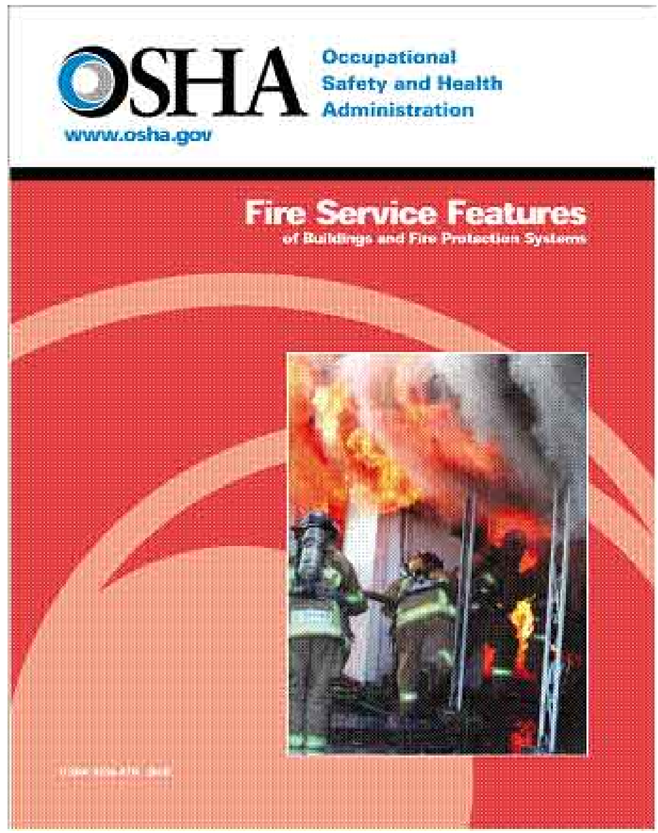
OSHA's Fire Service Features of Buildings: Commentary on an OSHA Publication Pertaining to Wood Trusses

Released July 6, 2007

Background:

In July 2006, The Occupational Safety and Health Administration published a document for building designers, owners and managers entitled *Fire Service Features of Buildings and Fire Protection Systems* (OSHA 3256-07N 2006). This is available for download on the internet at www.osha.gov/Publications/fire_features3256.pdf. "The manual is intended to increase building occupants' and emergency responders' safety by streamlining fire service interaction with building features and fire protection systems."[1]



Pages 26-27 *(see Appendix A)* of the document describe "Hazards to the Fire Service" including Lightweight Construction. This section raises a number of questions about the fire performance of trusses.

Issue:

Structural Building Components, including wood trusses, are being used, at an ever increasing rate in both residential and light commercial structures. The increased use of these products has raised concern within the fire service community. Their primary concern, rightfully so, is the life/safety of occupants and fire fighters when "new" products are introduced into construction that they are not immediately familiar with and do not want to be surprised by performance that they do not expect. The information that follows is being provided in order that all readers have the latest information concerning this topic.

The key questions that need to be addressed include:

- Are metal connector plates a weakness of these structural building components in fire?
- Do all members of a wood truss fail if one member fails?
- Would marking buildings that contain wood trusses provide useful information to firefighters?
- Are wood trusses a 'unique and unexpected hazard' in buildings?

[1] U.S. Fire Administration / National Fire Academy, "Warning: Hot Coffee! Hot Topic: Fire Service Features of Buildings and Fire Protection Systems." August 8, 2006. www.usfa.dhs.gov/downloads/pdf/coffee-break/hc-2006-0808.pdf.

This document will answer these and related questions as they regard wood truss performance in fire. Additional links and information can be viewed in *Appendix B*.

Key Definitions:

Structural Building Components[2]: Specialized structural building products designed, engineered and manufactured under controlled conditions for a specific application. They are incorporated into the overall building structural system by the Building Designer. Examples are wood or steel roof trusses, floor trusses, floor panels, wall panels, I-joists, or engineered beams and headers.

Metal plate connected wood truss[3]: Individual metal plate connected wood structure component manufactured by the Truss Manufacturer.

Metal connector plate[4]: Connector plate manufactured from ASTM A653/A653M, A591, A792/A792M, or A167 structural quality steel protected with zinc or zinc-aluminum alloy coatings or their stainless steel equivalent. The metal connector plate has integral teeth and shall be manufactured to various sizes (i.e., length and width) and thickness or gauges and shall be designed to laterally transmit loads in wood. Also known as truss plate, plate, metal plate, etc. (see Photo 1)

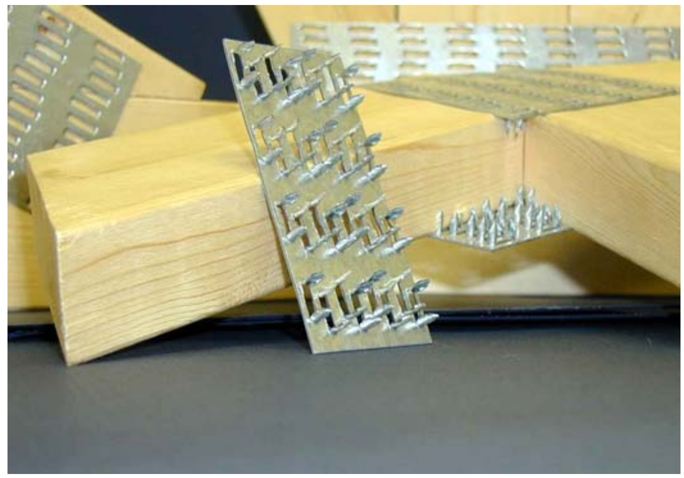


Photo 1

Analysis:

Facts about Wood Trusses

Fire Service Features of Buildings and Fire Protection Systems states: "Wood trusses have less mass than solid lumber…"[5] It goes on to say that "The higher surface area-to-volume ratio of trusses compared to joists allows trusses to burn more quickly."[6] While there is greater surface burning area in a wood truss compared to a solid sawn joist, research shows that the effect of surface area-to-volume ratio is not the key factor influencing fire performance of wood trusses. According to the National Fire Protection Research Foundation (NFPRF) report on lightweight construction:

> Product mass and surface burning area definitely influence the fire endurance performance of products when one compares a large cross-sectional beam versus a lightweight beam of any material. These effects are dramatically reduced when comparing materials having similar mass and surface area. The key to evaluating the effects of mass and surface area lie in analyzing the components that are effectively resisting fire degradation. For example, in evaluating a 2 x 10 joist and a 2 x 4 truss, the key fire performance resistance dimension is 1.5 in. Test results show similar fire endurance performance of these two products. The critical dimension usually degrades at a similar rate.[7]

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[2] Metal Plate Connected Wood Truss Handbook, 3rd Ed., WTCA, Madison, WI., 2002. www.sbcindustry.com/pubs/hb3-d

[3] Metal Plate Connected Wood Truss Handbook, 3rd Ed., WTCA, Madison, WI., 2002. www.sbcindustry.com/pubs/hb3-d

[4] Metal Plate Connected Wood Truss Handbook, 3rd Ed., WTCA, Madison, WI., 2002. www.sbcindustry.com/pubs/hb3-d

[5] Fire Service Features of Buildings and fire Protection Systems, Occupational Safety and Health Administration (OSHA 3256-07N 2006), pp. 26-7. http://www.osha.gov/pls/publications/pubindex.list.

[6] Ibid.

[7] National Engineered Lightweight Construction Fire Research Project, Technical Report: Literature Search & Technical Analysis, National Fire Protection Research Foundation, October 1992. p. 205. www.sbcindustry.com/images/fire/NFPRF_Report_WTCA_version.pdf.

"There is no known testing that relates the effect of surface burning to the ultimate fire endurance performance of the various products under study."[8] Given the fact that "2 x 10 joists and 12 inch deep trusses provide roughly the same unsheathed fire endurance performance time,"[9] the higher surface area-to-volume ratio of trusses does not necessarily predict poorer fire endurance performance.

This can be further analyzed by looking at generalized char rates for lumber. According to the USDA, "…the average constant charring rate [of wood] is about 0.6 mm/min (or 1.5 in/h)…"[10] The char rate affects fire endurance of structural members in this way:

> The loadcarrying capacity of a structural wood member depends upon its cross-sectional dimensions. Thus, the amount of charring of the cross section is the major factor in the fire endurance of structural wood members.[11]

Given that the generalized char rate is 1.5 inches per hour, the math indicates the following:

- A 2x10 (1.5" x 9.25") joist, with fire engulfing it on three sides will completely char through in about 30 minutes.
- A 2x4 (1.5" x 3.5") bottom chord of a truss, with fire engulfing it on four sides will completely char through in about 30 minutes.

Failure of each member type, 2x10 or 2x4 bottom truss chord, will be dependant on the applied load and generally will be less than 30 minutes where the joists or trusses are fully engaged in a fire.

Metal Connector Plates in Fire

Fire Service Features of Buildings and Fire Protection Systems describes "the metal gusset connection plates that appear to be at the root of many wood truss failures." [12] Metal connector plates are indeed a defining characteristic of a metal plate connected wood truss, but there is no evidence that fire degradation of the metal plates in a truss causes failure of the truss in fire.

According to Canadian fire researcher Leslie Richardson, in fire tests of wood truss assemblies, "Failures of bottom chord splices were the result of the teeth in the metal plates pulling out of the charred wood."[13] The researcher noted that, "it is important to point out that contrary to suggestions by some, these splice joints do not fail because the steel plates have been weakened by the fire exposure." [14]

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[8] Ibid. p. 197.

[9] Ibid. p. 197.

[10] Forest Products Laboratory. 1999. Wood handbook—Wood as an engineering material. Gen. Tech. Rep. FPL–GTR–113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. Chapter 17 Fire Safety. Robert H. White and Mark A. Dietenberger, p. 17-10. www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm

[11] Ibid. p.17-10.

[12] Fire Service Features of Buildings and fire Protection Systems, Occupational Safety and Health Administration (OSHA 3256-07N 2006), pp. 26-7. http://www.osha.gov/pls/publications/pubindex.list.

[13] Thoughts and Observations on Fire-endurance Tests of Wood-frame Assemblies Protected by Gypsum Board, *Fire and Materials*, 25, 223–239 (2001) Leslie R. Richardson, Fire Research Department, Building Systems Program, Forintek Canada Corp.

[14] Thoughts and Observations on Fire-endurance Tests of Wood-frame Assemblies Protected by Gypsum Board, *Fire and Materials*, 25, 223–239 (2001) Leslie R. Richardson, Fire Research Department, Building Systems Program, Forintek Canada Corp.

As an example, the connector plates in Photo 2 were exposed to an ASTM E119 test fire that burned for 60 minutes and reached 1700 degrees Fahrenheit. The plates show no visible signs of distress, and they look no different from normal plates other than the charred wood remaining on the teeth, and discoloration from having been exposed to extremely high temperatures.

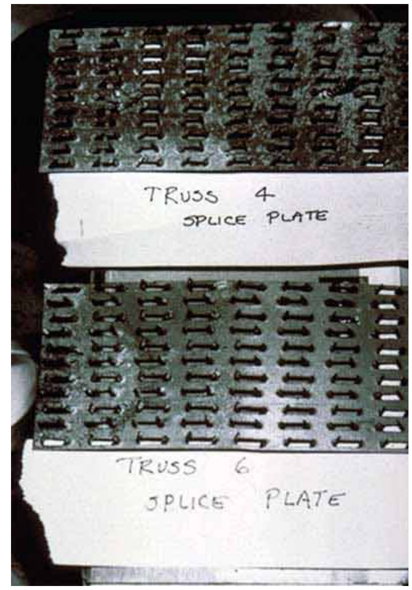

Photo 2

Truss joints typically fail as the fire degrades wood members they are connecting together the same way they fail under excessive loads – in withdrawal resistance failure mode. This failure mode is shown in Photo3 in which the two wood members were pulled apart with enough force to cause joint failure.

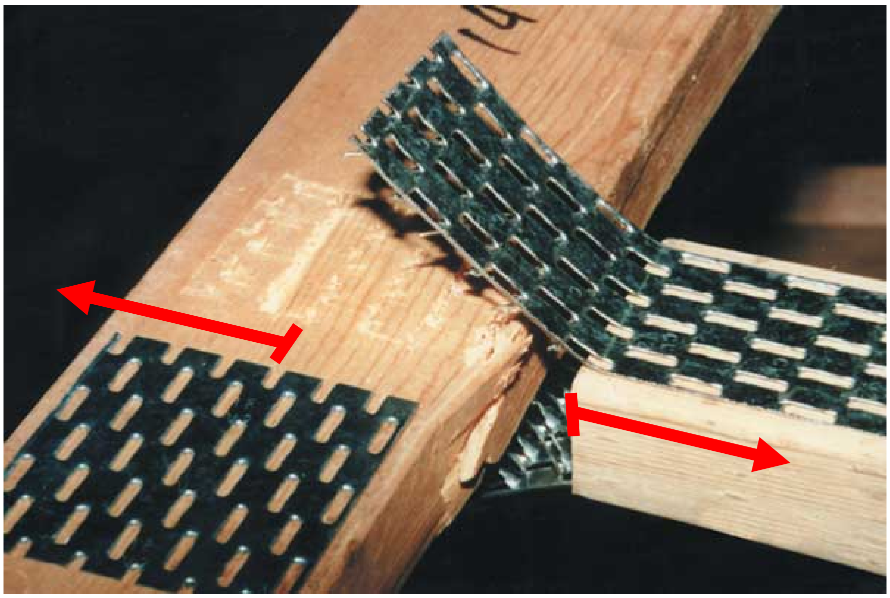

Photo 3

This failure mode can also be seen with this charred bottom chord splice joint in a truss (see Photo 4). The plate pulled out of the wood due to the forces exerted on it by the members pulling apart as shown. Note the characteristic curled shape taken by the connector plate in the withdrawal resistance failure mode.

Photo 4

If charring occurs in fire but the withdrawal forces are not great enough, connector plates can stay connected even after significant charring, as you can see in Photo 5.

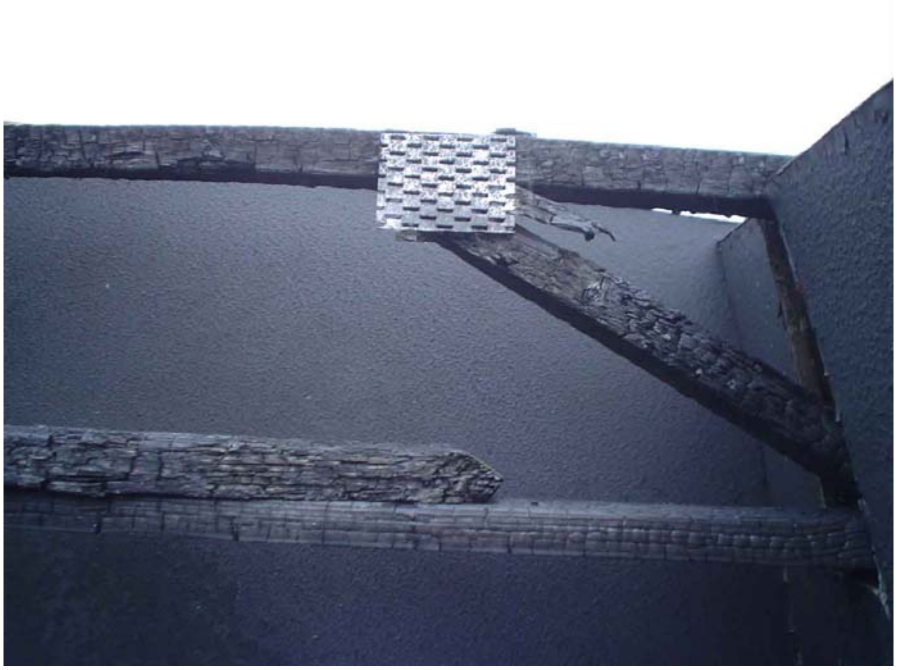

Photo 5

These concepts are described more fully in the Carbeck Education Program *Wood Truss Construction and Fire Performance*[15] and can be seen below in the following series of photographs of connector plates at successively greater fire exposures (see Photos 6 – 10). These photos come from a test fire where parts of the floor assembly happened to receive differing degrees of fire exposure, as evidenced by the increasing amounts of char seen on the joists toward the back of this assembly.

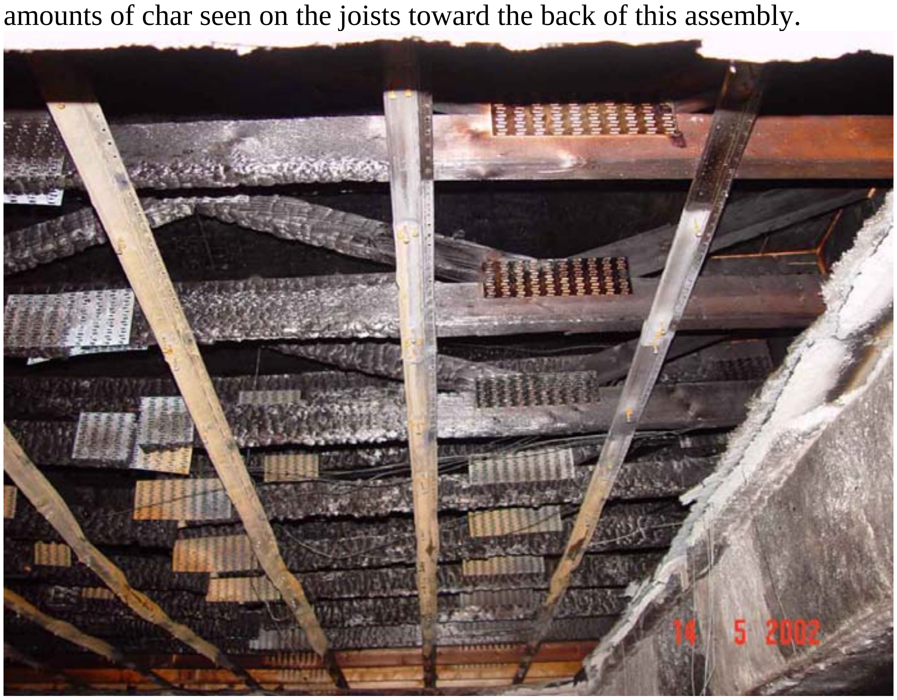

Photo 6

[15] Available from the Carbeck Structural Components Institute at www.fire.carbeck.org. See the presentation *Fire Performance of Metal Connector Plates*.

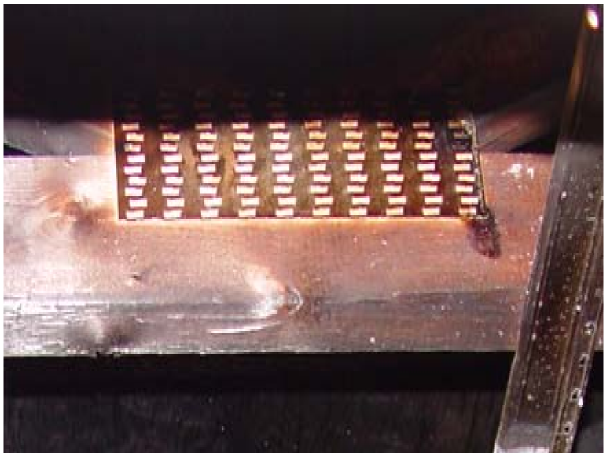

Photo 7

Photo 8

Photo 9

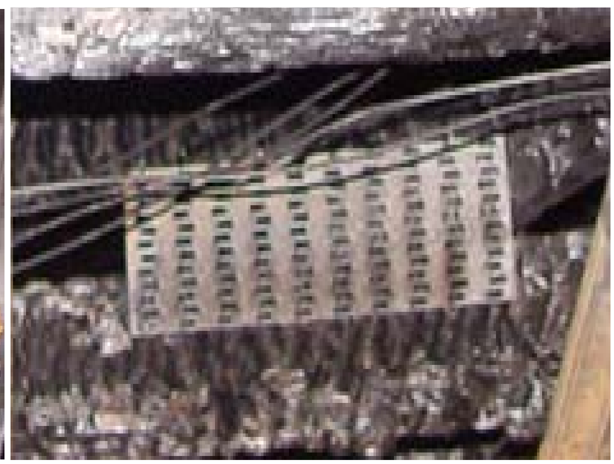

Photo 10

Another common misperception is that metal connector plates help promote failure in fire by accelerating char on the wood below them. As can be seen in the preceding photos, the truss plates do protect the wood for a period of time prior to becoming a heat conductor. This is due to the moisture in the lumber below the plate. According to Canadian fire researcher Leslie Richardson:

> Neither do they [truss joints] fail because the metal teeth conduct heat deep into the wood and accelerate char formation in the lumber. Examination of the trusses following the tests demonstrated that the metal plates partially shielded the underlying wood from the full effects of the fire and that there was slightly less char formation under the plates than in the remainder of the bottom chords.[16]

[16] Thoughts and Observations on Fire-endurance Tests of Wood-frame Assemblies Protected by Gypsum Board, *Fire and Materials*, 25, 223–239 (2001) Leslie R. Richardson, Fire Research Department, Building Systems Program, Forintek Canada Corp.

This concept is also more fully described in the Carbeck Educational Program[17] entitled *Fire Performance of Metal Connector Plates* and can be seen in Photos 11 and 12:

Photo 11
Courtesy NIST and Kelly Harman[18]

Photo 12
Result of Fire Barrel demonstration[19]

Mechanics of Truss Failure

Fire Service Features of Buildings and Fire Protection Systems states that "Both wood and metal trusses are made of interdependent members that all fail if one member fails."[20] This is a misunderstanding of how trusses are manufactured today and represents a common misconception about metal plate connected wood trusses. While trusses are made of interdependent members, the mechanics of a metal plate connected wood truss are very different from a pin-connected truss, the classic engineering example of a truss.

When a member or joint in a metal plate connected wood truss is broken, the truss loses much of its strength, but it retains some of its load carrying capacity. This is due to the moment carrying capacity of the metal plate connected joints, and the ability of the nearby members and joints of a truss to share loads.[21] This concept is also more fully described in the Carbeck Educational Program[22], entitled *Wood Trusses after a Church Fire*, and can be seen in the Photos 13 and 14:

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17 See the presentation *Fire Performance of Metal Connector Plates* on www.fire.carbeck.org.

18 From a draft thesis entitled "A Study of Metal Truss Plate Connectors When Exposed to Fire" by Kelly Harman, E.I.T and James Lawson, 2005. This was based on research done at the National Institute of Standards and Technology in 2005.

19 This photo shows a splice joint which had been exposed to fire over a barrel. This was done as part of a demonstration conducted during a truss plant tour for firefighters in Nashville, TN.

20 Fire Service Features of Buildings and fire Protection Systems, Occupational Safety and Health Administration (OSHA 3256-07N 2006), pp. 26-7. www.osha.gov/pls/publications/pubindex.list.

21 These concepts on the mechanics of truss failure are more fully explained in the Carbeck Educational Program at www.fire.carbeck.org. See the presentation *Fire Performance of Metal Connector Plates*.

22 See the presentation *Fire Performance of Metal Connector Plates* on www.fire.carbeck.org.

Photo 13

Photo 14

Failure Warning

Fire Service Features of Buildings and Fire Protection Systems states that "Wood trusses have less mass than solid lumber, which greatly reduces the "extra" wood compared to solid joists that burn through more slowly and provide indications to firefighters of an impending collapse."[23]

According to NIOSH, "The potential for structural collapse is one of the most difficult factors to predict during initial size-up and ongoing fire fighting. Structural collapse usually occurs without warning."[24]

Whether warning of failure is more evident with joists than trusses than with other types of construction is very unclear. While controlled fire tests of wood truss floor assemblies show trusses do sag significantly before failure (see Table 1[25]), and much more than joists do, this is not a reliable warning sign.

[23] Fire Service Features of Buildings and fire Protection Systems, Occupational Safety and Health Administration (OSHA 3256-07N 2006), pp. 26-7. www.osha.gov/pls/publications/pubindex.list.

[24] NIOSH Alert: Preventing Injuries and Deaths of Fire Fighters due to Structural Collapse, U.S. Department of Health and Human Services [NIOSH] Publication No. 99-146 (1999), p 2. http://www.cdc.gov/niosh/pdfs/99-146.pdf

[25] National Engineered Lightweight Construction Fire Research Project, Technical Report: Literature Search & Technical Analysis, National Fire Protection Research Foundation, October 1992. Table 19. Standardized Unsheathed Assembly Tests. p. 106. www.sbcindustry.com/images/fire/NFPRF_Report_WTCA_version.pdf.

Test	Structural Member	Spacing	Structural Failure (min:sec)	Avg. Defl. at Floor (in.)	Loading (psf) - % Design Stress
FM FC 209	2 x 10; 23/32"ply. w/vnl[5]	24 in. o.c.	13:34	**2.83**	62.1 (100%)
FM FC 212	2 x 10 ;23/32"ply. w/cpt[5]	24 in. o.c.	12:06	**3.58**	62.4 (100%)
NBS 421346 (2)	2 x 10; 2-½" ply.	16 in. o.c.	11:38	**2.7**	63.7 (100%)
NBS 421346 (4)	2 x 10; 2-½" ply. w/cpt.[5]	16 in. o.c.	11:38	**3.3**	63.7 (100%)
NBS 421346 (9)	2 x 8; ½ in. ply. w/blk[5]	16 in. o.c.	13:00	**7.0**	21.0[1] (40%)
NBS 421346 (10)	2 x 8; 5/8 in. ply. T&G[5]	16 in. o.c.	13:00	**12.0**	21.0[1] (40%)
FPL	2 x 10	16 in. o.c.	6:30	**4.0**	79.2[6] (100%)
FPL	2 x 10	16 in. o.c.	13:06	**N/A**	40.0[1]
FPL	2 x 10	16 in. o.c.	17:54	**1.7**	11.35[1]
FM FC 250	12 in. MPCT[7]	24 in. o.c.	10:12	**11.5**	60.0 (100%)
NFPA Tech Report 1	4 x 14 Wood Beam	3 ft. 7 in. o.c.	> 13:00[2]	**0.5**	30.0[1]
NFPA Tech Report 1	14 in. Steel bar joist	3 ft. 7 in. o.c.	13:00[2]	**18.0**	30.0[1]
FM FC 208	7¼ in. Steel C-joist	24 in. o.c.	7:30	**7.0**	69.8 (100%)
FM FC 211	7¼ in. Steel C-joist	24 in. o.c.	5:12	**10.0**	69.8 (100%)
NBSIR 73-141	6 x 1¾ in. C-joist	24 in. o.c.	3:45	**N/A**	51.4[1]
NBSIR 73-164	6 x 3 in. 14 ga C-joist	48 in. o.c.	9:00	**N/A**	40.0[1]
NFPA Tech Report 3	7 x 21 Wood Beam	Sngl. Elmt.	> 30:00[3]	**2.25**	30.0[1]
NFPA Tech Report 3	16 WF 40 Steel Beam	Sngl. Elmt.	30:00[3]	**35.5**	30.0[1]
NIWT (1)	11.5 X 9.3 in. Beam	5 PC. Beam	55:00	**N/A**	7,374 ft.-lbs.
NIWT (2)	11.5 x 10.8 in. Beam	6 PC. Beam	> 60:00	**N/A**	7,674 ft.-lbs.
NIWT (3)	3.77 x 7.79 in. Beam	2 PC. Beam	20:00	**N/A**	2,957 ft.-lbs.
NIWT (4)	5.66 x 9.3 in. Beam	3 PC. Beam	50:00	**N/A**	4,435 ft.-lbs.
BMS 92	2 x 10	16 in. o.c.	N/A	**N/A**	N/A
IITRI J6397	12 in. Steel Bar Joist	Sngl. Elmt.	10:06	**N/A**	dead ld

Table 1

The amount of sag before failure depends greatly on the applied load conditions in the room, the intensity of the fire that the trusses or joists are facing, the ventilation conditions, etc.

With any structural system, relying on sag as a warning sign of imminent collapse in fire can be very dangerous

Trusses as a Hazard to Firefighters

Fire Service Features of Buildings and Fire Protection Systems states that "Many firefighters have been killed in collapses attributed to trusses, particularly wooden ones…"[26] This statement gives the impression that wood trusses are a significantly greater fireground hazard than other types of construction. While wood trusses have fire performance characteristics that differ from other types of construction, no scientific study provides evidence that they present a significantly greater danger to firefighters.

In fact, more firefighters are killed in fires involving structural collapse of conventional wood frame construction than of truss construction. Collapse of wood frame and ordinary roof/floor construction was involved in 2.99% of firefighter fatalities between 1980 and 2005, while wood truss construction was

[26] Fire Service Features of Buildings and fire Protection Systems, Occupational Safety and Health Administration (OSHA 3256-07N 2006), pp. 26-7. www.osha.gov/pls/publications/pubindex.list.

involved in only 0.80% of firefighter fatalities.[27] Tables 2 and 3 provide a digest of the National Fire Protection Association's and United States Fire Administration's firefighter fatality statistics[28]:

Cause of Firefighter Fatalities, 1980-2005

	Fatalities	Heart Attack	Fell or Struck by Object	Electro-cution	Structural Collapse	Exposure to Fire Products
Number	2678	1201	496	31	121	144
Percent	100%	44.85%	18.52%	1.16%	4.52%	5.38%

Table 2

Structural Product Involved in Firefighter Death, 1980 - 2005

	Total Fatalities	Wood Frame Products	Ordinary Roof/Floor	Combust. Wall	Wood Trusses	Heavy Timber Trusses	Non-Combust. Roof/Floor	Non-Combust. Wall
Number	2678	56	24	10.5	21.5	7	11.5	18.5
Percent	100%	2.09%	0.90%	0.39%	0.80%	0.26%	0.43%	0.69%

Source: National Fire Protection Association, United States Fire Administration, and WTCA

Table 3

Labeling Truss Construction

Fire Service Features of Buildings and Fire Protection Systems states that "Marking these buildings that include trusses makes this information immediately available to firefighters."[29] While this sounds obvious, building labeling approaches probably will not produce the desired effect. In fact, labeling buildings that use truss construction can mislead firefighters, because:

- Most building labeling systems label only new construction. Because most new residential construction uses trusses, the labels will simply go on most new buildings. In most areas, firefighters can already assume that most new construction will include trusses, so no new information would be provided by the building labels.
- On the other hand, where there is no label, firefighters should also assume that trusses or other lightweight construction could be present. The label may not be applied because the building was grandfathered (i.e., built before labeling was implemented), because it contains multiple types of structural elements not just trusses, because of an oversight, etc.
- The building's contents have nothing to do with whether trusses are used or not. Contents that are highly flammable, such as fireworks, gunpowder, gasoline, munitions, etc. will have a much greater effect on firefighter safety than whether the building used trusses or not, yet buildings with these types of contents are generally not known, hence are not required to be labeled.

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27 WTCA, at www.sbcindustry.com/fire.php (select the PDF document *Causes of Firefighter Fatalities)*. Sources include: USFA Firefighter Fatalities in the United States in 2005, U.S. Fire Administration; NIOSH Fire Fighter Fatality Investigation and Prevention Program, National Institute for Occupational Safety and Health; "Firefighter Fatality Incidents – 2005" NFPA Journal, National Fire Protection Association; Firehouse Magazine.

28 Ibid.

29 Fire Service Features of Buildings and fire Protection Systems, Occupational Safety and Health Administration (OSHA 3256-07N 2006), pp. 26-7. www.osha.gov/pls/publications/pubindex.list.

According to the NIOSH report on truss construction,[30] there are better ways to provide safety related information to firefighters. The report states:

> Pre-incident planning is an important tool for identifying the type of building, the building contents, the load-bearing and interior wall locations, and the presence of trusses. This information will aid incident commanders in managing the multiple hazards in a fire.[31]
>
> Inspect buildings within your jurisdiction and note the type of construction, materials used, presence of trusses in the roof and floor, occupancy, fuel load, exit routes, and other distinguishing characteristics.[32]
>
> Whenever possible, inspect building during the construction phase to help assess the different types of construction, materials, etc.[33]
>
> Enter preplan information into the dispatcher's computer so that when a fire is reported at preplanned locations, the dispatcher can notify by radio all first responders with critical information.[34]
>
> Include information about roof and floor type (presence of trusses [figure 3], materials used), roof loads (heating, ventilation, and air conditioning units [HVAC], displays), sprinkler systems, utilities, chemicals on site, and contact numbers.[35]
>
> Record data regarding roof and floor construction (e.g., wooden joist, wood truss, steel joist, steel truss, beam and girder, etc.) [NFPA 2003].[36]

Through good pre-fire planning, not only the type of construction could be accurately conveyed, but various types of hazards could be brought to the firefighter's attention. The structural building components industry is very interested in working with the fire service as we can easily help streamline the implementation of pre-fire planning with digital records[37] of structural component designs and building plans.

Where there is resistance to putting in place an easy to implement and use pre-fire planning system, *universal* building labeling may be an option to be considered. In this second choice, all construction types in all buildings need to be labeled. This would provide all the information that firefighters need to guide fireground decision making and not mislead them.[38] Photo 15 provides an example of a label in such a labeling system.

Photo 15

In this example (see Photo 15), the top letter "T" denotes truss construction in the roof. The lower letter "I" denotes wood I-joist construction in the floors. Other construction types that could be indicated in this

[30] NIOSH Publication No. 2005-132: *Preventing Injuries and Deaths of Fire Fighters Due to Truss System Failures*, available at: www.cdc.gov/niosh/docs/2005-132/.
[31] Ibid. p. 7.
[32] Ibid. p. 8.
[33] Ibid. p. 8.
[34] Ibid. p. 8.
[35] Ibid. p. 10.
[36] Ibid. p. 8.
[37] Digital design is very much part of the structural building components industry, and the ICC and other organizations are part of an effort to make this digital building information available to code officials and the fire service. For more information see "buildingSMART for the future" and www.iccsafe.org/SMARTcodes/.
[38] For a more in-depth analysis of building labeling issues, see the Carbeck presentation *Labeling Buildings That Use Truss Construction* at www.fire.carbeck.org/info_for_firefighters.php.

label include "W" for sawn wood joist/rafter construction, "S" for steel, and "C" for concrete. The Roman numeral "V" denotes that the construction is Type 5 for the whole building in accordance with the building code classification system. In addition, the year of construction is indicated. This approach is more fully described in the Carbeck Educational Program[39] entitled *Labeling Buildings that Use Truss Construction.* A summary of this approach, *Example Language for Building Labeling*, can be downloaded from the Carbeck downloads page: www.fire.carbeck.org/downloads.php.

Trusses as a 'Unique or Unexpected' Hazard in Buildings

Fire Service Features of Buildings and Fire Protection Systems states that wood trusses represent one of several "unique or unexpected hazards"[40] in a building. In this section of the publication trusses are grouped with shaftways, which have been recognized as unique and unexpected hazards and are required by the building codes to be labeled. While wood trusses are not present in all buildings and are not apparent from the outside, their presence is not unique or unexpected in the same way as shaftways. Shaftways are not commonly found in most buildings, so they are somewhat unique. If present in a building, their location is typically not obvious. Sometimes an entrance to a shaftway can look like a normal doorway. Shaftways are, then, unexpected.

By contrast, metal plate connected wood trusses are not like shaftways in either of these characteristics:

- Wood roof trusses are installed in approximately 60% of all new residential and multifamily buildings, constructed in the United States, and also in 10% and 25% of the floors, respectively. Hardly 'unique,' buildings with trusses are very common.
- If trusses are present in a building, their location in the structure is obvious. While they are not seen from the outside of the building, today they are hardly an 'unexpected' feature of most residential buildings.

While shaftways have been recognized as a unique and unexpected hazard in the building codes and are required to be labeled, wood trusses have not been so recognized.

Conclusion:

The discussion of wood trusses in *Fire Service Features of Buildings and Fire Protection Systems* makes a number of points about the fire performance of wood trusses some of which depart from recognized research and facts that are in the public domain. These are general misunderstandings about trusses and how they perform under fire conditions, and this paper's goal is to clarify these points. Current research provides the following facts which should be used to make decisions about wood trusses:

- While there is greater surface burning area in a wood truss compared to a solid sawn joist, the 1-1/2 inch dimension of the lumber is the critical dimension for fire endurance performance. A 2x4 and a 2x12 both have the same critical dimension, and unprotected fire endurance performance is very similar.
- Trusses are made of interdependent members with the webs, chords and truss plates all adjusting to the applied loads and trying to resist them. Therefore not all members of a wood truss fail if one member fails.
- Metal connector plate performance in a fire is not well understood.
    - There is no evidence that fire causes metal connector plate joints to weaken at a rate faster than would be predicted by wood char rates when a truss is subject to a fire. Plates do not pop off when fire impinges on them. The wood they are attached to does degrade under fire conditions and causes the plates to lose their holding power as degradation continues.

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39 Ibid.

40 Fire Service Features of Buildings and fire Protection Systems, Occupational Safety and Health Administration (OSHA 3256-07N 2006), pp. 26-7. www.osha.gov/pls/publications/pubindex.list.

    - There is no evidence that metal connector plates accelerate charring of the wood below them.
- According to standardized fire tests, wood trusses generally deflect (sag) more than 2x10 solid sawn joists before failure.
    - The amount of sag before failure depends greatly on the applied load conditions in the room, the intensity of the fire that the trusses or joists are facing, the ventilation conditions, etc.
    - Counting on a sagging floor system as a warning sign of imminent collapse in fire can be very dangerous
- Firefighter fatalities on the fireground occur less often in buildings with truss construction than in buildings that use traditional conventional wood frame construction methods.
- The presence of wood trusses in a building is not 'unique or unexpected,' as shaftways are recognized to be. Wood trusses are common in buildings, and their location in floors and roofs today should be expected.
- Wood trusses are an important feature of buildings of which firefighters need to be aware, and accomplishing this along with generating other key fire fighter decision making information through pre-fire planning is the preferred method.
    - The structural building components industry is very interested in working with the fire service to streamline the implementation of pre-fire planning through the use of digital records of structural component designs and building plans.
- Where there is resistance to putting in place an easy to implement and use pre-fire planning system, *universal* building labeling may be an option to consider. Under this approach all construction types in all buildings need to be labeled so that firefighters have all the information they need to guide optimal fire ground decision making.

For more information on each of these topics and additional information pertaining to the fire performance of wood trusses, see the Resources for Fire Professionals page (www.sbcindustry.com/firepro.php) on the WTCA website.

Fire Service Features of Buildings and Fire Protection Systems
(OSHA 3256-07N 2006)
Pages 26 – 27

Hazards to the Fire Service

During a fire, any building may become inherently unsafe for occupants and fire service personnel. However, some building construction features present unique or unexpected hazards. This section discusses these hazards.

Lightweight Construction

Trusses are widely used in construction to span wide areas without the need for vertical supports, reducing both material and construction costs (Figure 2.24). Under ordinary conditions, trusses work well and building codes have permitted this type of construction for many years. However, trusses often fail suddenly and totally during fires. Both wood and metal trusses are made of interdependent members which all fail if one member fails. Adjacent trusses, in their weakened state, are then unable to carry the additional load and these also fail in quick succession. It is impossible for crews operating at a fire to predict the time or extent of a collapse since they cannot see how many trusses are affected, which components, and to what extent.

Wood trusses have less mass than solid lumber, which greatly reduces the “extra” wood compared to solid joists that burn through more slowly and provide indications to firefighters of an impending collapse. The higher surface area-to-volume ratio of trusses compared to joists allows trusses to burn more quickly. In addition, the metal gusset plates that hold wood truss components together may fail quickly as fire consumes the wood in which the gusset teeth are shallowly embedded.

Many firefighters have been killed in collapses attributed to trusses, particularly wooden ones, since the 1970s. Incident commanders and/or safety officers typically consider the presence of trusses in their fireground risk analysis. Marking these buildings that include trusses makes this information immediately available to firefighters. The State of New Jersey requires this as a direct result of five firefighters losing their lives in Hackensack in 1988 (Figure 2.25).

Another component used to maximize construction efficiency is the wooden I-beam. Similar to trusses, I-beams eliminate extra wood, thereby providing less warning prior to failure under fire conditions. However, they lack the metal gusset connection plates that appear to be at the root of many wood truss failures. Wherever these lightweight construction techniques are used, serious consideration should be given to providing sprinkler protection throughout the building, if not already required. Sprinkler protection of combustible concealed spaces is an important feature for firefighter safety. Further discussion about lightweight construction can be found in “Building Construction for the Fire Service, ” published by the NFPA.

Shaftways

Vertical shafts within buildings sometimes have exterior openings accessible to firefighters. Any such doors or windows should be marked “SHAFTWAY” on the exterior with at least 6 inch high lettering (Figure 2.26) as required by the IFC and NFPA 1. This warns firefighters that this would be an unsafe entry point. If properly marked, time will not be wasted attempting entry at these points. Normally, interior openings to shafts are readily discernable. Ordinary elevator doors are not likely to be mistaken for anything else. However, other interior shaft openings that could be mistaken for ordinary doors or windows should also have shaftway marking.

Skylights

Without special precautions, roof-mounted skylights obscured by heavy smoke or snow may collapse under the weight of a firefighter. Skylights should be designed to bear the same weight load as the roof.

The same applies to coverings over unused skylights. If this is not practical, mount barriers around skylights to prevent firefighters from inadvertently stepping on them.

Appendix B

For more information on this topic, see the following links and resources:

WTCA Resources for Fire Professionals page:
www.sbcindustry.com/firepro.php

Carbeck Structural Components Institute fire performance educational programs:
www.fire.carbeck.org

WTCA Fire & Wood Trusses page:
www.sbcindustry.com/fire.php

Open Joist 2000:
www.openjoist2000.com

Forintek Canada test results on fire resistance of floor assemblies:
ans.hsh.no/if/brann/InterFlam/InterFlam%2004/files/603.pdf

National Engineered Lightweight Construction Fire Research Project:
www.sbcindustry.com/images/fire/NFPRF_Report_WTCA_version.pdf

U.S. Department of Agriculture, Wood Handbook (Chapters 9, 10, 11, and 17):
www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm

Metal Plate Connected Wood Truss Handbook, 3rd Ed., WTCA:
www.sbcindustry.com/pubs/hb3-d

View all SBCA *Tech Notes* at www.sbcindustry.com/technotes.php