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Publisher's Message

Facts on the Fire Performance of Wood Trusses by Kirk Grundahl

There are two primary authors and lecturers that the Fire Service relies on for building construction training—retired New York Fire Chief Vincent Dunn and Mr. Frank Brannigan, whose book Building Construction for the Fire Service is an often used training text. Their training has led the fire service to believe the following concepts:

- Chief Dunn states, “There is a saying in the fire service: ‘Don't trust a truss.’ Why? Because a burning wood truss is the most dangerous structure you'll ever encounter when fighting a fire…The truss has finally been identified as the killer it is. We found out what causes burning trusses to collapse and kill firefighters, and we're passing on this information so that you can increase your chances for survival.”[1]
- Dunn has also stated, “Those sheet metal surface fasteners are likely to loosen—fast—whether or not the fire is hot enough to char the wood. It can cause the fastener to curl up and pull away from the truss. These killer connectors help make the lightweight wood truss the most dangerous of all roof trusses.”1
- Frank Brannigan’s book makes the following points regarding trusses:
  - A truss is a truss is a truss, and it has no redundancy.
  - Disastrous to firefighters.
  - Designed to provide long spans using the minimum amount of material.
  - Failure of one truss element (web or chord) causes the entire truss to fail.
  - Failure of one truss will cause adjacent trusses to collapse.
  - Trusses collapse without warning.
  - The collapse of a truss is sudden and catastrophic.
  - The failure of any connection may be fatal.
- Brannigan also makes the following points about building in general:
  - Buildings and their materials are the enemies of the fire service.
  - Training with ALL building types and materials is essential.

These thoughts can be distilled into a handful of claims that the fire protection industry believes to be true about trusses. What follows are these claims and then the facts on the fire performance of trusses.

CLAIM #1: "SHEET METAL SURFACE FASTENERS LOOSEN QUICKLY AND CURL AWAY FROM THE WOOD.”

THE FACTS (See photo 1.)

- The fire causes the lumber to char, reducing the lumber's strength.
- The lumber stress from the dead and live loads on the trusses increases.
- When the stress is higher than the lumber and plate's resistance, the plate pulls out as shown in photo 1.
- This is a truss plate withdrawal resistance failure, the typical truss plate failure mode.
- The curled plates that the fire service often sees after a fire is due to this failure mode where the steel was hot and malleable. When cool water hits the steel, the curled shape is permanent.

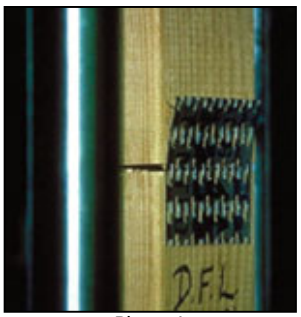

Photo 1

CLAIM #2: “STEEL TRUSS PLATES CONDUCT HEAT INTO THE WOOD CAUSING PREMATURE FAILURE.”

THE FACTS

- Initially, like any reflective surface (i.e., any reflective surface like those used in sheathing board products similar to Thermo-Ply), the

steel truss plate reflects heat away from it. (See photo 2. Notice in particular the brown, normal-looking wood in several slots.)

- Wood begins to char at 452 degrees Fahrenheit.
- The wood has about 12 percent moisture content.
- As the moisture heats up above boiling temperature, it rises to the surface of the wood fiber. This keeps the steel plate at 212 degrees F until all the moisture below the plate has risen.
- In every case, the charring on either side happens faster than under the plate because it is easier for moisture to rise. (See photo 5.)
- Eventually, the temperature of the plate increases beyond 212 degrees and the plate turns black with carbon. (See photos 2, 3 and 4 for carbon on plate.)
- Then it heats up to burn off the carbon. At that point, the plate conducts heat into the wood. (See photo 5 where the wood charred around the teeth.)
- Once the wood below the plate chars enough, the plate pulls out of the wood. (See photo 5.)


Photo 2

Photo 3

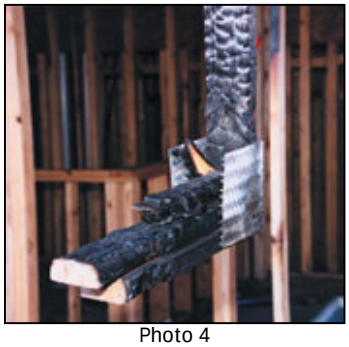
Photo 4

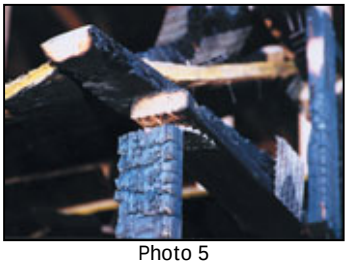
Photo 5

CLAIM #3: "A TRUSS IS A TRUSS IS A TRUSS, AND IT HAS NO REDUNDANCY. FAILURE OF ONE TRUSS WILL CAUSE ADJACENT TRUSSES TO COLLAPSE. FINALLY, THE FAILURE OF ANY CONNECTION MAY BE FATAL."

THE FACTS

- First, the ceiling fan in photo 6 shows where the firefighter in the other pictures (photos 7-9) is standing supported by only the cut trusses.
- Why do the trusses still have sound strength?
  - Truss plates are very strong and have moment carrying capacity.
  - The normal theoretical truss is pin connected and would fail if one member was cut or one entire connection was lost.
- These photos illustrate:
  - Metal plate connected trusses are unique.
  - There is structural redundancy.
  - The failure of one truss element (web or chord) does NOT necessarily cause the entire truss to fail.
  - The failure of one truss does NOT necessarily cause adjacent trusses to collapse.


Photo 6

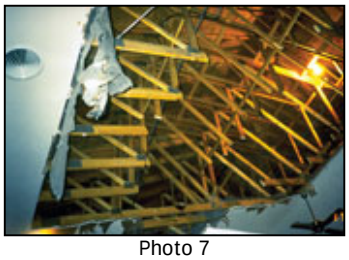
Photo 7


Photo 8


Photo 9

CLAIM #4: "TRUSS PLATES ARE CHEAP OR INFERIOR CONNECTORS COMPARED TO 16-PENNY NAILS."

THE FACTS (See photo 10.)

- A typical truss plate's 0 degree lateral resistance strength is about 200 psi.
- The design tooth withdrawal strength of the joint shown in photo 1 is 2,400 lbs (200 psi x 12 sq. in.).
- The ultimate tooth withdrawal strength of this joint is, at a minimum, 7680 lbs. (2,400 x 3.2 safety factor).
- A 16-d nail has a design capacity of roughly 100 lbs.
- The equivalent design strength for the plate in photo 1 would require 24 nails on each side of the butt joint.

CLAIM #5: "WHEN TRUSSES COLLAPSE IT IS ALWAYS SUDDEN AND CATASTROPHIC."

THE FACTS

- We have many photos that show that trusses do not always collapse in fires. (See photos 6-9 and 11.)
- In many cases the trusses are still standing as the sheathing burns away.
- Once the sheathing is weakened, the trusses are left with no lateral support, become very unstable and are more likely to collapse. Collapse can then be sudden.

Photo 10

Photo 11

CLAIM #6: "TRUSSES COLLAPSE MUCH FASTER THAN TRADITIONAL SOLID WOOD JOISTS AND IN ADDITION TO COLLAPSING WITHOUT WARNING."

THE FACTS

- The table below demonstrates that under identical fire conditions (100% of design load), solid wood joists fail in the range of 6:30 – 13:34. Trusses fail in this test at 10:12 (similar results).
- The above table also shows that trusses warn of collapse by deflecting under fire loading, in fact far more visibly than solid wood joists—11.5" of deflection to an average of about three inches.
- ALL structural members can fail quite quickly under the siege of fire, usually in less than 10 to 15 minutes.

ASTM E119 Assembly Tests at Full Design Load[1]

Test	Structural Member	Spacing (inches o.c.)	Structural Failure (min:sec)	Average Deflection at Floor (inches)	Loading (psf) - % Design Stress
FM FC 209	2 x 10	24	13:34	2.83	62.1 - 100%
FM FC 212	2 x 10	24	12:06	3.58	62.4 - 100%
NBS 421346 (2)	2 x 10	16	11:38	2.7	63.7 - 100%
NBS 421346 (4)	2 x 10	16	11:38	3.3	63.7 - 100%
FPL	2 x 10	16	6:30	4.0	79.2* - 100%
FM FC	12" Truss**	24	10:12	11.5	60.0 - 100%
FM FC 208	7¼ Steel C-joist	24	7:30	7.0	69.8 - 100%

*This load may be greater than 100% of design load. **Refers to a Metal Plate Connected Wood Truss.

Click on image for larger view.

CLAIM #7: "TRUSSES ARE DESIGNED TO PROVIDE LONG SPANS USING THE MINIMUM AMOUNT OF MATERIAL TO DO SO."

THE FACTS

- Trusses are highly engineered products whose specific purpose is to transfer loads applied to the structure to the ground in as efficient manner as possible.
- All engineers have the professional responsibility to provide economical and efficient designs.
- Buildings and, therefore, trusses are not designed to be burned; thus, they are not designed to provide resistance to fire loads. Trusses are only designed for environmental loads like snow, wind, rain or earthquakes.

CLAIM #8: "TRUSSES ARE DISASTROUS TO FIREFIGHTERS AND THEY HAVE FINALLY BEEN IDENTIFIED AS THE KILLERS THEY ARE."

THE FACTS

- Our best data is taken from Fire Command Magazine and NFPA Journal, which publish yearly articles on this topic. The data suggests that from 1980 to 2001, less than one percent (0.81 percent) of all firefighter deaths took place in buildings that contained wood trusses.
- This is in contrast to 3.08 percent of deaths that took place in what would be considered buildings that use traditional construction methods. The largest cause of firefighter deaths (45.10 percent) did not relate to building materials at all, but were due to heart attacks.

CONCLUDING FACTS ABOUT THE FIRE PERFORMANCE OF TRUSSES

- Buildings using trusses do not always have large roof or floor areas that collapse, trusses don't always collapse under fire conditions, and they don't always collapse suddenly.
- Cutting or burning one truss member does not cause the entire truss to fail.
- Truss plates don't loosen quickly and curl up when a fire starts; they do this under very adverse fire load conditions.
- Trusses perform in a similar manner to other structural elements during the siege of fire. All typical unprotected structural framing elements will collapse in less than 15 minutes under identical fire conditions.
- No buildings are designed specifically to resist fire loading conditions and no two fires are identical.
- Like Mr. Brannigan, we believe that buildings under the siege of fire are the firefighter's enemy and can certainly lead to death. We believe that in applying emotional terms to trusses like they have, Mr. Brannigan and Chief Dunn are emphasizing the extreme need for firefighter training for ALL building types and ALL structural framing materials.
- Finally, we feel that the following activities will reduce the risk of loss of life on the fire ground:
  - Conducting thorough, pre-incident evaluation of all structures.
  - Using only proper safety precautions when venting the roof.
  - Opening concealed spaces quickly to determine current fire location.
  - Being aware of the time factor by always asking, both prior to arrival and while on the fireground, “How long has the fire been burning?”
  - Communicating all abnormalities to fire ground command.
  - Watching for indications of structural deterioration.
  - Broadly disseminating new tactical safety concepts learned from each fire.[2]

The loss of one firefighter is one too many. Therefore, we believe that education and training may be the single most important collective activity the fire service and structural component industry can undertake to enhance protection of life at the scene of a fire.

FOR ADDITIONAL INFORMATION CONTACT:

- Wood Truss Council of America (WTCA) • www.woodtruss.com
- Carbeck Structural Components Institute (CSCI) • www.carbeck.org
- Truss Plate Institute (TPI) • www.tpinst.org
- National Engineered Lightweight Construction Research Project at the NFPA Research Foundation • www.nfpa.org/research
- Underwriters Laboratories • www.ul.com
- National Fire Protection Association (NFPA) • www.nfpa.org
- U.S. Fire Administration • www.usfa.fema.gov
- National Fire Sprinkler Association (NFSA) • www.nfsa.org
- Operation Life Safety • www.firesafehome.org
- The Gypsum Association • www.gypsum.org
- U.S. Forest Products Laboratory • www.fpl.fs.fed.us

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[1] Dunn, Vincent, Collapse of Burning Buildings Video Training Program, Part 3 (New York: Fire Engineering, 1990).
[2] National Engineered Lightweight Construction Fire Research Project Report, Chapter 8 (Quincy: National Fire Protection Research Foundation [NFPRF], 1991).

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