CDC
Workplace Safety and Health

# NIOSH ALERT

## Preventing Injuries and Deaths of Fire Fighters due to Truss System Failures


DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

## DISCLAIMER

Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH). In addition, citations to Web sites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these Web sites.

## ORDERING INFORMATION

To receive documents or other information about occupational safety and health topics, contact NIOSH at

NIOSH—Publications Dissemination
4676 Columbia Parkway
Cincinnati, OH 45226–1998

Telephone: **1–800–35–NIOSH** (1–800–356–4674)
Fax: 513–533–8573
E-mail: pubstaft@cdc.gov

or visit the NIOSH Web site at **www.cdc.gov/niosh**

DHHS (NIOSH) Publication No. 2005–XXX

April 2005

SAFER • HEALTHIER • PEOPLE™

INSERT FOLD-OUT FACTSHEET

BLANK PAGE

# NIOSH ALERT

# Preventing Injuries and Deaths of Fire Fighters due to Truss System Failures

**WARNING!**

**Fire fighters may be injured and killed when fire-damaged roof and floor truss systems collapse, sometimes without warning.**

**The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing injuries and deaths of fire fighters due to roof and floor truss collapse during fire-fighting operations. Roof and floor truss system collapses in buildings that are on fire cannot be predicted and may occur without warning. NIOSH recommends that fire departments review their occupational safety programs and standard operating procedures to ensure they include safe work practices in and around structures that contain trusses. Building owners should follow proper building codes and consider posting building construction information outside a building to advise fire fighters of the conditions they may encounter.**

**NIOSH requests that the information in this Alert be brought to the attention of all U.S. fire departments and fire fighters. To bring the recommendations in this Alert to the attention of the fire service community, NIOSH requests help from the following individuals and organizations: fire commissioners, fire chiefs, State and local fire district administrators, State fire marshals, safety and health officials, trainers, fire investigators, unions, labor organizations, insurance companies, and editors of trade journals and other publications.**

## BACKGROUND

According to the Wood Truss Council of America (WTCA), wooden trusses are used in roof systems in more than 60% of all buildings in the United States [SBCMAG 2004]. Truss and related engineered wooden floor systems are also becoming more common. Today, more engineered structures use lighter weight materials, producing larger spans and clear openings. Trusses can be designed to carry expected loads, be produced economically, be safely handled, and reduce construction costs (see Figure 1).

Engineered building components may provide adequate strength under normal loading; but under fire conditions, these truss systems can become weakened and fail, leading to the collapse of roofs, floors, and possibly the entire structure. Truss systems are usually hidden, and fires within truss systems may go unnoticed for long periods

**Figure 1.** Typical lightweight truss construction. (*Photo courtesy of Vincent Dunn.*)

of time, resulting in loss of integrity. Structural design codes often do not factor in this decreased system integrity, as fire degrades the structural members. Fire fighters typically rely on warning signs to indicate imminent truss failure such as roofs and floors that feel spongy or are visibly sagging. Quite often, these warning signs are not good predictors of truss system failures.

The United States Fire Administration (USFA) reports that during 1990–2000, structural fires and explosions accounted for 46.1% of all reported fire fighter fatalities (500 of 1,085) [USFA 2002]. Statistics compiled by the WTCA suggest that 4.7% of the total fatalities (108 of 2,286) during 1980–2001 were due to structural collapse [Grundahl 2003b]. Fifteen separate incidents investigated by NIOSH identified at least 20 fatalities and 12 injuries that have occurred from 1998–2003 during fire-fighting operations in buildings containing truss systems (see Appendix A).

## What is a Truss?

A truss can be defined as structural members (such as boards, timbers, beams, or steel bars) joined together in a rigid framework. They are most often in the shape of a triangle or series of triangles. Some trusses are rectangular. Trusses can be built of wood, steel, wood and steel, or aluminum. Concrete trusses are not common but do exist, usually in very large structures (see Appendices B and C for descriptions of different truss types). The truss framework is usually arranged in a single plane so that loads applied at points of intersecting members will cause only direct stress (compression or tension). Three-dimensional trusses (space frames) are very light in weight. The design of a truss, which separates compressive and tensile stresses, allows for a minimum of materials to be used, resulting in economic benefit.

The top and bottom members of a truss are called chords. The top chord of a truss is in compression, and the bottom chord is in tension. The inner members are called webs and give stability to the truss system. The unique characteristic of a truss is the inherent stability of the triangle. Web and chord members arranged in a triangle are much more stable than the same members arranged in a square. The square configuration requires diagonal bracing, which then produces multiple triangles.

## Truss Types

Although many types of trusses exist, three typical truss construction methods are most commonly used:

- Heavy timber roof and floor truss systems
- Lightweight wooden roof and floor truss systems
- Steel roof and floor truss systems

Each of these construction methods is described in detail in Appendices C and D, along with causes of failure for each under fire conditions.

## CURRENT STANDARDS

### National Fire Protection Association (NFPA)

The NFPA develops voluntary standards aimed at protecting fire fighters and civilians from fire-related injuries and deaths. The following NFPA standards address fire fighter safety related to roof and floor trusses:

- NFPA 1620, *Recommended Practice for Pre-Incident Planning*, presents a guide to help fire department officials develop a pre-incident plan to help responding personnel effectively manage emergencies with available resources. The pre-incident plan should not be confused with fire inspections, which monitor code compliance. Pre-incident planning involves evaluating occupancies before an incident to identify information critical for fire-fighting operations in case an incident occurs. Chapter 3 recommends that these pre-incident plans address the structural integrity of walls, roofs, and floors [NFPA 2003a].
- NFPA 1521, *Standard for Fire Department Safety Officer*, stresses pre-incident planning and requires that data regarding roof construction be recorded, including roof support components (e.g., wooden joist, wooden truss, steel joist, steel truss, and beam and girder), length of the support spans, roof deck material (e.g., wood, metal, concrete), and other features [NFPA 2002a].
- NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, requires Fire Fighter II candidates to be familiar with building construction and hazards such as indicators of imminent building collapse [NFPA 2002b].
- NFPA 921, *Guide for Fire and Explosion Investigations*, is intended to help the fire investigator understand the reaction of buildings and building assemblies to fire. Chapter 5 addresses manufactured lightweight wooden truss failures [NFPA 2001].

Other relevant NFPA Standards include the following:

- NFPA 5000, *Building Construction and Safety Code*, addresses the construction, protection, and occupancy features necessary to minimize danger to life and property by providing minimum design regulations for construction, quality of materials, use and occupancy, location, and maintenance. All framing methods are addressed, including the use of roof and floor trusses [NFPA 2003b].
- NFPA 13, *Standard for the Installation of Sprinkler Systems*, provides the minimum requirements for the design and installation of automatic fire sprinkler systems and exposure protection sprinkler systems. This standard addresses different sprinkler systems for protecting various roof systems [NFPA 2002c].
- NFPA 501, *Standard on Manufactured Housing*, covers the equipment and installations used in the design, construction, transportation, fire safety, plumbing, heating, and electrical systems of manufactured homes designed to be used as dwelling units. Chapter 5 addresses load requirements for roof trusses [NFPA 2003c].

## Building and Construction Codes and Standards

Roof and floor trusses are designed and manufactured to comply with American National Standards Institute (ANSI) and industry consensus standards. NFPA and the International Code Council (ICC) policy require that industry-accepted design standards be developed following ANSI consensus guidelines. However, these and other standards do not take into consideration exposure to real fire conditions and the impact of fire on structural performance [Brannigan 1988; Cutter 1990].

The fire endurance testing done to determine 1- and 2-hour rated assemblies does not accurately replicate structural fires, and as such does not take into consideration fire fighter safety [Grundahl 1992]. ASTM International (formerly known as the American Society for Testing and Materials) developed standardized test methods for building and construction materials (including roof and floor trusses). ASTM E119–00a, *Standard Test Methods for Fire Tests of Building Construction and Materials*, is the primary standard used to test roof and floor trusses and related assemblies. It is recognized and accepted by most building codes. However, test methods described in ASTM E119 may not be truly representative of real fire conditions. For example, ASTM E119 assumes fire spread will be upward, while many fires burn downward into floor truss voids and then spread horizontally [Brannigan 1999].

Building codes vary by jurisdiction. Since the early 1900s, various organizations have developed model building codes used throughout the United States. In 1994, the Building Officials and Code Administrators International (BOCA), International Conference of Building Officials (ICBO), and the Southern Building Code Congress International (SBCCI) combined to form the International Code Council (ICC). This resulted in the development of a consistent set of requirements for architects, engineers, building designers, and contractors to follow throughout the country. The ICC codes address both fire protection and fire fighter safety. However, the focus of building codes is not to protect fire fighters once a fire has started in a building. Building code provisions are developed so that occupants can evacuate safely and the fire service has adequate access (clear path for trucks, etc.) to the building to suppress the fire. The International Building Code (IBC) developed by ICC contains many of the same requirements found in the NFPA 5000 Building Construction and Safety Code.

## CASE REPORTS

At least three scenarios can occur in which fire fighters suffer fatalities and injuries while operating at fires involving truss roof and floor systems [Dunn 1992]:

1. While fire fighters are ***operating above a burning roof or floor truss***, they may fall into a fire as the sheathing or the truss system collapses below them.

2. While fire fighters are ***operating below the roof or floor inside a building with burning truss floor or roof structures***, the trusses may collapse onto them.

3. While fire fighters are ***operating outside a building with burning trusses***, the floor or roof trusses may collapse and cause a secondary wall collapse.

The following case reports describe incidents involving fire fighter injuries and deaths due to fires involving truss system failures. The incidents were investigated through the NIOSH Fire Fighter Fatality Investigation and Prevention Program.

## Case 1

On March 8, 1998, one male career fire fighter, a captain (victim), died when the wooden-bowstring trussed roof of a building collapsed and blocked his exit route. The first company on the scene reported light smoke showing from a one-story commercial building. While fire companies waited for the security doors to be opened, fire conditions changed dramatically on the roof. Heavy fire was coming from the ventilation holes opened by the ventilation crew. When the doors were opened, the fire fighters encountered heavy smoke with near-zero visibility approximately 15 feet inside the door. The engine crews advanced until deteriorating conditions forced them to withdraw. During this time, the victim became separated from his crew and did not exit from the building. Approximately 20 minutes after the engine crews entered the building, the roof partially collapsed, blocking the front entry and hampering rescue operations. The victim was later located by the Rapid Intervention Team, and cardiopulmonary resuscitation was performed immediately and enroute to the hospital, where the victim was pronounced dead [NIOSH 1998a].

## Case 2

On September 5, 1998, a 54-year-old male career fire fighter (the victim) died when an exterior brick parapet wall collapsed on him. The warehouse was constructed of brick masonry walls with heavy timber trusses supporting the roof. The front and rear masonry walls extended above the peak of the roof, forming parapet walls. The first responding officer ordered an exterior-only attack using deck guns and hose lines. The incident commander called dispatch to request mutual aid from three additional fire departments. A career department (including the victim) arrived on the scene approximately 15 minutes later and was positioned at the north end of the building and prepared for an exterior attack. The victim approached the building to open a set of large doors (each 15 feet high by 6 feet wide) so that hose lines could be directed through the doors. The doors closed as the victim returned to the hose lines. The victim was approaching the building a second time to prop the doors open when the brick parapet wall suddenly collapsed outward, killing him instantly. Fire fighters at the east side of the warehouse reported a partial roof collapse at approximately the same time the parapet wall on the north side collapsed [NIOSH 1998b].

## Case 3

On December 28, 2000, four career fire fighters were injured when a section of a church roof collapsed, trapping them inside. The roof system was formed using lightweight wooden trusses with gusset plate connectors. Two different truss systems were used in the different construction phases. The exterior peaked roof was covered with standard asphalt shingles. The interior ceiling consisted of ½-inch drywall attached to the bottom of the trusses. Three 1¾-inch hose lines were advanced into the building by three crews. The incident commander ordered the first crew to enter the structure for an aggressive fire attack, cautioning them not to enter the structure very far. Two subsequent crews were sent into the building through a different set of doors. Approximately 7 minutes after the first crew entered, the second and third crews met in a classroom. They noticed intense fire in the ceiling/truss void area where a small piece of ceiling in the classroom had fallen. Soon afterward, the roof collapsed in the classroom area, trapping and injuring four fire fighters. Three were able to escape by breaking through an exterior window. The fourth fire fighter located the classroom door, and the incident commander led him into the hallway and out of the structure. The lightweight truss roof collapsed less than 10 minutes after the fire fighters entered the building [NIOSH 2001].

## Case 4

On March 7, 2002, a 28-year-old male volunteer fire fighter (Victim 1) and a 41-year-old male career fire fighter (Victim 2) died after becoming trapped in the basement by a floor collapse in a residential fire. The victims were attempting to advance a hose line on the first floor of the structure. The roof and floor systems both consisted of lightweight, pre-engineered wooden trusses covered with plywood sheeting. The incident commander directed a crew of two fire fighters to take a hose line through the garage down the stairs toward the fire. They were unable to reach the basement because of heavy fire coming from the stairway. They were attempting to check the interior of the house through a second door leading from the garage when the nozzleman's low-air alarm sounded. They exited from the garage to exchange their air cylinders. Victim 1 and Victim 2 entered the house through the door inside the garage to relieve the initial attack crew on the hose line. The captain from the mutual aid department followed the hose line through the garage to the doorway to assist his crew. Soon after the two victims entered the house, the floor collapsed, dropping them into the basement. The captain encountered intense heat at the doorway but could not see any flames. He was unaware the floor had collapsed but heard Victim 2 yelling for help. As the captain attempted to lift Victim 2 out of the basement, the victim grabbed and ripped the captain's self-contained breathing apparatus (SCBA) mask from his face. The captain was forced to exit from the garage and was later transported to a local hospital. Two other fire fighters attempted to remove Victim 2, but they were overcome by intense flames shooting from the basement, which eliminated further rescue attempts. The area of entrapment was inaccessible because of the floor collapse. Rescue crews finally breached the masonry foundation wall and recovered both victims. The area of the floor collapse was directly above the origin of the fire [NIOSH 2002].

## Case 5

On June 15, 2003, a 39-year-old male career lieutenant (Victim 1) died, and another 39-year-old career fire fighter (Victim 2) was fatally injured while trying to exit from a commercial structure following a partial collapse of the building's flat metal roof, which was supported by lightweight metal trusses (bar joists). Victim 1, the lieutenant of the first responding engine company, reported light smoke on arrival at a discount store. The flat roof consisted of metal decking covered by wooden fiber insulation and asphalt. A suspended ceiling in the main store area approximately 12 feet high covered the metal roof trusses and obstructed their view from below. Victim 1 led his crew into the store to search for the fire. After proceeding approximately halfway to the rear of the store, he directed two fire fighters to go outside and bring in a preconnected hand line. Victim 1 and a lieutenant from the second engine company proceeded to the rear of the store. This lieutenant found the fire behind the closed office door and exited to pull a second hand line. Soon afterward, Victim 1 requested a truck company to enter the store and pull ceiling tiles to search for fire extension; a third lieutenant and a fire fighter immediately responded. The truck company searching for fire extension observed fire in the truss void above the suspended ceiling. The accumulation of smoke and hot gases within the truss void mixed with fresh air as the ceiling was opened and violently ignited. The fire rapidly spread from the rear office area to the main store room through the hidden truss void. Victim 1 radioed that it was getting too hot and everyone needed to back out. At this point, the roof system at the rear of the store room began to fail, sending debris downward, with several bar joists coming to rest on metal merchandise shelving. Several fire fighters were able to escape by following the hose lines toward the front of the store. Victim 1 and Victim 2 (the nozzleman from the first responding engine company) became separated from the rest of the fire fighters and were unable to escape. As conditions worsened, the building was evacuated, and a rescue attempt for the two missing fire fighters was initiated. Fire fighters working at the rear of the building heard a personal alert safety system (PASS) device and quickly entered to investigate. Victim 2 was located in the rear storage room close to the office. A second PASS device was also heard further into the building. Soon after Victim 2 was brought outside, the rear of the building collapsed, preventing further rescue efforts until the fire was brought under control. Victim 1 was located approximately 1½ hours later. Victim 2 was hospitalized and died the next day [NIOSH 2004].

## CONCLUSIONS

More than 60% of the roof systems in the United States are built using a truss system. By design, wooden truss systems contain a significant fuel load and are often hidden from sight. Fires in truss systems can burn for long periods before detection and can spread quickly across or through the trusses. Steel trusses are also prone to failure under fire conditions and may fail in less time than a wooden truss under the same conditions.

The number of fire fighter fatalities related to structural collapse could be significantly reduced through proper education and information concerning truss construction. Fire fighters should be discouraged from risking their lives solely for property protection activities.

Unfortunately, fires are not predictable: conditions often deteriorate quickly, and fire-damaged building components, including trusses, can collapse with little warning. Engineering calculations provide data for an approximate time of failure under specified fire conditions; however, under uncontrolled fire conditions, the time to truss failure is unpredictable.

Early detection of fires involving truss systems is important for safe fireground operations. 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. Today's construction methods incorporate lightweight building components, and this trend is expected to grow. Learning about trusses and their performance under fire attack can greatly enhance fire fighter safety. Lives will continue to be lost unless fire departments make appropriate fundamental changes in fire-fighting tactics involving trusses. These fundamental changes include the following:

- Venting the roof using proper safety precautions
- Opening concealed spaces quickly to determine fire location
- Being constantly aware of the time the fire has been burning
- Providing continuous feedback on changing conditions to the incident commander
- Watching for signs of structural deterioration
- Employing a defensive strategy once burning of truss members is identified
- Broadly disseminating new tactical safety concepts learned at each fire

## RECOMMENDATIONS AND DISCUSSION

NIOSH recommends that fire departments, fire fighters, building owners, and managers take steps to minimize the risk of injury and death to fire fighters during fire fighting operations involving structures with truss roof and floor systems:

### Fire Departments

- ***Ensure that fire fighters are trained to identify different types of roof and floor truss systems and the hazards associated with each.***
- ***Conduct pre-incident planning and inspections to identify structures that contain truss construction.***
  - — 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 [Brannigan 1999, Klaene and Sanders 2000].
  - — Check the structural integrity of walls, roofs, and floors.
  - — Record data regarding roof and floor construction (e.g., wooden joist, wood truss, steel joist, steel truss, beam and girder, etc.) [NFPA 2003a].
  - — Share this information with other departments who provide mutual aid response in the same area.
  - — Whenever possible, inspect buildings during the construction phase to help assess the different types of construction, materials, etc.
  - — 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 [Dunn 2001].
- ***Develop and implement standard operating procedures (SOPs) to combat fires safely in buildings with truss construction.***
  - — Modify existing work practices when necessary to ensure safety during operations around truss construction.
  - — Provide SOPs to all fire fighters for combating fires in buildings with all types of construction, including the different truss types. Also offer training on identifying buildings constructed with trusses.

— Use defensive strategies whenever trusses have been exposed to fire or structural integrity cannot be verified. Unless life-saving operations are under way, evacuate fire fighters and use an exterior attack [Brannigan 1999; Dunn 2001].

- ***Ensure that the incident commander conducts an initial size-up and risk assessment of the incident scene before beginning interior fire-fighting operations.***

— Consider using a thermal imaging camera as part of the size-up operation to aid in locating fires in concealed spaces.

— Account for the type of building construction (i.e., presence of truss construction) when determining (1) the number of fire fighters available, (2) the amount of apparatus and equipment needed to control the blaze, (3) the most effective point of fire extinguishment attack, (4) the most effective method of venting heat and smoke, and (5) whether the attack should be offensive or defensive.

— Continually conduct size-up from the time the alarm is received until the fire is under control [Brunacini 1985]. Analyze risk versus gain continuously during incident operations [Dunn 1998].

— Evaluate the type of structure (residential, commercial, etc), time of day, occupancy, contents of the structure, hazards, exposures, etc.

— Try to find out the type of construction, age of the building, and whether modifications or additions have been completed to help assess structural stability [Dunn 1996].

— Pay close attention to the conditions outside the structure, monitor the roof, and also check on interior conditions [Dunn 1996; NIOSH 1999].

— Plan for search and rescue operations before an emergency occurs in case a fire fighter becomes trapped.

— Immediately notify the Rapid Intervention Team when truss construction is identified.

- ***Ensure that fire fighters performing fire-fighting operations under or above trusses are evacuated as soon as it is determined that the trusses are exposed to fire (not according to a time limit).***

- ***Establish a collapse zone when operating outside a burning building, since truss roof collapses can push out on the walls, causing a secondary collapse of the exterior walls.***

— The collapse zone should be equal to the height of the building plus allowance for scattering debris [Brannigan 1999; Klaene and Sanders 2000; NIOSH 1999], usually at least 1½ times the height of the building.

- ***Use defensive overhauling procedures after fire extinguishment in a building containing truss construction. Use outside master streams to soak the smoldering truss building and prevent rekindling [Brannigan 1999; Klaene and Sanders 2000].***

- ***Consider becoming involved in the building code development and enforcement process.***

- ***For more information about preventing fire fighter injuries and deaths from structural collapse, see NIOSH***

*[1999] and relevant research on new structural collapse prediction technologies: www.usfa.fema.gov/inside-usfa/research/safety/nist1.shtm [USFA 2004a].*

## Fire Fighters

- ***Use extreme caution when operating on or under truss systems.***
  - — Notify the incident commander whenever truss construction is discovered.
  - — Communicate interior conditions to the incident commander as soon as possible and provide regular updates.
  - — Use a defensive fire-fighting strategy once burning of truss members is identified (unless someone is trapped).
  - — Expect imminent collapse once lightweight truss roofs or floors are involved in a fire [Klaene and Sanders 2000].
  - — If possible, avoid cutting the truss chords when cutting holes for roof ventilation. Cuts can weaken the roof.
  - — Avoid roof areas loaded by air conditioning units, air handlers, and other heavy objects.
  - — Be aware of alternative exit routes at all times when working above or below a truss.
  - — Consider using roof ladders or working from aerial ladders or platforms instead of walking or standing directly on the roof [Brannigan 1999; Dunn 1998].
- ***Immediately open ceilings and other concealed spaces whenever a fire is suspected in a truss system.***
  - — Be aware that fires can be in the truss void or other concealed areas (see Figure 2). Once the fire enters a concealed space, it can travel to remote locations rapidly, since the wooden web members surrounded by open air space provide an excellent fuel source [Brannigan 1999].
  - — When a truss is suspected to be above a ceiling, use a pike pole or other tools to open up the ceiling and check for truss construction [Brannigan 1999]. If there is a fire barrier in the void, use the same procedure on the opposite side.
  - — Be aware of the possibility of flashover or back draft when opening concealed spaces and take the appropriate safety precautions.
  - — When opening ceilings or other concealed spaces, have charged hose line(s) ready.
  - — Be aware of the nearest exit and of other fire fighters in the area. The incident commander must consider and provide for alternative exit routes from all locations where fire fighters are operating [Klaene and Sanders 2000].
- ***Understand that fire ratings may not be truly representative of real-time fire conditions.***

## Building Owners and Managers

- ***Consider placing building construction information outside the building. Include information about roof and floor type (presence of trusses***


**Figure 2.** Truss loft with space for ventilation ductwork, wiring, etc. (*Photo courtesy of National Fire Protection Association.*)

***[Figure 3], materials used), roof loads (heating, ventilation, and air conditioning [HVAC] units, displays), sprinkler systems, utilities, chemicals on site, and contact numbers.***

- ***Use and follow proper building codes.***

## ACKNOWLEDGMENTS

The authors of this ALERT were Timothy R. Merinar, Richard W. Braddee, Frank Washenitz II, and Tom Mezzanotte, Division of Safety Research, NIOSH; Vincent Dunn, Deputy Chief (retired) New York City Fire Department; and Frank Brannigan, fire and building construction expert. The authors thank the following for their reviews of draft versions: Robert Solomon, PE, National Fire Protection Association; David Stroup, PE, National Institute of Standards and Technology; Rob Neal and William Troup, U.S. Fire Administration; Robert Bland, American Forest and Paper Association; Kirk Grundahl, Wood Truss Council of America; Chief Al Rosamond, Dallas Bay Volunteer Fire Department (representing the National Volunteer

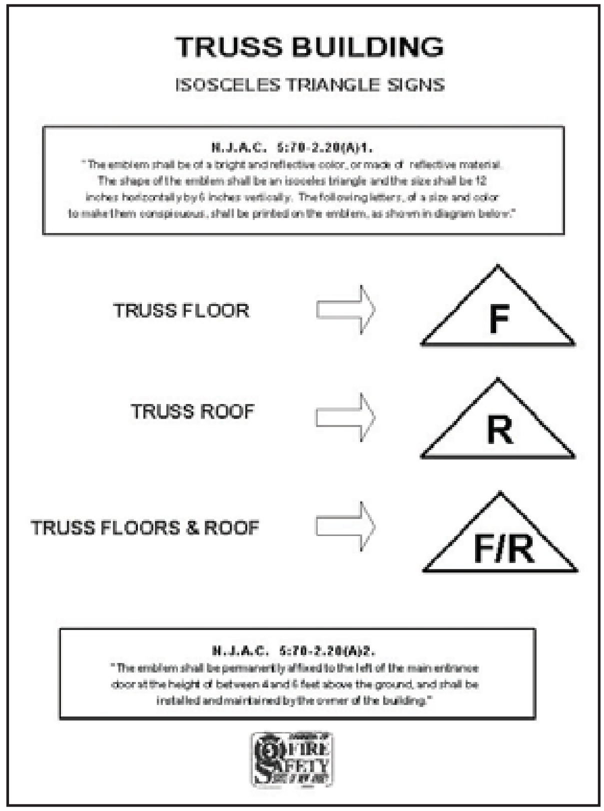



**Figure 3.** Truss Placard—State of New Jersey; NJAC 5:70–2.20(a) 1 and 2 [NJAC 1992].

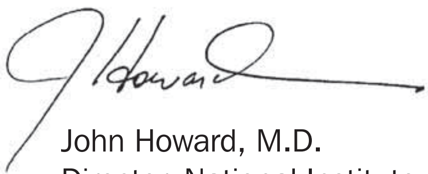
Fire Council); Chief Mark Young, Casper Fire Department (representing the International Association of Fire Chiefs); Rob Matuga, National Association of Home Builders; Pat Morrison and Elizabeth Harman, International Association of Fire Fighters.

Please direct any comments, questions, or requests for additional information to the following:

Dr. Nancy A. Stout, Director
Division of Safety Research
National Institute for Occupational Safety and Health
1095 Willowdale Road
Morgantown, WV 26505–2888

Telephone: 304–285–5894; or call
1–800–35–NIOSH (1–800–356–4674)

We greatly appreciate your assistance in protecting the safety and health of fire fighters.



John Howard, M.D.
Director, National Institute for Occupational Safety and Health
Centers for Disease Control and Prevention

## REFERENCES

Brannigan FL [1988]. Are wood trusses good for your health? The safety issue of lightweight wood truss floor assemblies provokes controversy. Fire Eng *141*(6):73–79.

Brannigan FL [1999]. Building construction for the fire service. 3rd ed. Quincy, MA: National Fire Protection Association, pp. 517–563.

Brunacini A [1985]. Fire command. Quincy, MA: National Fire Protection Association, pp. 37–52.

Cotes A [1997]. Fire protection handbook, 18th ed. Quincy, MA: National Fire Protection Association, pp. 7–61, 7–63.

Cutter B [1990]. The fire and wood truss debate: solution . . . working together! Woodwords May:1–5.

Dunn V [1992]. Safety and survival on the fireground. Saddle Brook, NJ: Fire Engineering Books and Videos, pp. 113, 361.

Dunn V [1996]. Systems analysis size-up: Part 1. Firehouse Oct:18–21.

Dunn V [1998]. Risk management and lightweight truss construction. New York: WNYF, Official training publication of the New York City Fire Department, Vol. 1.

Dunn V [2001]. The deadly lightweight truss. Firehouse Jan:16–20.

Grundahl K [1991]. Fire performance of trusses reference guide. [www.woodtruss.com/index1.html].

Grundahl K [1992]. National engineered lightweight construction fire research project. Quincy, MA: National Fire Protection Research Foundation.

Grundahl K [2003a]. Publisher's message: facts on the fire performance of wood trusses. Structural Building Components Magazine June/July:10–15.

Grundahl K [2003b]. Cause of firefighter fatalities, 1980–2001. E-mail message to Tim Merinar (tmerinar@cdc.gov), December 22, 2003.

Klaene BJ, Sanders RE [2000]. Structural fire fighting. Quincy, MA: National Fire Protection Association, pp. 95–135.

Meeks JE [2001]. Truss plate performance in fire: one person's observations. Structural Building Components Magazine June/July. [www.sbcmag.info/past/2001/01jun_jul/plateperformance.html]

NFPA [2001]. NFPA 921: Guide for fire and explosion investigations. Quincy, MA: National Fire Protection Association.

NFPA [2002a]. NFPA 1521: Standard for fire department safety officer. Quincy, MA: National Fire Protection Association.

NFPA [2002b]. NFPA 1001: Standard for fire fighter professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2002c]. NFPA 13: Standard for the installation of sprinkler systems. Quincy, MA: National Fire Protection Association.

NFPA [2003a]. NFPA 1620: Recommended practice for pre-incident planning. Quincy, MA: National Fire Protection Association.

NFPA [2003b]. NFPA 5000: Building construction and safety code. Quincy, MA: National Fire Protection Association.

NFPA [2003c]. NFPA 501: Standard on manufactured housing. Quincy, MA: National Fire Protection Association.

NIOSH [1998a]. Commercial structure fire claims the life of one fire fighter—California. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Fatality Assessment and Control Evaluation (FACE) Report 98F–07.

NIOSH [1998b]. Fire fighter dies while fighting warehouse fire when parapet wall collapses—Vermont. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Fatality Assessment and Control Evaluation (FACE) Report 98F–20.

NIOSH [1999]. NIOSH Alert: request for assistance in preventing injuries and deaths of fire fighters due to structural collapse. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99–146.

NIOSH [2000]. Restaurant fire claims the life of two career fire fighters—Texas. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Fatality Assessment and Control Evaluation (FACE) Report F2000–13.

NIOSH [2001]. Roof collapse injures four career fire fighters at a church fire—Arkansas. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Fatality Assessment and Control Evaluation (FACE) Report F2001–03.

NIOSH [2002]. First-floor collapse during residential basement fire claims the life of two fire fighters (career and volunteer) and injures a career fire fighter captain—New York. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Fatality Assessment and Control Evaluation (FACE) Report F2002–06.

NIOSH [2004]. Partial roof collapse in commercial structure fire claims the life of two fire fighters—Tennessee. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Fatality Assessment and Control Evaluation (FACE) Report F2003–18.

NJAC [1992]. Identifying emblems for structures with truss construction. New Jersey Uniform Fire Code. New Jersey Administration Code 5:70–2.20.

SBCMAG [2004]. U.S. Structural building components usage and market share statistics. Madison, WI: Structural Building Components Magazine. [www.sbcmag.info/legislative/itcfinalreport/US_Structural_Building_Components_Usage_and_Market_Share]

Tapley B [1990]. Eshbach's handbook. 4th ed. New York: John Wiley and Sons, Inc.

USFA [2002]. Firefighter fatality retrospective study. Arlington, VA: U.S. Department of Homeland Security, Federal Emergency Management Agency, U.S. Fire Administration. FA–220.

USFA [2004a]. Structural collapse prediction technology research. Arlington, VA: U.S. Department of Homeland Security, Federal Emergency Management Agency, U.S. Fire Administration. [www.usfa.fema.gov/inside-usfa/research/safety/nist1.shtm]

USFA [2004b]. Building performance awareness of lightweight construction during fires. U.S. Department of Homeland Security, Federal Emergency Management Agency, U.S. Fire Administration. [www.usfa.fema.gov/inside-usfa/research/construction.shtm]

# APPENDIX A

# Incidents Involving Structures Containing Truss Construction

The NIOSH Fire Fighter Fatality Investigation and Prevention Program has investigated the following incidents that involved structures containing truss construction. The complete NIOSH investigation report for each incident can be obtained at www.cdc.gov/niosh/facerpts.html.

**Table A-1. Reports of incidents involving structures containing truss construction**

| Report ID | State | Truss type | Number of injuries and fatalities | Event leading to death or injury |
|---|---|---|---|---|
| 98F005 | Illinois | Heavy timber | 2 F,* 3 I | Backdraft |
| 98F007 | California | Heavy timber | 1 F | Roof collapse |
| 98F020 | Vermont | Heavy timber | 1 F | Roof/wall collapse |
| 98F021 | Mississippi | Lightweight wood | 2 F | Roof collapse |
| 99F002 | Indiana | Lightweight wood | 1 F | Roof collapse |
| F2000–13 | Texas | Lightweight wood | 2 F | Roof collapse |
| F2000–26 | Alabama | Lightweight wood | 1 F | Floor collapse |
| F2000–43 | Delaware | Lightweight wood | 3 I | Fire spread through truss voids |
| F2001–03 | Arkansas | Lightweight wood | 4 I | Roof collapse |
| F2001–09 | Wisconsin | Heavy timber | 1 F, 1 I | Roof/wall collapse |
| F2001–16 | Ohio | Lightweight wood | 1 F | Floor collapse |
| F2001–27 | South Carolina | Lightweight wood | 1 F | Roof collapse |
| F2002–06 | New York | Lightweight wood | 2 F, 1 I | Floor collapse |
| F2002–50 | Oregon | Heavy timber | 3 F | Roof collapse |
| F2003–18 | Tennesse | Lightweight metal | 2 F | Roof collapse |

*F = Fatality, I = Injury

# APPENDIX B

**Triangular trusses** are the most common trusses used in single-family dwellings. Triangular trusses provide a peaked roof.

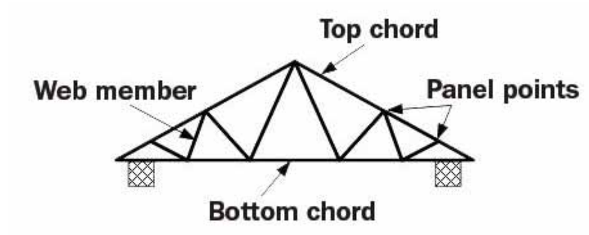



**Figure B-1.** Triangular truss

**Scissor trusses** are common in construction with cathedral ceilings. They are often found in churches.

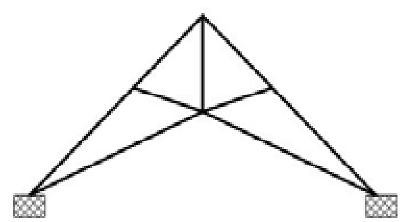


**Figure B-2.** Scissor truss

**Parallel chord trusses** provide a flat roof or floor. The top and bottom chords are parallel. They are commonly used in single-family dwellings, row houses, apartment buildings, and smaller office buildings.

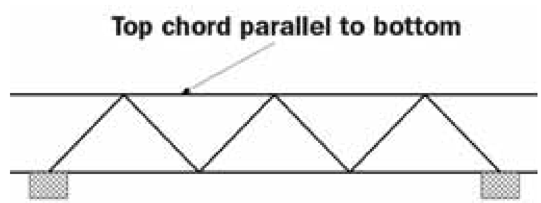



**Figure B-3.** Parallel chord truss

**Bowstring trusses** get their name from the curved shape of the top chord. Parapet walls may hide the curved roofline on large commercial buildings.

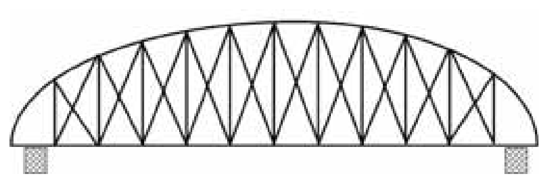


**Figure B-4.** Bowstring truss

**Inverted king/queen post trusses** are used in place of support columns to provide open floor space under the truss.

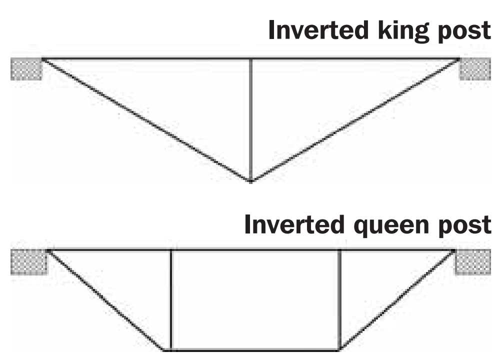



**Figure B-5.** Inverted king/queen trusses

# APPENDIX C

# Truss Systems

## Heavy Timber Roof and Floor Truss Systems

Heavy timber trusses are often engineered to provide large open areas—such as under a cathedral ceiling. The timbers in a heavy timber truss are usually joined together by bolts that pass through the center of metal or steel plates. The most common connector is the split-ring metal connector that is embedded in prepared depressions on the face of the timber. The embedded plates are used to transfer shear stresses and increase the load-carrying capacity of the bolted connection. Until the 1960s, the bowstring timber truss was one of the most common designs used in commercial construction and can be recognized by its curved top chord (see Figure B–4 in Appendix B). A classic example of a fire in a bowstring truss roof is the Hackensack, New Jersey, automobile dealership fire in 1988. Bowstring truss roofs are sometimes incorrectly described as arches or arched roofs [Brannigan 1999].

## Lightweight Wooden Truss Roof and Floor Systems

Engineered lightweight construction trends result in buildings designed and constructed using trusses manufactured from lumber (2 × 4, 2 × 6, or 2 × 8 inches)—where such trusses meet the engineering specifications and applicable building codes. Engineering and construction economics cause the design process to use the minimum-sized structural members necessary to support or carry the anticipated load. Engineered lightweight truss systems are the most commonly used truss systems in residential and single-family structures, and they are also used in many commercial buildings. This type of truss became popular in the early 1950s after the invention of the metal connector plate, also known as the gusset plate, gang-nail, nailer plate, or truss plate. This plate is used to rigidly connect the different wooden web members into various truss shapes.

The fastener is designed to connect the truss members by small teeth punched out of 20-, 18-, or 16-gauge galvanized steel sheets (see Figures C–1 and C–2). The teeth are hydraulically or roller pressed into the lumber so that the metal plate forms a bridge across the joint between the wooden web and chord members. These teeth may vary in size and length, but they typically do not penetrate more than ½ inch into the wood.

Concealed spaces are created when both the top and bottom of lightweight wooden truss systems are covered with wooden sheathing, gypsum wallboard, or other materials enclosing the area from roof to ceiling. These concealed spaces are also known as truss voids or truss lofts. Joist and rafter roof systems also have these concealed spaces.

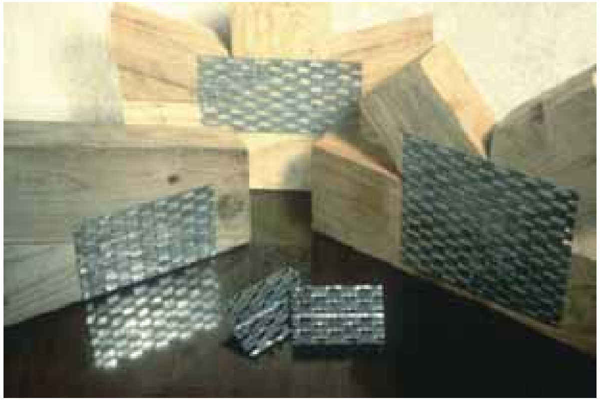


**Figure C-1.** Gusset plates used to connect wooden truss members. (*Photo courtesy of Kirk Grundahl.*)

**Figure C–2.** Gusset plates. Note length of teeth/ penetration depth. (*Photo courtesy of Vincent Dunn.*)

This truss void space is often used for HVAC ductwork, plumbing, and wiring. Truss voids are also found between floors of buildings constructed with floor trusses. The open area from the top chord of the truss to the bottom chord can create a path for rapid horizontal fire spread. Even if fireblocking is placed in the voids, openings for ductwork, appliance piping, electrical wires, conduit, or additional utility installations can still create a path for fire to spread throughout roof and floor systems (Figure C–3). The truss void provides a reservoir for hot gases that may flash over when the void is opened as a result of ceiling collapse or fire-fighting tactics (such as pulling ceiling or searching for the seat of the fire). Horizontal flame spread is also possible through open space created between roof rafters.

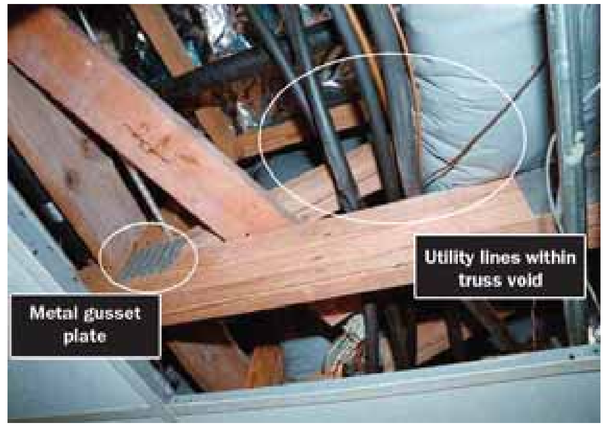



**Figure C–3.** Utility lines routed through truss voids. (*Source: NIOSH [2000].*)

## Steel Truss Roof and Floor Systems

Steel trusses are available in different types and shapes. The current trend is toward engineered, lightweight steel construction. Engineered structural steel building materials have been developed that are more cost effective than solid wood or masonry construction. For example, modern lightweight building practices have led to long-span steel trusses designed with a steel cable as the bottom chord [Brannigan 1999]. The steel bar joist (a parallel-chord truss) is commonly used for both roofs and floors in commercial buildings (see Figure C–4). To give steel trusses increased fire rating, they must be encased or covered with a spray-applied material to provide for the proper hourly fire resistance rating. This material insulates the steel from heat exposure and increases the time for the metal to reach the critical temperature (in the range of 800° to 1,200° F) at which the steel has lost too much strength and can no longer support its load. The insulation increases the time to failure but may not totally prevent it.

Steel trusses may fail in less time than a wooden truss under the same conditions.

**Figure C–4.** Lightweight steel trusses. (*Photo courtesy of Francis Brannigan.*)

Some of the worst incidents involving fire fighter fatalities have involved metal trusses. These include the Brockton, Massachusetts, Strand Theater disaster in 1941 (in which 13 fire fighters were killed) and the Wichita, Kansas, automobile dealership fire in 1968 (in which 4 fire fighters were killed) [Brannigan 1999]. The twin towers of the World Trade Center contained 60-foot steel bar joists in their floor construction.

For more information about truss construction and educational or training materials being developed for the fire service, visit www.usfa.fema.gov/inside-usfa/research/construction.shtm [USFA 2004b].

# Appendix D

# Truss Failure Modes Under Fire Conditions

All parts and connections of a truss are vital to the stability of the truss system. The bottom chord of a truss is under tension. A tension member acts like a rope. If the bottom chord of the truss breaks, the truss system may fail by pulling apart. Conversely, the top chord of a truss is under compression. The top chord acts like a column. Failure of a compression member reduces the overall load-bearing capacity of the truss. The failure of any one element can lead to failure of the entire truss. The failure of a single truss transfers additional load to the surrounding trusses, which results in multiple truss failures. The failure of one truss can cause serious problems to other parts of the structure, even parts separate from the initial failure point. However, when a truss member is cut or fails, the load may be redistributed to adjacent structural elements to mitigate the domino effect. The overall collapse potential depends on the supported load and how many adjacent trusses are also weakened. Fire fighters need to be aware of this phenomenon and use extreme caution when working around cut or damaged trusses.

An often overlooked hazard is found where interior trusses or wooden beams extend beyond the exterior wall to provide a balcony or a stairway landing. Fire burning inside the building can degrade the truss or beam, resulting in collapse of the cantilevered balcony or stairway landing. Fire fighters standing on or under the collapsing exterior landing may be injured or killed. Different types of trusses can fail in different ways, as described in the following subsections.

## Heavy Timber Truss Systems

Heavy timber truss systems may be constructed of wood or wood and steel. Heavy timber members are defined in building codes and are at least 6 inches wide and deep. The wooden web members connecting the top and bottom chords may be smaller dimensionally; however, they are critical to the overall strength of the truss section during a fire. In general, heavy timber trusses are long span and are placed at wide on-center spacings because they have such high load-carrying capacity. When impinged by flames and weakened to the point of collapse, large areas generally collapse. However, heavy timber trusses have the longest time to failure of any truss type because as the outer wood burns and turns to char, the char acts as an insulator and slows the rate of degradation to the inner wood [Grundahl 1992]. Hazards include the following:

- Although the heavy timber trusses may resist substantially more fire exposure than lightweight wooden trusses, another problem develops when the thinner roof boards (much thinner than the heavy timbers) are consumed. Fire fighters may fall through these weakened roof boards.

- Heavy timber trusses are spaced several feet apart—much further apart than lightweight trusses, which may be spaced on 16- or 24-inch centers. Roof ventilation on a heavy timber truss roof may leave the fire fighter standing on several feet of unsupported roof board.
- The metal connectors or pins holding the heavy truss system together can fail before the wooden timber fails.
- The metal connectors may also transfer heat to the wood and weaken the wooden timber through pyrolysis (a chemical change brought about by the action of heat), leading to early failure of the connection.
- A collapsing heavy wooden timber truss roof system can cause the subsequent collapse of the building's front, rear, or side masonry enclosure walls.
- Heavy timber trusses are often located so far apart that usable storage or office space can be constructed between them, or post-construction equipment such as air-conditioning units may be placed on the roof. Timbers weakened by fire could then fail much earlier than expected.

## Lightweight Wooden Truss Systems

Findings reported from the *National Engineered Lightweight Construction Fire Research Project* indicate that unprotected wooden assemblies fail within 6 to 13 minutes of exposure to fire [Grundahl 1992]. This 1992 report provides time to failure under laboratory conditions for a number of structural members and may not be truly representative of fireground conditions. Fire fighters should never rely solely on time-to-failure data to initiate fireground procedures. Continual evaluation of the fireground conditions, with emphasis on size-up and structural integrity, is necessary to ensure that fire suppression is carried out safely.

Lightweight chords are often continuous, and connecting web members often transfer substantial loads to other parts of the truss. This means that cutting a member may not automatically result in truss failure. There is much debate over whether fire immediately weakens or loosens the connecting gusset plates. Some researchers [Dunn 2001; Brannigan 1999] contend that these metal gusset plates can contribute to the degradation of wooden truss members through pyrolysis. Heat transferred through the metal fastener's teeth may destroy the wooden fibers held in tension by the gripping action of the metal teeth. This process loosens the plate and leads to a weakened truss and possible catastrophic failure if the gusset plate falls away and allows the weakened truss to pull apart. Other researchers [Grundahl 2003a; Meeks 2001; Cutter 1990] suggest that the metal plates protect the underlying wood during the initial stages of a fire. They suggest that the wooden members between truss joints may burn before the areas underneath the metal plates. The unprotected areas become charred to a depth that reduces the strength of the wooden member. Eventually, as the fire progresses, wood charring takes place underneath the metal connector plate. This causes the load-carrying capacity of the metal-plate-connected joint to be reduced. This reduction in the joint capacity eventually causes the metal connector plate to pull out and the joint to fail.

Lightweight wooden trusses are prefabricated at a factory and shipped to the construction site. If these trusses are improperly transported or stored at the site (exposed to the elements), or if they are dropped or handled improperly, the gusset plate or the entire truss can be significantly damaged. This can cause the plate to pull away from the wood surface or become weakened or loosened. In such cases, where the truss has not been properly repaired, the truss is weakened before installation and could fail under fire conditions much sooner than normally expected. Unexpected failure caused by mishandling is not unique to trusses and is difficult or impossible to predict during initial size-up.

The following are common causes of lightweight wooden truss failure that may be encountered in a fire:

- **Loose gusset plates.** The loss of a gusset plate on the bottom chord can lead to tensile forces pulling the truss apart. The loss of a gusset plate on the top chord will cause any web members attached to the top chord to pull away. Both situations will significantly reduce the load-carrying capacity of the installed truss and may even lead to a truss collapse.
- **Increasing the span width below the truss.** Trusses provide wide-open rooms below long, clear spans. For example, consider two adjoining rooms under a trussed roof, each 10 feet wide. The dividing wall serves as additional support in the center of the 20-foot span. In residential construction, catastrophic failure may be averted or minimized by the individual room walls supporting different sections of the failing truss. In a commercial building, the same truss (with clear-span space below and fewer partition walls to provide support as it deflects) could fail with less warning.
- **Alterations to individual trusses or to the building.** Although it is an unsafe practice, trusses are often cut or altered to accommodate plumbing, wiring, ventilation ducts, and other fixtures. This practice can significantly reduce the load-carrying capacity of the truss. These alterations are often hidden in the finished construction and go unnoticed until a failure occurs.
- **Excessive loads.** A truss is designed to support the roof above and to provide the desired clear span below. Adding weight that was not taken into consideration in the design stage can seriously compromise the load-carrying capacity of the truss and is a violation of building codes. Truss systems may be overstressed by heavy suspended ceilings, light fixtures, or other objects suspended below the truss; air conditioning units; ventilation systems; material storage; or other loads within or above the roof system that the truss was not designed to bear. Consider fireground conditions (including snow or ice and water from fire suppression operations), as well as the weight of fire fighters in full turnout gear. In a fire, all of these loads in combination can significantly reduce time to failure. Heavy loads of any type in any building should be of concern to the fire service.

## Steel Truss Systems

All-steel trusses present their own hazards when exposed to fire. The mass and surface area of steel truss components are factors that determine time to failure. A heavy, thick section of steel has greater resistance to fire than a lightweight section of the same length because of the increased mass. A large, solid steel truss can absorb heat and take longer to reach its failure temperature, whereas a lightweight steel truss such as an open-web bar joist will be heated to its failure temperature much faster. Once the failure temperature is reached, heavy steel trusses and lightweight metal trusses will react to the fire and fail in a similar manner. A steel member fails at the internal temperature of the steel and not at the ambient air temperature. This temperature is often referred to as the critical temperature of the steel member.

Findings reported by the *National Engineered Lightweight Construction Fire Research Project* indicate that unprotected lightweight steel C-joists fail within 4 to 6 minutes of exposure to fire [Grundahl 1992]. Testing conducted by the U.S. Bureau of Standards (now known as the National Institute of Standards and Technology, or NIST) showed that unprotected steel open-web bar joists reached 1,200° F in 6 to 8 minutes [Brannigan 1999]. Table D–1 illustrates that steel retains only 25% of its original strength at 1,200° F and retains only half its original strength at approximately 900 °F. Building design calculations are based on original strength at normal temperatures. At elevated temperatures, steel may retain no excess strength.

Steel is noncombustible and does not contribute fuel to a fire. This property may cause a false sense of security and overshadow the fact that steel loses strength when exposed to temperatures commonly found in structural fires. Steel has a high thermal conductivity, which means it can transfer heat away from a localized source and act as a heat sink. As long as the flame impingement is localized, the steel can transfer heat to other regions of the member—and thus the time to reach the critical temperature is delayed. If an intense fire is evenly distributed along the steel member, the critical temperature may be reached very quickly. Steel also has a high coefficient of expansion that results in the expansion of steel members as they are heated. As an example, a 50-foot-long steel beam heated uniformly over its length from 72° to 972° F will expand in length by 3.9 inches. The same beam uniformly heated to 800° F would expand by 3.2 inches; if heated to 1,200° F, the beam would expand by 4.9 inches [Grundahl 1991; Cotes 1997].

**Table D-1. Loss of strength by low-carbon steel as it is heated**

| Internal temperature of the steel (°F) | % of original strength retained by the steel | % yield strength lost by the steel |
|---|---|---|
| 70 | 100 | 0 |
| 400 | 87.5 | 12.5 |
| 600 | 72.5 | 27.5 |
| 800 | 57.5 | 42.5 |
| 1,000 | 42.5 | 57.5 |
| 1,200 | 25 | 75 |

Source: Tapley [1990].

Examples of steel truss failure modes that fire fighters may encounter in fires include the following:

- Cold-drawn steel cables can totally fail at 800° F [Brannigan 1999].
- At temperatures above 1,000° F, the expanding steel in bar joist trusses can exert lateral thrust forces on surrounding

masonry walls sufficient to cause their collapse. Higher temperatures can lead to failure of the steel itself [Brannigan 1999; Cotes 1997].

- Expansion within metal trusses may also cause the bottom chord to buckle and fail, resulting in downward thrust and collapse of the roof or floor.

# APPENDIX E

This unique truss contains web members made of steel cables.

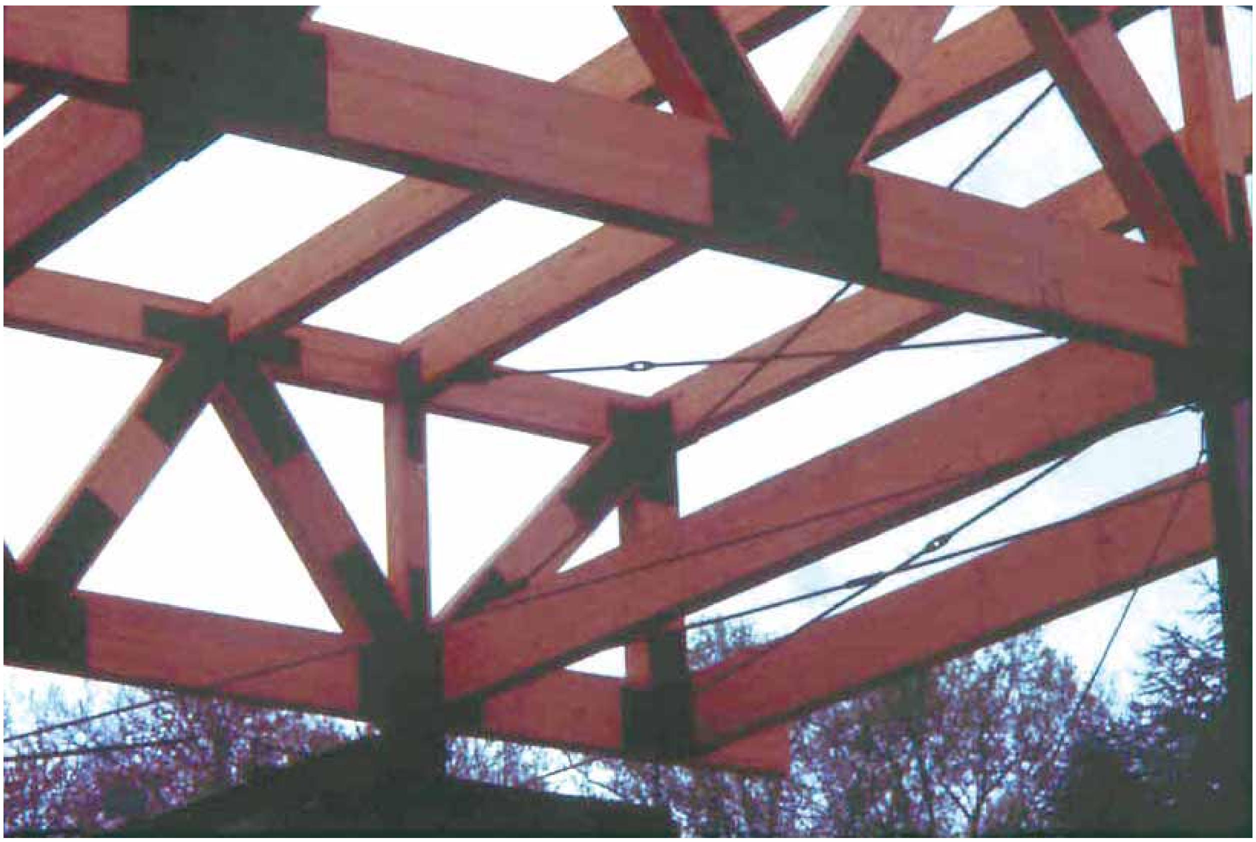


**Figure E–1.** Heavy timber truss with steel cable web members. (*Photo courtesy of Francis Brannigan.*)

## NOTES

## NOTES

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, Ohio 45226–1998

NIOSH

Delivering on the Nation's promise:
Safety and health at work for all people
through research and prevention

To receive NIOSH documents or more information about occupational safety and health topics, contact NIOSH at

1–800–35–NIOSH (1–800–356–4674)
Fax: (513) 533–8573
E-mail: pubstaft@cdc.gov

or visit the NIOSH Web site at www.cdc.gov/niosh

DHHS (NIOSH) Publication No. 2005–132

SAFER • HEALTHIER • PEOPLE™