THE HIDDEN DANGER – ROOF TRUSSES

BY: paramedicgirl999

Some times we look at teaching tools a wee better if we identify the subject to real life situations. So here we go:

Roof Collapse Kills Three

Three more firefighters are lost when a truss roof in an evacuated building collapses during a fire.

by Ed Comeau

Hackensack, New Jersey. Chesapeake, Virginia. Branford, Connecticut. In each of these towns, lightweight wood truss roof collapses have killed and injured firefighters. And now, in Lake Worth, Texas, another wood truss roof fire has killed three more firefighters and injured four.

On February 15, 1999, shortly after firefighters Brian Collins, Phillip Dean, and Gary Sanders went inside the Precious Faith Chapel, the roof failed and dropped on them. NFPA sent Fire Investigator Robert Duval to examine the scene and speak to crew members involved in the incident. Thanks to these firefighters and their chief, Mark Cone, Duval came back with facts that NFPA hopes will help prevent other tragedies in buildings with wood truss roofs.

The danger of wood trusses

Wood trusses are by no means new. Though they were once found only in certain parts of the country, builders nationwide now use them in all types of occupancies, from industrial to storage to residential. According to the Wood Truss Council of America, 46 percent of single-family homes and 60 percent of multifamily homes built in the United States from 1992 to 1997 used wood truss roofs. Since they're becoming so common, it's more important than ever that incident commanders understand how they behave in a fire.

Trusses, which are made up of chords and webs joined in a series of triangles, can span floors or roofs without any vertical supports, except at the ends. By creating one large structure, wood trusses cover long distances more efficiently than conventional wood beams or wood beams supported by columns. The strength of this configuration relies on a system of interdependent members.

Though the loss of one member affects the load-carrying capability of the entire truss, it doesn't always lead to structural collapse because adjacent trusses pick up some of the load. Roof sheathing and interior gypsum wall board ceilings help connect the trusses and also spread the load, making the truss efficient, from an engineering standpoint.

However, these same features raise serious fire safety concerns. Each truss component exposes more of its surface to a fire than a large wood beam does, and because the truss components have less mass than such beams, they're more quickly consumed by fire. According to Paul Fisette, director of the Building Materials and Wood Technology Program at the University of Massachusetts, Amherst, a wood truss will lose some of its load-carrying capacity whenever fire destroys a chord or web member. However, the metal plates, also known as gusset plates, that frequently hold the truss members together are of greater concern because of their potential to fail during a fire. NFPA investigators have learned from building collapses during earthquakes that such connections, and not the members themselves, are often the weakest parts of the structure.

These metal connectors have short teeth that bite into the wood, creating a strong, stable connection. In a fire, though, they may help weaken the wood. When the U.S. Forest Products Laboratory conducted limited fire tests on gusset plates, researchers found that they reflected the heat away from the connection during the initial stages of a fire, but as the fire progressed, they transmitted heat into the wood, charring it.

Examining the wood underneath and next to the plate after the tests, researchers found similar damage and concluded that it wasn't the plate itself that had failed-it was the wood the plate's teeth had penetrated.

An additional concern in a fire is that a number of truss components are affected simultaneously, making it difficult to predict the type of failure that might occur. According to Professor Alexander Chajes of the University of Massachusetts at Amherst's Civil Engineering Department, how the roof fails depends on whether the cause of failure is a weakened chord or web member and which way the failed member is oriented in the overall truss configuration.

On the fireground, other factors compound the danger posed by a burning truss. The weight of the firefighters themselves on a roof adds stress to an already weakened structure. And when crews vent roofs or open up ceilings to search for fire spread, they inadvertently impair the interconnected building components that keep the truss stable.

The Lake Worth fire

In the fire at Lake Worth, the roof in the main portion of the church was supported by scissor trusses made up of 2-by-4-inch and 2-by-6-inch wood chords. A layer of gypsum wallboard attached to the lower chords formed a ceiling between the occupied space and the truss space. At its peak, the roof, which consisted of a layer of asphalt shingles over plywood, was approximately 20 feet (6 meters) high.

The one-story building measured approximately 60 feet by 120 feet (18 meters by 36 meters) and had a masonry block wall exterior. The oldest part of the building, a west side foyer, had been built some time before the main portion of the chapel, which was approximately 20 years old. The Fellowship Hall on the southeast corner was about 15 years old. The church had no suppression or detection systems.

At approximately 10:40 a.m. on Monday, February 15, 1999, the pastor was in the church when a teenager knocked on the front door to report a fire outside the back of the building on the east side. When the pastor went out back with him to look, the teenager

said he'd called 911, and the pastor heard the sirens of the responding apparatus. At this point, the fire only involved the 6-by-6-foot (1.8-by-1.8-meter) shed, 10 feet (3 meters) from the building. However, wind blowing from the east to the west at approximately 30 miler per hour (48 kilometers per hour) pushed the flames toward the church.

The rear of the church abutted the town line between Lake Worth and Sansom Park. A police officer on patrol in Sansom Park saw the fire and reported it to his dispatcher, who, in turn, notified the Sansom Park Fire Department. Because two separate fire departments received the reports, units were dispatched from six communities.

Meanwhile, the pastor went inside the church and opened the double doors on the north side, thinking the firefighters would use these doors to enter the building and fight the fire. In fact, they used the west door, which was further from the fire. When he met with the first-responding company and told firefighters where the fire was, he also told them that no one was inside.

By this time, the fire had spread to the church, and a crew from the Lake Worth engine, which was positioned at the front door, and a crew from the Sansom Park engine, which was parked further away on the northwest corner of the building, advanced 13_4-inch handlines through the west door and down the right side of the church to fight the blaze. Unfortunately, however, the Sansom Park engine's line didn't reach the fire and was never charged.

As the crews advanced to the rear of the building, they pulled down the ceilings, checking for fire extension. They saw that the fire was in the building's northeast corner.

At about the same time, a firefighter went onto the roof to evaluate conditions. He removed the tops of the turbine ventilators and reported that only lazy, wispy smoke was coming out, which the incident commander interpreted as proof that there was no fire in the attic.

Soon after, the engine from River Oaks arrived on the scene, and two firefighters, Collins and Dean, advanced a third handline into the building. At any given time, about five firefighters from River

Oaks, Lake Worth, and Sansom Park were operating inside the church.

Despite their efforts, the fire kept growing, and the incident commander ordered a ventilation hole cut in the roof. The aerial apparatus from the Saginaw Fire Department arrived and was positioned on the northwest corner of the building. Four firefighters climbed up to the roof and started cutting a hole with a power saw, but they had problems with the saw and had to continue working with axes. Approximately 18 minutes after the initial call, the roof suddenly collapsed underneath them.

One of the men rode the roof down into the church, landing near the front of the building, and was able to scramble out. Another firefighter on the edge of the collapsed area hung on with his hands until a third firefighter reached over and pulled him back up. The collapse knocked the fourth man down, but he remained on top of the roof. When he regained his footing, he and the other two firefighters on the roof made their way back to the aerial platform.

Though all the rooftop firefighters were accounted for, an immediate head count indicated that three others were missing. Two appeared to have been found shortly afterward, when a firefighter opened a door connecting the church to the adjacent Fellowship Hall and found two uninjured firefighters trapped inside the church just behind the door. All three went out through the Fellowship Hall just as the fire started to spread into it.

Unfortunately, a second count showed that three firefighters were still missing. At this point, the building was too well involved for firefighters to enter, so they directed master streams into the building to knock down the flames. When this had been done, crews made a hole in the exterior wall where they thought the missing firefighters were. Two-Collins and Sanders- were found near this hole, and the third, Dean, was found about 20 feet (6 meters) away. All three firefighters were removed from the building.

Investigators have determined that the fire was deliberately set. As of this writing, however, no suspects have been charged.

Risk management

One of the troubling aspects of this fire, as well as those that occurred in Hackensack, Branford, and Chesapeake, is that firefighters put their own lives at risk in buildings known to have been evacuated.

According to NFPA statistics, 40 of the 91 firefighters who died in 1998 died on the fireground. This figure sends a message to firefighters that there's a real need to mitigate risk on the fireground.

According to NFPA 1500, Fire Department Occupational Safety and Health Program, the incident commander is required to integrate risk management into the regular functions of incident command. He or she must thus limit aggressive firefighting to situations where lives are endangered and can possibly be saved, which means reducing risks to firefighters operating to protect property only. The standard goes so far as to say that no risk to firefighters' safety is acceptable when there's no possibility of saving lives or property.

The incident commander is also charged with evaluating the risk to members in terms of the purpose and potential results of their actions in each situation.Where the risk to firefighters is excessive, the standard calls for use of defensive operations only. And when fire involves a wood truss, the risk is compounded by the fact that flames may stay hidden inside the truss structure, taking firefighters by surprise when the roof or floor fails.

Unfortunately, firefighters continue to risk their lives unnecessarily, and not just at fires involving wood trusses. On January 1, 1995, four firefighters died in a fire in Seattle, Washington, when the floor of a building that appeared to be of heavy timber construction collapsed underneath them, dropping them into the flames. This section of the floor had been modified using 2-by-4-inch supports, which were destroyed before the fire weakened the heavy timber structural components. The collapse occurred 36 minutes into the fire. There were no civilians inside the building.

In another incident, a fire officer died when the floor collapsed and he fell into the basement of a corner store in Washington, D.C., on October 24, 1997. This tragedy occurred despite the fact that the fire happened very early in the morning, before the store had opened, and the store owner, who lived in the apartment above the store, told firefighters no one was inside. Firefighters had to force entry, and a number of crews tried to locate and suppress the blaze. The fire started in the basement, but crews couldn't get into it, either from the exterior or interior. Nonetheless, at least four crews continued to operate in the building above an uncontrolled fire until the floor failed.

It's vital that incident commanders placing firefighters in hazardous situations ask themselves one fundamental question: "What are we trying to accomplish?" If lives can be saved, then calculated risks may be taken. If the building and its contents are the only things in danger, the fireground strategy must take this into account. Incident commanders with qualms about taking a less aggressive approach should ask themselves whether they should put their firefighters at risk for a building owner who hasn't protected his or her property with a sprinkler system. Why risk irreplaceable lives to save replaceable property?

Two days after her husband's death in the Lake Worth church fire, Phillip Dean's wife gave birth to a baby boy, Elijah Phillip Dean, who, like the children of many firefighters killed each year, will grow up without his father's guidance. Hopefully, this child will come of age in a safer world because of the lessons learned in Lake Worth and at other similar tragedies.

Wood Truss Collapse Fatality Reports

Among NFPA's fire investigations reports are several detailing fires that involved wood truss roof collapses. Tragically, incident commanders aren't always aware that they're dealing with a truss

roof fire until the structure fails. Smoke and flames can hide inside a truss, allowing fire to gain strength unseen.

All of these factors were present on July 1, 1988, in Hackensack, New Jersey, when an attic fire in an automobile dealership involved five bowstring trusses spaced 16 feet (4.9 meters) apart and spanning 78 feet (23.7 meters). According to NFPA's report, the collapse occurred 37 minutes after the first alarm, while firefighters were working on the roof and inside the building to save property, not lives. The roof failed and trapped five firefighters, two of whom were in a tool room. All five died. The building had no automatic sprinkler system.

On March 18, 1996, a fire in an occupied auto parts store in a strip mall in Chesapeake, Virginia, began in the space above the suspended ceiling inside the store after the bucket of a service truck struck the overhead electrical lines and quickly involved the wood trusses, which spanned 50 feet (15 meters). First-arriving firefighters didn't notice heavy fire conditions inside the unsprinklered store, so they canceled the rest of the incoming units. Within minutes, however, they discovered fire in the concealed space over their heads and requested additional units. Thirteen minutes later, the roof collapsed on two firefighters, who died of burns and smoke inhalation.

Later in 1996, a fire broke out at approximately 4:24 p.m. on Thanksgiving Day in an unoccupied carpet store in Branford, Connecticut. Upon arrival, firefighters reported light smoke at the front of the building near the eaves of the roof, which was composed of lightweight wood trusses spanning 60 feet (18 meters). Approximately 17 minutes later, the wood truss roof collapsed, trapping two of the seven firefighters who had entered the building. One of the men died. The building had no detection or suppression systems.

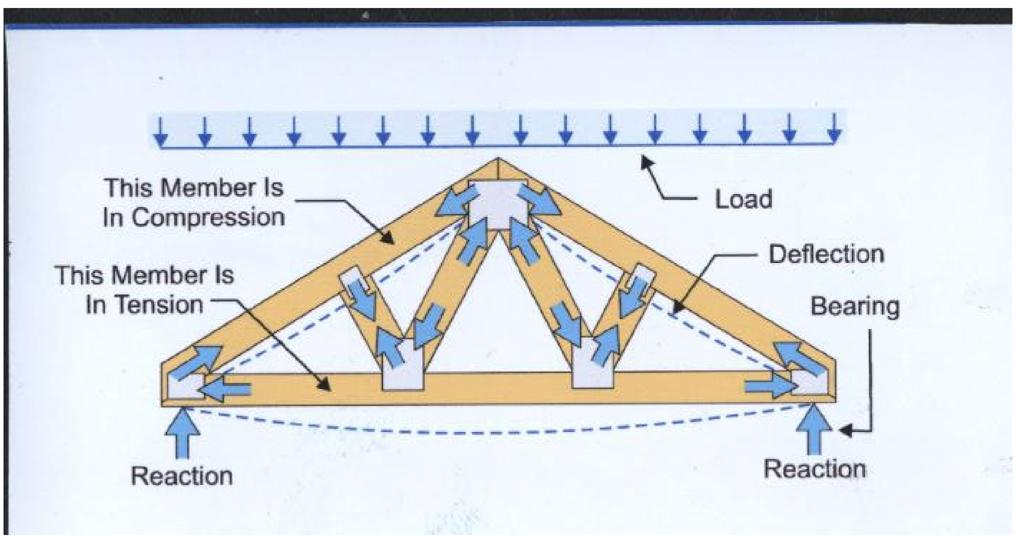
Full reports for each of these fires are available for a fee from the Charles Morgan Library at NFPA. Call (617) 984-7445 for more information.

Long Span Roof Trusses

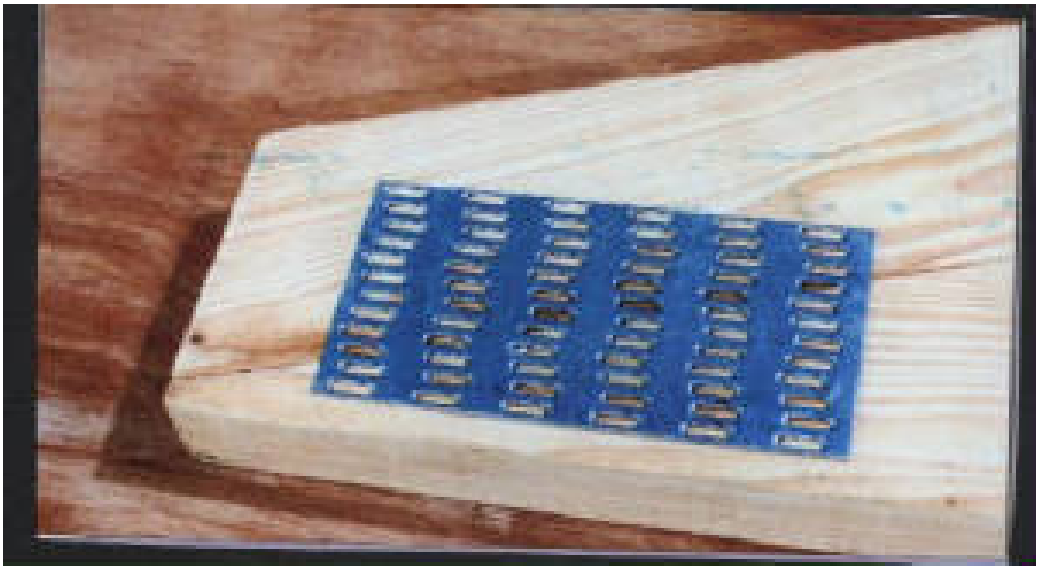
One of the biggest killers in structural fire fighting is the long span truss roof.

Through the engineering of multiple triangles, weight can be distributed over a vast span, but that span vitally depends on every member of every triangle. If we take away any member in the system, we can have a catastrophic failure of the whole system.

Look at the picture below; if we take one brace out of one truss, we can possibly shift the overall weight, compromising the whole structure.



If we study the arrows, we see that if one small piece is taken away, we could have a catastrophic collapse of the whole truss.



These trusses are held together by thin metal plates, with 3/8 - 1/2 in. teeth that are pressed into the wood on each side of the truss.

When the metal plates get hot, they transfer the heat to the teeth, the teeth then burn the wood around them, and the plates fall off, which leads to an instant collapse of the truss.

When the trusses are set in place, they are temporarily braced, until the decking is applied. Once the decking is in place the trusses become one self standing structure.

The decking is usually 4' x 8' sheets of 1/2 in. - 5/8 in. plywood or particle board, nailed epoxy. every 8" down each truss.

Shingles or tiles are then added to complete the roof.

Is fire resistance working for us or against us?

When the sheet rock is installed, it stops fire from reaching the attic, but once it reaches the attic the whole scenario changes. Now we have fire confined in a very small area with no ventilation. The heat builds fast, the gases have no where to vent, and flashing conditions occur very fast.

By this point in time, when we are dealing with a truss roof, we already have metal brackets falling off, we already have thin decking burning, and we will have people falling through the roof, and when any section of the decking is broken the rest of the trusses have nothing to support them, and they will fall, in a domino effect, and now we also have an attack crew inside under them.

Press Enterprise/Jimmy May

FIREFIGHTER of the West Berwick Hose Co. uses his ax to stop his fall as his left leg and arm break through the roof at 201 Maple Road in Berwick on Wednesday afternoon. Eveland suffered burns on both of his hands in the mishap during the attic fire.

This point is when we lose so many people. As firefighters we are a dedicated people, dedicated to saving lives, and preserving property. We are determined to save this building. To do so we are taught to vertically ventilate the highest point directly over the base of the fire. At the same time we are taught to attack simultaneously,

the crew on the roof, opens the hole, and immediately the crew inside attacks the fire.

According to incident reports the average truss roof will collapse with in 14- 20 min. from the time the fire reaches the attic space.

Roof Truss Bracing

What is a Brace?
A roof truss is made of several pieces of wood that are joined together. Each piece of the truss is referred to as a "member". A brace is a member that prevents a structural element from buckling or racking. Members are generally subjected to tensile or compressive forces. As shown in figure 1, tension forces tend to pull a member apart while compressive forces tend to push a member together.

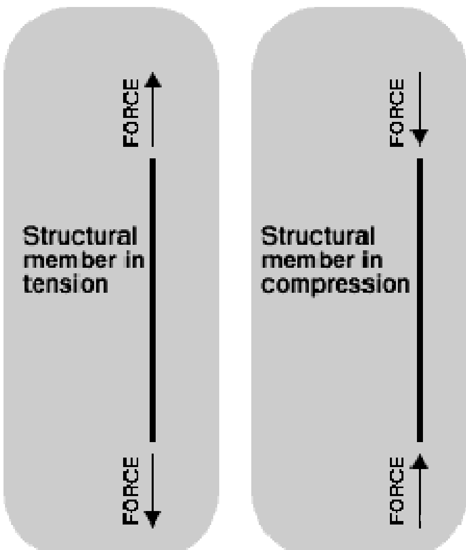


FIGURE 1

When a compressive force becomes great enough, it will tend to buckle or bow a member as shown in the left side of figure 2. This can be demonstrated by placing a yardstick on end on the floor while holding the upper end. When you push down on the upper end, the yardstick buckles in its narrow direction. The right side of figure 2 demonstrates the use of a brace at the middle of the structural member. Under the same compressive force, the brace prevents the member from buckling. This can be demonstrated by applying the same downward pressure on the yardstick with one hand, while restraining it at the middle with your other hand. The yardstick will not buckle under the same pressure.

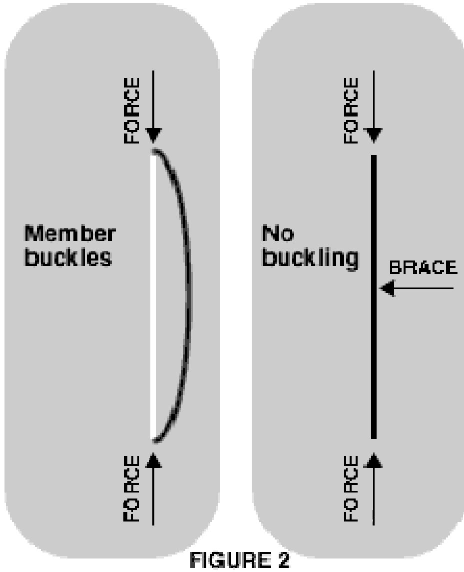


FIGURE 2

A brace can also be used to prevent structural elements from racking. The left side of figure 3 shows a rectangular structural frame that is racked due to a force applied to its top corner. The right side of figure 3 shows the same rectangular frame with a diagonal brace added to prevent racking when the same force is applied. The triangles formed by the addition of the diagonal brace are the fundamental basis for the structural design of trusses.

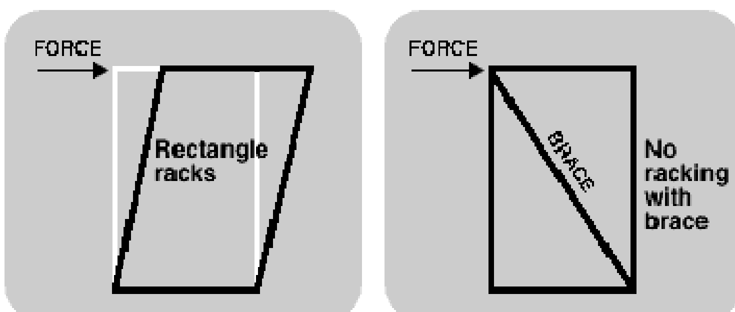


FIGURE 3

Truss bracing can be broken down into three categories; temporary bracing, permanent bracing of individual truss members, and permanent bracing for the overall stability of the structure.

Temporary bracing

Temporary bracing is used during the erection of roof trusses to prevent the trusses from bucking and falling over during the erection process. It is a series of continuous braces along the top and bottom chords of the truss and may include "X" bracing between vertical web members of the trusses. See figure 4 for the nomenclature of truss members.

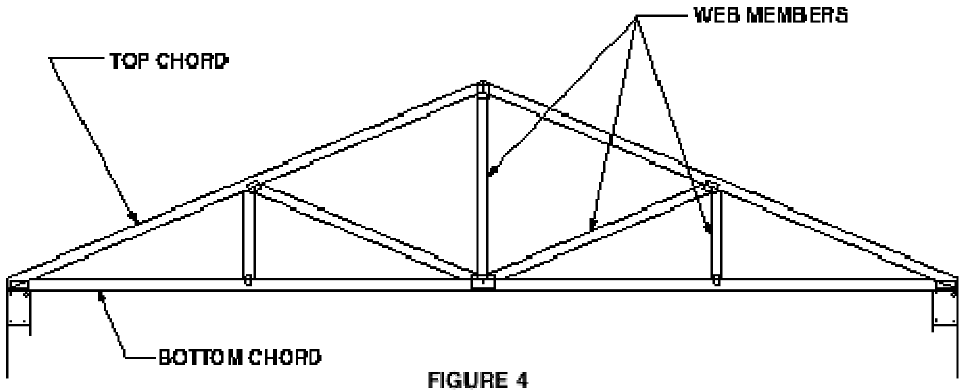


FIGURE 4

Temporary bracing is extremely important to life safety during the erection of trusses and is required by all major building codes. This bracing is the responsibility of the builder and the builder should consult the literature described in the code, and available from the truss industry, on the proper use of temporary bracing during the erection of trusses. Information on the use of temporary bracing of trusses is generally provided by the truss manufacturer.

Permanent bracing of individual truss members

Permanent bracing of individual truss members prevents certain members of individual trusses from buckling under compressive loads. During the design process of the truss, the members are checked for buckling and for slenderness restrictions. If a member is found to buckle in the narrow direction, a brace is added. If a member is found to buckle in the wide direction, the size of the member is increased.

Under normal gravity loads the top chord of a typical truss is in compression and tends to buckle in its narrow direction (sideways). The plywood roof sheathing prevents the top chord from bucking sideways. Other members of the truss, such as various web members and the bottom chord may also experience compressive forces under different load conditions. Some web members may be under compressive loads caused by gravity loads, while other web members or the bottom chord may be subjected to compressive forces due to uplift forces caused by high wind events such as hurricanes. Under certain combinations of member length and magnitude of the compressive force, the member may buckle in the narrow direction. When this combination is reached, bracing of the web member or bottom chord is required.

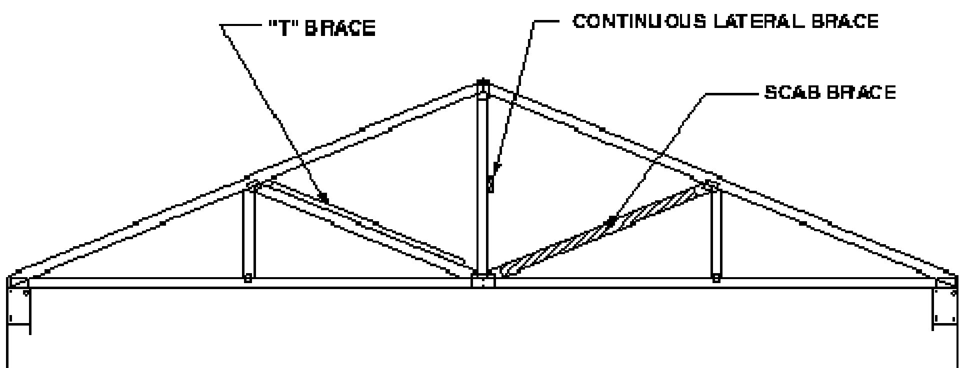


FIGURE 5

The three most common methods of bracing individual truss members are: (See in figure 5)

- **Continuous lateral bracing** is generally used when the members of adjacent trusses line up with each other. A 1x4, 2x4, or larger brace is run across the truss member and the adjacent members, perpendicular to the trusses. If one brace is required, it is placed at about the midpoint of the webs to be braced as shown in figure 5. If two braces are required due to a higher compressive force, they are placed at about the third points of the webs. The continuous lateral bracing must be restrained at the ends to prevent all the webs from buckling in the same direction. This is accomplished by fastening the ends of the lateral bracing to an appropriate point of the building structure, or by adding additional diagonal bracing at the ends, and intermediate intervals, to brace the lateral bracing.
- **"T" bracing** is generally used when the web requiring bracing does not line up with the webs of

adjacent trusses. It consists of adding a 1x4, 2x4, or larger brace along the length of the web to be braced forming a "T" when looking at the cross section of the web and brace.

- **Scab bracing**, like "T" bracing is generally used when the web requiring bracing does not line up with the webs of adjacent trusses. It consists of adding a member of the same size as the web, nailed to the side of the web, effectively doubling the thickness of the member.

The design of permanent bracing of individual truss members is the responsibility of the truss designer as is generally shown on the individual truss engineering.

Permanent bracing for the overall stability of the structure

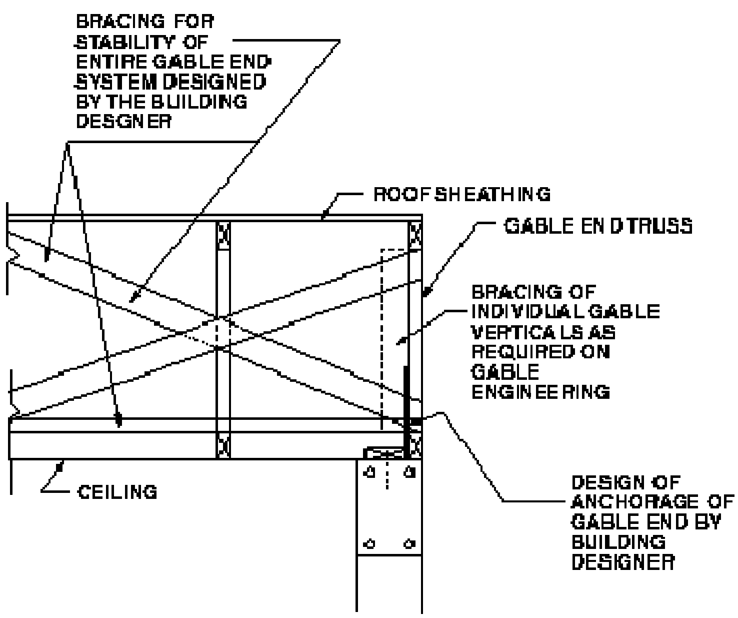
Permanent bracing for the overall stability of the structure is required by the major building codes and is required to brace the overall truss system and structure as an entire system. The design of this bracing is generally the responsibility of the building designer. An example of this bracing would be the bracing at the gable ends of a roof system to stabilize the gable ends. See figure 6 for the various types of bracing that may be required at a gable end.

Some building codes also require specific bracing as a minimum requirement. This bracing is generally necessary for the overall stability of the structure.

In 1992, Hurricane Andrew caused major damage to the South Florida area. Gable ends being pushed in or pulled off buildings caused a substantial amount of damage.

A hip roof slopes down to the walls on all four sides of a building. A gable roof slopes down to two sides that are opposite each other and forms a triangular wall section at the other two sides. The triangular wall sections above the eaves are called gable ends and provide a large vertical surface, which must resist wind forces. Some of the longer verticals of the gable end trusses require bracing to keep the verticals from bucking from sideward wind loads. The truss designer generally designs this bracing.

Many gable ends that failed during in hurricane Andrew had this bracing installed on the verticals. The gable end failures resulted because bracing of the overall gable system was not provided. This bracing is generally the responsibility of the building designer.



Cross section through gable end

FIGURE 6