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

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, 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, studs in walls, I-joists, trusses, and glulam beams.

The structural building components industry has grown from its metal plate connected roots to an industry which annually manufactures and distributes more than $15.3 billion in products, and employs over 123,000 people. Given the labor shortage in our country today and the desire to use wood resources more efficiently, there will be an ever increasing use of engineering and componentization to meet all the construction demands in the marketplace.

Issue:

There are times when products like finger-jointed trusses, in the marketplace since 1989, are ‘discovered’ and their relative newness causes concern. This was recently the case with a PowerPoint presentation distributed anonymously on the web that began with the following statement — “Folks, I just received a rather disturbing series of pictures of new construction currently going on in New Jersey. Apparently these new-style wood trusses are commercially available and no longer use the metal "gusset plates" that we are all familiar with. This new breed of firefighter-killers is simply 2x4 Finger Jointed lumber (yeah, it's not even dimensional lumber) held together by little spots of glue where the webs meet the chords. Check out the attached pics...[see Figures 1 and 2]”

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Figure 1: finger-jointed trusses in a ceiling

Figure 2: Close-up of finger-jointed trusses

This type of commentary raises serious questions about finger-joints from the perspective of fire safety. 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 answer these questions as they regard finger-jointed trusses.

Key Definitions:

Structural Building Components[1]: 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.

Finger-joints: Glued finger-joints are used in many types of wood structural building components, including long floor joists, ceiling joists and rafters, studs in walls, 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.[2]
- The *National Design Specification for Wood Construction* states that glued products with the proper grade stamps are acceptable for use in structural design.[3]

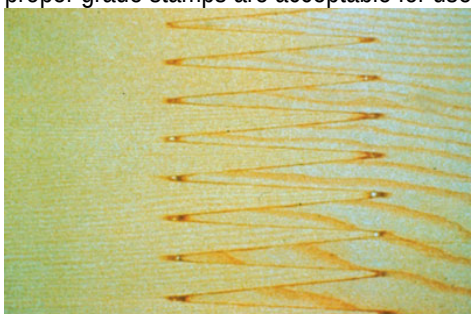

Figure 3: Glued finger-joint

Finger-jointed trusses: These are floor trusses made using a glued finger-joint process (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] Metal Plate Connected Wood Truss Handbook, 3rd Ed., Wood Truss Council of America, Madison, WI., 2002. http://www.sbcindustry.com/pubs/catalog.php?Fieldname=CategoryID&ID=66

[2] 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. http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm

[3] American Forest & Paper Association. 2005. National Design Specification for Wood Construction. http://www.awc.org/index.html 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.[4]
- 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*.[5]
- For more information, contact Open Joist 2000, the only company which markets finger-jointed trusses. Product literature can be found at: http://www.openjoist2000.com.

Figure 4: Finger-jointed truss

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.[6] 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 performance behavior.[7]" [8]

[4] ICC Evaluation Service. 2005. ES Report ESR-1035. http://www.icc-es.org/reports/pdf_files/ICC-ES/1035.pdf.
[5] 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
[6] Schaffer, E.L. and River, B., conversation on fire performance of adhesives, Forest Products Laboratory, May, 1992, Madison, WI.
[7] "Design of One-Hour Fire Resistive Wood Members (6-inch Nominal or Greater)", Council of American Building Officials Report No NER-250, NFiPA.
[8] National Engineered Lightweight Construction Fire Research Project, Technical Report: Literature Search & Technical Analysis, National Fire Protection Research Foundation, October 1992. p. 201. http://www.sbcindustry.com/images/fire/NFPRF_Report_WTCA_version.pdf.

The glue used in finger-jointed trusses is phenol resorcinol.

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[9] vs. 270°C to 470°C (520°F to 880°F) for wood.[10]
    b. At temperatures below the charring temperature of wood, it does not soften, lose bonding capabilities, or breakdown chemically.[11] [12]
    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."[13]
2. As used in finger-jointed trusses, 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*.[14]

Fire Performance of 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 their failure in fire.[15]

Fire Performance of Finger-Jointed Trusses

The main concern with finger-jointed trusses is that the adhesive will lose its bond and allow the members to come 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.[16]

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[9] INDSPEC Chemical Corporation. IUCLID Data Set. June 15, 2004. Available from US EPA at: http://www.epa.gov/chemrtk/resorcnl/c15385.pdf.
Chemical information on phenol: http://www.intox.org/databank/documents/chemical/phenol/cie29.htm

[10] 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.
http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm

[11] 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 http://ans.hsh.no/if/brann/InterFlam/InterFlam%2004/files/603.pdf

[12] National Engineered Lightweight Construction Fire Research Project, Technical Report: Literature Search & Technical Analysis, National Fire Protection Research Foundation, October 1992. p. 208
http://www.sbcindustry.com/images/fire/NFPRF_Report_WTCA_version.pdf

[13] 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
http://www.fpl.fs.fed.us/documnts/fplrn/fplrn175.pdf

[14] 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

[15] 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. http://www3.interscience.wiley.com/cgi-bin/abstract/93514730/ABSTRACT

[16] 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 http://ans.hsh.no/if/brann/InterFlam/InterFlam%2004/files/603.pdf

2. They also observed that when a web member or chord failed, it did not cause the others to dislocate.[17]
3. The bottom chord and web members burn through first, then the assembly sags significantly while supported by the top chord and floor sheathing.[18]

Finger-jointed trusses comply with building codes and are tested as fire rated construction under the ASTM E119 standard[19] by Intertek[20] and UL.[21] The links for viewing these assemblies follow:

1. Intertek assembly OJ/FCA 60-01
2. UL assembly L555

Conclusion:

The main concern with finger-joints in finger-jointed trusses is that the phenol resorcinol adhesive will fail earlier than expected – by either losing bonding capability or burning up more rapidly – when subject to a fire. The facts gathered suggest that the fire performance of the adhesive used in finger-joints of finger-jointed trusses is equal to or better than that of wood, based on research undertaken and vetted. Furthermore, research has shown that the finger-joints themselves are not weak points in fire performance under structural loading. The fire performance of the structural building component as a whole also was not affected by the use of finger-joints as a connection system.

[17] Ibid.
[18] Ibid.
[19] 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
[20] Intertek OJ/FCA-60-02 http://www.openjoist2000.com/DATA/BROCHURE/fire_en.pdf
[21] UL L555 http://database.ul.com/cgi-bin/XYV/template/LISEXT/1FRAME/gothernbr.html (Type "L555" in the top left box)

Appendix A

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

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

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

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

Open Joist 2000:
http://www.openjoist2000.com

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

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

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

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

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

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

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

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

Metal Plate Connected Wood Truss Handbook, 3rd Ed., Wood Truss Council of America
http://www.sbcindustry.com/pubs/catalog.php?Fieldname=CategoryID&ID=66

View all WTCA Tech Notes at www.sbcindustry.com/kb/technotes.php.