Welcome to eCourse MAT 100: The Basics of Wood Frame Construction.
MAT 100: Learning Outcomes

By the end of this complete modular eCourse, you will be knowledgeable of:

1. IBC Chapter 23 format; What is conventional construction?
2. Growth characteristics of wood; grade marks; protection against termites & decay

MAT 100 is a complete eCourse composed of MAT 101 through MAT 110 in one comprehensive program for building officials on wood frame construction basics. In each module, learning outcomes will be further refined respectively. MAT 100 learning outcomes (see slide).
MAT100: Learning Outcomes

3. Floor, roof/ceiling, wall framing
4. Wall bracing, introduction to *Wood Frame Construction Manual*
5. Fireblocking & draftstopping

Refined learning outcomes will be itemized within each module.

MAT 100 learning outcomes continued (see slide).
Let’s start at the beginning …
What do suppose was the first building code?
What Was the First Building Code?

Would you guess the 1927 edition of the *Uniform Building Code*?
Perhaps you would guess the Laws of Hammurabi. Hammurabi’s code regulated building construction in the Babylonian Empire.
Hammurabi’s Code

228 – If the builder builds a house for a man and completes it, that man shall pay him two shekels of silver per sar (approximately 12 sf) of house as his wage.

Hammurabi’s Code was very prescriptive (see slide).
Hammurabi’s Code

229 – If a builder has built a house for a man and his work is not strong, and if the house he has built falls in and kills the householder, that builder shall be slain.

But, Hammurabi’s Code was also performance-based as evidence by rule 229 (see slide). You might say this is the ultimate performance-based code.
Rule 230 – If a child of the householder is killed, the child of the builder shall be slain.
Rule 231 – If the slave of the householder be killed, he shall give slave for slave to the householder.
232 – If goods have been destroyed, he shall replace all that has been destroyed; and because the house was not made strong, and it has fallen in, he shall restore the fallen house out of his own material.

Rule 232 – If goods have been destroyed, he shall replace all that has been destroyed; and because the house was not made strong, and it has fallen in, he shall restore the fallen house out of his own material.
233 – If a builder has built a house for a man, and his work is not done properly and a wall shifts, then that builder shall make that wall good with his own silver.
We’ve come a long way in a few thousand years.
Chapter 23 -- Wood

• Three design methodologies
  – Allowable stress design (ASD)
  – Load & resistance factor design (LRFD)
  – Conventional construction

Although most of this program centers on the *International Residential Code (IRC)*, keep in mind that the *International Building Code (IBC)* addresses wood construction through one of three methods (see slide).
Chapter 23 -- Wood

• Three design methodologies
  – Allowable stress design (ASD)
  – Load & resistance factor design (LRFD)
  – Conventional construction

Allowable stress design – the “old” or “traditional” way of designing – is an engineering methodology recognized by the IBC.
The code’s reference document is the AF&PA *Allowable Stress Design (ASD) Manual*, a group of several documents. These are the Manual itself, the NDS, material-specific standards, and design guidelines.
Allowable Stress Design - NDS®

The 1997 *National Design Specification (NDS)* is the ASD wood document referenced in the 2000 editions of the *IBC & IRC*.

The 2001 *NDS* is referenced in the 2003 codes.

The *NDS* is the basic document in the ASD package and has been referenced in the codes for decades.
Allowable Stress Design - NDS®

• Nationally accepted
• ANSI standard
• Allowable stress design basis
• Contains design values for sawn & glued laminated lumber

The *NDS* is:
• Nationally accepted
• ANSI standard
• Allowable stress design basis
• Contains design values for sawn & glued laminated lumber
Chapter 23 -- Wood

• Three design methodologies
  – Allowable stress design (ASD)
  – Load & resistance factor design (LRFD)
  – Conventional construction

Load and Resistance Factor Design (LRFD) is the second engineering design methodology recognized by the code and is, at least for the wood industry, relatively new.
Like the ASD Manual package, the LRFD Manual is a package of several smaller documents.
2005 Wood Design Package

- ASD and LRFD together in the single-volume 2005 NDS®:
  - Provisions
  - Supplement of Design Values
  - Commentary
- Manual
- Worked example designs
- Wind & Seismic Standard

Now you get ASD and LRFD in one package with the current 2005 NDS bundled as the 2005 Wood Design Package.
Chapter 23 -- Wood

• Three design methodologies
  – Allowable stress design (ASD)
  – Load & resistance factor design (LRFD)
  – Conventional construction

And finally, the *IBC* recognizes conventional construction as the third method of designing with wood.
Chapter 23 - Wood

- Conventional construction in *IBC* has limited non-residential application
- Residential application is given to *IRC*
- IBC Section 101.2 (Scope): General applicability of *IBC*
  - Exception: Detached one- and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories high (*"...not more than three stories above grade in height ..." (as it appears in the 2003 edition)*) with separate means of egress and their accessory structures shall comply with the *International Residential Code*.

The *IBC* provisions for conventional construction, however, have little use since they’re almost completely residentially oriented, and since the *IBC* directs code users to the *IRC* for dwelling construction.
The **IRC** is based on the 1997 edition of *CABO One- & Two-Family Dwelling Code*, which was its final edition. The Dwelling Code provisions were updated to some extent, but the **IRC** closely resembles the older code. There are some differences between the wood framing requirements in the **IRC** and some of the conventional provisions in the **IBC**.
Conventional Construction
In the IRC

- Detailed discussion of code requirements taken from the IRC (both 2000 & 2003 editions)

Our discussions later on code requirements will be taken from the IRC. Where the IBC provisions are pertinent, these will be mentioned. We’ll talk about the IRC in general, and where there are differences in the requirements between the 2000 and 2003 editions of the IRC, we’ll explain those.
What is Conventional Construction?

This program deals with portions of the International Residential Code's (IRC) prescriptive requirements for wood construction. Typically these provisions address what is often referred to as “conventional construction.”
Learning Outcomes

By the end of this eCourse module, you will be:

1. Familiar with the term "conventional construction" as used in the International codes
2. Knowledgeable about it's limits
3. Knowledgeable about how to apply its provisions

Learn about the term "conventional construction" as used in the International codes. This course discusses the origination of conventional construction, it's limits, and points out that many elements we see in buildings that may be assumed to be of conventional construction aren't.
Conventional Construction

- One of 3 design methodologies recognized in IBC Chapter 23
- Time-tested prescriptive framing methods and design primarily for residential construction. Permitted to be used without design analysis or load calculations.

Although this program is centered on the IRC, let’s look at how the International Building Code (IBC) addresses wood design. In Chapter 23 of the IBC three methods of wood design are recognized – allowable stress design, load and resistance factor design, and conventional construction. Conventional construction is specifically called out as one of those methods.
Conventional Construction

• IBC - Definition
  – “A type of construction whose primary structural elements are formed by a system of repetitive wood framing members.”

• IBC - Limited application also defines conventional construction
  – Maximum 3 stories
  – Bearing wall height limited to 10 feet
  – Roof spans of 40 ft or less
  – Low-wind & low-seismic only
  – Loads are limited

Here is the IBC definition of the term and a summary of the limited application in that book.
Conventional Construction

- IBC has limited nonresidential application for conventional construction
- Most dwelling construction given to IRC
- IBC Section 101.2 (Scope): General applicability of IBC
  - Exception: Detached one- and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories above grade in height with separate means of egress and their accessory structures shall comply with the International Residential Code.

Although the conventional construction provisions of the IBC appear to address primarily residential uses, Section 101.2 of the IBC places most dwellings under the provisions of the IRC. The reference to height was slightly different in the 2000 edition of the IBC. Conventional construction in the IBC would apply to those dwellings that might fall outside of the scope of the IRC for some reason and portions of nonresidential buildings that fit within the limits of conventional construction as addressed in Chapter 23.
Conventional Construction

- IRC – Term isn’t used
- IRC - “Defined” by scope of the code
  - 1- & 2-family dwellings
  - Multiple single-family dwellings (townhouses)
  - Limit of 3 stories
  - Low-wind application
  - Loads are limited

The IRC doesn’t use the actual term conventional construction, but it’s scope tends to establish the limits of this methodology as permitted by that code.
The basis of conventional construction is not from engineering analysis, but rather is from historic methods of construction using wood members. These methods have displayed a reasonable level of performance over decades. It’s important to realize that the original structures from which this method of construction was derived were relatively small, with small horizontal spans and moderate wall heights. The floor plans for these buildings were typically rectilinear. Also the loading on the buildings was consistent, and the materials used were familiar and their limits well understood.
Derived From …

• Larger structures which also had
  – Small spans
  – Moderate wall heights
  – Regular floor plans

Even when larger versions of these early buildings were constructed, the basic structural forms of the buildings were simple.
High-wind Design

2003 IRC: Design wind speed limit of <110 mph (3-second gust)
2006 IRC: <100 mph in hurricane-prone regions & <110 mph elsewhere

It’s important to remember that conventional construction – not engineering-based prescriptive methods of construction such as are contained in AF&PA’s Wood Frame Design Manual – aren’t really intended for high loads. In fact, the IRC limits the use of its provisions to low-wind areas.
IRC High-wind Design

• Design using ASCE 7
• SBCCI Standard for Hurricane Resistant Residential Construction SSTD-10
• AF&PA’s Wood Frame Construction Manual for One- & Two-Family Dwellings

For high-wind areas, the IRC references the readers to other methods of design, one of which is using the AF&PA Wood Frame Construction Manual. The program will talk about that document later.
IRC High-Seismic Design

- IRC prescriptive limits of Seismic Design Categories A, B, C, D₀, D₁ and D₂
- Cannot be used for irregular structures (IRC Section R301.2.2.7)
- Beyond the IRC limits
  - Design using ASCE 7
  - AF&PA WFMC

Unlike the wind-related portions of the code, the IRC permits some prescriptive design of structures in high-seismic (earthquake) areas. There are some limits, however, on building configurations. If the buildings are outside the scope of the IRC, they can be engineered or designed in accordance with the WFCM.
Design of Portions

IRC R301.1.3: “When a building of otherwise conventional light-frame construction contains structural elements not conforming to this code, these elements shall be designed in accordance with accepted engineering practice. The extent of the design need only demonstrate compliance of nonconventional elements with other applicable provisions and shall be compatible with the conventional framed system. Engineered design in accordance with the International Building Code is permitted for all buildings and structures, and parts thereof, included in the scope of this code.”

The IRC permits mixing of professionally designed elements with conventional construction.
We’ve talked a little about what conventional construction is – at least within the limits of the IBC and IRC. But it’s important to keep in mind what conventional construction ISN’T.
Although the IRC addresses the general framing requirements, it doesn’t address situations like these in which concentrated loads are placed on beams or headers which, in the IRC, are considered to be uniformly loaded.
Very large wood buildings may have some elements that could be conventional construction – interior nonbearing walls for instances – but these types of buildings are beyond the scope of the IRC. And state engineering practice acts may require professional design.
Heavy timber structures are beyond the scope of the IRC.
Engineered wood products such as glued-laminated beams, which are common as headers and beams, aren’t addressed in conventional construction. These types of products shouldn’t be treated like solid-sawn lumber.
Trusses require professional design and the way that they connect to the rest of the structure should be closely examined. No changes should be made to these members without professional approval.
Other engineered wood products are also professionally designed and their use should be in compliance with the formal design and with the manufacturers’ recommendations.
Alterations of EWPs

ALTERATIONS:
R502.8.2 (floors) & R802.7.2 (roofs) prohibit alterations of EWPs unless specifically permitted by manufacturer’s recommendations or considered in the design of the member.

To emphasize the fact that engineered wood products are special elements and shouldn’t be altered the code specifically addresses that situation.
And some things are just too abstract to be considered as conventional construction.
Characteristics of Wood

This section of the program is a short discussion of the characteristics of wood that can (1) affect its appearance, (2) affect its serviceability, or (3) cause questions about its acceptability. This material isn't addressed in the codes, but it is general information that is useful.
Learning Outcomes

By the end of this eCourse module, you will be:

1. Knowledgeable about natural characteristics of wood
2. Knowledgeable about the impact of wood characteristics on the serviceability of lumber

In this eCourse module, you will learn about natural characteristics of wood and the impact of those characteristics on the serviceability of lumber.
Characteristics

As the moisture content in the cells of wood products changes, particularly as it dries out, wood members can change shape if the change in moisture content isn’t done in controlled conditions. As wood dries out the amount of shrinkage differs in the various directions. Shrinkage is limited parallel to the grain of the wood. It’s greatest when measured in a tangent to the growth rings. The amount of shrinkage along the radius of the wood is less than that tangentially. Depending upon where in the log the member is cut from, uncontrolled drying can cause wood members to exhibit unusual shapes as shown here in this exaggerated illustration.
Uncontrolled drying can also cause separation of the wood fibers. This can happen after the piece of lumber leaves the mill and is exposed to moisture prior to being incorporated into the framing. The condition in which the fibers separate across the growth ring, as shown here, is called a split. Some small amount of splitting is acceptable under the grading rules for lumber, the amount depending upon the grade of the piece. However, excessive splitting which may affect the member’s useability, is a condition that may warrant disapproval of that piece.
Here’s another moisture-related condition that you may see on lumber, but it’s a condition that is NOT a problem. As we’ll talk about in more detail later, wood-consuming organism need, among other things, moisture to live. What you see here is condition in which organisms in the log began to eat the wood fiber. After the piece of lumber was cut and dried out, the organisms became dormant. Any strength-reducing damage that might have occurred has been reflected by the grade of the piece of lumber. As long as this lumber isn’t subjected to moist conditions again, the damage to the wood won’t get any worse that what was seen when it was graded.
What you see here is a moisture-related condition that is a problem. In spite of the fact that we often refer to this dry, corky condition as “dry rot,” decay requires the lengthy presence of moisture. No amount of decay is permitted in the grading rules, and this condition occurred at some point after the lumber left the mill.
A common condition in a piece of lumber is the presence of knots. Knots are in-grown limbs. Their presence in a piece of lumber is one of several factors in determining the grade of that piece of lumber – their size, their locations, and the number of knots. From a practical standpoint, one of the problems that knots present is the fact that they often make nailing difficult if they’re located at a point where nails will be driven.
Wane is a condition in which the piece of lumber includes a portion of the outer edge of the log from which it was cut. Often some of the bark is still present, although what you may see may just be the curved surface of the log with no bark. A certain amount of wane is permitted by the grading rules, and the only practical problem that it presents is that wood fiber is missing, making a connection difficult or reducing bearing surfaces.
Characteristics

• Moisture affects
  – Shrinkage & expansion
  – Decay
• Control is important

Although not addressed in the codes, as we’ve seen the uncontrolled wetting and drying of wood, or the long-term presence of moisture, causes problems in lumber and other wood products. Proper storage of the materials on the job site is critical. As shown here, they should be stored off of the ground, and they should be covered to protect them from rain.
The undesirable conditions that we’ve seen often result from job site storage such as this.
This section of the program deals with the requirements of the code for grade marks. Grade marks identify lumber that has been through the industry’s voluntary grading program, and they provide information concerning the strength properties of lumber.
Learning Outcomes

By the end of this eCourse module, you will be:
1. Knowledgeable about and be able to apply the code requirements for grade marking of lumber
2. Familiar with:
   – what information grade marks should contain,
   – how grading is done,
   – variations in grade marks such as are found on finger-jointed lumber, and,
   – a code-accepted alternative to a grade mark.

Learn about and apply the code requirements for grade marking of lumber. This eCourse module explains what information grade marks should contain, how grading is done, variations in grade marks such as are found on finger-jointed lumber, and a code-accepted alternative to a grade mark.
Grade Marks

• IRC R502.1: “Load-bearing dimension lumber for joists, beams and girders shall be identified by a grade mark of a lumber grading or inspection agency that has been approved by an accreditation body that complies with DOC PS 20.”

R602.1 and R802.1 are similar

Here is the text from Chapter 5 of the IRC concerning grade marks. Because of the format of the code similar text appears in other chapter. The IBC text is comparable, although it specifically makes reference to comparable grading processes, none of which exist at this time. The IRC simply makes reference to the PS 20 process. A different grading process could be approved under the alternate methods and materials provisions of the code.
Now that we’ve establish the code’s requirement for a grade mark on all structural lumber, let’s see what a grade mark looks like, what information should appear on that grade mark, and how you can find out whether it’s a valid grade mark. Here’s our fictional grade mark. They all look somewhat different; some are simple, as we’re showing here, some are elaborate. But they all should contain the same minimum amount of information. Some may contain more than what we’re showing here.
Every grade mark should have an indication of the grade – or structural properties, as we’ll show in a minute – of that piece of lumber. Those grades are standardized by the process contained in PS 20. Some of those grades will be numbers – 1, 2, or 3 – but others may be words such as “Stud,” “Construction,” or “Standard.” At times you may see something similar to “Construction or Btr,” which is read as “Construction or Better” and means that the lumber designated with that grade is a mixture of grades but all are at least Construction grade. The design values, or structural strength properties, assigned will be for Construction grade, even though there may be some pieces that would be of a higher grade. Some lumber distributors, however, are misinformed and may say that one of these combinations such as Construction or Better is equal in strength to a higher grade such as No. 2. While it’s true that some pieces may very well have strength properties higher than Construction grade, there’s no way for you to know which pieces those will be. All should be assumed to have the design values for Construction grade.
The next element of this grade mark designates the species of lumber or type of lumber. The example here is Douglas Fir.
As you'll remember from our earlier conversation, excessive moisture has a detrimental effect on wood. For that reason, lumber is dried before it leaves the mill. The grade mark should contain an indication of what the moisture content was at the time the lumber was manufactured. Note that the actual moisture content of the lumber may be different if it has been exposed to moisture after leaving the mill.

The designation that we see here, S-Dry, stands for “surface dry” and means that the lumber was dried to 19% moisture content (by weight) or less. At this level decay won’t begin or continue. If the lumber hasn’t been exposed to moisture since leaving the mill, it may actually be lower than 19%. The service moisture content of lumber once it’s been enclosed in the structure may be as low as 10%.

Another designation that you may see is S-Grn, which means Surface Green. This is somewhat a misleading term because the lumber isn’t shipped green. It has been dried, but it was shipped at a moisture content somewhat above 19%. If it’s been kept protected since leaving the mill, it may very well be at or below 19% when it’s incorporated into the framing.

There’s also Kiln Dried (KD) lumber, wood with a very low moisture content. However, it’s normally seen on lumber used for finish purposes or for engineered wood products. KD wood is also used for furniture.
One of the more visually prominent elements of a grade mark is the trademark, or logo, of the agency which provided grading oversight at the mill where the lumber was produced. Some of these logos are very elaborate, others simple.
The final element to appear on a grade mark, and probably the least important to you, is the mill identification. While it isn’t important for code purposes, it provides information concerning the source of the lumber in the event that there are questions or problems.
You may see the letters “HT” on some grade marks. This indicates that the wood was exposed to heat to kill insects, a treatment which is required by some countries before they will permit importation of lumber. This isn’t the same as kiln-drying. HT exposes wood to a relatively high temperature for a relatively short time. Typically it won’t result in drying of the wood. KD exposes wood to lower temperatures, but for long periods to dry the wood.
Grade Marks

- IRC R502.1*: “Load-bearing dimension lumber for joists, beams and girders shall be identified by a grade mark of a lumber grading or inspection agency that has been approved by an accreditation body that complies with DOC PS 20.”

* R602.1 and R802.1 are similar

This is the text of the IRC’s requirement for grade marking again. At this point we’re going to talk about the reference to DOC PS 20.
The key to this requirement is this document, the American Lumber Standard. It is a publication of the US Department of Commerce (DOC), document PS (product standard) 20. PS 20 establishes the voluntary lumber grading process in the United States and Canada. In doing so it creates the American Lumber Standard Committee (ALSC) to oversee the writing of grade rules as well as oversee the grading process.

One of the things that PS 20 does is establish the American Lumber Standards Committee, an organization which oversees the writing of grading rules, approves grading agencies, and provides a third-party oversight of the grading process.

Although the codes require grade marks, the grading process is voluntary and lumber can be produced that is ungraded. It won’t, however, be acceptable for structural applications under the codes.
Grade Marks

• IRC R502.1: “Load-bearing dimension lumber for joists, beams and girders shall be identified by a grade mark of a lumber grading or inspection agency that has been approved by an accreditation body that complies with DOC PS 20.”

Here’s the text of the code again, requiring grade marks. Notice that the grading agency is supposed to be approved by some organization complying with PS 20. What does that mean?
We have PS 20 which sets up the softwood lumber grading program, establishes the American Lumber Standards Committee which oversees the grading process. And we have the codes requiring grade marks from grading organization that has been approved by a body that complies with PS 20. How do you know which agencies are approved in this fashion? ALSC publishes a facsimile sheet similar to what you see here that contains all approved grading agencies, in both the US and Canada, and facsimiles of their grade marks. Those sheets are updated on a regular basis. These sheets are accessible on the ALSC website and can be downloaded and printed. You can reach the ALSC site through the AWC site or you can go directly to the site.
Here’s an example of a real-world grade mark. Notice that it has all of the basic elements that are required on a grade mark.
Grade Marks

Here’s another real-world grade mark, however, that’s missing something. What?
The only thing missing is the species of wood. This is because the grading agency, SPIB, the Southern Pine Inspection Bureau, only grades southern pine. Their grade mark won’t appear on any other species of wood.
Here you see an actual grading line in a lumber mill. Highly skilled graders look at the finished lumber as it moves down a line, sorting it by grade in the process called “visual grading,” and discarding those pieces of lumber with defects.
Grade Marks

The sorted lumber moves through the stamping machine, and the grade mark is stamped 18” – 24” from one end of each piece. The pieces are then bundled.
There is a process for grading lumber other than visual grading, which is machine evaluation. In this process, of which there are variations, the lumber moves through a machine that non-destructively tests for a given property of the lumber such as density. The various structural properties of the wood can be derived by knowing this property. This procedure is typically used only on lumber in which the structural properties need to be determined as accurately as possible, such as that used in engineered wood products.
Grade Marks

Here’s the grade mark of a piece of machine rated lumber. What’s different about it?
What’s missing is the grade. However, the grade of a piece of lumber of a specific size and species will translate to structural properties, among them fiber stress in bending (Fb) – strength -- and modulas of elasticity (E), stiffness. In the case of this piece of machine evaluated lumber, rather than identify it by grade, it has been identified by two of its design values, or strength properties.
Grade Marks

- IRC R502.1: “Load-bearing dimension lumber for joists, beams and girders shall be identified by a grade mark of a lumber grading or inspection agency that has been approved by an accreditation body that complies with DOC PS 20. In lieu of a grade mark, a certificate of inspection issued by a lumber grading or inspection agency meeting the requirements of this section shall be accepted.”

Here’s a continuation of the grading requirements in the IRC. Notice that it sets up an alternative to having a grade mark and says that it SHALL be accepted. So, what is a certificate of inspection?
Grade Marks: Certificate of Inspection

- Not a letter from a manufacturer or supplier
- From an ALSC-approved grading or inspection agency
- Assurance that lumber is in conformance with grading rules
- On letterhead of accredited agency
- Information about lumber
  - Grade & species
  - Moisture content
  - Size & number of pieces inspected
- Identifying mark on each piece

A certificate of inspection provides the same essential information that’s provided by a grade mark. And it’s important to remember that it’s not something from the lumberyard or somewhere else attempting to explain what the purchased lumber was supposed to be. It must be from an ALSC-approved agency, typically one of the grading agencies.

This is not a simple or inexpensive “fix” to a red tag for lacking a grade mark. The person requesting the inspection must pay the expenses of the inspector and must wait until the grading or inspection agency can have an inspector free.

And it should be obvious as to what lumber has been inspected because the inspector is required to place his mark on each piece that he’s looked at, and a copy of that mark will appear in the formal report.
The grade marks on a finger jointed piece of lumber are very similar to those on solid sawn pieces of lumber. There are, however, some differences.
Finger Jointed Lumber

- Widely accepted for use by IBC and IRC
- Interchangeable with solid sawn lumber with certain limitations:
  - HRA
  - NON-HRA
  - Wet service
  - Orientation

Finger-jointed lumber has gained wide acceptance in the building and construction industry. This product is accepted for use under both the *International Building Code (IBC)* and the *International Residential Code (IRC)*, and is considered interchangeable with solid-sawn dimension lumber of the same size, grade, and species. The only difference between the IRC and IBC text is the exact wording. The codes use the term “end-jointed lumber” which is a generic term for lumber formed by gluing smaller pieces together end-to-end. One manner of making that connection, the most common, is finger jointing.

In 2006, as part of the North American wood product industry’s effort to ensure the safety of its products, research was initiated to better understand the performance of adhesives used in end-jointed lumber in fire-resistance-rated assemblies. Fire tests on finger-jointed lumber assemblies were conducted by *American Forest & Paper Association (AF&PA)*, in cooperation with *Forintek Canada Corp.*

As a result of the tests, the *American Lumber Standard Committee* in early 2007 revised its *Glued Lumber Policy* to add elevated-temperature performance requirements for labeling finger-jointed lumber. The amended policy established two new designations on grade stamps for finger-jointed lumber.

Products joined with qualified heat-resistant adhesives include the designation HRA in the grade mark. Finger-jointed lumber joined with other adhesives is marked as NON-HRA. As mills transition to the new designations, finger-joined lumber without HRA designations in the grade stamp are being considered as produced with Non-HRA adhesives. These products should not be used in assemblies where fire-resistance ratings are required, unless additional testing has been conducted to demonstrate compliance.
Finger Jointed Lumber

• HRA
  – Heat Resistant Adhesive
  – Designated on grade stamp
  – Used where fire rated assemblies are required by code
    • Exterior walls
    • Dwelling unit separations
    • Commercial tenant separations

The grade marks on a finger jointed piece of lumber are very similar to those on solid sawn pieces of lumber. There are, however, some differences.

*IBC Section 2303.1.1 Sawn Lumber*, states, “Approved end-jointed lumber is permitted to be used interchangeably with solid-sawn members of the same species and grade.” The new HRA marks are intended to provide regulators and users additional information to identify which finger-jointed products meet elevated-temperature performance requirements.

HRA-marked finger-jointed lumber should be used for assemblies that require a fire resistance rating under the *IBC* and *IRC*. Typically, fire ratings are required for multi-story or multi-family structures in separations between living units. Common walls in commercial structures may also require fire rated assemblies.
Finger Jointed Lumber

• NON-HRA
  – Adhesive not rated for heat resistance
  – Designated on grade stamp

NON-HRA grade marked lumber is generally permitted in residential construction. Under current building codes, detached single-family homes rarely require fire rated assemblies. NON-HRA marked lumber and finger-jointed products with no HRA designations can continue to be used in construction where no fire rating is required.
Finger-jointed products with no HRA designations are treated as NON-HRA. However, the material supplier should be given the opportunity to substantiate the type of adhesive used in unlabelled material. It is possible that qualified adhesive was used in the manufacture of the joints, but the label was not applied or it was manufactured prior to the new marking requirements.
Heat-resistant adhesives are currently evaluated according to the American Forest & Paper Association’s *Elevated Temperature Adhesive Qualification Procedure*. This protocol requires an adhesive to be exposed to elevated temperatures during a standard ASTM E119 fire test of a load-bearing end-jointed stud wall assembly loaded to 100 percent of the lumber’s allowable design load.

Fire tests are conducted on a wall assembly design specified in the 2003 and 2006 editions of the *International Building Code*, Table 720.1(2), Item Number 15-1.14. Adhesives qualify for the HRA designation if the wall assembly performs to design specifications for at least one hour in the *E119* fire test. All tests are conducted in International Accreditation Service - accredited laboratories in the US and Canada.

The American Lumber Standard *PS-20* provides the framework for quality control of structural-glued lumber under its *Glued Lumber Policy*, which results in predictable, reliable products that may be used for structural purposes. *DOC PS-20* is the referenced standard for lumber products in the I-Codes and predecessor “legacy” codes.
Structural finger-jointed lumber is manufactured to meet the requirements of two different types of end-use applications. The first category is basically an all-purpose product indicated by CERT EXT JNTS on the grade stamp. The second category is appropriate for use where the long-term loading will be in compression, as indicated by VERTICAL USE ONLY on the grade stamp.

Finger jointed lumber grade-stamped CERT EXT JNTS is intended for ALL structural applications subject to any additional fire rating requirements. This lumber is assembled with a waterproof, exterior-type adhesive, meeting the requirements of ASTM Product Standard D2559. Limitations on know size and placement near joints is highly restrictive, and testing and quality control procedures are also rigorous.

The exterior-type adhesives for CERT EXT JNTS products are suitable for bonding structural end-jointed and laminated wood products for use in general construction where a high strength, waterproof adhesive bond is required. Long lengths, up to 32’ or more, are one of the distinct advantages of structural-glued finger-jointed products. This lumber may be used as beams, joists, rafters, studs, plates, or in any other exterior or interior framing application. The species and grade indicated on the stamp can be expected to retain the same structural properties as its solid-sawn lumber counterpart.

As an example, here’s a grade mark of a finger-jointed piece of lumber. As you see, it contains the same information as is required for solid sawn lumber. The difference is that finger jointed lumber must also have an indication that it’s a jointed piece of lumber. In this case, the glue used in the joints is suitable for exterior use and this is stated by EXT JNTS. You’ll also note that since the HRA / NON-HRA mark is missing, this material should be considered as NON-HRA.
There is a geometric condition in which there is a limitation on the use of some finger jointed lumber. Some lumber may be labeled for VERTICAL USE ONLY or STUD USE ONLY as you see here. In this case, the glue in the joints is of a type that may creep under long term bending load, causing a joint failure. Studs labeled as such should be used only for long term vertical loading (compressive loads). They should not be used in applications where sustained bending is the dominant load to be resisted.

A question comes up at times about whether this limitation prohibits these studs from use in walls that are subject to high-wind or seismic loads since those walls see lateral loads which could induce bending in the studs. These bending loads are always of short duration, well within ability of these finger jointed studs to resist them.

These products are typically assembled with a water-resistive adhesive (indicated on the grade stamp as CERT GLUED JNTS). VERTICAL USE ONLY products indicated as CERT GLUED JNTS are limited to conditions where the glued joint will not be exposed to repeated wetting and the moisture content of the wood will not exceed 19% in use. This is the most common form of this product, and VERTICAL USE ONLY finger jointed lumber lengths are limited to 12 feet. However, customers may occasionally find VERTICAL USE ONLY products indicated as CERT EXT JNTS in the marketplace when a mill manufactures VERTICAL USE ONLY under a recognized CERT EXT JNTS program using waterproof exterior-type adhesives.

Note that studs with any of these grade marks are also considered NON-HRA, even though it's not a requirement.

As a handling advisory, although structural finger-jointed lumber grade stamped VERTICAL USE ONLY – CERT GLUED JNTS is assembled with water-resistant adhesives, these products should not be stored where water might collect in a stack of lumber for an extended period. If the material does get wet during storage or delivery, it should be separated so it will dry, or be installed so it may dry in place.

For more information on finger-jointed lumber products, testing, and standards, see: Western Wood Products Association TG-9: *Structural Glued Lumber.*
Finally, a word about grade marks as you might see them on lumber in the field. Each piece of lumber should have a grade mark that states that it is a jointed piece. But because the finished piece of lumber is composed of smaller pieces joined together, it’s possible that some of the smaller pieces may have a grade mark on them that originally applied to the piece of lumber from which they were cut. Those old grade marks are supposed to be obliterated as you see here (rubbed out black square in top of picture) but sometimes are missed in the process. They can be ignored as the grademark for the finger-jointed piece as applicable.
In this portion of the program we'll look at the code requirements that address the protection against damage from decay and termites.
Learning Outcomes

By the end of this eCourse module, you will be:

1. Knowledgeable about naturally durable and preservatively treated wood,
2. Familiar with code requirements for those materials,
3. Familiar with examples of those requirements.

In this eCourse module, learn about naturally durable and preservatively treated wood, about code requirements for those materials, and see examples of those requirements.
When the subject of protection against decay and termite comes up, most of us immediately think about decks and gazebos. However, there are numerous other applications of wood that both the IBC and IRC address in which protection against decay and termites must be provided.
We’re all familiar with the effect of decay organism on wood, particularly wood in its basic form.
But we're often not aware of the fact that the same sort of thing can happen to wood in structures if the conditions are right – or perhaps we should say if the conditions are wrong.
Protection against termite attacks is important also because the damage that termites do is often hidden and we may not be aware of it until it’s too late to correct the problem.
Let’s start our discussion by talking about those organisms that feed on, and destroy, wood. Decay, fungus, and mold organisms are somewhat different creatures, but they all need the conditions that you see here in order to exist. Removing any one of these items prevents the organism from developing or makes existing organism go dormant. If we look at these items, we’ll see that the only one that can be removed in most instances is moisture.
Moisture

- Moisture content
  - < 20%: No decay
  - > 20%: Optimum conditions for decay

As we mentioned in the discussion of grade marks, wood should be at a moisture content of 19% or less in order to avoid problems with decay destroying organisms.
The code’s traditionally have required that protection against both decay and termite damage be provided when certain conditions exist. We’ll talk about those conditions in a moment. Both the IBC and IRC follow traditional code provisions for protection against decay: Use of naturally durable wood or preservatively treated wood where protection is required. For termite protection, the IBC requires the same as for decay protection. The IRC, however, requires something different, and we’ll talk more about that in a moment.
Where protection is needed, the codes require either naturally durable wood or preservatively treated wood. Here are those species, or types, of wood that are naturally decay and termite resistant.
Protection

- Treatments effective against both decay & termites
- Waterborne preservatives
  - Residential/commercial/industrial
  - Recreational
- Oilborne preservatives: Creosote, pentachlorophenal, & creosote/coal tar mixtures
  - Railroad ties
  - Pilings
  - Utility poles

Chemically treated – or preservatively treated – are usually treated with one of two types of preservatives. The common one for the applications addressed by the codes are waterborne preservatives.
Preservative Treatment

- **Waterborne preservatives** – most common is CCA (chromated copper arsenate)
  - Being voluntarily phased out of residential use
  - Likely replacements
    - ACQ (alkaline copper quat)
    - CBA-A & CA-B (copper azole)
    - Inorganic borates
      - Minimal health risks
      - Water soluble: not useful in wet conditions

- **Other waterborne preservatives**
  - ACC: Acid copper chromate
  - ACA: Ammoniacal copper arsenate
  - ACZA: Ammoniacal copper zinc arsenate

The most common application for preservatively treating is the use of waterborne preservatives. This is particularly true for residential uses.

The most common preservatives are shown here. Those that contain inorganic arsenicals have been tested for health impacts. It is recommended that certain precautions be taken when working with CCA or ACA treated lumber and that the wood not be used for applications where it will come into contact with food or drinking water. Beyond that, the material has been shown to be safe in normal applications such as decks and playground equipment. However, the industry is voluntarily phasing out it’s use as other products demonstrate their effectiveness.

Borates are becoming more common, particularly for termite control. The drawback at this point for borates is that they shouldn’t be used for ground contact or exposure to liquid water.
Preservative Treatment

- Impact of withdrawal of CCA
  - Treated wood will still be available
  - CCA will remain on the market until stocks are used
  - Initial higher cost for newer treatments
  - 2 retentions available for newer treatments: above ground (primarily lumber and boards) & ground contact (primarily lumber, posts, and timbers)

Here is what we can expect with CCA being withdrawn.
Preservative Treatment

• Current ACQ and CA formulations are more corrosive than CCA
• ACQ, CA reformulation research ongoing
• Borates are less corrosive than CCA

Where the new treatments are used, there is the potential for a corrosive interaction between the chemicals and the metal of fasteners, connectors, hardware, etc.
Preservative Treatment

- Must be corrosion resistant: nails, screws, bolts, joist hangers, straps, hinges, etc.
- In contact with preservatively treated or fire retardant treated wood IRC Section R319.3 requires use of
  - Hot-dipped galvanized steel
  - Stainless steel
  - Silicon bronze or copper
- Hot-dip galvanized or stainless steel recommended by treating industry
  - Hot-dip fasteners should meet ASTM A153,
  - Connectors meet ASTM A653, Class G185
  - Stainless steel, type 304 or 316

Regardless of what treatment is used, metal in contact with the treated wood should be corrosion resistant.
Preservative Treatment

- Treating industry recommendations
  - Don’t use standard carbon steel nails with treated wood
  - Electroplated galvanized not recommended
  - Fasteners and connectors used together should be of same metallic composition

In addition to the code requirements, the treating industry recommends that regular steel nails not be used with treated wood. And it doesn’t recommend the use of electroplated galvanizing. That process puts a very thin coat of galvanizing on the nail that probably won’t survive the driving of the metal into the wood.
Preservative Treatment

• Service life
  – Tests sponsored & conducted by USDA Forest Products Lab
  – Stake tests from Canada to Mississippi Delta
  – CCA: In place for 40+ years & no failures

Preservatively treated wood has a long history of satisfactory service. For example, tests on CCA-treated wood over a period of 40 or more years has shown the treatment to retain its effectiveness.
Preservative Treatment

- Effectiveness of treatment
  - Chemical type
  - Penetration
  - Retention
  - Uniform distribution

In its service life, these elements determine the effectiveness of treated wood. All are checked as part of the quality control process in the production of the product. One of these, however, is important to know for both users and enforcers – retention levels.
Preservative Treatment

<table>
<thead>
<tr>
<th>RETENTIONS (CCA) (lbs/ cubic feet)</th>
<th>USES/ EXPOSURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>Above ground.</td>
</tr>
<tr>
<td>0.40</td>
<td>Ground contact.</td>
</tr>
<tr>
<td></td>
<td>Fresh water contact.</td>
</tr>
<tr>
<td>0.60</td>
<td>Wood foundations.</td>
</tr>
<tr>
<td>2.50</td>
<td>Salt water contact.</td>
</tr>
</tbody>
</table>

New treatments will have different retention levels, some substantially lower

Some of the things that we talked about in the last slide -- penetration of chemicals and their uniform distribution in the wood -- are checked by the quality control processes at the treating plants. But retention of chemicals varies, depending on the chemical and the intended use of the wood. And insuring that the wood is used properly is an enforcement issue. Several places in the IRC stipulate the use of treated wood suitable for ground contact.

Retention is expressed in the form that you see here, in pounds per cubic feet. What you see here is specific to CCA treating which is being phased out. But the general concept will apply to all treatment chemicals. The numbers will vary from what you see on this slide. Each retention is intended for a specific end-use. While a lesser retention used in a worse situation -- such as a piece of 0.25 wood used in contact with the ground shown here -- will provide better service than untreated wood, performance may not be satisfactory over a long period of time.
Preservative Treatment

• Quality mark is required
• In addition to grade mark
• Should show …

The IRC requires that a treater’s quality mark appear on treated lumber. Keep in mind that that treating occurs after manufacturing of the lumbers and the quality mark is in addition to the grade mark.
This is the basic information that you should find on a quality mark. From an enforcement standpoint, perhaps the most important pieces of information contained here are the retention level and the exposure category. The quality mark may appear as a stamp, similar to a grade mark, or as a plastic tag fastened to the wood.
Beginning with the 2006 edition of the codes the reference in the codes will be to AWPA’s Use Category system of identification. The standard will be shown as one of several UC designations, depending on the end use. Initially quality stamps will show both the C and the UC standards.

In the 2004 Supplement to the IBC and IRC you’ll see revisions that will show up in the 2006 editions of the codes that will require compliance with the AWPA UC (Use Category) standards rather than the C treating standards that have been referenced by the codes for years.
Let's talk briefly about how lumber is treated.

Treating is an after-market process. In other words, the treaters don't produce the lumber. They buy it from some source, and the bundles of lumber are moved into the cylinders that you see here.
Once in the cylinders, the air in the cylinder is exhausted and a vacuum is formed which draws moisture from the cells of the wood.

After the moisture is reduced, the cylinder is flooded with the treating chemical, and the liquid is placed under pressure to force the chemicals into the cells of the wood.
The most common species of wood that is treated is southern pine which readily accepts treatment. Some species, however, don't accept the chemicals as easily and have to be incised. Before being subjected to the chemical cylinders the wood is incised, leaving cuts on the surface to allow the treating liquid to better treat the inner portion of the wood.
After treating is complete the treating company makes its quality control checks, looking at things such as penetration and distribution of chemicals in the lumber.
Decay & Termites

• Decay: General requirements in IRC, IBC, UBC, & SBC are the similar
• Termites: Major differences between IRC & IBC
  – Similar to CABO OTFDC
  – Very different from UBC & SBC

After all that general information, let’s talk about specific code requirements. The requirements for decay protection in the IBC and IRC are nearly identical, although as we’ll see in a moment the IRC gets somewhat confusing because it refers to a map. And those requirements for decay protection are very similar to the way they were in the Uniform Building Code and the Standard Building Code. The IRC’s requirements for termite protection are quite different.

However, there are major differences between the IBC and IRC requirements for termite protection. And while those provisions in the IRC are similar to those in the CABO One- & Two-Family Dwelling Code, they are very different from those found in the UBC and SBC.
Since most wood construction will be residential and will fall under the scope of the IRC, let’s talk about the IRC requirements. Keep in mind, however, if a building isn’t a dwelling or is a dwelling that falls outside the scope of the IRC, the provisions of the IBC will apply.

The IRC identifies situations in which decay protection is needed and gives the reader the choice of using naturally durable wood or preservatively treated wood. Those situations that are identified typically involve inadequate separation between the wood and the soil, or wood and concrete or masonry.

The confusing aspect of the IRC is that it says that the requirements apply in areas of decay damage and refers the reader to a map. The map, which we’ll see in a moment, contains three identified areas, but those areas aren’t reflected in the text of the code. The map would seem to imply there are areas in the country in which there are greater chances for decay damage. But the text seems to make just a flat requirement out of its provisions. It is AF&PA’s opinion that while the climates of some regions may be wetter and more conducive to outside moisture problems, internal damage from decay is linked to problems that will occur in any area of the country – roof or wall leaks, drainage problems, condensation, etc.
Decay & Termites: 2003 IRC

Here’s the decay probability map, as the IRC identifies it. There is nothing in the text of the specific decay protection requirements that refers to the areas of the map.
In the 2006 IRC the map and some of the text in previous editions is deleted and decay protection provisions apply in all parts of the country.

The requirement for field-treating of cuts and bored holes has been added. Field treatment must comply with AWPA M4, but as you see there are some exceptions that apply to pines in recognition of the fact that pine readily accepts chemical treatment.
Decay & Termites: 2003 IRC

TERMITE PROTECTION

• Taken from CABO Dwelling Code
• Not tied to separation from soil or concrete
• Must consult map: “In areas favorable to termite damage …”
  – No correlation in text to map terms
• Requires protection in form of either
  – Chemical soil treatment (no guidelines)
  – Preservatively treated or naturally durable wood (used where?)
  – “Physical barriers” (no guidelines)

The termite-related provisions in the 2000 and 2003 IRC are flawed. They were brought forward from the CABO One- & Two-Family Dwelling Code, the source of most of what’s in the IRC. They aren’t tied to separating the wood from soil or concrete/masonry as is done in the IBC and as was done in the other old codes. Instead the reader is referred to another map and told that the provisions of the section apply in “areas favorable to termite damage.” However, as with the decay map, there’s no correlation between the map areas and the requirements except in one instance where foam plastic insulation on foundation walls is mentioned.

Once the reader decides that the requirements apply, the construction details that apply for decay protection (and which we’ll discuss shortly) and which typically also apply to termite protection aren’t stipulated. Instead the reader is told that the protection methods that you see on this slide should be applied, either individually or together. But as you’ll see from the comments on the slide, there are no guidelines given to the application of these methods.
Unlike decay, there may be some areas of the country where termites aren’t a problem and where there is no need to take special precautions. However, once termites are determined to present a problem, the protection can’t be graduated in some fashion as the 4 regional areas in this map would indicate. Termite protection should be required if termites are present.
In the 2006 IRC there have been changes made to the code. While the user is still given some options in protection methods, that information was updated and is written in such a way that it is easier to read.
Let’s talk now about some of the detailed code requirements. While it’s not important that you necessarily remember all of the details, particularly the minimum dimensions, keep in mind that the code addresses the use of wood when it’s close to the ground or to concrete or masonry. The details reflect the decay protection requirements of the IRC. Because the 2003 IRC’s termite protection requirements are so confusing, the use of naturally durable wood or treated wood – which are acceptable as protection methods, but for which details aren’t given -- in these locations will be consistent with the requirements of the IBC for termite protection.
Unless treated wood or naturally durable wood is used, wood should be placed no less than 8" from the ground for the bottom plate, as we see in this situation. A second circumstance addressed in the section seems to say that, regardless of how far it is from the ground, an impervious moisture barrier is also required under the plate if it's not treated or naturally durable. We’re showing this as a non-wood veneer because, as we’ll see in a moment, when wood veneer is used the details are somewhat different.
This is very commonly violated code provision. Here’s an example of a house in which the bottom of the brick veneer is approximately 1” from the ground line. If there is a brick ledge, the bottom plate is probably still less than 8” from the ground and preservatively treated wood or naturally durable wood is required.
Water flow along this wall is toward the front and back of the house, and to make matters worse you'll notice that the builder put a wing wall at the front of the building, forming a very effective dam. Bricks have been removed at the bottom of the wall to allow water to flow through it, and there is some slight slope of the soil from the wall to the end of the wing wall, perhaps allowing the worst of the runoff water to escape.
The codes require that wood veneer that isn’t treated or naturally durable must be no less than 6” from the ground. This maintains the 8” separation for framing and allows the veneer to overlap the framing and shed water.
This is another commonly overlooked code requirement. Here’s an example: hardboard siding which is approximately 1-1/2” from the ground. This clearance is as much a termite prevention as decay (termites are forced to build tubes on the foundation wall to get to the wood, making them visible), but in this case the siding regularly gets splashed when water strikes the soil, and thick plants keeps the area damp causing decay along the bottom of the siding.
As a result, the bottom 18" or so of the veneer panel is decayed. Here’s what it looks like, although on the end of the wall there was probably as much water absorption from the edge of the panel as from the bottom.
In addition to maintaining the minimum 6” clearance from the soil, a minimum separation from concrete such as a walk must be 2”.
Decay & Termites: 
Construction Details

Here’s the same wall that we saw a few slides back. In addition to a small separation between the veneer and the soil, notice that the porch floor has been poured against the hardboard panel. This is true around the porch – the veneer is too low and the concrete surface was poured against the hardboard.
Floor joists and their supporting girders are required to be minimum distances above the ground in crawl spaces unless treated or naturally durable wood is used. While this applies for moisture protection, the primary reason is for termite protection. These large distances make it difficult for termites in the soil to reach the wood without their presence being seen.
When girders and floor joists are supported by wood posts which rest on concrete piers in a crawl space, the post must be not less than 8" from the ground. An impervious moisture barrier of some sort is also required between the bottom of the post and the concrete.
When columns that are untreated or not of naturally durable wood are used in basements or in exposed areas such as porches, and when they are supported by piers or metal pedestals, they must be at least 1" above the concrete floor or porch and 6" above the soil.
When wood columns are used in basements or in exposed areas such as porches, and there is no concrete floor, the separation must be 6" or more.
Decay & Termites: Construction Details

GEOGRAPHICAL AREAS (‘03 IRC SEC. R323.1.2 & ‘06 SEC. R319.1.3):

• Relatively vague: “…where experience has demonstrated a specific need…”

• Mandatory use of treated or naturally durable wood
  – For supports of balconies, porches, and similar appurtenances
    • Where not protected by overhangs, eaves, other coverings & would allow moisture to accumulate on surface or at joints between members
  – Members include
    • Girders, joists, decking
    • Posts, poles, columns

Be aware that the IRC has a fairly vague requirement that appears to be aimed at outside conditions where circumstances – climate, construction details, whatever – permit water to remain either on the surface or between members and cause decay in balconies, porches, and similar other permanent building elements.
Unless they carry a treater’s quality mark, landscape timber shouldn’t be used for structural applications or for any application that is intended for long-term use. They are the left-over material from plywood manufacturing, commonly called peeler cores, and typically only receive a cursory exposure to a treating process, if at all. The peeler cores are the center of the log from which plywood is made and they contain the heartwood of the timber. Heartwood, being denser than the other wood, doesn’t readily accept treating chemicals, meaning that the center of each piece is highly susceptible to decay and termites.
Floor Framing

Because the common applications for wood framing are in residential construction, the details of this program will be based on the IRC which addresses residential uses. Similar provisions may be found in the IBC, but the scoping of the codes are such that the IRC is to be used for dwellings. Where there are differences in the two codes, however, the program will address those differences.
Learning Outcomes

By the end of this eCourse module, you will be:

1. able to learn the code requirements for framing of structures under conventional construction provisions
2. knowledgeable in some depth about the use of I-joists as floor framing products

In this eCourse module, begin to learn the code requirements for framing of structures under conventional construction provisions. Learn in some depth about the use of I-joists as floor framing products.
Floor Framing

Minimum Joist Bearing
• 1-1/2” on wood or metal
• 3” on concrete
• 1”x4” strip (if joists nailed to adjoining studs)

First, let’s talk about the code requirements for the minimum bearing surface needed to insure that wood joists and beams are adequately supported.

The code stipulates the minimum dimensions that you see here.
Here are some illustrations of those provisions as well as another portion of the code that addresses bearing.

1. A minimum of 1-1/2" bearing is required for joists or other wood framing members that rest on wood, whether it's on plates as shown in the upper right or whether it's on beams or girders. A bearing surface of this size will avoid crushing the wood fibers. The same minimum bearing dimension is required on metal, an example of which is bearing on joist hangers.

2. Bearing on concrete is required to be at least 3". This relatively wide distance is required to insure that a reasonable bearing surface will remain if the edge of the concrete should chip off under the joist.

3. The section of the code on bearing permits joists framed into studs to bear on a 1x4 when the joist is nailed to the side of the stud.

4. In separate sections, the IRC permits joists to frame into the side of beams if the end of the joist is supported by a 2x2 as you see shown in the lower left.
Enforcing these provisions is pretty simple. However, be aware that there may be other bearing-related problems that don't quite fit the specific situations addressed by the code.

Here's a situation in which we see both no bearing at all and bearing on some sort of small shim.
In this picture the truss has an adequate bearing dimension measured perpendicular to the front edge of the plate. But it's not being completely supported across the width of the truss. This is a situation not specifically addressed in the code but which should be corrected. Not having the full surface of the truss bearing on the plate may mean that it can lean if subjected to lateral loads.
In the older codes determining allowable spans of floor and ceiling joists was somewhat laborious. In the Standard Building Code the reader was referred to AF&PA's span tables for joists and rafters.

In the Uniform Building Code and the One- & Two-Family Dwelling Code, the reader was referred to a set of tables in the code based on our tables.

In all cases, it was necessary for the reader to calculate allowable spans. The process required a degree of knowledge that many users didn't have.
Floor Framing

Joist Span Tables
  • Pre-calculated
  • Spans for 4 most common species
  • Other species & conditions refer to AF&PA generic span tables

The IRC contains a set of pre-calculated span tables that are simple to use and require no number crunching. The tables list spans for the 4 most common species of lumber -- Douglas Fir Larch, Southern Pine, Hem-Fir, and Spruce-Pine-Fir (Canadian SPF, not U.S. SPF-S).

In situations where the species of wood is different or where the loading conditions are different than what's shown on these tables, the user is referred to AF&PA's generic span tables.
The code limits cutting and drilling of joists. To understand why the code provisions contain the restrictions that they do, an understanding of what's happening in a joist or rafter -- or any horizontal framing member -- that's under load is important.

The blue-green arrows in this drawing represent the uniform load on a floor, and the green arrows represent the resistance provided by the walls on which the ends of the joists bear.

The joist under load tries to bend, putting the wood fibers in the bottom half under tension. That is, the fibers are trying to pull away from each other. The fibers in the top half are under compression, being pushed together. For a joist under uniform loading, as is generally the case in dwellings, these forces are at their maximum at the center of the joist span.

At the centerline of the joist, as represented here by the red broken line, is the neutral axis where there is neither tension or compression.
As a further explanation of the reasons behind the prescriptive limitations on notching and boring of joists, let’s talk about bending moment. When a force is applied to an object, it will tend to try to rotate the object about it’s support, with the moment being equal to the force times the perpendicular distance from the support. In a uniformly loaded beam the moment is greatest at the center of the span as shown here.
With that explanation, perhaps the code requirements, as illustrated here, will make more sense.

First, note that in the middle third of the joist, no notches are permitted. This is because the bending moment is greatest at the center of the span and because the compression and tension are greatest at the edge fibers.

Remember that a neutral axis exits in the center of the joist? The limitations that you see on both the size of bored holes and the distance from the edge of a hole to the joist edge reflect that condition.

You’ll notice that there are two limitations on notch depths -- D/4 at the ends and D/6 elsewhere. Notches at the end of the member don’t affect the flexural strength of the member directly, so they can be somewhat larger than away from the support.

Notice that the limitation on notches applies whether the notches are in the top or bottom of the joist.

Keep in mind also that, although the examples of notches shown here are large cuts, these limitations apply even if the notch is a very small cut.
This brings us to the question of whether you can drill holes in the middle third of the span. The code says specifically that you can’t notch or cut in the middle third because of the bending moment and the fact that tension and compression in the edge fibers of the wood are so high. But it doesn’t mention drilling. As long as the hole is in the middle of the joist – in the neutral axis – it should cause no problems. However, as the hole is moved to the edge it begins to act like a notch by interrupting the wood fiber in areas where the stresses are highest. The code is silent on this situation, but our recommendations are that if holes are necessary in the mid-third of the span they shouldn’t be allowed anywhere but along the neutral axis.
Here is some background information on the effect of notching joists and other bending members such as rafters:

• The prescriptive limitation of D/6 for the maximum depth of notches away from the corners has almost no effect on the stiffness of the member.

• The Fb (bending) values for members in the NDS already reflect reduction in strength due to the assumed presence of edge knots, so it has little effect on Fb for a given species, grade, and size of lumber.

• Notches can result in problems if the prescriptive provisions aren't followed. Stresses are increased at notch corners (in fact the NDS recommends rounded corners), and stresses parallel to grain and tension perpendicular to grain are increased at notches.
Floor Framing

Background (cont’d)

• Affect of notches (cont’d)
  – They cause failure to begin at lower loads than expected from un-notched member of a depth equal to net depth of notched member

And finally, if the prescriptive provisions aren’t followed it’s possible that failure can occur at the notch for loads lower than what can be properly supported by an un-notched member of a depth equal to the net depth of the notched member.
Examples of violations of these provisions of the code are pretty common, as you see here.
However, keep in mind that what we're concerned with here is a disruption of the wood fiber in the compression or tension area of the member. And that disruption may be something that's not as neat as the notches that we saw in the drawings.

Here's an example of that. Although we've been talking about floor joists, the code limitations apply to floor and ceiling members and to rafters. In this example something has torn away the wood fiber in the middle of this joist on its upper edge. This missing fiber, just like a neat notch cut in the middle of the span, is a code violation.
Our discussion on cutting and drilling of joists has talked about solid sawn lumber. It's important to remember that engineered wood products, such as I-joists as shown here, are very different materials, and the prescriptive limits that we've been talking about don't apply.

I-joists often have knockouts for small holes to permit wiring and small piping. Larger holes may be permitted, but it's important to check with the manufacturer on both the permitted size and location of larger holes. Notches on the edges are seldom permitted. Any alteration to an I-joist should follow recommendations of the manufacturer.

Glue laminated beams are commonly used for beams and headers, and because they are made from solid wood elements, they might appear to be no different from solid sawn pieces of lumber. However, they are made by gluing together layers of solid sawn lumber, and any alterations -- including boring or notching -- should be made only if the effect of the alteration is considered on the design of the member, either by the glu-lam manufacturer or by a design professional.
Floor Framing

Lateral Support

• Ends of joists supported laterally by
  – Solid blocking
  – Attachment to header, band- or rim-joist, or adjoining stud
  – Other approved means

• IRC Sec. R502.7.1 requires support ≤ 8’ o.c. for joists > 2x12

Joists under load will tend to lay over, particularly at supports and when the joists are very tall in comparison to their width. This can be caused by either lateral loads being applied to the structure -- wind or seismic loads, for example -- or by vertical loads which cause the joists to buckle. To counter that tendency, the code requires supports at the ends to laterally bolster the joist.
Here's an example of the ends of the joists being laterally braced by nailing to a rim joist. In fact, this looks as if 2x2s have been added along one side of the joist.

Also you see an example of bridging that provides lateral support.
Lateral support is provided here by the joist hangers.
The IRC addresses the situation in which a bearing wall is supported by the joists of a floor. Ideally the supporting joists should be perpendicular to the wall and the bearing wall should be directly supported by a bearing wall below. There are two situations in which that may not happen:

1. When the joists run perpendicular to the bearing wall and the bearing wall is offset from the supporting wall below, under the IBC that offset is prescriptively allowed to be no greater than the depth of the joists unless the joists are sized to support the added load. The 2000 IRC doesn't address the situation. However, the 2003 IRC was amended to reflect the requirements of the IBC.

2. When floor joists run parallel to the wall, both codes require that the joists below the wall must be doubled or a beam of adequate size must be provided.
The IRC addresses cantilevered floor joists in two ways. The general limitation is contained in Section R502.3.3 and permits an overhang no greater than the actual depth of the joists.

However, there are two tables that permit more flexibility.
The tables address the two conditions shown here. Note that the tables are predicated on a number of conditions and are subject to the conditions contained in the various footnotes.
Let’s talk about the use of some engineered wood products as floor framing. We’ll begin with I-joists.
Floor Framing

- “I” profile similar to I-beam
- Substitute for solid sawn for
  - Floor framing
  - Roof framing
  - Headers

An I-joist has a simple configuration and can be used for a variety of purposes.
Wood I-joists are composed of two components -- the central portion called the web and the top and bottom edges called flanges. Both elements may be any of several materials.
Floor Framing

Flange Material: Structural Composite Lumber

In addition to solid sawn lumber, I-joist flanges can also be of structural composite lumber, two examples of which are shown here.
Webs are made of wood structural panels, the generic name for plywood and oriented strand board (OSB).
Floor Framing

Manufacturing Standard

• ASTM D5055: Specification for Establishing & Monitoring Structural Capacity of Prefabricated Wood I-Joists

• Establishes allowable capacity
  – Shear
  – Moment
  – Tensile
  – Deflection

The codes require that wood I-joists be manufactured in such a method that they will comply with ASTM D5055.
The depths of I-joists do not follow the nominal dimensions for solid sawn lumber. A specified I-joist depth could be 11-7/8" for example. Here you see an illustration of the variety of depths available.
Floor Framing

The spacing of I-joists is measured center-to-center of flanges, similar to measuring the spacing of solid sawn lumber.
The code requires that engineered wood products, including I-joists, must be installed in accordance with the engineered design. There are no standard prescriptive installation requirements for things such as bearing or fastening, although the WJMA has published a list of installation "do-s and don't-s" which would be applicable to all engineered systems. The major provisions from this list will be mentioned in a moment.

Additionally, it's important to emphasize that each manufacturer will have its own installation requirements for its products. These, along with the engineering design, will dictate how the I-joist should be installed.
Floor Framing

Attachment at Bearing Ends

All manufacturers will specify a minimum bearing length that may or may not be the same between the manufacturers. The intent is to provide adequate space to rest the I-joist, to provide room for fasteners, and to insure room for rim boards and other lateral support members.
Another common design element is the web stiffener which is intended to prevent the then web from buckling under concentrated loading.
Another way to resist web buckling at the ends is to provide a rim board. Or a cripple block can be added, which is somewhat similar to a web stiffener in function. The requirement to be 1/8” higher insures that the block won’t be cut too short – or shrink after drying out – and put the load directly onto the top flange and allowing some web deflection.
Here’s a typical suggestion when there are concentrated loads on the I-joist; simply bypass the joist altogether to avoid the load deflecting the web or causing the web to slice through the flange.
We’ve shown web stiffeners at the ends of the span. They should also be used where there are load concentrations elsewhere. Notice that the stiffeners, even at the end of the span, are suggested to be slightly less than the depth of the web. This is to insure that the length of the stiffener isn’t greater than the depth of the web, cause the web-flange bond to break when the stiffener is forced into place.
Here’s another common limitation.
I-joists are commonly supported by hangers, and the proper use of hangers is important to the service life of the joist.
Joist hangers should be designed for use with I-joists. Those for solid sawn lumber shouldn’t be used. And it’s important that the I-joist be completely supported.
Supporting a hanger from an I-joist should only be done in such a way as to not damage the supporting I-joist. And the supporting joist must be designed to support the load.
Even when not being hung from the top flange, it’s critical that the connection be detailed to insure that the complete supporting joist is supporting the hanger.
Openings in I-joists are different than those in solid-sawn members.
Manufacturers will specify details for providing openings in their members. I-joists behave differently from solid sawn members. The flanges, which should never be cut or drilled, carry the moment loads and the web carries shear, primarily at the ends. For that reason larger holes can be permitted in the web in midspan than at the ends.
Some manufacturers provide knockout holes along the length of their joists to accommodate small pipes and wires.
I-joists can, if designed properly, be used in a wide variety of uses. Here we see them as cantilevered joists.
They can be used to duplicate almost all elements of solid sawn construction. Here are some examples.
Like I-joists, parallel chord trusses are engineered products and should not be altered without approval of a design professional.
Floor Framing

- Parallel chord trusses normally made with dimension lumber
- Fastened with metal plate connectors

The code addresses references for design of wood trusses.
Wall Framing

This portion of the program will address the code requirements for wall framing, although we won't address bracing in this section. The program contains a separate bracing section.
Learning Outcomes

By the end of this eCourse module, you will be:

1. Knowledgeable about code requirements for general wall framing

Similar to the section on floors, this eCourse module addresses code requirements for general wall framing. Bracing requirements are discussed under Lateral Load Bracing.
Let’s start at the bottom. The default code requirements are that bottom plates be attached to the foundation with bolts. The code addresses minimum bolt diameter, minimum penetration into the foundation, maximum spacing between bolts, and the maximum distance from the end of each piece of plate for the first bolt.
Wall Framing

• Other devices must be approved

In practice, however, we often see other devices. All of those devices are proprietary and there aren’t any general statements to make about them except:

1. They aren’t specifically recognized by the code and must be accepted under the alternate methods and materials section of the code.

2. In order to insure that these devices provide connection strength comparable to bolts, they must be used in accordance with the manufacturers’ recommendations. Typically users in the field want to space these devices farther apart than what’s required by the manufacturers because they assume that they can be used in the same manner as bolts.
The IRC addresses minimum stud lengths, although the 2000 edition is somewhat confusing. Because Table R602.3.1 addresses stud heights above 10 ft, the implication is that the default maximum stud height is 10 ft. However, the 2000 edition isn’t specific. The ’03 edition has been revised to clarify that the maximum stud height is 10 ft unless the provisions of Table R602.3.1 are followed.

In the ’00 edition of the IRC there’s nothing to address nonbearing stud heights. The ’03 edition limits nonbearing studs to 20 ft, although there are some other requirements placed on studs that are that high.
### STUD SPACING

<table>
<thead>
<tr>
<th>STUD SPACING</th>
<th>2 FLR/ROOF/CEILING</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRC TABLE R602.3(5)</td>
<td>ROOF/CEILING</td>
</tr>
<tr>
<td>2X4</td>
<td>24 (10')</td>
</tr>
<tr>
<td>2X6</td>
<td>24 (10')</td>
</tr>
</tbody>
</table>

If greater than 10 ft. see Table R602.3(1)

Stud spacing is also limited, as we see here in a version of IRC Table R602.3(5). Spacing is limited by loading.
Wall Framing

- UTILITY GRADE STUDS
- IRC Section R602.2
  - Bearing walls can support no more than roof & ceiling (spacing ≤ 16” o.c.)
  - No grade-specific limitations – bearing wall height req’ts same as other grades
  - No limitations on use in nonbearing walls

Utility Grade studs are relatively low-strength members and often look pretty rough. However, the code permits their use under the limitations that you see here.
Wall Framing

GENERAL WALL FRAMING
• 3 studs at each corner
• Double top plate on exterior & bearing walls
  – Overlap corners and intersections
  – Offset end joints
  – Joist/rafter bearing near stud
• Single top plate on interior nonbearing walls
  – Overlap corners and intersections

The general framing provisions for walls are similar to what’s been in the UBC and SBC for a long time. We’ll talk more in a moment about the details.
Here are the requirements for top plates. Notice that the joints in the individual pieces of the top plates must be spaced no closer than is shown. The differences in the spacing requirements contained in the IRC and IBC shouldn’t be a concern. This same difference existed between the Uniform Building Code and Standard Building Code, and there was no evidence of either of these numbers being more correct structurally than the other.

Also notice that where roof/ceiling framing bears on the plate, it must be more-or-less above the studs if they are spaced at 24” o.c.
Wall Framing

CRIPPLE WALLS

• Stud size not less than wall above
• If more than 4’ high, stud size as req’d for an additional story
• If less than 14” high
  – Solid blocking
  – Sheathed one side with WSP
• If more than 14” bracing req’d

Cripple walls are addressed in some detail in the IRC, maybe more so than they were in the older codes. Because cripple walls often act like another story, details of their construction are important, particularly in high-seismic areas.
The IRC contains pre-calculated headers tables. Users of the UBC will remember that it was pretty vague about headers. The SBC contained header tables, but they were different than what’s contained in the IRC.
There are pre-calculated header tables in the IRC. These also appear in the IBC.
Cutting of studs is probably one of the most common code violations.
Wall Framing

- Size & location of notches & holes limited
- Bored holes not allowed in same section as notch

We’ll see some examples of both code requirements and common violations in a moment.

Although the code says that holes aren’t allowed in the same section as notches, it doesn’t explain what’s meant by “same section.” Keep in mind that the intent is to preserve as much continuous wood fiber as possible to transfer forces, while still permitting some limited cutting of the fiber. Holes and notches placed so close to each other that they effectively destroy most of the fiber would be in violation of this requirement.
Wall Framing

EXTERIOR & BEARING WALLS

5/8" min. from stud face

Hole diameter max. 40% of stud width (60% if stud doubled – max. 2 studs)

Notch max. 25% of stud width

NONBEARING WALLS

Hole diameter max. 60% of stud width

Notch max. 40% of stud width

Here are illustrations of what the code permits.
One of the functions of the top plate is to transfer lateral forces in the wall and help prevent racking (more on this in the bracing section). For that reason it’s important that continuity of the plate be maintained if it’s necessary to cut it. The code requirement is for

1. The metal splice plate to be of a minimum thickness and width, and
2. The nails on either side of the cut (6 req’d in the 2000 edition & 8 req’d in the 2003 edition)

What it doesn’t say is how those go together. This illustration is similar to what’s in the code. Putting so many nails so close together may split the wood. It might be better if the strap were wide enough to span the cut in both levels of the top plate and the nails distributed in a wider fashion. Or if the steel plate were longer and the nails a greater distance from each other.

Wood structural panels nailed across the cut would accomplish the same thing.

Also not addressed is whether the top plate can be completely cut and how to compensate for that situation.
Here's an example of notching and boring of studs in compliance with the code.

A point to make here is that the straps that you see on the face of the studs don't do anything to compensate for over-cutting. They simply provide protection of the pipes from nail puncture. There are, however, proprietary products that are intended to reinforce the stud if it's over-cut.
Wall Framing

Here’s an example of a violation – the holes are too near the face of the stud.
Wall Framing

At first glance, this appears to be in compliance with the code. However, it might be that these two pipes have effectively destroyed the continuity of the wood fiber in the stud by cutting out most of the wood fiber in one section of the stud. And it looks as if the black pipe may be too near the back face of the stud. Again, the strap doesn’t compensate for those problems.
Since most violations occur as a result of trying to put pipes into a wall, here’s a good solution: a double-stud wall.
Here’s another solution when accommodating large pipes – using wider studs. However, in this example because of the angle of the pipe the hole is larger than allowed, and it may be too close to the face of the stud.
Wall Framing

And when wider studs are used it’s important that they rest completely on a plate. The code requires for the plate to be at least as wide as the studs.
Wall Framing

And important consideration in the IRC’s wall requirements is bracing. We have a complete section on that subject.
Lateral Resistance in the IRC

Let’s continue our discussion of the IRC’s provisions which address wall construction and talk at length about bracing. Although the program will talk about the IRC’s prescriptive requirements for bracing, it will also talk about those conditions which necessitate the use of bracing.
Learning Outcomes

By the end of this eCourse module, you will be:

1. Knowledgeable in depth about the general concept of bracing wood structures
2. Knowledgeable in detail about the IRC requirements for wall bracing

In this eCourse module, learn in depth about the general concept of bracing wood structures and in detail about the IRC requirements for wall bracing.
Let’s start with a very basic question: why does the building code even require that bracing be provided in buildings?
Why Does the Code Require Bracing?

And what could cause this?

The IRC never says that buildings are supposed to remain square, but that’s the basic intent.
LOADS!

- Vertical loads
  - Dead
  - Occupancy (live)
  - Snow
- Lateral loads
  - Wind
  - Seismic (earthquakes)
- Building’s response

Loads on the framing tend to make the framing move. Even vertical loads such as snow loads can make the framing try to rack.
Most loads on a building are applied by vertical pressure or gravity. Roof framing bears on wall framing which bears on the foundation. Gravity loads, and relatively light wind loads, are what are addressed by the conventional construction provisions of the IRC that will be discussed shortly.
Lateral loads will also be applied to a structure. The most common is wind, and the IRC addresses winds up to a specific level in its conventional construction provisions. We’ll touch on those provisions also. Seismic forces will also occur in many parts of the country.
Lateral Loads

- Wind Loads – produced by extreme weather changes:
  - Thunderstorms
  - Tornadoes
  - Tropical storms
  - Hurricanes

Wind loads can be resisted by design. Normally we think about wind loading from high-wind events such as hurricanes or tornadoes, but high straight line winds like we often see in thunderstorm can load up the frame of a building. Later we’ll talk in more detail about hurricane winds, but let’s talk for a moment about tornadoes.
Buildings can be designed to resist damage from tornados, but it’s not economically feasible to do so for the more severe storms. The Fujita scale is used to rate the intensity of a tornado by examining the damage caused by the tornado after it has passed over man-made structures. F-0 has light damage while F-5 has incredible damage. Over 80% of all tornados are classified at F-3 or below.

The reason for this slide is to illustrate that different tornados pack different punches. The majority of tornados are not the incredible ones. A word of caution, however, these lower strength tornados can cause horrific damage. We don’t intend to imply otherwise.
The Fujita scale has recently been revised. The F-scale numbers have been increased to 8. These numbers are based on observed damage to 28 indicators with the indicators ranging from damage to large buildings to damage to trees.
This graphic shows the impact of the tornado. Homes in the direct path were completely destroyed while those a block or two away received a variety of damage. The home about three blocks away received minimal damage.

Structures which receive a direct hit from an F-4 or F-5 tornado will likely suffer extreme damage, regardless of how it’s constructed. It’s the buildings on the periphery of such an event and buildings involved in less severe storms that will perform differently depending on the construction. While applying high-wind design documents such as the AF&PA Wood Frame Construction Manual to all structures in areas that may see a tornado may be unwarranted, insuring that they are constructed to the general requirements of the code will go a long way toward insuring limited damages in near-misses or small storms.
The Basic Concept …

… is to tie it all together, regardless of where the building is located.

The code’s intent, even in conventional construction, is to attach all the parts to each other in such a way that the complete structure withstands both gravity and lateral loads. It should be, in effect, a box. But a box tied to the ground a little more thoroughly than what we see here.
Bracing – whether it’s to resist the day-to-day loads on the buildings and the typical storms or whether it’s to resist high-wind or high-seismic events – is critical to the performance of the building.
Wall Bracing …

- … comprises the vertical elements in the lateral force resisting system (LFRS) for many structures.
- … supports the horizontal diaphragms and transfer the resultant forces from the applied lateral loads into the foundation.
  - Seismic loads
  - Settlement loads
  - Wind loads

Here’s a summary of what we’ve discussed so far.
Without being braced in some fashion, wood frame walls tend to rack in response to loads. In this illustration we’re showing lateral loads, but the same holds true with vertical loads.
Wall Bracing Methodologies

- **Three concepts:**
  1. Triangle geometry
  2. Fastener moment couples
  3. Rigid joints

There are fundamentally three ways to stop a frame from racking. We’ll talk in some detail about the application of these methodologies, but all of the bracing materials and systems, even in low-load areas, involve some version of what you see here.
Let’s talk in some detail about the methods of providing bracing, starting with the use of triangles.

Diagonal tension ties create a triangular geometry within the frame that in itself, is a stiffening element. Compression ties are rarely effective, if at all. Diagonal board sheathing, however, works in this mode.
Wall Bracing Methodology 1

- Tension tie brace

This is one of the simplest ways of providing lateral resistance to a wall assembly. However, let-in braces require a perfect and well connected fit in order to work properly, which is often difficult to achieve. And, they cannot provide the same capacity as a properly constructed wood panel shear wall.
A very efficient way to brace walls, and one that was common years ago, is to sheath the wall in diagonally oriented boards.
Wall Bracing Methodology 2a

- Fastener Moment Couples

Secondly, the perimeter-nailed panel resists racking through the resisting action of the perimeter nails to the applied racking moment on the panel. Nailed horizontal boards with at least 2 nails on the same stud has the same effect, but to a lesser degree. Here the nails do most of the work.
In its prescriptive provisions the IRC refers to braced walls as braced wall lines. In engineered design, however, the bracing is provided by shear walls. Shear walls feature special nailing and hold-down connections designed to resist applied lateral loads in shear and overturning. Minimum wall aspect ratios apply in order to develop “shear wall action” as opposed to “cantilever beam action” when the wall panel aspect ratios become very slim. Typically, the closer to the minimum aspect ratio for a shear wall, the more dense the nail perimeter nail spacing. In shearwalls, it is the perimeter nailing that is the most effective in resolving the transferred applied forces.
Shear walls are a vertical building element that can resist lateral forces applied at the top of the wall. In a wood shearwall, the panel perimeter nails provide the bulk of the racking resistance through wood bearing and nail deformation when the lateral external force is applied. Horizontal wall sliding is resisted by nailing or other anchorage installed along the bottom of the shearwall sufficient to resist the external lateral force.
In order to make this concept work, panels must have a height-to-width aspect ratio of less than 3.5 to 1. This ratio is sufficient to develop “racking action” in the shear wall panel. Aspect ratio’s greater than this produce cantilever beam action - a completely different behavior that is much less effective in resisting lateral forces. The concept of aspect ratios is incorporated into prescriptive bracing requirements, but isn’t specifically addressed. We’ll soon discuss prescriptive limits to minimum widths of bracing panels, and that concept is generally based on the concept of aspect ratios.
Nailed horizontal boards with at least 2 nails on the same stud has the same effect as the use of panel product bracing, but to a lesser degree. Here, like in the panels, the nails do most of the work.
Wall Bracing Methodology 3

• Rigid Joints

A third method absorbs the racking moment directly in the rigid joints in the corners. This is called a moment frame since the rigid corners induce bending moments in all the members near the rigid connections, so indirectly, the frame members also resist the racking forces through flexure.
Remember this house? Notice the failure of the garage door header at the corners. In dwelling construction, this type of wall design – an opening with small braced wall sections on either side – is ideal for the application of a moment frame.
Proprietary systems such as APA Sturd-I-Frame try to utilize normal construction – a couple of anchor bolts and integrating the header and sheathing with nails. Notice the attention given to making the corners rigid.

Construction of these types of assemblies requires careful attention to details.
Now let’s look at the prescriptive method in which the IRC addresses wall bracing. The code approaches the subject by specifying where the bracing is to be placed, what materials are acceptable, and what quantities of bracing materials are needed.
Braced Wall Frame Systems

Braced Wall Lines

- **Series of braced wall panels**
  - Sections of walls in which bracing materials are located
  - Width of panels dependent on material
  - Number of panels dependent on material and loads
- Required in both directions, each story
- Spacing is vague in 2000 IRC for low-seismic areas. Maximum spacing in IBC is 35'. In 2003 IRC spacing limit of 35'.
- More restrictive in higher seismic
- Offsets \( \leq 4' \) (for a maximum total of 8')
- Panel start \( \leq 12-1/2' \) from end of wall line

Braced wall lines are walls made up of a series of unbraced sections and sections of walls that are braced with acceptable materials in the required amount. These braced sections are called braced wall panels.

The braced wall lines are required to be placed in both directions of the floor plan and are required in each story.

Often the exterior walls will provide the required braced wall lines. However, when the distance between exterior walls is too large, an interior wall is required to be a braced wall line. The IBC is specific about the maximum distance between braced wall lines being 35 feet. However, for some reason the 2000 IRC is vague. The only mention on spacing is in Section R602.10.11, which addresses spacing in high seismic areas. In the ’03 edition, the IBC’s 35 feet provision has been added.

Braced wall lines are permitted to have an out-of-plane offset of no more than 4 feet in one direction, with a provision saying that total offset can be no more than 8 feet. This would allow a wall to have a 4 foot offset in each direction.
The idea is to divide the building into boxes …

The concept in the IRC is to break the structure of the building into boxes with a limited aspect ratio.
Let’s try to talk in some detail about how the IRC bracing provisions would apply to a building. Here’s a footprint of a house. Let’s apply the provisions of the code to it.
First, the code requires that all exterior walls must be braced wall lines. On this example, this brings up two questions:

1. How does the inset at the entry affect the location of the braced wall line? Does the bracing wrap around the inset? Are the walls on either side of the entry considered separate braced wall lines?

2. Does the back wall have to be a continuous braced wall line, or can it wrap around the exterior of the garage?

We’ll talk about offsets and the entry in a moment, but the intent of the code’s provisions would be for the rear braced wall line to extend through to the side exterior wall, making the house/garage wall a portion of the braced wall line. The braced wall line can’t be taken around the garage’s exterior perimeter because of limitations on offsets that we will talk about in a moment.
The next thing to be considered is whether interior braced all lines are required. In low seismic areas, braced wall lines can be a maximum of 35' o.c. The code permits spacing up to 50' but requires a somewhat complex process to determine to what extent above 35' is permitted on a given structure.

Regardless of the exact spacing limitation, for the sake of example we’re showing a situation in which an interior braced wall line is required.
Now let’s talk about the entry and why the rear braced wall can’t be offset to wrap around the garage. The code permits the offset as shown here – 4’ in either direction from a braced wall line, for a maximum offset of 8’. There’s no requirement to treat the offset in any particular fashion – no extra bracing, no special connections, etc. The code isn’t specific about whether bracing is needed in the offset. If the minimum amount of bracing, and its spacing, can be provided in the portions of the wall not in the offset, nothing is needed in the offset itself.

The rear braced wall line can’t be wrapped around the garage because of the maximum offset limit of 4.’
Would this be counted as an offset? The code’s not clear. But probably not. These are two braced wall lines that happen to terminate on the same wall near each other.
Now that we know where the braced wall lines are required, let’s add some bracing and talk about the details. Table R602.10.1 specifies bracing amount and location. Let’s look at the table.
When Where How How Much

Table 602.10 in the IRC specifies the amount of bracing material that is required and where the bracing is to be applied.

Here is the first of the table. Notice that it's predicated on the SDC and/or wind speed for the location in question and the story to be braced. Then the acceptable types of bracing, identified by the numbers on the previous slide, are listed. The final column talks about the amount of bracing panels required and the location of the panels.

The lower seismic zones -- A, B & C -- require the least amount of bracing. Zones D1 and D2 require much more because of the intensity of seismic forces. Where wind speeds exceed 110 mph, engineered shear walls are required.
IRC Table R602.10.1 Wall Bracing

<table>
<thead>
<tr>
<th>SEISMIC DESIGN CATEGORY OR WIND SPEED</th>
<th>CONDITION</th>
<th>TYPE OF BRACE**</th>
<th>AMOUNT OF BRACING***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category A and B (S_s ≤ 0.35g and S_d ≤ 0.33g) or 100 mph and less</td>
<td>One story</td>
<td>Methods 1, 2, 3, 4, 5, 6, 7 or 8</td>
<td>Located at each end and at least every 25 feet on center but not less than 96% of braced wall line.</td>
</tr>
<tr>
<td></td>
<td>First story of two story</td>
<td>Second story of three story</td>
<td>Methods 1, 2, 3, 4, 5, 6, 7 or 8</td>
</tr>
<tr>
<td></td>
<td>First story of three story</td>
<td>Top of two or three story</td>
<td>Methods 2, 3, 4, 5, 6, 7 or 8</td>
</tr>
</tbody>
</table>

The site of the building must be reviewed for applicable Seismic Design Category and Design Wind Speed.

The lower seismic zones -- A, B & C -- require the least amount of bracing. Zones D1 and D2 require much more because of the intensity of seismic forces. Where wind speeds exceed 110 mph, engineered shear walls are required.
Here we see the acceptable types of bracing which are based on which story is being braced. We'll talk about the types of bracing in a moment.

Notice that all 8 bracing methods are acceptable in 2-story buildings and in the top 2 stories of a 3-story building. But Type 1, let-in 1x4, is not acceptable in the bottom story of a 3-story building.
The table specifies the amount of bracing material that is required and where the bracing is to be applied. Notice that for lower stories the overall amount of bracing varies with the type of bracing material and with loads carried from floors and walls above.

The higher floors require less bracing because they carry less load.
Let’s talk in some detail about how much bracing is required. Here’s part of the text from the table. Notice that it talks about both spacing (in this case every 25’ o.c.) and minimum quantity (not less than 16%). Let’s talk briefly about how that’s calculated.
"... at least every 25' on center but not less than 16% of braced wall line."

\[
\frac{b + c}{a} \geq 0.16 \times a
\]

The code isn’t specific about how to measure the distances, but the general interpretation is that it should be center-of-braced-panel to center-of-braced-panel. The minimum amount of bracing would be calculated by taking the sum of the linear length of braced panels “a” and “b” and dividing them by the overall wall length “a.” That quantity, multiplied by 100, should be equal to, or greater, than the amount calculated by taking 16% of “a.”
"… at least every 25’ on center but not less than 16% of braced wall line.”

If the separation between “b” and “c” is greater than 25 ft, another braced panel is required.
IRC Table R602.10.1 Wall Bracing

“… at least every 25’ on center but not less than 16% of braced wall line.”

The 25 ft minimum spacing will be figured as shown here.
IRC Table R602.10.1 Wall Bracing

“... at least every 25’ on center but not less than 16% of braced wall line.”

\[ \frac{b + c + d}{a} \geq 0.16 \times a \]

\[ \geq 25' \]

The calculation will be done just as before, although we’ll be adding the length of braced panel “d” into the numbers.
And there’s a more minor problem with the text of the table. As you see here, the code seems to require both the use of Method 3 and the other Methods. That’s obviously not the intent, but the use of “and” rather than “or” makes it somewhat confusing for people who tend to read literally. This problem was also corrected with a code change that is reflected in the ’06 edition of the code.
### IRC Table R602.10.1 Wall Bracing

<table>
<thead>
<tr>
<th>Category A and B</th>
<th>Condition</th>
<th>Type of Brace**</th>
<th>Amount of Bracing***</th>
</tr>
</thead>
<tbody>
<tr>
<td>(S_s≤0.35g and S_dd≤0.35g) or 100 mph and less</td>
<td>One story Top of two or three story</td>
<td>Methods 1, 2, 3, 4, 5, 6, 7 or 8</td>
<td>Located at each end and at least every 25 feet on center but not less than 16% of braced wall line.</td>
</tr>
<tr>
<td></td>
<td>First story of two story Second story of three story</td>
<td>Methods 1, 2, 3, 4, 5, 6, 7 or 8</td>
<td>Located at each end and at least every 25 feet on center but not less than 16% of braced wall line for Method 3 and 25% of braced wall line for Methods 2, 4, 5, 6, 7 or 8.</td>
</tr>
<tr>
<td></td>
<td>First story of three story</td>
<td>Methods 2, 3, 4, 5, 6, 7 or 8</td>
<td>Minimum 48-inch-wide panels located at each end and at least every 25 feet on center but not less than 20% of braced wall line for Method 3 and 35% of braced wall line for Methods 2, 4, 5, 6, 7 or 8.</td>
</tr>
</tbody>
</table>

*This is revised in the 2006 edition: “Located in accordance with Section R602.10 and at least every X’feet on center but not less than Y% of ...”*

The table in the 2000 and 2003 editions of the IRC contains a provision that is in conflict with Section R602.10. That section permits the first braced panel to start at a point 12 (or 12-1/2) ft from the corner. The table says that the bracing is required at the end of the wall. This appears to be a correlation error. The intent of the IRC drafting committee was to permit the bracing panel to be placed some distance from the end of the wall. This table was, in all likelihood, borrowed from some other source and this “at the corner” statement was erroneously retained. A code change proposal approved in the 2004-2005 cycle deletes this reference to “at each end” and appears in the 2006 edition.
Let’s go back to our example house and discuss two matters: do the braced wall panels have to occur at the corners and does the wall containing the garage door have to be braced?
The braced wall panels can be located as far away from the corner as 12-1/2’. The 2000 & 2003 IRC requires that a collector (but doesn’t define the term) be provided if the distance is 12’ or more. This was deleted in the 2006 edition for the following reasons:

1. The difference between 12’ and 12-1/2’ isn’t enough to suddenly require additional connection between the panels and the corner.

2. A similar provision in the IBC, which was also changed, makes the limit 8-1/2’ and 8’, indicating that there isn’t a technical substantiation behind this.

3. The conventional construction bracing provisions are based as much on common practice, and proven performance, as on engineering. So we don’t know enough about the loads being resisted by the walls to know how to size the collector that had been required.
And as for having to brace this wall, the answer is yes. And it brings up two more questions – how do we provide the total quantity of bracing required by R601.10.1 and how do we provide the minimum width of bracing required for a specific type of bracing materials. We’ll touch on some options in a moment.
Impact of Bracing Req'ts

Based on Table R602.10.1 & Sec. R602.20-4 impact will be on
• Garage door walls & narrow wall sections
• Acceptance of small panels

The point to make here is that the provisions of Table R602.10.1 and Section R602.20-4 -- which addresses minimum width of bracing panels -- is going to mean that often narrow wall sections won't be acceptable as braced panels in braced wall lines.
Braced Wall Panels

Braced Wall Panel Materials
- 8 materials accepted prescriptively
- Not all materials accepted at all times
- Location & quantity of bracing material depends on:
  - Seismic category or wind speed zone
  - Building height in stories
  - Story to be braced

Now let’s talk about acceptable bracing materials. The code lists 8 general materials that are acceptable as bracing, and we’ll talk more about those in a moment. Not all of those materials, however, are acceptable as bracing materials in all instances.

The seismic category or wind speed zone, as well as which story is being braced, will determine whether a specific material can be used and how much of the wall must be braced using that material.
Braced Wall Panels

Braced Wall Panel Materials:
1. 1x4 diagonal bracing
2. 5/8" wood boards
3. Wood structural panels
4. Fiberboard sheathing
5. Gypsum board sheathing
6. Particleboard wall sheathing
7. Portland cement plaster
8. Hardboard panel siding

Here are the 8 general bracing materials. The numbers that you see here are the numbers that you saw on the table that we’ve talked about. We’ll also talk in some detail about the various materials.

These are the materials that the code accepts outright. That's not to say that there aren't other materials that will provide adequate wall bracing. However, any other material must be addressed under the alternate methods and materials provisions of the code.
Attaching the bracing materials properly is critical; none of the materials will function properly if fasteners are improper (either too few or of the wrong size). It’s important that care be given to compliance with these requirements.
Wall Bracing Materials & Methods

- Relative shear strength of the bracing methods is unknown
  - Lateral force resisting capacity of wall bracing is more a function of the overturning restraint than the shear capacity of the material.
  - Since braced walls don't have explicit overturning restraint, it is difficult to determine shear capacity.
    - Implicit overturning restraint provided by dead loads, overlapped nailing, etc.
    - Shear capacity highly affected by the dead load of the wall and the structure above.

This is a relatively formal way to say that we’re not sure exactly what resistance to lateral loads are being provided by prescriptive bracing. We know from experience that it works under the limitations of conventional construction. However, since the wall isn’t formally designed and it lacks elements of a shear wall, such as connections to the foundation or floor, it’s hard to quantify the resistance to any exact degree.
### Wall Bracing Materials & Methods

<table>
<thead>
<tr>
<th>Bracing method</th>
<th>Estimated Allowable Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Let-in diagonal 1x4</td>
<td>0 – 100 plf?</td>
</tr>
<tr>
<td>2. 5/8-in. diagonal boards</td>
<td>300 plf?</td>
</tr>
<tr>
<td>3. 3/8-in. WSP</td>
<td>220 plf?</td>
</tr>
<tr>
<td>4. 1/2-in. fiberboard</td>
<td>180 plf?</td>
</tr>
<tr>
<td>5. 1/2-in. gypsum board</td>
<td>100 plf?</td>
</tr>
<tr>
<td>6. 1/2-in. particleboard</td>
<td>140 plf?</td>
</tr>
<tr>
<td>7. 7/8-in. PC stucco</td>
<td>180 plf?</td>
</tr>
<tr>
<td>8. 7/16-in. hardboard</td>
<td>Unknown?</td>
</tr>
</tbody>
</table>

In a formal shear wall design, we can quantify the shear resistance in bracing material; in fact, the code provides those numbers for everything but let-in bracing. But because the overall resistance to racking in conventional construction isn’t completely understood, we don’t know exactly what shear resistance is being provided by the bracing material itself. Here are some estimates of the shear strength of the 8 allowed bracing materials applied according to the IRC. The widely varying numbers explain why different materials must be provided in different amounts.
Now, let's talk about the details of the various methods of bracing.
Wall Bracing Methods & Materials

- METHOD 1 – LET-IN 1x4
  - Most problematic & questionable
  - Depends on workmanship
  - Unknown shear resistance

One of the bracing methods accepted in the code is 1x4 let-in bracing such as you see here.
Wall Bracing Methods & Materials

*Caution: Max notch 25% of stud width per R602.6

R602.10.3(1) calls for the let-in bracing to be no less than 45 degrees from the horizontal and no more than 60. It also calls for the 1x4 to be let-in to the top and bottom plates as well as the studs.
But let-in bracing will be effective only if it's installed properly. Here you see an example of poor installation. The notches in the studs are so wide that the 1x4 isn't being held tightly. If the wall tries to move the wide notches are going to permit some racking before the 1x4 comes into contact with the edge of the notches.

In addition to racking resistance provided by the board being in a notch, the use of two nails is intended to provide a fastener moment couple like what we saw earlier with horizontal boards being a type of bracing. Here it appears that some of the nails may not be properly driven into the studs. Notice that the nail head in the yellow circle appears to fall right on the outside edge of the stud, meaning that probably only one of the nails is providing any resistance.
As mentioned before, diagonal boards provide a very efficient bracing material, but that method has fallen out of favor because of the availability of panel products.
Wall Bracing Methods & Materials

- METHOD 3 – WOOD STRUCTURAL PANELS
  - 5/16” (studs 16” o.c.) or 3/8” (studs 24” o.c.)
  - If entire wall is sheathed, then optional provisions are allowed.
  - Method most frequently used in high-seismic & high-wind areas.
    - Very strong
    - Easily constructed

Wood structural panels are very desirable bracing materials, particularly when used in lower floors of multi-story buildings or in buildings subject to high lateral loads. Additionally, the use of panels beyond the minimum will offset some other problems that we’ll talk about in a moment.
Wall Bracing Methods & Materials

• METHOD 4 – STRUCTURAL FIBERBOARD
  – Must comply with minimum standards
  – Maximum stud spacing 16” o.c.
  – 1/2” or 25/32”
  – Method frequently used in low- to moderate-load areas.
    • Fairly strong, but flexible
      – Some products have higher shear resistance than generic values of code.
    • Easily constructed

Keep in mind that structural fiberboard and particleboard must be manufactured in accordance with standards referenced in the code. While they might look like the materials used in cheap, short lived furniture, compliance with those standards assures a long lasting structural product.
Wall Bracing Methods & Materials

• METHOD 5 – GYPSUM BOARD
  – Specific nailing requirements
  – Requires 48” panels on both sides of wall or 96” on one side.
    • This requirement might not be a big problem if the interior walls are to have drywall finish.
    • Center-to-center spacing of panels will depend on whether one or two side coverage is chosen.
    • Minimum percentage of coverage will depend on whether one or two side coverage is chosen.
    • Resistance to moisture penetration?
    • Resistant to exterior fire exposure
    • Brittle
    • Easily constructed

Gypsum wallboard is acceptable as a bracing material, but because it’s brittle and easily crushed, it’s values are limited and longer lengths of it are required to provide racking resistance.
Wall Bracing Methods & Materials

• METHOD 6 - PARTICLEBOARD
  – Specific grades req’d
  – Max. stud spacing of 16” o.c.
  – Requires 48” panels
    • Minimum percentage of coverage depends upon 48-in. minimum panels.
    • Fairly strong, but brittle
    • Resistance to moisture?
    • Easily constructed

Keep in mind that structural fiberboard and particleboard must be manufactured in accordance with standards referenced in the code. While they might look like the materials used in cheap, short lived furniture, compliance with those standards assures a long lasting structural product.
Wall Bracing Methods & Materials

- METHOD 7 – 7/8” PORTLAND CEMENT STUCCO
  - Not EIFS or other faux-stucco finishes
  - Maximum 16” o.c. stud spacing
    - Labor intensive
    - Resistant to fire exposure

Also keep in mind that the prescriptively permitted stucco cited in code is traditional portland cement stucco and not EIFS or other stucco-looking material.
Because it has a rather soft surface, it’s important to prevent overdriving of fasteners. If over driven, two problems are created:

1. If driven far enough, the amount of the nail shaft that bears on the wood fiber to resist shear is less, lowering the shear resistance value.
2. Broken surface permits moisture get into the panel around the fastener, creating decay.
Wall Bracing Methods & Materials

• ALTERNATES
  – Proprietary products & systems
  – Require engineering or compliance reports to substantiate testing

As previously stated, alternate bracing methods and materials may be accepted. However, it’s important that their acceptance be based on the knowledge that they will perform adequately when loaded.
Narrow Wall Bracing

- Narrow wall sections not always acceptable as bracing

The point to make here is that the provisions of Table R602.10.3 and Section R602.20-4 -- which addresses minimum width of bracing panels -- is going to mean that often narrow wall sections won't be acceptable as braced panels in braced wall lines. Remember the slide that we saw earlier that showed approximate shear resistance of various bracing materials in conventional construction? It indicated that various materials have different plf strength. As a result, every material is required by the code to have a minimum length wall to be considered a bracing panel in a braced wall line. And none of those materials will qualify as bracing for sections of wall as small as you see in this example.
Narrow Wall Bracing

- Narrow wall sections not always acceptable as bracing: Section R602.10.4 stipulate minimum widths for some materials
- Built-in minimum aspect ratio
  - Methods 2, 3, 4, 5, 6, 7, & 8
    - 48" in length (16" o.c. - 3 stud spaces & 24" o.c. - 2 stud spaces)
  - Method 5
    - Each panel minimum 96" on one side or 48" on one side

The code stipulates a minimum length of braced wall panel for most of the materials. This means that the short sections of walls, even if they’re wood structural panels (Method 3), can’t be counted toward the required amount of bracing. This is an example of a built-in aspect ratio limitation similar to the 1:3.5 aspect ratio we talked about for engineered shearwalls.
IRC Sec. R602.10.5:

- Reduced braced wall panel length permitted if continuously sheathed
  - Must use Method 3 (wood structural panels)
    - On all exterior walls & interior braced walls (if applicable)
    - Above doors and windows
  - Must be installed at corners
    - Must comply with details of Fig. R602.10.5
  - Reduction depends on presence of openings

Here’s a summary of that provision. This will permit narrower braced wall panels, but keep in mind that there will still be some limitation on how narrow they can be.
Narrow Wall Bracing

• Does this require completely sheathing the building in WSPs?

However, the IRC permits narrow all sections if the building is sheathed with wood structural panels. But to what extent?
Confusion and disagreement over wording of R602.10.5, “Continuous structural panel sheathing”

- **2000 Edition of IRC**
  - When continuous wood structural panel sheathing is provided in accordance with Method 3 … including areas above and below windows, braced wall panel lengths shall be in accordance with Table R602.10.5 (allowable reductions).

- **2003 & 2006 Edition of IRC**
  - When continuous wood structural panel sheathing is provided in accordance with Method 3 … on all sheathable areas of all exterior walls and interior braced wall lines, where required, including areas above and below windows, braced wall panel lengths shall be in accordance with Table R602.10.5 (allowable reductions).

There is some disagreement within the code community – including materials people, enforcement individuals, and builders – over the real meaning of this section. The question seems to be whether the whole house has to be sheathed in wood structural panels in all solid areas of all walls, or whether a mix of solidly sheathed walls and bracing with other code-recognized materials is permitted.

Here’s the wording found in the 2003 and 2006 editions of the IRC and that found in the original 2000 edition.
Narrow Wall Bracing

• 2000 Edition of IRC
  – When continuous wood structural panel sheathing is provided in accordance with Method 3 … including areas above and below windows, braced wall panel lengths shall be in accordance with Table R602.10.5 (allowable reductions).

• Original proposal
  – Initial proposal different; revised during hearing
    • “When continuous wood structural panel sheathing is provided in accordance with Method 3 of R602.10.3 on all areas of all walls …”
  – Reason given initially: Intent of 2000 text to require sheathing on all parts of all walls.
  – Reason given for modification of proposed text: “… to clarify the application to exterior and interior sheathed walls.”

The initial proposal that led to the current wording added “on all areas of all walls” after “…in accordance with Method 3 of R602.10.3 …” in the 2000 wording. During the hearing the wording was revised to read as shown in the present text, but at this point it’s unclear where the new wording came from. The reason given in ICC’s Report on Public Hearings for amending the proposal was for further clarification as shown here.

The original proponent said that the text in the 2000 edition was based on wall test done by NAHB and the intent was for all portions of all walls to be sheathed. His proposal, he said, clarified that intent. However, in the current controversy over the meaning of all of this, a former NAHB engineer who was involved in those test says that the intent wasn’t to require that all walls be sheathed.
Narrow Wall Bracing

• 2003/2006 Edition of IRC
  – When continuous wood structural panel sheathing is provided in accordance with Method 3 … on all sheathable areas of all exterior walls and interior braced wall lines, where required, including areas above and below windows, braced wall panel lengths shall be in accordance with Table R602.10.5 (allowable reductions).

• Confusion
  – What is “continuous” sheathing?
  – What are “sheathable” areas of the wall?
  – What is meant by “where required”?

One of the points of confusion on all of this is the term “where required.” Some interpretations are that, since the code section deals with narrow bracing panels, “where required” means that the application is on the wall where the narrow panels are found. Other walls, it is reasoned, still have to be braced according to the code, but aren’t required to be completely sheathed.
Garages Too?

Do the braced wall line provisions apply to garage walls? Here’s a very good example of why narrow sidewalls at garage doors can compromise structural capabilities of a building. With the mass above the garage door, applying lateral forces in the plain of the garage door wall is going to require a certain amount of resistance in the lower wall. The lack of sufficient wall length will mean that the resistance won’t be present without special attention. In this case, there’s no doubt that bracing around the garage doors is needed.
Garages Too?

Do the braced wall line provisions apply to garage walls in this sort of application? Yes. If the narrow walls on the sides of the garage opening can’t comply with the minimum widths required for the bracing material chosen there are options permitted by the code. However, they are very restrictive.
Garages Too?

- **Alternate braced wall system**
  - Allowed to replace each 4' of required braced wall panel
  - For 1-story building
    - Length ≥ 2'-8" & height ≤ 10'-0" (aspect ratio again!)
    - 3/8" WSP with specific nailing requirements
    - 2 anchor bolts & tie-down with capacity ≥ 1,800 lbs at each end of panel
    - Foundation details specified
  - For 1st story of 2-story building similar but …
    - Sheathing required both sides
    - Nailing schedule more restrictive
    - 3 bolts required
    - Tie-down capacity ≥ 3,000 lbs

Here’s a summary of the alternate braced wall system provisions of the code that were intended to be used in the narrow sections of wall on either side of a garage opening.
Garages Too?

• OR USE ALTERNATE PRODUCTS AND SYSTEMS

But it may be that there are proprietary methods of bracing that will work in the narrow walls by garage door openings.
Garages Too?

• OR USE ALTERNATE PRODUCTS AND SYSTEMS

APA – The Engineered Wood Association successfully had a code change proposal approved that will revise the alternate braced panel section of the code to permit wall construction similar to what you see here. This will permit a more user-friendly and less expensive alternative in lieu of what’s currently in the code. Details of this method are critical however.
Is This Important …

... if I'm not in a high seismic or high wind area?

The results of 40 – 50 mph straight-line winds

Here's an example of what can happen when the lower floor of a building doesn't have adequate bracing, even in low-wind, low-seismic areas.

This was 9 separate tall and narrow units, some of them 3-stories tall, which collapsed in 40 - 50 mph wind. A structural collapse while under construction isn't unusual because not all of the required bracing may be in place when a storm strikes. But as you can see in this case, the exterior walls were being bricked and framing was essentially complete. If you look at the unit on the left, you will see that the lower floor had mostly doors and windows and very little braced wall area, indicating poor design.
Roof/Ceiling Framing

Now let’s talk about the code’s requirements for roof and ceiling framing.
Learning Outcomes

By the end of this eCourse module, you will be:

1. Knowledgeable in detail about the code requirements for roof framing
2. Knowledgeable about the use of engineered wood products for roof framing such as I-joists and trusses as alternates to conventional solid-sawn lumber

In this eCourse module, learn in detail about the code requirements for roof framing, and about the use of engineered wood products such as I-joists and trusses as alternates to conventional solid-sawn lumber.
Roof/Ceiling Framing

GENERAL
• Roofs < 3:12 – Members supporting joists and rafters designed as beams
• Notches & holes controlled
• Joists & rafters supported laterally

A few general comments here about the IRC requirements:

For relatively flat roofs (slope less than 3:12) the joists and rafters have to be designed as beams. Notches and holes are controlled as they are in floors. And joists and rafters must be supported laterally.
The governing concept in the roof/ceiling framing provisions is that loads on the roof are going to attempt to push the walls out, and some resistance to that push must be provided. Ideally that resistance would be provided by connections between rafters and parallel ceiling joists.
However, there are situations in which joists aren’t parallel to the rafters and the IRC makes provisions for that. Here’s one such solution. However, the code doesn’t provide the details of how this is to be done.
Roof/Ceiling Framing

Rafter
Nailed to rafter
Exterior Wall

Lookout

Subflooring
Joists

2003 IRC Ceiling Joists Perpendicular To Rafter

This is another solution, but again there are no details.
A third solution is listed, but again no details. In fact the whole subject of rafter ties is muddled in the 2000 and 2003 editions of the IRC.
In the 2006 edition of the IRC, the subject of rafter/joist connection has been simplified. The general requirement is for all joists to be connected to rafters at the top of the wall.
Where joists are located above the top of the wall the joists have to be nailed to each rafter or a rafter tie is required.
Where ceiling joists are perpendicular to rafters, a rafter tie is required.
The revised section in the 2006 IRC also requires collar ties (or straps over the ridge board) as shown here. The intent is to reduce uplift of the upper rafter ends in high wind loading similar to what’s seen in thunderstorms.
Roof/Ceiling Framing

At first glance, this appears to be the ideal situation – rafters and joists parallel and meeting at the ends. However, if you’ll look closely you’ll see that the rafters don’t actually meet the joists. For some reason there’s a horizontal 2x4 separating them. Even though both are apparently connected to that 2x4 the degree of continuity is questionable. And if you’ll look at the ends of the rafters, some of them seem to have some sort of splice at the very end, and since it’s a very small splice the very continuity of the rafter – not to mention it’s connection to the joists – is likely to be compromised.
Let’s talk some more about specific code requirements. The code requires that the ends of rafters either be framed to each other, connected by gusset plate, or bear against a ridge board. The intent is to provide both solid bearing surface and a resistance to lateral movement. The caution here to avoid horizontal shear isn’t found in the code but rather is a recommendation from the wood industry.
Like joist spans, there are rafter span tables in the code.
A provision that was carried over from the UBC and the old Dwelling Code is the use of struts and purlins to brace rafters and increase their spans.

The struts must be supported on a bearing wall. While it's conceivable that the struts could be supported by a beam designed for that purpose, they shouldn’t simply be supported by ceiling joists (even doubled ones).
We talked at some length about I-joists when we were talking about floor framing. Let’s mention some other related matters.
You can frame the roof out of I-joists, duplicating much of what’s done with solid sawn lumber, but it’s important that the manufacturer’s recommendations be followed just as was the case with floor framing.
Here’s another example of duplicating traditional construction using I-joists.
Keep in mind that the ridge in this application isn’t just a ridge board as we’ve seen with solid sawn construction, but rather is a beam and should be designed as such.
This is a variation of supporting I-joists on the ridge beam. Note that lateral support of the joists is still provided.
Notice in this example that the end of the I-joist is supported by a hanger that supports the full joist assembly. A detail like you see on the right may support the joist, but because it places all of the load on the web it may cause failure.
These are more examples of the flexibility of doing roof framing with I-joists.
As is always the case – but particularly in this type of framing where the loads may be concentrated in manners not seen with solid sawn framing – it’s important to provide a continuous load path to the foundation.
Now, let’s talk about metal plate connected roof trusses. They are so common in construction today as to be almost invisible.

Be aware that the IRC provisions for trusses are much more extensive than what’s been seen in the codes in the past. The code specifies specific information to be provided on the truss drawings, requires that bracing be provided in accordance with the drawings, and makes clear that alteration to trusses shouldn’t be done without the approval of a design professional.
GENERAL TRUSS REQUIREMENTS

• Truss drawings submitted to AHJ before installation
  – Detailed slope/depth, span, spacing
  – Location of joints
  – Design loads
  – Joint connector type & description
  – Lumbers size, species, grade
  – Deflection
  – Permanent bracing

• Professional design where required by AHJ
• Bracing required in compliance with drawings

In contrast to what the older codes have required, the IRC increased the requirements that apply to trusses. Drawing are required to be submitted to the Building Official for approval before installation. The minimum contents of those drawings are contained in Section R802.10. What you see here is just a sampling.
Roof/Ceiling Framing

• Trusses made with traditional solid sawn lumber
• Normally use dimensional lumber as chords and webs
• Fastened with metal plate connectors
• *National Design Standard for Metal Plate Connected Wood Truss Connection, ANSI/TPI 1-1995 (Truss Plate Institute)*

Typically trusses are made with solid sawn lumber chords and webs. The IRC references the ANSI/TPI standard that you see here for the design of metal plate connected wood trusses.
Trusses are designed to support loads in a plane parallel to the plane of the truss. They aren’t intended to support lateral loads, which is why bracing is required.
Roof/Ceiling Framing

- HB-91, Commentary & Recommendations for Handling, Installing & Bracing Metal Plate Connected Trusses
- DSB-89, Recommended Design Specifications for Temporary Bracing of Metal Plate Connected Wood Trusses
- Wood Truss Council of America (WTCA) job site warning poster

Temporary bracing, as well as permanent bracing that we'll touch on in a moment, should be provided. The truss industry provides job site warning posters with bracing information.
Roof/Ceiling Framing

• Permanent bracing
  – Transfer lateral loads from wind, seismic, construction, or deadloads to the tops of the walls and to the foundation
  – Contribute to performance of individual trusses or groups of trusses over their service life

Temporary bracing insures that the trusses remain in place during construction, but permanent bracing insures that the truss system will perform properly during the life of the building.
Permanent bracing is required in the 3 planes shown here. Often final building elements – roof sheathing and ceiling finish in particular – may provide a portion of that bracing. But bracing in the web plane has to be added.
Even then lateral loading will still cause the trusses to bow. They just do so in chorus.
For that reason lateral bracing is needed.
Roof/Ceiling Framing

- Design of permanent bracing is responsibility of building designer, not truss designer or manufacturer
  - Only building designer can know all anticipated loads
  - Design of permanent bracing must be on truss drawings

The code is silent on who has responsibility to design what elements of roof truss systems. What you see here is the philosophy of the truss industry.
The truss designers provide a truss erection plan, and when in doubt about some element of the roof framing, that plan should be consulted.
Even though truss design and erection can be tricky, it’s important to realize that there are any number of serious problems that can be caught just by paying attention to the basics. Here’s an example – improper spacing.
Here’s another example of a serious, but easily spotted, problem – missing metal plate connectors.
The 2003 edition of the IRC now requires the use of connectors of some sort to tie trusses to the top of the wall. Unless needed for uplift resistance greater than the capacity of the nails, nailed connections are still allowed for solid sawn rafters.
One of the documents published by AF&PA is the Wood Frame Construction Manual for One- & Two-Family Dwellings. The WFCM is referenced in the IRC and IBC, and its intent to provide the user with a method of designing a building prescriptively, with the prescriptive elements derived from engineering design. As you will see, the manual is geared to high-loading conditions.
Learning Outcomes

By the end of this eCourse module, you will be:
1. Beginning to learn the scope of the Wood Frame Construction Manual and its format
2. Understand the concept of perforated shear walls

In this eCourse module, begin to learn the scope of the Wood Frame Construction Manual, its format, and the concept of perforated shear walls.
The WFCM is accompanied by a commentary.
Proper design of wood structures to resist high lateral loads requires the correct use of load provisions and member design properties. A thorough understanding of the interaction between loads and material properties is important in the design process.
Wind-structure interaction is highly complex. Wind can induce a variety of structural responses as a whole building, and on individual components and assemblies, as seen here. Each of these responses needs to be checked for structural integrity as part of the wind design process.
When wind is applied to one side of a structure, it wants to push the end wall and roof in the prevailing direction. In addition, the wind wants to pull the opposite end wall. While this is occurring, the foundation acts to hold back the walls. Hence, the wall is subjected to most of the force. The same is true with seismic loading; the earth moves in one direction and the building attempts to stay where it was.
In seismic events inertia tends to keep the building from moving when the earth moves, so it moves the structural frame as shown in this simplified illustration. However, the earth quickly moves again in a different direction, and the building responds by moving again in a different direction. The building is always trying to catch up with the motion of the ground, placing strain on the structural frame of the building.
Buildings move under dynamic conditions. Two principle movements are: racking and twist.
Both wind & seismic
• horizontal force transfer
  – in-plane shear

$V_{max} \text{ at edges}$

Structures have horizontal surfaces that can be used to transfer loads applied laterally to the structure. An inertial mass load can originate in the surface and transfer the same way. Resulting shear forces develop across the surface, with maximum values occurring at the supported edges of the surface. These maximum “reaction” forces are the lateral forces that are transferred into the vertical building elements below. The vertical elements – almost always walls – are braced with structural material such as sheathing and act as a single unit to transfer the load to the walls below, if they exist, and on to the foundation.

With wind loading, the wall receiving the wind transfers half the load to resisting element above (horizontal diaphragm – floors or roof/ceiling) and half to the resisting element below (foundation or horizontal diaphragm like a floor). The horizontal diaphragms then transfer the force to the walls as described above.
Code Limitations

- **IBC prescriptive limits (IRC applies in most cases)**
  - Wind: ≤ 100 mph (3-second gust)
  - Seismic: Seismic Design Categories A - E
  - Snow: 50 psf (ground snow load)

- **IRC prescriptive limits**
  - Wind: ≤ 110 mph (3-second gust)
  - Seismic: Seismic Design Categories A - D1 & D2
  - Snow: 70 psf (ground snow load)

*Note: 2006 IBC/IRC now address ≤100 mph in hurricane-prone areas & ≤ 110 mph elsewhere*

The intent of the WFCM is to pick up where the prescriptive provisions of the codes leave off. This is true for wind, seismic and in some instances snow loading. However, it should be pointed out that the provisions of the IRC permit prescriptive seismic design to a level comparable with that of the WFCM. For that reason the WFCM may not be as useful in seismic design as it is in wind design.
In the IBC the WFCM is accepted in lieu of design. In Chapter 16, the code is very specific about accepting the WFCM for wind design. However, acceptance for seismic design is a little more convoluted. In Chapter 23 the WFCM is accepted as an alternative to conventional construction. Chapter 16 accepts construction under conventional construction (2308) in lieu of seismic design. If the WFCM is considered an alternate to conventional construction, it can be accepted in lieu of design.
The IRC Chapter 3 provisions are somewhat overlapping. The WFCM, along with the steel industry’s manual, is accepted as an alternate to formal design for snow, wind, & seismic. The WFCM is also specifically accepted as a wind design methodology (Section R301.2.1.1 is the original text of the IRC and was left in when R301.1 was amended to cover all loading in the 2003 edition).
The 1995 Edition of the WFCM, which is referenced in the 2000 editions of the IBC and IRC, was initially referenced by the Standard Building Code. That edition of the WFCM, which was purely targeted to wind design, was based on the low-rise wind provisions of the SBC. The 2001 edition of the WFCM, which is now referenced in the 2003 I-codes, addresses wind-, seismic- and snow-loading.
As the full title of the WFCM indicates, the document is geared to 1- and 2-family dwellings. The maximum height of the structures permitted under the WFCM is 3 stories, with a maximum mean roof height also stipulated which we will address in a moment.
Scope: Design Loads

- Systems sized using 2000 IBC load provisions
- Loads
  - Ground snow: 0 – 70 psf
  - Wind: 85 – 150 mph (3-second gust)
  - Seismic: Seismic Design Categories A - D

The systems and building elements addressed by the WFCM are sized using the loads contained in the 2000 IBC, meaning that they are ASCE-7 based. Here you see the load limits of the WFCM. Notice that the seismic loads go to Seismic Design Category D, which is comparable to the limitations of the IRC.
In addition to a height limit of 3 stories, the WFCM also limits the mean roof height to 33 ft and provides this diagram to illustrate how that number is figured. The 33-ft limit is based on wind design Exposure B, and there are adjustments in the book for other exposure categories.
One of the limiting factors in the use of the WFCM is in building dimensions. The maximum dimension on the building is 80 feet, and the aspect ratio (length-to-width ratio) is a maximum of 4:1 and a minimum of 1:4.
Vertical floor offsets are permitted prescriptively, but the maximum offset is limited as shown here. This diagram is shown in the WFCM to illustrate the limitation, but it contains information that’s not detailed elsewhere in the book. For example, the shear connection is shown as both nailing to blocking and the use of a metal connector of some sort. The details for this connection, however, aren’t given since the shear will vary with building size and other details.
The aspect ratio for floor and roof diaphragms is limited in the book’s scope to not greater than 4.
Scope: Floor Systems

Openings in those diaphragms for stairs, chimneys, skylights, etc. are permitted as you see here. If the edge of the opening is less than 2 ft from an exterior wall, the studs in that wall must be full-height studs.
This illustration addresses only one wall, but all exterior walls would be shearwalls. Interior shearwalls might be needed to maintain building dimension and aspect ratio limits. This shows a portion of the shearwall offset from the main wall line by a distance of 4 ft. The WFCM would allow an offset in both directions, but the total distance couldn’t exceed 4 ft. In the IRC’s seismic provisions, an offset of 4 ft is allowed in each direction, making the total out-of-plane spacing 8 ft.
The 4' limit to shearwall line offset presents what is probably the largest detriment to design flexibility in the WFCM. However, by separating the building into separate structures as shown here, that limit can be dealt with without sacrificing design flexibility. Also, if the structure is small enough, it can be inscribed.
This illustration is contained in the WFCM to show that shearwall offsets from story-to-story is prescriptively limited. It’s been pointed out that in practice it’s very unlikely to see this configuration; it’s more likely that the upper story would cantilever over the lower story. Again, as with the floor offsets, this shows blocking under the offset wall to help transfer shear, but there are no details given in the book.
The braced section of a shearwall, similar in concept to the braced wall panel in a braced wall line as addressed by the IRC, has a height to width ratio limit to insure that the segment isn’t too narrow. The IRC doesn’t address aspect ratio specifically in braced wall panels, but it does specify minimum widths of bracing materials, which accomplishes the same thing to some extent.
Organization

- General Information
- Engineered Design
- Prescriptive Design
- Supplement
- Commentary (separate document)

The book itself is organized as you see here. We'll discuss each section in a little more detail.
The General Information chapter addresses subjects that we’ve already talked about – design loads and applicability (the scope of the document). But it also lists a series of materials standards that will apply to the products used in the construction of the building. These standards are the same as those listed in both the IBC and the IRC. The chapter also contains a lot of other information pertinent to the document as a whole.
The Engineering Design chapter provides minimum loads for the purpose of establishing specific resistance requirements for buildings within the scope of the WFCM. The provisions of this chapter – which includes some building details for the convenience of the designer – are provided so that the designer can select acceptable materials or alternatives to the specific prescriptive solutions in the Prescriptive Design chapter. The Commentary addresses this chapter by providing background information, interpretations, and examples for specific sections of this chapter, and it provides background information and examples for specific tables found in the chapter.
The Prescriptive Design chapter is a prescriptive – or cookbook – solution to the loads found in the codes, and reflected in the Engineering chapter. Note that the details in this chapter, in the tables and figures, are one set of solutions to the loads. There are other ways of designing that will resist the same loads. In fact, if prescriptive solutions in this chapter aren’t acceptable, or if the desired detail isn’t addressed, the designer can use the loads in the Engineering chapter to generate his or her own solution. For wind design, these prescriptive solutions are based on Exposure B. But there is an additional section for Exposure C.
The Supplement chapter of the WFCM contains a great deal of information that the reader will find useful in applications in addition to the WFCM.
The Commentary, which is organized in the same way in which the Manual is arranged, is intended to provide the reader with background information as well as sample calculations of the development of the technical provisions in the various chapters.
Buildings subjected to the lateral loads of high winds or earthquakes require the use of shearwalls to resist loading. The major innovative element of the WFCM is the introduction of the concept of perforated shearwalls.
The traditional shearwall concept has been to brace those sections of the wall between corners and openings, and between openings. This is similar to the IRC’s concept of braced wall lines in which exterior walls (and, depending on distances between exterior walls, perhaps even interior walls) are considered as braced wall lines. Portions of those braced wall lines, the exact amount depending on various conditions, must provide the actual bracing. The concept of shearwalls is the same – walls are considered overall as shearwalls, but the actual shear resistance is typically provided by segments of the wall. Additionally, these segments require the use of holddowns, which can be a very expensive necessity due to the cost of the hardware and the labor to install it correctly.
Here’s a braced segment on our shearwall. In braced wall lines, where loads are relatively small, the resistance to lateral loads is provided by the resistance of the bracing material itself and by the fasteners which connect the material to the framing. Shearwall segments resist lateral loads in the same fashion.
However, because the loads on shearwalls are typically much higher than are seen in low-wind and -seismic areas, when the segment is loaded from one side, it tries to overturn, in spite of being nailed to the studs and to the top and bottom plates.
And because the wind blows from all directions and earthquakes shake the building in all directions, the overturning can also happen in the other direction.
To resist these loads in both directions, which are higher than can be resisted by just nails alone, holldown devices are required at the ends of the braced segment. These devices are expensive and require additional labor to install them properly.
Perforated Shearwalls

TRADITIONAL SHEARWALL

For this reason, use of traditional shearwalls can be expensive as you might imagine if all of these shearwall segments are necessary to resist the lateral loads on this building. And each exterior wall, and possibly some interior walls depending on the building aspect ratio, will require holddowns at the corners of each segment in that wall.
In the perforated shearwall concept, the whole shearwall is treated as a braced segment, including those areas above and below openings, and the only holddowns required are at corners of the wall.
AF&PA also publishes a simplified version of the WFCM’s wind provisions. The WFCM was initially intended for user with a relatively high level of technical know-how – not design professionals necessarily but users with a high comfort level for technical material.

Suggestions have been made since the development of the WFCM that a simplified version of the book be created. Many users were uncomfortable with the complex tables and all-encompassing application (wind, seismic, and snow). After Katrina’s devastation of the Gulf coast there was an urgent need for wind-only versions of the WFCM that were easier to use. AF&PA responded by creating the WFCM Guides.
Guide Background

- Guides in compliance with WFCM

The content of the Guides was derived from the WFCM with the differences being that the material was often simplified. The simplification meant that the Guide was more conservative. Although not specifically cited in the codes, the Guides will be acceptable in the same fashion that the WFCM is. The Guides are, in reality, simpler versions of the WFCM based on the same engineering.
Guide Background

- Guides in compliance with WFCM
- **Guides intended to**
  - Provide only wind-related requirements

One way in which the Guides simplified the WFCM is that they address only the wind-related provisions. There is no mention of seismic or snow loading.
Guide Background

- Guides in compliance with WFCM
- Guides intended to
  - Provide only wind-related requirements
  - Contain requirements for specific wind speed zones in separate books
    - 90 mph
    - 100 mph
    - 110 mph
    - 120 mph

The WFCM contains wind-, seismic-, and snow-related design provisions. Each of those topics is then broken down further. In the wind design all design wind speeds are addressed, making the various tables rather complex for a user needing information only about one wind speed zone. The Guides are published as separate books for each wind speed zone. That way the user only needs to have a book targeted to the zone in which the building under design will be located.
Guide Background

• Guides in compliance with WFCM

• Guides intended to
  – Provide only wind-related requirements
  – Contain requirements for specific wind speed zones in separate books
    • 90 mph
    • 100 mph
    • 110 mph
    • 120 mph
  – Provide better illustrations

While the WFCM has some illustrations in it, the Guides contain a number of new illustrations intended to reinforce the intent of the text and tables.
Guide Background

- Guides in compliance with WFCM
- Guides intended to
  - Provide only wind-related requirements
  - Contain requirements for specific wind speed zones in separate books
    - 90 mph
    - 100 mph
    - 110 mph
    - 120 mph
  - Provide more illustrations
  - Be simpler to use
    - Limited to Exposure B
    - Use only perforated shearwall

In addition to having the wind design provisions for all wind speed zones in the WFCM, it also contains requirements for both Exposure C and B areas. In a further effort to simplify the WFCM, the Guides address only Exposure B.
Availability of Guides

- **www.awc.org**
  - Downloadable for no charge
- **ICC**
  - Hard copies can be purchased

Copies of the Guides are available from two sources. Electronic copies in .pdf format can be downloaded from AF&PA’s American Wood Council website. If hard copies are desired, they can be purchased from the International Code Council.
Although it’s not structurally related, fireblocking and draftstopping are fire-safety items that are specifically tied to the use of wood framing. In fact, it’s only required in wood framed buildings.
Learning Outcomes

By the end of this eCourse module, you will:

1. Understand and apply the code requirements for controlling the spread of fire, smoke, and gases

In this eCourse module, learn and apply the code requirements for controlling the spread of fire, smoke, and gases. Examples are given.
Fireblocking & Draftstopping

• Fireblocking
  – No longer called “firestopping”
  – Prevents movement of flame, smoke, gases through concealed spaces
  – Primarily addresses vertical movement (although code addresses horizontal direction in walls)

• Draftstopping
  – Prevent movement of smoke and gases through concealed spaces
  – Primarily addresses horizontal movement

For a long time what the code now calls “fireblocking” was called “firestopping.” However, the materials which provide annular protection around pipes and ducts are generically referred to as “firestopping,” so the application that we will talk about here became “fireblocking.”

Fireblocking and draftstopping have similar, but slightly different, purposes. As you see here, fireblocking is intended to resist the movement of flames, where draftstopping is intended to resist the passage of smoke and gases.
Fireblocking & Draftstopping

FIREBLOCKING

• Locations
  – Walls at floors & ceilings & at 10’ intervals (both vertical & horizontal)
  – Interconnections between concealed vertical and horizontal spaces (example: between walls and furrdowns)
  – Concealed spaces between stair stringers at top & bottom of run
  – Openings for vents, piping, chimneys, etc
  – Cornices of 2- or more family dwellings at unit separation line

Fireblocking is intended to resist upward movement of flames, smoke, and gases. Here you see the general locations cited in the code. We’ll show some simple examples in a moment, although it must be admitted that real-world applications of the code’s requirements may be more complex than our examples.

While studs typically provide built-in protection horizontally and top and bottom plates do the same vertically, in high walls fireblocking must be added to limit the vertical distance to 10 ft or less.
You’ll notice that acceptable fireblocking materials tend to be rather substantial since they’re intended to inhibit the passage of fire. As we’ll see in a moment, draftstopping materials are lighter materials because they’re intended to reduce the passage of smoke and gases.
Here’s the first of several admittedly simplified examples of what is intended by the code’s requirements. Without the presence of the fireblocking fire in a concealed space could spread through interconnected concealed spaces as indicated by the orange arrow. Note that, as mentioned on an earlier slide, plates provide built-in fireblocking.
In balloon framing, or methods of framing with long studs in which the inherent protection offered by plates is missing, specific material must be added to act as fireblocking.
There are instances in which the plates may not provide the protection that they do otherwise. Here we see a soffit, similar to what you see above cabinets, in which the opening to the floor-ceiling assembly occurs below the top plate. In this instance, fireblocking is required as shown.
A similar situation may exist with a dropped ceiling.
And cove ceilings may provide the same problem.
Stair stringers must be fireblocked, keeping fire in the floor assemblies from getting into the space below the stairs and burning the stringers away. It also prevents fire in the stringers from getting into the floor assemblies. Some of the older codes had more extensive requirements for fireblocking stairs than does the IRC.
Holes in plates must be fireblocked with approved material to “… resist the free passage of flame …” This means that latex chaulk or foam insulation, which would likely melt out rather quickly, wouldn’t be accepted.
Fireblocking of spaces where chimneys pass through floors and ceilings, must be done with noncombustible material securely fastened in place. Some details are provided in Section R1001.16.
Fireblocking & Draftstopping

DRAFTSTOPPING

• Where useable space is both above & below concealed space of floor/ceiling assemblies
• Concealed space not to exceed 1,000 sf on each side of draftstop & approximately of equal sizes

There are some points to be made about the draftstopping requirements:

1. If there is no useable space above the assembly (an attic) or below it (a crawlspace), draftstopping isn’t required.
2. If the assembly isn’t concealed (an open floor/ceiling assembly above a basement), draftstopping isn’t required.
3. If draftstopping is required the 1,000 sf limit applies but the divided spaces must be approximately equal. For example, in a 1,500 sf floor/ceiling assembly you can have 1,000 sf on one side of the protection and 500 sf on the other.
DRAFTSTOPPING

• Accepted materials
  – 1/2” gypsum board
  – 3/8” WSP
  – 3/8” Type 2-M-W particleboard
  – Other approved materials

Here you’ll note that acceptable draftstopping materials are lighter materials than those required for fireblocking. However, it would seem logical that fireblocking materials could be used for draftstopping since they will resist the passage of fire.
Solid sawn joists or other solid joists such as I-joists provide more than adequate draftstopping when the ceiling finish is added to the bottom of the joists. And it’s very unlikely that the 1,000 sf limit would come into play here since the spans of the joists are going to be limited.

However, if the ceiling finish is added to a resilient channel for sound deadening purposes, the resulting space between the bottom of the joists and the finish material would have to be draftstopped.
Where a dropped ceiling is used, draftstop material must be suspended in some fashion to block the space between the joist and the ceiling material.
Fireblocking & Draftstopping

Even though the ceiling finish is added to the bottom of a truss, the inside of the truss is open to the passage of smoke and gases. For that reason the draftstop material must be added as you see here.
Finally let's talk about fire separation between units of duplexes and multi-family dwellings.

The IRC requires that a 1-hour rated assembly must extend from the foundation to the roof.
In multi-family dwellings that separation must be either a single 2-hr rated assembly or two 1-hr assemblies. The IRC is applicable to multi-family dwellings only when each unit extends from the foundation to the roof. So, the fire separation of stacked units as you see on the left isn’t addressed.
Questions?

- **www.awc.org**
  - Online eCourses
  - FAQ’s
- **HelpDesk**
  - AWCinfo@afandpa.org
  - (202) 463-4713 or (800) 292-2372
- **Comments**
  - AWC_education@afandpa.org

This concludes this approved continuing education program.