The Dangers of Lightweight Construction as Related to the Highland Heights Fire Department

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Certification Statement

I hereby certify that 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.

Signed: Jeremy Smelcer
Abstract

Modern construction has incorporated the use of lightweight construction to increase the productivity and cost effectiveness of building homes. The use of these lightweight systems and products can lead to extremely hazardous situations for fire fighters. The City of Highland Heights has seen a large amount of new construction in the past fifteen years. The majority of new homes and buildings that have been built were constructed using these lightweight construction methods. I will use action research to investigate the types of construction methods used in the city and to determine what can be done in terms of implementing new standard operating procedures and methods of fire fighting to improve our effectiveness and safety when fighting fires in these types of structures.
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Introduction

Lightweight construction has been used in building construction for more than thirty-five years.¹ Fire fighters have been dealing with the dangers of this type of construction since it was developed. The main problem is the decreased load carrying capability and stability of the manufactured members under fire conditions. A large portion of the city of Highland Heights that was undeveloped has been developed with new housing in the past fifteen years. This new construction was built primarily using lightweight construction. If our department does not properly prepare with training and through written standard operating procedures the result could be injuries or even death of department members. Through action research I will investigate the problems created when lightweight construction is involved in fire and determine the best procedures for the Highland Heights Fire Department to follow in order to identify this type of construction and the operational procedures that should be followed.

Lightweight construction includes lightweight truss system, pre-manufactured I-beams, glue laminated beams, I-joists, structural composite lumber, structural insulated panels, wood structural panel, gusset plates and other metal joints. When subjected to fire these components burn and fail faster than traditional wood lumber. Another factor is that they do not have the fire stopping capabilities that wood lumber has. If fire fighters do not identify that a house is constructed with these types of materials than they could be endangered by floors that will collapse faster than traditionally constructed floors and ceilings and roofs that will fail quickly when exposed to high heat conditions. In this paper I will look at previous cases of firefighter deaths caused by the failure of lightweight construction, studies done by Underwriters Laboratories on pre-manufactured

components and how they react under fire conditions and I will look at recommendations by industry professionals on how to improve fire fighters recognition of these types of homes constructed with these materials and industry recommendations on how to improve fire protection and resistance of these members.

**Background and Significance**

The construction industry began using pre-manufactured components and lightweight construction methods in order to improve the efficiency of the construction process and in order to reduce costs associated with materials. These members include pre-manufactured I-beams and I-joist, truss systems, and plywood and OSB boards. I-beams and joist are manufactured by placing a plywood or particle board sheet in between two 2x3 or 2x4 boards that form the top and bottom chords. If one of these chords fails because of charring from impinging heat and fire that the joist loses its structural strength to support a load. Truss structural members use a system of triangles along a plain to give strength to support the forces that are applied to the members. Truss systems give strength along long spans and are considerably lighter than the comparable beams that it would take to span the same area. The problem that arises with truss systems is that if the top or bottom chord of the truss fails than the entire truss fails, causing the supported floor or roof to collapse. Plywood is composed of thin layers of wood that are glued together to form a panel. OSB is composed small strips of shredded wood that is joined together by compressing the wood and heating the resin that coats the wood until it cures into a single panel. These members are very cost effective and allow for precise engineering that give exceptional strength under normal conditions. Under fire and high
The Dangers of Lightweight Construction

heat conditions however, these component will fail due to the thinness of their members, the glue and resins that are used to compose them and because of the metal components that are used to join them. Metal gusset plates are often used to join members in truss systems. These gusset plates are thin pieces of metal with small teeth that hold the wood members together. Many of these gusset plates are designed with teeth that only penetrate 0.38 inch into the wood that they hold together. These plates will also fail to hold if the wood behind them is charred away by impinging fire. Over sixty percent of roof structures in the United States are constructed using lightweight wood truss construction techniques. Another issue that increases the chances for these members to fail is the increased heat release rates of the items and materials found in residential properties. The problem that firefighters face is one that has been prevalent over the past thirty years. The National Institute of Standards and Technology reports that between the years 1979 and 2002 there were 180 firefighter fatalities due to structural collapse, with an increase in the latter years in the deaths that occurred in residential properties. This shows a trend in the risk of fighting fires in residential properties with the increase use of lightweight construction techniques.

Several NIOSH case studies of firefighter deaths in structures that utilized lightweight construction techniques are presented here:

- On January 26, 2007 a 24 year old firefighter died after he fell through a floor in a residential structure that was supported by engineered wooden I-beams. The firefighter worked for a volunteer department that consisted of 55 members and four

3 http://fire.nist.gov/bfrlpubs/fire07/PDF/07004.pdf
stations. The victim and the engine crew that he was working with advanced towards the fire that originated in the basement and that had extended into the first floor. The IC requested a thermal imaging camera and the victim exited the structure to retrieve it. When he returned the crew was exiting the building because of the high heat and smoke conditions. He requested the nozzle and went back into the structure with one firefighter that backed him up from the doorway. He noted that the floor was spongy and as the firefighter entered the structure the floor collapse beneath him and he fell to the basement floor. The floor collapsed approximately twenty-eight minutes after the fire department was dispatched for the fire. Several attempts were made to rescue the firefighter with an attic ladder and a roof ladder that were placed through the hole created by the collapse. Rescue attempts were also made to enter the basement to rescue the victim but the remainder of the floor collapsed and the firefighters had to be pulled from the basement before they could rescue the firefighter. The coroner ruled that the victim died from inhalation of smoke and toxic products of combustion. The engineered “I” beams that supported the floor were constructed in the manner mentioned above.6

- On August 13, 2006 a 55 year old male died and another firefighter was injured after they fell through the floor while conducting a primary search of the first floor. The fire at this residence originated in the basement of the home. When the first attack crew entered the building a PPV fan was placed in the front doorway to facilitate horizontal ventilation after the windows were broken on the first floor. As the attack was initiated down the stairs and into the basement the victim and the other firefighter were ordered to conduct a primary search of the first floor. They sounded the first

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5 http://fire.nist.gov/bfrlpubs/fire03/PDF/03024.pdf
floor before they entered the room on their hands and knees and as soon as they entered the room they heard a crack and the floor gave way. Both firefighters fell through to the basement and were separated by the debris. The victim fell into the room of origin of the fire and the female firefighter fell into a room separated by a concrete block wall and was able to shield herself with debris. The firefighter then called for a “MAYDAY” four times. Even after her facemask was melted through by the high heat conditions she was able to find a window where she was pulled to safety by exterior crews. After the “MAYDAY” was called the incident commander ordered the rapid intervention team to initiate a rescue of the firefighters. The RIT advance down a stairway and other crews entered through basement windows, the victim could not be located however due to the high heat and large amount of debris. All crews then had to be evacuated due to imminent collapse and operations were changed to defensive until the fire was extinguished. The coroner ruled the victims cause of death to be smoke inhalation and thermal burns. The female firefighter suffered first degree burns to fifteen percent of her body and a fractured hip and ribs.

- On December 28, 2000 four firefighters were injured when a section of a truss constructed roof collapsed on top of them. The fire was in church that was constructed of wood construction with a brick veneer and the roof system was constructed of trusses built of 2x4s and 2x6’s held together with metal and plywood gusset plates. The injured firefighters where making an interior attack on the fire that was in the void spaces between the drywall ceiling that was attached to the wood trusses. While they were attacking the fire part of the roof collapsed down on top of

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6 [http://www.cdc.gov/niosh/fire/pdfs/face200707.pdf](http://www.cdc.gov/niosh/fire/pdfs/face200707.pdf)
7 [www.cdc.gov/niosh/fire/reports/face200626.html](www.cdc.gov/niosh/fire/reports/face200626.html)
them. The firefighters were knocked to the ground. One firefighter found his way out of the classroom through the door where he met up with the Incident Commander who led him out of the building. One of the injured firefighters was able to find a window on the wall and broke it open by smashing his helmet into it. A captain was then able to assist the three firefighters out of the window. Exterior crews began spraying water into the classroom area and three of the firefighters were able to escape by following the water spray out of the building by running through heavy fire and debris. The fire was then extinguished with an exterior deck gun after all members were evacuated from the structure. One firefighter had third degree burns on his hands and the other firefighters had minor burns and smoke inhalation.8

These cases show the severity of the conditions that are presented when lightweight construction is involved with fire.

The city of Highland Hts. follows the Ohio Building Code. Applicable building codes can be found in Appendix A. In these building the only sections that can be found about fire prevention are the ones that relate to fire blocking. This is an important item to have in the building codes in order to stop fire from spreading from one level to the next or into concealed spaces, however there are no standards that deal with fire resistance of engineered wood members or trusses or the techniques that could be used to prolong their strength under fire conditions.

The Highland Hts. Fire Department does not currently have any standard operating procedure that specifically addresses handling fires in structures that are constructed with lightweight construction methods. We have been fortunate to not have any incidents to

8 www.cdc.gov/niosh/fire/reports/face200103.html
date with this type of construction that has caused any injury or death. It is in the best interest of the department to create standard operating procedures that deal with this topic. We do have training from time to time on the hazards of lightweight construction and the methods that should be used when fighting a fire that involves them.

**Literature Review**

Three experts in the field published an article “Structural Collapse: The Hidden Dangers of Residential Fires”. In this article they posted four goals for firefighters to improve on:

1. Gain an understanding of the behavioral differences between solid wood joist and lightweight wood structural members under fire attack.

2. Gain an understanding of the American Society for Testing and Materials (ASTM) E119 test used to establish structural fire resistance, with modified loading conditions.

3. Gain knowledge concerning the collapse times of various floor and roof assemblies in tests recently conducted by Underwriters Laboratories (UL).

4. Gain an understanding of the benefits of 1/2-inch gypsum board applied to the underside of an assembly, delaying collapse.

In this article the authors discuss the fact that there are several known ways to the fire resistance of lightweight construction members but the National Association of Homebuilders has been reluctant to incorporate any of these methods into homebuilding procedures because of the increased cost associated with them. Some of these methods include making changes to building codes to make residential sprinkler system standard, protecting floor and roof systems with ½ inch gypsum board to extend fire resistance, improving the metal connections from the current gusset plates and joist connectors to
connectors that last longer under fire conditions and also on a structure that indicates lightweight construction methods were used in the construction. The authors also suggest taking a legal approach by having firefighters take legal actions against manufacturers, suppliers of these components and home builders that use lightweight construction methods.9

Study by Underwriter Laboratories

In 2008 Underwriters Laboratories conducted a study of lightweight wood structural components using the standards of ASTM E119. The tests were conducted to replicate a 180 square foot room with a ceiling or roof at which the temperature was 1000 degrees Fahrenheit at 5 minutes and 1700 degrees at sixty minutes. A load of 40 psf was placed on two sides of the simulated room to replicate the loads on the perimeter of the room and two three hundred pound mannequins were placed on the ceiling or roof assembly. Nine different structures were tested. The reason for the test was to compare “legacy” construction which is saw cut lumber with solid sub and finish flooring to protected and unprotected lightweight construction techniques. The results overwhelming found that legacy construction techniques outlasted lightweight construction techniques, especially when protect by gypsum board or plaster. The testing also found that the lightweight construction lasted longer under the fire conditions when protected by ½ inch gypsum board ceiling. The actual results of the test can be found in Appendix A.10

Results

The results from the Underwriter Laboratories tests showed the marked difference in exposed legacy construction and exposed lightweight construction. When comparing the 2x10 flooring system with the 12 inch I joist, the I joist failed in 6 minutes and 3 seconds and the 2x10 failed in 18 minutes and 45 seconds. The legacy construction lasted three times as long. When covering these same construction types with ½ inch gypsum board the times were increased to 44 minutes and 45 seconds for the 2x10 and the 26 minutes and 45 seconds for the I joist. When comparing roof truss systems against 2x6 and 2x10 construction the 2x6 construction was covered by a ½ inch gypsum ceiling and collapsed in forty minutes. The 2x10 construction was covered by a ¾ inch plaster ceiling and collapsed in 79 minutes and forty seconds. The truss construction was covered by a ½ inch gypsum board ceiling and collapsed in 23 minutes and 15 seconds. The 2x10 and plaster combination was clearly the most fire resistive. It is clear through testing that the legacy construction is more fire resistive that lightweight construction methods. The addition of the ½ gypsum ceiling to the lightweight systems did greatly improve the time to collapse. In the 12 inch I joist test the time to collapse was more than quadrupled with the addition of the ½ gypsum board. 11

Discussion

The history of the NIOSH cases, the results of the Underwriters Laboratory test recommendations from field experts and the current practices of the Highland Hts. Fire Department prove that improvements need to be made on the current standards of lightweight construction methods and in the City of Highland Hts. Fire Department current practices. It is not probable to think that this type of construction could be prohibited from being used. It is therefore up to fire departments to do their best to

prepare firefighters to deal with structure fires that involve lightweight construction. In order to improve the safety for homeowners and the firefighters that put their lives at risk to save lives and property mandatory requirements should be made that require new homes that are constructed with lightweight trusses or I-joist or beams to be protected either by residential sprinkler systems or by a minimum of ½ inch gypsum board. Residential sprinkler protection systems are estimated to cost $1.00 to $1.50 per square foot of new construction.\textsuperscript{12} The implementation of a code that states that all truss systems and engineered lumber must be protected by ½ inch lumber would be a very effective way to protect these members from failure as shown in the Underwriters Laboratories testing. An educational campaign to the public dealing with the risks associated with lightweight construction and how it endangers the homeowners and the men and woman who respond to protect them may also be a good way to get homeowners to consider installing residential sprinkler systems or installing ½ gypsum board over exposed lightweight truss or engineered beams. Pre-existing homes should be required to have some sort of marking that identifies the home to have lightweight members. Having this marking will alert firefighters to the potential hazards and allow them to make the best decision related to rescue and fire attack. The City of Chesapeake, Virginia Fire Department uses the sticker shown in Appendix C to mark commercial buildings that use lightweight truss construction.\textsuperscript{13} I believe that this type of sticker could be used to mark residential homes and commercial structures that use lightweight truss and engineered I-joist construction. The stickers could be applied after homeowners and business owners fill out a questionnaire like it is recommended by NIOSH. Standard operating procedures should be written and implemented that detail responses to these

\textsuperscript{12} \url{http://www.usfa.dhs.gov/citizens/all_citizens/home_fire_prev/sprinklers/}
types of structures and the type of attack that should be used depending on the severity of the fire condition and risk to health and life.

**Recommendations**

The following recommendations are based on the research done in this paper and from NIOSH recommendations in the cases reviewed.

- Improve departmental training and knowledge on fighting fires that involve lightweight wood trusses or engineered wood members
- Implement standard operating procedures that instruct the Incident Commander to evacuate crews and change all operations to defensive once it has been determined that fire is impinging on lightweight wood trusses or engineered members.¹⁴
- Increase training on operating above floors when the rooms below are involved with fire, and instruct firefighters on signs of a weakened floor system such as spongy feel, downward bow.¹⁵
- Instruct firefighters that floors can collapse without any warning signs
- Implement a standard operating procedure that instructs the first arriving attack crew leader to use a thermal imaging camera to evaluate the fire spread and involvement inside the structure, including whether fire has spread into concealed spaces or involve lightweight members. Training must also teach the limitations of the thermal imaging camera.¹⁶
- Incorporate walk-throughs of new construction to note lightweight construction techniques that are in use and to look for building code infractions such as alterations

¹³ [http://www.chesapeake.va.us/services/depart/fire/truss.shtml](http://www.chesapeake.va.us/services/depart/fire/truss.shtml)
¹⁴ [www.cdc.gov/niosh/fire/reports/face200103.html](http://www.cdc.gov/niosh/fire/reports/face200103.html)
¹⁶ [www.cdc.gov/niosh/fire/reports/face200626.html](http://www.cdc.gov/niosh/fire/reports/face200626.html)
made to engineered members and improper use of fire blocking.  

- Push for changes to building codes that are use in the city to incorporate the use of ½ inch gypsum board to protect wooden truss construction and engineered members or the use of residential sprinkler systems.

- Push for the city to implement a city ordinance that mandates that all existing homes and buildings and new construction must use some sort of visible marking to alert fire fighters to the use of lightweight construction techniques.

- Incorporate the use of a questionnaire that would be mailed to residents and business owners in order to gain information on each individual home and buildings’ use of lightweight construction materials to be use for preplanning.

- Implement an educational campaign in the city to make residents and business owners aware of the risks associated with lightweight construction so that they may consider installing sprinkler systems or ½ inch gypsum board to protect lightweight trusses and I-beams and I-joist.

References


20 http://www.cdc.gov/niosh/fire/pdfs/face200707.pdf
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Appendix A

R502.1.4 Prefabricated wood I-joists. Structural capacities and design provisions for prefabricated wood I-joists shall be established and monitored in accordance with ASTM D 5055.
R502.1.5 Structural glued laminated timbers.
Glued laminated timbers shall be manufactured and identified as required in AITC A190.1 and ASTM D3737.

R502.11.1 Design.

Wood trusses shall be designed in accordance with approved engineering practice. The design and manufacture of metal plate connected wood trusses shall comply with ANSI/TPI 1. The truss design drawings shall be prepared by a registered professional where required by the statutes of the jurisdiction in which the project is to be constructed in accordance with Section R106.1.

R502.11.2 Bracing.

Trusses shall be braced to prevent rotation and provide lateral stability in accordance with the requirements specified in the construction documents for the building and on the individual truss design drawings. In the absence of specific bracing requirements, trusses shall be braced in accordance with the TPI, HIB.

R502.11.3 Alterations to trusses.

Truss members and components shall not be cut, notched, spliced or otherwise altered in any way without the approval of a registered design professional. Alterations resulting in the addition of load (e.g., HVAC equipment, water heater, etc.), that exceed the design load for the truss, shall not be permitted without verification that the truss is capable of supporting the additional loading.

R502.11.4 Truss design drawings.

Truss design drawings, prepared in compliance with Section R502.11.1, shall be provided to the building official and approved prior to installation. Truss design drawing shall be provided with the shipment of trusses delivered to the job site. Truss design drawings shall include, at a minimum, the information specified below:

1. Slope or depth, span, and spacing.
2. Location of all joints.
3. Required bearing widths.
4. Design loads as applicable.
4.1. Top chord live load (including snow loads).
4.2. Top chord dead load.
4.3. Bottom chord live load.
4.4. Bottom chord dead load.
4.5. Concentrated loads and their points of application.
4.6. Controlling wind and earthquake loads.
5. Adjustments to lumber and joint connector design values for conditions of use.
6. Each reaction force and direction.
7. Joint connector type and description (e.g., size, thickness or gauge); and the dimensioned location of each joint connector except where symmetrically located relative to the joint interface.
8. Lumber size, species and grade for each member.
9. Connection requirements for:
9.1. Truss-to-truss girder.
9.2. Truss ply-to-ply.
9.3. Field splices.
10. Calculated deflection ratio and/or maximum description for live and total load.
11. Maximum axial compression forces in the truss members to enable the building designer to design the size, connections and anchorage of the permanent continuous lateral bracing. Forces shall be shown on the truss drawing or on supplemental documents.
12. Required permanent truss member bracing location.

**R502.12 Draftstopping required.**

When there is usable space both above and below the concealed space of a floor/ceiling assembly, draftstopping shall be installed so that the area of the concealed space does not exceed 1,000 square feet (92.9 m²). Draftstopping shall divide the concealed space into approximately equal areas. Where the assembly is enclosed by a floor membrane above and a ceiling membrane below draftstopping shall be provided in floor/ceiling assemblies under the following circumstances:

1. Ceiling is suspended under the floor framing.
2. Floor framing is constructed of truss-type open-web or perforated members.

**R502.12.1 Materials.**

Draftstopping materials shall not be less than ½-inch (12.7 mm) gypsum board, 3/8-inch (9.5 mm) wood structural panels, ³/₈-inch (9.5 mm) Type 2-M-W particleboard or other approved materials adequately supported. Draftstopping shall be installed parallel to the floor framing members unless otherwise approved by the building official. The integrity of all draftstops shall be maintained.

**R502.13 Fireblocking required.**

Fireblocking shall be provided in wood-frame floor construction and floor-ceiling assemblies in accordance with Section R602.8.

**R602.8 Fireblocking required.**

Fireblocking shall be provided to cut off all concealed draft openings (both vertical and horizontal) and to form an effective fire barrier between stories, and between a top story and the roof space. Fireblocking shall be provided in wood-frame construction in the following locations.

1. In concealed spaces of stud walls and partitions, including furred spaces and parallel rows of studs or staggered studs; as follows:
   1.1. Vertically at the ceiling and floor levels.
   1.2. Horizontally at intervals not exceeding 10 feet (3048 mm).
2. At all interconnections between concealed vertical and horizontal spaces such as occur at soffits, drop ceilings and cove ceilings.
3. In concealed spaces between stair stringers at the top and bottom of the run. Enclosed spaces under stairs shall comply with Section R311.2.2.
4. At openings around vents, pipes, and ducts at ceiling and floor level, with an approved material to resist the free passage of flame and products of combustion.
5. For the fireblocking of chimneys and fireplaces, see Section R1001.16.
6. Fireblocking of cornices of a two-family dwelling is required at the line of
dwellng unit separation.

**R802.3 Framing details.**

Rafters shall be framed to ridge board or to each other with a gusset plate as a tie. Ridge board shall be at least 1-inch (25.4 mm) nominal thickness and not less in depth than the cut end of the rafter. At all valleys and hips there shall be a valley or hip rafter not less than 2-inch (51 mm) nominal thickness and not less in depth than the cut end of the rafter. Hip and valley rafters shall be supported at the ridge by a brace to a bearing partition or be designed to carry and distribute the specific load at that point. Where the roof pitch is less than three units vertical in 12 units horizontal (25-percent slope), structural members that support rafters and ceiling joists, such as ridge beams, hips and valleys, shall be designed as beams.

**R802.7 Cutting and notching.**

Structural roof members shall not be cut, bored or notched in excess of the limitations specified in this section.

**R802.8 Lateral support.**

Rafters and ceiling joists having a depth-to-thickness ratio exceeding 5 to 1 based on nominal dimensions shall be provided with lateral support at points of bearing to prevent rotation.

**R802.10.1 Truss design drawings.**

Truss design drawings, prepared in conformance with Section R802.10.1, shall be provided to the building official and approved prior to installation. Truss design drawings shall include, at a minimum, the information specified below. Truss design drawing shall be provided with the shipment of trusses delivered to the jobsite.

1. Slope or depth, span and spacing.
2. Location of all joints.
3. Required bearing widths.
4. Design loads as applicable.
4.1. Top chord live load (including snow loads).
4.2. Top chord dead load.
4.3. Bottom chord live load.
4.4. Bottom chord dead load.
4.5. Concentrated loads and their points of application.
4.6. Controlling wind and earthquake loads.
5. Adjustments to lumber and joint connector design values for conditions of use.
6. Each reaction force and direction.
7. Joint connector type and description (e.g., size, thickness or gauge) and the dimensioned location of each joint connector except where symmetrically located relative to the joint interface.
8. Lumber size, species and grade for each member.
9. Connection requirements for:
   9.1. Truss to truss girder.
9.2. Truss ply to ply.
9.3. Field splices.
10. Calculated deflection ratio and/or maximum description for live and total load.
11. Maximum axial compression forces in the truss members to enable the building
designer to design the size, connections and anchorage of the permanent continuous
lateral bracing. Forces shall be shown on the truss design drawing or on supplemental
documents.
12. Required permanent truss member bracing location.

R802.10.2 Design.

Wood trusses shall be designed in accordance with accepted engineering practice. The
design and manufacture of metal plate connected wood trusses shall comply with
ANSI/TPI 1. The truss design drawings shall be prepared by a registered professional
where required by the statutes of the jurisdiction in which the project is to be constructed
in accordance with Section R106.1

R802.10.3 Bracing.

Trusses shall be braced to prevent rotation and provide lateral stability in accordance
with the requirements specified in the construction documents for the building and on
the individual truss design drawings. In the absence of specific bracing requirements,
trusses shall be braced in accordance with TPI/HIB.

R802.10.4 Alterations to trusses.

Truss members shall not be cut, notched, drilled, spliced or otherwise altered in any
way without the approval of a registered design professional. Alterations resulting in
the addition of load (e.g., HVAC equipment, water heater) that exceeds the design
load for the truss shall not be permitted without verification that the truss is capable
of supporting such additional loading.

R802.10.5 Truss to wall connection.

Trusses shall be connected to wall plates by the use of approved connectors having a
resistance to uplift of not less than 175 pounds (79.45 kg.) and shall be installed in
accordance with the manufacturer’s specifications. For roof assemblies subject to wind
uplift pressures of 20 pounds per square foot (0.958 kN/m²) or greater, as established in
Table R301.2(2), adjusted for height and exposure per Table R301.2(3), see section
R802.11.

Appendix B
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### Table 1 — Description of Test Samples

<table>
<thead>
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<th>Supports</th>
<th>Ceiling</th>
<th>Floor or Roof</th>
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<tbody>
<tr>
<td>1</td>
<td>2 inch x 10 inch with 16-inch centers</td>
<td>None</td>
<td>1 inch x 6 inch subfloor and 1 inch by 4 inch finish floor</td>
</tr>
<tr>
<td>2</td>
<td>12 inch deep &quot;I&quot; joist with 24-inch centers</td>
<td>None</td>
<td>23/32 inch OSB subfloor, carpet padding and carpet</td>
</tr>
<tr>
<td>3</td>
<td>2 inch x 10 inch with 16-inch centers</td>
<td>½ inch regular gypsum wallboard</td>
<td>1 inch x 6 inch subfloor and 1 inch by 4 inch finish floor</td>
</tr>
<tr>
<td>4</td>
<td>12 inch deep &quot;I&quot; joist with 24-inch centers</td>
<td>½ inch regular gypsum wallboard</td>
<td>23/32 inch OSB subfloor, carpet padding and carpet</td>
</tr>
<tr>
<td>5</td>
<td>14-inch parallel chord truss with steel gusset plate connections with 24-inch centers</td>
<td>½ inch regular gypsum wallboard</td>
<td>23/32 inch OSB subfloor, carpet padding and carpet</td>
</tr>
<tr>
<td>6</td>
<td>14-inch parallel chord truss with gusset connections with 24-inch centers</td>
<td>½ inch regular gypsum wallboard</td>
<td>23/32 inch OSB subfloor, carpet padding and carpet</td>
</tr>
<tr>
<td>7</td>
<td>2 inch x 6 inch with 16-inch centers and 2/12 pitch</td>
<td>½ inch regular gypsum wallboard</td>
<td>1 inch by 6 inch roof deck covered with asphalt shingles</td>
</tr>
<tr>
<td>8</td>
<td>2 inch x 10 inch with 16-inch centers</td>
<td>¾ inch plaster</td>
<td>1 inch by 6 subfloor inch and 1 inch by 4 inch finish floor</td>
</tr>
<tr>
<td>9</td>
<td>Roof truss with steel gusset plate connections with 24-inch centers and 2/12 pitch</td>
<td>½ inch regular gypsum wallboard</td>
<td>7/16 inch OSB covered with asphalt shingles</td>
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### Table 2 — Summary of Test Results to ASTM E119

<table>
<thead>
<tr>
<th>Test Assembly</th>
<th>Time of 250°F average temperature rise on surface of floor/roof (in minutes)</th>
<th>Time of 325°F maximum temperature rise on surface of floor/roof (in minutes)</th>
<th>Flame passage through floor/roof (in minutes)</th>
<th>Collapse (in minutes)</th>
<th>Fire Resistance Rating (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>18:30</td>
<td>18:45</td>
<td>19</td>
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<td>06:30</td>
<td>6</td>
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<td>*</td>
<td>44:15</td>
<td>44:45</td>
<td>44</td>
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<tr>
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<td>*</td>
<td>26:45</td>
<td>27</td>
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<tr>
<td>5</td>
<td>*</td>
<td>20:15</td>
<td>28:40</td>
<td>29:15</td>
<td>29</td>
</tr>
<tr>
<td>6</td>
<td>*</td>
<td>24:15</td>
<td>26:00</td>
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<td>24</td>
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<td>26</td>
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<tr>
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<td>*</td>
<td>79:45</td>
<td>51**</td>
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<tr>
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<td>*</td>
<td>*</td>
<td>23:15</td>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>

* This condition was not achieved during the fire test.
** Plaster ceiling in contact with furnace thermocouples at 51 minutes. The test method requires that the junction of the thermocouples in the furnace be placed 12 inches from the ceiling surface at the beginning of the test and shall not touch the sample as a result of deflection.

Appendix C