Underwriters Laboratory Confirmation of
Metal Plate Connected Wood Truss Floor Assemblies
Demonstrating Equivalent Fire Performance
per 2012 IRC Section R501.3

Background Research, Evaluation and Analysis

Report Written by:
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Introduction:
Object Statement
The IRC states that floor assemblies, not required elsewhere in this code to be fire resistance rated, shall be provided with a ½" gypsum wallboard (GWB) membrane, 5/8" wood structural panel (WSP) membrane, or equivalent on the underside of the floor-framing member, with a few exceptions. This code language is evaluated in the context of existing ASTM E119 standardized comparative equivalency fire endurance performance testing as confirmed by Underwriters Laboratory’s (UL’s) literature search in its report, Full-Scale Floor System Field and Laboratory Fire Experiments (UL report)\(^1\).

The 2012 IRC Section R101.3 states:

R101.3 Intent. The purpose of this code is to establish minimum requirements to safeguard the public safety, health and general welfare through affordability, structural strength, means of egress facilities, stability, sanitation, light and ventilation, energy conservation and safety to life and property from fire and other hazards attributed to the built environment and to provide safety to fire fighters and emergency responders during emergency operations. [emphasis added]

Regulations have been adopted, using the IRC as model code language, that treat floor assemblies that are, “not made using dimension lumber or structural composite lumber equal to or greater than 2" by 10" nominal dimension,” in a special manner with respect to the building and fire code provisions.

The 2012 IRC includes Section R501.3, which states:

R501.3 Fire protection of floors. Floor assemblies, not required elsewhere in this code to be fire resistance rated, shall be provided with a ½" gypsum wallboard membrane, 5/8" wood structural panel membrane, or equivalent on the underside of the floor framing member.

Exceptions:
1. Floor assemblies located directly over a space protected by an automatic sprinkler system in accordance with Section P2904, NFPA13D, or other approved equivalent sprinkler system.
2. Floor assemblies located directly over a crawl space not intended for storage or fuel-fired appliances.
3. Portions of floor assemblies can be unprotected when complying with the following:
   3.1 The aggregate area of the unprotected portions shall not exceed 80 square feet per story
   3.2 Fire blocking in accordance with Section R302.11.1 shall be installed along the perimeter of the unprotected portion to separate the unprotected portion from the remainder of the floor assembly.
4. Wood floor assemblies using dimension lumber or structural composite lumber equal to or greater than 2" by 10" nominal dimension, or other approved floor assemblies demonstrating equivalent fire performance. [emphasis added]

In 1992, the National Fire Protection Association (NFPA) assessed the impact of fire on lightweight construction and helped point the way to improvements and key concepts intended to aid in fire fighter safety. The National Engineered Lightweight Construction Fire Research Project–Technical Report: Literature Search & Technical Analysis (NFPRF report)\(^2\), sponsored by the National Fire Protection Research Foundation, offered a look at studies published over the previous 20 years of relevant fire safety analysis of lightweight wood construction. The NFPRF report was used as foundational reference in Table 12 on page 29 of the UL report. The full set of ASTM E119 standardized test data provided in the UL report can be found in the following Table 1.

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1 http://www.carbeck.org/pdfs/2009_NIST_ARRA_Appendix_C_Full_Scale_Floor_System_Field_and_Laboratory_Fire_Experiments.pdf
<table>
<thead>
<tr>
<th>Test</th>
<th>Structural Member</th>
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<th>Structural Failure (min : sec)</th>
<th>Loading (psf)</th>
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<td>24&quot; o.c.</td>
<td>5:12</td>
<td>69.8 (100%)</td>
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<td>60.0 (100%)</td>
</tr>
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<td>NBS 421346 (2) (Son B., Fire Endurance Tests of Unprotected Wood-Floor Constructions for Single Family Residences: NBSIR 73-263, 1973)</td>
<td>2 x 10; (\frac{1}{2})&quot; &amp; (\frac{5}{8})&quot; ply</td>
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<td>11:38</td>
<td>63.7 (100%)</td>
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</tbody>
</table>

Table 1: ASTM E119 Assembly Tests at Full Design Load\(^3\)  
ASTM Comparative Test Data Using 100% Design Load as the Common Denominator

\(^3\) Ibid, page 29.
SBCA Research Report

Additional Background Research, Data Evaluation and Analysis:

The UL report states the following in its introduction.

2. Introduction
Engineered floor products provide financial and structural benefits to building construction; however, adequate fire performance needs to be addressed as well. Adequate fire performance provides a necessary level of safety for building occupants and emergency responders responsible for mitigating fire incidents. Basement fires can be one of the most dangerous and challenging fires for the fire service. The fire service often operates above the fire which is arguably the most dangerous place to be. Changes in building construction practices have made extinguishing basement fires even more dangerous. Unprotected wood floor assemblies and engineered floor assemblies have reduced the time to safely operate on top of these floor systems. Previous research by various organizations, including UL (Underwriters Laboratories, Inc., 2008), NIST (Harman, 2007), NFPA (FPRF, 1992) and National Research Council Canada (Sultan, Seguin, & Leroux, 2008), provided evidence of the greater risk in structural failure …

The UL report states the following in its literature review section, which consolidates all the past research on unprotected floor system performance, both non-standardized (non-standard loading or not at full design load as required by ASTM E119) and ASTM E119 standardized (loading conditions that can be used for performance comparisons and benchmarking).

4. Literature Review
The following sections discuss the various, formal and informal, research projects that have been undertaken to evaluate the fire endurance performance issues of unprotected wood assemblies. Prior to the start of this experimentation a variety of related topics were researched: documented Line of Duty Injuries (LODI) and Line of Duty Deaths (LODD) involving unprotected combustible dimensional and engineered lumber assemblies, the fire endurance performance of unprotected combustible wood assemblies; inclusive of informal fire service testing, floor furnace testing, full scale laboratory and site testing, and a review of related fire service publications. The literature search was conducted in order to review and evaluate previous research methodologies utilized in the testing of unprotected combustible dimensional and engineered lumber assemblies. This information was then referenced during the development of the various research parameters for the current study.

The literature search was composed of six main activities: a review of the National Engineered Lightweight Construction Fire Research Project (NELCFRP) sponsored by the National Fire Protection Research Foundation (FPRF) in October of 1992

SRR No. 1406-01
Non-standardized Demonstrative Testing
The following information can be found beginning on page 15 of the UL report.

4.2. Fire Endurance Performance of Unprotected Assemblies - Non-Standardized Demonstrative Testing
Fire resistive testing methodologies are very well established for combustible assemblies designed to achieve an hourly fire resistive rating with passive fire protection. Less understood is the structural stability of unprotected combustible dimensional and engineered lumber assemblies exposed to fire conditions. When combustible wood assemblies are constructed without the protection of passive tire resistive technologies or active suppression systems, both dimensional and engineered lumber assemblies are vulnerable to collapse within the operational timeline of fire suppression operations.

The only demonstrative test of the UL report literature search tests that was performed using reasonably identical testing conditions was the demonstration test conducted by the Illinois Fire Service Institute (IFSI) in 1986, where the test assembly, fire load and applied loading were the same for all floor systems

4.2.2. Demonstrative Testing Conducted by the Illinois Fire Service Institute, 1986.
Conducting Agency: The Illinois Fire Service Institute (IFSI) in 1986 conducted a similar demonstrative study of lightweight constructed floor systems citing similar fire performance concerns (Straseske, 1988). The ISFI test series sets out to, "help determine the time available for firefighters to suppress a fire within a structure utilizing types of lightweight construction." The ISFI report states, "There is a lot of speculation on what specific floor systems might due under fire conditions, but very little gathered data."

Test Series: The following floor systems were tested: conventional 2 x 10 joists on 16 in. centers, wood I-beams on 24 in. centers, open-web trusses with wood members and gusset plates on 24 in. centers, open-web trusses with a stamped out steel webs on 24 in. centers, and open webbed trusses with a wooden top and bottom chord and pipe web members on 24 in. centers.

All floor systems were constructed with a 3/4" oriented strand board (OSB) subfloor and load similarly with an applied load of 31 pounds per square foot. In order to provide some uniformity all decks were 8' x 16' and were supported on 24" high concrete masonry unit wall. The perimeter was enclosed with 3/4" plywood on three sides. The fuel load was 4 gallons of diesel fuel and 1 gallon of gas in a cut off 55 gallon barrel approximately 12" high.

Test Results: The collapse times ranged from: 4 minutes and 40 seconds for the engineered 1-Joist floor system, 13 minutes for the 2x 10 dimensional lumber floor system, and 15 minutes and 45 seconds for the floor constructed with metal plate connected trusses.
Review and Comment: This test series demonstrates a limited work time for firefighters operating in a building constructed with an unprotected wood floor system exposed to fire conditions. However, this series makes a comparative performance analysis difficult due to parameter variability. The products were tested without respect to their spacing, allowable spans and the applied load created variability for the internal member stresses. The characterization of the fuel load for the fire was not analyzed and the ventilation conditions, although partially controlled, added a degree of variability. A review of the video for this test series was conducted and these video images suggest a degree of variability in the fire development which may have additionally influenced the time to failure for the tested assemblies. A summary of these tests results is shown in Table 3.

There are only a limited number of documented Non-Standardized tests of unprotected combustible assemblies that conform to the ASTM E 119, "Standard Methods of Fire Tests for Building Construction and Materials." Non-standardized tests conform to most of the requirements of the ASTM E 119 standard, the exception being loading. Numerous agencies have conducted Non-Standardized tests with modified loading conditions, i.e. loading less than 100 % of the design load.

Standardized ASTM E119 Testing
The only test in the UL report performed using identical ASTM E119 standardized testing conditions were the tests documented by the NFPRF report. ASTM E119 states the following as a requirement for the ability to compare the performance of one ASTM E119 test to the next.

Designation: E 119 – 00a

An American National Standard

Standard Test Methods for Fire Tests of Building Construction and Materials¹

28. Size and Characteristics of Specimen
28.1 The area exposed to fire shall be not less than 180 ft² (16 m²) with neither dimension less than 12 ft (3.7 m). Structural members, if a part of the construction under test, shall lie within the combustion chamber and have a side clearance of not less than 8 in. (203 mm) from its walls.
28.2 Specimens representing forms of construction in which restraint to thermal expansion occurs shall be so restrained in the furnace.
The only standardized testing conducted that allows for precise comparison of unprotected assembly performance was defined in the NFPRF report.

4.4.1. National Engineered Lightweight Construction Fire Research Project Report:


Report Series: The components examined in this study include: metal plate connected (MPC) wood trusses, MPC metal-web wood trusses, pin-end connected steel-web wood trusses, wooden I-joists, solid-sawn (chg., 2 x 10) wood joists, composite wood joists, steel barjoists, and steel C joists. The following is a list of the testing citing for standardized ASTM E119 furnace testing conducted with modified loading conditions respective of the structural elements being examined for this research project.

Review and Comment: The FPRF report and the source literature were reviewed for testing conducted prior to 1992. The majority of the tests conducted were of unprotected dimensional lumber floor assemblies. A summary of these tests results is shown in Table 12.

<table>
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<tr>
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In the case of the literature review, UL undertook and delineated the complete set of FPL tests that show the low end of 2x10 ASTM E119 standardized fire endurance performance. The original NFPRF report only reported on the summary averaged results of this testing.
Concluding Comments:
The literature search performed by UL (2012) confirms that metal plate connected wood trusses perform in compliance with R501.3 fire protection of floors exception 4 where it states, “other approved floor assemblies demonstrating equivalent fire performance.” The testing found in UL’s Table 12 shows definitively that metal plate connected wood trusses perform equivalently to 2x10 joists when testing is undertaken using standardized testing procedures.

Further, UL states that a key goal of the NELCFRP (NFPRF report):

One overall objective of the NELCFRP was to define the actual fire performance characteristics of engineered components through a review of existing documented research. The components examined in the NELCFRP included: solid-sawn (e.g., nominal 2 x 10) wood joists, metal plate connected (MPC) wood trusses, MPC metal-web wood trusses, pin-end connected steel-web wood trusses, engineered wooden I -joists, composite wood joists, steel bar joists, and light gauge steel C joists.

Finally the Demonstrative Testing Conducted by the Illinois Fire Service Institute, 1986 provided the following comparative results confirming metal plate connected wood truss performance equivalency to 2x10s.

Test Results: The collapse times ranged from: 4 minutes and 40 seconds for the engineered I-Joist floor system, 13 minutes for the 2x 10 dimensional lumber floor system, and 15 minutes and 45 seconds for the floor constructed with metal plate connected trusses. [emphasis added]

Therefore, a definitive technical case can be made that metal plate connected wood trusses are “other approved floor assemblies demonstrating equivalent fire performance.”