Tech Notes SBCA

Fire Performance of Phenol Resorcinol Based Finger-Jointed Structural Building Components

Released May 16, 2007

Issue:

Structural Building Components that contain phenol resorcinol finger-jointed members are being used, at an ever increasing rate, in both residential and light commercial structures. The increased use of these products has raised concern within the Fire Service community. This led to a recent PowerPoint presentation, that was distributed anonymously through the Internet, that provided a heads-up and warning about the use of finger joints in floor trusses. Their primary concern, rightfully so, is the life/safety of occupants and firefighters when they encounter new products in construction that they do not see regularly. Firefighters do not want to be surprised by either unfamiliar products or unexpected performance in structures. This information is being provided in order that all readers have greater information concerning this topic, so that well informed decisions can be more easily made.

The key questions that need to be addressed include:

- How do the glues used in finger-joints perform in fire conditions?
- Are the finger-joints a weakness?
- How do finger-jointed structural building components perform in fire?

This document will address these questions as they pertain to structural building components that contain phenol resorcinol based finger-jointed wood based products.

Background:

Structural building components such as I-joists and trusses are manufactured products which replace the more traditional joist and rafter construction with a more sophisticated engineering approach to construction. These products, due to superior performance while using our wood resources more efficiently, are now widely used in light framed construction. One type of connection used in the manufacture of wood structural building components is the glued finger-joint. Glued finger-joints are used in many types of structural building components, including long floor joists, ceiling joists and rafters, wall studs, I-joists, trusses, and glulam beams. These types of products have been used in the marketplace for a very long time. Glulam beams, for instance, have been used heavily since they were patented in 1906. The use of finger joints became even more prominent with the advent of I-joists in the

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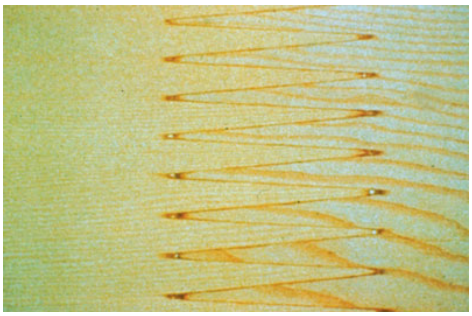
1970s. This paper addresses the fire performance concerns of finger-jointed structural building components using phenol or phenol-resorcinol adhesives, the most common type of adhesive in this application.[1]

Key Definitions:

Structural Building Components[2]: Specialized structural building products designed, engineered and manufactured under controlled conditions for a specific application. They are incorporated into the overall building structural system by the Building Designer. Examples are wood or steel roof trusses, floor trusses, floor panels, wall panels, I-joists, or engineered beams and headers made up of glued laminated members.

Finger-joints: Glued finger-joints are used in many types of wood structural building components, including long floor joists, ceiling joists and rafters, wall studs, I-joists, trusses, and glulam beams *(see Figure 3)*.

- Their characteristic interlocking fingers provide for a strong structural connection. Longer fingers with a slope of 1 in 8 on their cut edges are typical for structural products. A finger-joint can have up to 90% of the tensile strength of clear wood and exhibit similar behavior.[3]
- The *National Design Specification for Wood Construction* states that glued products with the proper grade stamps are acceptable for use in structural design.[4]



Glued finger-joint
FIGURE 3

Structural finger-joints: Structural building components used in horizontal load applications, such as floor joists, have Structural Finger-Joints. They are able to carry long duration bending loads. Structural Finger-Joints use phenolic type glues such as phenol resorcinol.

Finger-jointed trusses: Any type of wood truss may contain finger-joints. For example, a metal plate connected wood truss may use a structural finger-joint as a splice joint in its top chord material. One particular type of wood truss, defined as a "finger-jointed truss" in this paper, uses glued finger-joints at all of its joints (see Figure 4). These finger-joints occur wherever two wood members need to be joined together (e.g. web member to top or bottom chord and top or bottom chord splice joints.)

- They are used in parallel chord applications primarily as floor joist replacements.
- They can be used in any construction type that allows wood floor joists to be used. Currently their use is primarily in residential construction.
- They were introduced to the marketplace in 1989.

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[1] Other types of adhesives, such as melamine, melamine-urea, isocyanate, etc., are sometimes used in finger-joints that are not *structural finger-joints* (see Key Definitions). For more information, see Wood handbook—Wood as an engineering material. Gen. Tech. Rep. FPL–GTR–113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. See Table 9-3 in Chapter 9 Adhesive Bonding of Wood Materials, Charles B. Vick. www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm

[2] Metal Plate Connected Wood Truss Handbook, 3rd Ed., WTCA, Madison, WI., 2002. www.sbcindustry.com/pubs/hb3-d

[3] Forest Products Laboratory. 1999. Wood handbook—Wood as an engineering material. Gen. Tech. Rep. FPL–GTR–113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. Chapter 9 Adhesive Bonding of Wood Materials. Charles B. Vick, pp. 9-18 and 9-19. www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm

[4] American Forest & Paper Association. 2005. National Design Specification for Wood Construction. www.awc.org Chapter 4 states the following: "4.1.2.1 When the reference design values specified in the NDS are used, the lumber, including end-jointed or edge-glued lumber, shall be identified by the grade mark of, or certificate of inspection issued by, a lumber grading or inspection bureau or agency recognized as being competent (see Reference 31). A distinct grade mark of a recognized lumber grading or inspection bureau or agency, indicating that joint integrity is subject to qualification and quality control, shall be applied to glued lumber products."

- They are tested for structural strength by third party agencies and are built to specified standards.[5]
- The adhesive used in these trusses is phenol resorcinol and complies with the industry standard ASTM D2559, *Standard Specification for Adhesives for Structural Laminated Wood Products for Use under Exterior (Wet Use) Exposure Conditions*.[6]

Finger-jointed truss
FIGURE 4

Analysis:

Fire Performance of Phenol Resorcinol Adhesive

"The premise that adhesives soften during a fire is erroneous. The adhesives used in engineered wood components (I joists, LVL, glulam beams, etc.) are typically thermo-setting adhesives that do not soften when subjected to high temperatures. In fact, they get harder. Most often, these adhesives are formulated for durability and resistance to delamination when placed in exterior exposure conditions (i.e., outdoors). These adhesives are typically phenol-formaldehyde or phenol-resorcinol based, and have a char rate that is equal to or better than that of the wood they are bonding.[7] Generally, these adhesives do not ignite at the bond line, but do pyrolyze. Glue laminated beams [also laminated veneer lumber, parallel strand lumber, and other structural composite lumber] using these adhesives types are used under heavy timber code classifications, which means they have been proven to have extremely good fire endurance[8] performance behavior." [9]

1. Phenol resorcinol adhesive behaves as follows in fire:
    a. It starts burning at a higher temperature than wood. The autoignition temperature is 608°C (1130°F) for phenol resorcinol[10] vs. 270°C to 470°C (520°F to 880°F) for wood.[11]
    b. At temperatures below the charring temperature of wood, it does not soften, lose bonding capabilities, or breakdown chemically.[12] [13]
    c. In tests of glued wood blocks, "phenol resorcinol adhesives will not allow separation to occur in either the char or the wood during fire exposure."[14]

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[5] ICC Evaluation Service. 2005. ES Report ESR-1035. /www.icc-es.org/reports/pdf_files/ICC-ES/1035.pdf.
[6] ASTM. 2004. D2559-04 Standard Specification for Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet Use) Exposure Conditions, ASTM International; West Conshohocken, PA. www.astm.org
[7] Schaffer, E.L. and River, B., conversation on fire performance of adhesives, Forest Products Laboratory, May, 1992, Madison, WI.
[8] "Design of One-Hour Fire Resistive Wood Members (6-inch Nominal or Greater)", Council of American Building Officials Report No NER-250, NFiPA.
[9] National Engineered Lightweight Construction Fire Research Project, Technical Report: Literature Search & Technical Analysis, National Fire Protection Research Foundation, October 1992. p. 201. www.sbcindustry.com/images/fire/NFPRF_Report_WTCA_version.pdf.
[10] INDSPEC Chemical Corporation. IUCLID Data Set. June 15, 2004. Available from US EPA at: www.epa.gov/chemrtk/resorcnl/c15385.pdf. Chemical information on phenol: www.intox.org/databank/documents/chemical/phenol/cie29.htm
[11] Forest Products Laboratory. 1999. Wood handbook—Wood as an engineering material. Gen. Tech. Rep. FPL–GTR–113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. Chapter 17 Fire Safety. Robert H. White and Mark A. Dietenberger, p. 17-6. www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm
[12] Failure of floor assemblies constructed with timber joists, wood trusses or I-joists during fire resistance tests, Leslie R. Richardson, Forintek Canada Corp. p. 6 ans.hsh.no/if/brann/InterFlam/InterFlam%2004/files/603.pdf
[13] National Engineered Lightweight Construction Fire Research Project, Technical Report: Literature Search & Technical Analysis, National Fire Protection Research Foundation, October 1992. p. 208 www.sbcindustry.com/images/fire/NFPRF_Report_WTCA_version.pdf
[14] Schaffer, E.L. Nov. 1968. A Simplified test for adhesive behavior in wood sections exposed to fire. Research Note FPL-0175. USDA Forest Service. Forest Products Laboratory. Madison, WI. p. 13 www.fpl.fs.fed.us/documnts/fplrn/fplrn175.pdf

2. As used in finger-jointed structural building components, phenol resorcinol complies with the industry standard ASTM D2559, *Standard Specification for Adhesives for Structural Laminated Wood Products for Use under Exterior (Wet Use) Exposure Conditions.*[15]

Fire Performance of Structural Finger-Joints

After conducting dozens of fire tests on wood frame floor assemblies, including finger-jointed trusses and I-joists, researchers at Forintek Canada concluded that the finger-joints did not contribute to the assembly's failure in fire.[16]

Fire Performance of Structural Building Components with Structural Finger-Joints

The main question with finger-jointed structural building components is whether the adhesive will lose its bonding strength and allow the members to fall apart. Given the information provided, though, tests of the adhesive and of finger-jointed building components show that this does not occur. Observations of fire tests on finger-jointed trusses confirm this:

1. The Forintek Canada researchers found that in finger-jointed trusses, the finger-joints withstood exposure to fire until the wood members themselves were consumed.[17]
2. They also observed that when a web member or chord failed, it did not cause the others to dislocate.[18]
3. The bottom chord and web members burn through first, then the assembly sags significantly while supported by the top chord and floor sheathing.[19]

Finger-Jointed Structural Building Components in Fire-Rated Construction

Finger-jointed structural building components such as trusses and I-joists comply with building codes and are tested as fire rated construction under the ASTM E119 standard[20] by Intertek and UL. The following table provides examples of listed assemblies that contain finger-jointed lumber and provides links to each assembly report:

[15] ASTM. 2004. D2559-04 Standard Specification for Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet Use) Exposure Conditions, ASTM International; West Conshohocken, PA. www.astm.org

[16] Richardson, L.R. 2002. Thoughts and observations on fire-endurance tests of wood-frame assemblies protected by gypsum board. Fire Mater. 25(6):223-240. www3.interscience.wiley.com/cgi-bin/abstract/93514730/ABSTRACT

[17] Failure of floor assemblies constructed with timber joists, wood trusses or I-joists during fire resistance tests, Leslie R. Richardson, Forintek Canada Corp. p. 6 ans.hsh.no/if/brann/InterFlam/InterFlam%2004/files/603.pdf

[18] Ibid.

[19] Ibid.

[20] ASTM. 2000. Standard test methods for fire tests on building construction and materials. Designation E 119-00a. ASTM International; West Conshohocken, PA. www.astm.org

Fire-Rated Assemblies Using Finger-Jointed Lumber			
Structural Building Component	*Design Number(s)*	*Agency*	*Referenced Standards and Reports*
Metal Plate Connected Wood Truss	See WTCA Fire Assembly TTB for a summary list of wood truss designs		ANSI/TPI 1[21]
	L542, P522, and many more at the UL Online Certifications Directory[22]	UL	
	TSC/FCA 60-02, and many more at the Intertek Directory[23]	Intertek[24]	
Finger-Jointed Truss (proprietary)	L555	UL	ASTM D2559[25] ICC ES Report ESR-1035[26]
	OJ/FCA 60-01, OJ/FCA 60-02, OJ/FCA 120-01	Intertek[27]	
Steel-Web Truss (proprietary)	L518, L530, L538, L547, L570, L581, L583	UL	ICC ES Report ESR-1774[28]
	TJ/FCA 60-04, and more at the Intertek Directory[29]	Intertek[30]	
Wood I-Joists	L518, L530, L538, L547, L570, L571, L581, L583	UL	ASTM D5055[31]
	TJ/FCA 60-01, and more at the Intertek Directory[32]	Intertek[33]	

Conclusion:

From the most current research available, it can be concluded that structural building components that contain phenol resorcinol finger-jointed members are acceptable replacements for conventional building materials. The facts gathered suggest that the fire performance of this adhesive is equal to or better than that of wood, based on research undertaken and vetted. Furthermore, research has shown that the fire performance of the structural building component as a whole also is not adversely affected by the use of these finger-joints as a connection system. Additionally, the finger-joints themselves are not weak points in the fire performance of the structural floor assembly overall.

[21] ANSI/TPI 1 can be found at http://www.tpinst.org/my_news_ANSITPI1_available.html. Section 3.4.5 states: "Structural finger-jointed lumber shall be permitted to be used interchangeably with solid-sawn members of the same grade and species if the finger joints are manufactured with an adhesive meeting the requirements of ASTM D2559."

[22] To browse the UL Online Certifications Directory, click on "Numbering information for Fire Resistive Designs" to narrow a search. Look in group L 500-599 for gypsum protected floor assemblies, and in group P 500-599 for gypsum protected roof-ceiling assemblies.

[23] To browse the directory, go to the Index, look under the heading "ROOF/CEILING, FLOOR/CEILING, BEAM & COLUMN ASSEMBLIES", copy a design number, and paste into the Search box in the Directory.

[24] Intertek is also known as Warnock Hersey and ETL SEMKO.

[25] ASTM. 2004. D2559-04 Standard Specification for Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet Use) Exposure Conditions, ASTM International; West Conshohocken, PA. www.astm.org

[26] ICC Evaluation Service. 2005. ES Report ESR-1035. /www.icc-es.org/reports/pdf_files/ICC-ES/1035.pdf.

[27] Intertek is also known as Warnock Hersey and ETL SEMKO.

[28] ICC Evaluation Service. 2005. ES Report ESR-1774. http://www.trusjoist.com/PDFFiles/Code_PDFs/ESR-1774.pdf.

[29] To browse the directory, go to the Index, look under the heading "ROOF/CEILING, FLOOR/CEILING, BEAM & COLUMN ASSEMBLIES", copy a design number, and paste into the Search box in the Directory.

[30] Intertek is also known as Warnock Hersey and ETL SEMKO.

[31] ASTM-D5055 *Specification for Establishing and Monitoring Structural Capabilities of Prefabricated Wood I-Joists* can be found at www.astm.org. Section 5.1.2 states "End joints in purchased flange stock are permitted…" Section 6.4.2 states: "End joints produced by the I-joist manufacturer shall be qualified in accordance with 6.4.1 or the provisions of this specification."

[32] To browse the directory, go to the Index, look under the heading "ROOF/CEILING, FLOOR/CEILING, BEAM & COLUMN ASSEMBLIES", copy a design number, and paste into the Search box in the Directory. "Unless otherwise noted listed [wood I-joist] products and plants have been evaluated in accordance with the requirements of ASTM-D5055…" Intertek ETL Semko *2003 Directory of Listed Building Products*, p. 372.

[33] Intertek is also known as Warnock Hersey and ETL SEMKO.

Appendix A

For more information on this topic, see the following links and resources:

Carbeck Structural Components Institute fire performance educational programs:
www.fire.carbeck.org

WTCA Resources for Fire Professionals page:
www.sbcindustry.com/firepro.php

WTCA Fire & Wood Trusses page:
www.sbcindustry.com/fire.php

ICC News, Performance of Finger-Jointed Lumber in Fire-Resistance-Rated Wall Assemblies
http://www.iccsafe.org/news/afpa.html

Open Joist 2000:
www.openjoist2000.com

Evaluation Report from the International Code Council Evaluation Service:
www.icc-es.org/reports/pdf_files/ICC-ES/1035.pdf

Forintek Canada test results on fire resistance of floor assemblies:
ans.hsh.no/if/brann/InterFlam/InterFlam%2004/files/603.pdf

US Department of Agriculture test results on adhesive behavior in wood construction:
www.fpl.fs.fed.us/documnts/fplrn/fplrn175.pdf

National Engineered Lightweight Construction Fire Research Project:
www.sbcindustry.com/images/fire/NFPRF_Report_WTCA_version.pdf

U.S. Department of Agriculture, Wood Handbook (Chapters 9, 10, 11, and 17):
www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm

Chemical information on resorcinol:
www.epa.gov/chemrtk/resorcnl/c15385.pdf

Chemical information on phenol:
www.intox.org/databank/documents/chemical/phenol/cie29.htm

American Forest & Paper Association. 2005. National Design Specification for Wood Construction. Ch. 4:
www.awc.org/index.html

Metal Plate Connected Wood Truss Handbook, 3rd Ed., WTCA:
www.sbcindustry.com/pubs/hb3-d