Reducing the Risk of Firefighter Deaths and Injuries Due to Structural Collapse in the City of Aurora, Ohio

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CERTIFICATION STATEMENT

I hereby certify that the following statements are true:

1. This paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

2. I have affirmed the use of proper spelling and grammar in this document by using the spell and grammar check functions of a word processing software program and correcting the errors as suggested by the program.

Signed: ________________________________

Printed Name: Matthew Mc Birney
ABSTRACT

The structural collapse of buildings, particularly those of lightweight construction designs, during firefighting operations continues to represent a great risk of firefighter deaths and injuries. The problem addressed by this study is the question of Aurora Fire Department members’ abilities to recognize lightweight construction hazards and to choose appropriate, safe, and risk management based tactics.

The purpose of this study was to reduce the risk of death and injury to firefighters, engaged in fireground operations, due to the structural collapse of buildings in the City of Aurora, Ohio. This study examined this problem using the descriptive (survey) method.

The research questions this study investigated were:

1. What policies, practices, and training are now utilized by the Aurora Fire Department to reduce the risk of death or injury due to the structural collapse of buildings while firefighters are engaged in fireground operations?

2. When presented with common buildings in Aurora, Ohio, can Aurora Fire Department members identify building construction types and characteristics, particularly those that pose the greatest threats to firefighters?

3. Do Aurora Fire Department members recognize the hazards associated with fires in modern lightweight construction buildings and the appropriate tactics to apply while fighting those fires?

4. What can the Aurora Fire Department do to improve firefighter recognition of lightweight construction hazards and reduce the risk of firefighter death or injury due to a structural collapse while engaged in fireground operations?
The research revealed that the Aurora Fire Department does engage in training on building construction and lightweight constructions hazards, but that many members still find it difficult to correctly identify the characteristics of local buildings. Aurora firefighters have also had training on risk management principles relative to fireground operations, but many may not be prepared to make the safest and most appropriate tactical choices, possibly secondary to not recognizing the presence of lightweight construction. This study challenges the Aurora Fire Department to involve firefighters in more regular building construction training including local building tours, walk-throughs, and construction site visits. This study also challenges the Aurora Fire Department to engage political officials and code enforcement personnel to advocate for a new code requiring a protective finish on all floor joists and for the adoption of a placard system to identify the presence of lightweight construction elements in commercial and residential buildings.
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INTRODUCTION

Statement of the Problem

National statistics indicate that 30 firefighters died due to the structural collapse of buildings from 2004 to 2010. In both residential and commercial construction, the use of lightweight construction framing members has become widespread. Lightweight construction components rapidly lose their strength when exposed to fire, unlike the legacy construction methods and materials the preceded them. On the exterior, buildings of lightweight construction look nearly identical to legacy construction buildings. Firefighters who enter lightweight constructed buildings to extinguish a fire are exposed to the risk of a collapse that may occur much more quickly than their previous experience would indicate.

The problem this study addressed is the risk of firefighter deaths and injuries due to the structural collapse of buildings.

Lightweight construction materials have become increasingly popular since the 1960’s, and fire service experts and educators have been warning firefighters of the dangers associated with lightweight construction in earnest since the mid 1980’s. Even though many firefighters have heard the phrase, “The building is your enemy” (Brannigan, 2008) and that “trusses kill,” many firefighters find it difficult to accurately recognize lightweight construction hazards, which may lead to unsafe tactical decisions. This study examined this problem using the descriptive (survey) method.

Purpose of the Study

The purpose of this study was to reduce the risk of death and injury to firefighters due to structural collapses while fighting fires in the City of Aurora, Ohio.
Research Questions

The research questions this study investigated were:

1. What policies, practices, and training are now utilized by the Aurora Fire Department to reduce the risk of death or injury due to the structural collapse of buildings while firefighters are engaged in fireground operations?

2. When presented with common buildings in Aurora, Ohio, can Aurora Fire Department members identify building construction types and characteristics, particularly those that pose the greatest threats to firefighters?

3. Do Aurora Fire Department members recognize the hazards associated with fires in modern lightweight construction buildings and the appropriate tactics to apply while fighting those fires?

4. What can the Aurora Fire Department do to improve firefighter recognition of lightweight construction hazards and reduce the risk of firefighter death or injury due to a structural collapse while engaged in fireground operations?

BACKGROUND AND SIGNIFICANCE

The City of Aurora, Ohio is a suburban community located in Northeast Ohio, Southeast of Cleveland and Northeast of Akron, covering an area of 25 square miles and is home to approximately 15,000 residents. Aurora is largely a residential town with four nursing homes, three retail shopping centers, and a small light industrial commercial presence. The City of Aurora Fire Department employs 15 full time and 25 part time personnel and has a daily 24 hour duty crew of 5-7 Firefighter/Paramedics as well as a full time Chief and Assistant Chief during daytime business hours. In 2011, Aurora firefighters responded from two fire stations to 2082 emergency calls, 424 of which were fire alarms (AFD, 2011).
On May 21, 2010, the Aurora Fire Department responded to an automatic fire alarm at 521 Brighton Drive. On arrival, heavy smoke was showing and the occupants of the house were confirmed to have evacuated. An attack line was advanced in the front door, through a foyer, to a hallway where the crew knocked down some flames, and then continued to the kitchen. They determined that the fire was in the basement and then descended the basement stairs and knocked down the fire. After returning to the front door where they had entered, and now with the smoke clearing, firefighters who had been on the hoseline observed that the foyer floor they crossed, as they advanced the attack line, had sagged approximately three inches. The floor joists were made of unprotected engineered wood I-beams which had burned through. They may have been saved from collapse by an extra layer of plywood floor decking installed to support marble floor tiles. This case was a close call or near miss, but many firefighters have not been so fortunate.

Lightweight construction products commonly used in residential building construction include lightweight truss roof assemblies, lightweight truss floor joists, and engineered wood I-beam floor joists fabricated from grooved top and bottom chord sections affixed to a web panel made of oriented strand board (OSB). Lightweight steel building products are frequently use in Type II Noncombustible commercial construction. These products include rigid steel frame assemblies, steel columns, girders, beams, bar joists, wall panels, and sheet metal roofing decks. These products are classified as noncombustible because they contribute no fuel to a potential fire; however, in contrast to the impression held by many, they too are subject to weakening and failure when exposed to fire. Type II Noncombustible steel buildings over 10,000 sq. ft. are typically required to be protected by a sprinkler system for this reason.

The City of Aurora, Ohio has a mixture of buildings types classified as Type I Fire Resistive, Type II Noncombustible, Type III Ordinary Construction, Type IV Heavy Timber, and
Type V Wood Frame construction buildings (NFPA, 2012). The housing stock of wood frame homes is a mixture of a few old balloon frame constructed homes, many platform frame built homes built with legacy materials and methods such as dimensional lumber and floor joists, ridge beam and rafter roof assemblies, and many more platform frame built wood frame homes with lightweight floor joists and roof assemblies. Commercial buildings in Aurora, Ohio are largely of Type II Noncombustible construction with few exceptions.

Because lightweight construction materials are much more prone to failure and collapse under fire impingement compared to legacy construction buildings, firefighters must be able to identify the likely characteristics of buildings that are on fire before engaging in suppression operations. (Brannigan & Corbett, 2008) Risk management principles guide firefighters to risk a lot to save a lot, risk a little to save a little, and risk nothing when there are no lives to be saved and the property is lost. Firefighters can only make the appropriate risk management decisions if they can recognize the risks present in a given scenario. (NIOSH, 2010)

Firefighter safety should be the number priority of any fire service organization. This study challenged the Aurora Fire Department to examine the risks that lightweight construction designs pose to firefighters and to consider ways to reduce the risk of firefighter death or injury due to structural collapse during firefighting operations.

LITERATURE REVIEW

A literature review was conducted to examine published research, facts, and professional opinions relating to the hazards that lightweight construction presents to firefighters. Academic research, government publications, and fire service trade journals were searched and reviewed for inclusion in this research project.
In Francis Brannigan’s Building Construction for the Fire Service – 4th edition, Francis Brannigan and Glenn Corbett describe a truss as a structure in a single plane built of members formed into a triangle or multiple triangles. The economy of the truss derives from the separating of compressive and tensile forces among the individual components so that a minimum of material can be used. Engineering schools emphasize high strength to weight ratios and often stage competitions for students to challenge them to design the lightest structure that can bear the greatest load. In a competitive building materials market, trusses are often engineered to meet the lowest price point while satisfying the required load carrying ability. When exposed to fire, the failure of one individual leg or the gusset plate connector can allow the whole truss to fail. The failure of one truss often impacts the remaining trusses and may lead to their collapse. In addition to their use in pitched roofs, wood trusses are also used as floor joists. Lightweight wooden I-beams made of an oriented strand board (OSB) web sandwiched between grooved top and bottom cord members are also in common use now. Buildings with these features ordinarily give no outward sign of their presence. (Brannigan & Corbett, 2008)

Any additional weight or movement across a truss supported roof that has lost one web member or connector plate can initiate a collapse. Interior activities such as pulling ceiling or directing water streams into attic spaces can trigger the same reaction. The Phoenix Fire Department worked with the National Institute of Science and Technology (NIST) to test a variety of room and contents fires in wood frame test structures that had gypsum board wall and ceiling coverings and a lightweight truss roof. They found, on average, that fire penetrated the gypsum board in eight minutes and collapse of the roof deck, which supported two simulated firefighters, occurred seventeen minutes after the start of the fire. (Morris, 2005)
In August, 2010, researchers from Underwriters Laboratories and the Chicago Fire Department published key results of extensive scientific testing of lightweight residential floor and roof assemblies. The research was funded by the Department of Homeland Security and the Federal Emergency Management Agency’s Assistance to Firefighters Grant. The researchers applied the accepted standard fire testing method known as ASTM E119 to establish the fire resistance of building materials of six structural elements, three different ceiling finishes, four floor or roof finishes, and three floor penetration configurations. All assemblies tested measured fourteen by seventeen feet, and although standard ASTM E119 temperatures were applied, the surface loads in the test were less than ASTM E119 standard. Researchers found that due to the large open unprotected interior spaces and modern synthetic fuel loads, today’s residential fires are as hot and intense as commercial fires. They found also that thermal image cameras were ineffective at detecting the intense heat below a floor assembly and of no use in predicting imminent collapse. Average temperatures below the tested floor assemblies were 1200° F while the average temperature seen on top of the floor assembly was less than 100° F. The least durable assembly tested was a floor assembly of unprotected engineered twelve inch wood I-beam joists with OSB floor decking and carpet. This assembly failed after only six minutes of fire exposure from below. The researchers recommended that fire departments should take advantage of available literature, multimedia training aids, and after action reports to conduct department wide awareness training about the hazards of lightweight building construction. Preplans were also recommended to provide information to fire companies planning or about to engage in suppression operations in an unfamiliar building. The study recommended that officers should assume the building is of lightweight construction unless known otherwise, and that firefighters should distinguish between a contents fire and a structural fire. Once fire has breached the walls
and is in the structure, it is time to get out. The study stressed risk-benefit analysis and proposed that aggressive interior operations should not be performed when interior conditions preclude victim survival. When many tasks must be accomplished, the researchers recommended extinguishing the fire as the first action in order to protect and save occupants. Incident commanders must remain flexible and ready to switch to a defensive operation if occupants are accounted for and interior fire cannot be controlled since the time when the countdown to collapse started is unknown. (Dalton, Van Dorpe, Backstrom, & Kerber, 2010)

On August 13, 2006, two firefighters from the Green Bay, Wisconsin, Fire Department were performing a primary search on the first floor of wood framed home that was on fire when they fell through the floor. One of the firefighters was killed and the other severely injured. The floor assembly was constructed of unprotected parallel cord wood trusses and engineered wood I-beams, and the seat of the fire was in the basement below the area of collapse. In the investigative report following this incident, the National Institute of Occupational Safety and Health (NIOSH) recommended that firefighters conduct pre-incident planning and inspections of buildings in their jurisdictions to facilitate the development of safe fire ground tactics, ensure firefighters are trained to recognize lightweight construction and the hazards of operating above a fire, and that building codes should be modified to require fire protection above and below truss assemblies. (NIOSH, 2007)

The Elmsford, New York was dispatched to a possible house fire, and when the chief arrived first on scene, he reported a fully involved wood frame single family home with fire already spreading to a neighboring exposure. The last occupant of the building self-evacuated before the first apparatus arrival. Members of the fire department were already aware that this home, built in 2005, was of lightweight construction. Given that occupants were out, and the fire
involvement was heavy, the chief announced to all companies over the radio, “Lightweight construction: exterior operations only.” A large section of roof collapsed shortly after the radio announcement. Aerial ladder pipes, a deck gun, and 2 ½” hand lines were deployed and successfully contained the fire to the area of involvement. The fire department based their tactics on the lessons learned about how fast and hot trusses and particle board burn, and due to their likelihood of early collapse. (Henry, 2008)

NIOSH studied the hazards of lightweight construction and the risks posed to firefighters. More than sixty percent of roof systems in the United States are built upon truss systems, and fires in a truss system can grow rapidly in a fuel rich environment while remaining hidden from view. Steel trusses were also found to be prone to failure when exposed to fire, possibly failing even earlier than wood trusses. Firefighters should open concealed spaces quickly to determine fire location, be constantly aware of the time fire has been burning, provide feedback to the incident commander, watch for signs of structural deterioration, and employ defensive strategies once burning truss members are identified. NIOSH also recommended that fire departments should ensure that firefighters are trained to identify different types of roof and floor truss assemblies and the hazards associated with each, conduct pre-incident planning and inspections, develop standard operating procedures to safely fight fires in truss construction buildings, ensure the incident commander conducts a size-up and risk assessment before interior fire fighting operations begin, and ensure firefighters operating over or under trusses are evacuated immediately when the trusses are exposed to fire. (NIOSH, 2005)

The NIOSH Fire Fighter Fatality Investigation and Prevention Program investigated eighty-four incidents at structure fires from 1998 to 2008, wherein 118 firefighters died and 126 were injured. Sixty-two of the eighty-four incidents involved structures that were known or
suspected to be unoccupied at the time of the fire. NIOSH recommended that incident commander should use risk management principles in determining if offensive interior operations should be conducted without exceeding reasonable risk to firefighters. Incident commanders should consider the presence of occupants in the building, a realistic evaluation of occupant survivability and rescue potential, size, construction and use of the building, age and condition of the building, nature and value of the contents, location and extent of the fire, exposures, fire involvement or compromise of the buildings structural components, and a realistic evaluation of the ability to accomplish a successful offensive attack with available manpower. Defensive operation should be considered when the risk to firefighters’ lives and safety outweighs the possible benefit of an offensive attack, the building is structurally unsound, and no lives are to be saved and the building is essentially lost. (NIOSH, 2010)

Large dimensional lumber joists such a 2x10s derive strength from their mass, while lightweight trusses derive their strength from engineering. Trusses and engineered wood I-beams have plenty of surface area available as fuel to a fire but lack the mass to endure exposure. The gusset plates used to secure the joints of truss web members are made of a piece of sheet metal with small barbs of about 3/8” pressed into the wood. As charring approached 3/8”, these gusset plates cannot hold on, and the joint separates leading to truss failure. Most homes built in the last thirty years will have a truss roof and possibly a form of lightweight floor joist. When responding to a residential basement fire in a wood frame constructed home, if family members are all confirmed evacuated, a hoseline should be readied while a firefighter uses a ten foot pike pole from the door to open the ceiling and check for lightweight construction. If lightweight construction is noted, the tactics should change from entry at the front door to an attack through basement windows or a walk-out basement door if present. (Gustin, 2006)
Lightweight steel framing members are also part of a designed system that relies on the strength of its connections. A failure of one connection or part of the system can lead to collapse of the building, and this is very likely in the case of exposure to fire because the heated steel loses its strength and cannot handle its rated load. Steel framed buildings rely on the attachment of the steel roof deck to provide lateral stability to the structure, and cutting vertical ventilation openings in it could significantly weaken it and shorten the time to collapse. In addition, steel roof decks are often have large spans between supports, and cutting through the deck may leave firefighters on unsupported cantilevered sections that will not support them, allowing them to fall through into the fire below. Due to the short time steel bar joists can withstand fire exposure, horizontal ventilation is recommended. (Havel, 2005) Steel structural building components lose strength rapidly when heated to over 1000° F. Components with less mass will succumb earlier than more massive components; unprotected lightweight steel bar joist trusses will fail in about seven minutes. (Brannigan & Corbett, 2008)

Several states and cities have adopted ordinances requiring buildings to be labeled with a placard to identify the presence of lightweight construction components. Florida passed the Aldridge-Benge Firefighter Safety Act of 2008, named in honor of two Orange County, Florida firefighters who perished in a roof collapse at a gift shop fire. The law requires the owners of all commercial, industrial, or multi-unit residential buildings to mark their buildings with a state approved placard to identify lightweight construction structural components. Other similar laws are in effect in New York State, New Jersey, Vermont, San Francisco, CA, Wheeling, IL, and Greencastle, IN. (Naum, 2009) In New Jersey, the truss identification law exempted one and two family detached homes. However, in 2011, the City of Englewood, NJ adopted a local code mandating the placard label on all new and remodeled detached homes as well. The placards are
placed to the left of the main entrance on the street side, and allow firefighters entering the building to view the identification of lightweight construction members as they enter the building. This labeling system greatly enhances firefighter safety and operational effectiveness in Englewood, NJ. (Moran, 2011)

**PROCEDURES**

Photographs were taken of a variety of different building types found in the City of Aurora, Ohio. The photographs were incorporated into a multiple choice survey questionnaire that challenged the participant identify characteristics of the building. They were also asked to choose appropriate tactical actions based on their understanding of the building and Aurora Fire Department (AFD) Standard Operating Guidelines (SOG). The survey was distributed to 40 AFD firefighters via an email link to the survey hosted at surveymonkey.com. Participants were asked to answer to the best of their understanding, without consulting other persons or references. The anonymous survey was designed not to judge individual knowledge, but rather to identify areas to direct future AFD training efforts.

Thirty-four AFD members responded to the survey request. The survey allowed members to skip questions without answering. Whether intentional or not, not all members answered all questions. The survey was divided into two parts, one residential and one commercial, due to surveymonkey.com size limitations.

Also, Aurora Fire Department training records and SOG documents were reviewed to determine what guidance departments members are given regarding lightweight construction, collapse potential, firefighter safety, and risk management.

**Definition of Terms**

Joists. Floor beams, in the case of steel bar joists may also be used as roof supports.
**Legacy construction.** Construction materials and practices common to a previous generation, in the case of wood frame construction this would include dimensional lumber such as 2x10s or larger used for floor joists and roof assemblies constructed with a ridge beam and rafters.

**Lightweight construction.** Characterized by the use of products such as trusses, wood I-beam floor joists, steel bar joists, steel framing members, steel wall panels, and steel roof decks engineered to be lightweight and low cost yet capable of bearing the required load.

**Oriented strand board.** Made of layers of strands of wood cut from logs, with a fairly constant width to length ratio, said to have less tendency to expand due when exposed to moisture, also called flakeboard.

**Truss.** A framed structure made up of triangles arranged in a single plane. In wood frame construction they typically are made of 2x4 boards with metal gusset plates utilized as connectors. Steel bar joists are also a type of truss.

**RESULTS**

Thirty-four firefighters from the Aurora Fire Department completed the survey with questions designed to gauge their knowledge of building constructions characteristics and appropriate tactical fireground actions based on the building characteristics.

The first image, shown below, was of a house on Willard road. This house was built in the 1970’s and it is confirmed to be of legacy Type V wood frame platform construction. Although this house is constructed with a ridge beam and rafter roof system, sixty-five percent of participants surmised that it had a lightweight truss roof system. In the follow on question, nearly eighty percent of participants believed that this building, which actually has a zero hour fire rating, has walls and floors with one hour or more of fire resistance.
Using your knowledge of the neighborhoods and buildings in the City of Aurora, answer the following questions about this building on Willard Road.

1. **Your best guess is that the roof assembly of this building is supported** by:

<table>
<thead>
<tr>
<th>Option</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge beam and rafters</td>
<td>35.3%</td>
<td>12</td>
</tr>
<tr>
<td>Lightweight Trusses</td>
<td>64.7%</td>
<td>22</td>
</tr>
</tbody>
</table>

**Figure 2.**
Figure 3.

The next image, shown below, was of a house on Walnut Ridge Trail. This house is approximately ten years old, it is an example of Type V wood frame construction, and the roof assembly is of lightweight truss construction. Ninety-seven percent of participants identified the roof construction correctly. In the follow on question, ninety-one percent of participants concluded that such a roof assembly could withstand direct exposure to fire for less than twenty minutes; nine percent expected it to last for thirty minutes.
Figure 4.

Walnut Ridge Trail

Using your knowledge of the neighborhoods and buildings in the City of Aurora, answer the following questions about this building on Walnut Ridge Trail.

Figure 5.

<table>
<thead>
<tr>
<th>Question</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge beam and rafters</td>
<td>2.9%</td>
<td>1</td>
</tr>
<tr>
<td>Lightweight Trusses</td>
<td>97.1%</td>
<td>33</td>
</tr>
</tbody>
</table>

answered question 34
skipped question 0
Figure 6.

The next image, shown below, was of a house on Winslow Circle. This house was constructed less than one year ago and it is a Type V Wood Frame building. Ninety-four percent of participants correctly concluded that this building has a lightweight truss roof assembly and that one could not tell from the street whether or not this building has lightweight engineered lumber floor joists. When told to assume this building has lightweight unprotected engineered wood I-beam floor joists, and that they had been exposed to a basement fire for at least eight minutes, seventy percent of participants recognized that collapse of the floor may be imminent. Nine percent believed that there was additional safe operating time to be expected on such a floor assembly, and twenty-one percent responded that sounding the floor with a tool or utilizing a thermal imaging camera would give the needed feedback to make the decision about proceeding in with a hose line.
Winslow Circle

Using your knowledge of the neighborhoods and buildings in the City of Aurora, answer the following questions about this building on Winslow Circle.

<table>
<thead>
<tr>
<th>5. Your best guess is that the roof assembly of this building is supported by:</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge beam and rafters</td>
<td>6.1%</td>
<td>2</td>
</tr>
<tr>
<td>Lightweight Trusses</td>
<td>93.9%</td>
<td>31</td>
</tr>
</tbody>
</table>

Figure 8.
The next image, shown below, was of a building that is over one hundred years old on East Garfield Road. This building is an example of Type III Ordinary construction, with substantial masonry load bearing exterior walls and interior wood beam floor joists. Forty-two
percent of participants correctly concluded that the exterior walls of this building have a two hour fire rating.

Figure 11.
East Garfield Road

Use your knowledge of the types of commercial construction in the City of Aurora to answer the following questions to the best of your knowledge. This building is located on East Garfield Rd.
The next building considered was a Type II 0-0-0 Noncombustible commercial warehouse on Aurora Industrial Parkway. The load bearing members of this building are rigid steel frames with two rows of interior columns supporting the span. The exterior has a partial masonry façade in combination with steel wall panels. The roof deck is made of sheet metal as well, and it does not have a built-up or tar coating. The 0-0-0 rating of this type of construction means that the load bearing walls, floor, and roof structure are all rated for zero hours of fire resistance. For this reason, and in consideration of the square footage of the building, this building is required to have sprinkler protection. Only thirty percent of participants correctly recognized the zero hour inherent fire resistance of this building. When offered a scenario in which there is a fire in this warehouse that the sprinkler system was unable to control, fifty-seven percent of participants questioned an order to work on top of this sheet metal roof, while forty-three percent were concerned with choosing the correct saw blade for cutting metal.
Aurora Industrial Parkway

Use your knowledge of the types of commercial construction in the City of Aurora to answer the following questions to the best of your knowledge. This building is located on Aurora Industrial Parkway.

<table>
<thead>
<tr>
<th>2. This building type is called &quot;Noncombustible.&quot; Without sprinkler protection, what is the fire resistance rating of the load bearing exterior walls and the roof of this building?</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 hours</td>
<td>30.0%</td>
<td>9</td>
</tr>
<tr>
<td>1 hour</td>
<td>20.7%</td>
<td>8</td>
</tr>
<tr>
<td>1.5 hours</td>
<td>10.0%</td>
<td>3</td>
</tr>
<tr>
<td>2 hours</td>
<td>33.3%</td>
<td>10</td>
</tr>
</tbody>
</table>

answered question 30
skipped question 3
The building shown below is of Type I Fire Resistive construction and it is located on South Aurora Road. It is a single story building, the load bearing walls are masonry construction, and the roof is made of precast concrete. Forty-three percent of participants correctly identified the Type I Fire Resistive construction, while half the participants thought the rafters were of heavy timber or steel bar joist construction. Seven percent suggested attempting to cut a ventilation hole in the precast concrete roof deck.
Use your knowledge of the types of commercial construction in the City of Aurora to answer the following questions to the best of your knowledge. This building is located on South Aurora Rd.

4. You have responded to fire alarm at this building, and on arrival you see smoke and fire in the front window. You make a 360 degree survey of the structure and this is your view of the "C" side. What can you tell about this structure thus far?

<table>
<thead>
<tr>
<th>Option</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is lightweight commercial construction with a bar joist roof assembly.</td>
<td>13.3%</td>
<td>4</td>
</tr>
<tr>
<td>It is Type I fire resistive construction with a precast concrete roof.</td>
<td>43.3%</td>
<td>13</td>
</tr>
<tr>
<td>Firefighters should consider ventilating the roof to relieve heated smoke and gases.</td>
<td>6.7%</td>
<td>2</td>
</tr>
<tr>
<td>It is constructed of block walls with heavy timber roof beams.</td>
<td>36.7%</td>
<td>11</td>
</tr>
</tbody>
</table>

answered question 30
skipped question 3
The final building in the survey, pictured below, is a combination skilled care and assisted living residential institution on South Chillicothe Road. This building is a Type V Wood Frame building with 2x4 stud walls and parallel chord lightweight wood truss floor joists. The roof assemblies are lightweight trusses, and the exterior finish is a combination of brick and vinyl siding. Due to the size and type of occupancy, this building is required to be protected by a sprinkler system, including in the void spaces of the lightweight roof trusses. Seventy-six percent of participants recognized that this building is of wood frame and truss construction, while twenty-four percent imagined that this building has masonry or steel underpinnings. Seventy percent recognized that, in the absence of a properly functioning sprinkler system, the lightweight wood truss roof assemblies would only be able to resist fire for fifteen to twenty minutes before collapse. Thirty percent expected the roof assembly to be more fire resistant, some choosing an hour or more.

Figure 18.
South Chillicothe Road
Use your knowledge of the types of commercial construction in the City of Aurora to answer the following questions to the best of your knowledge. This building is located on South Chillicothe Rd.

Figure 19.

A review of Aurora Fire Department training records revealed that in the past four years, building construction was identified as the monthly shift training topic twice. Fireground SOGs and risk management were also each a monthly shift topic once each in the past four years. Monthly training topics are presented to all members of the department by their respective shift.
officers or other certified instructors. These training sessions are generally two hours long. Aurora Fire Department SOGs directly address the hazards of lightweight construction and identify potentially hazardous situations and the signs of impending collapse. (Appendix 1) The AFD SOG specifically suggests that fifteen to twenty minutes is the limit of fire exposure for lightweight trusses, and recommends that incident commanders use this number to guide their tactical decisions. They also stress the risk management principles of risking a lot to save a lot as in a rescue from a fire, risking a little to save a little as when engaged in fire suppression operations to save property, and of taking no risk when there is nothing to be saved (no possible survivors and building lost). (Appendix 2)

**DISCUSSION**

Lightweight wood truss roof assemblies have been used in residential construction for over fifty years, and it is difficult to accurately determine their presence versus legacy construction from the street unless one personally observed the construction of the building or development. Even then, homes originally built with legacy construction methods may be remodeled or expanded later with lightweight construction assemblies. It is not surprising, then that figure 2 shows a majority impression of lightweight construction when it is in fact a legacy example. In this case, it is safer to err on the side of expecting a less fire resistant building until proven otherwise. (Dalton, Van Dorpe, Backstrom, & Kerber, 2010)

The results reported in figure 3 are concerning. Only twenty percent of participants recognized that residential wood frame construction, unless it was finished with fire rated Type X gypsum board, is not fire rated. (Brannigan & Corbett, 2008)
The results reported in figure 5 and figure 6 are encouraging in that over ninety percent of participants recognized lightweight wood frame construction and the fifteen to twenty minute guideline for expected truss assembly fire resistance.

The results reported in figure 8 and figure 9 were also encouraging. Over ninety percent recognized a recently built example of lightweight construction, and admitted that they could not tell from the street if lightweight floor joist assemblies were present. Seventy percent of participants recognized the imminent collapse potential of engineered lightweight wood I-beam floor joists. The thirty percent who thought there was more time available, thought that sounding with a tool would help, or that a thermal imaging camera would tell them whether it was safe to proceed or not would benefit from some additional training that incorporates the results of the extensive testing done on floor assemblies by Underwriters Laboratories (UL). UL showed that unprotected wood I-beam floor joists are likely to fail after six minutes of fire exposure and that a thermal image camera will not reveal the intense heat and fire below a floor assembly. (Dalton, Van Dorpe, Backstrom, & Kerber, 2010)

When shown an old Type III Ordinary construction example, more than half of the participants did not recognize the substantial two hour fire rating of real masonry load bearing walls (figure 12). I was not overly concerned with this, as under estimating this does not lead to dangerous tactics. This building was actually added to the survey for variety and to contrast the older real brick building with masonry facades seen on lightweight commercial buildings.

The results represented in figure 14 reveal that seventy percent of participants incorrectly concluded that a modern lightweight steel framed commercial building has a one hour or more fire resistance rating. This is a common misunderstanding about steel framed buildings. Because steel appears to be of great strength and contributes no fuel to the fire, many people imagine it
has greater resistance to fire that it actually does. When heated to 1000° F, structural steel framing members lose approximately one half of their load carrying capacity. (Brannigan & Corbett, 2008)

Figure 15 reports the results relative to the scenario of uncontrolled fire in a steel warehouse building. When order to work on a sheet metal roof deck over an uncontrolled fire, fifty-seven percent recognized that they should stop and have a talk about safety with the incident commander. Unfortunately, forty-three percent were concerned more about choosing the correct saw blade. A fire that has grown beyond the ability of the sprinkler system to control it, is one that will significantly weaken the steel frame of the building. Also, the span between rigid steel frames is large and these buildings rely on the roof deck for lateral support. Attempting to cut ventilation holes can easily lead instability and to unsupported cantilevered flaps of steel roof deck that pose the risk of firefighters falling through into the fire below. (Havel, 2005)

Figure 17 reports the results of a question about a Type I Fire Resistive building. Less than half of the participants correctly identified the characteristics of this building, but underestimating the resistance is not likely to lead to a dangerous tactical decision. This building was included in the survey for variety and to keep participants from seeing a pattern or too many lightweight construction collapse hazards. As professional firefighters, though, we should be able to identify this building, and we should recognize that attempting to cut a ventilation hole in this roof would be a nearly impossible task.

The results shown in figure 19 reveal that seventy-six percent of participants correctly recognized Type V Wood Frame construction in a commercial setting. One quarter of respondents thought it to be of more substantial framing material. Figure 20 reveals that thirty percent responding did not understand that without sprinkler protection, a commercial
lightweight wood roof truss is same as a residential truss, and that fifteen to twenty minutes of direct fire exposure is all it can take.

Lightweight construction assemblies with their limited fire resistance are everywhere and they are here to stay. A solid foundation in knowledge of building construction, particularly regarding buildings in the community we serve, is a vital part of our effort to ensure firefighter safety on the fireground. Firefighters and fire officers who correctly appreciate the characteristics of the buildings we work in, can then make the appropriate tactical fireground decisions. It is only when we really understand the risks that we can know when if we are properly applying risk management principles in our operations. Risk a lot to save a lot, risk a little to save a little, risk nothing when the building is lost.

RECOMMENDATIONS

Based on the results of the research compiled here, it is recommended that the Aurora Fire Department conduct building construction and risk management training on an annual basis. This annual training should emphasize the identification of lightweight construction, the characteristics of lightweight construction, steel lightweight commercial construction, and collapse hazards. Underwriters Laboratories (UL) utilized a Department of Homeland Security / Federal Emergency Management Agency Assistance to Firefighters Grant to research and test various legacy and lightweight floor and roof assemblies. A valuable online training experience based on the UL research is available free for firefighters at http://www.uluniversity.us/catalog/display.resource.aspx?resourceid=187716, and it is recommended that all members of the Aurora Fire Department individually enroll in this online course. In addition to class room efforts, AFD building construction training should include on
shift building tours and inspections of buildings in town to familiarize firefighters with the features and characteristics of local buildings.

The UL research revealed that simply finishing the underside of first floor joists with half inch thick standard gypsum board greatly increased the fire resistance of floor assemblies. (Dalton, Van Dorpe, Backstrom, & Kerber, 2010) The Aurora Fire Department should work with the mayor and the City Council of the City of Aurora to advocate for a local building code that requires all floor assemblies on new construction and remodeled buildings to be finished and protected from fire below. This should be paired with a public education effort to urge homeowners to upgrade their own homes in compliance with the proposed new standard.

In addition, the Aurora Fire Department should work with the Mayor and the City Council of the City of Aurora to advocate for a local building code requiring new construction and remodeled buildings to affix a readily visible placard to the building identifying lightweight building assemblies if present. This should be coupled with public education and a drive to promote voluntary participation in the placard program for existing residential and commercial building owners.

A greater emphasis on building construction training for firefighters, a push for local building codes that require a protective finish on the underside of floor joists, and the adoption of a building placard system would likely reduce much of the guesswork and mistakes in the identification of lightweight construction that leads to unsafe tactics, and would reduce the risk of death and injuries to firefighters in Aurora, Ohio.
REFERENCES


APPENDIX 1 – AFD FIREGROUND SAFETY SOG

AURORA FIRE DEPARTMENT
STANDARD OPERATING GUIDELINE

Fireground Safety

TACTICAL POSITIONING

Positioning of operating companies can severely affect the safety/survival of such companies. Personnel must use caution when placed in the following positions:

- above the fire (floors/roof)
- where fire can move in behind them
- where the company cannot control position/threat
- when involved with opposing fire streams
- combining interior and exterior attack
- with limited access – one way in/out
- operating under involved roof structures
- in areas containing hazardous materials
- below ground fires (basements, etc.)
- in areas where backdraft potential exists
- above/below ground rescue

The safety of firefighting personnel represents the major REASON for an effective and well-timed offensive/defensive decision and the associate write-off by Command. When the rescue of savable victims has been completed, Command must ask:

"IS THE RISK TO MY PERSONNEL WORTH THE PROPERTY I CAN SAVE?"

When operating in the defensive mode, operating positions should be as far from the involved area as possible while still remaining effective. Position and operate from corners of the structure or behind barriers if available (fences, walls, etc).

The intent is for personnel to utilize safe positioning where possible/available, in an effort to safeguard against sudden hazardous developments such as backdraft explosion, structural collapse, etc.

When operating in the offensive mode, be aggressively offensive. An effective, coordinated interior attack operation directed toward knocking down the fire eliminates most eventual problems.

Due to the inherent hazards of the immediate fire or incident scene, efforts will be made by Command to limit the number of personnel on the fireground to those assigned to a necessary function. All personnel shall be:

- positioned by staging
- assigned to a task or operating within a division/group

Having completed an assignment and no other assignment is available with that division/group, crews should be assigned to a Resource, Staging or Rehabilitation until such time as they can be reassigned to an operation or released to “in-service” status.

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APPENDIX 1 – AFD FIREGROUND SAFETY SOG

AURORA FIRE DEPARTMENT
STANDARD OPERATING GUIDELINE
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The intent of the procedure is to minimize fireground confusion/congestion by limiting the number of personnel exposed to fireground hazards to only those necessary to successfully control the operation. Individuals or crews shall be restricted from wandering about the fireground or congregating in non-functional groups. If personnel have not been assigned a task or do not have a necessary staff function to perform, they shall remain outside the fireground perimeter.

When it is necessary to engage in exceptionally hazardous circumstances (i.e. perform a rescue), Command will limit the number of personnel exposed to an absolute minimum and assure that all feasible safety measures are taken.

In extremely hazardous situations (flammable liquids, LP gas, hazardous materials, etc.), Command will engage an absolute minimum number of personnel within the hazard zone. Unmanned master streams will be utilized wherever possible.

In situations where crews must operate from opposing or conflicting positions, such as front-vs-rear attack streams, roof crews-vs-interior crews, etc., utilize radio or face-to-face communications to coordinate your actions with those of the opposing crew in an effort to prevent needless injuries. Command should notify your Division/Group Officers or Company Officers of opposing or conflicting operations.

Ground crews must be notified and evacuated from interior positions before ladder pipes go into operation.

Do not operate exterior streams (i.e. hand lines, master streams, ladder pipes, etc.) into an area where interior crews are operating. This procedure is intended to prevent injuries to personnel due to a stream blast and the driving of fire and/or heavy heat and smoke onto interior attack crews.

When laddering a roof, the ladder selected shall be one which will extend 2 feet to 3 feet above the roofline. This shall be done in an effort to provide personnel operating on the roof line with a visible means of egress.

If possible, when laddering buildings under fire conditions, please ladders near building corners or fire walls, as these areas are generally more stable in the event of structural failure.

When operating either above or below ground level, establish at least two (2) separate escape routes/means where possible (such as stairways, ladders, exits, etc.) preferably at opposite ends or diagonal corners of the building or separated by considerable distance.

Many safety principles revolve around action that takes place within the fireground perimeter or on the fireground.

For the purpose of Aurora Fire Department operations, the fireground perimeter can be defined as: the area inside a boundary that has been determined by safety considerations according to the foreseeable hazards (collapse zone, smoke, gas or fuel leak) of the particular incident.

The flexible boundary that determines the fireground can be altered by other various safety factors.
APPENDIX 1 – AFD FIREGROUND SAFETY SOG

AURORA FIRE DEPARTMENT
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All personnel entering the fireground perimeter shall:

a. wear protective clothing and SCBA

b. have their crew intact

c. have a job assignment

ALL OTHERS STAY OUTSIDE

The fireground perimeter is not necessarily marked by any warning device. The area is defined, in most cases, by standard definitions described in this procedure. Where a hazard exists, banner tape may be used to identify the specific area where special precautions are necessary.

Yellow FIRE LINE tape is intended to keep civilians and spectators out of an area where a hazard exists or where operations are in progress. This tape may also be used as a warning device for personnel authorized to operate on the fireground. Yellow tape indicates that personnel should be aware of a hazard and should cross the tape only when precautions have been taken.

Red and white HAZARDOUS AREA tape is used to define a special hazard zone. NO personnel shall cross this tape under any circumstances except through an entrance/exit (lobby control) when provided. This tape will be used to define hazard areas involving hazardous materials, structural collapse or similar perils.

DIVISIONS and GROUPS

The safety of firefighting personnel represents a major reason for fireground geographic divisions or functional groups. Division/Group Commanders must maintain the capability to communicate with forces under command so they can control position and function of their companies.

Division/Group Officers and Company Officers shall be able to account for the whereabouts and welfare of all crews/crew members under their assignment (see Personnel Identification System, Page 7).

Company Officers shall insure that all crew members are operating where assigned. Crews will not leave their respective assignment unless approved by their Officer.

When crews are operating with a Division, Company Officers shall keep the Division Officer informed of changing conditions within the sector area, particularly those changing conditions which may affect the safety of personnel.

Hazards that will affect a specific Division only should be dealt with within that Division and need not necessarily affect the entire operation.

REHABILITATION

In an effort to regulate the amount of fatigue suffered by fireground personnel during sustained field operations, Officers should frequently assess the physical condition of their assigned companies. When crew members exhibit signs of serious physical or mental fatigue, the entire crew should be reassigned to a “rehabilitation area”, if possible. Officers shall request reassignment to a rehabilitation area from Command.

Revised 1/15/08
APPENDIX 2 – AFD STRUCTURAL COLLAPSE SOG

AURORA FIRE DEPARTMENT
STANDARD OPERATING GUIDELINE

Fireground Safety

STRUCTURAL COLLAPSE

In recent times, structural collapse has been a leading cause of serious injuries and death to firefighters. For this reason, the possibility of structural collapse should be a major consideration in the development of any tactical plan.

Structural collapse is always a possibility when a building is subject to intense fire. In fact, if fire is allowed to affect a structure long enough, some structural failure is inevitable.

Regardless of the age and exterior appearance of the building there is always the possibility that a principal structural supporting member is being seriously affected by heat and may collapse suddenly, inflicting serious injury to firefighters.

**EXAMPLE:** A 100-foot length of unprotected steel will expand approximately 9 inches when heated to 1100 degrees F.

In the typical fire-involved building, the roof is the most likely candidate for failure; however, failure of the roof may very likely trigger a collapse of one or more wall sections. This is especially true if the roof is a peak or dome-type, which may exert outward pressure against both the bearing and non-bearing walls upon collapse.

In multi-story buildings or building with basements, the floor section above the fire may collapse if supporting members are directly exposed to heat and flames.

A knowledge of various types of building construction can be invaluable to the Fire Officer, from a safety standpoint, as certain types of construction can be expected to fall sooner than others. For example, under fire conditions, lightweight truss and truss joist roof construction can be expected to fail after minimal fire exposure.

Structures have been known to collapse without warning but usually there are signs which may tip off an alert Fire Officer. Action might be taken to avert any imminent hazard.

_Tell Tale Signs:_

- Cracks in exterior walls
- Bulges in exterior walls
- Sounds of structural movement – creaking, groaning, snapping
- Smoke or water leaking through walls
- Flexible movement of any floor/roof where firefighters walk
- Interior/exterior bearing walls or columns – leaning, twisting, flexing
- Sagging or otherwise distorted roof lines

The following construction features or conditions have been known to fail prematurely or to contribute to early structural failure when affected by fire.

_Contributing Factors:_

- Parapet walls
- Large open (unsupported) areas – supermarkets, warehouses, etc
- Cantilevered canopies – which usually depend on the roof for support and may collapse as the roof fails

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- Ornamental/secondary front or sidewalks – which may pull away and collapse
- Buildings with lightweight truss, bar joist or bow string truss roofs
- Building supported by unprotected metal – beams, columns, etc.

Buildings containing one of more of the previously mentioned features must be constantly evaluated for collapse potential. These evaluations should be of major consideration toward determining the tactical mode, i.e. offensive/defensive.

It is the principal Command responsibility to continually evaluate and determine if the fire building is tenable for interior operations. This on-going evaluation of structural/fire conditions requires the input of Company Officers advising their Division Officers and the Division Officers advising Command of the conditions in their area of operation.

Structures other than fire protected/heavy timber construction are not designed to withstand the effects of fire and can be expected to fail after approximately 20 minutes of heavy fire involvement. If, after 10-15 minutes of interior operations, heavy fire conditions still exist, Command should initiate a careful evaluation of structural conditions and be fully prepared to withdraw interior crews and resort to a defensive position.

If structural failure of a building or section of a building appears likely, a perimeter must be established a safe distance from the area which may collapse. ALL personnel shall remain outside this perimeter.

SEE: FIREGROUND PERIMETERS

EVACUATION

Interior firefighting operations should be abandoned when the extent of the fire prohibits control or the structure becomes unsafe to operate within. When such conditions make the building untenable, evacuate, regroup, account for personnel, recommunicate and redeploy.

The primary concern, when a hazard which may affect the safety of fire personnel becomes apparent, is the welfare of those personnel. In an effort to protect personnel who may suffer the adverse effects of such hazards such as structural collapse, explosion, backdraft, etc., a structured method of area evacuation must be utilized – one which will provide for the rapid/effective notification of those personnel involved and one which will be able to accurately account for personnel.

The method of evacuation selected will vary depending on the following circumstances:

- Imminence of the hazard
- Type and extent of the hazard
- Perception of the area affected by the hazard

The “Emergency Traffic” announcement is designed to provide immediate notification for all fireground personnel of a notable hazard that is either about to occur or has occurred.

The use of “Emergency Traffic” should be initiated only when the hazard appears to be imminent. Any member has the authority to utilize the “emergency traffic” announcement, when it is felt that a notable danger to personnel is apparent, however, considerable discretion should be applied to its use – emergency traffic announcements will become ineffective if overused!