

Chapter 23: Wood

General Comments

This chapter contains information required to design and construct buildings or structures that 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). Chapter 23 includes elements of all three previous regional model codes—the *BOCA® National Building Code* (BNBC), the *Standard Building Code* (SBC) and the *Uniform Building Code®* (UBC™). It most closely follows the format of the UBC.

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 referenced design methods to provide a minimum level of safety. This chapter also contains requirements both for the use of products in conjunction with wood and wood-based structural elements, and for prevention of decay.

In general, only Type III, IV or V buildings 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 construction (specified in Chapter 6) can be Type III, IV or V. Another basis for referencing Chapter 23 is when wood elements are used in Type I or II structures as permitted in Section 603. This chapter gives information on the application of fire-retardant-treated wood, interior wood elements and trim in these structures. All structural criteria for application of referenced standards and procedures included in Chapter 23 are based on the loading requirements of Chapter 16 or on historical performance.

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.

Section 2301 identifies three methods of design. Compliance with one or more is required.

Section 2302 contains a list of the most commonly

used terms to describe wood and wood-based products. Some engineering terms are also included. Refer to Chapter 2 for the definitions of the terms listed.

Section 2303 provides reference to manufacturing standards, necessary specification criteria and use and application provisions.

Section 2304 contains general provisions for the proper design and construction of all wood structures and the use of all wood products. Note that the general provisions in Section 2304 apply to all design methods. This section also includes the typical fastening schedule, which is the minimum requirement for fastening various wood members.

Section 2305 references the American Wood Council's (AWC) *Special Design Provisions for Wind and Seismic* for design of lateral-force-resisting systems. It also contains provisions not found in the standard, such as design values for staples. Whether the structure is engineered using ASD or LRFD, the provisions of this section apply to the design of the lateral-force-resisting system.

Section 2306 contains provisions for the design of structures using ASD and references applicable standards. The two primary design standards are the AWC *National Design Specification for Wood Construction* (NDS) and SDPWS. 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. As the section title implies, the provisions of this section only apply to ASD and are not appropriate for LRFD.

Because the ANSI/AWC NDS and SDPWS are dual format standards permitting both ASD and LRFD design procedures, Section 2307 also references these consensus standards for the design of structures using the LRFD methodology.

Although fairly limited in application, Section 2308 contains the prescriptive provisions for conventional construction that may be used to construct certain wood-frame structures that conform to the restrictions and limitations. Limitations on the use of the conventional construction provisions in this section are provided in Section 2308.2 for a quick determination. Note that structures of otherwise conventional construction are allowed to contain portions or elements that are designed by the engineering provisions of Chapter 23 (see commentary, Sections 2308.1.1 and 2308.8).

Section 2309 permits designs utilizing the AWC *Wood Frame Construction Manual* (WFCM) for buildings that fit within the WFCM's applicability limits for building size, configuration and loads as set out in that standard.

Purpose

This chapter provides minimum guidance for the design of buildings and structures that use wood and wood-based products in their framing and fabrication. Altern-

tive methods and materials can be used where justified by engineering analysis and testing. In all cases, the provisions of Section 2304 apply to all elements of wood-frame construction.

SECTION 2301 GENERAL

2301.1 Scope. The provisions of this chapter shall govern the materials, design, construction and quality of wood members and their fasteners.

❖ Section 2301 includes specifications for use of and standards for production of wood and wood-based products such as boards, dimensional lumber and engineered wood products, such as I-joists, glued-laminated timber, structural panels, trusses, particleboard, fiberboard and hardboard. Also included are criteria and specifications for the 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.

The scope of this chapter is established in Section 2301.1, and broadly encompasses wood products and the limitations placed on them and their various applications within the code.

2301.2 General design requirements. The design of structural elements or systems, constructed partially or wholly of wood or wood-based products, shall be in accordance with one of the following methods:

1. *Allowable stress design* in accordance with Sections 2304, 2305 and 2306.
 2. *Load and resistance factor design* in accordance with Sections 2304, 2305 and 2307.
 3. *Conventional light-frame construction* in accordance with Sections 2304 and 2308.
 4. AWC WFCM in accordance with Section 2309.
 5. The design and construction of log structures in accordance with the provisions of ICC 400.
- ❖ This chapter includes three methods of designing with wood or wood-based products. This section limits designs to one of these three methods unless an alternative 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.

2301.3 Nominal sizes. For the purposes of this chapter, where dimensions of lumber are specified, they shall be

deemed to be nominal dimensions unless specifically designated as actual dimensions (see Section 2304.2).

❖ The use of nominal sizes for lumber is part of the traditional nomenclature for grading and identification of manufactured pieces. “Nominal” simply refers to the short-hand term such as “2 × 4” when the actual piece of lumber has a real dimension of 1½ inches by 3½ inches (38 mm by 89 mm)—not 2 inches by 4 inches (51 mm by 102 mm). Section 2304.2, however, prescribes that in determining the required size for design purposes, computations must be based on the actual size, rather than the nominal size, of the lumber.

SECTION 2302 DEFINITIONS

2302.1 Definitions. The following terms are defined in Chapter 2:

ACCREDITATION BODY.

BRACED WALL LINE.

BRACED WALL PANEL.

COLLECTOR.

CONVENTIONAL LIGHT-FRAME CONSTRUCTION.

CRIPPLE WALL.

CROSS-LAMINATED TIMBER.

DIAPHRAGM, UNBLOCKED.

DRAG STRUT.

ENGINEERED WOOD RIM BOARD.

FIBERBOARD.

GABLE.

GRADE (LUMBER).

HARDBOARD.

NAILING, BOUNDARY.

NAILING, EDGE.

NAILING, FIELD.

NOMINAL SIZE (LUMBER).

PARTICLEBOARD.

PERFORMANCE CATEGORY.

**PREFABRICATED WOOD I-JOIST.
SHEAR WALL.**

Shear wall, perforated.

Shear wall segment, perforated.

STRUCTURAL COMPOSITE LUMBER.

Laminated strand lumber (LSL).

Laminated veneer lumber (LVL).

Oriented strand lumber (OSL).

Parallel strand lumber (PSL).

STRUCTURAL GLUED-LAMINATED TIMBER.

TIE-DOWN (HOLD-DOWN).

TREATED WOOD.

Fire-retardant-treated wood.

Preservative-treated wood.

WOOD SHEAR PANEL.

WOOD STRUCTURAL PANEL.

Composite panels.

Oriented strand board (OSB).

Plywood.

- ❖ Definitions facilitate the understanding of code provisions and minimize potential confusion. To that end, this section lists definitions of terms associated with wood construction. Note that these definitions are found in Chapter 2. The use and application of defined terms, as well as undefined terms, are set forth in Section 201. In addition to the terms listed in this chapter, other notations and definitions related to wood construction can be found in the various referenced standards, such as the ANSI/AWC NDS and SDPWS.

**SECTION 2303
MINIMUM STANDARDS AND QUALITY**

2303.1 General. Structural sawn lumber; end-jointed lumber; prefabricated wood I-joists; structural glued-laminated timber; wood structural panels; fiberboard sheathing (when used structurally); hardboard siding (when used structurally); particleboard; *preservative-treated wood*; structural log members; structural composite lumber; round timber poles and piles; *fire-retardant-treated wood*; hardwood plywood; wood trusses; joist hangers; nails; and staples shall conform to the applicable provisions of this section.

- ❖ When the components of a wood structure comply with the various standards listed in Section 2303, a building or structure is deemed to comply with the minimum standards of quality prescribed by the code. When combined with the construction requirements of Section 2304 and the design standards referenced

in Sections 2305 and 2306, these standards contain most of the information needed to adequately design a structure. For engineered structures, it is necessary for the designer to have a working knowledge of engineering principles and experience with construction to properly interpret the recommendations and meet the provisions of other applicable sections of the code. For conventional wood-frame structures, the standards in Section 2303 combined with the construction requirements of Section 2304 and the prescriptive construction provisions in Section 2308 can be used to construct code-complying wood-frame buildings.

Section 2303.1 lists the various materials that have production and quality control standards. The section covers minimum standards of quality for sawn lumber; end-jointed lumber; wood I-joists; glued-laminated timber; wood structural panels; fiberboard sheathing; hardboard siding; particleboard; preservative-treated wood; log members; composite lumber; round timber poles and piles; fire-retardant-treated wood; hardwood plywood; wood trusses; joist hangers; and nails and staples. The use of these standards is fundamental for manufacturers in producing products and maintaining quality control procedures. Designers, owners and building officials must understand these standards and the methods prescribed in them to be able to properly identify products that have been produced in accordance with their criteria. Without the knowledge that the various products and components meet the applicable standards, there is little assurance that a safe and efficient building or structure will be constructed.

2303.1.1 Sawn lumber. Sawn lumber used for load-supporting purposes, including end-jointed or edge-glued lumber, machine stress-rated or machine-evaluated lumber, shall be identified by the grade *mark* of a lumber grading or inspection agency that has been approved by an accreditation body that complies with DOC PS 20 or equivalent. Grading practices and identification shall comply with rules published by an agency approved in accordance with the procedures of DOC PS 20 or equivalent procedures.

- ❖ 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 that vary from piece to piece, such as knots, slope of grain, checks, etc. Without adequate identification, it would be impossible to verify that the proper material is being used in the field. 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. Commentary Figure 2303.1.1 illustrates typical grade mark labels.

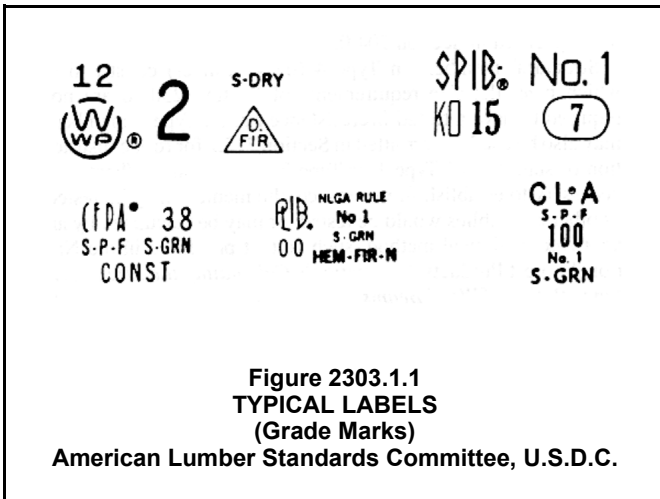


Figure 2303.1.1
TYPICAL LABELS
(Grade Marks)

American Lumber Standards Committee, U.S.D.C.

2303.1.1.1 Certificate of inspection. In lieu of a grade mark on the material, a certificate of inspection as to species and grade issued by a lumber grading or inspection agency meeting the requirements of this section is permitted to be accepted for precut, remanufactured or rough-sawn lumber and for sizes larger than 3 inches (76 mm) nominal thickness.

❖ Certification is an acceptable alternative to a grade mark from both United States and Canadian grading agencies. Grading agencies are certified by the American Lumber Standards Committee (ALSC).

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 include those applicable to the weaker species in the group.

The code also allows certain types of structural lumber to have a certificate of inspection instead of a grade mark. A certificate of inspection is acceptable for precut, remanufactured or rough-sawn lumber and for sizes larger than 3 inches (76 mm) nominal in thickness. It is 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 its size, number and location of strength-reducing characteristics; therefore, one log may produce lumber of two or more different grades.

It is also industry practice not to label lumber having a nominal thickness larger than 3 inches (76 mm), 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.

If defects exceeding those permitted for the allegedly installed grade are visible, then a grader would

be able to determine that the wood is definitely not of a suitable grade. To determine if the wood in question is definitely of a suitable grade, the grader must inspect all four faces of the piece. This cannot happen once the lumber is installed in the building, as other components of the building will be covering up some of the faces of the pieces.

2303.1.1.2 End-jointed lumber. *Approved* end-jointed lumber is permitted to be used interchangeably with solid-sawn members of the same species and grade. End-jointed lumber used in an assembly required to have a fire-resistance rating shall have the designation “Heat Resistant Adhesive” or “HRA” included in its grade mark.

❖ End-jointed or edge-glued lumber is acceptable when identified by an appropriate grade mark. Section 4.1.6 of the ANSI/AWC NDS permits the use of such lumber for light framing, studs, joists, planks and decking. Where finger-jointed lumber is marked “Stud Use Only,” then it is limited to applications where bending or tension stresses are subjected to short-term loading only. Where end-jointed lumber is used in fire-resistant-rated assemblies, it must be joined with heat-resistant adhesive and must be indicated on the grade stamp.

2303.1.2 Prefabricated wood I-joists. Structural capacities and design provisions for prefabricated wood I-joists shall be established and monitored in accordance with ASTM D5055.

❖ 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 structural capacity. Wood I-joists are 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 (see definition of “Prefabricated wood I-joist” in Section 202). 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 address 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. Glued-laminated timbers shall be manufactured and identified as required in ANSI/AITC A 190.1 and ASTM D3737.

❖ Glued-laminated timbers are required by this section to be manufactured following ANSI/AITC 190.1 and ASTM D3737 for procedures to establish allowable structural properties. Knowing the standards these products must meet makes it easier to determine that the product found in the field will meet the design requirements.

2303.1.4 Structural glued cross-laminated timber. Cross-laminated timbers shall be manufactured and identified in accordance with ANSI/APA PRG 320.

- ❖ Cross-laminated timber was first developed in Europe nearly 20 years ago, where it has been used extensively. As a new product in North America, ANSI/APA PRG 320 provides a consensus manufacturing standard for cross-laminated timber.

2303.1.5 Wood structural panels. Wood structural panels, when used structurally (including those used for siding, roof and wall sheathing, subflooring, diaphragms and built-up members), shall conform to the requirements for their type in DOC PS 1, DOC PS 2 or ANSI/APA PRP 210. Each panel or member shall be identified for grade, bond classification, and Performance Category by the trademarks of an *approved* testing and grading agency. The Performance Category value shall be used as the “nominal panel thickness” or “panel thickness” whenever referenced in this code. Wood structural panel components shall be designed and fabricated in accordance with the applicable standards listed in Section 2306.1 and identified by the trademarks of an *approved* testing and inspection agency indicating conformance to the applicable standard. In addition, wood structural panels when permanently exposed in outdoor applications shall be of Exterior type, except that wood structural panel roof sheathing exposed to the outdoors on the underside is permitted to be Exposure 1 type.

- ❖ “Wood structural panels” is a collective term referring to plywood, oriented strand board (OSB) and other composite panels of wood-based materials (see definition of “Wood structural panel” in Chapter 2). As noted in this section, wood structural panels must conform to the specific requirements of Department of Commerce (DOC) PS 1, PS 2 or ANSI/APA PRP 210. An American National Standards Institute (ANSI) standard for engineered wood panel siding, ANSI/APA PRP-210, *Standard for Performance-Rated Engineered Wood Siding*, was included in the 2012 *International Building Code*® (IBC®) and *International Residential Code*® (IRC®). The standard was developed by American Plywood Association (APA) under the ANSI consensus process based on APA’s PRP-108, *Performance Standards and Policies for Structural-Use Panels*. ANSI/APA PRP-210 provides requirements and test methods for qualification and quality assurance for performance-rated engineered wood siding intended for use in construction applications as exterior siding.

Identification of grade for plywood includes N, A, B, C Plugged, C and D (from no knots or patches to large knots and knotholes).

Plywood is manufactured with an odd number of layers that have their grain direction placed perpendicular to each other and are bonded together with a strong adhesive. Each individual layer may consist of an assembly of several different plies laminated together with their grains running in the same direction. Alternating the grain direction in successive lay-

ers gives a plywood panel dimensional stability across its width. Stamped on top of most panels is a span rating that indicates the maximum roof and floor joist spacings that can be accommodated. Additionally, an exposure rating is assigned as Exterior (designed for applications subject to permanent exposure to the weather or moisture), Exposure 1 (designed for applications where long construction delays may be expected prior to providing protection against moisture or weather extremes) or Exposure 2 (intended solely for protected construction applications where only moderate delays in providing protection from moisture are expected).

APA-rated Stud-I-floor panels are commonly used for thicker sheathing applications where added stiffness is desired. This type of panel has a single span rating, indicating that it is specifically engineered for floors, as the name would suggest. Adjoining panel edges may be blocked or may be ordered as tongue-and-groove, which provides added stability in an unblocked diaphragm. If a diaphragm has the necessary load capacity without the addition of blocking at all panel edges, such a specification can lower installation costs and decrease framing mistakes.

2303.1.6 Fiberboard. Fiberboard for its various uses shall conform to ASTM C208. Fiberboard sheathing, when used structurally, shall be identified by an *approved* agency as conforming to ASTM C208.

- ❖ All fiberboard must meet the requirements of ASTM C208, as well as being verminproof, resistant to rot-producing fungi and water repellent. This standard gives physical requirements for construction grades of fiberboard, including sheathing grade and roof-insulating grade. The sheathing grade of fiberboard is further broken down into regular and intermediate densities.

2303.1.6.1 Jointing. To ensure tight-fitting assemblies, edges shall be manufactured with square, shiplapped, beveled, tongue-and-groove or U-shaped joints.

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

2303.1.6.2 Roof insulation. Where used as roof insulation in all types of construction, fiberboard shall be protected with an *approved* roof covering.

- ❖ 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 delamination and to avoid decay and destruction of the glue bond by moisture.

2303.1.6.3 Wall insulation. Where installed and fireblocked to comply with Chapter 7, fiberboards are permitted as wall insulation in all types of construction. In fire walls and fire barriers, unless treated to comply with Section 803.1 for Class A materials, the boards shall be cemented directly to the concrete, masonry or other noncombustible base and shall

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be protected with an *approved* noncombustible veneer anchored to the base without intervening airspaces.

- ❖ Fiberboard is permitted without any fire-resistance treatment in the walls of all types of construction (see Section 603.1). When used in fire walls and fire barrier walls, fiberboard must be either treated to comply with Class A flame spread or adhered directly to a noncombustible base and protected by a tight-fitting, noncombustible veneer that is fastened through the fiberboard to the base. This is intended to prevent the fiberboard from contributing to the spread of fire.

2303.1.6.3.1 Protection. Fiberboard wall insulation applied on the exterior of foundation walls shall be protected below ground level with a bituminous coating.

- ❖ 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 has the risk of being damaged by a lawn mower; rocks or soil kicked up against it; water from a garden hose; rainwater splash back; etc. Protection is required for all fiberboard insulation on the exterior face of foundation walls.

2303.1.7 Hardboard. Hardboard siding used structurally shall be identified by an *approved agency* conforming to CPA/ANSI A135.6. Hardboard underlayment shall meet the strength requirements of $\frac{7}{32}$ -inch (5.6 mm) or $\frac{1}{4}$ -inch (6.4 mm) service class hardboard planed or sanded on one side to a uniform thickness of not less than 0.200 inch (5.1 mm). Prefinished hardboard paneling shall meet the requirements of CPA/ANSI A135.5. Other basic hardboard products shall meet the requirements of CPA/ANSI A135.4. Hardboard products shall be installed in accordance with manufacturer's recommendations.

- ❖ Hardboard siding that is to be used structurally must be manufactured in accordance with CPA/ANSI A135.6 and 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 lignocellulosic fibers. There are five classes based on strength values. Underlayments are limited to $\frac{7}{32}$ -inch (5.6 mm) or $\frac{1}{4}$ -inch (6.4 mm) service class.

Prefinished hardboard is required to be manufactured to the CPA/ANSI A135.5 standard, and 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.

2303.1.8 Particleboard. Particleboard shall conform to ANSI A208.1. Particleboard shall be identified by the *grade mark* or certificate of inspection issued by an *approved agency*. Particleboard shall not be utilized for applications

other than indicated in this section unless the particleboard complies with the provisions of Section 2306.3.

- ❖ Sponsored by the Composite Panel Association (CPA), ANSI A208.1 is the basic specification for the manufacture of particleboard, which establishes a system of marks for the boards' grade, density, and strength.

Particleboard used in construction is medium density and is first designated by an "M." The second digit or letter in the designation is related to grade. The designations range from 1 to 3, with higher designations being 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 part of the grade designation indicates that the particleboard has a special characteristic. The grades of particleboard specified in Table 2306.5, M-S and M-2 "Exterior Glue," are manufactured with exterior glue to increase their durability characteristics.

While ANSI A208.1 has provisions for Grade M-3 particleboard, panels that meet the requirements of this higher grade are more commonly evaluated and used as wood structural panels, commonly referred to as oriented strand board, in accordance with DOC PS-2. Therefore, Grade M-3 material is not addressed in Table 2306.5.

2303.1.8.1 Floor underlayment. Particleboard floor underlayment shall conform to Type PBU of ANSI A208.1. Type PBU underlayment shall not be less than $\frac{1}{4}$ -inch (6.4 mm) thick and shall be installed in accordance with the instructions of the Composite Panel Association.

- ❖ Although similar 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 those 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 by ANSI A208.1 for Grade "PBU" floor underlayment.

Particleboard underlayment is often applied over a structural subfloor to provide a smooth surface for resilient-finish or textile floor coverings. The minimum $\frac{1}{4}$ -inch (6.4 mm) thickness is applicable over panel-type subflooring. Particleboard underlayment installed over board or deck subflooring that has multiple joints should have a thickness of $\frac{3}{8}$ inch (9.5 mm). Joints in the underlayment should not be over joints in the subflooring.

All particleboard underlayment with thicknesses of $\frac{1}{4}$ through $\frac{3}{4}$ inch (6.4 through 19.1 mm) should be attached with a minimum of 6d annular threaded nails