Research Report

Single Membrane Floor Protection Requirements of 2012 IRC Section R501.3 & 2015 IRC Section R302.13

SRR No. 1509-05

Structural Building Components Association (SBCA)

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This research report is based on practical scientific research (literature review, testing, analysis, etc.), with the goal of supporting strategic needs for code and standards development and market expansion. This research report complies with the following sections of the building code:

- *IBC* Section 104.11.1 and Section 1703.4.2 – "**Research reports.** Supporting data, where necessary to assist in the approval of materials or assemblies not specifically provided for in this code, shall consist of valid research reports from *approved sources*."
- *IBC* Section 202 – "**APPROVED SOURCE.** An independent person, firm or corporation, *approved* by the *building official*, who is competent and experienced in the application of engineering principles to materials, methods or systems analyses."

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Introduction:

Structural Building Components Association (SBCA) and its members strongly believe in a key engineering and building code principle of providing structural building component solutions that safeguard the public health, safety and general welfare, while serving the general public's desire to have affordable and environmentally responsible built construction. Likewise, the *International Residential Code* (*IRC*) includes the following:

> **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.

SBCA's general policy is unless there is sufficient comparative data provided to show increased life-safety risk, any regulation created shall be structural element independent so that trade is not inappropriately restricted and a level competitive playing field is assured.

This general policy pertains especially well to this report, which aims to enhance fire performance and fire safety characteristics through the application of a gypsum wallboard membrane.

The requirements included in 2012 *IRC* Section R501.3 or 2015 *IRC* Section R302.13 do not actually meet the intent of the code change proposal adding this section (protection of the fire service) nor do they reflect the most current data on the fire performance of unprotected floor systems.

Background:

At the request of the fire service and based on several National Institute for Occupational Safety and Healthy (NIOSH) reports a number of code change proposals were submitted to the *IRC* code change process in 2009 regarding the fire protection of floor systems. Some proposals required 30 minute protection, others required 15 minute protection. A number of test reports were referenced to support these proposals: one by the National Research Council of Canada, one by Tyco Fire Suppression and Building Products and another by Underwriters Laboratories. The latter was commissioned by the Chicago Fire Department and the International Association of Fire Chiefs under a grant from the Department of Homeland Security.

Subsequently, more testing was completed by the National Research Council of Canada as well as UL testing funded by National Institute of Standards and Technology's (NIST) American Recovery and Reinvestment Act Grant Program. The stated goal of the latter was "to improve firefighter safety by increasing the level of knowledge on the response of residential flooring systems to fire." The results of this testing provides data that was not readily available at the time the code change was introduced.

Application:

The following is the code requirement included in 2015 *IRC* Section R302.13. Besides moving the requirement from 2012 *IRC* Section R501.3, the sentence in red was added in the 2015 edition.

> Floor assemblies, not required elsewhere in this code to be fire resistance rated, shall be provided with a ½-inch gypsum wallboard membrane, 5/8-inch wood structural panel membrane, or equivalent on the underside of the floor framing member. Penetrations or openings for ducts, vents, electrical outlets, lighting, devices, luminaires, wires, speakers, drainage and similar openings or penetrations shall be permitted.
>
> **Exceptions:**
>
> 1. Floor assemblies located directly over a space protected by an automatic sprinkler system in accordance with Section P2904, NFPA 13D, 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-inch by 10-inch (50.8 mm by 254 mm) nominal dimension, or other approved floor assemblies demonstrating equivalent fire performance.

Underwriters Laboratories report, Improving Fire Safety by Understanding the Fire Performance of Engineered Floor Systems and Providing the Fire Service with Information for Tactical Decision Making, addresses many of the concerns of the fire service regarding the above code language, especially with exception #4.

The following is from the summary of this report (pages 3-4 and 68). Note especially the bolded sentences:

> The results of the study have been prepared to provide tactical considerations for the fire service to enable improved decision making on the fire scene.
>
> There are several tactical considerations that result from this research that firefighters can use immediately to improve their understanding, safety and decision making when sizing up a fire in a one or two family home.
>
> - **Collapse times of all unprotected wood floor systems are within the operational time frame of the fire service regardless of response time.**
> - Size-up should include the location of the basement fire as well as the amount of ventilation. Collapse always originated above the fire and the more ventilation available the faster the time to floor collapse.
> - When possible the floor should be inspected from below prior to operating on top of it. Signs of collapse vary by floor system; Dimensional lumber should be inspected for joist rupture or complete burn through, Engineered I-joists should be inspected for web burn through and separation from subflooring, Parallel Chord Trusses should be inspected for connection failure, and Metal C-joists should be inspected for deformation and subfloor connection failure.
> - **Sounding the floor for stability is not reliable and therefore should be combined with other tactics to increase safety.**
> - **Thermal imagers may help indicate there is a basement fire but can't be used to assess structural integrity from above.**
> - Attacking a basement fire from a stairway places firefighters in a high risk location due to being in the flow path of hot gases flowing up the stairs and working over the fire on a flooring system that has the potential to collapse due to fire exposure.
> - It has been thought if a firefighter quickly descended the stairs cooler temperatures would be found at the bottom of the basement stairs. The experiments in this study showed temperatures at the bottom of the basement stairs were often worse than the temperatures at the top of the stairs.
> - Coordinating ventilation is extremely important. Ventilating the basement created a flow path up the stairs and out through the front door of the structure, almost doubling the speed of the hot gases and increasing temperatures of the gases to levels that could cause injury or death to a fully protected firefighter.
> - **Floor sag is a poor indicator of floor collapse, as it may be very difficult to determine the amount of deflection while moving through a structure.**
> - Gas temperatures in the room above the fire can be a poor indicator of both the fire conditions below and the structural integrity of the flooring system.
> - Charged hose lines should be available when opening up void spaces to expose wood floor systems.
>
> **During all of these controlled experiments where the variables were systematically controlled there were no reliable and repeatable warning signs of collapse. In the real world, the fire service will never respond to two fires that are exactly the same**.

The report's stated objectives include the following (page 8):

1. Understanding the impact of span, fuel load, ventilation and fire location to system failure.
2. Examine different fire protection methods and develop data to assess their effectiveness.
3. Provide scientific data to substantiate code changes related to residential floor systems to result in improved building fire safety.

This report first investigated the time to failure of dimensional lumber floor assemblies as shown in Table 23, page 51 (see Figure 1).

Table 23. Dimensional Lumber Floor Assemblies with Protection Methods under the same modified loading conditions

Test Assembly	Supports	Time to failure
1	Dimensional Lumber (2 x 10) - Unprotected	18:35
2	Dimensional Lumber (2 x 10) – Gypsum Wallboard (1/2 in)	44:40
3	Dimensional Lumber (2 x 10) – Plaster and Lath	79:00
4	Dimensional Lumber (2 x 10) w/ 100% Loading	7:04
5	Old Dimensional Lumber (2 x 8) w/ 100% Loading	18:05

Figure 1 – Dimensional Lumber Floor Assemblies with Protection Methods Under the Same Modified Loading

The report addresses the operational timeframe on pages 51-52 and includes the following statistics:

> Every fire department has a wide range of response times within their response area depending on factors such as distance from the fire station, type of fire department and time of day just to name a few. In an analysis done by the United States Fire Administration (USFA) in 2006 they conclude, "In most of the analyses done here, response times were less than 5 minutes nearly 50% of the time and less than 8 minutes about 75% of the time. Nationally, average response times were generally less than 8 minutes. The overall 90th percentile, a level often cited in the industry, was less than 11 minutes." (USFA, 2006)
>
> These response times don't take into consideration the time between ignition and notification to the fire department to begin their response. It is important to note that the fire department rarely knows when the fire started. Conservatively for this discussion let's assume that it takes 4 minutes from the time of ignition, for the fire to be discovered, for the fire department to be notified and for the fire department to begin their response.

The conclusions regarding exception #4, which allows 2-inch by 10-inch nominal lumber or larger to be unprotected, are given on page 64, 66 & 69. See especially the bolded sentences:

> Conservatively, taking the slowest time to collapse (18:43), it can (be) argued that this is not an acceptable level of performance because 18:43 can be justified as being within the fire services operation timeframe as described in the previous section, which provides little to no factor of safety. The intent of the code states "The purpose of this code is to establish the minimum requirements to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate 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 [IBC Chapter 1, Part 1, Section 101.3 & IRC Chapter 1, Part 1, Section R101.3]. **Based on the collapse times from these experiments there is little to no safe operating time for firefighters in a structure with an unprotected dimensional lumber floor system**.
>
> The final floor furnace experiment with old dimensional lumber raises the question as to whether all dimensional lumber can be adequately described by its nominal dimensions. The older reclaimed dimensional lumber didn't reach failure until 160% longer than the modern dimensional lumber even though its dimensions were actually smaller. While the fire service suggests that the factor of safety provided by older dimensional lumber was acceptable the experimental results show that new dimensional lumber is significantly different in terms of performance under fire conditions. **Protecting the dimensional lumber as well as engineered lumber floor systems in future code requirements would eliminate this fire performance change in dimensional lumber and provide a more reasonable factor of safety for the fire service**.
>
> In the full-scale field experiments the dimensional lumber outperformed all of the lightweight alternatives however they did not resist collapse for a period of time that could be seen as providing an acceptable level of safety for the responding firefighters. The two floor systems with 2-inch by 10-inch nominal flooring members collapsed at 11:09 and 12.45 respectively. The first experiment assumes having sufficient ventilation to allow the fuel load and floor system to burn at or near optimal levels which could be considered the worst case scenario. The second simulated operations of the fire department that began at 8 minutes after ignition. This could be interpreted to mean that the fire department would need to eliminate the hazard in less than 5 minutes to avoid the collapse. This assumes the fire is witnessed, called into the fire department, the fire department is dispatched, the fire department arrives and the fire department begins their firefighting operation in 8 minutes. While possible, this is not the case for the majority of fires that occur across the United States. **This emphasizes the importance of protecting all types of flooring system, including dimensional lumber**.

Improve occupant safety by allowing for longer egress times.

By applying a protective layer of gypsum board to unprotected floor systems, not only does it extend the time to collapse but it also separates the large fuel load that is the floor system from the fuel load in the room. When unprotected the combustible floor system is in the ideal location above the fire to quickly spread and grow the fire when sufficient air is available. This separation or protection allows for slower fire growth and longer times for occupant egress.

Provide data to substantiate code changes related to fire rated engineered floor systems to result in improved building fire safety.

Based on some previous research by UL and others as well as concerns from the fire service a code change to the 2012 International Residential Code has gone into effect that was the result of compromises made between all of the parties that worked to develop the final proposal. This change requires gypsum wallboard protection, or equivalent, of engineered lumber floor systems in new homes. This research project examined what "equivalent" could mean and if there were technologies that could meet this definition. Intumescent coating technology showed promise however it did not provide equivalent protection as tested. There are several exceptions in the code language that were examined in this research project. **One exception is that there is no protection required for dimensional lumber floor systems. This research study provides data to substantiate the need to protect dimensional lumber floor systems to improve firefighter safety**. The second exception examined was the allowance of an exposed 80 ft^2 exposed area. Limiting the fuel load in relation to the exposed floor area or placing the exposed floor area in a separate room from the finished section of the basement would increase the safety when the floor area must be exposed.

SBCA recently undertook testing at NGC Testing Services (NGC), an International Accreditation Service (ICC-IAS) accredited ISO/IEC 17025 *ASTM E119* fire testing facility. SBCA chose to test at NGC versus UL so the SBCA *ASTM E119* test procedure and resulting test data would be an independent assessment of floor assembly performance. SBCA testing found unprotected 2x10 floor assembly performance was 10:35 minutes. This result confirms the UL testing results for dimension lumber and i-joists and adds information regarding trusses, as seen in Table 1.

UL and SBCA ASTM E119 100% Design Load Fire Test Data is Aligned- Says Protect Everything

UL ASTM E119, Unprotected Floor Assembly, 100% Design Load Fire Endurance Performance Benchmark Tests

Test Member Recent UL[1] Test Data	UL Test [% design load]	Time of Total Structural Failure	Time of Failure Load Bearing
Today's 2x10 Dimension Lumber	UL Data [100%]	7:04 (min:sec)	7:04 (min:sec)
9-1/2" I-Joist	UL Data [100%]	2:20 (min:sec)	2:20 (min:sec)

SBCA ASTM E119, Unprotected Floor Assembly, 100% Design Load Fire Endurance Performance Benchmark Tests

Test Member March 2015 SBCA Test Data	NGC Test [% design load]	Total Applied Load (psf)	Time to Failure (min:sec)
2x10 Southern Pine (16" o.c.)	NGC FC-853 [100%]	42.0	10:35 (min:sec)
12" Trusses no SPs (24" o.c.) (1)	NGC FC-858 [100%]	48.5	6:54 (min:sec)
9-1/2" Flak Jacket I-joist (19.2" o.c.) (3)	NGC FC-857 [100%]	75.5	6:37 (min:sec)
12" Trusses no SP (24" o.c.) (2)	NGC FC-854 [100%]	48.5	6:02 (min:sec)
9-1/2" I-Joist (19.2" o.c.) (4)	NGC FC-855 [100%]	84.0	4:25 (min:sec)
12" Trusses w/SPs (24" o.c.) (2)	NGC FC-856 [100%]	52.3	3:33 (min:sec)

Notes on this table: (1) SP=splice joint & this test had strong-back to bearing. (2) SP=splice joint & this test had strong-back but NOT to bearing. (3) Flak Jacket was ICC-ES ESR -1153 approved 2013 product from market to be sold inventory. ICC-ES approved design values and holes were incorporated. (4) ICC-ES approved design values and holes were incorporated.

Table 1 – UL & SBCA *ASTM E119* Test Comparison

SBCA Views on *IRC* Policy Risks:

Conclusions Based on UL and SBCA Testing Facts:

- Do not adopt 2012 *IRC* Section R501.3 or 2015 *IRC* Section R302.13
  - Test data and good science does not support using unprotected 2x10 floor assemblies, which also effectively and arbitrarily limits the use of trusses and I-joists
  - Test data and good science shows current dimensional lumber does not perform in fire conditions like older dimensional lumber
  - Test data and good science does not support allowing use of fire retardants or intumescent coatings to provide equivalent protection to that of a ½" layer of gypsum
- Use ½" gypsum wallboard on all unprotected structural elements excluding uninhabited or mechanical spaces.
- Use automatic sprinklers through-out.
- Unjustified public policy will undoubtedly invite questions of responsibilities, if a fire fighter dies on an unprotected 2x10 floor;
  - Could this public policy be classified as negligence, considering the supporting test results?
  - How do the public policy decision makers evaluate the risks, given public policy is to safeguard public safety, health and general welfare?

Conclusions:

In jurisdictions that have adopted the 2012 or 2015 *IRC* with the requirements for ceiling protection as given in 2012 *IRC* Section R501.3 or 2015 *IRC* Section R302.13, testing shown in Table 1 illustrates that metal plate connected wood floor trusses with strongback perform very similar to 2x10 wood joists. Neither performs with the expected 15 minutes of fire performance.

In jurisdictions that are evaluating adoption of the 2012 or 2015 *IRC* we highly recommend they eliminate exception number 4, thus requiring all floor systems to include ceiling protection.

References:

Underwriters Laboratories, Improving Fire Safety by Understanding the Fire Performance of Engineered Floor Systems and Providing the Fire Service with Information for Tactical Decision Making, 2012. Available online.

NGC Testing Services, Reports FC-853, FC-858, FC855, FC-854, FC-855, FC-856, March, 2015

National Institute for Occupational Safety and Health Report F2006-26. July, 2007.

National Institute for Occupational Safety and Health Report F2007-12, May, 2008.

National Institute for Occupational Safety and Health Report F2006-24, September, 2007.

National Institute for Occupational Safety and Health Report F2007-07, November, 2007.

National Institute for Occupational Safety and Health Alert, "Preventing Injuries and Deaths of Fire Fighters due to Truss System Failures". Available online.

NIST, Examination of the Thermal Conditions of a Wood Floor Assembly above a Compartment Fire, Tech Note 1709, 2011. Available online.

National Institute for Occupational Safety and Health Workplace Solutions, Preventing Deaths and Injuries of Fire Fighters Working Above Fire-Damaged Floors, February, 2009. Available online.

National Research of Canada, Institute for Research in Construction; Fire performance of Houses, Phase I, Study of Unprotected Floor Assemblies in Basement Fire Scenarios, December, 2008. Available online.

National Research of Canada, Performance of Protected Ceiling/Floor Assemblies and Impact on Tenability with a Basement Fire Scenario, *IRC*-RR-307, 2011. Available online.

Tyco Industries, A Technical Analysis: The Performance of Composite Wood Joists Under Realistic Fire Conditions, September 2008. Available online.

Underwriters Laboratories, Structural Stability of Engineered Lumber in Fire Conditions, September 30, 2008. Available online.

International Residential Code, 2012 & 2015, by the International Code Council.

Other SBCA information on this subject:

- SBCA's R501.3 and R302.13 Resource Page
- Answering the Question: What Is Equivalent Protection to a 1/2-inch Gypsum Wallboard Membrane?
- SBCA's Views on Creating Fair Code Policy in Contrast to the AWC & NAHB Proposal Effectively Banning Floor Truss and I-joist Use
- NIOSH Data Affirms AWC/NAHB Approach to Firefighter Safety not Fact Based
- AWC & NAHB Author Original Code Change Proposals Effectively Banning Floor Truss and I-joist Use
- How Floor Trusses Became an Endangered Species, the Politics of it All
- SBCA Continually Advocates for a Common Sense, Fact-Based Approach to Fire Safety
- 7 Reasons to Immediately Delete Exception 4 from R501.3