability. Clarifies that for pile or pier groups to be considered to provide lateral stability, they must meet the radial spacing requirements defined herein. With the exception of smaller one- and two-family dwellings, foundation walls are required to be supported by two lines of piles or piers. These should provide the building official with better guidelines as to what is acceptable.

1807.2.7 Splices. Specifies the requirements for splicing of piles. One provision that raised questions during the drafting process is the second sentence of the section:

> "Splices shall develop not less than 50 percent of the least capacity of the pier or pile in bending."

While this may appear to be allowing the pile or pier to be underdesigned in bending, the preceding sentence does require the splice to be able to transmit the driving and service loads acting on the pile or pier at that location. The 50 percent requirement actually provides more strength where the bending moments are low, since it is based on the capacity of the pile or pier, not the design loads.

1807.2.8.3 Load tests. Specifies the standards to be used to load test piles or piers, where compressive loads that are higher than those allowed in other sections of the code are used in design. Questions were raised at the public hearings as to whether or not ASTM D 4945, which is a dynamic test, is sufficient by itself to verify the pile capacity. Many standards, including ASTM D 4945, indicate that a dynamic test may not be sufficient without a static test (ASTM D 1143) to calibrate the results, yet leave it up to the design engineer to decide if the dynamic test alone is sufficient. Other standards require a static load test to calibrate the dynamic test. Section 1807.4 of the 1997 UBC only refers to a static load test.

1807.2.8.5 Uplift capacity. Gives both designer and building official needed guidance on the design of piles or piers for uplift. Although the 1997 UBC was silent on the requirements, the IBC requires a test or approved method of analysis, with a safety factor of three. The capacity of pile or pier groups is also limited to two-thirds of the weight of the group and the soil contained in the group. This is consistent with requirements in other sections of the code on uplift and overturning, where the dead-load resistance is limited to two-thirds of the weight.

1807.2.9 Lateral support. As compared to the 1997 UBC, this section provides needed guidance to the designer and building official on what constitutes adequate lateral support for piles and piers. Section 1807.2.9.1 specifies that any soil other than fluid soil is allowed to be considered to provide lateral support to prevent buckling of piles or piers, and Section 1807.2.9.3 establishes the acceptance criteria for tests that establish the allowable lateral load.

1807.2.18 Use of existing piers or piles. Allows the reuse of existing piles or piers where sufficient information is submitted to the building official that demonstrates they are adequate. While the 1997 UBC was silent on this issue, the IBC introduces flexibility for both the building designer and the building owner to make use of existing materials where it is reasonable to do so.

1807.2.23 Seismic design of piers or piles. Specifies the requirements for pile or pier designs in Seismic Design Categories C through F. Whereas the 1997 UBC required interconnection of "individual pile caps and caissons of every structure subjected to seismic loads" regardless of seismic zone, the 2000 IBC requires interconnection of pile caps, anchorage of the piles to pile caps, transverse reinforcement in the pile, strength of pile splices, consideration of group effects, and a consideration of nonlinear interaction of the pile and the soil starting in Seismic Design Category C. This again reflects the CRDC's concern that significant ground motions can occur in Seismic Design Category C, despite the approximate correspondence to Seismic Zone 2 in the 1997 UBC. Additional requirements are imposed on piles and piers in Seismic Design Categories D through F, including a requirement that the upper portion of piles be detailed as special moment resisting frame columns, in order to prevent failure of the piles under severe ground motions.

1808 Driven Pile Foundations

1808.2.2.2 Precast nonprestressed piles. These sections specify minimum reinforcement for precast nonprestressed and prestressed piles, respectively. Consistent with the CRDC's concern for anticipated ground motions, special reinforcing requirements start in Seismic Design Category C, with additional requirements imposed in Seismic Design Categories D through F.

1808.2.3.2 Design. The IBC does not include the 1997 UBC requirement for an absolute limit (12,600 psi) on the allowable axial stresses in structural steel piles. The need for this limit could not be substantiated.

1808.3.4 Dimensions of steel pipe piles. The IBC replaces the requirement in the 1997 UBC for a minimum ¼-inch thickness for steel pipe piles with a requirement for a minimum amount of cross-sectional area per 1000 pounds of driving force. This is a more rational approach and gives guidance to both the designer and the building official as to what is adequate.

1808.3.5 Design in Seismic Design Category D, E or F. Specifies a maximum unsupported flange width-to-thickness ratio for structural steel piles in Seismic Design Categories D through F. The maximum ratio is based on the requirements for other compression members in Section 2213 of the IBC, and is consistent with the CRDC intent to treat piles in the same manner as other compression members.

1809 Cast-in-place Concrete Pile Foundations

1809.1 General. This section covers the requirements that are common to all cast-in-place concrete pile foundations. As is true throughout this chapter, additional seismic design requirements start in Seismic Design Category C (see analysis for Section 1802.2.6 relating to Seismic Design Category C), with further requirements imposed in Seismic Design Categories D through F. One requirement to be noted is that the minimum required reinforcement must extend for the entire flexural length of the pile in Seismic Design Categories C through F. Although flexural length is undefined in the IBC, the 1997 UBC (from which the requirements were derived) defines flexural length as the "length of the pile from the first point of zero lateral deflection to the underside of the pile cap or grade beam."

1809.2 Enlarged base piles. The requirements for enlarged base piles will be new to users of the 1997 UBC, as this type of pile did not appear in the UBC. Enlarged base piles are defined in the IBC as "cast-in-place concrete piles constructed with a base that is larger than the diameter of the remainder of the pile." The enlarged base is intended to spread the end-bearing loads in the pile over a larger area of soil, thereby increasing the capacity.

1809.3.2 Dimensions. Drilled or augered uncased piles are limited to a length-to-diameter ratio of 30, a requirement that is retained from the 1997 UBC. The UBC has an exception allowing greater length-to-diameter ratios if there is a soils report that justifies it. A similar exception is in the IBC, but there is some additional assurance that piles are installed properly through the requirement that the installation is to be "under the supervision" of a registered design professional who is knowledgeable about soil mechanics and pile foundations. This registered design professional must also "certify" to the building official that the piles were installed in accordance with the approved design. The building official will need to determine what is considered to be adequate "supervision" and "certification."

1809.4 Driven uncased piles. The requirements for driven uncased piles will also be new to users of the 1997 UBC, since this type of pile did not appear in the UBC. Driven uncased piles are defined in the 2000 IBC as piles that are "constructed by driving a steel shell into the soil to shore an unexcavated hole that is later filled with concrete." After the steel shell is driven and the soil within it is excavated, it is removed while the concrete is being placed.

1809.4.2 Dimensions. Driven uncased piles are placed under the same length-to-diameter limitation as drilled or augered uncased piles. Since the end condition is the same in both cases (the ultimate result is an uncased pile), it is reasonable to limit them in the same manner.

1809.7 Caisson piles. The requirements for this section are new to users as this type of pile did not appear in the 1997 UBC. Caisson piles are cast-in-place concrete piles that are socketed into bedrock at their tip. Above the bedrock, caisson piles look like cased piles. Below the bedrock, they are uncased. A steel core provides continuity across the bedrock/soil interface.

1810 Composite Piles

This section contains the requirements for another new category of piles, composite piles. These are piles that are constructed as composites of two or more of the pile types defined in Section 1807.1. Composite piles must meet the requirements for each type of pile, as prescribed in Sections 1808 and 1809.

1811 Pier Foundations

Because the 1997 UBC did not differentiate between piles and piers, the requirements for piers contained in this section will be new to those users familiar with the UBC. As defined in Section 1807.1, piers are relatively short in comparison to their cross-sectional dimension, although lengths that exceed 12 times the cross-sectional dimension are permitted in some cases.

1811.4 Reinforcement. Sections 1809.1.2.1 and 1809.1.2.2 of the IBC require that piers be reinforced as for cast-in-place concrete piles. However, small one- and two-family dwellings need not provide full seismic detailing, as it is recognized that the seismic demand is lower for these types of structures. The 1997 UBC did not contain corresponding exceptions, which probably resulted in unreasonable requirements for these small structures.

1811.8 Concrete. In general, concrete piers must be designed as columns. However, very short piers or piers with adequate lateral support from the soil may be designed as concrete pilasters. This recognizes the difference in behavior of piers versus piles under load.

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Chapter 19 of the IBC Concrete

Introduction

Chapter 19 of the 2000 IBC is based on the 1999 edition of ACI 318 Building Code Requirements for Structural Concrete (ACI 318-99) (Reference 1), whereas Chapter 19 of the 1997 UBC is based on ACI 318-95 (Reference 1). Two readily noticeable changes in the makeup of IBC Chapter 19 are:

1. The chapter is much shorter in length
2. Modifications to ACI 318 provisions have been greatly reduced in number.

The reason the chapter is shorter in length dates back to the Working Draft of the IBC, published in May 1997. It was at this early stage the drafting committee decided the only portions of ACI 318 necessary to reproduce in the IBC were the inspection-related provisions. Thus only portions of Chapters 2 through 7 of ACI 318-99 are reproduced in the IBC. Appropriate changes in format have been made to conform to the IBC style. The remainder of ACI 318-99 is adopted by reference. This is in keeping with the recent trend of adoption of national consensus standards by reference into the model codes. The reproduction of much of Chapters 2 through 7 is for the convenience of the inspector who, in smaller jurisdictions, may not have easy access to the ACI 318 Standard. The engineering provisions of ACI 318 are not transcribed because it is assumed that design professionals and structural plan reviewers would normally have ready access to the Standard. It is also thought that the design professional should have the benefit of the official ACI 318 Commentary (ACI 318R-99) which is published under the same cover with the ACI 318 Standard.

The reason why there are far fewer modifications to ACI 318 provisions in the IBC also goes back to the Working Draft published in May 1997. This document adopted ACI 318-95 by reference, subject to a large number of fairly significant modifications. Many of these modifications reflected changes made to the ACI 318-95 provisions in the 1997 UBC. By far the majority of these modifications were to the provisions of Chapter 21 (Special Provisions for Seismic Design) of ACI 318-95. This situation continued through the First Draft and the Final Draft of the IBC. Faced with this situation, ACI Committee 318 carefully considered the modifications and adopted many of them (some with significant amendments) into ACI 318-99. This minimized the need for too many amendments to ACI 318-99 when it was approved for adoption into the 2000 IBC.

Chapter 19 of the 2000 IBC includes substantive provisions that are in addition to those of the ACI 318 Standard, as does Chapter 19 of the 1997 UBC. This additional material is contained in Sections 1911 Minimum slab provisions, 1912 Anchorage to concrete-allowable stress design, 1913 Anchorage to concrete-strength design, 1914 Shotcrete, and 1915 Reinforced gypsum concrete.

Table 1: Organization of the concrete chapters of the 2000 IBC and the 1997 UBC

IBC 2000	UBC 1997
1901 General 1902- ACI 318-99 1907 Chapters 2-7	1900 General 1901 Scope 1902- ACI 318-95 1907 Chapters 2-7
—	1908-1920 ACI 318-95 Chapters 8-20
1908 Modifications to ACI 318	—
1909 Structural plain concrete	1922 Structural Plain Concrete
1910 Seismic design provisions	1921 Reinforced Concrete Structures Resisting Forces Induced by Earthquake Motions
1911 Minimum slab provisions	1900.4.4 Minimum slab thickness
1912 Anchorage to concrete—Allowable stress design	1923 Anchorage to Concrete
1913 Anchorage to concrete—Strength design	
1914 Shotcrete	1924 Shotcrete
1915 Reinforced gypsum concrete	1925 Reinforced Gypsum Concrete
1916 Concrete-filled pipe columns	—
	1926- ACI 318-95 1928 Appendices A-C

Chapter 19 of the IBC also includes Section 1916 on Concrete-filled pipe columns whereas the UBC does not contain any provisions on these elements. Table 1 presents a direct comparison of the contents of Chapters 19 of both codes and the different sections are discussed in sequence in the following pages. Section 1908 contains modifications to ACI 318-99 provisions and its adoption results in differences in certain key provisions in both chapters which are clearly pointed out.

1901 Adoption of ACI 318-99 by Reference

Section 1901.2 states that "Structural concrete shall be designed and constructed in accordance with the requirements of this chapter and ACI 318 as amended in Section 1908 of this code." Chapter 35 specifies the particular edition of ACI 318 that must be used. The adoption of ACI 318-99 into the IBC entails several important differences between the 1997 UBC Chapter 19 provisions (which are transcribed, with amendments shown in italics, from ACI 318-95) and the corresponding provisions of the IBC. Changes in Sections 1902-1907, transcribed in the IBC, are discussed in the next section. Other significant changes are briefly described below:

1. **ACI 318-99 Section 7.6.7.1 (1997 UBC Section 1907.6.7.1).** A reduction has been made in the allowable spacing of prestressing strands for concrete strengths at the transfer of prestress of 4000 psi or greater, based on several research projects sponsored by the Federal Highway Administration (References 2, 3).

2. **ACI 318-99 Section 7.10.4.5 (1997 UBC Section 1907.10.4.5).** Splice requirements have changed for epoxy-coated and plain

spirals. Lap splice lengths have been modified; full mechanical or welded splices are now allowed.

3. **ACI 318-99 Section 10.6.4 (1997 UBC Section 1910.6.4).** Provisions concerning distribution of flexural reinforcement for crack control have been totally rewritten. The *z* factor requirements of the 1995 and previous code editions have been replaced. The maximum bar spacing is now specified directly.

Actual crack widths in structures are highly variable. In previous codes, provisions were given for distribution of reinforcement that were based on empirical formulas using a calculated crack width of 0.016 in. The new provisions for spacing are intended to restrict surface cracks to a width that is generally acceptable in practice but may vary widely in a given structure.

The role of cracks in the corrosion of reinforcement is controversial. Research shows that corrosion is not clearly correlated with surface crack widths in the range normally found with reinforcement stresses at service load levels (References 4, 5). For this reason, the former distinction between interior and exterior exposure has been eliminated.

4. **ACI 318-99 Section 11.2.1 (1997 UBC Section 1911.2.1).** In the 1995 edition of ACI 318, reference to torsion was omitted for cases where lightweight concrete affects design values. This has now been rectified in ACI 318-99.

5. **ACI 318-99 Sections 11.3.3 and 11.5.6.3 (1997 UBC Section 1911.5.6.2).** ACI 318-95 had no specific provisions for shear strength of circular columns, whereas the 1997 UBC Section 1911.5.6.2 does contain a specific provision. The newly added Section 11.3.3 of ACI 318-99 specifies the computation of the contribution of concrete to the shear strength of a circular member. The newly added Section 11.5.6.3 specifies how to compute the contribution of shear reinforcement to shear strength when circular hoops, ties or spirals are used. The ACI 318-99 and IBC provision is somewhat different from the existing 1997 UBC provision.

6. **ACI 318-99 Section 14.8 (1997 UBC Section 1914.8).** This section presents an alternative to the requirements of ACI 318-99 Section 10.10 (1997 UBC Section 1910.10). The UBC, since its 1988 edition, has had a section on alternate design of slender walls that was not contained in ACI 318 until its 1999 edition. The new Section 14.8 is based on the 1997 UBC Section 1914.8. The following modifications have been included:

   - Changes have been made in nomenclature and wording to comply with the ACI 318 style.
   - The whole procedure has been limited to out-of-plane flexural effects on simply supported wall panels with maximum moments and deflections occurring at midspan.
   - The procedure has been converted from one based on working stresses to one based on factored load stresses.
   - The procedure has been made as compatible as possible with the procedure for obtaining the cracking moment and the effective moment of inertia in Section 9.5.2.3 of ACI 318 (Section 1909.5.2.3 of the 1997 UBC).

7. **ACI 318-99 Section 18.8.3 (1997 UBC Section 1918.8.3).** The joint ACI-ASCE Committee 423 on prestressed concrete has long recommended the waiving of the ACI 318 requirement for a total amount of prestressed and non-prestressed reinforcement sufficient to develop 1.2 times the cracking load for two-way slab systems with unbonded tendons (Reference 6). ACI 318-99 Section 18.8.3 now permits the waiving of this requirement for two-way, unbonded post-tensioned slabs.

8. **ACI 318-99 Section 18.9.3.3 (1997 UBC Section 1918.9.3.3).** ACI 318-95 requirements for minimum bonded reinforcement in negative moment areas of two-way flat plates with unbonded tendons result in less reinforcement than recommended by research at interior columns supporting rectangular panels. Section 18.9.3.3 has been revised to increase the minimum reinforcement requirement over interior columns for rectangular panels in one direction. For square panels, the revision doubles the minimum reinforcement requirement over exterior columns normal to the slab edge.

9. **ACI 318-99 Sections 18.13, 18.14, 18.15 (1997 UBC Section 1918.13).** Section 18.13 of ACI 318-95 has been modernized and expanded into three sections. They apply to post-tensioned anchorages. There have not been many serious problems with monostrand tendons meeting the PTI Specifications (Reference 7); so the requirements of that Specification are included by reference in Section 18.14.

Much of the new provisions is now directed at the proper anchorage of large multi-strand post-tensioning tendons using the very compact proprietary anchorage systems now in widespread usage. Such tendons have been widely used in bridge systems and their use resulted in a number of failures, many incidences of severe cracking requiring repair, and a number of major claims, delays and lawsuits. A comprehensive study was summarized in NCHRP (National Cooperative Highway Research Program) Report 356 (Reference 8), and design and construction provisions were adopted in the 1994 AASHTO Standard Specifications for Highway Bridges (Reference 9). Previous AASHTO Specifications and ACI Building Codes gave little guidance to control of bearing, bursting and spalling stresses in the tendon anchorage areas. Most of the modern compact tendon anchorage devices for multiple strands require substantial confining reinforcement immediately around the anchor device and many require supplemental face steel in the anchorage region to fully develop strength and control cracking.

The growing usage of multi-strand tendons in building-type structures and the experience of AASHTO made it timely to expand ACI 318 coverage in this area. It was decided by Committee 318 to not utilize the full AASHTO provisions but to condense them for building-type applications. The AASHTO acceptance test procedures for special anchorage devices are adopted by reference. Detailed design requirements given in AASHTO Specifications (Reference 9) are cited in the ACI 318 Commentary for guidance. This expansion of Section 18.13 should result in more consistent, safer and better detailed tendon anchorage zones.

10. **ACI 318-99 Section 18.16, 18.17 (1997 UBC Section 1918.14 and 1918.15, respectively).** The sections on corrosion protection

of unbonded prestressing tendons and on post-tensioning ducts have been rewritten to provide surer protection of unbonded prestressing strands against corrosion.

11. **ACI 318-99 Section 18.22 (no corresponding 1997 UBC section).** This section on external post tensioning is new in the 1999 edition of ACI 318. External attachment of tendons is a versatile method of providing additional strength, or improving serviceability, or both, in existing structures. It is well suited to the repair or upgrade of existing structures and permits a wide variety of tendon arrangements. Additional information on external post tensioning is given in Reference 10. The 1997 UBC does not contain any provisions concerning external posttensioning.

The adoption of ACI 318-99 by reference into the 2000 IBC results in the following important differences between the 1997 UBC Section 1921, Reinforced Concrete Structures Resisting Forces Induced by Earthquake Motions, and the corresponding provisions of the 2000 IBC:

1. **ACI 318-99 Section 9.3.4 (1997 UBC Section 1909.3.4).** There is a new requirement that the strength reduction factor for shear in diaphragms shall not exceed the minimum strength reduction factor for shear used for vertical components of the primary lateral-force-resisting system. Also, the strength reduction factor of 0.85 for shear in joints has now been extended to shear in diagonally-reinforced coupling beams. The requirements apply to structures that rely on special moment resisting frames or special reinforced concrete shearwalls to resist earthquake effects.

2. **ACI 318-99 Section 21.0 (1997 UBC Section 1921.0).** The definitions of reinforcement ratios ρ_n and ρ_v have been clarified in a change that has been needed for quite some time.

3. **ACI 318-99 Section 21.1 (1997 UBC Section 1921.1).** A quantity termed "design displacement" has now been defined. The design displacement is an estimate of the maximum lateral displacement that is expected in the design-basis earthquake. The design displacement is calculated using static or dynamic linear-elastic analysis under code-specified actions considering effects of cracked sections, effects of vertical forces acting through lateral displacements, and modification factors to account for expected inelastic response. The design displacement generally is a few times as large as the displacement calculated from design-level forces applied to a linear-elastic model of the building.

Under the definition of seismic hook, the use of a 90-deg hook instead of a 135-deg hook is now permitted in circular column hoops.

ACI 318-99 has also introduced terminology that defines framing types on the basis of anticipated levels of inelastic response in a manner that is compatible with terminology commonly used in model codes. Thus, three categories of structural walls have been defined: ordinary reinforced concrete structural wall, ordinary structural plain concrete wall and special reinforced concrete structural wall.

4. **ACI 318-99 Section 21.2.1 (1997 UBC Section 1921.2.1).** For compatibility with terminology commonly used in recent editions

of U. S. model codes other than the UBC, provisions applicable in regions of low, moderate and high seismic risk are now made applicable to structures assigned to low, intermediate and high seismic performance or design categories, respectively. Where the design seismic forces are computed using provisions for intermediate or special concrete systems, the requirements of Chapter 21 for intermediate or special systems, as applicable, must be satisfied, irrespective of the seismicity of the site where the structural system may be used. These sections also specify that for structures assigned to intermediate seismic design categories, intermediate or special moment frames, or ordinary or special reinforced concrete structural walls shall be used to resist forces induced by earthquake motions. For structures assigned to high seismic design categories, special moment frames, special reinforced concrete structural walls, and diaphragms and trusses complying with ACI 318-99 Sections 21.2 through 21.8 must be used to resist forces induced by earthquake motions.

5. **ACI 318-99 Section 21.2.4.2 (1997 UBC Section 1921.2.4.2).** ACI 318-99 limits the compressive strength of lightweight concrete to 4000 psi. Lightweight aggregate concrete with higher design compressive strength is permitted "if demonstrated by experimental evidence that structural members made with that lightweight aggregate concrete provide strength and toughness equal to or exceeding those of comparable members made with normal-weight aggregate concrete of the same strength." The 1997 UBC imposes an absolute upper limit of 6000 psi on the design compressive strength of lightweight concrete, a requirement which is not part of the IBC. The ACI 318 restrictions were judged sufficient to provide structurally safe buildings that incorporate structural lightweight aggregate concrete. With today's technology, high-performance structural lightweight concrete is being used in many parts of the world in various applications at strengths far exceeding 6000 psi.

6. **ACI 318-99 Section 21.2.6 (1997 UBC Section 1921.2.6).** In ACI 318-99, the definition of a Type 2 splice is as follows: "Type 2 mechanical splices shall develop the specified tensile strength of the spliced bar." In the 1997 UBC, a Type 2 splice is a mechanical connection that develops in tension the lesser of 95 percent of the ultimate tensile strength or 160 percent of the specified yield strength f_y of the bar.

The 1997 UBC does not allow welded or Type 1 mechanical splices (splices that are capable of developing just 125 percent of the specified yield strength of the spliced reinforcing bars) on billet steel A 615 or low-alloy A 706 reinforcement within an anticipated plastic hinge region, within a distance of one beam depth on either side of the plastic hinge region or within a joint, in Seismic Zones 2, 3, and 4. ACI 318-99 and the IBC prohibit welded and Type 1 mechanical splices "within a distance equal to twice the member depth from the column or beam face or from sections where yielding of the reinforcement is likely to occur as a result of inelastic lateral displacements" in structures assigned to high seismic design categories. Type 2 mechanical splices are allowed to be used at any location by both sets of provisions.

7. **ACI 318-99 Section 21.4.2 (1997 UBC Section 1921.4.2).** This section now requires that closely spaced transverse reinforcement

be provided along the length of longitudinal bar lap splices in columns.

8. **ACI 318-99 Section 21.4.3.2 (1997 UBC Section 1921.4.3.2).** If the thickness of the concrete outside the confining transverse reinforcement in a column exceeds 4 inches, additional transverse reinforcement is now required by this section.

9. **ACI 318-99 Section 21.4.4.2 (1997 UBC Section 1921.4.4.2).** This section permits longitudinal spacing of transverse reinforcement in regions of potential plastic hinging to be increased from the previous maximum value of 4 inches to as much as 6 inches in cases where horizontal spacing between hoop legs or cross ties is reduced from the maximum permitted spacing of 14 inches.

10. **ACI 318-99 Section 21.6.5 (1997 UBC Section 1921.6.6).** ACI 318-99 has adopted a design procedure for shear walls for structures assigned to high seismic design categories, subjected to combined bending moments and axial forces, that represents an evolution of the 1997 UBC design procedure. The ACI procedure uses neutral axis depth, rather than compressive strains in the concrete, as the quantity that drives the trigger for requiring boundary elements. The ACI procedure is significantly simpler. Based on limited studies, it is expected to produce shear wall designs remarkably similar to those of 1997 UBC, except possibly under high axial loads.

11. **ACI 318-99 Section 21.6.7 (1997 UBC Section 1921.6.10).** ACI 318-99 has adopted the 1997 UBC Section 1921.6.10 on coupling beams with a few significant modifications. The 1997 UBC requires that coupling beams with $l_n/d<4$ and with factored shear force V_u exceeding $4\sqrt{f'_c}\,b_w d$ shall be reinforced with two intersecting groups of symmetrical diagonal bars. Experiments show that diagonal reinforcement is effective only if the bars are placed with a large inclination. Therefore, ACI 318-99 restricts diagonally-oriented reinforcement to coupling beams having aspect ratios $l_n/d<4$. In the opinion of ACI 318, coupling beams with an aspect ratio l_n/d between 2 and 4 are not deep enough to merit a mandatory requirement of diagonally-oriented reinforcement. Thus, ACI 318-99 specifies that coupling beams with $l_n/d<2$ and with V_u exceeding $4\sqrt{f'_c}\,b_w d$ shall be reinforced with two intersecting groups of diagonally placed bars "symmetrical about the midspan unless it can be shown that loss of stiffness and strength of the coupling beams will not impair the vertical load carrying capacity of the structure, egress from the structure, or the integrity of the nonstructural components and their connections to the structure." The escape clause is incorporated from the 1997 NEHRP Provisions (Reference 11). Also, the 1997 UBC requires that reinforcement parallel and transverse to the longitudinal axis shall be provided and, as a minimum, shall conform to Sections 1910.5, 1911.8.9 and 1911.8.10. ACI 318-99 omits Section 10.5 (same as UBC Section 1910.5 Minimum Reinforcement of Flexural Members) from the corresponding list, because when diagonally-oriented reinforcement is used, the function of the additional reinforcement specified is to contain the concrete outside the diagonal cores in the event of damage caused by earthquake excitation.

12. **ACI 318-99 Section 21.7 (1997 UBC Section 1921.6.11, 1921.6.12).** Diaphragm design provisions for structures in regions of high seismic risk (or assigned to high seismic design categories) have been completely and extensively rewritten in ACI 318-99. The 1997 UBC allows a cast-in-place topping on a precast floor system to serve as the diaphragm, provided the cast-in-place topping acting alone is proportioned and detailed to resist the design forces. ACI 318-99 allows this design option, but also allows composite design of the cast-in-place topping and the precast floor system. There is a new requirement that reinforcement in the topping must resist the entire in-plane shear. There are specific limitations on this reinforcement. Also, the strength reduction factor for shear in diaphragms shall not exceed the minimum strength reduction factor for shear used for vertical components of the primary lateral-force-resisting system.

13. **ACI 318-99 Section 21.9 (1997 UBC Section 1921.7).** The deformation compatibility requirements of Section 1617.6.4.3 of the IBC are essentially the same as those of the 1997 UBC Section 1633.2.4, except that the design earthquake displacement is obtained from the equivalent of s by applying an amplification of C_d/I (C_d = deflection amplification factor, I = importance factor) rather than 0.7R. Also, the detailing requirements for frame members designated not to be part of the lateral-force-resisting system are somewhat modified from Section 21.7 of ACI 318-95 to Section 1921.7 of the 1997 UBC. Section 21.9 of ACI 318-99, adopted into the IBC, is essentially the same as Section 21.7 of ACI 318-95, and does not include the modifications made to this section by the 1997 UBC.

14. **ACI 318-99 Section 21.8 (no corresponding 1997 UBC Section).** The new section 21.8 giving requirements for foundations supporting buildings assigned to high seismic design categories was added to ACI 318 in 1999. The section represents a consensus of a minimum level of good practice in designing and detailing concrete foundations including piles and drilled piers and caissons. It is generally desirable that inelastic response in strong ground shaking occur above the foundations, as repairs to foundations can be extremely difficult and expensive. Section 1805.9 of the IBC requires: for structures assigned to Seismic Design Categories D, E, and F, provisions of ACI 318 Section 21.8.1 to 21.8.3 shall apply when not in conflict with the provisions of Section 1805. Section 1807.2.23.2, Seismic Design Categories D, E, and F, similarly requires that the provisions of ACI 318 Section 21.8.4 shall apply when not in conflict with the provisions of Sections 1807 to 1811. In both Sections 1805.9 and 1807.2.23.2, a minimum value of 3000 psi is imposed on the specified compressive strength of concrete, to conform to the ACI 318 Chapter 21 restriction on the strength of concrete used in members resisting earthquake-induced forces. In both cases Group R Division 3 or Group U Division 1 Occupancies of light frame construction two stories or less in height are exempt.

SECTIONS 1902-1907

The following significant changes from ACI 318-95 to ACI 318-99 have been incorporated in the transcribed IBC Sections 1902-1907, which will cause the affected sections to be different from the corresponding 1997 UBC sections based on ACI 318-95.

1. **Section 1901.4 Construction documents.** Construction documents for structural concrete construction must now include:

   - Minimum concrete compressive strength at time of posttensioning,
   - Stressing sequence for posttensioning tendons,
   - For structures assigned to Seismic Design Category D, E or F, a statement if slab on grade is designed as a structural diaphragm.

2. **Section 1905.6.1 Qualified technicians.** This section contains the new ACI 318-99 requirement that technicians performing code-required tests on fresh concrete in the field, including fabricating strength test specimens (i.e. concrete cylinders), and code-required tests on concrete in the laboratory be qualified to perform such tests. Technicians desiring to perform field tests can demonstrate their qualifications to the satisfaction of the building official by becoming certified by ACI as a "Concrete Field Testing Technician—Grade I," or by meeting the requirements of ASTM C 1077 or a comparable program. Similarly, laboratory technicians can demonstrate their competence by becoming certified by ACI as a "Concrete Laboratory Testing Technician," "Concrete Strength Testing Technician," or by meeting the requirements of ASTM C 1077 or a comparable program.

In the transcribed Sections 1902-1907, the IBC makes a small number of modifications to the provisions of ACI 318-99:

1. **Section 1903.1 General.** The IBC has added the following two sentences: Tests of concrete and the materials used in concrete shall be in accordance with ACI 318 Section 3.8. Where required, special inspections and tests shall be in accordance with Chapter 17. This addition is not in the 1997 UBC.

2. **Section 1903.2 Cement.** This section states that in addition to the cements permitted by ACI 318, cement complying with ASTM C 1157 is permitted. This addition is already included in the 1997 UBC Section 1903.2.

3. **Table 1904.2.1 Air entrainment.** Table 1904.2.1 has an additional footnote b, taken largely from the ACI 318 Commentary Section R4.2.1, that is not part of the ACI 318-95 Table 4.2.1 or the 1997 UBC Table 1904.2.1.

4. **Section 1904.2.2 Concrete properties.** This section has added an exception requiring that for Group R (residential) Occupancies and appurtenances thereto that are in buildings less than four stories in height, normal weight aggregate concrete that is subject to weathering (freezing and thawing), as determined from Figure 1904.2.2, or deicer chemicals shall comply with the requirements of Table 1904.2.2(2). Neither Figure 1904.2.2 nor Table 1904.2.2(2) is part of ACI 318-99. The exception, the table and the figure are not part of the 1997 UBC. These are adopted into the IBC from the *International* (formerly CABO) *One- and Two-Family Dwelling Code* (Reference 12).

5. **Section 1905.1.1 Strength.** This section has added the requirement that for concrete designed and constructed in accordance with Chapter 19, f'_c shall not be less than 2500 psi. This modification is not part of the 1997 UBC.

1908 Modifications to ACI 318-99

7. **1908.1.1.** The first modification prohibits the use of the Alternate Design Method of Appendix A in the seismic design of reinforced (including prestressed) concrete structures. The 1997 UBC does not explicitly impose a similar restriction.

8. **1908.1.2.** The second modification requires the use of the strength design load combinations of ASCE 7-98, as adopted into IBC Sections 1605.2, rather than the strength design load combinations of ACI 318-99, in the seismic design of reinforced concrete structures. This requirement is the same as in the 1997 UBC. There is one important difference, however. The 1997 UBC requires the design loads given by the seismic strength design load combinations of ASCE 7-95 to be amplified by a factor of 1.1. The Working, the First and the Final Drafts of the IBC contained a corresponding requirement that the reduced strength reduction factors of Appendix C of ACI 318, rather than those of Chapter 9, be used in conjunction with the seismic strength design load combinations of ASCE 7-95. This requirement has been deleted from the IBC for reasons outlined in References 13 and 14.

3. **1908.1.3.** This section modifies (a modification not to be found in the 1997 UBC) ACI 318-99 Section 18.9.3 as follows (underlining indicates addition, strike-out indicates deletion):

   "For two-way <u>slab systems</u>, ~~flat plates, defined as solid slabs of uniform thickness~~, minimum area and distribution of bonded reinforcement shall be as follows:"

   The present Section 18.9.3 of ACI 318 relates only to flat plates and not to other two way slab systems. The ACI Commentary to this section states that while recognizing that the behavior of other two-way slab systems is similar to that of the two-way flat plate, a conservative limitation is placed in the code requiring two-way slabs to have minimum reinforcement similar to that in a one-way system "until more complete information is available." This section of the code has been one of the most widely ignored sections in design and practice. Generally, unbonded post-tensioned two-way slab systems (not just two-way flat plates) have been designed according to this section for the past thirty years. The successful performance in practice of these unbonded two-way slab systems have demonstrated clearly that the present practice under ACI 318 Section 18.9.3 and not 18.9.2 provides safe and desirable structures.

7. **1908.1.5, 1908.1.6, 1908.1.7, 1908.1.9.** These modifications add specific design requirements for precast structures assigned to Seismic Design Categories D, E, and F, which are not part of ACI 318-99. Until recently, precast concrete structures could only be

built in Seismic Zones 3 and 4 under the 1994 UBC and prior editions if it could be "demonstrated by experimental evidence and analysis that the proposed system will have strength and toughness equal to or exceeding those provided by a comparable monolithic reinforced concrete structure...". The interpretation, implementation and enforcement of this vague, qualitative requirement was, for obvious reasons, not uniform. The very first set of specific design provisions ever developed in this country for precast concrete structures exposed to high seismic risk appeared in the 1994 edition of the NEHRP Provisions (Reference 11). These provisions, with significant modifications and additions, were adopted into the 1997 UBC. The 1997 UBC provisions (Sections 1921.2.1.6, 1921.2.1.7, 1921.2.2.5, 1921.2.2.6, 1921.2.2.7, 1921.2.7), applicable in Seismic Zones 3 and 4, have been adopted without any further modification in the IBC, and have been made applicable to structures in Seismic Design Categories D, E, and F. The provisions are applicable to frames only (excluding panel systems) and are formulated to emulate monolithic reinforced concrete construction. Reference 15 may be consulted for further details on these provisions.

5. **1908.1.8.** This section of the IBC and Section 1921.2.5.1 of the 1997 UBC permit prestressing tendons to be used to resist earthquake-induced flexural and axial forces in frame members provided:

   (i) The prestress f_{pc} calculated for an area equal to the member's shortest cross-sectional dimension multiplied by the perpendicular dimension, does not exceed the lesser of 700 psi (4.82 MPa) or $f'_c/6$ at locations of nonlinear action. This requirement also originated with the NEHRP Provisions. The 1997 UBC Section 1921.2.5.3 requires f_{pc} not to exceed the lesser of 350 psi or $f'_c/12$. The limits were relax (Reference 16).

   (ii) For members in which prestressing tendons are used together with mild steel reinforcement to resist earthquake-induced forces, prestressing tendons must: (a) not provide more than one-quarter of the strength for both positive and negative moments at the joint face; (b) extend through exterior joints; and (c) be anchored at the exterior face of the joint or beyond. These restrictions are the same as in the 1997 UBC Section1921.2.5.4.

   (iii) Shear strength provided by prestressing tendons is not considered in design. This requirement is the same as in the 1997 UBC Section 1921.2.5.5.

   The prestressing limitations given refer to systems in which the prestressing steel in the frame is not the primary reinforcement, but is there because of the choice of the floor system.

6. **1908.1.10.** This section represents one of the modifications made by the 1997 UBC to ACI 318 requirements, that will not be part of ACI 318-99. The section specifies transverse reinforcement requirements for wall piers, defined in IBC Section 1908.1.5, when they are not designed as part of a special moment frame.

7. **1908.1.11.** This section introduces an important amendment to ACI 318-99 Section 21.9.2.2. The difference between ACI 318 (same as UBC 1997, see Section 1921.7.2.2) and this IBC amendment to ACI 318 is that ACI 318 as well as the 1997 UBC requires that lap splices be located within the middle half of the column height in columns not proportioned to resist earthquake effects, whereas the amendment allows the lap splices to be located anywhere including the column ends, taking designers back to UBC editions prior to 1997 and ACI 318 editions prior to 1995. This amendment is justified because gravity columns are required to sustain only their gravity-load-carrying capacity under the design earthquake displacements, whereas columns forming part of the lateral-force-resisting system are required to sustain full gravity as well as lateral loads under the same displacements. Also, ACI 318-99 requires gravity columns to be reinforced throughout their height with ties at a spacing not to exceed (1) 6 diameters of the smallest longitudinal bar enclosed, (2) 16 tie-bar diameters, (3) one-half the least cross-sectional dimensions of the column, and (4) 6 in. (150 mm). This close tie spacing makes it unnecessary to restrict the lap splice locations.

1909 Structural Plain Concrete

This section reproduces parts of Chapter 22 of ACI 318-99, refers to the rest of it, reformats and rearranges the reproduced text, but otherwise makes only two deviations from ACI 318-99. First, under Section 1909.2 Limitations, the IBC directs the user to Section 1910 (Seismic Design Provisions) for additional limitations on the use of structural plain concrete. Second, an exception is added under Section 1909.4 Design. For detached one- and two-family dwellings and other occupancies less than two stories in height of frame construction, the required edge thickness of ACI 318 (8 inches) is permitted to be reduced to 6 inches, provided the footing does not extend more than 4 inches on either side of the supported wall.

The 1997 UBC Section 1922 on Structural Plain Concrete is transcribed from Chapter 22 of ACI 318-95 (there are no changes in this chapter from ACI 318-95 to ACI 318-99). Only two modifications are made. First, an exception is added under UBC Section 1922.1.1 stating that design according to this UBC section is not required when the minimum foundation for stud walls is in accordance with Table 18-1-C. Second, UBC Section 1922.10 Seismic Requirements for Plain Concrete, is added. The IBC makes a different exception to ACI 318 Chapter 22 requirements, as noted above. Also, the IBC seismic design requirements for plain concrete have been made a part of Section 1910 (Seismic Design Provisions).

1910 Seismic Design Provisions

This section first provides a classification of seismic force resisting systems, in the same manner as the 1997 NEHRP Provisions, Section 9.3. Reinforced concrete moment frames are classified into three categories: ordinary moment frames, intermediate moment frames, and special moment frames. Structural concrete shear walls are classified into four categories: ordinary plain concrete shear walls, detailed plain concrete shear walls, ordinary reinforced concrete shear walls, and special reinforced concrete shear walls. For each of the reinforced concrete structural systems, the applicable provisions of ACI 318-99 Chapter 21 are spelled out, thereby providing much needed coordination with that chapter. Ordinary plain concrete shear walls are specifically required to conform to ACI 318-99 Chapter 22. Detailed plain concrete shear walls are additionally required to contain a specified minimal amount of reinforcement.

Following the above, Section 1910.3 provides specific requirements for structures assigned to Seismic Design Category B. Additional detailing requirements found in the 1997 NEHRP Provisions, but not in the 1997 UBC, are imposed on the ordinary moment frame of reinforced concrete assigned to Seismic Design Category B.

1910.4 Seismic Design Category C. Provides specific requirements for structures assigned to Seismic Design Category C. Ordinary moment frames, ordinary plain concrete shear walls and detailed plain concrete shear walls are prohibited from use in Seismic Design Category C. Specific detailing requirements are given for columns supporting reactions from discontinuous stiff members such as walls. Also, provisions are included for structural plain concrete members in structures assigned to Seismic Design Category C.

1910.4.4.2 Footings. Contains the provisions for plain concrete footings that were found in Section 1806.7 of the 1997 UBC. However, the 2000 IBC requires seismic reinforcement for footings starting in Seismic Design Category C (roughly corresponding to Seismic Zone 2 in the 1997 UBC), whereas the UBC required seismic reinforcement only in Seismic Zones 3 and 4. The amount of reinforcing required is essentially the same between the two codes, as is the required placement. However, the IBC adds exceptions to allow plain concrete footings without longitudinal reinforcement for detached one- and two-family dwellings of light-frame construction, three stories or less in height, regardless of the seismic design category. Note that in the 1997 UBC, it was intended that the minimum reinforcement requirements would only apply to "conventional" footings, not to those that were designed, or for posttensioned slabs-on-ground.

1910.5 Seismic Design Category D, E or F. Gives specific requirements for structures assigned to Seismic Design Categories D, E, and F. The only reinforced concrete structural systems allowed are the special moment frame or the special shear wall. Frame members not proportioned to resist forces induced by earthquake motions are required to conform to Section 21.9 of ACI 318-99.

The 1997 UBC Section 1921 transcribes the entire ACI 318-95 Chapter 21 (with modifications shown in italics) and any needed correlation between UBC terminology (seismic zones) and ACI 318 terminology (regions of low, moderate and high seismicity) is provided under UBC Section 1921.2. Seismic requirements for plain concrete, as mentioned earlier, are to be found in Section 1922.10 of the 1997 UBC.

SECTIONS 1911-1916 PROVISIONS NOT IN ACI 318

Section 1911 Minimum Slab Provisions; Section 1912 Anchorage to Concrete—Allowable Stress Design; Section 1913 Anchorage to Concrete—Strength Design; Section 1914 Shotcrete; Section 1915 Reinforced Gypsum Concrete; and Section 1916 Concrete-filled Pipe Columns have been adopted from the existing model codes or other sources. ACI 318 through its 1999 edition does not address these topics. Section 1.1.6 of ACI 318-99 specifically excludes soil-supported slabs from its scope "unless the slab transmits vertical loads or lateral forces from other portions of the structure to the soil." This explains why Section 1911 or something similar is not part of ACI 318-99. The last three topics of shotcrete, reinforced gypsum concrete and concrete-filled pipe columns have similarly been considered to be outside the scope of ACI 318. Anchorage to concrete, on the other hand, is considered to be within the scope of ACI 318. However, attempts to develop consensus provisions on this topic and incorporate them into ACI 318 have so far been unsuccessful. During the development of the IBC Working Draft it was determined that the provisions of the *Uniform Building Code* and the other model codes on the above topics provided valuable code requirements that merited inclusion in the IBC.

1911 Minimum Slab Provisions (Section 1900.4.4 of the 1997 UBC)

Contains minimum thickness requirements for floor slabs supported directly on the ground. In addition, provisions aimed at retarding vapor transmission through the floor slab are also included. The provisions are essentially the same as those found in the 1996 Edition of the BOCA/National Building Code (Reference 17) and the 1997 edition of the Standard Building Code (Reference 18). These provisions should not change current practice because typically the soil investigation report already required such a vapor retarder.

1912 Anchorage to Concrete—Allowable Stress Design and Strength Design

Section 1912.2 of the 2000 IBC contains the same allowable stress design provisions for anchorage to concrete as are found in Section 1923.1 of the 1997 UBC. The provisions have been successfully used for many years. The footnotes to the 1997 UBC Table 19-D, which is the same as the 2000 IBC Table 1912.2, are reformatted and presented in Sections 1912.3, 1912.4, and 1912.5 of the 2000 IBC.

1913 Anchorage to Concrete—Strength Design

Section 1913 of the IBC contains strength design provisions for anchorage to concrete that are quite different from the 1997 UBC provisions found in Section 1923.3. IBC Section 1913 is based on work-in-progress for eventual incorporation into Appendix D of ACI 318. IBC Section 1913.4.2 includes a performance statement that allows any "design models that result in predictions of strength in substantial agreement with results of comprehensive tests" to be used. The generalized wording allows current procedures such as those in ACI 349 Appendix B (Reference 19) or the PCI Design Handbook (Reference 20) to be used in applicable ranges if desired. The section also allows the use of test results "for design by test" as long as they are interpreted to give the 5 percent fractile values and not the mean. A rectangular prism model for both single anchors and anchor groups is provided as a "deemed to comply" method (References 21 and 22). The provisions consider anchors in both cracked and uncracked concrete.

1914 Shotcrete

The provisions are essentially the same as those in UBC Section 1924, however, there are only two notable differences. First, Section 1914 includes a subsection on natural curing that is not in the UBC. Second, the inspection provisions of UBC Section 1924.11 are not included in IBC Section 1914, because inspection of shotcrete is covered in IBC Table 1704.4.

1915 Reinforced Gypsum Concrete

This section refers to ASTM Standards C 317 and C 956 and contains the minimum thickness requirements of Section 1925 of the 1997 UBC.

1916 Concrete-filled Pipe Columns

These provisions are adopted from Section 1912.0 of the 1996 Edition of the BOCA/National Building Code (Reference 17).

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Chapter 20 of the IBC
Aluminum

The title of Chapter 20 in the 1997 *Uniform Building Code* is Lightweight Metals. This title of the chapter was more appropriately revised to Aluminum in the IBC because the subject matter has always been limited to one material, aluminum. The term "lightweight metals" could also mean lightweight steel which is addressed in Chapter 22 Steel.

The IBC Structural Committee decided to reference aluminum industry standards rather than transcribe the provisions into the code. Some advantages to this approach are that the referenced standards can be easily updated by revising the year in Chapter 35 Referenced Standards, and the standards may include important information which may not otherwise be transcribed in the code.

Chapter 21 of the IBC
Masonry

Introduction

The masonry provisions in the *International Building Code* (IBC) contain a mix of provisions from a variety of different sources to provide the most up-to-date and useful set of masonry design and construction provisions. While the 1997 *Uniform Building Code* (UBC) was a prime resource for the IBC provisions, numerous changes in both content and format exist. One of the main differences between the IBC and the UBC is the use of referenced standards. The IBC Structural Subcommittee used consensus standards throughout the development of the IBC, which significantly shortened structural chapters since design provisions were no longer contained in the body of the text. This was also true with material standards and test procedures, where consensus standards were often adopted instead of similar UBC Standards (which were in fact, often based on the same consensus standards). Because of this, users of the UBC will find that many familiar code sections are no longer covered in the masonry chapter (and other chapters as well) since they are contained in referenced standards. An example of this is Section 2107, which references the ACI 530-99/ASCE 5-99/TMS 402-99 *Building Code Requirements for Masonry Structures* (Reference 21-1) for the allowable stress design of masonry. This section contains a few modifications to these provisions that the committee agreed were needed, but do not contain the bulk of the provisions that had formerly appeared in a similar form in Section 2107 of the UBC. Accordingly, the provisions in Chapter 21 of the IBC are concise and directly related to code enforcement, rather than specific procedures for structural design.

Masonry provisions in IBC Chapter 21 are contained in 13 sections:

2101 General
2102 Definitions and Notations
2103 Masonry Construction Materials
2104 Construction
2105 Quality Assurance
2106 Seismic Design
2107 Working Stress Design
2108 Strength Design of Masonry
2109 Empirical Design of Masonry
2110 Glass Unit Masonry
2111 Masonry Fireplaces
2112 Masonry Heaters
2113 Masonry Chimneys

The content of these sections is described in more detail below, along with noted changes to major subsections.

As previously noted, the IBC references ACI 530-99/ASCE 5-99/TMS 402-99 *Building Code Requirements for Masonry Structures* and the companion ACI 530.1-99/ASCE 6-99/TMS 602-99 *Specification for Masonry Structures* (Reference 21-1) for the design and construction of masonry. These documents are commonly referred to as the MSJC Code and Specification (for the Masonry Standards Joint Committee that oversee the standards) and will therefore be referred to as the MSJC Code and Specification for the remainder of this analysis of IBC Chapter 21. The MSJC Code and Specification are produced through an ANSI (American National Standards Institute) approved consensus process. The MSJC is made up of experts on masonry design, construction and inspection from around the world.

The MSJC documents are comprised of four parts: the Code (ACI 530/ASCE 5/TMS 402); the Specification (ACI 530.1/ASCE 6/TMS 602); and their respective Commentaries. The Code covers the design and construction of masonry structures, with requirements for working stress design of masonry, prestressed masonry, empirical design of masonry, glass unit masonry, anchored and adhered veneer, quality assurance, and reinforcing details. The Specification provides minimum requirements for materials, labor and construction. It contains minimum inspection requirements for masonry that were used as the basis for the inspection requirements in IBC Chapter 17. It also contains information on hot and cold weather construction, masonry erection, reinforcing installation, grouting, prestressing and job-site conditions. The Code Commentary provides background information on the subjects covered by the Code. It helps explain the Code provisions, with particular emphasis on new or revised provisions. The Specification Commentary provides similar information on the subjects covered by the Specification.

2101 General

Section 2101 contains a basic road map for the user, similar in style and intent to UBC Sections 2101.1 and 2101.2. IBC Section 2101.2 directs the user to specific sections for the particular design methods or particular masonry elements. A specific reference has been added in Section 2101.2.5 to refer the reader to the veneer chapter since the IBC Structural Subcommittee noted that some readers erroneously believed that masonry veneer either must comply with Chapter 21, or that it did not need to meet any requirements since it was not specifically noted in Chapter 21.

Requirements for construction documents were based on requirements in other codes and standards.

2102 Definitions and Notations

Definitions and notations are contained in Section 2102 to help clarify terms and symbols used in the IBC for masonry. The majority of these definitions and notations were taken from Sections 2101.3 and 2101.4 of the UBC with some modifications. Additional definitions for fireplaces and chimneys were added based on UBC Section 3102.2 and for shear wall types based on the seismic design provisions in the 1997 NEHRP Provisions (Reference 2).

2103 Masonry Construction Materials

This section contains minimum requirements for masonry materials, much as UBC Sections 2102 and 2103 do. The IBC, however, adopts ASTM Standards rather than UBC Standards. For most materials, the UBC Standards were based on ASTM Standards, so there will be little change in specific requirements for masonry.

2103.1 Concrete masonry units. Concrete masonry units permitted for use in structural masonry are shown with the appropriate ASTM Standard. Non load-bearing concrete masonry units, permitted under UBC Section 2102.2, Item 5.3, are not permitted for structural masonry in the IBC by their omission from Section 2103.1. UBC Section 2106.1.12.3, Item 5 specifically prohibits these units for buildings located in Seismic Zone 2 and higher.

2103.2 Clay or shale masonry units. Clay and shale masonry unit specifications are listed and are generally consistent with those in Section 2102.2, Item 4 of the UBC. ASTM standards are referenced instead of UBC standards.

2103.3 Stone masonry units. Standards have been cited for those stone masonry units that may be used.

2103.4 Ceramic tile. References for ceramic tile mortar have been added based on requirements in other model codes. During the development of the IBC, it was often questioned whether such materials belonged in this chapter, which was intended to deal with structural masonry. However, due to the lack of a better place for these provisions, they were placed here, as they had in other model codes.

2103.5 Glass unit masonry. Requirements for glass unit masonry have been added. The requirement for treating surfaces to be in contact with mortar are similar to those in UBC Section 2110.2.

2103.6 Second-hand units. These requirements are similar to those in UBC Section 2102.1, and generally discourages the use of reclaimed (used) units unless they meet the requirements of new units. IBC Section 2103.5 prohibits the reuse of reclaimed glass unit masonry units.

2103.7 Mortar. Table 2103.7(1) is essentially identical to UBC Table 21-A except that the referenced standards in the footnotes to the table have been changed to those of ASTM. Table 2103.7(2), a mortar proportion table, has been added as another permitted method for specifying mortar. Requirements for mortar for glass unit masonry are similar to those in UBC Section 2110.2.

2103.8 Surface-bonding mortar.
2103.9 Mortars for ceramic wall and floor tile.
These requirements for surface-bonding mortar and ceramic tile have been carried over from other model codes. During the development of the IBC, it was often questioned whether provisions for ceramic tile belonged in this Chapter that was intended to deal with structural masonry. Due to the lack of a better place for these provisions, they were placed here, as they had in other Model Codes.

2103.10 Grout. Grout proportion requirements in Table 2103.10 are similar to those in UBC Table 21-B. The minimum grout strength requirement of 2000 psi has been removed since ASTM C 476 requires grout either to comply with this minimum strength requirement, or to meet the proportion requirements of Table 2103.10, which have been shown to provide a strength in excess of 2000 psi.

2103.11 Metal reinforcement and accessories. Requirements for metal reinforcement and accessories reflect consensus standards. Deformed reinforcement must meet the same requirements in Section 2103.11.1 as was required in UBC Section 2102.2, Item 10.2. A new standard has been approved for joint reinforcement and is thus referenced in Section 2103.11.2.

2104 Construction

The provisions in IBC Section 2104 and the referenced specification, ACI 530.1/ASCE 6/TMS 602, impose minimum construction requirements for masonry designed by this chapter. If more stringent construction requirements are needed to satisfy aesthetic and architectural criteria, these should be included in the construction documents.

Many of the construction requirements in UBC Section 2104 are also contained in the MSJC Specification. Because of their inclusion in the referenced standard, the IBC Structural Subcommittee decided not to repeat many of these in the IBC. They did, however, want certain minimum construction requirements related to placement of units and cold and hot weather construction. Once users of the IBC become familiar with the referenced standard, these provisions may also be deleted since they are redundant with those of the standard. This will avoid conflicts between the IBC and the referenced standard.

2105 Quality Assurance

The quality assurance provisions in the IBC are modeled after those in the 1997 UBC and the MSJC Code and Specification. Requirements are similar to those in the UBC, with a few exceptions. First, compliance with the specified compressive strength of the masonry, $f¢_m$, can no longer be verified by the Prism Test Record method as was permitted in the 1997 UBC. This procedure to verify compliance was deleted because the masonry industry noted that it has rarely been used and the requirements make it less likely to be used in the future. Moreover, such a procedure is not permitted in the MSJC Specification.

Another difference is that the IBC no longer permits half-stress design of uninspected masonry construction. This is consistent with the MSJC, which requires a minimum level of inspection for all masonry structures. During the development of the IBC, it was noted that masonry damaged in past earthquakes and high wind events often showed extremely poor workmanship, which contributed greatly to the damage. Many failed masonry structures showed evidence of missing reinforcement, missing grout or missing connectors, as well as other inappropriate construction techniques. It was argued that even if half stresses had been used for such designs, there would likely not have been sufficient strength in such poorly constructed masonry to support the expected loads. Accordingly, noninspected masonry designed by the half-stress design method is no longer permitted, and inspection requirements have been added in Section 1704.5.

IBC Section 2105 also requires testing of materials in accordance with ASTM Standards instead of UBC standards. Requirements on how often tests must be performed have been moved to Section 1708.1 with other testing requirements.

2106 Seismic Design

IBC Section 2106 contains minimum requirements for masonry structures in seismic areas. The section was based on requirements in the Seismic Design Section of the MSJC Code (Section 1.13), the NEHRP Chapter 11 Requirements and the 1997 UBC, (Section 2106.1.12). Requirements are established for various seismic risk categories, as they were previously in the 1997 UBC, with requirements being cumulative for lower seismic risk to higher seismic risk. However, seismic risk is now designated using Seismic Design Categories (as in the 1997 NEHRP Provisions) instead of seismic zones (as in the UBC). Seismic Design Categories are based not only on the location of the structure in relation to known seismically active areas, but also on its importance and the underlying soil type. More information on Seismic Design Categories (Seismic Design Category) is contained in the analysis of Chapter 16 of the IBC and in the Commentary to the 1997 NEHRP Provisions.

2106.1 Seismic design requirements for masonry. General seismic design requirements are contained in this section. Basic seismic force-resisting systems are described based on the 1997 NEHRP Provisions. Five shear wall types have been added to indicate the expected performance of the walls with certain construction techniques. These five shear wall types are assigned different design parameters such as response modification factors based on their expected performance and ductility. Certain shear wall types are required in each seismic region, and unreinforced shear wall types are not permitted in regions of intermediate and high seismic risk. The following table summarizes the requirements of each of the 5 types of masonry shear walls:

Shear wall Designation	Design Methods	Reinforcement Requirements (See Section 2106.1.1)	May be Used In
Ordinary Plain Masonry Shear Wall	Plain (Unreinforced) masonry design per IBC Section 2107 (specifically MSJC Section 2.2) or IBC Section 2108.10	None	Seismic Design Categories A and B
Detailed Plain Masonry Shear Walls	Plain (Unreinforced) masonry design per IBC Section 2107 (specifically MSJC Section 2.2) or IBC Section 2108.10	Per IBC Section 2106.4.2.3.1	Seismic Design Categories A and B
Ordinary Reinforced Masonry Shear Walls	Reinforced masonry design per IBC Section 2107 (Specifically MSJC Section 2.3) or IBC Section 2108.9	As required, but as a minimum per IBC Section 2106.4.2.3.1	Seismic Design Categories A, B and C
Intermediate Reinforced Masonry Shear Walls	Reinforced masonry design per IBC Section 2107 (Specifically MSJC Section 2.3) or IBC Section 2108.9	As required, but as a minimum per IBC Section 2106.4.2.3.1 In addition, the maximum spacing of vertical reinforcement shall not exceed 48 inches.	Seismic Design Categories A, B and C
Special Reinforced Masonry Shear Walls	Reinforced masonry design per IBC Section 2107 (Specifically MSJC Section 2.3) or IBC Section 2108.9	As required, but as a minimum per IBC Section 2106.5.3.1	Seismic Design Categories A, B, C, D, E and F

2106.1.2 Alternate seismic design requirements for structures designed by the working stress design method. This section permits a designer to comply with the requirements of Section 1.13 of the 1999 MSJC Code since the provisions in IBC Section 2106 are largely taken from that document. This section was added so that designers using the MSJC Code could use it in its entirety and still comply with the IBC Seismic requirements. This section however modifies the MSJC Code provisions since it is based on earlier editions of ASCE 7 and NEHRP which did not include the IBC concepts of Seismic Design Categories (SDC) and the Basic Seismic Force Resisting Systems.

2106.2 Seismic Design Category A. Minimum requirements for masonry in Seismic Design Category A are contained in this section. Buildings classified in this low seismic risk category are permitted to be designed by any of the methods listed in IBC Chapter 21, and need only meet minimal anchorage requirements to elements providing lateral support. These requirements are similar in concept to those contained in 1997 UBC Sections 2106.1.7 and 2106.1.12.2.

2106.3 Seismic Design Category B. Requirements in Seismic Design Category B are slightly more restrictive than in Seismic Design Category A. Since the requirements are cumulative with each successive Seismic Design Category, masonry assigned to Seismic Design Category B must meet all the requirements for Seismic Design Category A (IBC Section 2106.2) as well as those in Section 2106.3. Therefore, besides those requirements in Section 2106.2, masonry shear walls must also be rationally designed in this Seismic Design Category and above per Section 2106.3.1. As a minimum, these shear walls must comply with the requirements of ordinary plain, or ordinary reinforced masonry shear walls.

2106.4 Seismic Design Category C. In many ways this section containing requirements for Seismic Design Category C parallels UBC Section 2106.1.12.3. Minimum reinforcing requirements are included to provide some ductility and load transfer capability in masonry structures assigned to Seismic Design Category C.

2106.4.2.2 Connections to masonry columns. Column reinforcement and tie requirements parallel those in UBC Section 2106.1.12.3, Item 1. Many of the referenced sections in that UBC Section (Sections 2106.3.6, 2106.3.7 and 2107.2.13) are contained in the noted sections of the MSJC Code. Additionally the requirements for ties around anchor bolts are similar to those in UBC Section 2106.3.7.

2106.4.2.3.1 Minimum reinforcement requirements for masonry shear walls. Requirements for horizontal reinforcement in masonry shear walls in Seismic Design Category C are similar to those in UBC Section 2106.1.12.3. Requirements for vertical reinforcement are also similar to those in that UBC section, with the exception that the maximum spacing of vertical reinforcement is permitted to be up to 10 ft. This requirement is consistent with the requirements in the MSJC Code, and was debated during the development of the IBC. The Structural Subcommittee agreed to use the requirements in the MSJC Code since there was no evidence as to how much reinforcement was needed in this area of moderate seismic risk. Moreover, it was noted that because of the probable increase in force levels for masonry structures in this Seismic Design Category, reinforcement more consistent with the requirement in the UBC would most likely be required anyway.

2106.5 Seismic Design Category D. Provisions of this section cover the requirements for Seismic Design Category D and parallel most of the requirements in UBC Section 2106.1.12.4, and some of those contained in UBC Section 2106.1.12.3.

2106.5.2 Minimum reinforcement requirements for masonry walls. The minimum reinforcement requirements for masonry walls are nearly identical to those in UBC Section 2106.1.12.4, Item 2.3.

2106.5.5 Material requirements. Restrictions on the use of Type N mortar and masonry cement in the lateral- force resisting system are similar to those in UBC Sections 2106.1.12.4, Item 3 and Section 2106.1.12.3, Item 5.

2106.6 Seismic Design Category E or F. Provisions of this section cover the requirements for Seismic Design Categories E and F.

2106.6.1 Design of elements that are not part of the lateral-force-resisting system.
2106.6.2 Design of elements that are part of the lateral-force-resisting system.
Additional restrictions are imposed on stack bond masonry in buildings assigned to the highest seismic risk categories. These restrictions are similar to, and slightly more restrictive than, those in UBC Section 2106.1.12.4, Item 2.4.

2107 Working Stress Design

Section 2107 provides an overall reference to the working stress design method in the MSJC Code with modifications that the Structural Subcommittee agreed were needed. The Structural Subcommittee chose to refer to the MSJC Code rather than transcribe provisions as does UBC Section 2107 because of the basic philosophy to adopt standards for design procedures. The Subcommittee consistently did this in the masonry chapter, with the exception of Section 2108, since no consensus standard currently exists for the strength design of masonry.

The allowable stress design provisions in the referenced standard are nearly identical to those contained in Section 2107 of the UBC. Key differences are that the MSJC Code is based on the use of full design stresses only, assuming that structural masonry will receive some minimum level of inspection. These minimum levels of inspection have accordingly been incorporated into IBC Section 1704.5. Thus, the MSJC Code does not permit the half-stress design procedure permitted by UBC 2107.1.2.

Other minor differences between the MSJC Code and the UBC do exist, such as slightly different values for modulus of elasticity. In general, however, the procedures and allowable design values are quite consistent, and designers will easily be able to switch from the working stress procedures of the UBC to those of the MSJC Code, which is adopted by reference in the IBC.

2107.2 Modifications to ACI 530/ASCE 5/TMS 402. The Structural Subcommittee considered and adopted several modifications to the MSJC Code. The first, contained in Section 2107.2.2, permits lightly loaded masonry columns in structures with low seismic exposure to be reinforced with a single vertical reinforcing bar, if the column can adequately support all applicable loads and deformations. This provision is similar to a provision in the *Standard Building Code* (Reference 3), and is intended to correct a discrepancy in the MSJC Code, in which columns are defined by geometry rather than applied load. According to that document, masonry members of a certain geometry, even though they act primarily in flexure, are classified as columns, thus must meet certain minimum reinforcing requirements for columns. Section 2107.2.2 exempts lightly loaded columns, such as those that support carport roofs which experience primarily axial tension and flexure in high wind events, from these prescriptive requirements.

2107.2.3 ACI 530/ASCE 5/TMS 420, Section 2.1.8.6.1.1, lap splices. This modification brings consistency to the requirements for splice lengths for reinforcement according to working stress design and strength design. The IBC Structural Subcommittee accepted this modification based on broad support from the masonry industry and structural engineers since it was noted that existing splice-length requirements are overly conservative for small bar sizes and under conservative for large bar sizes.

2108 Strength Design of Masonry

Section 2108 has detailed requirements for the strength design of masonry, since the MSJC Code currently does not have a formal strength or limit state design procedure. It was a primary goal of the IBC Structural Subcommittee to reference standards rather than contain such provisions within the IBC. To permit the inclusion of a strength design method, however, the Subcommittee chose to provide strength procedures in this section, and to encourage the MSJC to develop consensus strength-design provisions as soon as possible. The Subcommittee intended to delete the provisions in this section if the MSJC could adopt strength design provisions prior to the final hearings of the IBC. Since that goal was not achieved, this section has been provided in the interim.

The provisions in Section 2108 were originally based on the strength design provisions of UBC Section 2108, and were further modified to more closely resemble the strength design provisions in the 1997 NEHRP Provisions. Additional changes were made to reduce differences between those two documents. The following highlights new provisions and significantly revised UBC provisions.

2108.4 Design strength. Requirements for determining the design strength of a member are similar to those of UBC Section 2108.1.4. The limit of 0.04 f'_m on unfactored loads throughout Section 2108 has been modified to a limit of 0.05 f'_m on factored loads. This was done to clarify those limits and make them consistent throughout the chapter. The effect on designs will be minor. Design shear strengths and corresponding strength reduction factors have been changed considerably based on requirements in the 1997 NEHRP Provisions.

Similarly, anchor bolt provisions have been substantially revised based on the 1997 NEHRP Provisions, and provisions developed within ACI Committee 318. These changes reflect the significant differences between headed and bent-bar anchor bolts (see analysis to Section 2108.6). Corresponding strength reduction factors have also been modified.

2108.5 Deformation requirements. Deformation requirements are intended to ensure that masonry will be able to undergo the required deformations as well as required loads. Calculated story drifts must not exceed allowable story drifts. Deflection calculations for reinforced masonry may be based on Equation 21-7 (which was in the 1994 UBC but was later deleted since other methods may also be used), or a more exact procedure may be used.

2108.6 Headed and bent-bar anchor bolts. Anchor bolt provisions have been substantially modified. During the development of the IBC, it was noted that the requirements in UBC Section 2108.6 were very conservative and were simply the working stress values increased by a factor. In the early drafts of the IBC the values were updated to those contained in the 1997 NEHRP Provisions. Those values were thought by some to be unjustifiably high compared to values for anchor bolts in concrete. The provisions adopted by the IBC lie between the values of the 1997 UBC and the 1997 NEHRP Provisions. The new provisions also reflect the superior tensile pullout performance of headed anchors compared to bent-bar anchors, and require that void areas within or around the masonry be neglected when calculating the projected area of a masonry breakout body.

2108.9.2.10 Development. Provisions for the development of reinforcement in masonry were based on UBC Section 2108.2.2.6, and were updated based on new research findings. IBC Equation 21-23 is similar in form to UBC Formula 8-13 with several updates. The limit of $52d_b$ has been removed based on new test results that show that this upper limit on splice length may not be sufficient for larger bar sizes. A new term has also been added to reflect the need for longer lap lengths for large bar sizes. The cover limit has also been increased from $3d_b$ to $5d_b$ since the tests showed that splices at these larger cover depths performed more favorably than those at the smaller cover depth, yet still did not experience pullout failure. A minor change has also been made to the numerical coefficient based on test results. The net result of these changes will be that for small bar sizes, lap lengths will be smaller than those traditionally used in the UBC while for larger bar sizes, lap lengths will become larger.

2108.9.2.13 Maximum reinforcement percentages. The IBC includes a major change regarding the method by which maximum reinforcement is prescribed. Previously, UBC Section 2108.2.3.3 provided a method to determine a balanced reinforcement ratio, and sections such as UBC Section 2108.2.4.2 based the maximum permitted amount of reinforcement on this ratio. This method, while straightforward, is potentially unsafe for members subjected to high compressive loads. The new provisions in this section of the IBC account for this. Additionally, UBC Section 2108.2.5.6 contained mandatory requirements for boundary members of shear walls. The new provisions permit shear walls to meet similar boundary member requirements or, as an alternative, to meet the more stringent maximum reinforcement requirements discussed above.

2108.9.3 Design of beams, piers and columns. Requirements for the design of beams, piers and columns are based on the requirements in UBC Section 2108.2.3 with two major exceptions. The first relates to the calculation of the maximum reinforcement ratio, which is described in the analysis to Section 2108.9.2.13. The second relates to the calculation of the nominal shear strength in IBC Section 2108.9.3.5.2. As previously described, the nominal shear strength and related strength reduction values are based on the 1997 NEHRP Provisions.

2108.9.4 Design strength. This section was based on UBC Section 2108.2.4. As noted earlier the calculation of the maximum reinforcement ratio has been modified, the axial stress limit has been modified to $0.05f'_m$ under factored loads, and the nominal shear strength has been modified.

2108.9.5 Wall design for in-plane loads. Again, this section was based on UBC Section 2108.9.5, but the nominal shear strength is based on the 1997 NEHRP Provisions. As described in the analysis to Section 2108.9.2.13, boundary elements are no longer required if the more restrictive maximum reinforcement requirements of Section 2108.9.2.13, Method A are met. Other minor updates have also been made.

2108.9.6 Special masonry moment frames (wall frames). The requirements for Special Masonry Moment Frames are very similar to those in UBC Section 2108.2.6, with modifications based on the 1997 NEHRP Provisions.

2108.10 Design of plain (unreinforced) masonry members. The requirements in this section for the strength design of plain (unreinforced) masonry members were taken from the 1997 NEHRP Provisions. No similar requirements exist in the UBC.

2109 Empirical Design of Masonry

Section 2109 contains empirical design requirements for masonry that are nearly identical to those contained in the MSJC Code and are similar to those in the 1997 UBC. This section also contains requirements for adobe masonry that are similar to those contained in the SBC and the UBC.

2109.1 General. The limitations in this section are based on extensive discussion of the IBC Structural Subcommittee considering limits on empirical design in several documents. The limitation in IBC Section 2109.1.1 permits the use of empirical design for the lateral force resisting system in Seismic Design Category A only, and in elements that are not part of the lateral force resisting system in Seismic Design Categories B and C. The 1997 UBC permits empirically designed masonry in Seismic Zones 0 and 1. Because of new mapping issues, soil considerations and building types, it is difficult to compare those limits. It is likely, however, that the IBC will prohibit the use of empirical design for the lateral-force-resisting system of buildings covering a larger area than did the 1997 UBC because of these new limitations. The new restrictions may permit greater use of the empirical design method for nonstructural masonry. Since most masonry is structural, however, this possible increase in scope is not likely to significantly affect the use of this method.

Based on the IBC Structural Subcommittee's interest in having a well-defined trigger, they restricted the use of empirical design to those areas with 3-second gust wind speeds less than 110 miles/hr (a criterion which had been used in other model codes), rather than to zones with a wind-pressure limit of 25 psf (the criterion used by the MSJC Code).

2109.2 Lateral stability. This section is nearly identical to UBC Section 2109.3. Requirements for surface-bonded masonry walls were included in IBC Section 2109.2.3 based on similar requirements in other model codes.

2109.3 Compressive stress requirements. This section is similar to UBC Sections 2109.4.1, 2109.4.2 and 2109.4.3. The allowable compressive stresses listed in IBC Table 2109.3.2, however, are consistent with those in the MSJC Code. Accordingly, values for "Grouted masonry, of clay or shale; sand-lime or concrete" laid in Type M or S mortar are slightly lower than those in UBC Table 21-M. In addition, there is no entry in this table for Unburned clay masonry as in the UBC table since requirements for adobe masonry were added to IBC Section 2109.8. Note that IBC Section 2109.8.1.1 requires a higher strength than does the UBC.

2109.4 Lateral support. The requirements in this section are similar in content and intent to those in UBC Section 2109.5.

2109.5 Thickness of masonry. These requirements are similar to those contained in UBC Section 2109.6, with the exception of those governing the design of foundation walls. It was suggested that empirical foundation wall requirements from the MSJC Code should be used rather than those in the UBC. The IBC Structural Subcommittee elected not to include any empirical foundation wall requirements, and instead use the prescriptive tables of Section 1805.5. Because these prescriptive tables are based on strength design, the IBC Structural Subcommittee agreed that they were more appropriate than either set of empirical requirements.

2109.6 Bonding with wall ties or joint reinforcement. This section contains requirements similar to those in UBC Section 2109.7 with updates based on the MSJC Code. IBC Section 2109.6.2.3 was added to ensure that the facing and backing of masonry bonded hollow walls are adequately bonded. Adjustable wall ties are permitted for connecting masonry wythes together. Requirements for bonding stone wythes together have also been added. Empirical requirements for stone masonry in this section are consistent with those in UBC Section 2109.10.

2109.7 General. Anchorage requirements in the IBC are similar to those in Sections 2109.8.1, 2109.8.2 and 2109.8.3 of the UBC.

2109.8 Adobe construction. The IBC identifies two types of adobe masonry: unstabilized and stabilized. Since unstabilized adobe was not recognized in the UBC, these requirements were taken from *Standard Building Code* (SBC) Appendix G. Requirements for stabilized adobe were based on both the provisions in the UBC and those in SBC Appendix G.

UBC anchor bolt requirements from UBC Table 21-Q have been maintained in IBC Table 2109.8.3.1. Similarly the height to thickness ratio for stabilized adobe masonry walls in UBC Section 2109.9.1 has been maintained in IBC Section 2109.8.4.2. IBC Section 2109.8.4.1 extends the height limit of adobe buildings from 1 story to 2 stories if the building is designed by a registered design professional.

Requirements for foundations, piers and columns, tie beams, exterior finish, and lintels are taken from SBC Appendix G and provide users with additional information and guidance on the proper use of adobe masonry.

2110 Glass Unit Masonry

Glass unit masonry provisions are similar to those in the UBC with updates and revisions based on the 1999 MSJC Code.

2110.1 Scope. This section provides general information and requirements for glass unit masonry. As with the 1997 UBC, glass unit masonry is permitted only in non load-bearing applications. The limitations on the use of glass unit masonry in fire walls and assemblies with the listed exceptions were recommended by the IBC Fire Safety Committee based on requirements in other codes.

2110.2 Units. These requirements are consistent with those in the MSJC Code. Standard unit thickness requirements are slightly greater than the 3 inch (76 mm) required in 1997 UBC Section 2110.1. Requirements for thin glass unit masonry units have been added.

2110.3 Panel size. Requirements for panel sizes are expanded from those contained in 1997 UBC Section 2110.5. Panel area limits are similar to those in the UBC, but the maximum spacing between supports is greater than the UBC values, based on testing.

2110.4 Support. Support requirements are similar to those in UBC Section 2110.3, but have been expanded based on the requirements in the MSJC Code. Support by channel-type anchors is permitted, since this system is very popular and performs well. Additional requirements have been added for maximum deflection of glass masonry unit panels so that the panels will perform adequately.

2110.5 Expansion joints. As with UBC Section 2110.6, expansion joints of not less than 3/8 in. (9.5 mm) must be provided along the top and sides of glass unit masonry panels to ensure that load is not transferred to the non load-bearing panels. Guidance on acceptable coatings of sills is also provided, based on requirements in other codes.

2110.6 Mortar. Requirements for mortar for glass unit masonry are contained in Section 2103.7, which is similar to UBC Section 2110.2. See also Section 2103.5.

2110.7 Reinforcement. Reinforcement requirements for glass unit masonry parallel those in UBC Section 2110.4. The reference to the joint reinforcement standard reflects the new ASTM specification on joint reinforcement. Minimum wire sizes have also been added to ensure proper performance of the panels under the permitted out-of-plane loads.

Sections 2111, 2112 and 2113—Masonry Fireplaces, Heaters and Chimneys

These sections contain requirements from several sources for masonry fireplaces, heaters and chimneys. It was a goal of the ICC to coordinate the provisions in the IBC with those in the *International Residential Code*. The resulting language accomplishes this goal.

1997 UBC Section 2111 and Chapter 31 were used as a reference for these requirements, although many of the provisions have been updated or revised. The IBC contains consistent requirements for seismic anchorage, hearths, minimum dimensions for fireboxes, clearances and flue sizes.

The new provisions, however, are dramatically different in format, and have numerous changes to achieve consistency between the IBC and the IRC.

An Additional Note

The following discussion addresses the decision of the IBC Structural Subcommittee not to include UBC Appendix Chapter 21, Prescriptive Masonry Construction in High Wind Areas.

The IBC Structural Subcommittee wanted to provide some requirements for residential structures in high-wind areas. For masonry, two resources were available: the UBC Appendix to Chapter 21 and the provisions in SBCCI SSTD-10 (Reference 4), which provides prescriptive requirements, tables, drawings and details for masonry construction in high-wind areas.

It was noted during the discussion of these resources that the appendix chapter was predominately based on recommended practice. The SBCCI standard had been developed based specifically on design of masonry at various wind levels. Because of this, the IBC Structural Subcommittee decided that the SBCCI standard was more appropriate and should be referenced in Section 1609.1.1 of the IBC.

References

1. *Building Code Requirements for Masonry Structures* (ACI 530-99/ASCE 5-99/TMS 402-99), *Specification for Masonry Structures* (ACI 530.1/ASCE 5-99/TMS 602-99), *Commentary on Building Code Requirements for Masonry Structures, and Commentary of Specification for Masonry Structures,* Reported by Masonry Standards Joint Committee, American Concrete Institute, Structural Engineering Institute of the American Society of Civil Engineers, and The Masonry Society, Boulder, CO, 1999.
2. *NEHRP (National Earthquake Hazards Reduction Program) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures,* 1997 Edition, Building Seismic Safety Council for the Federal Emergency Management Agency, Washington, D.C., 1997.
3. *Standard Building Code,* Southern Building Code Congress International, Inc., Birmingham, AL, 1997.
4. SBCCI SSTD-10 – 97, *Standard for Hurricane Resistant Residential Construction,* Southern Building Code Congress International, Inc., Birmingham, AL, 1997.

Chapter 22 of the IBC
Steel

Introduction

Chapter 22 of the IBC is formatted in a very similar fashion to the 1997 UBC. The code essentially gives the user a roadmap to the use of design standards appropriate for various types of steel construction. The format of the IBC is a continuation of a trend in the UBC that began with the reformatting of the steel chapter in the 1996 UBC Supplement.

Prior to the 1996 Supplement, all design standards were transcribed directly into the code. Unfortunately they were not always incorporated in their entirety, thus leaving the design engineer and code official to determine the differences between the building code and the design manuals and software being used by design professionals. The 1997 edition of the UBC began the transition of adopting design standards by reference in the UBC in a manner similar to the *National Building Code* and the *Southern Building Code,* thereby smoothing the transition into the IBC. In 1997 the UBC adopted all design standards for steel structures by reference with only one exception. The 1992 edition of the AISC Seismic Provisions was reprinted so a designer wishing to use Load and Resistance Factor Design (LRFD) would have provisions in the code in parallel with those for Allowable Stress Design (ASD). The latter were the traditional seismic provisions for steel structures developed by the Seismology Committee of the Structural Engineers Association of California. It is important to note that the scope of each section in IBC Chapter 22 that adopts a specification is often different from the scope of other sections. The scope of these sections is intended to reflect the scope of the particular adopted standard.

The IBC steel chapter was developed by placing the provisions from the steel chapters in the three model codes side by side and making a selection of the most appropriate language for incorporation into the IBC. The following discusses some of the background associated with each section.

2202 Definitions and Nomenclature

These definitions were taken from the *National Building Code* as it was felt that the IBC needed clear definitions of the terms.

2203 Identification and Protection of Steel For Structures

Section 2203.1 Identification, is taken from the same section in the UBC. Earlier drafts of Chapter 22 in the IBC contained more of UBC

Section 2203 but the IBC Structural Committee assessed this information as unnecessary and should be covered by the appropriate referenced standards.

2203.2 Protection. Taken from the *National Building Code* to alert the user that when protection of structural steel members is required it shall be in accordance with the appropriate AISC specifications. Also, cold-formed steel structural members need to be of corrosion resistant steel, or have a corrosion resistant metallic coating, paint or other approved coatings. The UBC was silent on this issue.

2204 Structural Steel Construction

Section 2204 requires that structural steel (see definition in IBC Section 2202) be designed in accordance with one of three specifications published by the American Institute of Steel Construction. The IBC cites referenced standards by short titles in the body of the code and the complete title is cited in Chapter 35, along with the appropriate date. The three standards permitted for structural steel members are:

AISC ASD (1989)	Structural Steel Buildings—Allowable Stress Design, Plastic Design
AISC LRFD (1993)	Load and Resistance Factor Design for Structural Steel Buildings Including Supplement No. 1 1998
AISC HSS (1997)	Specification for the Design of Steel Hollow Structural Sections

The latter is a new standard specifically developed for the design of round, square and rectangular steel tubular structural sections, and is not included in the 1997 UBC. Both AISC ASD and AISC LRFD have been adopted by the UBC for many years.

2205 Cold-formed Steel

2205.1 General. Adopts the new Specification for the Design of Cold-formed Steel Structural Members AISI (1996) published by the American Iron and Steel Institute. This new specification is a revolution in design standards since it incorporates both Load and Resistance Factor Design and Allowable Stress Design into a single specification. It is also dimensionless, so that it needs no metric conversion. For an excellent discussion of the major differences between this specification and earlier versions, the reader is referred to the Preface and the Commentary of the Specification. The UBC adopts earlier specifications that were published individually for each design method.

2205.2 Composite slabs on steel decks. Adopts the Specification for Structural Design of Composite Slabs (ASCE 3-84). The UBC adopted no standards for the design of composite concrete and steel deck slabs. Such diaphragms have been designed using ICBO ES reports.

2206 Steel Joists

As in the UBC, the IBC requires steel joists to be designed and manufactured in accordance with the specifications published by the Steel Joist Institute (SJI). Both the UBC and IBC adopt the same edition of the SJI standards.

2207 Steel Cable Structures

2207.1 General. The UBC and IBC both adopt the standard Structural Applications of Steel Cables for Buildings (ASCE 19-95) for the design of steel cable structures.

2207.2 Seismic requirements for steel cable. This section provides the user with appropriate modifications where structural cables are intended for use in seismic applications. These modifications were first developed by Building Seismic Safety Council for incorporation into the first edition of the NEHRP Provisions.

2208 Welding

This section does not adopt the AWS specifications for the design and details of welding. Rather, it requires that welding be accomplished in accordance with the requirements of the appropriate design specification. This was done because the referenced standards sometimes adopt different editions of the appropriate AWS specification or, as in the case of steel joists, the welding requirements are contained within the Steel Joist Institute Standards. For example, the AISC ASD and AISC LRFD specifications adopt different editions of AWS D1.1, the structural welding code. Since the two AISC specifications were published several years apart they adopt and make separate modifications to different editions of AWSD 1.1. This is very similar to the method of adoption in the UBC.

2209 Bolting

This section is very similar to the previous section on welding in that is does not adopt bolt installation standards separately. The requirements for the design, installation and inspection for bolting are found in the standards referenced by Sections 2204 and 2205.

2209.2 Anchor bolts. This language was taken directly from UBC Section 2205.11. However, the section on oversized holes was deleted since it was decided that this is more appropriately covered by the AISC specifications.

2211 Wind and Seismic Requirements for Light Framed Cold-Formed Steel Walls.

The 1997 UBC was the first of the model codes to contain requirements for shear walls framed with cold-formed steel framing members (see Division VIII of the 1997 edition). These provisions are based upon monotonic and cyclic tests performed under the direction of Dr. R. Serrette at Santa Clara University in 1996 and sponsored by AISI. The provisions in the IBC are similar to those in the UBC but have been revised to include additional shear values for systems tested by Serrette in 1997 which were not available for inclusion in the UBC. The IBC also contains some additional editorial refinements. The following discusses the significant differences:

Probably the most significant difference between the shear walls in the UBC and IBC are the factors of safety used for wind design. The IBC uses a factor of safety of 2.5 for both wind and seismic. The UBC requires a factor of safety for wind of 3.0. The reason the factor of safety for wind design was reduced to 2.5 can be attributed to the lack of an adjustment factor of 1.4 applied to the allowable loads on wood framed shear walls for wind design in the UBC. Since the IBC now allows this adjustment factor for wood framed walls for wind design (See IBC Section 2306.4.1), it was deemed appropriate to use a consistent factor of safety for both wind and seismic design for steel framed walls. It should be noted that the 1.4 adjustment factor is not permitted to be applied to steel framed walls.

The IBC contains new shear values for:

- Sheet steel.
- Additional shear values for framing consisting of 43 mil studs (18 ga).
- Allowing narrow shear walls with a height to width aspect ratio of 4:1 for wind design and in Seismic Design Categories A through C.

The IBC was reformatted to place system requirements in the body of the code rather than in footnotes as is done in the UBC.

In Seismic Design Categories D and above (Zones 3 and 4 in the UBC) wall studs are limited to a maximum thickness to prevent the premature failure of sheathing screws under high seismic demands. The desire was to limit the thickness to a maximum nominal 18 gage steel stud. Unfortunately gage thickness is no longer used to regulate steel thickness. In the UBC, the maximum thickness was set at 0.043 inches which is the minimum base metal thickness used for 18 gage. It is impractical to set a maximum thickness allowed as the minimum thickness of a stud. This was clarified in the IBC by placing the maximum thickness of studs at 0.048 inches which is half way between the minimum base metal thickness for 18 gage (0.043 inches) and 16 gage (0.054 inches).

2212 Seismic Requirements for Structural Steel Construction

Probably the most significant technical difference between the IBC and the UBC are the seismic requirements for structural steel. The IBC adopts the state of the art seismic requirements based upon AISC Seismic Provisions for Structural Steel Buildings (AISC 97 including Supplement No. 1, 1999). These provisions incorporate the latest requirements based upon the NEHRP 97 Provisions and include results of recent FEMA funded research. The user is referred to the commentary of AISC 97 for a detailed discussion of the seismic provisions.

AISC Seismic is divided into three parts. Parts I and III are the requirements for structural steel and Part II are the requirements for combining structural steel and concrete. Traditional seismic design in the UBC has been based upon ASD. However, AISC Seismic is primarily based upon LRFD provisions which are contained in Part I. Part III contains provisions that allow the use of ASD.

The AISC Seismic requirements are state of the art and incorporate significant research results from the FEMA funded SAC research program which began as a result of the Northridge earthquake damage to steel moment frames.

2213 Seismic Requirements for Composite Construction

The IBC contains the first concise technical provisions for combining structural steel and concrete in the lateral force resisting system. The use of composite construction has been growing in nonseismic areas but its use has been hampered in high seismic areas due to the lack of technical design requirements. Since these are new requirements it was felt necessary to require the designer to submit substantiating evidence for building official approval in high seismic regions. Where the design relies on composite elements that are expected to undergo inelastic demands, the evidence must include cyclic tests in accordance with the test protocol and acceptance criteria established by AISC 97.

Chapter 23 of the IBC
Wood

Introduction

Chapter 23 of the 2000 IBC is in part a combination of the 1996 *National Building Code* (NBC), the 1997 *Standard Building Code* (SBC), and the 1997 *Uniform Building Code* (UBC). The provisions placed in the IBC were neither consistently the most restrictive nor the least restrictive of the three model codes. The IBC Structural Committee reviewed the provisions of all three model codes and selected the provisions based on technical merit, clarity and necessity. Some provisions were added because they appeared in one or more of the model codes. At first Chapter 23 was a compilation of the three model codes. During the course of reviewing drafts, many revisions based on the latest research were included into the code. Seismic requirements were obtained from the 1997 *National Earthquake Hazard Reduction Program (NEHRP) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures.* The 1997 NEHRP Provisions is a national consensus document and has been adopted by reference in the other model codes.

A major change in the IBC from the UBC is the change to Seismic Design Categories (SDC), which are assigned to each structure based on several factors. Because of the way Seismic Design Categories are determined, a direct comparison between Seismic Design Categories and Seismic Zones is not possible. To provide some guidance, Seismic Design Categories A, B and C generally correlate with Seismic Zones 0, 1 and 2; and Seismic Design Categories D, E and F generally correlate with Seismic Zones 3 and 4. See the analysis in Chapter 16 for a more detailed comparison.

Chapter 23 is formatted into 8 major sections and now follows a more logical and easier to use format than did the UBC.

2301 General
2302 Definitions
2303 Minimum Standards and Quality
2304 General Construction Requirements
2305 General Design Requirements for Lateral-force-resisting Systems
2306 Allowable Stress Design
2307 Load and Resistance Factor Design (LRFD)
2308 Conventional Light-frame Construction

2301 General

2301.2.2 Load and resistance factor design. Added by reference as a design method. See the analysis in Section 2307. The 1997 UBC listed this as a recognized standard in Section 2303.

2302 Definitions. Added for Accreditation Body, Adjusted Resistance, Boundary Element, Collector, Cripple Wall, Diaphragm (Blocked), Diaphragm Boundary, Diaphragm Chord, Diaphragm Rigid, Diaphragm (Unblocked), Drag Strut, Nailing (Boundary), Nailing (Field), Oriented Strand Board (OSB), Preservative-Treated Wood, Reference Resistance, Shear Wall, Tie down, and Wood Shear Panel. These terms are used in Chapter 23 and were added for clarity.

The definition of Grade (Lumber) now references USDOC PS 20, American Softwood Lumber Standard, [listed under DOC (US Department of Commerce) in Chapter 35] rather than UBC Standard 23-1, which adopted ASTM D 1990, ASTM D 245, ASTM D 2555, Wood Handbook No.72 published by the U.S. Department of Agriculture and Voluntary Product Standard PS20-94 published by the U.S. Department of Commerce.

Naturally Durable Wood includes black walnut under decay resistant in the IBC. In the UBC Naturally Durable Wood was defined as Wood of Natural Resistance to Decay or Termites and did not include black walnut.

The Treated Wood definition has been changed from the UBC to now include both fire treated wood and wood treated to resist decay and termites

2303 Minimum Standards and Quality

2303.1.1 Lumber. Reference to USDOC PS 20, or equivalent, is now used for the identification and grading of lumber. See the analysis of Section 2302.2, definition of Grade (lumber).

2303.1.5 Fiberboard. Although not referenced in this section, Table 2308.9.3(4) prescribes shear values for fiberboard sheathing. The footnotes in Table 2308.9.3(4) cover many of the requirements for fiberboard sheathing found in UBC Section 2315.6. New provisions permitting fiberboard to be used as insulation have been added and are from the NBC.

2303.1.8.1 Identification. These provisions have been added in the code for the identification and maximum moisture content for preservative treated wood used for protection against decay and termites and are based on the requirements from the NBC.

2303.1.9 Structural composite lumber. Structural composite lumber has been added due to its widespread use.

2303.2 Fire-retardant-treated wood. Reference to a specific pressure process for chemical impregnation in accordance with AWPA C20 or C27, or other means, has been added to provide a specific treatment standard for pressure impregnation of fire treated wood. UBC Standard 23-4 referenced ASTM D 2898-91, which is now referenced in IBC Section 2303.2.3 and D 3201-79, which is now referenced in IBC Section 2303.2.4, for fire-retardant treated wood.

2303.2.6 Type I and II construction applications. A helpful cross reference has been added to Section 603.1 for limitations on the use of fire retardant treated wood in Types I and II construction in order to assure that the designer is aware of the limitations set forth in Chapter 6.

2303.4 Trusses. The provisions for metal plate connected wood trusses are moved here and were located in Division V of the UBC. The truss marking requirements of UBC Section 2321.4 have been deleted because the IBC Structural Committee believed this was of limited value. Usually the only time the markings are readily visible is during construction, and the inspector will have the approved truss drawings available. Insulation will more than likely cover the markings making them difficult to find at a later date.

A list of specific items required to be included with the truss drawings has been added. The truss construction documents are now specifically required to be prepared by a registered design professional and are required to be submitted to and approved by the building official prior to installation.

2303.6 Nails and staples. This new section adds the requirement for nails and staples to conform to ASTM F 1667. Minimum average bending yield strength requirements for nails were added to 1) standardize nails used in the field and 2) facilitate design calculation procedures for nail size and spacing determination.

2304 General Construction Requirements

2304.3 Wall framing. Reference is made to Section 2308, Conventional Construction, for the framing of exterior and interior walls.

2304.3.1 Bottom plates. This is very similar to the last paragraph of UBC Section 2320.11.2. Because this is now located in the General Construction Requirements, rather than in the conventional light-framed construction requirements as in the UBC, a minimum 2-by sill plate is required, even if design calculations show a lesser size would be adequate.

2304.3.2 Framing over openings. Requirements for framing over openings has been changed from UBC Section 2320.11.6 and is now more general in nature.

2304.5 Framing around flues and chimneys. Specific wording has been added in this Chapter requiring 2 inch minimum clearance from combustible framing around chimneys and flues. This requirement is also in Chapter 21.

2304.6.1.1 Wood structural panel sheathing. An exterior exposure durability classification requirement was added for wood structural panel sheathing used as the exterior wall finish.

2304.6.2 Interior paneling. Interior paneling now needs to comply with DOC PS 1 or PS 2.

2304.7 Floor and roof sheathing. The specific requirements in UBC Sections 2312.1 and 2312.2 for the concentrated load and the deflection limits have been eliminated. The use of the tables referenced in this section are deemed to comply with code design criteria.

Roof sheathing must be bonded by exterior glue, which is more restrictive than UBC Section 2312.2, which required intermediate or exterior glue.

Table 2304.9.1 Fastening Schedule. The UBC includes a Table 23-II-B-2, Wood Structural Panel Roof Sheathing Nailing Schedule, which addresses nail size and spacing for roof sheathing given the site's fastest mile wind speed. This table was first introduced into the 1997 UBC. Table 2304.9.1 of the IBC references footnotes b and l in Item 31 for roof sheathing which requires 8d nails spaced at 6 inches on center edge nailing and 12 inches on center field nailing regardless of the wind speed.

Power driven fasteners, sizes and staples have been added to the table because of their widespread use. The sizes indicated in the table are common to all manufactures. The number of fasteners and spacing were taken from National Evaluation Report (NER) 272. See analysis of Table 2306.3.1.

2304.9.3 Joist hangers and framing anchors. Reference is made to Section 1715.1 for test standards for determining the capacity of joist hangers and framing anchors, in accordance with ASTM D 1761. This is a new requirement not found in the UBC. The IBC Structural Committee chose to include these provisions because they were in both the NBC and the SBC.

2304.9.6 Load path. This is a new section and requires a continuous load path for wall members from the foundation sill to the roof, to help ensure that design loads will be carried down to the foundation when wall members are discontinuous.

2304.10 Heavy timber construction. Provisions for heavy timber construction have been added in Chapter 23. These requirements pertain to the general construction requirements for heavy timber, such as anchoring to supporting members and tying members together. Sizes for heavy timber are located in Section 602.4. These provisions came from the NBC.

2304.11 Protection against decay and termites. The requirements for protection against decay and termites, which were in UBC Section 2306, have been better organized in the IBC by dividing the requirements into specific sections for clarity. The new sections are: 2304.11.2 Wood used above ground; 2304.11.3 Laminated timbers; 2304.11.4 Wood in contact with the ground or fresh water; 2304.11.5 Supporting member for permanent appurtenances; 2304.11.6 Termite protection; and 2304.11.7 Wood used in retaining walls and cribs.

2304.11.2.2 Framing. Two new provisions have been added to this section from that required in the UBC. One requires wood framing members, including wood sheathing, less than 8 inches from exposed earth, to be naturally durable or preservative treated. This is more restrictive than the UBC requirement of 6 inches and was added because the IBC Structural Committee believed it is needed to address all areas of the country.

The other new provision requires wood framing and furring strips attached to exterior masonry or concrete walls below grade to be approved naturally durable or preservative treated wood. This was added because it is needed for some areas of the country and was included in the SBC.

2304.11.2.3 Sleepers and sills. All sleepers and sills on a concrete slab are required to be naturally durable or preservative treated wood. The exceptions found in UBC Sections 2306.4 and 2306.8 are not included in the IBC because the IBC Structural Committee believed the UBC exceptions did not provide adequate protection.

2304.11.2.5 Wood siding. A specific requirement for 6 inch clearance between wood siding and earth has been added, which is consistent with UBC Section 2306.8. This adds clarity to the IBC in that UBC Section 2306.8 did not specifically note wood siding. Note that this section deals with wood siding, while Section 2304.11.2.2 deals with wood sheathing (see analysis of Section 2304.11.2.2). What is now permitted in the IBC is that wood siding can extend 2 inches below the foundation plate to within 6 inches of the earth, but sheathing material must be terminated and nailed to the foundation plate to maintain 8 inch clearance. The intent is to require wall sheathing that serves as a structural element, such as shear wall sheathing, to have 8 inches of clearance, while nonstructural wood siding need only have 6 inches of clearance. Where panel siding serves the dual purpose of both structural sheathing and siding, it must comply with the 8 inch clearance requirement.

2304.11.2.6 Posts or columns. This section is a compilation of the three model codes and is more restrictive than UBC 2306.5. In this case the most restrictive aspects of the three model codes were included in the IBC in order to adequately address all portions of the country.

2304.11.4 Wood in contact with the ground or fresh water. The first paragraph permits wood which is in direct contact with the earth, and which is supporting permanent structures, to be naturally durable wood. Although this is less restrictive than UBC Section 2306.2, it only applies to wood in contact with the ground. (Wood posts or columns embedded in the ground are still required to be pressure treated, as is in the UBC). This was included because the IBC Structural Committee believed these provisions provide adequate protection for the wood. A specific requirement for the treatment of wood in accordance with AWPA C2 or C9, or other applicable AWPA standards, has been added.

2304.11.6 Termite protection. The first paragraph adds a requirement for naturally durable or preservative treated wood, or other approved methods of termite protection, when there is a heavy hazard of termite damage. This was added for areas of the country which have a serious termite hazard.

2304.11.8 Attic ventilation.
2304.11.9 Underfloor ventilation (crawl space).
Cross references to Chapter 12 Interior Environment, for attic and underfloor ventilation have been added. These provisions are maintained by the IBC General Committee.

2305 General Design Requirements for Lateral-force-resisting Systems

This section is based on the 1997 NEHRP Provisions.

There are now separate sections for wood diaphragms (Section 2305.2) and wood shear walls (Section 2305.3), unlike the UBC, which combined the two into one section. See the definitions of diaphragm and shear wall in Section 2302. The IBC uses the terms "shear wall" and "diaphragm" exclusively, where "diaphragm" refers to horizontal diaphragms (such as roof or floor diaphragms), whereas the UBC occasionally used vertical diaphragms and occasionally shear walls when referring to the same lateral load resisting element. Thus, the IBC will clarify the terminology.

2305.1.5 Wood members resisting horizontal seismic forces contributed by masonry and concrete. Based on the language in the respective codes, the limitations in the IBC for wood members resisting horizontal forces contributed by masonry and concrete only apply to seismic loads, whereas the limitations in the UBC apply to both seismic and wind. This is from the 1997 NEHRP Provisions. Because of the significant in-plane stiffness differences between wood and masonry or concrete systems, the use of wood members to resist seismic forces due to concrete and masonry is not allowed.

2305.2.2 Deflection. Deflection calculation formulae for wood diaphragms and shear walls have been added to the body of the code. These formulae are based on the 1997 NEHRP Provisions and UBC Standard 23-2.

Table 2305.2.3 Maximum Diaphragm Dimension Ratios Horizontal and Sloped Diaphragm. This table is applicable to sloped as well as horizontal diaphragms. The maximum length to width ratio for wood structural panel diaphragms, blocking omitted at intermediate joints, is 3:1, versus 4:1 in the UBC. The aspect ratios in the table are based on the 1997 NEHRP Provisions.

2305.2.4.1 Seismic Design Category F. Special requirements for the installation of wood structural panel shear walls and diaphragms in Seismic Design Category F have been added, based on the 1997 NEHRP Provisions.

2305.2.5 Rigid diaphragms. This is a new section dealing with rigid diaphragms and is based on the 1997 NEHRP Provisions. This section contains the requirements and limitations for torsional force distribution on open front structures and cantilevered diaphragms (rotation in UBC Section 2315.1). In order to adequately distribute lateral forces by rotation the diaphragm must be rigid. The significant change in the IBC from the UBC is that to use these provisions the diaphragm must meet the definition of rigid. (See definition of rigid diaphragm in Section 2302) This will require the calculation of the lateral deformation of the diaphragm, as noted in Section 2305.2.1.

Figures 2305.2.5(1) and 2305.2.5(2). These have been added to clearly illustrate diaphragm length to width ratios and limitations at open front buildings and for cantilevered diaphragms and are based on the 1997 NEHRP Provisions.

2305.3.1 General. A new requirement limits shear wall sheathing in Seismic Design Categories E and F to wood structural panels only. No particle board, fiberboard or diagonal sheathing may be used in these Seismic Design Categories. These limitations are based on the 1997 NEHRP Provisions. See analysis of Sections 2306.4.3 and 2306.4.4.

2305.3.2 Deflection. See analysis of Section 2305.2.2.

Table 2305.3.3 Maximum Shear Wall Aspect Ratios. The shear wall aspect ratios in the IBC are based on the 1997 NEHRP Provisions. The aspect ratios in the table have changed from UBC Table 23-II-G. Fiberboard has been included in the table. Materials other than wood structural panel are only permitted in Seismic Design Categories A through D. (see Sections 2305.3.1 and 2306.4.4). Footnote 3 in UBC Table 23-II-G is not included due to recent experience gained from the 1994 Northridge earthquake with respect to damage from slender, flexible wood panel shear walls.

2305.3.5 Shear wall width definition. Specific wording describing shear wall width has been added, which includes a reference to overturning restraint, and was added to provide a clear and easy to understand definition.

2305.3.6 Overturning restraint. A specific provision for checking for overturning restraint has been added which clarifies when hold down devices are required. A continuous load path is required from the anchoring device to the foundation.

2305.3.7.2 No force transfer around openings.
Table 2305.3.7.2 Shear Capacity Adjustment Factors.
This is an entirely new section for shear walls with openings, which is permitted to be used where there is no design for force transfer around the openings. This perforated shear wall methodology came from the SBC, where it is used for wind design only. The IBC Structural Committee discussed this item at length and the latest research in wind and earthquake design was presented. The provisions in the IBC can be used for both wind and seismic design and are only applicable to wood structural panel shear walls.

2305.3.8 Summing shear capacities. Prohibits adding the shear capacities of different materials applied to the same wall. This section combines the requirements from UBC Sections 2319.3 and 2513.1. An exception for wind design, which is not in the UBC, permits adding the shear values of dissimilar materials applied to both faces of the wall. Some testing has shown the cumulative values of dissimilar materials can be considered for wind design.

2305.3.9 Adhesives. This new IBC section prohibits adhesive attachment of shear wall sheathing, either as a substitute for mechanical fasteners, or with mechanical fasteners, in Seismic Design Categories D, E and F and is based on the 1997 NEHRP Provisions. Adhesives, when tested in assemblies subjected to cyclic loading, have had a brittle mode of failure.

2305.3.10 Sill plate size and anchorage in Seismic Design Category D, E or F. Specific requirements for sill plate, anchorage and plate washers in Seismic Design Categories D, E and F have been added. These are more inclusive than UBC Section 1806.6.1 and are based on the 1997 NEHRP Provisions. Shear values are now given for both LRFD and ASD, since LRFD is an acceptable design method. See Section 2307. The foundation reinforcement requirements in the UBC for Seismic Zones 3 and 4 are not included. See IBC Section 1910.4.4.2.

The exception is often used in retrofit work where it is not practical to remove existing plates, and in new residential construction where short sections of wall with design loads greater than 350 plf would require all the sill plates to be increased to 3-inch members due to detailing difficulties when wood floor framing bears on intermixed 3-by and 2-by plates. Existing footnote 3 found in Tables 23-II-I-1 and 23-II-I-2 of the UBC (see errata dated September, 1997) is incorporated into the exception to improve organization and clarity.

2306 Allowable Stress Design

2306.1 Allowable stress design. This section adopts the AF&PA NDS-97, National Design Specification for Wood Construction by reference, with no amendments. The amendments found in UBC Chapter 23, Division III are not in the IBC. One major change is that the NDS permits a load duration factor of 1.60 for earthquake loads, whereas the UBC amended this duration factor to 1.33. The 1.60 duration factor is supported by extensive testing and research.

2306.1.1 Joists and rafters.
2306.1.2 Plank and beam flooring.
These are new sections and permit the design of rafter spans and plank and beam flooring in accordance with specific AF&PA reference documents.

2306.1.3 Treated wood stress adjustments. This section is similar to UBC Section 2316.2, numbers 7 and 8.

2306.2.1 Wall stud bending stress increase. This new section permits the bending stress in wood studs, which are part of wall assemblies resisting wind loads to be increased in accordance with IBC Table 2306.2.1. This section came from the SBC and recognizes the load sharing and composite action of walls constructed in accordance with this section. Tests and other supporting data were submitted to SBCCI to support this methodology. The increase factor varies with stud size because the required minimum sheathing thickness remains constant for all stud sizes, which results in the sheathing having a greater influence on the smaller stud sizes in developing composite action.

2306.3.1 Shear capacity modifications.
2306.4.1 Wood structural panel shear walls.
These new sections permit the shear values for horizontal diaphragms and shear walls to be increased by 40 percent for wind design and came from the SBC. Over the last few years the ASCE wind loads on structures have increased. In addition, recent research has provided a better understanding of how wind forces affect structures. Based on this, a recommendation was made to lower the factor of safety for wind (which translated into the 40 percent increase for shear values). This recommendation was accepted first into the SBC and carried over into the IBC.

Table 2306.3.1 Recommended Shear (pounds per foot) for Wood Structural Panel Diaphragms with Framing of Douglas-Fir-Larch, or Southern Pine for Wind or Seismic Loading.
Table 2306.4.1 Diagonally Sheathed Lumber Diaphragm Nailing Schedule.
Staples have been added to both tables because they are used extensively in wood diaphragms and shear walls. Proposed diaphragm lateral strengths reflect adjustments to nailed diaphragm values for relative lateral strength of staples with respect to listed nails. Stapled connections are supported by studies and recent cyclic testing. See analysis of IBC Table 2304.9.1.

The minimum nail penetration requirements have been reduced where 8d and 10d nails are used. Studies undertaken using the European Yield Method (EYM) for calculating nail lateral values showed that the penetrations indicated in the tables are not necessary. The EYM is an accepted methodology, is included in the NDS and provides a more sophisticated method to evaluate nail penetration requirements. This change will now permit the use of 2-by flatwise blocking in diaphragms and shear walls in which 10d nails are used, since only 1½ inch penetration is now required for 10d nails.

Table 2306.4.1 Allowable Shear (pounds per foot) for Wood Structural Panel Shear Walls with Framing of Douglas-Fir-Larch, or Southern Pine for Wind or Seismic Loading. This was UBC Table 23-II-I-1. Footnotes e and f require 3-inch or wider framing members at adjoining panel edges where nail spacing at panel edges is 2 inches or less, or where 10d nail spacing at panel edges is 3 inches or less. Recent earthquakes have shown that highly loaded shear walls with close nail spacing sustained major damage because there was not adequate nail edge distance.

Footnote i, which was footnote 3 in the UBC Table, was changed to apply to Seismic Design Categories D, E and F. See analysis of IBC Section 2305.3.10.

2306.4.3 Particleboard shear walls. The prohibition of the use of particleboard to resist seismic forces in Seismic Design Categories D, E and F is more restrictive than the UBC. These Seismic Design Categories categories include many regions currently covered by UBC Seismic Zones 3 and 4. Cyclic testing has not been performed showing that particleboard can provide satisfactory performance in a seismic event.

2306.4.4 Fiberboard shear walls. A prohibition against using fiberboard in Seismic Design Categories D, E and F was added to this section. Cyclic testing has not been performed showing that fiberboard can provide satisfactory performance in a seismic event.

2306.4.5 Shear walls sheathed with other materials.
Table 2306.4.5 Allowable Shear for Wind or seismic Forces for Shear Walls of Lath and Plaster or Gypsum Board Wood-framed Wall Assemblies.
The information included in IBC Table 2306.4.5 is found in UBC Chapter 25. Since this table deals with lath and plaster and gypsum board applied to wood framed shear wall construction, the table was relocated from Chapter 25 to Chapter 23. See analysis of IBC Section 2505. Similarly, steel stud shear wall values are found in Chapter 22. An addition to this section and to footnote a prohibits the use of this

table for Seismic Design Categories E and F. Experience in the Northridge earthquake showed that gypsum board and stucco shear walls did not exhibit adequate structural strength and ductility necessary to resist seismic forces. The UBC 50 percent reduction for loading due to earthquake in Seismic Zones 3 and 4 has been changed in the IBC to apply to Seismic Design Category D.

Power driven fasteners and staples have been added to this table to address commonly used fasteners. Documentation was submitted to the IBC Structural Committee supporting this change.

2307 Load and Resistance Factor Design (LRFD)

The permitted use of the Load and Resistance Factor (LRFD) Design Standard for Engineered Wood Construction, AF&PA/ASCE 16, has been adopted as a referenced standard and can be used for all wood design. The 1997 NEHRP Provisions uses this standard as the primary design procedure for engineered wood construction and adopted it by reference.

2308 Conventional Light-frame Construction

Division IV of the UBC was the basis for the requirements in this section. Neither the NBC or the SBC had a specific comprehensive set of requirements for conventional light frame construction as existed in the UBC. Both the NBC and SBC had some general and broad requirements for conventional construction. At the first committee meetings, suggestions were made not to include conventional construction provisions in the IBC and questions were raised over what was the basis for the provisions in the UBC. Because conventional construction is used extensively by the UBC users, and information was provided to the IBC Structural Committee showing the basis for many of the provisions, the decision was made to include these provisions in the IBC. There was considerable discussion and participation, and time spent by the IBC Structural Committee and the participants in developing, reviewing and accepting these provisions.

Many provisions from the NBC and SBC which were related to conventional construction have been included in the IBC. Most of the seismic provisions are based on the 1997 NEHRP Provisions. The NEHRP Provisions generally followed the requirements of the *One- and Two-Family Dwelling* code, with additions and modifications made to address the seismic issues. Provisions were also added by the IBC Structural Committee.

2308.1 General. Although IBC Section 2308 contains the provisions for conventional light frame construction, it should be noted that the Exception in Section 101.2 permits the use of the *International Residential Code* (IRC) for one- and two-family dwellings and multi-family dwellings (townhouses) which meet the criteria noted in the exception.

2308.2 Limitations. This section sets the conditions where conventional construction provisions can be used. These conditions have been taken from various references, including the three model codes, the CABO *One- and Two-Family Dwelling Code* and the 1997 NEHRP Provisions.

1. This came from the 1997 NEHRP Provisions. The 14 inch exception for solid blocked cripple walls came from the IBC Structural Committee based on UBC Section 2320.11.5
2. The building story limitation is from the 1997 NEHRP provisions.
3. The load limitations are from the 1997 NEHRP provisions, except the 50 psf ground snow load limitation, which was in the SBC and the UBC.
4. The 100 mph (3-second gust) wind speed limitation was added by the IBC Structural Committee based on issues raised by committee members, and was also included in the SBC. The 100 mph (3-second gust) wind speed is equivalent to the 80 mph (fastest mile) wind speed. The basis of the wind speed used in design has been changed from the "fastest mile" to the "3-second gust," in order to be consistent with the changes in wind design in Chapter 16. See the analysis of IBC Section 1609.
5. This was added by the IBC Structural Committee to limit loads and uplift forces, which are developed at roof truss and rafter supports.
6. This prohibition on the use of these provisions in Seismic Design Category F is from the 1997 NEHRP provisions. In order to be assigned Seismic Design Category F, a structure must be in Seismic Use Group III, which are essential facilities. (See analysis of Sections 1616.2 and 1616.3). Conventional construction provisions are not considered adequate for structures that must sustain the potentially high seismic demands expected in Seismic Design Category F, and are not applicable to essential facilities that are expected to be functional following a major seismic event.
7. The use of these provisions for irregular structures in Seismic Design Categories D and E is limited as specified in Section 2308.12.6. See the analysis of IBC Section 2308.12.6.

2308.2.1 Basic wind speed greater than 100 mph (3-second gust). This section permits the use of the *AF&PA Wood Frame Construction Manual,* or the provisions of the *SBCCI Standard for Hurricane Resistant Residential Construction* (SSTD-10) when the wind speed is greater than 100 mph (3-second gust), or 80 mph (fastest mile). High wind loading presents specific design and construction issues which are not adequately addressed in the conventional construction provisions. The UBC Appendix Chapter 23 provisions have not been included in the IBC because the above referenced documents can now be used in the high wind areas. See the analysis of IBC Section 2308.2, item 4.

2308.2.2 Buildings in Seismic Design Category B, C, D or E. This section was added by the IBC Structural Committee in order to clearly identify the additional requirements for buildings in Seismic Design Categories B and C as well as D and E. The IBC Structural Committee chose to limit the applicability of these additional requirements to those buildings in higher seismic risk areas.

The first paragraph guides the user to Section 2308.11 for additional requirements for Seismic Design Categories B and C. Because many parts of the country which were in the lower Seismic Zones 0, 1, and 2 will now have structures in Seismic Design Categories B and C, the IBC Structural Committee choose to add the two exceptions for detached Group R-3 dwellings. Exception 1 is consistent with the IRC and with Section 1614, Exception 1.

The second paragraph guides the user to Section 2308.12 for additional requirements for Seismic Design Categories D and E.

2308.3.1 Spacing. The 35 foot spacing of braced wall lines came from the 1997 NEHRP Provisions. This is a slight change from the 34 foot requirement of UBC Section 2320.4.1. It should be noted that Section 2308.12.3 sets the spacing at 25 feet in Seismic Design Categories D and E, which are also in the 1997 NEHRP Provisions. UBC Section 2320.5.1 set the 25 foot spacing for Seismic Zone 4.

2308.3.2 Braced wall panel connections. These requirements came from the 1997 NEHRP Provisions and are intended to be prescriptive provisions that assure a complete load path.

The second sentence of item 1 was added to specifically require interior braced wall lines to be continued through the attic to the roof diaphragm. The exception to item 1 was added to provide a prescriptive method to transfer lateral forces from the roof diaphragm to the braced wall where trusses are used.

2308.3.3 Sill anchorage. This section works in combination with IBC Section 2308.6 Foundation plates or sills. The 4 foot spacing for anchor bolts in structures over two stories is based on the 1997 NEHRP Provisions.

2308.3.4 Braced wall line support. The requirement for all braced wall lines to be supported on continuous foundations was added by the IBC Structural Committee. This is more restrictive than UBC Section 2320.5.6, which only requires interior braced wall line support in Seismic Zone 4. The IBC Structural Committee had a lengthy discussion on this issue and the consensus was that this issue was not just a seismic issue but should apply to all conventionally constructed structures regardless of the type of load. The exception is from the 1997 NEHRP Provisions.

2308.4 Design or portions. This section is the same as UBC Section 2320.2, except a sentence has been added at the end to alert the designer and code official of the need to consider how the nonconforming elements may impact the lateral force resisting system of the overall structure.

2308.6 Foundation plates or sills. These requirements are a compilation from the NBC, SBC and the UBC. The requirements were relocated from UBC Chapter 18 to Chapter 23. See analysis of IBC Sections 2305.3.10, 2308.12.9 and 1805.6.

Prescriptive foundation plate and anchorage requirements are found exclusively in IBC Chapter 23, and are only applicable to conventional construction. The UBC provisions in Chapter 18 appeared to specify minimum requirements for all wood plates and sills, regardless of whether conventional construction was used or whether a design was provided.

Tables 2308.8(1) and 2308.8(2) Floor Joists Spans for Lumber Species. These are from the AF&PA span tables. Table 2308.8(1) is for a floor live load of 30 psf, since IBC Table 1607.1 permits a 30 psf live load for residential sleeping areas. The AF&PA Construction Manual is developed through an approved consensus process and the span tables are considered equivalent to meeting code requirements.

2308.8.5 Lateral support. Provisions for lateral support for floor, attic and roof framing have been added here. These requirements were from UBC Sections 2320.8.6 and 2320.12.8 and were combined into one section for clarity.

2308.9.2.1 Top plates. This requirement for 8-16d face nails on each side of the joint was added from the 1997 NEHRP provisions and is more restrictive than item 10 in both IBC Table 2304.9.1 and in UBC Table 23-II-B-1, which require a total of 8-16d nails at this splice.

2308.9.2.3 Nonbearing walls and partitions. This section allowing nonbearing walls to have studs spaced at 28 inches and set with the long dimension parallel to the wall was added by the IBC Structural Committee and was also included in the SBC. It should be noted that the NBC permitted studs to be spaced at not more than 48 inches with the long dimension parallel to the wall.

Table 2308.9.3(1) Brace Wall Panels. This table is applicable to Seismic Design Categories A, B and C only, and is taken from UBC Table 23-IV-C-1. Seismic Zones have been changed to Seismic Design Categories. It should be noted that Table 2308.12.4 is used for Seismic Design Categories D and E.

2308.9.3 Bracing. The last paragraph references the user to Section 2308.3.2 for braced wall panel connections. These requirements were found in UBC Table 23-II-B-1. The provision allowing a 12 inch by 12 inch continuous footing or turned down slab at door openings was added to allow a common footing construction practice at garage doors.

2308.9.3.1 Alternate bracing. This section is similar to UBC Section 2320.11.4. In numbers 1 and 2 the locations of the anchor bolts have been better described and clarified by re-wording.

2308.9.4.1 Bracing. See analysis of IBC Section 2308.12.4.

2308.9.5 Openings in exterior walls.
2308.9.6 Openings in interior-bearing partitions.
These sections, and Tables 2308.9.5 and 2308.9.6 add prescriptive header and girder span tables for exterior and interior bearing walls which can be used for one- and two-family dwellings. This is something that was never provided in the UBC and adds an important element to the IBC. These tables are based on the provisions in the SBC.

Section 2308.10.1 and Table 2308.10.1. These provisions were added by the IBC Structural Committee to address wind uplift forces which can occur at the connections of the roof assemblies and trusses to the walls below. The resultant uplift loads are also required to be transferred to the foundation. Under UBC Table 23-II-B-1 only 3-8d toenails were required for this connection, and questions frequently arose whether this connection was adequate for the uplift forces that may be developed.

Sections 2308.10.2 and 2308.10.3, and Tables 2308.10.2(1) through 2308.10.3(6). These allowable span provisions are from the AF&PA Span Tables for Joists and Rafters and are in a different and easier to use format than the UBC span tables.

2308.10.4.1 Ceiling joist and rafter connections. This section is a combination of the SBC and UBC, with some additional modifications to ensure that adequate ceiling joist/rafter connections will be provided. Table 2308.10.4.1 was added to ensure adequate rafter tie connections for both no snow and roof snow load conditions.

2308.10.7 Wood trusses. This section is new and is from the SBC. Truss members, because they are part of an engineered system, cannot be cut or altered without written approval from a registered design professional.

2308.10.10 Attic ventilation. A cross reference to Section 1202.2 for attic ventilation has been added.

2308.11 Additional requirements for conventional construction in Seismic Design Category B or C. This section contains additional requirements and limitations for Seismic Design Categories B and C. This provision is based on the 1997 NEHRP Provisions, and was added to clearly identify and separate the additional requirements applicable to these Seismic Design Categories and to make the code easier to use.

2308.11.1 Number of stories. Structures in Seismic Design Category C shall not exceed 2 stories in height. This is a new requirement that was not in the UBC and is based on the 1997 NEHRP Provisions. The exception permits detached one- and two-family dwellings to be three stories in height.

2308.11.2 Concrete or masonry. This section limits the height of concrete or masonry walls and masonry veneer to the basement level only. Two exceptions were added by the IBC Structural Committee to permit masonry veneer up to three stories above grade under specific conditions. The UBC did not limit the height of masonry veneer, but rather the thickness to 5 inches.

2308.11.3.2 Stepped footings.
Figure 2308.11.3.2 Stepped Footing Connection Details.
Specific requirements and details were added for stepped footings. The 1997 NEHRP provisions recommended that this apply to all Seismic Design Categories but the IBC Structural Committee exempted Seismic Design Category A because of the low seismic risk. Section 2308.11.3.3 and Figure 2308.11.3.3. Blocking requirements around openings greater than four feet in horizontal diaphragms have been added. The 1997 NEHRP Provisions recommended that this apply to all Seismic Design Categories but the IBC Structural Committee exempted Seismic Design Category A because of the low seismic risk.

2308.12 Additional requirements for conventional construction in Seismic Design Category D or E. This section adds additional requirements for Seismic Design Categories D and E.

2308.12.1 Number of stories. Structures in Seismic Design Categories D and E shall not exceed one story in height. An exception permits detached one- and two-family dwellings to be two stories in height. This is more restrictive than the limitation set forth in UBC Section 2320.1 and is based on the 1997 NEHRP Provisions.

2308.12.2 Concrete or masonry. This section does not permit concrete or masonry walls, or masonry veneer, to extend above the basement. This is more restrictive than Section 2320.5.3 of the UBC, which limited anchored masonry and stone veneer to one story in Seismic Zone 4 and is based on the 1997 NEHRP Provisions.

2308.12.3 Braced wall line spacing. While the UBC limited the spacing between interior and exterior braced wall lines to 25 feet only in Seismic Zone 4, this section applies the 25 foot limitation to Seismic Design Categories D and E.

2308.12.4 Braced wall line sheathing.
Table 2308.12.4 Wall Bracing in Seismic Design Categories D or E.
This is a new table and is used for wall and cripple wall bracing requirements for Seismic Design Categories D and E. This came from the 1997 NEHRP Provisions and is triggered by the design spectral response acceleration at short periods, S_{DS}, rather than Seismic Design Categories as used in Table 2308.9.3(1).

In some instances Table 2308.12.4 is more restrictive than the UBC, and in some cases less restrictive. For example, when S_{DS} is greater than or equal to 0.75, the use of gypsum board, fiberboard, particleboard, lath and plaster and gypsum sheathing board is permitted to be used only for the top or only story of one- and two-family detached dwellings. This is more restrictive than UBC Table 23-IV-C-1 which permits these materials to be used for braced wall panels for all conventional construction in all seismic zones.

Cripple walls exceeding 14 inches in height are considered a story for Seismic Design Categories D and E and are required to be braced in accordance with Table 2308.12.4. This is based on the 1997 NEHRP Provisions. This is less restrictive than UBC Table 23-IV-C-2, which required the bracing of all cripple walls exceeding 14 inches in height with wood structural panels, regardless of seismic zone.

The second paragraph of IBC Section 2308.12.4 adds new requirements for increasing the length of exterior cripple wall bracing by one and one-half times the lengths specified by Table 2308.12.4 where interior braced wall lines occur without a continuous footing below.

2308.12.5 Attachment of sheathing. Adhesives cannot be used to attach wall sheathing. See analysis of IBC Section 2305.3.9

Section 2308.12.6 and Figures 2308.12.6(1) through 2308.12.6(8). Portions of structures considered irregular in Seismic Design Categories D and E cannot use conventional construction, and these figures have been added to graphically illustrate the various conditions in order to aid the user of the code.

The conditions describing irregular structures are from the 1997 NEHRP Provisions and are similar to the UBC conditions.

Condition 6 is different from UBC 2320.5.4.4 and is more inclusive.

2308.12.7 Exit facilities. This provision is identical to UBC Section 2320.13 except it now applies to Seismic Design Categories D and E.

2308.12.8 Steel plate washers. This provision requires 3⁄16-inch by 2-inch by 2-inch plate washers in Seismic Design Categories D and E, which is consistent with the UBC requirements for plate washers in UBC Section 1806.1.1 for Seismic Zones 3 and 4.

In the first drafts of the IBC plate washers were included for all Seismic Design Categories except A, as recommended by the 1997 NEHRP Provisions. There was considerable and lengthy IBC Structural Committee debate and discussion, as well as public testimony, as to when plate washers should be required. The IBC Structural Committee chose to require plate washers only in the higher seismic risk areas.

2308.12.9 Anchorage in Seismic Design Category E. This section requires 5⁄8-inch diameter steel anchor bolts for Seismic Design Category E. This is only required for conventional construction. Where a design is provided by other provisions of the code, 1⁄2-inch diameter anchor bolts may be used. UBC Section 1806.6 has been interpreted to require 5⁄8-inch anchor bolts in Seismic Zone 4 regardless of whether conventional construction was used or a design was provided. See analysis of IBC Sections 2305.3.10 and 2308.6.

Chapter 24 of the IBC
Glass and Glazing

Introduction

With the exception of how allowable glazing areas and thicknesses are determined, Chapter 24 of the 2000 IBC is not substantially different than the 1997 UBC. While modifications have been made (as highlighted below) that represent changes from the UBC provisions, most are minor in nature. Some of the more substantial differences from the 1997 UBC include:

- Sections 2403.1 and 2406.1 allow more flexibility in labeling of glazing.
- Section 2404 and its associated Figures 2404(1) through 2404(12) contain an entirely new design method for determining allowable glazing sizes and thickness.
- Section 2406 regarding safety glazing has been reorganized.
- Section 2409 applies the new design methodology in IBC Section 2404 to glazing in floors and sidewalks.

As is the case with the entire IBC, standards referenced in the text are generally the nationally recognized standards, as opposed to reprinting or separately adopting these standards as code standards (e.g., CPSC 16 CFR, Part 1201 is referenced in IBC Section 2406.1, instead of UBC Standard 24-2).

The following analysis of this chapter is not intended to be a comprehensive point-by-point comparison of the IBC to the 1997 UBC, but rather highlight some of the differences between the two codes.

2401 General

2401.1 Scope. The revisions to this section broaden the application of the code requirements to all types of glazing, both exterior and interior, and to all occupancy groups. The UBC exemptions for Group R and U occupancies do not appear in the IBC, since the same standards should apply to all glazing, whether residential or commercial. For example, resistance to weathering, allowable loads on window assemblies, labeling of glazing, and support of glazing.

2403 General Requirements for Glass

2403.1 Identification.
2406.1 Human impact loads.
These sections contain the requirements for labeling of glass. There is some overlap between the two sections, one of which has general labeling requirements and the other has the labeling requirements for safety

glass. A revision common to both Sections 2403.1 and 2406.1 allows all safety glazing to be identified with a type of label that cannot be removed without being destroyed (for example, a mylar label). See the comparison table below. There was concern expressed by some building officials at the public hearings that once the label is removed, there is no way to identify if the pane is tempered glass. Thus, if the glass were to be replaced for whatever reason, there would not be an easy way to know what type of glass is required to replace the existing pane. However, the requirement for a permanent etched label applies only to tempered glass in the UBC, and not to other types of safety glazing, such as laminated glass, where the issue of identifying existing materials is the same. In addition, because the same issue could be a problem in many other areas of the building code where it is not easy to verify what is needed to replace something that is existing, it is not reasonable to single out tempered glass as needing special labeling requirements.

Identification Requirements for Glazing

	1997 UBC	**2000 IBC**
Nonsafety Glazing	Label or affidavit (UBC 2402)	Label or affidavit (IBC 2403.1)
Tempered Glass	Permanently etched or ceramic fired mark (UBC 2406.2)	Permanently acid etched, sand blasted, ceramic fired, or embossed label, or a label of a type that cannot be removed without being destroyed (IBC 2403.1)
Tempered Spandrel Glass	Removable paper label (UBC 2406.2)	Removable paper marking (IBC 2403.1, 2406.1.1)
Other Safety Glazing	Permanent label (UBC 2406.2)	Permanently acid etched, sand blasted, ceramic fired, or embossed label, or a label of a type that cannot be removed without being destroyed; OR Certificate, affidavit, or other evidence confirming compliance with the code (IBC 2406.1.1)

2403.4. This section limits the deflection of interior glazing panels installed adjacent to a walking surface, in order to prevent children's fingers, etc. from getting pinched between the panels.

2404 Wind, Snow and Dead Loads on Glass

This section specifies the method to be used to determine the adequacy of glazing installed in both vertical and horizontal assemblies. This is a wholesale revision to the 1997 UBC requirements and is based on the latest national standard ASTM E1300. Some features of the revised section are:

- The 1997 UBC used an outdated empirical method based on the area of the glass pane, and resulted in unconservative designs in some cases. Because glass is not necessarily sensitive to overall area, but to its aspect ratio (length versus width), the new method uses the length and width of the glass pane to determine the allowable loads.

- The text in ASTM E1300 describing how to calculate the allowable loads on the glass has been converted to formulas with defined notations for ease of use (See IBC Sections 2404.1 and 2404.2).
- For sloped glazing, the formulas take into account the weight of the glass (defined in the notations as 13 pounds per square foot per inch of thickness) and different load conditions.
- Instead of using one graph to cover all cases as in the UBC Graph 24-1, the IBC provisions are shown in several graphs as Figures 2404(1) through 2404(12) for accuracy and ease of use. Each figure represents the requirements for a given thickness of glass. However, these figures do not represent all the thicknesses of glass that are available. More information is available in ASTM E 1300, and there are computer programs that can be used to design glass using the provisions of ASTM E 1300.

It should be noted that glazing in hurricane-prone regions must not only meet the load requirements of this section, but may be required to be protected from small or large objects impacting the glass. See analysis IBC Section 1609.1.4.

Figures 2404(1) through 2404(12). These graphs replace UBC Graph 24-1. Glass is a brittle material and is extremely sensitive to surface or interior imperfections or damage. Because an absolute allowable value cannot be determined for glass, the allowable loads that can be derived from these graphs are based on the industry standard of a probability of failure of 8 in 1000. The "wavy" lines on the graphs represent the maximum allowable equivalent load on the glass in pounds per square foot. This value is modified by the factors in Sections 2404.1 and 2404.2. There is also a dotted line labeled on the graphs that represents the point at which the deflection exceeds ¾ inch. See IBC Section 2403.3.

The graphs are read in the following fashion, for a given glass thickness and size:

- Find the length on the horizontal axis and draw a vertical line at that point. (The length is the longest dimension of the glass, irrespective of the orientation of the glass.)
- Find the width of the glass on the vertical axis and draw a horizontal line at that point.
- Find the point at which the two lines intersect.
- sing the straight diagonal lines to interpolate between the "wavy" lines, determine the maximum allowable equivalent load for given piece of glass.

The graphs may also be used in reverse, in order to determine the maximum allowable dimensions of a pane of glass.

2405 Sloped Glazing and Skylights

2405.3 Screening. This section contains provisions for placing mesh screens below heat-strengthened and fully tempered glazing, similar to those requirements in Section 2409.3 of the 1997 UBC. However, a revision to this section requires that the screening material and its fastenings must be capable of supporting twice the weight of the glazing material. This will provide a safety factor against mesh failure, as opposed to the UBC, which had no safety factor.

2406 Safety Glazing

Table 2406.1 Minimum Category Classification of Glazing. This table specifies what category of safety glazing is required for a given size and location. In the 1997 UBC, this table appeared in UBC Standard 24-2, where it could be easily overlooked. Having this table in the code is more user-friendly, and will make the provisions easier to enforce.

2406.1.1 Identification of safety glassing. In addition to the change to labeling requirements for safety glazing described previously under Section 2403, a new exception appears in the IBC that allows the building official to accept certificates or affidavits of code compliance in lieu of the permanent label on safety glass. This will give designers some added flexibility in complying with the code. This exception does not apply to tempered glass, which will continue to be required to have a label on the glass. This has been debated many times at UBC code change hearings. In this case, it was believed to be a reasonable alternative to labels, since the language of the revision is such that the building official is provided with an option, and is not required to accept the certificate.

2406.1.2 Multi-light assemblies. Allows only one pane of glass in a multi-light window required to meet the requirements for safety glazing to be fully labeled in accordance with Section 2406.1.1. All other panes may have a label with less information, allowing the labels to be less obtrusive. This has been a topic of debate for several UBC code cycles, but the drafting committee for the IBC allowed the change on the basis that allowing the additional design flexibility did not compromise safety.

2406.2 Hazardous locations. This section on hazardous locations of glass has been reformatted as compared to the 1997 UBC for ease of use. The exceptions are now tied more directly with the items which they modify. Exceptions that apply to several items have been grouped together in Section 2406.2.1.

The UBC has required safety glazing adjacent to doors and within a 24-inch arc of either door jamb for several code cycles (Section 2406.4, Item 6 of the 1997 UBC). A new exception to Item 6 of this section of the IBC allows nonsafety glazing in walls perpendicular to the plane of the door in individual dwelling units. The application of the exception is limited to dwelling units because the intent of the original provision was to address commercial occupancies, where increased traffic at doors would increase the risk of persons impacting the glazing within vestibules and walls adjacent to doors. Within dwelling units, there is significantly less risk of slipping and impacting glazing that is perpendicular to the direction of travel.

The provisions in the 1997 UBC for safety glazing adjacent to stairs were difficult for both designers and building officials to understand.

Item 10 of this section in the IBC has been reworded to clarify where safety glazing is required. Because the chances of tripping and impacting glazing is greater at the bottom of a run of stairs as opposed to at the top of a run, the IBC provisions only require safety glazing within 60 inches of the bottom tread of a stairway, whereas the UBC required safety glazing at the top and bottom of the stair (1997 UBC Section 2406.4, Item 10). A new exception to this item also allows a railing that is placed at least 18 inches from the glazing to waive the requirements for safety glass. This is more reasonable than the 1997 UBC provisions which did not recognize any sort of protection for the glazing, even though the railing reduces the chance of impacting the glass when falling.

2409 Glass in Floors and Sidewalks

This section contains the requirements for glass installed in floors and sidewalks. There have been extensive revisions made in comparison to the 1997 UBC, in order to incorporate the design requirements in ASTM E 1300. (See also the analysis for Section 2404.)

2409.4 Design formula. Specifies the formulas to be used in designing glass installed in walking surfaces. The formulas are similar to those in Section 2404.2, but the allowable loads are two-thirds of the allowable loads for horizontal glazing such as skylights, as an additional safety factor against breakage.

Chapter 25 of the IBC
Gypsum Board and Plaster

Introduction

Since Chapter 25 of the *International Building Code* (IBC) is a combination of provisions derived from all three model codes, it is somewhat broader in scope than the NBC (Reference 1), SBC (Reference 2), and UBC. The most significant difference between the provisions contained in the UBC and the other model codes is that detailed installation requirements are included in the UBC, whereas the other model codes generally refer to American Society for Testing and Materials (Reference 3) standards for installation of materials and accessories. Like the NBC and SBC, referring to ASTM installation standards is the also approach taken in the IBC. Although the IBC refers to ASTM material and installation standards, many of the prescriptive requirements of the 1997 UBC have been incorporated into the IBC as well.

A standard is a document that has been developed through an established consensus process. ASTM employs a consensus process that ensures technically competent standards that have the highest credibility when used as the basis for regulatory policy. Organized in 1898, ASTM has evolved into one of the largest voluntary standards development systems in the world, publishing a host of standard test methods, specifications, practices, guides, classifications, and terminology. The ASTM standards referenced in the IBC are very comprehensive in scope, giving detailed descriptions of test methods, material specifications and installation procedures. Each ASTM Standard generally includes a variety of references to other ASTM standards, thereby expanding the scope of that particular standard.

The trend in code writing is to reference national consensus standards rather than incorporate the standards into the code by transcription. This is the approach taken in the IBC. It is imperative, therefore, that code users obtain the necessary standards in order to have access to the full range of code requirements and any applicable conditions of approval.

As in the three model codes, standards that are referenced in the IBC are listed in Chapter 35. In Chapter 35 of the IBC, the standards are grouped alphabetically based on the specific industry or organization responsible for maintaining and publishing the particular standard.

2501 General

Contains the scope of the chapter, which covers materials, design, construction, quality and installation of gypsum and cement plaster products. The section requires that materials and construction methods comply with the requirements of Chapter 25, as well as Chapter 7, when materials are also used for fire rated assemblies or fire resistive construction. Materials other than those covered in the code are permitted provided they comply with approved manufacturers installation requirements and any applicable conditions of approval.

2503 Inspection

Plaster and gypsum board installations are required to be inspected in accordance with Section 109.3.5 of the IBC. As in the UBC, lath installations are required to be inspected prior to plastering, and gypsum board is required to be inspected prior to taping joints.

2504 Vertical and Horizontal Assemblies

Section 2504 of the IBC is a result of combining the two separate sections in the UBC that cover vertical and horizontal assemblies. As in the UBC, wood framing supports and wood stripping or furring for lath or gypsum board is required to be a minimum of 2 inches nominal thickness in least dimension, unless solid backing is provided. If solid backing is provided, furring strips shall be not less than 1 inch by 2 inch nominal dimension.

2505 Shear Wall Construction

In all three model codes, the allowable shear table for plaster or gypsum board shear walls is located within Chapter 25 of the respective code. Unlike the model codes, the IBC does not have a comparable shear wall table in Chapter 25, but refers to tables in the specific material chapter for the particular type of framing system involved. Thus, the tabulated allowable shear for wood-framed walls with plaster or gypsum board is in Chapter 23 in Table 2306.4.5, and the tabulated allowable shear for cold-formed light gauge steel-framed walls with gypsum board is in Chapter 22 in Table 2211.1(2) .

Although each of the model codes has a table of allowable shear values for wood-framed plaster or gypsum board walls, they are not all identical in scope. Of the three model codes, the most extensive is Table 2506 of the SBC, which served as the basis for Table 2306.4.5 of the IBC. Some key features and limitations of the table should be noted. Wood-framed shear walls of plaster or gypsum board are not permitted to resist lateral loads from masonry or concrete construction. This limitation appears in all three model codes. Also, the tabulated shear values must be reduced 50 percent when used to resist seismic forces in Seismic Design Category D, and plaster or gypsum board shear walls are not permitted to resist seismic forces in Seismic Design Categories E and F.

The three most current editions of the model codes (1997 UBC, 1999 SBC and 1999 NBC) include a table of nominal shear values for cold-formed light gauge steel framed gypsum board shear walls. Table

2211.1(2) of the IBC is essentially the same as those found in the current model codes. The nominal shear values given in the table are based on testing and data developed for the American Iron and Steel Institute (Reference 4) by the University of Santa Clara.

Some important features and limitations of this shear wall Table 2211.1(2) should be noted. The table only applies to gypsum board shear walls designed to resist wind loads. It does not include cement plaster (stucco), and is not intended to be used for shear walls resisting seismic loads. The table is very versatile from a design standpoint, since it gives tabulated nominal shear values that can be used with either allowable stress design or strength design procedures. When using allowable stress design, one must divide the tabulated nominal shear value by the factor of safety (Ω =2.5), and when using strength design procedures one must multiply the tabulated nominal shear value by the resistance factor (ϕ =0.55). When applying this table to the design of shear walls, it is imperative that the designer comply with all applicable requirements outlined in the referring section, which is Section 2211. For further information, see the discussion of Section 2211.

2506 Gypsum Board Materials

Gypsum board materials and accessories are required to be identified by the manufacturer to indicate compliance with the applicable standards. Materials and accessories must be properly handled, stored and adequately protected from weather.

As in the three model codes, the IBC references standards for gypsum board materials and accessories. The applicable ASTM standards for gypsum products are listed in Table 2506.2. Although the standards listed in the IBC are found in Section 2502 of the UBC, the grouping of materials in tabular format is an improvement from a code user standpoint. Where gypsum materials are also used in fire rated assemblies and fire-resistant construction, the materials and method of installation are also required to comply with the applicable provisions of Chapter 7.

Under the UBC, suspended ceiling systems are installed in accordance with the prescriptive requirements of Section 2504 and Table 25-A, or UBC Standard 25-2, which are based on ASTM Standards C635 and C636. For suspended systems and materials used in acoustical and lay-in panel ceilings, the IBC references ASTM C635, which is the Standard for Manufacture, Performance, and Testing of Metals Suspension Systems for Acoustical Tile and Lay-in panel Ceilings.

In addition to the ASTM standard, the IBC also refers to Section 1621.2.5 for the design and installation of suspended ceiling systems in high seismic areas. This section describes two methods for designing suspended ceiling systems, called industry standard construction, and integral ceiling/sprinkler construction. Unless the system is designed as an integral ceiling/sprinkler system, suspended ceilings are required to be designed in accordance with the industry standard construction requirements prescribed by Section 1621.2.5.2.

The provisions under industry standard construction requires that suspended ceilings be designed in accordance with specific standards published by the Ceiling and Interior Systems Construction Association (Reference 5). Suspended ceilings in Seismic Design Category C must be designed and installed in accordance with CISCA 0-2, and systems in Seismic Design Category D, E or F must be designed and installed in accordance with CISCA 3-4. In either case, the seismic design forces must be determined by the code provisions outlined in Sections 1621.1.4 and the design of anchorage and connections must be in accordance with Section 1621.1.7. In addition to conformance to the referenced standards, the code has prescriptive requirements that must also be adhered to that are dependent upon the particular seismic design category.

2507 Lathing and Plastering

As with gypsum products and accessories, the IBC references standards for lath and plaster materials and accessories in tabular format. The applicable ASTM standards for lath and plaster materials and accessories are listed in Table 2507.2. Materials and accessories used in lath and plaster construction are required to be identified by the manufacturer to indicate compliance with the applicable standards. Materials and accessories must be properly handled, stored and adequately protected from weather. Where lath and plaster is also used in fire rated assemblies or fire resistive construction, the materials and method of installation are also required to comply with the applicable provisions of Chapter 7.

2508 Gypsum Construction

Unlike the 1997 UBC, which generally includes detailed installation requirements within the code itself, the current SBC and NBC reference ASTM standards for installation of gypsum products. This is also the approach taken in the IBC. In addition to conformance to the referenced standards, the code has prescriptive requirements and specific limitations that are in addition to requirements outlined in the standards. These prescriptive requirements are essentially the same in the three current model codes.

Gypsum wallboard is not permitted on exterior surfaces where the gypsum is exposed to weather. Gypsum sheathing can be installed on exterior walls as water-resistant underlayment for various siding materials, in accordance with ASTM Standard C1280. Gypsum products cannot be installed until adequate weather protection is provided to prevent damage.

As in the UBC, the IBC requires gypsum board used in fire-resistant assemblies to have treated joints and fasteners with the following exceptions:

1. Where the board has a decorative finish such as wood paneling that provides an equivalent protection as typical joint treatment.

2. Single layer applications where joints occur over wood framing members.
3. Square edge or tongue and groove gypsum board or gypsum sheathing.
4. Multi-layer assemblies where adjacent layers have the joints offset from one another.
5. Assemblies that are demonstrated to be adequate based on testing conducted without joint treatment.

Although items 1, 2 and 5 are also exceptions in the UBC, items 3 and 4 are not. Item 3 permits the untreated joints for gypsum board or gypsum sheathing with square or tongue and groove edges.

Item 4 allows the base layer of multi-layer assemblies to have untreated joints. Joint treatment may be required, however, if the manufacturers installation instructions require it for the particular application.

ASTM Standard C11, Terminology Related to Gypsum and Related Building Materials and Systems, should be referred to for a complete list of definitions of terms applicable to gypsum construction.

2509 Gypsum Board in Showers and Water Closets

The IBC provisions for gypsum board in showers and water closets is essentially the same as those found in the 1997 UBC. Sections 1210.2 and 1210.3 are referenced for requirements pertaining to shower and toilet room walls. Water resistant gypsum board is required as a substrate when used in tubs, showers and water closet compartment walls. In other areas, regular gypsum board is permitted to be used under tile and wall panels when installed in accordance with Gypsum Association (Reference 6) GA-216 or ASTM C 840.

Water resistant gypsum board is not permitted as backing in the following areas:

1. Over a vapor retarder in shower and bathtub compartments.
2. In high humidity areas such as saunas, steam rooms, gang showers and indoor pools.
3. On ceilings where the spacing of the framing members exceeds 12 inches on center for ½ inch thick gypsum board and 16 inches on center for ⅝ inch thick gypsum board.

Although the UBC has a provision stipulating that spacing of framing should not exceed 12 inches on center when supporting water resistant gypsum board, the IBC permits framing spaced at 16 inches on center for ⅝ inch thick gypsum board.

2510 Lathing and Furring for Cement Plaster (Stucco)

Interior and exterior lath and plaster construction materials and accessories must conform to standards referenced in Table 2507.2.

Material is also required to be stored so as to be protected from weather.

Unlike the 1997 UBC which has detailed installation requirements for application of interior and exterior lath, the IBC references ASTM Standards C926 and C1063. These standards cover both the application of portland cement plaster (C926), and installation of lath and furring to receive plaster (C1063). In addition to the requirements outlined in the standards, the IBC also contains some prescriptive requirements that are essentially the same as those found in the 1997 UBC.

Similar to the 1997 UBC, the IBC refers to Chapter 14 in regards to weather protection requirements for cement plaster construction. Weather-resistant barriers are required in accordance with Section 1403.3. When applied over wood-based sheathing, the weather-resistant barrier is to include a weather resistive vapor permeable barrier with the equivalent performance of two layers of Grade D paper. It should be noted that the requirement in the IBC specifies a performance level equivalent to two layers of Grade D paper rather than explicitly requiring two layers of Grade D paper as is required by the UBC.

The requirements for cement plaster applied to masonry or concrete are essentially the same as that of the 1997 UBC. Surfaces must be clean, damp and rough enough to ensure proper bonding of plaster. If not sufficiently rough, bonding agents or a portland cement dash bond coat must be applied prior to plastering.

2511 Interior Plaster

Installation of interior lath and plaster systems must conform to standards referenced in Table 2511.1 as well as the applicable portions of Section 2508 that pertain to gypsum plaster.

Cement or gypsum plaster is required to be three coats when applied over metal or wire lath, may be two coats when installed on other bases, and may be one coat when the system is specifically designed and approved as a single coat application. One coat plaster applications are generally proprietary systems that are manufactured and approved as alternate materials under Section 104.11.

Interior plaster cannot be applied directly to fiber insulation board. Cement plaster cannot be applied directly to gypsum lath or gypsum plaster unless it conforms to the limitations and backing requirements outlined in Sections 2510.5.1 and 2510.5.2.

When interior plaster is applied to concrete or masonry, surface conditions must conform to the requirements of Section 2510.7. The section requires surfaces to be sufficiently clean, damp and rough enough to ensure proper bonding of the plaster. If the surface is not sufficiently rough, approved bonding agents or a portland cement dash bond coat must be applied prior to plastering. When applied to concrete ceilings, base coat thicknesses conform to ASTM C 842 or C 926. If a greater thickness is required than the maximum permitted by the standards, metal or wire lath must be installed before plastering.

During interior plastering construction, the building is to be enclosed and conditioned to provide adequate ventilation. When installing gypsum plasters, the temperature within the building must be maintained at least 40°F (4°C) but not more than 80°F (27°C) seven days prior to plastering and continue until seven days after or until plaster is dry.

Showers and public toilet walls shall be constructed in accordance with the requirements of Sections 1210.2 and 1210.3. Where wood framing is used in walls and partitions located in areas subject to water splash and are covered on the interior with cement plaster, an approved moisture barrier must be installed to protect the framing.

2512 Exterior Plaster

Installation of exterior lath and plaster systems must conform to the standards referenced in Table 2511.1. Cement plaster is required to be three coats when applied on metal or wire lath, and must be at least two coats when installed over masonry, concrete or gypsum board backing as specified in Section 2510.5. If the plaster surface is to be covered by veneer or other facing or is concealed by another wall, it may consist of two coats provided the thickness complies with ASTM C 926.

Exterior cement plaster applied to wood or steel stud, slab on grade construction is required to cover but not extend below the lath and paper. Lath, paper, flashing and drip screed installations must comply with ASTM C 1063.

The purpose of a metal weep screed at the base of exterior plaster walls is to direct drainage water to the exterior of the building. The weep screed requirements of the IBC are based on the provisions of the 1997 UBC. The code requires a minimum 0.019 inch thick corrosion resistant weep screed at or below the foundation plate at all exterior walls. The weep screed must have a 3½ inch vertical attachment flange and must be kept at least 4 inches above the ground or at least 2 inches above paved areas. The weather-resistant barrier and exterior lath must lap down and cover the vertical flange.

In addition to the requirements of the ASTM standards, the IBC has prescriptive requirements that are stated differently but are essentially the same as the UBC. The IBC requires that the ambient or maintained temperature must be above 40°F during application and 48 hours thereafter.

First and second coats of cement plaster must be moist cured in accordance with ASTM C 926 and Table 2512.6. The curing intervals for cement plaster found in Table 2512.6 of the IBC are based on a portion of the 1997 UBC table that prescribes general requirements for cement plaster construction.

Finish coats are to be applied over base coats that have been in place for the time periods prescribed by ASTM C 926. The third or finish coast must be applied over the brown coats with sufficient pressure to develop adequate bond and have enough material to cover and conceal the brown coat.

2513 Exposed Aggregate Plaster

The provisions for exposed aggregate plaster are taken from the 1997 UBC.

Pneumatically Placed Plaster (provision not in IBC). Pneumatically placed portland cement plaster, known as gunite, is a mixture of portland cement and sand that is mixed dry, hydrated at the nozzle and deposited by pneumatic (air) pressure. It is distinguished from shotcrete in that shotcrete is concrete or mortar that is mixed wet and ejected onto a surface at high velocity. Although both the UBC and the SBC have specific sections covering pneumatically placed plaster, no such section appears in the IBC.

References

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Cross Reference

IBC-UBC

Structural

Chapter 16: Structural Design Requirements

Note: This chapter has been revised in its entirety.

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Chapter 19: Concrete

Note: This is a new division

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Chapter 20: Lightweight Metals

The IBC adopts the following standards by reference for this chapter and there are no other code sections:

1) AA-94 *Aluminum Design Manual,*:
   Part 1-A—*Aluminum Structures, Allowable Stress Design*;
   Part 1-B—*Aluminum Structures, Load and Resistance Factor Design of Buildings and Similar Type Structures,*
2) AA ASM 35-80 *Aluminum Sheet Metal Work in Building Construction.*

Therefore there are no cross reference tables for this chapter.

Chapter 21: Masonry

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Chapter 23: Wood

Note: This chapter has been revised in its entirety

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Cross Reference

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Chapter 16: Structural Design Requirements

Note: This chapter has been revised in its entirety

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Chapter 19: Concrete

Note: This is a new division

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1927 UNIFIED DESIGN PROVISIONS FOR REINFORCED AND PRESTRESSED CONCRETE FLEXURAL AND COMPRESSION MEMBERS	
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Appendix Chapter 19: Protection of Residential Concrete Exposed to Freezing and Thawing

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Chapter 20: Lightweight Metals

The IBC adopts the following standards by reference for this chapter and there are no other code sections:

1) AA-94 *Aluminum Design Manual,*:
   Part 1-A—*Aluminum Structures, Allowable Stress Design*;

   Part 1-B—*Aluminum Structures, Load and Resistance Factor Design of Buildings and Similar Type Structures,*
2) AA ASM 35-80 *Aluminum Sheet Metal Work in Building Construction.*

Therefore there are no cross reference tables for this chapter.

Chapter 21: Masonry

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Note: This chapter has been revised in its entirety

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