Code Conforming Wood Design

Commentary on the International Building Code (IBC) Chapter 23 - Wood

AF&PA™

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PART 1. INTRODUCTION

1.1 Chapter. 23 and the Three Model Codes

1.1.1 Chapter 23 of the *International Building Code* (*IBC*) includes elements of all three previous regional model codes—the BOCA National Building Code (NBC), the Standard Building Code (SBC), and the Uniform Building Code (UBC). It most closely follows the format of the UBC. Comparison tables are included throughout the commentary, as a quick reference to types of provisions which do or do not appear in the previous model codes. Compliance with the provisions of Chapter 23 will assure that wood products perform as they are intended to.

1.2 Contents and Organization

1.2.1 This chapter includes commentary for every IBC provision of Chapter 23, except the tables. It contains required information to design and construct buildings or structures which include wood or wood-based structural elements, and is organized around the application of three design methodologies: Allowable Stress Design (ASD), Load and Resistance Factor Design (LRFD), and Conventional Construction. Included are references to design and manufacturing standards for various wood and wood-based products; general construction requirements; design criteria for lateral force resisting systems; and specific requirements for the application of the three design methods (ASD, LRFD and Conventional Construction).

The acceptable standards for the manufacture of wood or wood-based products include provisions for sizes, grades (labels), quality control, and certification programs, or similar methods of identification. Specific requirements and tables have been developed using the referenced design methods to provide a minimum level of safety. The chapter also contains requirements for the use of products in conjunction with wood and wood-based structural elements, as well as requirements for prevention of decay.

1.3 When to use Chapter 23

1.3.1 In general, only buildings of Construction Types 3, 4, and 5 may be constructed of wood. Accordingly, Chapter 23 is referenced when the combination of the occupancy (determined in Chapter 3) and the height and area of the building or structure (determined in Chapter 5) indicate that the Type of Construction (specified in Chapter 6) can be Type 3, 4 or 5. Another basis for referencing Chapter 23 is when wood elements are used in Type 1 or 2 structures as permitted in Section 603, whereby, the chapter gives information on the application of fire retardant wood, interior wood elements and trim in these structures. All structural criteria for application of the referenced standards and procedures included in Chapter 23 are based on the loading requirements of Chapter 16 or on historical performance.

1.4 Purpose

1.4.1 This chapter provides minimum guidance for the design of buildings and structures that use wood and wood-based products in their framing and fabrication. Alternative methods and materials can be used where engineering analysis and testing justify their use. In all cases, the provisions of Section 2304 apply to all elements of wood frame construction.

Chapter 23 is not a textbook on construction. It is assumed that the reader has both the training and experience needed to understand the principles and practices of wood design and construction. Without such understanding, some sections may be misunderstood and misapplied. This commentary should help to promote better understanding of the structure and application of the methods specified in Chapter 23.

1.5 Chapter Organization

! **1.5.1 2301 General**
Three methods of design are identified and compliance with one or more is required.

! **1.5.2 2302 Definitions**
Most commonly used terms to describe wood and wood-based products are defined. Some engineering terms are included.

! **1.5.3 2303 Minimum Standards and Quality**
Provides reference to manufacturing standards, necessary specification criteria, and use and application provisions.

! **1.5.4 2304 General Construction Requirements**
Provisions for the proper design and construction of all wood structures and the use of all wood products are provided. This section also includes the fastening schedule.

! **1.5.5 2305 General Design Requirements for Lateral Force Resisting Systems**
Whether the structure is engineered using ASD or LRFD, the provisions of this section apply.

! **1.5.6 2306 Allowable Stress Design (ASD)**
Provisions for the design of structures using ASD are provided. Historically, all of the industry publications have been developed for ASD. More recently, LRFD has been introduced, making it necessary to distinguish clearly which provisions are appropriate for ASD or LRFD. The provisions of this section are not appropriate for LRFD.

! **1.5.7 2307 Load and Resistance Factor Design (LRFD)**
This section is simply a reference to the consensus standard, which governs the design of structures using the LRFD methodology.

! **1.5.8 2308 Conventional Construction**
Although fairly limited in application, the provisions for conventional construction may be used to construct certain wood frame structures. The limitations on the use of this section are

provided in Section 2308.2.

1.6 Keywords

- Allowable Stress Design ASD
- Conventional
- Decay
- Diaphragm
- Fastener
- Fire-Retardant Treated Wood
- Framing
- Girder
- Glued-Laminated
- Grade Mark
- Hardboard
- Heavy Timber
- Joist
- Load and Resistance Factor Design (LRFD)
- Moisture Content
- Nail
- Nominal Dimension
- Particleboard
- Preservative-Treated
- Rafter
- Shear Panel
- Shear Wall
- Sheathing
- Staples
- Stud
- Subfloor
- Underlayment
- Wood
- Wood Structural Panel
- Wood-Based

PART II - COMMENTARY ON CHAPTER 23

2301 GENERAL

2301. This section includes specifications for use of and standards for production of wood and wood-based products such as boards, dimensional lumber, engineered wood products such as I-joists, glued laminated timber, structural panels, trusses, particleboard, fiberboard, and hardboard. Also, included are criteria and specifications for use of other materials such as connectors used in conjunction with wood or wood-based products. Other chapters of the code also affect the use of wood materials in buildings and should be referenced prior to making final decisions on the use of any product.

2301.1 Scope. The scope of Chapter 23 is established in this section and broadly encompasses wood products and the limitations placed on them and their various applications within the code.

2301.2 General design requirements. Chapter 23 includes three methods of designing with wood or wood-based products. This section limits designs to one of these three methods unless an alternate method has been proven to be acceptable as permitted in Section 104.11. It is not uncommon for only one element of a structure to require engineered design. This section recognizes "partial" design.

2301.2.1 Allowable stress design. Allowable stress design (ASD) is the traditional method of engineering wood structures. This section prescribes the use of the load combinations specified in Chapter 16. In addition, it requires the use of the general requirements in Section 2304, the lateral resistance requirements in Section 2305, and the Allowable Stress Design requirements of Section 2306.

2301.2.2 Load and resistance factor design. Load and resistance factor design (LRFD) is a relatively new method of engineering wood structures. This section also requires the use of the load combinations in Chapter 16, the general requirements in Section 2304, and the lateral resistance requirements in Section 2305. The requirements for design using the LRFD method are found in Section 2307.

2301.2.3 Conventional light-frame wood construction. The term "conventional construction" in this case means the design and construction of buildings using typical configurations and methods, which do not require the calculation of loads or analysis by a design professional. The descriptive and prescriptive provisions of the conventional light-frame construction sections are based on commonly accepted engineering practice and experience. The use of these provisions is limited to buildings of relatively small volume that do not incorporate unusual configurations, elements, or loadings. Conventional light-frame wood construction is not really new, but may appear to be unique to some code users. This section references the general criteria in Section 2304, which is applicable to all wood construction. Section 2308 contains the prescriptive limits and methods applicable to wood construction, which has not been designed using the design methodologies of Sections 2301.2.1 or 2301.2.2.

2301.3 Nominal sizes. The use of nominal sizes for lumber is part of the traditional nomenclature for grading and identification of the manufactured pieces. "Nominal" simply refers to the short-hand term such as "2X4", when the actual piece of lumber has a real dimension of 1 1/2" x 3 1/2"—not 2" x 4". However, Section 2304.2 prescribes that in determining the required size for design purposes, computations must be based on the actual size of the lumber instead of the nominal size.

2302 DEFINITIONS

2302. Definitions are included in Chapter 23 for terms common to wood products that are not found elsewhere in the text of the code. It is important to emphasize that these terms are not exclusively related to this chapter, but are applicable everywhere the term is used in the IBC.

2302.1 General. Definitions of terms can help in understanding the application of the code requirements. The purpose for including these definitions within this chapter is to provide more convenient access to them without having to refer back to Chapter 2. For convenience, these terms are also listed in Chapter 2 with a cross-reference to this section. The use and application of all defined terms, including those defined herein, are set forth in Section 201.1.

ACCREDITATION BODY. The process of determining the grade of lumber includes not only the actual method of applying the grade stamp to the product, but also the certification of the grading agency, and their methods of quality control, its rules and the work of their agents. For example, an independent third-party quality control program meeting the accreditation requirements of the American Lumber Standards Committee, Inc., or an equivalent process is required for all softwood lumber that is to be graded for use in construction in the United States.

ADJUSTED RESISTANCE (D'). The LRFD method for design of diaphragms utilizes D and D' as the reference and adjusted diaphragm shear resistance per unit length. Table 2.6-1 in the AF&PA/ASCE Standard 16-95 identifies all the adjustments to be used for LRFD based on the material and the service conditions. Section 7.1.3 (ASCE 16) provides adjustment factors for connections and 7.1.4 will not allow the time effect factor to exceed 1.0. Adjusted lateral resistance in Section 7.4.3.3 adds a penetration factor for nails and spikes.

BOUNDARY ELEMENT. The boundary elements in wood diaphragms and shear walls are typically the rim joists (diaphragms) and the studs and plates surrounding the sheathing (shear walls). The boundary elements are important in transferring the loads that the diaphragm or shear wall carries into the structure below.

BRACED WALL LINE. A braced wall line consists of conventionally framed shearwalls which provide lateral force resistance for buildings constructed in accordance with Section 2308.

BRACED WALL PANEL. A braced wall panel is a segment of a braced wall line. Braced wall panels are discussed in Section 2308.9.3.

COLLECTOR. The collector is a portion of the diaphragm that transfers the load from the point of application into the adjoining elements, usually the braced wall lines.

CONVENTIONAL LIGHT-FRAME WOOD CONSTRUCTION. Conventional light-frame wood construction is one of the three methods for designing wood buildings or structures that are recognized by Chapter 23. Section 2308 provides the limits for use of the prescriptive provisions and the specifications for construction when this method is chosen.

CRIPPLE WALL. Cripple walls are built on the top of footings or foundation walls. They can typically be found along the top of stepped foundation walls where the grade adjoining the structure changes height on the structure. Cripple walls must be properly braced in-plane to resist lateral forces. They are often treated the same as a first story wall when applying the bracing requirements. Provisions for the bracing of cripple walls are in Section 2308.9.4.

DIAPHRAGM. The most typical diaphragm in wood structures is the assembly of floor or roof framing and sheathing. Diaphragms act to transfer the lateral forces of wind or seismic loads to the braced wall lines or shearwalls supporting them at the diaphragm perimeter or intermittent locations.

DIAPHRAGM, BLOCKED. Blocked diaphragms are nearly horizontal or horizontal assemblies designed to resist high shear forces. Diaphragm sheathing may be applied with the long dimension of the sheathing either perpendicular or parallel to the main framing members. When the edge of the sheathing is not supported by the main framing member it considered to be unblocked. Blocking is accomplished by providing a framing member parallel to the otherwise unsupported edge of the sheathing. This allows for uninterrupted perimeter fastening of the sheathing. Various tables in Chapter 23 provide different values for structural sheathing when it is blocked and when it is not blocked.

DIAPHRAGM BOUNDARY. Diaphragm boundary is typically the connection between the floor or roof sheathing and the band board surrounding the diaphragm. Where a braced wall is located inside the building diaphragm, and is structurally tied to the diaphragm, there would be a diaphragm boundary that would occur at that point as well.

DIAPHRAGM CHORD. A diaphragm acts as a deep horizontal beam. The chords of the beam are the elements at the boundary of the diaphragm which are perpendicular to the direction of the assumed load that is to be applied to the diaphragm.

DIAPHRAGM, RIGID. This definition is similar to a definition in Chapter 16 for the same term, except in that case, the term is defined as being the opposite of a soft diaphragm, which is defined as having a lateral deformation of more than two times the average story drift.

DIAPHRAGM, UNBLOCKED. Unblocked diaphragms can resist low and moderate shear forces. Diaphragm sheathing may be applied with the long dimension of the sheathing either perpendicular or parallel to the main framing members. The edge of the sheathing not supported by the main framing member is considered to be unblocked. Perimeter nailing of sheathing can only occur on framing lines. Various tables in Chapter 23 provide different values for structural sheathing when it is blocked and when it is not blocked.

DRAG STRUT. A drag strut is a type of collector for lateral loads when the diaphragm is not continuous. This can be found when there are openings in a floor, or the floor is not all on one level.

FIBERBOARD. Fiberboard is used primarily as an insulating board and for decorative purposes, but may also be used as wall or roof sheathing. The cellulosic components of fiberboard are broken down to individual fibers and molded to create the bond between the fibers. Other ingredients may be added during processing to provide or improve certain properties such as strength and water resistance, in addition to surface finishes for decorative products. Fiberboard is used in all locations where panels are desirable, including wall sheathing, insulation of walls and roofs, roof decking, doors and interior finish.

GLUED BUILT-UP MEMBER. Typically these built-up beam and column sections consist of one or more webs with glued- lumber flanges and stiffeners. They are custom designed structural elements which require the application of ASD or LRFD design standards.

GRADE (LUMBER). The grade of lumber identifies how capable a particular piece of lumber is to resist the applied loads. The mark is applied to solid sawn pieces of wood and includes the species, grade and whether it was surfaced-to-size green or dry. The species and grade designation on the grade mark, when used in conjunction with the design value in the NDS Supplement or the LRFD Manual provides all the information necessary to determine what load the piece of lumber is capable of holding. The American Lumber Standards Council provides facsimile sheets for all the agencies that they accredit to grade lumber. Although rare, fake grade stamps can be found in the market place. The most recent facsimile sheet is available on the website: www.awc.org.

HARDBOARD. Hardboard is used for various interior applications, as well as siding applications. Other ingredients may be added during processing to provide or improve certain properties such as strength, water resistance, and general utility.

NAILING, BOUNDARY. When designing a diaphragm or a shearwall, the sheathing for those elements must be attached to provide the design resistance to the applied load. Shear capacity tables for wood structural panels specify the nail size and spacing of the nails to be used along the edge and in the field of each panel. Boundary nailing is the required nailing pattern for panels located along the edges of diaphragms where the stresses are typically highest.

NAILING, EDGE. The outer-most nails placed nearest the edge of the panel. When designing a diaphragm or a shear panel, the sheathing for those elements must be attached in a fashion that will provide the design resistance to the applied load. Shear capacity tables for wood structural panels used as sheathing specify the nail size and spacing of the nails to be used. For example, Table 2306.3.1 requires 6 penny (6d) nails to penetrate 1 1/4” when a 5/16” panel is used on 2” wide framing. To use a shear capacity of 250 plf, the nail spacing at boundary conditions where the diaphragm is blocked is recommended to be 4” oc.

NAILING, FIELD. Nails, other than edge nails, place in the interior of the panel. When designing a diaphragm or a shear panel, the sheathing for those elements must be attached in a fashion that will provide the design resistance to the applied load. Shear capacity tables for wood structural panels used as sheathing specify the nail size and spacing of the nails to be used. For example, footnote b in Table 2306.3.1 indicates that the maximum spacing for nails along intermediate framing members must be 12” oc.

NATURALLY DURABLE WOOD. Because of their natural ability to resist deterioration, the harder portions of some species of wood are considered to be naturally durable. The code specifies that “occasional” sapwood is permitted if heartwood constitutes 90% of each side.

DECAY RESISTANT. Redwood, Cedar and Black Locust and Black Walnut lumber is known to resist deterioration due to the action of microbes which enter the wood fibers. The code defines these species of lumber as being decay resistant.

TERMITE RESISTANT. Redwood and Eastern Red Cedar are considered to be resistant to infestation by termites and are thus listed as naturally durable. However, the Formosan Termite is capable of destroying all naturally durable species of wood. Borate treatments, in accordance with AWPA C31, have been shown to be effective in resisting the Formosan termite.

NOMINAL SIZE (LUMBER). Unless specifically required by the code, all the dimensions listed in the code for wood member sizes, are nominal dimensions for lumber, not actual. DOC PS 20-99 specifies the required minimum dimension of lumber for each stated nominal size. The process used to smooth and finish the surface of the lumber and to dry the wood to its final size, removes a certain thickness of wood on each side of the piece. Therefore, a 2 by 4 is approximately 1 1/2 inches by 3 1/2 inches. The actual dimension, otherwise known as dressed size, of the lumber is specified to assure consistency in lumber sizes. Consistent lumber sizes are essential to the satisfactory construction of a wood frame building.

ORIENTED STRAND BOARD. Oriented Strand Board (OSB) is one of two readily available wood structural panels; the other is plywood. It is manufactured from strands of wood veneer, oriented to achieve maximum strength. The code does not differentiate between OSB and plywood, since manufacturing is done according to either PS1 for industrial plywood or PS2 for OSB and performance rated plywood.

PARTICLEBOARD. Particleboard is one of the family of wood-based products that can be used as wood panels. The definition describes the characteristics unique to particleboard as compared to other types of wood-based composite panels. Particleboard intended for use as wood structural panels is subject to the requirements of Section 2303.1.7. Particleboard intended for use in shear panels is regulated by the requirements of Section 2306.4.3.

PLYWOOD. Plywood is one of two readily available wood structural panels; the other is OSB. It is manufactured from full sheets of veneer, glued together in layers, with alternating direction of grain. The code does not differentiate between OSB and plywood, since manufacturing is done according to either PS1 for industrial plywood or PS2 for OSB and performance rated plywood.

PRESERVATIVE-TREATED WOOD. Wood that is exposed to high levels of moisture or heat is susceptible to decay by fungus and other organisms, and to insect attack. The damage caused by decay or insects can jeopardize the performance of the wood members so as to reduce the performance below that required by the code. Section 2304.11 identifies the locations where the use of preservative-treated wood is required. It is important to note that preservative treatment requires a pressure-treatment process. Painting, coating or other surface treatment does not produce preservative-treated wood that will perform as required. The treatment process uses pressure to achieve the depth of penetration of preservative into the wood which is needed to verify that the wood will be resistant to decay and insects over time. Surface treatments may be washed away by rain or ground water, or may chip or peel. The American Wood Preservers Association is the consensus standard writing organization for treated wood.

REFERENCE RESISTANCE (D). The LRFD method for design of diaphragms utilizes D and D' as the reference and adjusted diaphragm shear resistance per unit length. Table 2.6-1 in the AF&PA/ASCE Standard 16-95 identifies all the adjustments to be used for LRFD based on the material and the service conditions.

SHEAR WALL. Shear walls are the vertically-oriented transfer element for the lateral forces that are applied to a floor or roof diaphragm. They function structurally to provide a path for these loads to floors below or the foundation. Typically in wood framing these walls are framed with studs and have a structural wood panel attached to the outside using specific nailing patterns to provide the necessary stiffness. They also may have a down-strength tie attached at both ends of the wall to prevent overturning of the wall.

STRUCTURAL GLUED LAMINATED TIMBER. Structural wood members can be created by laminating smaller pieces of lumber together in a specific way using glues to create high performing structural members. Typically, these 2" thick members are arranged in a specific order so that their strength characteristics are used most efficiently. Although these members are made of smaller pieces of lumber, they act together to create sizes which are included in the requirements for heavy timber framing members. Section 2303.1.3 specifies the method of manufacturing these members, and the means of identifying their performance capabilities.

SUBDIAPHRAGM. Subdiaphragms can be used by the designer to distribute large diaphragm forces into walls. They are especially common in buildings which incorporate concrete and masonry walls and are subject to seismic forces.

TIE-DOWN (HOLD-DOWN). A shearwall collects lateral forces, which are typically applied at the top of the wall and parallel to the wall. This load will rack the wall and attempt to turn it over. If the strength of the sheathing and framing is correct for the load and are appropriately attached, the fastened sheathing will resist the tendency to rack the wall. To prevent the wall from overturning, it must be adequately anchored to the structure below. Anchor bolts are not typically designed to resist these loads. Hold-downs are often necessary at the ends of the shear wall designed to resist high lateral loads due to wind or seismic events. Section 2305.3.6 specifies the conditions when hold-downs are required.

TREATED WOOD. Treated wood is manufactured to reduce the ability of the wood to propagate flame or to resist damage caused by fungus or insects. Several American Wood Preserver Association (AWPA) standards are prescribed in Section 2303.1.8. These include water borne as well as several oil borne standards for treatment testing and quality control of various wood and wood-based products. The American Lumber Standards Committee (ALSC) also accredits third-party inspection agencies, in a manner similar to their grading rules certification, for the quality control of preservative treated wood products. Facsimiles of accredited agencies' quality marks for treatment are available from ALSC.

WOOD STRUCTURAL PANEL. The code defines wood structural panels in terms of the materials commonly used in their manufacture. Wood structural panels which are intended for structural use must comply with DOC PS1 or PS2 according to Section 2303.1.4. Both of these documents specify the required structural performance characteristics of the wood structural panels, and detail the requirements for the third-party label each panel is to bear.

WOOD SHEAR PANEL. Wood shear panels are horizontal (diaphragms) or vertical (wood shear walls) panels, which transmit forces in the plane of the sheathing caused by lateral loads transmitted from one component of the structure to another. Wood shear panels usually consist of wood framing (studs or joists), either singly or doubly sheathed. The code gives design provisions for wood shear panels which are sheathed in 4-foot by 8-foot wood structural panels. As boundary elements and at changes in framing directions, the panels can be smaller.

2303 MINIMUM STANDARDS & QUALITY

2303 Minimum Standards and Quality.

When designed and built in accordance with the standards listed in this section, a building or structure is deemed to comply with the code. These standards contain most of the information needed to adequately design a structure. It is necessary for the designer to have a working knowledge of engineering principles and experience with construction to properly interpret the recommendations and to meet the provisions of other applicable sections of this code.

2303.1 General. This section simply lists the various materials that have production and quality control standards included here. The use of these standards is fundamental for manufacturers in producing products, and in maintaining their quality control procedures. Designers, owners and code officials must understand these standards and the methods prescribed in them to be able to identify products that have been produced in accordance with their criteria. Without an ability to know that the products meet the standard there is little assurance that a safe and efficient building or structure can be built.

2303.1.1 Lumber. All lumber used to support loads in a building or structure is required to be properly identified. Every species and grade of lumber has a unique inherent strength value. These values are further modified in sawn timber by the presence of growth characteristics which vary from piece to piece, such as knots, slope of grain, checks, etc. Without adequate identification, it would be impossible to verify safe construction. The required grade mark must identify the species or species grouping, grade and moisture content at the time of surfacing, the grading agency and the mill name or grader's number. For a complete list of rules writing agencies and their grade stamps see www.awc.org/pdf/alscgrade2001.pdf

Certification is an acceptable alternative to a grade mark from both United States and Canadian grading agencies. A list of all grading agencies certified by the American Lumber Standards Committee is available by writing them at P.O. Box 210, Germantown, MD 20874.

Design values are published by lumber-grade rules-writing agencies for both individual and grouped species. A grouped species is lumber that is cut and marketed in lots containing two or more species, such as Spruce-Pine-Fir. These species grow together in large areas. It is more economical to market the lumber as a species group than attempt segregation. The assigned strength values for the group include those applicable to the weaker species in the group.

The code text also allows structural lumber to have a certificate of inspection instead of the grade mark for certain types of lumber. A certificate of inspection is acceptable for precut, remanufactured, rough-sawn lumber and for sizes larger than 3 inches nominal in thickness. It is an industry practice to place only one label (grade mark) on a piece of lumber, which may be removed on precut and remanufactured lumber. Each piece of lumber is graded after it has been cut to a standard size. The grade of the piece is determined based on the size, number and location of strength-reducing characteristics in that piece. Therefore, one log may produce lumber of two or more different grades.

It is also an industry practice not to label lumber having a nominal thickness larger than 3 inches, or rough-sawn material where the label may be illegible. A certificate of inspection from an approved agency is acceptable instead of the label for these types of lumber. The certificate should be filed with the permanent records of the building or structure. It is difficult to label lumber once it is installed in a building.

If defects exceeding those permitted for the grade allegedly installed are visible, then a grader would be able to determine that the wood is definitely not of a suitable grade. In order for a grader to determine if the wood in question is definitely of a suitable grade, the grader would have to be able to inspect all four faces of the piece. This cannot happen once the lumber is installed in the building since other components of the building will be covering up some of the faces of the pieces.

End- joined or edge-glued lumber is acceptable when identified by an appropriate grade mark. The National Design Specification® for Wood Construction (NDS®) permits the use of such lumber in Section 4.1.6 of the standard.

2303.1.2 Prefabricated wood I-joists. This section specifies that the shear, moment and stiffness capacities of prefabricated wood I-joists be established and monitored by ASTM D5055. This standard also specifies that application details such as bearing length and web openings are to be considered in determining the structural capacity. Wood I-joists are defined as structural members typically used in floor and roof construction manufactured out of sawn or structural composite lumber flanges and structural panel webs, bonded together with exterior adhesives forming an "I" cross section. The standard requires I-joist manufacturers to employ an independent inspection agency to monitor the procedures for quality assurance. Finally, the standard specifies that proper installation instructions accompany the product to the job site. The instructions are required to include weather protection, handling requirements and, where required, web reinforcement, connection details, lateral support, bearing details, web hole-cutting limitations, and any special situation.

2303.1.3 Structural glued laminated timber. Glulam timbers are required by this section to be manufactured following the ANSI/AITC 90.1 and ASTM D3737 standard. By knowing what standard is to be used for these products and that they must be identified as meeting these standards, it is easier to determine that the product found in the field will meet the design requirements

2303.1.4 Wood structural panels. Wood structural panels is the inclusive term for plywood, oriented strand board, and other composite panels of wood-based materials. Identification of grade for plywood includes N, A, B, C Plugged, C, and D (from no knots or patches to large knot and knotholes). The identification of glue type is by means of the exposure durability classifications: Exterior, Exposure 1, Exposure 2, and Interior.

2303.1.5 Fiberboard. All fiberboard must meet the requirements of ANSI/AHA A194.1, as well as being vermin-proof, resistant to rot-producing fungi and water repellant. ANSI/AHA A194.1 gives physical requirements for construction grades of fiberboard. These grades include sheathing grade and roof-insulating grade. The sheathing grade of fiberboard is further broken down into regular and intermediate densities.

2303.1.5.1 Jointing. Tight-fitting joints in the fiberboard are required for all applications, including insulation, siding and wall sheathing.

2303.1.5.2 Roof insulation. Fiberboard is not intended for prolonged exposure to sunlight, wind, rain or snow. Where fiberboard is used as roof insulation, it must be protected with an approved roof covering to prevent water saturation and subsequent de-lamination and to avoid decay and destruction of the glue bond by moisture.

2303.1.5.3 Wall insulation. Fiberboard is permitted without any fire resistance treatment in the walls of all types of construction (see Section603.1). When used in fire walls and fire barrier walls, the fiberboard must be adhered directly to a noncombustible base and protected by a tight-fitting, noncombustible veneer that is fastened through the fiberboard to the base. This will prevent the fiberboard from contributing to the spread of fire.

2303.1.5.3.1 Protection. Fiberboard insulation applied to the exterior side of foundation walls is required to be protected from the weather to improve its service life and maintain its performance characteristics. Of particular concern is foundation insulation that is in close proximity to grade and runs the risk of being damaged by a lawn mower, rocks or soil that is kicked up against it, water from a garden hose or rainwater splash back, etc. Protection is required for all fiberboard insulation on the exterior face of foundation walls.

2303.1.5.4 Insulating roof deck. Fiberboard roof panels are used on open-beam type roofs for insulation and structural purposes. A minimum thickness of 1 inch is specified to reduce the possibility of early burn-through in a fire.

2303.1.6 Hardboard. Hardwood siding that is to be used structurally must be manufactured in accordance with ANSI/AHA A135.6 and must be marked to indicate conformance with the standard, whether primed or unprimed, and to identify the producer and the type, either lap or panel. Hardboard products are produced primarily from inter-felted ligno-cellulosic fibers. There are five classes based on strength values. Underlayments are limited to 7/32 or 1/4 inch service class.

Prefinished hardboard is required to be manufactured to ANSI/AHA A135.5 standards must be marked to indicate the standard and to identify the producer, flame spread index, finish class, type of gloss, and type of substrate, or must be accompanied by written certification of the same information.

2303.1.7 Particleboard. Sponsored by the Composite Panel Association (CPA), ANSI A208.1 is the basic specification for the manufacture of particleboard which establishes a system of grade marks for particleboard that provides a code for the board's grade, density, and strength.

Particleboards used in construction are medium-density boards, and are designated by "M" as the first digit of the grade. The second digit in the designation is related to grade. The designations range from 1 to 3, and higher designations are the strongest. Grade M-S refers to medium density, "special grade" particleboard. This grade was added to ANSI A208.1 after the M-1, M-2 and M-3 grades had been established. Grade "M-S" falls between M-1 and M-2 in physical properties.

An optional third digit of the grade designation indicates that the particleboard has a special

characteristic. The grades of particleboard specified in Table 2306.4.3, M-S, and M-2 "Exterior Glue," are manufactured with exterior glue to increase their durability characteristics.
It should be noted that while ANSI A208.1 has provisions for M-3-grade particleboard, panels that meet the requirements of this higher grade are more commonly evaluated and used as wood structural panels, in accordance with DOC PS-2. Therefore, Grade M-3 material is not addressed in Table 2306.4.3.

2303.1.7.1 Floor underlayment. Although similar in characteristics to medium-density, Grade 1 particleboard— particleboard intended for use as floor underlayment is designated "PBU" and has stricter limits on levels of formaldehyde emission permitted than limits placed on Grade "M" particleboard. Particleboard intended for use as floor underlayment is not commonly manufactured with exterior glue, which could emit higher levels of formaldehyde than that permitted for "PBU" grade floor underlayment by ANSI A208.1.

Particleboard underlayment is often applied over a structural subfloor to provide a smooth surface for resilient-finish floor coverings or textile floor coverings. The minimum 1/4-inch thickness is applicable over panel-type subflooring. Particleboard underlayment installed over board or deck subflooring which has multiple joints should have a thickness of 3/8 inch. Joints in the underlayment should not be over the joints in the subflooring.

All particleboard underlayment with thicknesses of 1/4 inch through 3/4 inch should be attached with a minimum of 6d annular threaded nails spaced 6 inches on center on the edges and 10 inches on center for intermediate supports.

2303.1.8 Preservative-treated wood. Wood is able to absorb chemicals applied under pressure because of its cellular characteristics. Preservative treatment procedures wood that will repel termites and destroy decay-causing fungus take advantage of this. The process includes placing the wood in a large cylinder and applying a vacuum to remove as much air as possible from the wood. The chemical solution is then introduced and pressure is applied to force the solution into the wood. The pressure is maintained until the desired absorption is obtained. A final vacuum is often applied to remove as much excess preservative as possible.

Some species are very difficult to treat because of their anatomical structure and occlusions that are created during drying. These species are often incised in order to expose the large open tracheid along the longitudinal direction.

There are several variations of this basic program, all of which must provide the required retention of preservatives. AWPA P1/P13, P2, P5, P8 and P9 prescribe the requirements for the preservatives that are used, while AWPA C1, C2, C9 and C22 specify the minimum results of the treatment process, including the depth of penetration of the chemical into the wood, and the amount of chemical retained by the wood once the process is completed. Additional requirements for wood used in foundation systems are given in Section 1805.4.6.

2303.1.8.1 Identification. Quality marks are necessary to determine that preservative-treated wood conforms to the applicable standards. The identifying mark must be by an approved inspection agency that has continuous follow-up services. Additionally, the inspection agency must be listed and certified as being competent by an approved organization. ALSC provides certification of treating agencies. Facsimiles of their quality marks are available by contacting ALSC.

The required quality mark is not a substitute for a grade mark. When wood or wood-based materials are being used structurally, both the quality mark and grade mark must be displayed on the piece.

2303.1.8.2 Moisture content. All structural members are presumed to have a moisture content of 19 percent or less prior to enclosing.

2303.1.9 Structural composite lumber. The purpose of this section is to specify the appropriate standard for structural composite lumber. Included within the standard are criteria for laminated veneer lumber and parallel strand lumber. The ASTM standard includes requirements for testing, criteria for determining allowable stresses, requirements for independent inspection and quality assurance procedures.

2303.2 Fire-retardant treated wood. Fire retardant treated wood is defined as plywood and lumber which has been pressure impregnated with chemicals to improve its flame spread characteristics beyond that of untreated wood. The effectiveness of the pressure- impregnated fire retardant treatment is determined by subjecting the material to tests conducted in accordance with ASTM E84, with the modification that the test is extended to 30 minutes rather than 15 minutes. Using this procedure, a flame spread index is established during the standard 10-minute test period. The test is continued for an additional 20 minutes. During this added time period, there must not be any significant flame spread. At no time must the flame spread more than 10 1/2 feet past the centerline of the burners.

The result of impregnating wood with fire retardant chemicals is to produce a chemical reaction at certain temperature ranges. This reaction reduces the release of certain intermediate products which contribute to the flaming of wood, and also results in the formation of a greater percentage of charcoal and water. Some chemicals are also effective in reducing the oxidation rate for the charcoal residue. Fire retardant chemicals also reduce the heat release rate of the fire retardant treated wood when burning over a wide range of temperatures. This section gives provisions for the treatment and use of fire retardant treated wood.

2303.2.1 Labeling. For continued quality, each piece of fire retardant treated wood must be identified by an approved agency having a reinspection service. The identification must show the performance rating of the material, including the 30-minute ASTM E84 test results determined in Section 2303.2, and design adjustment values determined in Section 2303.2.2. The third-party agency that provides the FRTW label is also required to state on the label that the FRTW complies with the requirements of Section 2303.2, and that design adjustment values have been determined for the FRTW in compliance with the provisions of Section 2303.2.2.

The FRTW label must be distinct from the grading label to avoid confusion between the two. The grading label gives information about the properties of the wood before it is fire retardant treated. The FRTW label gives properties of the wood after FRTW treatment. It is imperative that the FRTW label be presented in such a manner that it complements the grading label, and does not create confusion over which label takes precedence.

2303.2.2 Strength adjustments. Experience has shown that certain factors can affect the physical properties of FRTW. Among these factors are the pressure treatment and redrying processes used, and the extremes of temperature and humidity that the FRTW will be subjected to once installed. The design values for all FRTW must be adjusted for the effects of the treatment and environmental conditions, such as high temperature and humidity in attic installations. This section requires the determination of these design adjustment values, based on an investigation procedure which includes subjecting the FRTW to similar temperatures and humidities, and which has been approved by the code official. The FRTW tested must be identical to that which is produced. Items to be considered by the code official reviewing the test procedure include species and grade of the untreated wood, and conditioning of wood, such as drying before the fire retardant treatment process. A fire retardant wood treater may choose to have its treatment process evaluated by BOCA International Evaluation Services (BOCA-ES) or the National Evaluation Services (NES). Listings of active reports with these two agencies are included in BOCA Evaluation Services' International Product Evaluation Listing.

The FRTW is required, by Section 2303.2.1, to be labeled with the design adjustment values. These design adjustment values can take the form of factors which are multiplied by the original design values of the untreated wood to determine its allowable stresses, or new allowable stresses which have already been factored down in consideration of the FRTW treatment.

2303.2.3 Exposure to weather. Some fire retardant treatments are soluble when exposed to the weather or used under high-humidity conditions. When a fire retardant treated wood product is to be exposed to weather conditions, it must be further tested in accordance with ASTM D2898. The testing requires the material to meet the performance criteria listed in Section 2303.2. The material is then subjected to the ASTM weathering test and retested after drying. There must not be any significant differences in the performance recorded before and after the weathering test.

When a fire retardant treated wood product is intended for use under high-humidity conditions, it must be further tested in accordance with ASTM D3201. The material must demonstrate that when tested at 92 percent relative humidity, the moisture content does not exceed 28 percent. The label of the product must indicate the results of this testing.

2303.2.4 Interior applications. The environment in which the fire retardant treated wood is used can affect its performance. In order to make sure that in a humid interior condition the method of testing per ASTM D3201 must show that the moisture content of the material does not exceed 28% when the relative humidity is at 92%. This will assure that the identified material will perform as anticipated in the humid environment.

2303.2.5 Moisture content. These moisture content thresholds are necessary to prevent leaching of the fire retardant from the wood.

2303.2.6 Type I and II construction applications. Although Types I and II construction typically would only allow noncombustible materials, Section 603.1 will allow various parts of a building to be combustible. Specifically, there are 22 items listed that are exceptions to the strict limits on Types I and II. There are three conditions listed in that section that will allow fire retardant wood to be used: in nonbearing partitions where their fire resistance is two hours or less; in nonbearing exterior walls which do not require a fire resistance rating; and in roof construction of buildings not over two stories in height.

2303.3 Hardwood plywood. Hardwood plywood, like any other product that undergoes a change in the process of being configured for use in construction, has standard criteria for the manufacturing process and the quality of the materials that are to be used. ANSI/HPVA HP-1 is the standard for hardwood plywood, and is one of the family of standards for this type of product.

2303.4 Trusses. Metal plate connected wood trusses have been a popular product for construction of wood frame buildings for many years. There are significant benefits accrued to building with these engineered systems of wood and metal connectors, however, there are also criteria associated with the manufacturing, transportation and placement of the trusses that is critical to their productive use in a structure. ANSI/TPI 1 is the industry developed standard for managing this process.

A manufacturer of trusses is also required by this section of the code to have an agency review of their operations to determine their compliance with this standard. Without this type of evaluation by a dependable person who performs this oversight, the consumer and the builder can not be assured of the quality of the product, or its ability to perform as designed.

2303.4.1 Truss design drawings. Truss design drawings are an important subject for most designers and contractors. The code requires the information be provided so that there is a documented record of what the truss is supposed to do and how it is supposed to do it. Designers and contractors must depend on the fabricator in most instances to design the truss. Contracts for the fabricator do not typically track with the general contractor, making the availability of the truss drawings for review sometimes problematic.

The majority of the items listed in the code provision are readily available from any designer of trusses. The fact that the code has had to specify the information needed is based on the difficulty determining the appropriateness of the trusses in the field. With the documentation included with the plans reviewed, the inspector has an easy time verifying that the trusses meet the designer’s intent.

2303.5 Test standard for joist hangers and connectors. Tests for joist hanger and connections are included in the criteria for special inspections for Materials and test Standards in Section 1715.1. There they reference ASTM D 1761 and establish the criteria for use of lumber with a specific gravity of 0.49 or greater, but not more than 0.55, per the *National Design Specification*. Also, in Section 1715.2, the code adds limits on the vertical load capacity for joist hangers by requiring that there be consistency of the tested capacity within 20% of the average ultimate load. If this can not be achieved, then additional testing is specified.

2303.6 Nails and Staples. The code specifies the minimum criteria for nails and staples that is necessary to perform the work assumed when applying the loads to the normal connections that are included in the nailing schedule in Table 2304.9.1.

2304 GENERAL CONSTRUCTION REQUIREMENTS

Section 2304. The general criteria for construction with wood as the structural framing material are contained in this section.

2304.1 General. Section 2301.2 simply lists all the methods of designing a wood structural member. These include the Allowable Stress Design, Load and Resistance Factor Design, and conventional light-frame wood construction as prescribed in Sections 2304 and 2308. When a design is based on any of these methods, they are still required to conform to the requirements of Section 2304.0.

2304.2 Size of Structural Members. ASD and LRFD designs assume that actual member sizes (ex: 1 1/2" x 3 1/2") are being used, rather than nominal sizes (ex: 2"x4"). Conventional construction design (2308.0) does not require computations to determine the sizes of members, since by its very nature all the computations have been completed. However, there are limitations to the applicable buildings and occupancies for which conventional construction design could be used. This provision is an attempt to make sure that if design principles are applied to a specific element, the designer uses design values which are consistent with the actual load carrying capacity of the element, as reflected in the referenced design standards.

2304.3 Wall Framing. The conventional construction criteria in Section 2308 provide a great deal of detail and specifications for the construction of walls. Under the majority of circumstances, the methods and procedures for framing a wall in accordance with Section 2308.9 will provide the necessary resistance to all loads that a typical wall will see. The exception may be construction conditions that fall outside the limitations within Section 2308.

2304.3.1 Bottom plates. In order to assure that the loads imposed on a stud are fully transferred into the supporting structural members below, it is required that the studs bear on a transfer member which is required to be the minimum thickness of a nominal 2-by framing member. The plate is required to be at least the same width as the stud to assure that the full capacity of the stud is being realized. If the plate were narrower than the stud and the entire area of the stud were required to transfer the bearing load without crushing the stud's fibers, there would likely be a local failure of the wall. If the wall were designed so that the bearing on the bottom plate was not a critical issue (ex: an interior, non-bearing wall), the design would have to demonstrate that the plate can be smaller than the studs, and compensate for the irregular construction.

2304.3.2 Framing over openings. Walls depend upon the studs to be continuous and carry the imposed loads from the top plate to the bottom plate and eventually to the foundation. When there is an opening in the wall, this continuity is interrupted. It is necessary to transfer the loads from above the opening to other structural supports. These could be adjoining studs, ganged studs, cripple studs that support the member framing over the opening, or even columns installed as part of the wall.

An important structural consideration is the connection between the member spanning the opening and the support. Whether that connection is a simple direct support, a hanger or some other type of connection, it is necessary to know its capacity.

2304.4 Floor and Roof Framing. Similar to the criteria for wall construction, floors may be designed using the methods prescribed in Section 2308. Among the problems associated with the use of the tables for conventional construction are the limitations on allowable loads. The span tables 2308.8 (1), (2); 2308.10.2 (1), (2); and 2308.10.3 (1), (2), (3), (4), (5), and (6) each describe a different loading condition for the floors, roof and rafters. The maximum floor load in Table 2308.8 is for a 40 pound per square foot(psf) live load. Table 2308.10.2 covers only dead loads of 5 psf for ceiling rafters, and Table 2308.10.3 only provides for up to a 50 psf ground snow load. The range of required loading is much larger as demonstrated in Table 1607.1. The only structures for which a 40 psf live load on the floor is allowed are catwalks, fire escapes on single-family dwellings, private rooms and wards in a hospital, cell blocks, school classrooms, and all areas of residential occupancies other than public areas. All other occupancy require a higher load capacity. Therefore, these tables do not apply.

2304.5 Framing around flues and chimneys. This provision is duplicated in the *International Mechanical Code*, but must be included in both places in order to alert the framer, installer, and inspector of the requirement. The characteristics of wood when exposed to heat for a prolonged period of time may change and the temperature at which it will ignite may be lowered because of it. By providing separation, the wood will not be directly exposed because of the air space between it and the heat source.

2304.6 Wall sheathing. Wall sheathing can be constructed of many materials. The fundamental reason for having sheathing is to stabilize the wall framing members (typically 2x pieces of lumber) when it is loaded. Studs nailed to the top and bottom plate are stable to a degree, but with any force placed on the wall, it would rack and collapse. Sheathing, whether it is a heavy structural membrane found on exterior bearing walls or a light one that would be used for non-bearing interior partitions, provides that necessary stability for the walls. Some sheathing may be used strictly for the purpose of insulating the building, or may, in addition to providing lateral bracing, provide a finish for the wall. Sheathing is not the only means of bracing a wall.

2304.6.1 Wall sheathing. This section establishes that only the sheathing types listed in Table 2304.6.1, which includes board and various panel products (structural panels, boards, gypsum, and reinforced cement mortar), shall be used for walls. There is an allowance that other materials may be used if it is shown they are capable of providing equivalent strength and durability. Strapping or “let-in” braces can perform adequately in some situations where they are designed as part of the wall system.

2304.6.1.1 Wood structural panel sheathing. Wood structural panels are defined by this chapter of the code as being plywood, oriented strand board, and composite panels. Each of these types of panel products has identical performance characteristics when manufactured according to PS 2. This section requires equivalent exposure durability performance. It requires the classification to be Exposure 1 or Exterior when the material is likely to be exposed to the weather.

Table 2304.6.1 reinforces the requirement of Section 2304.6.1 which requires all sheathing to meet minimum limitations. Because of loading conditions or the design of the assembly to which the wall sheathing is attached, the sheathing may have to be thicker. The table is simple to use: simply determine the type of sheathing and then the thickness of the sheathing to be used, and the maximum wall stud spacing that must be used to install the material is provided.

2304.6.2 Interior paneling. Interior paneling, similar to exterior paneling, must meet minimum standards of acceptance. USDOC PS 1-95 and PS 2-95 establish the general standards for all softwood veneer panel products. ANSI/AHA A135.5 and ANSI/HPVA HP-1-1994 address the criteria for hardwood veneered plywoods.

2304.7 Floor and Roof Sheathing. Floor and roof sheathing perform several functions. They are the primary base for the walking surface for the floor and the roofing materials on the roof. Floor sheathing may be the only structural element transferring the live loads to the floor joists. Most floor covering is non-structural. The sheathing may also serve as a subfloor or a substrate for another finish, such as hardwood.

Roof sheathing is similar in that it is typically covered by the roofing material. Some roof covering can be of structural value, but the sheathing typically provides the only means by which loads from wind and snow are transferred to the structural framing members.

Sheathing is a critical element in the transfer mechanism of lateral forces.

2304.7.1 Structural floor sheathing. See Commentary, Section 2304.7.2. The tables referenced are used for both floor and roof applications.

2304.7.2 Structural roof sheathing. There are four tables that describe the various spans for structural sheathing typically produced by North American mills. Using the tables is straightforward: enter the table with the span between structural framing members, and depending on the direction of the framing, determine the minimum thickness required by the code. It may be necessary to install thicker material if the loads require additional resistance.

Two additional pieces of information that may be needed to enter the tables are the grade and span rating of the material being used. Lumber and structural sheathing both are required to be marked with grade stamps indicating the capabilities of the lumber or panels, based on the testing and conditions of the material.

TABLE 2304.7a—Allowable Spans for Lumber Floor and Roof Sheathing. In Table 2304.7(2), the table asks for "Surfaced Dry" or "Surfaced Unseasoned." These terms refer to the condition of the lumber at the time it was surfaced, or finished. This is only critical when determining the actual dimension of the lumber. A piece that is surfaced dry is narrower than a piece that is surfaced unseasoned (often referred to as surfaced green). The grade stamp will indicate whether it is surfaced dry or surfaced green.

Table 2304.7b—Sheathing Lumber, Minimum Grade Requirements: Board Grade (Solid Floor or Roof Sheathing; Spaced Roof Sheathing; Grading Rules). The grading rules are listed and are part of the important criteria in determining the adequacy of lumber to perform the necessary work. In this table, the grading rules are listed, but there are agencies not listed that use these rules and will be marking the lumber. The NDS® lists all agencies that write grading rules and the agencies that use the rules to grade the lumber. A full up-to-date listing of all approved agencies can be obtained from the American Lumber Standards Committee.

Table 2304.7c—Allowable Spans and Loads for Wood Structural Panel Sheathing and Single-Floor Grades Continuous over Two or More Spans with Strength Axis Perpendicular to Supports. Structural wood panels are also graded, but the type of grade stamp used identifies the thickness and the span capabilities of the piece. The span rating (first column of the table) will appear on the grade stamp of the panel. The first number on the span rating indicates the allowable spacing of support members (rafters or trusses) in a roof application. The second number indicates the allowable spacing of floor joists or trusses in a floor application. For instance, if the span rating is 24/16, the panel may be used on rafters spaced 24 inches on center, and on floor joists spaced 16 inches on center. Span ratings were developed for easy identification and correct application of panels in the field.

For the span rating to be applicable, other conditions of the table for loading and use must be met. For instance, for a 24/16 to be used on roof rafters spaced 16 inches on center, the snow load for the roof cannot exceed 40 psf (listed in the sixth column of the table). The allowable spacing of support members is also dependent on the type of edge support provided for the panels (see footnote f). The table is applicable only when the strength axis of the panel is perpendicular to the supports– in other words, when the long edge of the panel is perpendicular to the joists or rafters.

Table 2304.7d—Allowable Span for Wood Structural Panel Combination Subfloor-Underlayment (Single Floor)—Panels Continuous over Two or More Spans and Strengths Axis Perpendicular to Supports. Often a combination of a wood subfloor and a finish floor is used and there is additional capacity for that composite floor action. This table provides the additional capacity associated with that installation. It is necessary to go to DOC PS 1 to identify the species groups represented by the numbers in the table.

Table 2304.7e—Allowable Load (PSF) for Wood Structural Panel Roof Sheathing Continuous over Two or More Spans and Strength Axis Parallel to Supports. The table provides criteria for panels which may be used on roofs with significant snow loads. The allowable spacing of rafters or trusses and the allowable load are determined by the grade and thickness of the panel.

2304.8 Mechanically Laminated Floors and Decks. One method of floor construction employs individual wood members set on edge, connected with nails, and mechanically laminated to produce a monolithic surface. Section 2304.8.1 prescribes the nailing requirements for the construction of such a floor.

2304.8.1 General. This section gives the fastening requirements for floors which are constructed of individual wood members set on edge and mechanically laminated to produce a continuous surface. For the floor to act as a unit, fastening is critical and therefore it is prescribed in this section. If the floor is constructed in accordance with these fastening requirements, then for purposes of design it can be considered a solid wood floor, acting as one element.

2304.9 Connections and Fasteners. Prescriptive requirements for fastening of wood construction is set out in these subsections. In some cases, a design standard for fastening is referenced.

2304.9.1 Fasteners requirements. Section 2301.2 gives alternative design methodologies for wood construction: the allowable stress design method (the applicable standard in accordance with Section 2306 is the AF&PA's National Design Specification for Wood Construction), the load and resistance factor design method (the applicable standard is ASCE 16, in accordance with Section 2307), and the conventional light-frame methodologies which are embodied in Sections 2304 and 2308 of the code. The ASD and LRFD methods contain design provisions for fasteners, and the specification of fastening based on design calculations is appropriate when those methods are used. In addition, the prescriptive requirements of Table 2304.9.1 must be met. If the conventional provisions are used and there is no design being conducted by means of the ASD or LRFD methodologies, then the prescriptive fastening of Table 2304.9.1 is all that is required. However, when the ASD or LRFD methods are used, fastening must comply with the associated design standards as well as the prescriptive Table 2304.9.1.

Table 2304.9.1—Fastening Schedule Familiarity with the terms and configurations of conventional frame construction is necessary to apply this table. For an understanding of terms such as "sole plate" or "rim joist," a basic framing text should be consulted. See Figure 2304.9.1 for an illustration of certain nail types. This table provides the minimum fastening required for all lightweight wood frame constructions. Buildings designed using either the ASD or LRFD methodologies because of greater loadings must have fasteners which comply with the criteria of this table. It would be common for designed structures to have greater fastening requirements than prescribed in Table 2304..9.1.

2304.9.2 Sheathing fasteners. This is a matter of workmanship. Protruding nails do not provide the intended connecting capacity and could be hazardous. Likewise, nails overdriven into structural sheathing may not perform as expected.

2304.9.3 Joist hangers and framing anchors. This section provides for the use of joist and framing anchors instead of conventional nailing or the use of ledger strips. Joist and framing anchors are engineered components and they must be used in accordance with the manufacturer's instructions and design specifications. The capacity for each hangar must be specified by the manufacturer and is determined in accordance with the test methods outlined in Section 1715.1. Typically the dimensions of the framing elements connected, the number and size of nails used for installation, and the loading conditions are all specified by the manufacturer. Approval by the code official should depend on verification that the anchors have been tested and that they are being used in accordance with the manufacturer's specifications.

2304.9.4 Other fasteners. In addition to joist hangers (see Commentary, Section 2304.9.3), there are other fastening methods that can be approved. Approval should be based on evidence of testing by the manufacturer and that they are being used in accordance with the manufacturer's recommendations.

2304.9.5 Fasteners in preservative treated and fire-retardant treated wood. Corrosion-resistant fasteners are required for treated wood, since the use of treated wood is associated with locations where the wood and fasteners could be subjected to moisture. This applies to fire-retardant treated wood as well as pressure-preservative treated wood, since FRTW is also commonly used in applications where moisture could occur, such as the roofs of buildings.

If treated wood is used for purposes of termite resistance and in locations where moisture accumulation is not likely, there is no practical necessity for the use of corrosion resistant fasteners. AF&PA Technical Report No. 7 requires specific types of corrosion resistant nails for locations below grade and above grade in wood foundations, based on the increased exposure to moisture in below-grade applications.

2304.9.6 Load path. In conventional construction, the fastening required by Table 2304.9.1 provides for a continuous connection between framing elements as required by this section. If the loads on the building exceed the parameters established in Section 2308.2, the building must be designed in accordance with the ASD or LRFD design methodologies and the connections must be designed in accordance with those standards as well to assure a continuous load path in accordance with this section. The designed connections may incorporate engineered tie or strap components with capacities specified by the manufacturer. This section specifies the minimum thickness of sheet metal for fabricated straps or ties.

2304.9.7 Framing requirements. This section requires that the framing workmanship be such that the ends of wood columns and posts be fully bearing for the entire cross section of the column or post. If it does not bear fully on the entire cross section, then design calculations must show that the bearing provided will be capable of supporting the loads. It also requires there to be a positive connection (not merely a friction connection) to resist incidental lateral forces and anticipated uplift forces. For instance, a wood column supporting beams in the basement of a structure could not simply bear on the concrete pad beneath it without a means of positive anchorage to the concrete, to prevent it from being displaced on impact by a person or object. If the combination of loads on the structure could result in uplift forces, then a connection to resist uplift would also be required.

2304.10 Heavy timber construction. Heavy timber construction originated in New England to serve the needs of the growing textile industry. As the industry modernized, the need for larger open space, unobstructed by columns, gradually reduced the demand for this type of construction. Today, due primarily to its aesthetic value, heavy timber construction is used in many other occupancies. It is commonly used for assembly and mercantile buildings, such as schools and churches, auditoriums, gymnasiums, and supermarkets. The provisions of this section must be used with the minimum dimension requirements in Section 602.4. For a building to be classified as heavy timber, all structural elements must comply with the minimum dimensions and the detailing provisions of this section. A structural analysis must be performed to assure that the minimum dimensions are adequate.

2304.10.1 Columns. The American Forest & Paper Association's publication, *Heavy Timber Construction Details–Wood Construction Data 5*, provides details for the proper connection of columns and beams. Traditionally, heavy timber structures were designed and constructed using a prescriptive approach, much like today's conventional construction for light-frame buildings. The number and size of bolts, lag screws or connectors should be determined through analysis of the loads to be supported.

Pintles provide a method to fasten the butt ends of beams or columns. A pintle acts like a short column, connecting the ends of the structural elements.

2304.10.1.1 Column connections. Where columns and girders or beams intersect, care must be taken to assure load transfer. Proper detailing at the intersection of columns and girders will limit the effects of shrinkage. Elements which are not continuous must be properly tied to transfer design forces. Today's engineered wood products are available in multiple depths and widths, and in lengths up to 60 feet, so continuous span structural elements are readily available. Bolster blocks are used to reduce the compression perpendicular to grain stresses where roof beams bear on columns. The shrinkage of the bolster block must be considered in the roof design. Roof beams must have positive connection to the column to resist uplift.

2304.10.2 Floor framing. Wood members must not bear directly on masonry or concrete. Typically, a steel bearing plate or a custom steel hanger is used to support heavy timber elements. Bearing plates provide an even distribution of load on the wall. Wall plate boxes should be designed for positive connection to the masonry. The plate should also prevent lateral movement of the beam, but allow the beam to fall away if it is burnt through. Wood bearing directly on masonry or concrete may absorb moisture, resulting in the loss of bearing capacity. Where direct bearing on top of girders is not possible or desirable, a metal hanger designed to transfer all induced loads is permitted. An additional advantage to using a hanger is less shrinkage. Green beams should be installed so their top edge is slightly above the top edge of the girder to allow for shrinkage during drying.

2304.10.3 Roof framing. Anchorage of roof beams and girders should be in accordance with the engineered design. The provisions of this section provide minimum acceptable anchorage practice. Sawtooth roof construction is used to provide large amounts of daylight into the floor immediately beneath the roof. The roof line looks much like the cutting edge of a saw, with regularly spaced peaks and valleys. The vertical or near vertical line connecting the peaks and valleys is filled with glazing. This unique framing pattern must be anchored to the main roof supports.

2304.10.4 Floor decks. Flooring will expand and contract as the relative humidity in the building changes. To accommodate expansion, a 1/2 inch gap is required at the wall. The gap will also prevent moisture in the walls from migrating into the floor boards. The fire integrity of the floor assembly must be maintained, so either trim, base molding, or corbeling of the wall below is required to prevent the passage of smoke and hot gases.

2304.10.5 Roof decks. The roof deck must be anchored with sufficient regularity to resist uplift forces. Anchorage must be in accordance with the engineered design.

2304.11 Protection against decay and termites.

2304.11.1 General. Conditions favorable for decay and fungus attack are discussed in 2304.11.2 and 2304.11.4, together with preservative treatments. This section sets forth specific locations of concern and the minimum construction practices to prevent such an attack. Termite protection is also defined.

2304.11.2 Wood used above ground. The American Wood Preservers' Association (AWPA) is the principal standards writing body for the wood preserving industry in the United States. AWPA standards cover all aspects of the treated wood from the treating process to appropriate treatment retention levels for specific applications. Wood products used in locations identified in this section are particularly susceptible to deterioration. Deterioration can result from continuous or intermittent contact with moisture or termites.

Decay is caused by fungi which are low forms of plant life that feed on wood. For fungi to attack wood in service, all the following conditions must be present: (1) temperature in the range of 35°F to 100 °F, (2) adequate supply of oxygen, and (3) wood moisture content in excess of 20 percent.

2304.11.2.1 Joists, girders and subfloor. The separations specified in this section are recommended for all buildings and are those considered necessary to: (a) maintain wood elements in permanent structures at safe moisture contents for decay protection, (b) provide a termite barrier and, (c) facilitate periodic inspection. When it is not possible or practical to comply with the clearance specified, the use of naturally durable or pressure preservative treated wood is recommended. However, when termites are known to exist, space must be provided for periodic inspection.

2304.11.2.2 Framing. Traditionally, termite shields were used to obstruct the construction of tunnels from the soil, up the face of the foundation, and into the frame. Eight inches of exposed foundation wall provides adequate surface area for a visual inspection for termite tubes. Wood attached directly to masonry or concrete will draw moisture from these materials, and may reach a moisture content greater than 20%, depending on the relative humidity of the basement.

2304.11.2.3 Sleepers and sills. Wood in contact with the earth or in contact with material that retains moisture must be naturally durable or preservative treated. The moisture content of wood will change based on the relative humidity of the air and the moisture of products with which it is in contact. Interior slabs which are protected from the earth by an impervious moisture barrier should not be considered in direct contact with the earth for purposes of this requirement.

2304.11.2.4 Girder ends. Clearance around the ends of girders prevents moisture from migrating from the concrete into the wood. The 1/2-inch space allows for air circulation and periodic inspection for termites.

2304.11.2.5 Wood siding. Exterior wood siding should extend at least 1 inch below the top of the foundation to provide a drip line protecting the sill from rainwater. The siding is typically held off the foundation with a starter strip attached to sheathing which ends at the bottom of the plate. The 1" overhang causes the rainwater to drip off the bottom edge of the siding, rather than being absorbed by the underlaying sheathing.

2304.11.2.6 Posts or columns. A permanent structure is not defined in the building code. It is a term used by the AWPA in Standard C-15 to describe appropriate retention levels of pressure treated wood. Permanent structures are those structures that are suitable for human occupancy and are placed on a footing. When the post or column is directly embedded in the earth or embedded in concrete in direct contact with the earth, it must be naturally durable or treated in accordance with AWPA standards. The exceptions permit the use of common framing lumber when the post or column is isolated from the earth or concrete. Generally, structural elements in basements or cellars are easier to inspect, which explains the lower clearances. Posts or columns in crawl spaces are required to have a greater separation distance to safeguard against termites between inspections. In both exceptions, an impervious moisture barrier must be provided to assure the post or column does not absorb water from the earth or concrete pier.

2304.11.3 Laminated timbers. It is common practice to design large glued-laminated arches which "spring" or are connected to foundations near the ground level. Exterior walls are built inside the span of these arches, leaving the initial few feet of the wood arches exposed to the weather. Experience has shown that covering the tops of these arches with metal or other water seals is not sufficient to prevent decay. Therefore, such arches and other exposed wood members not protected by roofs or similar covers must be laminated of naturally durable or pressure treated wood.

2304.11.4 Wood in contact with the ground or fresh water. Wood which has been completely submerged below the ground-water table or in fresh water has been known to last in good condition for thousands of years. This method of preservation is the only exception to requiring preservative treatment of all wood in contact with or embedded in the ground.

2304.11.4.1 Posts or columns. This requirement is similar to Section 2304.11.2.6, but emphasizes that posts and columns encased or embedded in concrete must be of preservative-treated wood. The condition is generally more severe than wood placed directly on concrete or embedded in the earth. The embedded portion of the column will most likely be at a moisture content in excess of 20%. At some point very near where the concrete ends, the conditions will be ideal for decay—having both a high moisture content and the presence of air. Unless treated wood is used, decay will occur very near where the encasing begins.

2304.11.4.2 Wood structural members. The framing condition described is uncommon, but the requirement for naturally durable or preservative treated-wood is appropriate. Concrete or masonry can contain sufficient moisture to raise the moisture content in wood structural elements above 20%. Therefore, an impervious moisture barrier or naturally durable or preservative treated wood is required.

2304.11.5 Supporting member for permanent appurtenances. Decks and porches exposed to rain and snow are subject to deterioration. In desert areas where rainfall is slight, there may not be enough moisture to cause any deterioration, and therefore the exception is provided.

2304.11.6 Termite protection. Most termites found in the United States are classified as subterranean termites, which indicates their need to live in the ground. For many years, metal termite shields were considered the best method of preventing infestation. Properly installed, such shields are still a good defense. Today, soil poisoning is considered the more efficient method of controlling termites. However, the chemicals used are highly toxic.

Additionally, all possible locations of infestation must be poisoned. Therefore, the work should be carefully monitored and performed by professionals who are competent and understand the referenced document. Under no circumstances should soil poisoning be attempted by those unfamiliar with toxic products and their application.

2304.11.7 Wood used in retaining walls and cribs. Where the structure is regulated by the building code, wood used to retain soil shall be preservative treated wood. Presumably, where the failure of the retaining wall or crib may threaten life safety or result in property damage, the safeguard provided by preservative- treated wood is necessary.

2304.11.8 Attic ventilation. Adequate ventilation is necessary to assure that moisture laden air can readily escape from the attic space.

2304.11.9 Underfloor ventilation (crawl space). Enclosed spaces under floors of buildings are referred to as crawl spaces when not designed and constructed as basements. The earth is usually exposed or covered with a vapor retarder. Regardless, there is always the potential for a large amount of moisture vapor from the ground being present. This moisture must be removed to prevent wetting and drying cycles which can cause decay and fungus attack in wood members. Experience has shown that crawl spaces constructed in conformance with this section and ventilated to the exterior as required by 1202.3 do not develop decay problems.

Where a high ground water table exists or where moisture is abnormally high, the crawl space must be adequately drained in accordance with 1806.1.2. It should be recognized that the moisture problem may be exaggerated in colder months. Therefore, operable vents should be used with caution. Once insulation in such spaces becomes wet, it seldom dries out, thus negating its performance.

2304.12 Wood Supporting Masonry or Concrete. It is common for wood structural elements to support masonry and concrete construction. When properly designed, taking into consideration long term deflection, wood can adequately support these products. The limitations on wood supporting masonry and concrete are recommended by that industry. Masonry and concrete are brittle materials, which do not tolerate movement. Wood is hygroscopic, meaning it changes dimensions as a result of absorbing or releasing (drying) water. When improperly detailed, dimensional change in wood can result in damage to masonry and concrete.

The exceptions provide some relief. Flooring and roof coverings meeting specific thickness criteria may be supported by wood. The wood must be designed to carry the weight of the material. A strict interpretation would prohibit wood piles from supporting buildings containing masonry or concrete components; an exception permits this. Likewise, brick veneers are permitted to rest on foundation walls constructed using the permanent wood foundation system. Lastly, glass block can rest on wood floors, provided consideration is given to deflection and shrinkage.

2305 General Design Requirements for Lateral Force Resisting Systems

2305.1 General. General design requirements for lateral force resisting systems are described in this section and are applicable to engineered structures. Elements discussed in this section are designed using either Allowable Stress Design (ASD) or Load and Resistance Factor Design (LRFD) methodologies.

When elements within structures constructed according to Section 2308 need to be engineered, provisions of 2305 can be applied without engineering the entire structure. The extent of design to be provided must be determined by the design professional and building official. However, the minimum acceptable extent is often taken to be force transfer into the element, design of the element, and force transfer out of the element. When more than one braced wall line or diaphragm in any area of conventional structures requires engineering analysis, the assumptions used to develop Section 2308 may have changed, and a complete analysis may be appropriate for the entire lateral-force-resisting system. For example, the absence of a ceiling diaphragm may be considered to create a configuration that is non-conventional.

2305.1.1 Shear resistance based on principles of mechanics. In lieu of using the tabular values for shear capacity, such as those in Table 2306.3.1, this section permits calculation of shearwall and diaphragm resistance by principles of engineering mechanics. Methodologies are described in the technical literature that allow for an analytical determination of shear capacity. Design values for wood members and fastener strength in wood members can be determined in accordance with the *National Design Specification® (NDS®) for Wood Construction*, and *AF&PA/ASCE 16 Load and Resistance Factor Design (LRFD) for Engineered Wood Construction*.

2305.1.2 Framing. The transfer of forces into and out of diaphragms and shearwalls is necessary in the analysis of load path continuity. Boundary elements must be sized and connected to the diaphragm to assure force transfer. This section provides basic framing requirements for boundary elements in shear walls and diaphragms. Good construction practice for boundary elements utilizes framing members in the plane or tangent to the plane of the diaphragm. Where splices occur, transfer of forces is usually through addition of framing members or metal connectors - not the diaphragm or shear wall sheathing.

2305.1.2.1 Framing members. Prescriptive requirements in this section are intended to provide an adequate connection between sheathing and framing in shear wall and diaphragm construction. The edge spacing is measured from the panel edge to the nail line. Edge spacing of nail line to panel edge is intended to prevent splitting of the wood structural panel. The fastener spacing is consistent with the minimum spacing provided in Table 2304.9.1.

2305.1.3 Openings in shear panels. Openings occur in shearwalls and diaphragms for stairs, windows, doors, shafts, and other purposes. The transfer of shear forces around openings must be effectively addressed in design to assure adequate capacity exists around the perimeter of the opening to transfer shear forces.

2305.1.4 Shear panel connections. This section restates the requirement for connections and anchorage capable of resisting design forces with a limitation on the use of toe-nail connections for shear transfer in Seismic Design Categories D, E and F. Where the transfer of lateral forces from seismic loads is in excess of 150 pounds per foot, other connection methods should be utilized.

2305.1.5 Wood members resisting horizontal seismic forces contributed by masonry and concrete. The use of wood diaphragms with masonry or concrete walls is common practice. Often referred to as "tilt-up" construction, buildings of this type can be very large in floor area. Another common construction type addressed in this section is found in buildings constructed of three masonry or concrete walls with the fourth wall being all glass, with the roof being wood frame construction. The compatibility of wood and other less ductile construction materials is regulated in the section. Many of the provisions of this section are subjective and based on field observations following major seismic events.

2305.2 Design of wood diaphragms

2305.2.1 General. General requirements for wood diaphragms include consideration of diaphragm strength and deflection. The transfer of forces into and out of the diaphragm must be considered. General requirements for diaphragms can be found in AF&PA/ASCE 16, Supplements to the LRFD and ASD Manuals, and APA Research Report 138—*Plywood Diaphragms*.

2305.2.2 Deflection. Equation 23-1 provides the estimate of the deflection of a blocked, uniformly nailed wood structural panel diaphragm. Total deflection represents the sum of four components contributing to the overall deflection: bending deflection, shear deflection., nail slip, and chord splice slip. Guidance on the selection of various equation inputs such as nail deformation, effective panel thickness, and sum of individual chord-splice values can be obtained from AF&PA/ASCE 16 and supplements to the AF&PA ASD Manual.

2305.2.3 Diaphragm aspect ratios. Table 2305.2.3 provides maximum aspect ratios for floor and roof diaphragms using wood structural panel or diagonal board sheathing. Additional requirements for glass front facade structures and cantilevered diaphragms are described in 2305.2.5 and figures 2305.2.5 (1) and (2).

2305.2.4 Construction. Basic prescriptive requirements for diaphragm construction require the use of 4' x 8' sheets except that a sheet not less than 2 feet in width may be used to fit the dimensions of the particular diaphragm. In addition to panel thicknesses covered in Tables 2304.7(3) and 2304.7(5), 1/4" thickness panels may be used where design for loads perpendicular to the panel indicate it has sufficient strength and stiffness. This may occur for light loads or in situations where framing members are closely spaced.

2305.2.4.1 Seismic Design Category F. As an additional precaution in Seismic Design Category F, additional requirements apply to the attachment wood structural panel sheathing to framing members, solid lumber planking, or laminated decking.

2305.2.5 Rigid diaphragms. For diaphragms defined as rigid, rotational or torsional behavior is expected and results in redistribution of shear to the vertical force resisting elements. Additional prescriptive limits are placed on rigid diaphragms based on the type of irregularity and diaphragm construction.

2305.3 Design of Wood Shearwalls

2305.3.1 General. General requirements for wood shear walls include consideration of shear wall strength and deflection. General requirements for wood shear walls can be found in AF&PA/ASCE 16, Supplements to the LRFD and ASD Manuals, and APA Research Report 154--Wood Structural Panel Shear Wall.

2305.3.2 Deflection. Equation 23-2 provides an estimate of the deflection of a wood structural panel shear wall. Total deflection represents the sum of four components contributing to the overall deflection: chord deformation, shear deflection, nail slip, and anchorage deformation. Guidance on the selection of various equation inputs can be obtained from AF&PA/ASCE 16 and supplements to the AF&PA ASD Manual.

2305.3.3 Shearwall aspect ratios Table 2305.3.3 provides maximum shear wall aspect ratios for shear walls composed of wood structural panel, particleboard, fiberboard or diagonal sheathing. When resisting seismic loads in Seismic Design Category D and higher, the maximum aspect ratio for wood structural panels or particleboard is 2:1 height to width ratio. This limit addresses a concern that reduced stiffness associated with larger aspect ratios is not accounted for in the current design process. One approach for addressing larger aspect ratios in high seismic areas is provided in the *2000 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (2000 NEHRP). In the 2000 NEHRP, shear wall aspect ratios greater than 2:1, but not exceeding 3.5:1, are permitted provided the shear resistance values are multiplied by $2w/h$ where w is the shear wall width and h is the shear wall height. This adjustment, based on review of test data of larger aspect ratio shear walls, reduces shear wall resistance to account for reduced stiffness associated with shear wall aspect ratios greater than 2:1, but not exceeding 3.5:1.

2305.3.4 Shearwall height definition. Shear wall height, as defined in this section, is provided for the purpose of calculating maximum height to width ratios for shear walls.

2305.3.5 Shearwall width definition. Shear wall width, as defined in this section, is provided for the purpose of calculating maximum height to width ratios for shear walls. When used to calculate shear wall aspect ratio, it is intended that a standard 4' x 8' panel used in standard 8' wall construction should qualify as meeting a panel aspect ratio of 2:1.

2305.3.5.1 Shearwall segment width definition. Shear wall segment width is applicable to perforated shear walls and represents the width of full-height sheathing sections within a perforated shear wall (see Commentary, Sections 2305.3.7 and 2305.3.7.2, for discussion on perforated shear walls). Only shear wall segments with widths meeting aspect ratio limits as defined in 2305.3.3 may be used in calculation of perforated shear wall resistance per 2305.3.7.2.

2305.3.6 Overturning restraint. This section provides a general requirement to maintain a continuous load path to the foundation for uplift due to wall overturning forces. Overturning restraint is usually located at wall ends as close to the ends of the wall as practical and consist of metal straps or other hardware attached to the shear wall end posts.

2305.3.7 Shearwalls with openings Provisions for designing shear walls with openings are divided into two categories. When framing and connections around the openings are specifically designed and detailed for force transfer around the opening, provisions of 2305.3.7.1 apply. When framing and connections for force transfer around openings are not specifically designed and detailed for force transfer around the opening, provisions of 2305.3.7.2 apply. Shear walls resulting from provisions of 2305.3.7.2 are commonly referred to as "perforated shear walls."

The design provisions of 2305.3.7.1 and 2305.3.7.2 are fundamentally different from each other. In 2305.3.7.1, design and detailing around openings is based on a rigid body behavior and utilizes the full shear resistance developed in the wood structural panel shear wall. In 2305.3.7.2, the wall is not assumed to act as a rigid body and shear capacity is reduced, accounting for the reduced strength and stiffness of shear wall segments within the perforated shear wall.

2305.3.7.1 Force transfer around openings Shear walls designed using provisions for force transfer around openings utilize aspect ratio limits defined in Table 2305.3.3, however, definitions of wall pier height and width are used to calculate the aspect ratio. Wall pier width and height are shown in Fig. 2305.3.4(b) of the code. In this approach for design of shear walls with openings, design for force transfer around the openings involves developing a system of piers and coupling beams within the shear wall. Load paths for the shear and flexure developed in the piers and coupling beams generally require blocking and strapping extending from each corner of the opening to some distance beyond. This approach is often utilized in highly loaded walls when limited amounts of sheathing are present around openings and often results in shear wall detailing involving many metal tension straps around the openings.

2305.3.7.2 No force transfer around openings Shear walls resulting from provisions of 2305.3.7.2 are commonly referred to as perforated shear walls. Aspect ratio limits of 2305.3.3 apply to shear wall segments within the perforated shear wall.

The perforated shear wall approach presented in this section utilizes empirically based reductions (see Table 2305.3.7.2) of wood structural panel shear wall capacities to account for the presence of openings that have not been specifically designed and detailed for moment resistance. This method accounts for the capacity that is inherent in standard construction, rather than relying on special construction requirements. It is not expected that sheathed wall areas above and below openings behave as coupling beams acting end to end, but rather that they provide local restraint at their ends. As a consequence, significantly reduced capacities are attributed to interior perforated shear wall segments with limited overturning restraint.

Further background on development of provisions for perforated shear walls and example problems are provided in the *2000 NEHRP Recommended Provisions for New Buildings and Other Structures Commentary*. The 2000 NEHRP also contains an equation format version of provisions for perforated shear walls that is consistent with provisions of 2305.3.7.2.

2305.3.7.2.1 Deflection of shearwalls with openings. The provision for calculation of deflection of a perforated shear wall is based on the observation from testing that the reduction in strength is comparable to the reduction in stiffness. See Commentary, Section 2305.3.7.2.

2305.3.8 Summing shear capacities. This section provides general requirements for summing shear capacities of materials applied to one side of a wall or both sides of the same wall. Historically, when a wall is sheathed on opposite sides with dissimilar materials, doubling the shear value of the lesser material is the shear resistance of the wall assembly. In 1995, testing was conducted to confirm that the sum of shear resistance of the dissimilar materials is the shear resistance of the wall assembly. Test results were reported in *Wood Structural Panel Shear Walls with Gypsum Wallboard and Window/Door Openings, Report 157, APA - The Engineered Wood Association*, 1995. The report shows that the maximum shear capacity of the shear wall with combined materials demonstrated higher maximum shear capacities than the sum of the individual capacities.

2305.3.9 Adhesives. The restriction against adhesive attachment of shear wall sheathing in high seismic areas addresses a concern that the increased stiffness associated with use of adhesives will attract more load to the shear wall than anticipated and could cause brittle failure of anchoring devices.

2305.3.10 This provision addresses a concern over bottom plate damage observed in highly loaded sill plates in Seismic Design Category D, E, or F. A minimum 3/16" by 2 inch by 2 inch plate washer is required between the sill plate and nut when attaching the sill plate to the foundation. The nut should be snug tight against the washer. It is expected that this plate washer will reduce cross-grain bending forces in the sill plate. In addition, a 3" sill plate is required when the design load is greater than 350 plf (ASD) as an added measure of strength against cross-grain bending forces. Where the single 3" sill plate is used, longer end nails should be substituted to provide sufficient penetration into the stud.

The exception permitting 2" plates enables the use of 2" sill plates for design loads up to 600 plf (ASD) provided that twice the number of anchor bolts required by design are used to anchor the sill plate. While this requirement may not be practical for new construction, it is expected that this option would be used to upgrade existing structures with 2" sill plates.

2306 Allowable Stress Design

2306.1 Allowable stress design. This section contains a number of specifications intended to provide guidance to nonprofessional as well as professional users of the *IBC*. These specifications, based on accepted engineering practices and experiences, are considered to be the minimum acceptable methods for constructing wood elements in structures. When designed and built in accordance with the standards listed in this section, a building or structure is deemed to comply with the code. These standards contain most of the information needed to adequately design a structure in accordance with the allowable stress design method. It is necessary for the designer to have a working knowledge of engineering principles and experience to properly interpret these recommendations and meet the provisions of other applicable sections of the code.

The most common and applicable practices are summarized in the standards listed in 2306.1. These standards contain references to additional technical publications which address special problems and design criteria for wood structures. The users of these standards should have training and expertise in engineering and construction in order to properly interpret the standards' requirements. These standards employ allowable stress design (ASD)—that is, the traditional format for presenting safety checking equations in structural design standards. The basic design equation for ASD requires that the specified product allowable design value meet or exceed the actual (applied) stress or other effect imposed by the specified loads. In ASD, the allowable design values are set very low and the nominal load magnitudes are set at once in a lifetime levels. This combination produces designs that maintain high safety levels, yet remain economically feasible.

While the design against structural collapse remains the primary purpose of structural design, the designer must also consider how the design will perform from the perspective of serviceability, durability and fire safety. The allowable stress design approach is to provide adequate resistance to certain limit states for serviceability. Serviceability limit states are those that restrict the normal use and occupancy of the structure such as excessive deflection and vibration. The *IBC* defines these limits as a ratio of the member span—for example, L/360 computed under live load or L/240 under total load for floors. The designer is always at liberty to choose more restrictive serviceablity limits.

The *ANSI/AF&PA National Design Specification® (NDS®) for Wood Construction* is promulgated and distributed by the American Forest & Paper Association (AF&PA), listed in Chapter 35. The *NDS®* was first adopted in 1944 and has been updated periodically to reflect new knowledge under the auspices of AF&PA and its predecessor organizations, the National Lumber Manufacturers Association (NLMA) and the National Forest Products Association (NFPA). A supplement to the *NDS* collates all of the recommended working stress values published by the approved grade-rules writing agencies. The *NDS®* is included in AF&PA's *Allowable Stress Design Manual for Wood Construction (ASD-Manual)*. The *ASD-Manual* provides guidance for selection of most wood-based structural products used in the construction of wood buildings.

AF&PA also publishes *Wood Construction Data (WCD) No. 5, Heavy Timber Construction Details*. It is written in code language for easy reference. WCD No. 5 contains detailed specifications for sizes of members required and other provisions, which collectively provide a definition of heavy timber construction. Recommendations are also included for the fabrication and erection of this unique construction. It should be used in conjunction with the *NDS* and AITC specifications when the members are glued laminated.

The *Supplement to the National Design Specification (NDS®)* is a collation of the allowable working stress values for sawn lumber as published by seven grade-rules writing agencies: National Lumber Grades Authority (Canada) ! Northern Softwood Lumber Bureau ! Northeastern Lumber Manufacturers Association ! Redwood Inspection Bureau ! Southern Pine Inspection Bureau ! West Coast Lumber Inspection Bureau ! and Western Wood Products Association.

These allowable working stress values, often called design values, have been approved by the Board of Review of the American Lumber Standards Committee (ALSC) with advice from the U.S. Forest Products Laboratory of the U.S. Department of Agriculture. They have been certified for conformance with the U.S. Department of Commerce Voluntary Standard PS 20-94, "American Softwood Lumber Standard." Regional grading agencies formulate and publish grading rules, and ALSC approves these rules as conforming with PS 20-94.

PS 20-94 requires that design values for visually graded lumber be developed in accordance with appropriate ASTM standards or other technically sound criteria. The design values reflected in the 1997 *NDS Supplement* are derived from ASTM D 1990, "Standard Practice for Establishing Allowable Properties for Visually Graded Dimension Lumber from In-Grade Test of Full-Size Specimens." As suggested by the title, ASTM D 1990 is utilized to derive strength values from full-sized samples of lumber.

Design values for visually graded timbers, decking and some species and grades of dimension lumber are based on the provisions of ASTM D245, "Standard Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber." The methods in ASTM D245 involve adjusting the strength properties of small clear specimens of wood for the effects of knots, slope of grain, splits, checks, size, duration of load, moisture content and other influencing factors, to obtain design values applicable to normal conditions of service.

The design values given in the supplement are for normal loading conditions and under dry service conditions in a covered building. If other conditions of loadings or wet end-use conditions exist, these values must be adjusted in accordance with the recommendations of the *NDS*.

American Institute of Timber Construction. The AITC standards listed are primarily intended for glued laminated structural members, but also include recommendations for sawn timber members. These standards supplement the provisions of the *NDS* and WCD No. 5 with no conflicting provisions. All the standards should be used collectively.

ANSI/AITC Standard A190.1 is intended to provide nationally recognized requirements for the production, inspection, testing, and certification of structural glued laminated timber. Section 6 of the standard provides detailed requirements for in-plant quality control and for the qualification of third party inspection and testing agencies. These specifications include provisions for required testing during and after fabrication. Section 7 outlines the requirements for marking.

Truss Plate Institute, Inc. ANSI/TPI 1 is the standard for the design, fabrication, quality control, and erection of light-framed metal plate connected wood trusses. The standard was prepared through a joint effort by the American National Standards Institute (ANSI) and the Truss Plate Institute (TPI). This standard should be used in conjunction with other standards for wood construction.

APA-The Engineered Wood Association. APA recommendations and design documents are considered to provide the best criteria for the design and erection of structures incorporating plywood and other structural-use panel products.

2306.1.1 Joists and rafters. Spans for joists and rafters may be designed in accordance with the *AF&PA Span Tables for Joists and Rafters* or in accordance with approved engineering standards. When sizes of floor joists are other than standard sizes conforming to U.S. Department of Commerce PS 20, they must conform to the NDS. When applicable, other span tables may be used, such as those from the *International Residential Code*, Southern Forest Products Association, Western Wood Products Association, and Canadian Wood Council. The spans given in these tables are the same as those published in *AF&PA Span Tables for Joists and Rafters*. The AF&PA span tables were developed to provide uniformity in use of wood joists and rafters for light wood-framed structures where the live loads do not exceed those for which the tables were designed. The tables for floor joists were designed with the live load, dead load and deflection criteria shown in Chapter 16.

2306.1.2 Plank and beam flooring. The plank-and-beam method for framing floors and roofs has been used in buildings for many years. The adaptation of this system to residential construction has raised technical issues concerning details of application. AF&PA's *Wood Construction Data No. 4, Plank and Beam Framing for Residential Buildings* contains information pertaining to design principles, advantages and limitations, construction details and structural requirements for the plank-and-beam method of framing.

2306.1.3 Treated wood stress adjustments. The allowable stresses for fire-retardant treated wood products must be determined by testing that takes into account anticipated temperatures and humidity levels that will be encountered during service. The allowable stresses for untreated products are not applicable to fire-retardant treated products, because the treatment chemicals can reduce the strength of materials. This is particularly true for products such as roof sheathing which are subject to conditions of high temperature and humidity.

Before approving the use of fire-retardant treated wood products, the building official should require the manufacturer of each subject product to submit their recommended allowable stresses and provide documentation on how those values were determined. This documentation should be required for each chemical that is to be used, because performance will vary between formulations. Some manufacturers maintain Evaluation Reports with the National Evaluation Service or the evaluation services of one of the three model building code organizations (BOCA, ICBO and SBCCI)—which can be used by the building official in reviewing these products.
Additionally, the building official should enforce any restriction on the use and location of any such treated product recommended by the manufacturer or justified based on the nature of the testing performed. For example, when these products are proposed for use in attics, the building official should make sure that they have been tested under conditions that will insure suitable performance under conditions of high temperature and humidity typically found in attics.
The building official should also be alerted to the fact that the attic ventilation requirement in the code takes on added importance when such products are used in attics. The ventilation requirements

of the code should be strictly enforced, and the building official should consult the manufacturer to determine if any additional ventilation above the code requirements might be necessary. Ventilation is needed to control temperature and humidity levels to which the products will be subjected. A lack of adequate ventilation can change the service conditions to which the products are subjected and, as a result, reduce the strength of the products below the values published by the manufacturer.

2306.2 Wind provisions for walls. See Commentary, Table 2306.2.1.

2306.2.1 Wall stud bending stress increase.

Design values for structural lumber are published in the *Supplement to the National Design Specification® (NDS®) for Wood Construction*. The tabulated design values are for normal load duration under the moisture conditions specified. Bending design values, F_b, for dimension lumber may be multiplied by the repetitive member factor, $C_r = 1.15$, when such members are used as joists, truss chords, rafters, studs, planks, decking or similar members which are in contact or spaced not more than 24 inches on centers, are not less than three (3) in number and are joined by floor, roof or other load distributing elements adequate to support the design load.

For wall systems composed of 2x4 to 2x10 studs faced on one side with a minimum of 3/8-inch wood structural panel and with a minimum of 1/2-inch gypsum board on the other side, the repetitive member factor may be increased to the values in Table 2306.2.1 as a result of the load sharing and composite action actions of the wall framing system in a high wind condition.

2306.3 Wood Diaphragms. A diaphragm is a relatively thin structural element, e.g., floor or roof assembly, usually rectangular in plan, capable of resisting shear parallel to its edges. The three major elements of a diaphragm are the web (wood structural panels and joists/rafters), the chords (edge members), and the fasteners (such as nails). The web is usually composed of several panels. It is also very seldom that the chords are one piece. Therefore, the fasteners and connection chords splices must be considered as major factors in the performance of a structural diaphragm.

Most floors, roofs and walls can function as a diaphragm. Full diaphragm action can be obtained by detailing the sheathing fasteners and framing connections. Diaphragm construction is used extensively to resist horizontal forces of wind and earthquakes. Diaphragms may be either vertical (often referred to as shear walls) or horizontal. In special designs, they may be oriented in any direction.

A diaphragm acts in the same manner as an I beam. The plywood panel skin acts as the web and the edge members act as the flanges, which are called chords. However, due to the relatively greater depth of a diaphragm, the reactions to stress are somewhat different. The diaphragm design assumes that stresses are uniformly distributed across the panel and the web does not contribute to the resistance of tension and compression stresses as it does in a shallow beam.

A series of diaphragms may be tied together to develop a very rigid structure. Their ability to resist large shear stresses have led to their use in innovative construction methods such as folded plate roof elements, geodesic domes, and space frames.

Diaphragms must be securely connected to supporting members and to foundations which are capable of resisting all design forces. Anchorage for floors and roof generally present no special problems. It is only required that the stresses be transferred to the chords, assuming they are adequately supported. Shear walls, however, require special attention to their anchorage to the foundation. The foundation and the connections thereto must be designed to resist the uplift, compression, and shear forces applied.

Openings in diaphragms, such as skylights, doors and windows, disrupt the uniform distribution of shear stresses across the diaphragm. Provisions must be made to provide continuity and compensation for this disruption. Reinforcement, for instance, may be necessary at windows.

2306.3.1 Shear capacities modifications. The permitted 40 percent increase is based on reducing the load factor of 2.8, used to develop shear capacities for structural sheathing, to 2.0. The rationale for this increase is that it is no longer prudent to retain the previous minimum safety factor of 2.8 on wood structural sheathing materials. The judgment is that a factor of 2.0 is adequate—resulting in the 1.4 factor relative to today's allowable values.

2306.3.2 Wood structural panel diaphragms. Wood structural panel diaphragms may be designed using the information in Table 2306.3.1. It should be remembered that the panel thickness and the joist spacings must also comply with the requirements for sheathing of floors and roofs. Wood structural panel diaphragms may also be designed using accepted engineering principles. *ANSI/AF&PA National Design Specifications (NDS®) for Wood Construction®* provides information on shear resistance of mechanical fasteners and chord design. Working stresses for wood structural panels and other materials are contained in other references in the *IBC*.

The design of horizontal diaphragms to resist shear stresses depends on the direction of continuous panel joints relative to the direction of load and not on the direction of the long dimension of the panel or framing direction. Six cases of panel orientation are illustrated in Table 2306.3.1. The nailing schedule and the resultant shear resistance will be affected by the panel layout (relative to load) selected. It should also be noted that a diaphragm usually must resist loads in both the transverse and longitudinal direction. Each direction must be considered separately and a different case of panel orientation, and thus allowable load, will be applicable to each direction.

Blocked diaphragms have all panel edges supported by and fastened to framing members. Blocking is used at the edges of panels which are not over joists to provide for connecting units and to assist in the transfer of shear forces to the adjacent panel. *Unblocked diaphragms* may be used provided the applicable nailing schedule in Table 2304.9.1 is used and the shear stresses do not exceed those tabulated. Unblocked diaphragms are often controlled by the buckling of the panel (skin). With the same nail spacing, allowable design loads for blocked diaphragms are 1 1/2 to 2 times the design loads for unblocked diaphragms. In addition, the maximum loads for which blocked diaphragms may be designed are many times greater. The forces which must be resisted usually serve as the basis for choosing blocked or unblocked construction.

2306.3.3 Diagonally sheathed lumber diaphragms. Table 2306.3.3 presents a prescriptive schedule for nailing of nominal 1-inch and 2-inch lumber sheathing placed diagonally to the structural framing. The nail schedule is intended to be used in accordance with the requirements of 2306.3.4 for single diagonally sheathed lumber diaphragms and 2306.3.5 for double diagonally sheathed lumber diaphragms.

2306.3.4 Single diagonally sheathed lumber diaphragms. The reduction factors are based on common wire nail shear design values for three classifications of lumber:

- specific gravity, G, >0.49 (for example, southern pine and Douglas fir-larch);
- 0.42 < G < 0.49 (for example, spruce-pine-fir and hem-fir), and
- 0.42 < G (for example, aspen, balsam fir, and cedars).

The specific gravity of lumber species can be found in Table 12A of *ANSI/AF&PA National Design Specification® (NDS®) for Wood Construction*.

2306.3.4.1 End joints. End joints of individual boards are required to be staggered in locations as described in this section to maintain the shear capacity specified in Section 2306.3.4.2.

2306.3.4.2 Single diagonally sheathed lumber diaphragms. The shear capacity referenced in this section is conservative since tests of wood shear panels with 2-inch nominal lumber sheathing are not readily available.

2306.3.5 Double diagonally sheathed lumber diaphragms. This section provides the shear capacity for various configurations of double diagonal board-sheathed shear panels. This type of construction is seldom used because of the labor costs of individual board installation. Double diagonal construction has a higher shear capacity than the single diagonal construction described in Section 2306.3.4. For comment on the reduction factor, see Commentary, Section 2306.3.4.

2306.4 Shearwalls. A shearwall is a vertical diaphragm designed to resist lateral forces parallel to the plane of the wall. Therefore, much of the commentary in 2306.3 on diaphragms is also applicable to this section.

Detailing is critical in the design of shearwalls to ensure that forces are properly distributed to top plates, ledgers, bond beams, or any other continuous element at the perimeter to the diaphragm. Therefore, it is important that splices be designed to transmit tension or compression forces occurring at the location of a splice. Panel sheathing joints must occur over studs or blocking and common framing members.

2306.4.1 Wood structural panel shear walls. The allowable shear capacities for wood structural panel shearwalls in Table 2306.4.1 were developed on engineering principles and monotonic testing.

The 40-percent increase in shear capacities is based on engineering principles. Full scale monotonic testing was conducted to validate the model. The increase takes into effect the short time duration of loading associated with a wind event.

Shearwalls may also be designed without limitations by a rational method using the values for nail strength in the ANSI/AF&PA *NDS®* or by using wood structural panel design properties in *APA/PDS*. For shearwalls utilizing wood framing, energy dissipation is almost entirely due to nail bending. Since fasteners other than nails and staples have not been extensively tested under cyclic load applications, the rational method is limited to nail strength values. When screws or adhesives have been tested in assemblies subjected to cyclic loading, they have tended to have a brittle mode of failure.

2306.4.2 Lumber sheathed shear walls. Although wood structural panel sheathed shearwalls is the method most prevalent in use today, diagonally sheathed lumber shearwalls are still used for new construction in some regions and are encountered in the alteration of existing structures. The shear resistance values are applicable to buildings exposed to seismic or wind forces.

2306.4.3 Particleboard shearwalls. Limitations of use in shearwalls are greater for particleboard than for wood structural panels and lumber. The design shear capacity of particleboard shearwalls is limited to the values listed in Table 2306.4.3 and particleboard shearwalls may only be used to resist shear forces. Further, this section attempts to emphasize that special care must be taken to ensure that all panel edges are properly attached to, and fully blocked with, 2-inch nominal framing in order to ensure transfer of shear forces to boundary elements.

2306.4.4 Fiberboard shearwalls. For structural fiberboard to be used in the construction of shearwalls, the long dimension of the panel must be parallel to the studs. This ensures that a 2:1 aspect ratio is established. The shear capacity of fiberboard shearwalls is limited to the values listed in Table 2308.9.3(4). Further, this section attempts to emphasize that special care must be taken to ensure that all panel edges are properly attached to and fully blocked with 2-inch nominal framing in order to ensure transfer of shear forces to boundary elements.

2306.4.5 Shearwalls sheathed with other materials. This is intended to recognize the shear capacities of gypsum board sheathing and expanded metal or woven wire lath and portland cement plaster in shearwalls. Because of the brittleness of these materials, their use to resist seismic forces is limited or prohibited in certain Seismic Design Categories. In wind design, the shear capacities of these materials are often added to the shear capacity of the wood structural panel or wood sheathing to determine the total shear capacity of the shearwall to resist wind forces.

2306.4.5.1 Application of gypsum board or lath and plaster to wood framing This section presents general prescriptive details on the application of gypsum board and lath and plaster to wood framing. It is deemed that compliance with these prescriptions will develop a structurally sound and serviceable wall surface.

2306.4.5.1.1 Joint staggering. This is common practice, and serves to add to the overall shear capacity of the wall.

2306.4.5.1.2 Blocking. Full-sized blocking is required at unsupported edges. This increases the overall shear capacity by allowing direct transfer of shear forces from the gypsum board to the framing elements.

2306.4.5.1.3 Nailing. Table 2304.9.1 is the fastener schedule for all wood connections in conventional framing. This section simply emphasizes that the proper connections are essential to the wall's performance in resisting shear.

2306.4.5.1.4 Fasteners. The minimum edge spacing of nails around panel perimeters assures that the nails develop their full load resisting capacity without splitting the panel near the edge.

2306.4.5.1.5 Gypsum lath. The values in Table 2306.4.5 assume a perpendicular application.

2306.4.5.1.6 Gypsum sheathing. For gypsum sheathing, the values in Table 2306.4.5 assume application in either orientation, except for two-foot-wide sheets in the first row of the gypsum sheathing portion of the table.

2306.4.5.1.7 Other gypsum boards. For typical gypsum board, the values in Table 2306.4.5 assume application in either orientation.

2307 LOAD AND RESISTANCE FACTOR DESIGN

2307.1 Load and resistance factor design. The design of wood structures has historically been governed by the general design provisions and recommended practices of the *National Design Specification® (NDS®) for Wood Construction*, an allowable stress design specification. ASCE/AF&PA's *Load and Resistance Factor Design (LRFD) Standard for Engineered Wood Construction* was created to provide alternate design provisions based on reliability theory and a uniform practice in the design of engineered wood structures. ASCE/AF&PA 16 is included in AF&PA's *Load and Resistance Factor Design (LRFD) Manual of Engineered Wood Construction*, a multi-part design manual for engineers.

Theoretical reliability-based analysis has been used for many years in the electronics and aerospace industries with great success. The extension of theoretical reliability concepts to building applications has proven to be somewhat more difficult, but still achievable. LRFD has evolved to become the preferred format for converting structural design standards to a so-called limit states approach. The LRFD Standard is intended for use in conjunction with competent engineering design, accurate fabrication, and adequate supervision of construction.

The basic design equation for LRFD requires that the specified product strength or resistance meet or exceed the stress or other effect imposed by the specified loads. The load and resistance factors for strength are derived from a rational statistical approach tied to a target probability of failure. Factored load equations are standardized across most material groups. Resistance factors vary by material and mode of use. The design process for strength is very similar to that of ASD since the same design equations are used only with resistance factors included.

AF&PA/ASCE 16 and its supporting ASTM standards adopt the reliability refinements embodied in the load factors of ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. The procedures in ASTM D5457, *Standard Specification for Computing the Reference Resistance of Wood-Based Materials and Structural Connections for Load and Resistance Factor Design*, are consistent with other standards in their use of reliability concepts in the background of calculations.

Section 2308 CONVENTIONAL LIGHT FRAME CONSTRUCTION

Section 2308.0 Conventional Light Frame Construction. The provisions of this section recognize that light-frame wood construction, as discussed in 2308.1, is deemed to comply with the engineering requirements of the code. The conventional construction provisions are prescriptive regulations that result in construction, which will successfully resist gravity and lateral loads, within the limits of 2308.2, to which the structure can reasonably be expected to be exposed. Certain provisions of conventional construction may rely upon historic performance, rather than principles of engineering.

2308.1 General. These specifications are generally only applicable to light wood frame building construction having closely spaced framing—using studs up to 2 x 6 in size and joists and rafters up to 2 x 12 inches in size. With a few exceptions, a "conventional" structure is framed in the "western platform" style. Repetitive, closely spaced framing is not specifically defined by the code, however, it is usually assumed to include framing that does not exceed a spacing of 24 inches on center. This is the greatest spacing commonly found in these types of structures, the greatest spacing covered by *AF&PA Span Tables for Joists and Rafters*, and the maximum spacing for which referenced standards allow increases in bending stresses for repetitive member use.

For structures within the scope of conventional construction, however, other methods of construction are permitted, provided that they are designed to comply with either allowable stress design methodology or load and resistance factor design methodology, as discussed in the commentary for 2301.2.

Some interior non-bearing applications are permitted to use the provisions of 2308, even though the remainder of the building does not fall within the limitations of 2308.2. These buildings would be of both light wood frame construction as well as other types of construction in which wood framing is permitted under other portions of the code.

2308.2 Limitations. It is acknowledged that conventional construction provisions concerning framing members and sheathing that carry gravity loads are adequate. For resistance to lateral loads (wind and seismic), however, experience has shown that additional requirements—or limits on the application of conventional construction provisions are needed.

1. The requirements of conventional construction are based on anticipated loads, both gravity and lateral. Buildings greater than three stories in height load the lower stories to a level higher than addressed by these provisions.

2. Studs in bearing walls have a tendency to bow, or move laterally, along the plane of the wall. Although this lateral movement can be restrained by design, the prescriptive provisions of 2308 don't attempt to address the problem for studs taller than 10 feet, which is assumed as the maximum stable height using the typical grades and species (type) of wood in general use in conventional construction.

3. As the requirements of 2308 are based on anticipated loads, this item limits both dead and live loads in the structure. The prescriptive provisions of conventional construction are based on relatively light dead loads and do not address support of masonry or concrete other than veneer. Additionally, the span tables for joists are based on live loads of residential uses, and other elements which support floor loads assume residential loading.

4. While some elements of conventional construction are acceptable for use in buildings in high-wind areas (as will be seen in the documents referenced in 2308.2.1), the general framing and sheathing requirements are not. Buildings in Exposure Categories A and B, as addressed in 1609.4, are somewhat sheltered by other buildings and by trees and other obstructions. For that reason, the exception recognizes that conventional construction will provide adequate lateral resistance in buildings in those areas.

5. In buildings with roof framing spans in excess of 40 feet, the horizontal thrust of that framing on the top plate on which it rests is greater than can be resisted by the ceiling joist and rafter connections required in 2308.10.4.1. Note that the limitation is on the span of the truss or rafter and not on the width of the building. The building width could exceed 40 feet as long as the actual span of the roof framing was not more than 40 feet.

6. Structures in Seismic Design Category F require an engineered design. The anticipated lateral forces in such an area are greater than can be resisted by conventional construction.

7. Irregular portions of buildings (see the commentary on 2308.12.6) are not permitted to use conventional construction in the higher seismic design categories.

2308.2.1 Basic wind speed greater than 100 mph (3-second gust). Where the basic wind speed exceeds the limitation in 2308.2, #4, the provisions of the section cannot be used in constructing the building. Engineering design, however, is not always required. The engineered, yet prescriptive provisions of *AF&PA's WFCM* and *SBCCI's SSTD-10* may be used on buildings that are within the scope of those documents.

2308.2.2 Buildings in Seismic Design Category B, C, D or E. In recognition of additional lateral forces anticipated in Seismic Design Categories B and C and those in D and E, additional limits are placed on the application of conventional construction. See the Commentary on 2308.11 and 2308.12.

2308.3 Braced wall lines. Exterior walls of buildings that do not require a seismic analysis in accordance with 1614.1 and that are located in regions where hurricane winds are not anticipated (see 2308.2) are required to be braced in accordance with this section. In addition, if the spacing between the braced exterior walls exceeds 35 feet (see Section 2308.3.1), interior braced wall lines are also required.

The requirements for wall bracing vary, depending both upon the level of seismic activity for the region in which the building under consideration is located and upon whether the story in question is supporting other stories. The bracing requirements increase for higher seismic design categories and for those walls which support the weight of additional stories above. Various types of structural sheathing materials are permitted, although not every material is permitted in every instance.

Nailing requirements are critical to the performance of the wall bracing. To insure that the bracing material is effective in resisting racking of the wall, it must be installed in the manner prescribed.

2308.3.1 Spacing. While model building codes in the past have been quite specific as to the type of bracing materials to be used and the amount of bracing required in any wall, no limits on the number or maximum separation between braced walls have been established. Now, however, by mandating the maximum spacing of braced wall lines and thereby limiting the lateral forces acting on these vertical elements, this spacing requirement provides a lateral-force-resisting system that will be less prone to overstressing.

2308.3.2 Braced wall panel connections. The connection described in this section serve to effectively tie the structure together, so that forces can be adequately transferred from walls and roofs to the braced wall lines. In this regard, the connections are critical.

In regard to item 1, when the maximum dimension of a roof exceeds 50 feet in any direction without being fastened to a braced wall line, the force resulting from the mass of the roof during an earthquake would exceed the resistance capability of the braced walls. Since the spacing of the walls cannot exceed 35 feet in accordance with Section 2308.3.1, if the roof is fastened to all braced wall lines then this requirement will be fulfilled.

2308.3.3 Sill anchorage. See Commentary, Section 2308.6. The more restrictive spacing is required since the braced wall is designed to resist greater loads than a non-braced wall.

2308.3.3.1 Anchorage to all-wood foundations. There are no prescriptive provisions currently in the code for anchorage of braced wall lines to wood foundations. Therefore, transfer of the forces from the wall line to the foundation must be provided. Connections must be designed to meet the capacity of the of the bolts described in Section 2308.6.

2308.3.4 Braced wall line support. An exception has been added allowing horizontal dimensions of up to 50 feet between continuous foundations. This is intended to permit residential cripple walls to be braced at exterior walls only, within the limitations described.

Connections between horizontal and vertical resisting elements and transferring of forces to the foundations are prescribed in this section.

2308.4 Design of portions. Although the code envisions the use of the conventional construction provisions without the need to formally design elements of the building, there may well be certain portions of the building's structural system which do not comply with the requirements of 2308. In such an instance, that structural component must be designed to comply with the requirements of Chapter 16 of the code. See Commentary, Section 2305.1 for additional comments.

2308.5 Connections and fasteners. As discussed in the Commentary for 2304.9, the section on fasteners and connectors applies to all types of wood construction addressed in Chapter 23, and the number of fasteners stipulated in Table 2309.9.1 is the minimum number of fasteners to be used. This section emphasizes that requirement and also requires compliance with other portions of the section which address specific fastener applications.

2308.6 Foundation plates or sills. This section prescribes the size and spacing of foundation bolts or anchors for those wood structures which are permitted to use conventional construction. Note that regulations pertaining to the foundation or footing are to be found in Chapter 18. Also, note that types of anchors other than bolts and anchor straps are permitted when approved by the building official.

2308.7 Girders. Girders of a single piece of wood must meet the size requirement of this section. Those which are built up—constructed of two or more pieces of 2-inch (nominal) wide lumber—must comply with the specified tables. Other girders are permitted if properly designed. Where girders are long enough to require the use of more than a single piece of wood, the joints between the pieces must be supported and cannot occur in mid-span. If several members comprise a beam, they should be adequately tied together to provide continuity and to insure that the members act compositely.

The minimum bearing length for girders supported by concrete or masonry walls is 3 inches. This minimum requirement is based on the anticipated loads for the construction typical in this chapter and the allowable compressive stresses perpendicular to the grain for beam sizes and grades typical of the requirements in this chapter, in addition to consideration of shear failure of the masonry.

2308.8 Floor joists. The spans shown in these tables were derived from the *AF&PA Span Tables for Joists and Rafters*. For simplicity, spans of only the most common species, or types, and grades of wood are shown. When other species or grades of wood are used, the AF&PA tables should be consulted to determine the proper span. Additionally, span tables published by the Southern Forest Products Association, the Western Wood Products Association, and the Canadian Wood Council can also be consulted. The spans published in those tables were derived in the same manner as those published in the AF&PA tables.

Spans are based on species of wood, grade, live load, dead load, and deflection criteria.

2308.8.1 Bearing. This section insures that floor joists have adequate bearing surface on their supports. A minimum bearing distance is stipulated for bearing on wood or steel. The 3 inches of bearing required on masonry, which should also apply to bearing on concrete, is to minimize the potential for shear failure of the masonry or concrete. As an exception to the minimum 1 1/2 inches bearing surface on wood, joists are permitted to bear on a ribbon strip nailed to the narrow face of the studs, as long as the ends of the joists are also nailed to the adjoining studs.

2308.8.2 Framing details. The general requirement of this section is that joists be laterally supported by solid blocking at each end and at each support. The blocking is intended to prevent lateral torsional buckling of the joist. The blocking is permitted to be omitted where the ends of the joists are restrained either by nailing or by the use of some other means, such as a joist hanger, to resist buckling.

Wood is comprised of relatively small elongated cells oriented parallel to each other and bound together physically and chemically by lignin. The cells are continuous from end to end of a piece of lumber. When a beam or joist is notched or cut, the cell strands are interrupted. In notched beams, the effective depth is reduced equal to the depth of the notch.

Some designs and installation practices require that limited notching and cutting occur. Notching should be avoided when possible. Holes greater than 1" in diameter bored in beams and joists create the same problems as notches. When necessary, the holes should be located in areas with the least stress concentration, generally along the neutral axis of the joist and within the middle third of the span. Beams subject to high horizontal shear stress (short span/heavy load) should never be bored. Wood members having a thickness of over 4 inches should never be notched, except at the ends of the members.

Joists must be adequately tied together to provide continuity and prevent horizontal separation of the building and must be adequately supported when not bearing on the top of girders.

2308.8.3 Framing around openings. Framing around floor openings, such as, stairwells, requires special attention. The provisions of the section assume that the joists are not able to bear on exterior or interior walls, or beams. Rather, joists which are shortened as a result of the opening are supported by headers, which span between adjacent joists. Headers shorter than 4 feet, e.g., not supporting more two joists at 16" o/c may be single 2X's. Headers more than 4 feet in length must be double 2X or a solid member of equivalent width and depth. Headers more than 6 feet in length must be supported with positive bearing, either bearing on a ledger or supported by a double joist hanger. The floor joists which are interrupted as a result of the opening must be supported if they span more than 12 feet. Otherwise, end nailing in accordance with the fastener schedule is required.

2308.8.4 Supporting bearing partitions. The floor joist spans provided in the tables assume uniform loading conditions and will support only limited concentrated loads. Unless designed by engineering analysis, bearing partitions must be supported by other bearing partitions, beams, or girders. This may be accomplished one way by continuing a bearing partition through a joist space to the lower partition, installing headers between joists which rest on the lower partition, and placing headers on top of flooring which are supported adequately.

A major problem that frequently occurs is the orientation of heavy loads, such as bathtubs, parallel with the floor joists. Additional joists should be installed to support these loads.

Bearing partitions oriented perpendicular to joists cannot be offset from supporting girders, walls, or partitions more than the depth of the joists unless the joists are of sufficient size to carry the additional load.

Although not specifically required, it is typically advantageous to double-up floor joists supporting non-load bearing partitions oriented parallel to the joists or to provide solid blocking between the joists to transfer the wall load to the supporting joists.

2308.8.5 Lateral support. When the depth-to-thickness ratio of joists and rafters exceeds 5:1, as would be the case in members larger than 2x10s, the lateral support required by 2308.8.2 is not sufficient to prevent lateral buckling between supports. Additional resistance is required. Sheathing, sub-flooring, decking, and similar materials attached to each joist or rafter is considered to provide edge restraint.

These requirements are cumulative. The support required by 2308.8.2 applies to all joists. Additionally, members greater than 2x10 must have one edge held in line, and members greater than 2x12 must have one edge held in line as well as a line of bridging at each 8 feet of span (which may be omitted if both edges are held in line).

2308.8.6 Structural floor sheathing. Sub-flooring is considered to be a structural element, whereas underlayment is related to serviceability. Both must comply with the appropriate tables for maximum span referenced in Section 2304.7.1.

2308.8.7 Underfloor ventilation. This reference to 1202.4 is incorrect; the section dealing with underfloor ventilation is actually 1202.3. Enclosed spaces under floors of buildings are referred to as crawl spaces when not designed and constructed as basements. The earth is usually exposed or covered with a vapor retarder. Regardless, there is always the potential for a large amount of moisture vapor from the ground being present. This moisture must be removed to prevent wetting and drying cycles which can cause decay and fungus attack in wood members. Experience has shown that crawl spaces constructed in conformance with 2308 and ventilated to the exterior as required by 1202.3 do not develop decay problems. Access to crawl spaces is required as specified in 1208.1.

It should be recognized that moisture problems may be exaggerated in colder months. Therefore, operable vents should be used with caution. Once insulations in such spaces becomes wet, it seldom dries out, thus negating its performance.

2308.9 Wall framing.

2308.9.1 Size, height and spacing. The specifications in these sections are empirical interpretations of accepted engineering design practices and traditional designs for light wood frame buildings. When stud heights exceed 10 feet or the structure is outside the scope of applicability of the conventional construction requirements, studs must be designed in accordance with accepted engineering practice.

2308.9.2 Framing details. Wood frame exterior walls support all vertical imposed loads and also must act as braced walls to resist lateral loads, such as from wind and earthquakes. Adequately secured and sufficient corner posts are required to assist in this function, in addition to providing a degree of continuity in the exterior walls. Traditionally, three studs were installed. Experience has shown that two studs will adequately perform this function, provided other means are employed to support any interior finish which may be installed. Note that these other means may not be acceptable if they affect the fire resistance or shear resisting capacity of the walls.

2308.9.2.1 Top plates. Double top plates serve three major functions:

1. They overlap at corners and interior wall intersections, thus tying the building together;

2. They serve as beams to support joists and rafters which are not located directly over the studs (See 2308.9.2.2); and

3. They serve as chords for floor and roof diaphragms (See 2305.2).

The tolerance of 1 inch with which the rafters or joists are to be centered over the studs is required to prevent over-stress or excessive deflection in the single top plate. The steel strap provides a minimum level of continuity.

2308.9.2.2 Top plates for studs spaced at 24 inches. Ideally, joists, rafters, or trusses should be located directly over the bearing studs. The empirical provisions of this section allow joists or trusses to bear within 5 inches of the stud below when the joists or trusses are spaced more than 16 inches on center, and the studs are spaced 24 inches on center. This provision assumes double top (bearing) plates which have all joints located over the studs. Additional support is required if the offset is more than 5 inches.

2308.9.2.3 Nonbearing walls and partitions. Nonbearing partitions are not intended to add to the rigidity or structural performance of the building. They are, however, expected to stay in place and have the ability to support finished membranes applied. The code limits stud spacing to 28 inches o.c., but allows the stud to be oriented with the wide dimension parallel to the wall length. Partitions must be able to support the lateral loads to which they are subjected, but not less than 5 psf lateral load, per 1607.13.

Support of the ceiling membranes next to nonbearing partitions requires special consideration. Partitions may be held in place by two floor or ceiling joists or spacers. If a spacer is used, additional support for a ceiling membrane may be obtained by attaching a 1-inch board to the top of the partition. Nonbearing partitions should never be attached rigidly to trussed roofs or floors. Many instances have been cited where such connections have caused partitions to be raised above floor level.

2308.9.2.4 Plates or sills. The single bottom plate serves to anchor the wall to the floor. Studs are attached to the sill by end-nailing or toe-nailing.

2308.9.3 Bracing. This section continues the provisions that were started in 2308.3 for bracing of walls to resist lateral forces. Braced wall panels are portions of walls, as required by Table 2308.9.3(1), composed of the bracing materials discussed below. Portions of braced wall lines are permitted to be offset from each other, and braced wall panels are not required to extend to the end of the braced wall line.

These are the materials that are prescriptively permitted to be used to form the braced wall panels in braced wall lines. The location and minimum acceptable length of material are specified in Table 2308.9.3(1). Note, too, that detailed requirements for various materials—grades, thickness, nailing schedule, stud spacing, and similar requirements—are contained in the tables referenced for each material. Also, see the Commentary for 2303 concerning the minimum standards and quality of these materials

2308.9.3.1 Alternate bracing. This provision allows a minimum 32 inch wall bracing length in lieu of the 48 inch length required elsewhere. This bracing detail allows more flexibility in constructing braced wall panels adjacent to garage door and other similar openings. This detail was developed by APA and is supported in *APA Research Report No. 156.*

For two-story construction, braced wall panels in the first story are required as prescribed by 2308.9.3.1, item 1, except the sheathing is required on both faces of the segment, three anchor bolts are required at panel quarter points, and the tie-down is required to have a capacity of 3000 lbs.

2308.9.4 Cripple walls. Cripple walls (sometimes referred to as foundation stud walls or knee walls) are stud walls usually less than 8 feet in height that rest on the foundation plate and support the first immediate floor above. The minimum stud length of 14 inches is based on the length necessary to properly fasten the studs to the foundation wall plate and the double plate above. Where the studs are less than 14 inches in length, they should be installed with wall plates and with the solid blocking tightly fit between each stud. This blocking performs two purposes: it provides a level uniform bearing surface for the support of the floor above and it transmits lateral forces from the floor to the foundation.

2308.9.4.1 Bracing. When the cripple wall stud height is more than 14 inches, the wall is to be considered as a first-story wall and the bracing requirements of Table 2308.9.3(1) will apply for buildings in lower seismic design categories. In Seismic Design Categories D or E, the increased bracing requirements of Table 2308.12.4 will apply.

2308.9.4.2 Nailing of bracing. As is the case with wall bracing in general, nailing of the specific structural sheathing material is critical in order to insure the anticipated racking resistance of the cripple wall.

2308.9.5 Openings in exterior walls.

2308.9.5.1 Headers. Headers are required to transfer loads that are received from the wall and floor/roofs above. Header spans for exterior bearing walls of one- and two-family dwellings may be sized and supported in accordance with Table 2308.9.5. Headers for other structures must be designed.

Table 2308.9.5, as well as Table 2308.9.6, provides an empirical procedure for determining header sizes in exterior walls. The tables were developed using the following design load criteria:

Roof LL = 20 psf

Roof DL = 10 psf

Ceiling LL = 5 psf

Ceiling DL = 5 psf

Floor LL = 40 psf

Floor DL = 10 psf

Wall DL = 11 psf

The spans were developed by using the given loads and performing moment and deflection calculations to determine the maximum span length for specific size headers shown in the tables. The span length calculations also included a load combination reduction factor. Current ASD design loads do not address load combination reduction factors. The load combination reduction factors were developed in accordance with LRFD load combinations of the smaller of 1.6L + 0.5S or 1.6S + 0.5L where S is the snow load and L is the live load. The appropriate factor is then divided by 1.6 to adjust from LRFD to ASD.

The header span in the tables are determined based on the ground snow load in accordance with Figure 1608.2, the building width, the supporting conditions, and the size of the header to be used. The header sizes must comprise the required lumber sizes shown in the tables, or may be of solid lumber of equivalent size.

2308.9.5.2 Header support. The header studs (jack studs) on which the headers rest should be continuous from the header to the bottom plate (or sill plate). Cutting the header stud to support a sill is not allowed. Headers should be adequately nailed together and to the wall studs. This critical nailing is specified in Table 2304.9.1.

2308.9.6 Openings in interior-bearing partitions. As is required for exterior bearing walls, loads from the framing above must be transferred around openings in interior bearing walls.

! See Commentary, Section 2308.9.5.1.

2308.9.7 Openings in interior-nonbearing partitions. Nonbearing partitions are not intended to add to the rigidity or structural performance of the building. They are, however, expected to stay in place and have the ability to support finished membranes applied.

2308.9.8 Pipes in walls. This section requires that installation of piping in partitions and through floors does not compromise the framing. Rather than cutting joists or leaving partitions improperly supported , planning is needed in order to provide clearance for pipes which extend through floors and adequate support for partitions which contain piping.

2308.9.9 Bridging. Where stud partitions do not have adequate sheathing to restrain the studs laterally in their weaker, or smaller, dimension, stud walls or partitions of such a height that the height-to-least-thickness ratio exceeds 50 are required to have bridging (in this case, solid blocking) cut in between the studs with a minimum thickness of 2 inches and the same width as the studs. Location will vary with the height of the wall, with the blocking installed to reduce the height-to-least-width ratio to less than 50.

2308.9.10 Cutting and notching. Studs should not be cut, notched, or bored when possible to maintain the cross-sectional bearing area. When the damage exceeds that specified in 2308.9.10, the studs should be doubled or otherwise reinforced to provide the required strength.

2308.9.11 Bored holes. Due to the redundancy of this type of construction, limited notching and hole boring are allowed. See also Commentary, Section 2308.9.10.

2308.10 Roof and ceiling framing. The code intends that the framing details for roofs in 2308.10 apply only to roofs having a minimum slope of 3 vertical to 12 horizontal. For roofs flatter than 3:12, the side thrust becomes so large as to exceed the capabilities of conventional construction. In that situation, members that support rafters must be designed as beams and must be supported by exterior or interior bearing walls.

2308.10.1 Wind uplift. The subject of resisting wind uplift on roofs in areas that fall within the limitations of conventional construction and are not considered to be high-wind areas was not addressed in any of the previous building codes. However, in developing the provisions of 2308, it was believed that there was justification for addressing this situation.

This section requires compliance with both Table 2304.9.1, which is the fastening schedule, and with Table 2308.10.1, which specifies the minimum uplift resistance to be provided between the roof framing and the wall below. Although the nail connections required by Table 2304.9.1 could conceivably provide enough uplift resistance to satisfy Table 2308.10.1 for short roof spans in the lower wind speed areas, in almost all instances, additional uplift resistance is required in the form of approved connectors.

For basic wind speeds of less than 85 miles per hour, ties are not required. When ties are required by the table, a tie is required on every rafter or truss to the stud below, assuming the roof framing is spaced 24 inches on center, in accordance with footnote b.

In addition, the other footnotes to Table 2308.10.1 may modify the tabular requirements. Also note that the text of this section requires that in addition to tying the roof framing to the wall below, a load path must then be established to the foundation. Footnote “f” modifies the load requirements for the connections which establish the load path.

2308.10.2 Ceiling joist spans. See commentary, Section 2308.10.3.

2308.10.3 Rafter spans. The spans shown in these tables were derived from the *AF&PA Span Tables for Joists and Rafters*. For simplicity, spans of only the most common species, or types, and grades of wood are shown. When other species or grades of wood are used, the AF&PA tables should be consulted to determine the proper span. Additionally, span tables published by the Southern Forest Products Association, the Western Wood Products Association, and the Canadian Wood Council can also be consulted. The spans published in those tables were derived in the same manner as those published in the AF&PA tables.

Spans are based on species of wood, grade, live load, dead load, and deflection criteria.

2308.10.4 Ceiling joist and rafter framing. Traditional practice is to provide a ridgeboard between opposite rafters as a nailing base and to provide a full bearing for the rafter. Rafters must be placed directly opposite each other, and the ridgeboard must have a depth equal to or greater than the cut end of the rafter. The rafter ends must be flush against the ridgeboard to avoid excessive horizontal shear in the rafters.

2308.10.4.1 Ceiling joist and rafter connections.

Sloped rafters will exert lateral loads on the walls of buildings. Therefore, unless the ridge is otherwise supported, as in post and beam framing, the building must provide horizontal ties to prevent spreading of walls. When ceiling joists are parallel to the rafters and adequately connected to the top plate and rafters, the continuous tile requirements of this section are met.

Ceiling joists are sometimes raised above the wall support of the rafters to provide additional ceiling height. Only when such design is accompanied by engineering analysis or tests should this be allowed.

Structural problems are often found in houses having cathedral ceilings. Since no joists are present to tie the walls together across the building, properly designed beams and posts must be used to support the rafters to satisfy code requirements.

Wind blowing across the roof develops negative pressures on the rafters, causing uplift. Rafter ties are intended to prevent separation of the rafters at the ridge under such uplift conditions. Rafter ties must never be considered as a means of reducing the span of rafters.

2308.10.4.2 Notches and holes. Wood is comprised of relatively small elongated cells oriented parallel to each other and bound together physically and chemically by lignin. The cells are continuous from end to end of a piece of lumber. When a rafter is notched or cut, the cell strands are interrupted. In notched rafters, the effective depth is reduced equal to the depth of the notch.

Some designs and installation practices require that limited notching and cutting occur. Notching should be avoided when possible. Holes bored in rafters create the same problems as notches. When necessary, the holes should be located in areas with the least stress concentration, generally along the neutral axis of the rafter. Beams subject to high horizontal shear stress (short span/heavy load) should never be cut. Wood members having a thickness of over 4 inches should never be notched, except at the ends of the members.

2308.10.4.3 Framing around openings. See Commentary, Section 2308.8.3.

2308.10.5 Purlins. This section permits the use of purlins and struts to reduce the span of rafters. Where the roof slope is less than 3 vertical to 12 horizontal, the code requires that members supporting rafters such as ridge boards, for example, be designed as beams. However, struts can be installed from a load bearing partition up to the ridge board to reduce the span, in such a way that the vertical load path is complete.

2308.10.6 Blocking. In the unusual situation in which the ends of rafters are not provided with built-in lateral support, the ends must be braced specifically to resist the tendency to twist or lay over.

2308.10.7 Wood trusses.

2308.10.7.1 Design. Trusses are to be designed in accordance with Chapter 16 and are to comply with 2303.4 (see the commentary on that section). While trusses used in most light-frame construction have members connected with metal connector plates, this section recognizes that other methods exist to connect truss members.

2308.10.7.2 Bracing. To prevent collapse during construction, and until permanent bracing is installed, trusses should be adequately braced temporarily. When final bracing is in place, trusses should be positioned as vertical as possible: tilted trusses will not perform as designed.

2308.10.7.3 Alterations to trusses. Trusses are engineered products, and any alteration to specific elements may well prevent the truss from performing as intended. Also, trusses are designed to resist specific loads; changing the loading on the truss or on any of its members should not be done without approval of a registered design professional.

2308.10.8 Roof sheathing. See commentary, Section 2304.7.2.

2308.10.8.1 Joints. When board sheathing is used, the ends of the boards must be located over the joists or rafters. Such support is not required when endmatched tongue-and-groove lumber is used or when the ends are otherwise prevented from moving relative to each other.

2308.10.9 Roof planking. Lumber planking on roofs must conform to the requirements of Section 2304.7.2, and Table 2304.7(1) for typical lumber roof sheathing. This section provides an alternative using 2-inch tongue-and-groove planking. Table 2308.10.9 gives allowable span (spacing of roof supports) based on the live load and deflection limits (from the code) and the design values for the used.

2308.10.10 Attic ventilation. Large amounts of water vapor migrate by movement of air carrying water or by diffusion through the building envelope materials because of a vapor pressure difference. The sources of water vapor include cooking, laundering, bathing, and breathing and perspiration of humans. These can account for an average daily production of 25 lbs. of water vapor in a typical family of four dwelling. The average can be much higher where such appliances as humidifiers, washers, and dryers are used.

As the vapor moves into the attic, it may reach its dew point, thus condensing on wood roof components. This wetting and drying action will cause rotting and decay. To avoid this, the attic must be ventilated to prevent the accumulation of water on building components. The installation of a vapor retarder acts to significantly reduce the passage of moisture to the attic. An effective vapor retarder allows a decrease in ventilation. Vapor retarders are ineffective when openings in the membrane are allowed where moisture can be carried by air into the attic. This is the reason exhaust fans must terminate outdoors and not in the attic. Care should be exercised to assure that attic vent openings remain unobstructed.

Attic ventilation is also required for the removal of excess heat. Access to attic spaces is required by 1208.2.

2308.11 Additional requirements for conventional construction in Seismic Design Category B or C.

2308.11.1 Number of stories. This section limits conventional construction to two stories in height in Seismic Design Category (SDC) C.

When the Conventional Construction provisions are used for one and two-family dwellings in SDC C, the allowable number of stories is increased to three stories. These buildings have performed well in recent earthquakes and the limit to two stories is very restrictive.

2308.11.2 Concrete or masonry. Masonry veneer used above the basement places lateral loads from seismic events on the exterior walls which are not considered conventional. An exception has been added which allows masonry veneer to go two stories in height in SDC B provided the structural use panel wall bracing is 1.5 times the required width as determined in Table 2308.9.3(1). Additionally, a separate exception also allows masonry veneer to go above the basement level in the lower seismic areas.

2308.11.3 Framing and connection details.

2308.11.3.1 Anchorage. Braced wall lines must be anchored to the foundation so that they will not overturn because of a moment created by the lateral loads. Anchorage for overturning will nearly always be more critical for the individual shear panel than for the entire wall.

2308.11.3.2 Stepped footings. The primary objectives of footing design are to provide a level surface for construction of the foundation wall, to provide adequate transfer and distribution of the building loads to the underlying soil, to provide adequate strength to prevent differential settlement of the building, and to provide adequate anchorage or mass to resist potential uplift and overturning forces from lateral loads placed on the structure. The most common footing type in residential construction is a continuous concrete spread footing. These concrete footings are recognized in prescriptive footing size tables for most typical conditions. In contrast, when special conditions present themselves such as stepped footings which might be required in steeply sloped sites, special consideration must be given.

2308.11.3.3 Openings in horizontal diaphragms. Horizontal diaphragms are floor and roof assemblies that are usually clad with structural wood sheathing panels such as plywood or OSB. Though more complicated and difficult to visualize, the lateral forces which are applied to a building from wind or seismic events follow a load path that distributes and transfers shear and overturning forces from the lateral loads. When openings are punched into the diaphragm, it complicates a problem of how to transfer the lateral loads around the opening. Another concern is the stiffness of the diaphragm. These provisions are a prescriptive solution for openings not greater than 4 foot in dimension and provide a general means for providing a load path in these specific cases in lieu of an engineered design.

2308.12 Additional requirements for conventional construction in Seismic Design Category D or E. Conventional Construction is a type of construction which has been used successfully for many years and relies on standard practice as governed by prescriptive building code requirements. In conditions where the lateral loading on the building is greater, such as in the higher seismic areas of the country, Seismic Design Categories D and E, additional prescriptive methods or limitations are considered necessary.

2308.12.1 Number of stories.

2308.12.2 Concrete or masonry.

2308.12.3 Braced wall line spacing. In order to keep the existing bracing element capacities which have been used in conventional construction for years, braced walls were introduced. They limit the lateral forces supported by the elements by limiting the wind and seismic tributary area and the building area. This concept introduced the mandating the maximum spacing between lines of bracing elements and limiting offsets within a line. A series of braced wall panels comprise a braced wall line. A two dimensional grid of interior and exterior braced wall lines break up the building into a series of boxes. The size of the box is either 25 or 34 feet, depending on seismic zone and wind speed. The dimension of 25 feet between braced wall lines comes from the exceptions to the California Architects and Engineers Acts that were in affect until several years ago. The dimension also is related to the maximum framing spans which are included in other sections of this chapter.

2308.12.4 Braced wall line sheathing. Braced wall lines are required to be braced in accordance with one of the methods specified in Table *2308.12.4.* All vertical joints of the panel are required to occur over studs. Horizontal joints are required to occur over blocking equal in size to the studding unless waived by the installation requirements for the specific sheathing materials. A collector or drag strut, which is usually a system of members in light frame construction, collects and transfers loads by tension or compression to the shear resisting segments of a wall line. In a typical home, special design of chord members may involve some modest detailing of splices at the diaphragm boundry. Compressive forces are rarely a concern when at least a double top plate is used as a collector, particularly when the collector is braced against lateral buckling by attachment to other construction. Therefore, it is typical practice to design the collector and any splices in the collector, to resist a tension force as calculated by general engineering procedures.

2308.12.5 Attachment of sheathing.

2308.12.6 Irregular structures. Irregular structures are those which require engineered design in Seismic Design Category D or E because of their unusual shape or because of discontinuities in the lateral force resisting system. These conditions produce torsional response or result in forces considered too high to be addressed prescriptively. When a structure falls within the description of irregular, it is required that either the entire structure or the non-conventional portions be engineered. The design professional is left to judge the extent of the portion to be designed. This often involves design of the nonconforming element, force transfer into the element, and a load path from the element to the foundation. A nonconforming portion will sometimes have enough of an impact on the behavior of a structure to warrant that the entire lateral-force-resisting system receive an engineered design.

1. This limit applies when braced wall panels are offset out-of-plane from floor to floor. In-plane offsets are discussed in another item. Ideally, braced wall panels would always stack above each other from floor to floor with the length stepping down at upper floors as less length of bracing is required. Because cantilevers and set backs are very often incorporated into structures, the exception offers rules by which limited cantilevers and setbacks can be considered conventional.

2. This limitation applies to open-front structures or portions of structures. The conventional construction bracing concept is based on using braced wall lines to divide a structure up into a series of boxes of limited dimension, with the seismic force to each box being limited by the size. The intent is that each box be supported by braced wall lines on all four sides, limiting the amount of torsion that can occur. The exception, which permits portions of roofs or floors to extend past the braced wall line, is intended to permit construction such as porch roofs and bay windows. Walls with no lateral resistance are allowed in areas where braced walls are prohibited.

3. This limitation applies when braced wall panels are offset in-plane. Ends of braced wall panels supported on window or door headers can be calculated to transfer large vertical reactions to headers that may not be of adequate size to resist these reactions. The exception permits a 1 foot extension of the braced wall panel over a 4 by 12 (actual 3 1/2 by 11 1/4 in.) header on the basis that the vertical reaction is within a 45 degree line of the header support and therefore will not result in critical shear or flexure. All other header conditions require an engineered design. Walls with no lateral resistance are allowed in areas where braced walls are prohibited.

4. This limitation results from observation of damage that is somewhat unique to split-level wood

frame construction. If floors on either side of an offset move in opposite directions due to earthquake or wind loading, the short bearing wall in the middle becomes unstable and vertical support for the upper joists can be lost, resulting in a collapse. If the vertical offset is limited to a dimension equal to or less than the joist depth, then a simple strap tie directly connecting joists on different levels can be provided, and the irregularity eliminated.

5. This limitation applies to non-perpendicular braced wall lines. When braced wall lines are not perpendicular to each other, further evaluation is needed to determine force distributions and required bracing.

6. This limitation attempts to place a practical limit on openings in floors and roofs. Because stair openings are essential to residential construction and have long been used without any report of life-safety hazards resulting, these are felt to be acceptable conventional construction.

2308.12.7 Exit facilities. Because of their importance, exit facilities in buildings in Seismic Design Category D or E must be anchored to the structure in such a manner as to resist the lateral forces.

2308.12.8 Steel plate washers. Walls subjected to the lateral loads anticipated in Seismic Design Category D and E, particularly tall walls, will tend to try to tip over. To resist this overturning, the code increases the bearing area on the sill plate at each bolt by stipulating a minimum size of plate washer which spreads the load over a wider area.

2308.12.9 Anchorage in Seismic Design Category E. Lateral seismic loads on buildings cause the bottom of the walls to slide, and the tendency of sill plate bolts is to rip through the wood. Dowel-type connectors (bolts, nails, screws, and pins) rely on metal-to-wood bearing for transfer of lateral loads. One of the factors that determines the dowel bearing strength is the diameter of the bolt. By increasing the minimum diameter of the bolts from 1/2 inch as specified in 2308.6, the bearing surface area of the bolt is increased to provide a connection to resist the increased seismic forces of Seismic Design Category E.