Code Acceptance

4

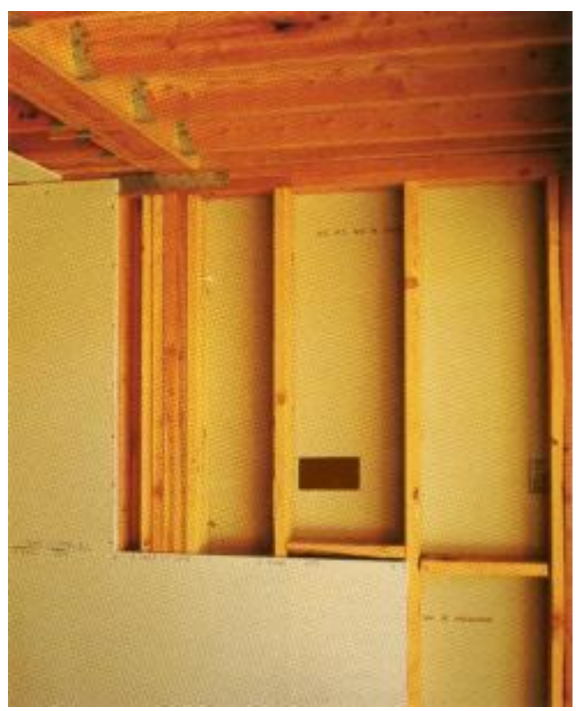
Component Additive Method (CAM) for Calculating and Demonstrating Assembly Fire Resistance

Wood-frame walls and floors offer designers a unique opportunity to provide structures with economy as well as proven energy performance. Where these assemblies are required by the building codes to achieve a minimum fire resistance rating, a wide range of options for design exists.

Building Code Requirements

For both new and existing construction, many building codes require structural elements such as exterior walls, load bearing partitions, floor/ceiling assemblies and roofs to achieve a minimum fire resistance rating. Historically, these assemblies have been tested in accordance with ASTM E119 Standard Test Methods for Fire Tests of Building Construction and Materials or UL 263 Standard for Fire Tests of Building Construction and Materials, and assigned an hourly fire resistance rating based on assembly performance. Many sources are available for obtaining information on the fire resistance of assemblies: The 2012 International Building Code-Table 721; the American Wood Council's Fire Rated Wood Floor and Wall Assemblies (DCA3), Gypsum Association's GA 600 Fire Resistance Design Manual; and Underwriters' Laboratories ULtimate Fire Wizard, to name a few.

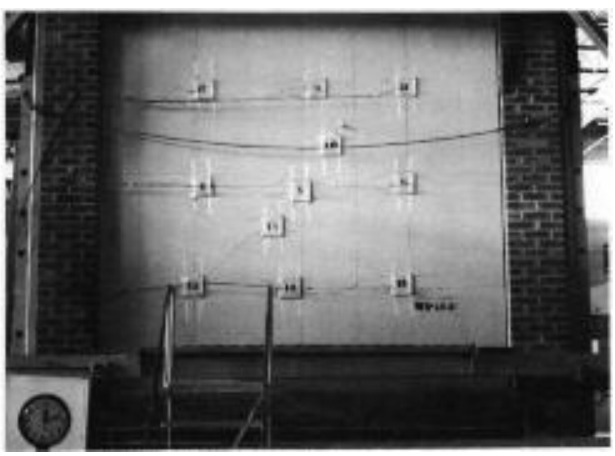
Building codes include both tested assemblies as well as methods for calculating fire resistance, developed from conducting a series of fire resistance tests. The Component Additive Method (CAM) provides for calculating the fire resistance of load bearing and non-load bearing floor, wall, ceiling and roof assemblies. The calculated fire resistance provisions within Section 722.6 of the *International Building Code® (IBC)* were developed using CAM.



Component Additive Method (CAM)

History

The original methodology for calculating fire resistance ratings of assemblies by CAM was developed in the early 1960's by the Fire Test Board of the National Research Council of Canada (NRCC). The methodology resulted from their detailed review of 135 standard fire test reports on wood stud walls and 73 test reports on wood-joist floor assemblies, and the *Ten Rules of Fire Endurance Rating* by Tibor Harmathy, an eminent fire researcher from NRCC. The "Ten Rules" provided a method for combining the individual component contributions to obtain the fire resistance rating of the assembly. The fire tests were used to validate this methodology, and to derive assigned time values for contribution to fire resistance ratings of each separate component of an assembly. These tests included both load bearing and non-load bearing assemblies with wood, gypsum wallboard and other membranes. Fire resistance ratings ranged from 20 to 90 minutes.



Use and Application

In developing the methodology, the NRCC Fire Test Board broke down the fire resistance of the assembly into the fire resistance contribution of the exposed membrane and the framing members. As a result, the calculated fire resistance would equal the sum of 1) the contribution of the fire-exposed membrane, 2) the performance time of the framing members, and if applicable 3) any additional protection due to use of cavity insulation or reinforcement of the membrane.

The times assigned to protective wall and ceiling coverings are given in Table 722.6.2(1) of the 2012 IBC. These times are based on the ability of the membrane to remain in place during fire tests. For wall assemblies, the membrane should be attached using nails or drywall screws with a minimum 1.5 inch penetration into the framing members, and spaced not more than 7 inches on center. For floor/ceiling assemblies, the ceiling membrane should be attached using nails or drywall screws with a minimum 1 inch penetration into the framing members, and spaced not more than 7 inches on center. This "assigned time" should not be confused with the "finish rating" of the membrane. The "finish rating" is the time it takes for the temperature to rise an average of 250° F on the unexposed surface of a material when the material is exposed to a heat source following the ASTM E119 Time-Temperature curve.

Ten Rules of Fire Endurance (Resistance) Rating

Rule 1. *The "thermal" fire endurance of a construction consisting of a number of parallel layers is greater than the sum of the "thermal" fire endurance characteristics of the individual layers when exposed separately to fire.*

Where two layers of panel materials, such as gypsum wallboard or plywood, are fastened to studs or joists separately, their combined effect is greater than the sum of their individual contributions to the fire endurance rating of the assembly.

Rule 2. *The fire endurance of a construction does not decrease with the addition of further layers.*

This is a corollary to Rule 1. The fire resistance will not decrease with the addition of layers such as wallboard or other panel materials, regardless of how many layers are added or where they are located within the assembly.

Rule 3. *The fire endurance of constructions containing continuous air gaps or cavities is greater than the fire endurance of similar constructions of the same weight, but containing no air gaps or cavities.*

Wall and ceiling cavities formed by studs and joists protected and encased by wall coverings adds to the fire resistance rating of these assemblies.

Rule 4. *The farther an air gap or cavity is located from the exposed surface, the more beneficial its effect on the fire endurance.*

In cases where cavities are formed by joists or studs and protected by 2-inch-thick panel materials against fire exposure, the beneficial effect of such air cavities is greater than if the protection is only 1/2 inch thick.

Rule 5. *The fire endurance of an assembly cannot be increased by increasing the thickness of a completely enclosed air layer.*

An increase in the gap distance between separated layers does not change the fire resistance of an assembly.

Rule 6. *Layers of materials of low thermal conductivity are better utilized on the side of the construction on which fire is more likely to happen.*

A building material having relatively low thermal conductivity, such as a wood-based material, is more beneficial to the fire resistance of the assembly if placed on the fire-exposed side of the framing than it would be on the opposite side.

Rule 7. *The fire endurance of asymmetrical constructions depends on the direction of heat flow.*

Walls which do not have the same panel materials on both faces will demonstrate different fire resistance ratings depending upon which side is exposed to fire. This rule results as a consequence of Rules 4 and 6, which point out the importance of location of air gaps or cavities and of the sequence of different layers of solids.

Rule 8. *The presence of moisture, if it does not result in explosive spalling, increases fire resistance.*

Materials having a 15 percent moisture content will have greater fire resistance than those having 4 percent moisture content at the time of fire exposure.

Rule 9. *Load-supporting elements, such as beams, girders and joists, yield higher fire endurance when subject to fire endurance tests as parts of floor, roof, or ceiling assemblies than they would when tested separately.*

A wood joist performs better when it is incorporated in a floor/ceiling assembly, than tested by itself under the same load.

Rule 10. *The load-supporting elements (beams, girders, joists, etc.) of a floor, roof, or ceiling assembly can be replaced by such other load-supporting elements which, when tested separately, yielded fire endurance not less than that of the assembly.*

A joist in a floor assembly may be replaced by another type of joist having a fire resistance rating not less than that of the assembly.

The times assigned to wood studs and joists were determined from ASTM E119 fire resistance tests, and represent the contribution of the framing members to the total fire resistance rating of the assembly. The times assigned to framing members are given in Table 722.6.2(2) of the 2012 IBC.

These time values are, in part, the result of full-scale tests of unprotected wood studs and floor joists where the structural elements were loaded to design capacity. They apply to all framing members and do not increase if, for example, 2x6 studs are used rather than 2x4 studs as implied by Harmathy's rule #5. It should be noted that the intent of footnote b to Table 722.6.2(2) of the 2012 IBC is not to limit the table's applicability to 2x4 studs *only*, but rather, to require 2x4s as the *minimum* stud size.

Walls

Additional fire resistance can be provided to wall assemblies by the use of specific insulation materials, as described in IBC Table 722.6.2(5). For a wall or partition where only plywood is used as the membrane on the side assumed to be exposed to the fire, insulation must be used within the assembly.

In developing this methodology it was also determined that the primary function of the membrane on the unexposed side of an exterior wall is to keep the insulation in place and prevent the transmission of heat. Fire resistance of wall assemblies is consistently dependent upon the fire exposed-side membrane. As a result, it is permissible to substitute various exterior cladding materials as the membrane on the unexposed side of exterior wall assemblies[1]. Therefore, where a fire resistance rating for an exterior wall is to be determined using CAM, any combination of sheathing, paper, and exterior finish listed in IBC Table 722.6.2(3) may be used.

Roofs and Floor/Ceiling Assemblies

In the case of a roof or floor/ceiling assembly, fire testing is normally done with exposure from below the assembly. To comply with this calculation methodology, floor and roof assemblies must have a protective membrane in conformance with Table 722.6.2(1) of the 2012 IBC. The upper membrane must consist of a subfloor or roof deck and finish in conformance with Table 722.6.2(4) of the 2012 IBC. Alternatively, any combination of membranes listed in Table 722.6.2(1) of the 2012 IBC, with an assigned time of at least 15 minutes, may be used on the unexposed (upper) side.

1 For examples of fire-resistance-rated exterior walls see "Design for Code Acceptance No. 3: One-Hour Fire Rated Wood-Frame Wall and Floor/Ceiling Assemblies" American Wood Council, 2013.

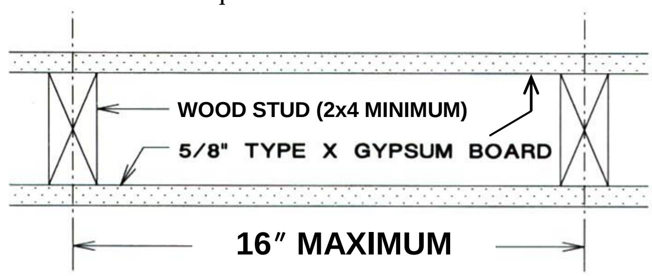
Example Calculations

Example 1: *Determine the fire endurance rating of a wall assembly having one layer of 5/8 inch Type X gypsum wallboard attached to wood studs on the fire exposed side (interior, see Figure 1).*

Table 722.6.2(1) of the 2012 IBC shows that 5/8 inch Type X gypsum wallboard has an assigned time of 40 minutes. IBC Table 722.6.2(2) shows that wood studs spaced no more than 16 inches on center have an assigned time of 20 minutes. Thus, the combined fire resistance rating of the assembly is 60 minutes. (Adding additional membranes to the framing would also be permitted according to Harmathy's rule #2.)

If the wall is assumed to be exposed to fire from both sides (e.g., for interior fire rated partitions and exterior walls with a fire separation distance of 10 feet or less), each surface of the framing member would be required to be fire protected with a membrane or combination of membranes having an assigned time of at least 40 minutes, as shown in the example, in order to achieve a one-hour fire-resistance rating from either side. If the proposed wall is assumed to be exposed to fire from one side only, as is required of an exterior wall having a fire separation distance greater than 10 feet, the fire exposure is assumed to be from the interior, which would require protection on the interior side with a membrane or combination of membranes having an assigned time of at least 40 minutes in order to achieve a one-hour fire-resistance rating. For this latter case, it should be noted that to achieve the assigned fire resistance rating for the interior side, the exterior side must be protected in accordance with IBC Table 722.6.2(3) or any membrane that is assigned a time of at least 15 minutes as listed in IBC Table 722.6.2(1).

If wall cavities between studs had been filled with mineral wool insulation, which has an assigned time of 15 minutes as noted in IBC Table 722.6.2(5), the 5/8 inch Type X gypsum wallboard could be replaced by 1/2 inch Type X gypsum wallboard. Thus, adding the assigned times for the 1/2 inch gypsum wallboard, wood studs, and insulation (25 minutes + 20 minutes + 15 minutes) the resultant fire resistance rating for the wall would also equal 60 minutes.



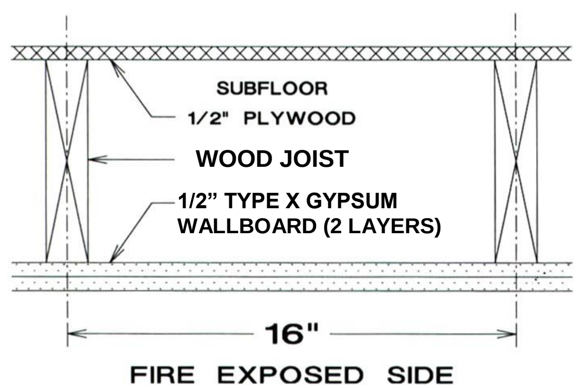
5/8 inch Type X gypsum wallboard	=	40 minutes
Wood studs	=	20 minutes
Combined Assembly Fire Resistance Rating	=	60 minutes

Figure 1 Interior Wall

Example 2: *Determine the fire resistance rating of a floor/ceiling assembly having wood joists spaced 16 inches on center and protected on the bottom side (ceiling side) with two layers of 1/2 inch Type X gypsum wallboard and having a 1/2 inch plywood subfloor on the upper side (floor side).*

IBC Table 722.6.2(1) shows that the assigned time for each layer of 1/2 inch Type X gypsum wallboard is 25 minutes. The time assigned for wood joists, as shown in IBC Table 722.6.2(2), is 10 minutes.

Adding the assigned times of two layers of gypsum wallboard and wood joists, a fire resistance rating of 60 minutes or one hour is calculated.



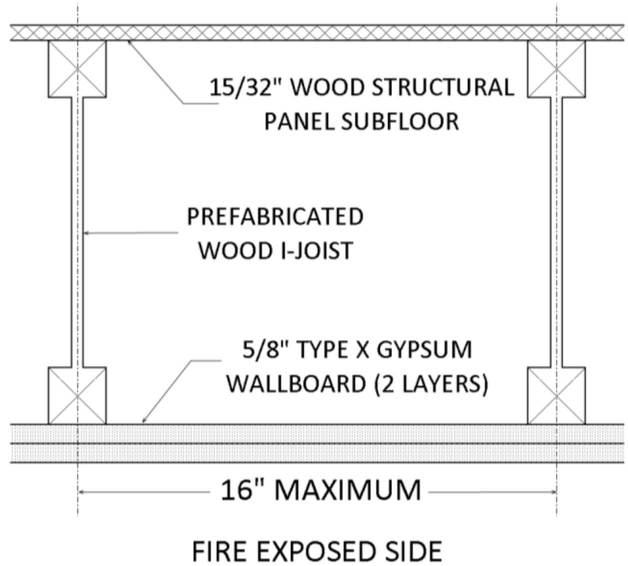
1/2 inch Type X Gypsum wallboard	=	25 minutes
1/2 inch Type X Gypsum wallboard	=	25 minutes
Wood joists	=	10 minutes
Combined Assembly Fire Resistance Rating	=	60 minutes

Figure 2 Floor/Ceiling Assembly

Example 3: *Determine the fire resistance rating of a floor/ceiling assembly having prefabricated wood I-joists spaced 16 inches on center and protected on the bottom side (ceiling side) with two layers of 5/8 inch Type X gypsum wallboard and having a 15/32 inch wood structural panel subfloor on the upper side (floor side).*

IBC Table 722.6.2(1) shows that the assigned time for each layer of 5/8-inch Type X gypsum wallboard is 40 minutes. IBC Table 722.6.2(2) does not assign a time contribution for prefabricated wood I-joists, so for the purposes of this example, no additional time is added to account for the contribution of the I-joist framing members.

Adding the assigned times of two layers of 5/8 inch Type X gypsum wallboard yields a time of 80 minutes; however, IBC Section 722.6.1.1 limits fire resistance ratings calculated in accordance with Section 722.6 to one hour. Thus, a fire resistance rating of 60 minutes or one hour is calculated.



5/8 inch Type X Gypsum wallboard	=	40 minutes
5/8 inch Type X Gypsum wallboard	=	40 minutes
Sum of assigned component times	=	80 minutes
Combined Assembly Fire Resistance Rating (limited to 1 hour per IBC 722.6.1.1)	=	60 minutes

Figure 3 Floor/Ceiling Assembly with Prefabricated Wood I-joists

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Conclusion

Assemblies of wood construction are used increasingly in architectural designs because of their adaptability to a variety of style preferences, economies of construction, and the energy saving performance of such systems. These assemblies can now be evaluated to determine their fire resistance rating by a Component Additive Method, avoiding expensive fire testing.

Designers are also encouraged to review AWC's online Heights and Areas Calculator[2] for additional information.

The procedure described in this publication is intended to assist the designer of wood-frame structures in meeting specified fire resistance requirements. Special effort has been made to ensure the accuracy of the information presented. However, AWC does not assume responsibility for particular designs or calculations prepared from this publication.

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2 Online Heights and Areas Calculator available free of charge on the American Wood Council website: www.awc.org.