



BY MARK EMERY

Trusses are strong, efficient, reliable, predictable, and, once you get to know them, pretty cool. For too long the fire service has vilified this structural engineering marvel. In this article you'll get to know the truss—up close and personal. You'll understand a truss' components and how it works. And later, you'll discover what's really the most unreliable, unpredictable and dangerous factor at any fire-ground operation.

As an informed company officer, you must acknowledge that without lightweight building construction, particularly trusses, many communities couldn't afford to have a modern fire department. Because of the high cost of conventional building construction, it would be too expensive to build strip malls, warehouse stores or garden-type multi-family complexes. Without lightweight building construction, most of us couldn't afford to own a home. It's quite possible that the structure you're sitting in while reading this article wouldn't exist.

You must embrace the truss as a reliable and predictable engineering marvel, rather than perpetuating irrational fear and loathing akin to the villagers' misguided fear of Victor Frankenstein's engineered monster. Had the village-folk been open-minded and taken the time to understand Frankenstein's creation, they may have liked the big guy. Heck, if the monster had a decent jump shot, they would have lined up for autographs.

### TRUSS TRIVIA

Question: When were trusses first used in building construction?

- A) After World War II;
- B) Medieval Europe;
- C) America's industrial revolution; or
- D) The Roman Empire.

Answer: D, the Roman Empire. Roman engineers and architects used trusses to support bridges and roofs.

The earliest known description of a true

# Truss Truce

## It's time for the fire service to make peace with an old nemesis



Trusses make it possible for buildings made of light-weight construction materials to last for years.

truss appears in *The Ten Books of Architecture*. Published in the first century B.C. by the Roman architect Vitruvius, the text describes a simple truss as: "... the upper parts of all buildings contain timber work to which various terms are applied. The main beams are those which are laid upon columns and pilasters; tie-beams and rafters are found in the framing."

It wasn't until the 1800s that truss design became a function of engineering rather than rules of thumb passed down for generations by skilled craftsmen to their apprentices. The rise of structural engineering as a profession paralleled the North American industrial revolution.

Truss technology continues to evolve. Plywood gusset plates appeared soon after World War II, and in 1952, Mr. A. Carroll Sanford of Pompano Beach, Fla., invented the infamous metal gusset plate. The truss soon became a mass production industry.

### ANATOMY OF A TRUSS

The triangle is the secret of truss strength and stability. A truss is simply a series of

triangles. The triangle is a naturally rigid geometric shape that resists distortion, such as bending. Because it's impossible to change the shape of a triangle without lengthening one of its three sides, a triangle is rigid, stable and strong.

Consider a four-sided geometric shape such as a rectangle. Because you can lean the rectangle to one side without having to lengthen or shorten a side, you can create a different geometric shape, specifically a parallelogram. Thus, a four-sided form is unstable and has limited structural value.

The net effect of triangulation efficiency means that a truss comprised of multiple panels essentially behaves as if the entire truss was the size of a single panel within the truss. Although it's not magic, truss engineering comes pretty close.

Older conventional buildings were supported by mass, such as the excess wood

within a heavy timber beam, and numerous compressed columns. Modern, lightweight buildings have reduced their structural reliance on mass and compression by supporting themselves with math—specifically geometry. A structural system that relies on mathematics relies heavily on tension.

Virtually all trusses used to support structures have the same components and behave the same way. All trusses are derivatives of three basic truss configurations: 1) the flat/parallel truss; 2) the triangular truss; or 3) the arch/bowstring truss. Each truss configuration relies on the same system of connections and members that create triangles. Three panel points create a triangle and the more triangles, the stronger the truss. Because it doesn't rely on triangulation, the original bowstring isn't a truss. Over the years, the arch truss has assumed the bowstring moniker.

## COMMAND-O-QUIZ

Question: Of the trusses listed below, which is the most dangerous to firefighters?

- a. Parallel;
- b. Bowstring;
- c. Queen Post; or
- d. Scissors.

Answer: Sorry, trick question. Actually, each truss presents approximately the same risk to firefighters. All trusses work the same way—chords, web members, panel points, compression, tension and triangles.

The point of the question is to emphasize that the failure of a single bowstring truss can be more catastrophic than the failure of 10 parallel trusses. Allow me to explain: Let's say that a single bowstring truss has a 50' span and is spaced 30 feet from adjacent bowstring trusses. The failure of this single bowstring truss would compromise more than 3,000 square feet of roof! Compare that with lightweight parallel trusses spaced four feet apart. If 10 parallel truss purlins each have a 50' span and are spaced four feet apart, it would compromise 2,200 square feet of roof should all 10 trusses fail. So, the failure of a single bowstring truss would compromise 2,100 more square feet of roof than the failure of 10 lightweight parallel chord trusses! However, because of its mass, a timber bowstring truss is more fire resistant than a lightweight parallel truss, thus the timber bowstring should resist fire longer than its lightweight parallel relative.



## HOW A TRUSS WORKS

The business portions of a truss are the top and bottom chords—especially the bottom chord. The chords do most of the work; in fact, they do three to four times more work than a given web member. For example, a triangular truss' top chord may need to resist a compressive force of around 2,400 lbs. while a compressive web member in the same truss may experience a force of just 500 lbs.

Because its entire length is in tension, the bottom chord is the most critical truss component. When loaded, the bottom chord strains to resist three to four times more tension than a shorter web member. Conversely, when loaded, the top chord strains to resist three to four times more compression than a shorter web member. Because it's compressed, feel free to cut through the top chord of a truss. Because it's in tension, I don't recommend cutting through the bottom chord of a truss. I strongly recommend that you never molest a bottom chord truss panel point.

A truss distributes forces created by a load through a series of web members, which deliver these forces, alternately as tension or compression, to the top and bottom chords. Web members are connected to the chords at panel points. Typical lightweight panel point connectors include metal plate connectors (referred to as gusset plates and gang nails), metal pins and other connection methods.

The photos in this article show lightweight, open-web trusses held together by true plywood gusset plates. Notice there are no metal connectors—not a bolt, not a nail, not a staple, not even a thumbtack. These

Like simple beams, trusses are supported at two bearing points near their distal ends.

trusses are entirely held together by glue! (A truck company on auto-pilot who stampedes directly onto this roof and begins vertical ventilation over the seat of the fire is suicidal.) These trusses support the entire roof of an unsprinklered school in Woodinville, Wash. They were manufactured by a company in Everett, Wash., in the early 1960s, which means there are more out there.

Trusses are designed to be supported the same way as conventional simple beams—at two bearing points near their distal ends. *Note:* A truss is not a beam; it's an engineered structural component that replaces a conventional beam. Beams deflect (bend) due to direct stressing of each member; truss deflection is minimal. There shouldn't be any continuous compressive support members between the two bearing points. If a truss requires an intermediary structural support, such as a column between the bearing points, this should raise a red flag—there is a serious problem with the truss. Supports installed between the bearing points effectively reengineer the truss and voids any design safety factor.

## THE ENGINEER AS A FIREGROUND STRATEGIST

I once asked an engineer whom designs steel trusses, "What happens to the safety factor of a steel bar joist parallel truss if a single web member is removed?" Considering a steel bar joist might have more than a dozen web

members, you would think that perhaps it would reduce the safety factor by maybe 5 percent. His answer: "There is no longer any safety factor; the safety factor is zero." He further elaborated that his company would no longer be responsible for the truss' performance. In other words, since the truss had been modified, it was no longer their truss. A contents fire can quickly modify an unprotected steel truss.

The engineer asked why the failure of a web member was a concern of the fire service. I explained that a truck company might want to operate on a roof supported by bar joist trusses in order to cut a hole to vent heat and smoke. He couldn't believe humans would operate above a fire, supported by trusses he designs and knows intimately.

### FINAL REALITY CHECK

Question: Which represents the most danger to firefighters during a structure fire? (*Hint: one is much less reliable and much less predictable than the others.*)

- A) Flashover;
- B) Trusses;
- C) Fire officers; or
- D) Backdraft.

Answer: C, fire officers. The most dangerous factor during any fireground operation is the uninformed, inexperienced, overly aggressive fire officer. Such a fire officer is much more unreliable, unpredictable and thus more dangerous, than any other factor listed.

Is it rational to blame the building if a firefighter is killed by a failing structural component? Buildings don't think or make decisions. Consider this: Why was the firefighter there when the structural system failed? Professor Francis Brannigan cautions firefighters to "beware the truss" during structure fires. I believe better advice (albeit more controversial) is for firefighters to beware the fire officer who doesn't strategically factor in building construction.

One classic Brannigan maxim worth remembering is "know your buildings." I'll add that the most important building to know is the one that's being attacked by fire while you're there. It's impossible to make intelligent and safe fireground decisions if you're uninformed about a building being assaulted by fire. Rolling the dice and letting the chips fall where they may is not an acceptable strategic option—especially when you've determined there is no civilian life-safety problems.

**Right: A truss distributes forces created by a load through a series of web members.**

### CALL TO ACTION

Marine biologists understand shark behavior, so they don't consider them evil monsters. They know that a shark is simply a fish. However, because marine biologists respect the power and grace of sharks, they wouldn't do something stupid to make themselves vulnerable to attack. Likewise, fire officers who understand the grace, power and behavior of trusses don't consider them evil. Trusses don't think; trusses are not aware. On the fireground, the fire officer must continuously observe, think and plan.

A truss is nothing more and nothing less than a wood and metal system designed to resist the force of gravity. Trusses are predictable and reliable. Fire officers are neither predictable nor reliable. Trusses can be duplicated; fire officers cannot be duplicated. Often fire officers forget that gravity is the most reliable force on the fireground. Should trusses become involved in a fire, the informed strategist recognizes and factors this risk.

Your call to action is to make sure you're an informed strategist, and acknowledge that you don't possess magical powers that make you invincible. Fire, trusses and gravity are the same in Seattle as they are in Miami and everywhere in between. Become an informed strategist so that none of your firefighters dies because you didn't understand the principles of building construction, and in particular, truss behavior.

Obtain a copy of Brannigan's *Building Construction for the Fire Service* (3<sup>rd</sup> edition). Study chapter two over and over until you've assimilated the principles of building construction therein. Once you have a strong understanding of chapter two, study chapter six. Once you understand the principles of fire resistance, study chapter 12; once you have a strong understanding of trusses, move on to chapters three, four, seven, eight and then the remaining chapters. The informed strategist should never need to blow dust off



**Below: Do a sizeup of trusses in your response area before an incident.**



Brannigan's book.

The informed strategist acknowledges that when a truss failure kills a firefighter, it's not because the truss is evil. It's not because fire is evil. It's not because gravity is evil. It's because a fire officer allowed the firefighter to be there when the truss failed.

Make sure your firefighters aren't there when it happens in your community. ☹



*A fourth-generation career firefighter, Mark Emery is currently assigned as an Operations Battalion Chief in King County (Woodinville), Wash. BC Emery is a partner with*

*Fire Command Inc. (FCI) in Seattle; FCI has provided incident management solutions to fire and life-safety organizations since 1986. He is co-developer of the Integrated Tactical Accountability System (ITAC) and author of The Ten Commandments of Intelligent and Safe Fireground Operations. Emery is a graduate of the National Fire Academy Executive Fire Officer Program, a National Fire Academy Instructor Specialist and earned a Baccalaureate Degree in Education from California State University at Long Beach. He is also noted for founding and developing the six-week Officer Development Academy and the popular Advanced Pump Operator*