ASTM C 79/C 79M-01, ASTM C 588/C 588M-01, ASTM C 630/C 630M-01)

Product Standards Updated

- *ANSI A208.1-99, Particleboard,* ANSI, New York, NY, 1999.
- *PS 1-07 Structural Plywood,* United States Department of Commerce, National Institute of Standards and Technology, Gaithersburg, MD, 2007.
- *PS 2-04 Performance Standard for Wood-Based Structural Use Panels,* United States Department of Commerce, National Institute of Standards and Technology, Gaithersburg, MD, 2004.

2008 SDPWS Commentary

Updates to the *SDPWS Commentary* based on input from users and new information considered in development of the *2008 SDPWS* standard will be available in early 2009.

Building Codes and Standards

The *2008 SDPWS* has been approved as a reference document in the *2009 International Building Code* and has been submitted for adoption as a reference document in *ASCE 7-11 Minimum Design Loads for Buildings and Other Structures.*

Conclusion

AWC's *2008 SDPWS* was approved August 4, 2008 as an American National Standard. *SDPWS* covers materials, design, and construction of wood members, fasteners, and assemblies to resist wind and seismic forces.

As an update to the *2005 SDPWS* standard, several notable new provisions of the *2008 SDPWS* standard provide new design options for wood construction to resist forces from wind or seismic coupled with limitations on the use of new design options. Examples include new criteria for wood structural panels designed to resist combined shear and uplift from wind, addition of provisions for unblocked shear walls, and an increased aspect ratio for structural fiberboard shear walls.

The *2008 SDPWS* standard is available to download free at www.awc.org.

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Fire Resistance of Log Walls

Rob Pickett

Introduction

In the modern age of log construction, reports have documented that fires have burned inside or outside of log buildings without destroying the building's structural integrity. Proving that this performance is typical has been difficult, since most log home companies do not have the resources for testing to demonstrate fire resistance of their wall system(s). Therefore, the intent of this paper is to explain why and how those reports can be supported.

Building Code Requirements

The four fire principals are prevention, detection, evacuation, and containment, in that order. Detection and evacuation requirements are clearly stated in the building codes and apply to log buildings just as they would for any other type of construction. Code requirements for containment are taken from the *2006 International Residential Code® (IRC)*, published by the International Code Council, Inc. (ICC).

Section R315 pertains to flame spread and smoke density. Wall and ceiling finishes are required to have a flame-spread classification of not greater than 200 and a smoke-developed index of not greater than 450 when tested in accordance with ASTM E-84, *Standard Test Method for Surface Burning Characteristics of Building Materials*. To provide standard conditions, the test machine is calibrated to an index of 0 for noncombustible materials and 100 for 23/32 in. red oak flooring. Indices for tested materials can range from 0 to over 1,000. The ratings are grouped in three classes:

- Class A rating = 0 to 25; typical of escape routes in buildings with large occupancy expectations.
- Class B rating = 25 to 75; typical of rooms over 1,500 ft^2 in area and escape routes in buildings with moderate size occupancy loads.
- Class C rating = 75 to 200; elsewhere in low to moderate fire hazard conditions.

A vast group of *ASTM E-84* tested samples has provided flame spread ratings for softwoods from 60 to over 150. A collection of wood species and flame spread ratings is provided in AF&PA's *Flame Spread Performance of Wood Products – DCA 1* (www.awc.org/Codes/dcaindex.html#FirePubs).

Section R602.8 pertains to fireblocking and states, "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."

Where logs stack directly on one another, the walls are an assembly of solid wood and do not have cavities through which flames can spread. For log wall technologies that incorporate a space (horizontally) between logs, it is quite common to provide solid wood bearing blocks on regular intervals not exceeding 10 feet to comply with R602.8. Many second floor and roof assemblies are constructed using beam and deck assemblies, again without concealed cavities conducive to flame spread.

Section R317 pertains to containment by separating dwelling units. A rated fire-resistant barrier built between different occupancies such as the wall between the living area of a dwelling and a garage attached to it separates the occupancies and provides containment. When a 1-hour fire-rated assembly is required for separation, the conventional response is to apply 5/8 in. Type "X" gypsum board on common walls/ceilings with a 20-minute fire-rated door (wood solid core) with automatic closing device. This wall assembly is acceptable as a fire-rated assembly because sufficient testing in accordance with ASTM E-119, *Fire Tests of Building Constructions and Materials* has been performed.

Fire-resistance ratings are based on E119 tests. The tests produce rates, by time, for which an assembly maintains structural integrity under full design load, prevents flame penetration, and limits temperature increase on the side opposite the burn to less than 250°F. Specific log wall assemblies have been tested and rated for a 1-hour duration, but the sample of tested assemblies is still small.

What Happens to Wood in a Fire?

Fire can be controlled by removing heat, oxygen, or a fuel source: the wood itself.

Insulating Effect of Char

As an organic material, wood is combustible. Yet its insulating and charring characteristics produce an astounding response to fire. While wood begins to char at 300°F, commonly exceeded in the first 5 minutes of an accidental fire, the wood beneath the char remains structurally sound. Compare this unique response to that of structural steel which loses 50 percent of its strength at 1000°F.

Chapter 17 of the USDA Forest Products Lab *Wood Handbook* explains the effect of charring: "The temperature profile within the remaining wood cross-section can be used with other data to estimate the remaining load-carrying capacity of the uncharred wood during a fire and the residual capacity after a fire." This is essentially what AF&PA demonstrates in Technical Report 10, *Calculating the Fire Resistance of Exposed Wood Members* and summarizes in *Design for Code Acceptance, DCA 2 – Design of Fire-Resistive Exposed Wood Members*. These documents are relevant to the discussion as they are the original research that effectively became Chapter 16 of ANSI/AF&PA NDS-2005, the *National Design Specification® (NDS®) for Wood Construction*.

The *NDS* notes that a nominal char rate of 1.5 in./hr. in the direction perpendicular to the surfaces of exposure to fire is commonly demonstrated. The wood that remains within the estimated char layer is analyzed in accordance with the *NDS* to determine its remaining strength after a fire. Essentially, the initial size of the timber is specified to provide the required section properties plus the estimated char layer per surface that is exposed. For beams (3-sided exposure) and columns (4-sided exposure), this is illustrated in **Figure 1** which is from AF&PA's Technical Report 10.

Charring must also be considered when designing the connection of timbers with hangers and/or fasteners. For example, if the connection is intended to survive a 1-hour fire event, it is likely that the fastener length will need to be longer so that it is connected to structurally sound wood. Its diameter may also be a factor to resist the heat flux of the fire. APA–The Engineered Wood Association Technical Note #Y245 also presents the approach taken by AF&PA, but this paper goes further to describe and illustrate how connections can be protected for fire-resistive construction. Concealed by 5/8 in. Type "X" gypsum or 1-1/2 in. of wood, the fasteners are less likely to conduct heat through the connection.

Code Comparison: Solid Wood Walls vs. Heavy Timber Construction Type

Until 2007, when ICC published *ICC 400, Standard on the Design & Construction of Log Structures*, there was a lack of recognition of log construction in building codes. *ICC 400*, formally referenced in the 2009 International Codes, adopted the precedent set by the *1997 Urban Wildland Interface Code*.

To establish performance of a log home in a fire, designers had to reference the ICC *International Building Code (IBC)* for the definition of heavy timber construction. The most similar type of construction in the codes continues to be heavy timber (Type IV), using massive beams, posts, rafters, and other structural members. The *IBC* lists requirements for Type IV construction in Section 602.4:

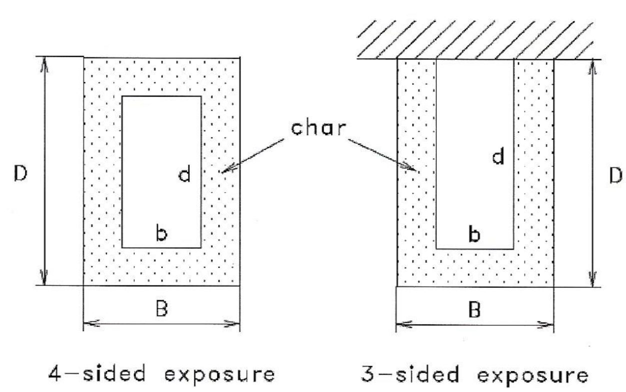

Figure 1.—Symbols for cross-sectional dimensions (Courtesy of American Forest & Paper Association, Inc., Washington, DC).

- Beams and girders: Not less than nominal 6 by 10 (in., width by depth)
- Columns: Not less than 8 in. nominal when supporting floor loads; nominal 6 by 8 (in., width by depth) or greater for roof and ceiling loads only
- Rafters, purlins, timber trusses: Not less than nominal 4 by 6 (in., width by depth)
- Decking: Floors and roofs shall be without concealed spaces. "Wood floors shall be of sawn or glued-laminated planks, splined or tongue-and-groove, of not less than 3 inches nominal in thickness covered with 1-in. nominal dimension tongue-and-groove flooring, laid crosswise or diagonally…" For wood roof decks, the dimension changes to 2 in. nominal.

An interesting component of the *IBC* Type IV Construction is the allowance for exterior structural members in Section 602.4.7: "Where a horizontal separation of 20 feet or more is provided, wood columns and arches conforming to heavy timber sizes shall be permitted to be used externally." This is a relevant note because the typical exterior wall of Type IV construction is masonry or other material that provides a 2-hour fire-resistance-rated construction. Further in 602.4.7, "Partitions shall be of solid wood construction formed by not less than two layers of 1-inch matched boards or laminated construction 4 in. thick, or of 1-hour fire-resistance-rated construction." It would appear that most log walls would satisfy the partition component of Type IV construction.

The importance of being recognized as Type IV construction goes beyond just the size of the structural elements. Expected use, or occupancy group, of the building is also a factor in establishing the required fire-resistance rating for exterior walls as determined by the fire separation distance between structures and the height of the wall. For residential construction where neighboring structures are 30 feet or more apart, the exterior wall is not required to be fire-resistance rated, but a 1-hour rating from both sides is required within 5 feet of another structure.

Comparison of log buildings to Type IV construction is relevant because many log structures likewise employ structural timbers as joists, rafters, beams, and posts. The log home distinction is that the timbers also act as the structural component of the walls. As wall-logs, the wall members have structural capacity and are fully supported along their length. Stacking logs to form a solid wall, however, produces a different dynamic in fire, more like that of a glued laminated beam. The key section in the code is really *IBC* 704.6: "The wall shall extend to the height required by Section 704.11 and shall have sufficient structural stability such that it will remain in place for the duration of time indicated by the required fire-resistance rating."

Load Transfer Comparison

In heavy timber construction, the structural loads placed on the assembly are transferred from spanning members (beams, rafters, joists) to specific bearing areas (post, column, mullion, bearing wall). In log structures, the exterior bearing wall is a continuously supported solid wood member supporting the same heavy timber structural frame members.

- Rather than substantial concentrated loads on a few vertical members supporting the entire framework, log wall construction spreads the loads throughout the entire structure.
- Secondly, the log wall assembly is likely to be only fully exposed to fire on one side, and partially exposed to fire at the log to log interface, while the timber column will have all three or all four surfaces exposed.

These are important considerations since the log building is likely to be less prone to collapse in any one area under a fire condition.

Fire Exposure Comparison

Like the requirement for structural members in Heavy Timber Construction to have a minimum 6 in. nominal dimension, ICC 400 equates a minimum 6 in. at the narrowest point to a 1-hour fire-rated assembly. In the absence of supporting research and/or testing, it is impractical to include log wall technologies that have narrower dimensions. It is also important to note that ICC 400 does not consider sealants or other materials between logs, so that the fire-resistance is considered only on the basis of the width of the log wall. Sealants (e.g., chinking systems) can have a dramatic effect on the wall's performance, but ASTM E-119 testing of the specific materials and assembly would be required to acknowledge a rating.

Paths for Code Compliance

Section 303 of *ICC 400*, creates three distinct paths for establishing fire resistance ratings of log walls.

- 303.2.1 Prescriptive rating. Log walls are equivalent to 1-hour fire-resistive-rated construction where the smallest horizontal dimension of each log is at least 6 in.
- 303.2.2 Calculated rating. Log wall fire resistance shall be calculated in accordance with Chapter 16 of the *NDS*.
- 303.2.3 Tested rating. Log wall fire resistance shall be tested in accordance with ASTM E 119 by an accredited laboratory.

Calculating Fire Resistance Rating

In DCA 2 – *Design of Fire-Resistive Exposed Wood Members*, guidelines are given for calculating the effect of fire on columns (exposed on four sides) and beams (exposed on three sides). This simplified approach based on empirical testing provides the calculation of fire resistance rating for a given timber beam size, in minutes, equal to:

$$\text{Minutes of fire resistance rating} = 2.54\,Zb\,[4 - (b/d)].$$

where:

b = the breadth (width) of a beam or larger side of a column before exposure to fire, in. By definition of this section, the minimum breadth is 6 in. nominal (5.5 in., actual per the *NDS*).

d = the depth of a beam or smaller side of a column before exposure to fire, in. It is assumed that each horizontally laid wall-log (as defined by ASTM D-3957) acts as a beam to support roof/floor loading

Z = the load factor is typically established at 1.3 for a beam

Using these criteria, the ratings for a nominal 4-in.-, 6-in.-, and 8-in.-thick log wall were calculated as follows. The first three calculations maintain the premise assumed above. The last provides a more conservative approach that coincides with the definition of heavy timber construction.

If b>=3.5 in., d=3.5 in., and Z=1.3;
(2.54*1.3*3.5*[4 – (3.5/3.5)]) = 34.67 minutes

If b>=5.5 in., d=5.5 in., and Z=1.3;
(2.54*1.3*5.5*[4 – (5.5/5.5)]) = 54.48 minutes

If b>=7.25 in., d=7.25 in., and Z=1.3;
(2.54*1.3*7.25*[4 – (7.25/7.25)]) = 71.82 minutes

If rating = 60 minutes, b=d, and Z=1.3;
(60/(2.54*1.3*[4 – (4/4)])) = 6.057 inches

Applying *NDS* Principles to a Log Wall

While it has been established that the log wall is capable of acting as a beam (a structural member that is designed to resist bending), the nature of the wall assembly is similar to that of decking when exposed to fire. In the discussion of fire design in Chapter 16 of the *NDS*, there is a provision for Timber Decks (Section 16.2.5) that can be applied to log walls. This section can be applied in that the log wall should be "designed as an assembly of wood beams fully exposed on one face" if a tongue and groove (T&G) exists between logs.

Section 16.2.5 also makes a distinction between T&G decking as opposed to pieces that are butted to each other. In a log wall, like in a plank floor or roof, these butted joints can be at the ends of the piece and/or along the sides. A conservative approach to designing a log wall with butt joints to resist a 1-hour fire event would be to include the required effective char layer to the exposed face and to be sure that the edges at the butt joints are reduced by 33 percent of the effective char rate. For 1-hour fire endurance, the horizontal dimension of the log section would be reduced by a 1.8-in. char layer, and the vertical dimension would be reduced by 0.6 in. along the top and bottom edges (**Fig. 2**).

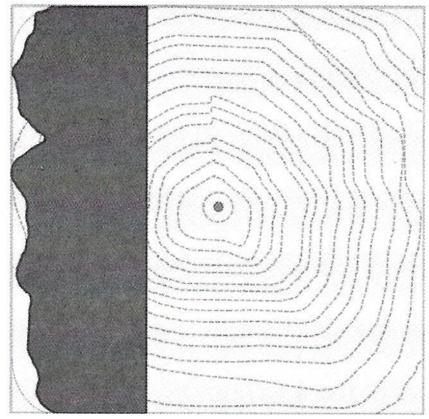

Figure 2.—Charring on the exposed face of a 6 by 6 after 1 hour.

Whether horizontal or vertical, it is clear that the design of the joint between logs and the sealants used to protect them have as much of an effect on fire performance as they do on air infiltration. The reported performance of planks, T&G decking, and glued laminated beams substantiates this concept.

When designing the fastening schedule for the log wall, the fire-resistance rating of the wall should be considered in addition to edge and end distance or the need for lead holes. For a 1-hour rated assembly, the fasteners should be placed a minimum of 1.8 in. from either edge of the log profile. Fastened along the centerline, a 3.6-in.-wide bearing area of log-on-log will protect the connection. When sealants or coatings approved for the required endurance time are used, this distance to the edge of the log can be reduced (e.g., when covered by a rated chinking product).

Table 1 from AF&PA *TR10* demonstrates the design load ratios for exposed butt-joint timber decks. It is relevant to log walls in that the tabulated values (resulting from principles of engineering mechanics presented in the report and included in *NDS* Chapter 16) show that a wall assembly

Table 1.—*TR 10* Table 10.—Butt-Joint timber decking (American Forest & Paper Association, Inc., Washington, DC).

Rating	1 hour				1.5 hour			2 hour	
Beam width	1.5	2.5	3.5	5.5	2.5	3.5	5.5	2.5	5.5
Beam depth	Design load ratio, R_s								
2.5	0.05	0.12	0.15	0.18	--	--	--	--	--
3	0.09	0.24	0.30	0.36	0.03	0.04	0.05	--	--
3.5	0.14	0.35	0.44	0.53	0.08	0.12	0.16	--	--
4	0.18	0.45	0.57	0.68	0.14	0.21	0.28	0.02	0.08
4.5	0.21	0.54	0.68	0.80	0.19	0.30	0.39	0.04	0.16
5	0.24	0.61	0.77	0.92	0.24	0.38	0.50	0.06	0.24
5.5	0.27	0.68	0.85	1.00	0.29	0.45	0.59	0.09	0.32

consisting of nominal 6 by 6 timbers would remain at 100 percent of the structural capacity of the original cross-section after a 1-hour fire event.

At openings in the log wall, the common practice of installing a wood frame (buck) in which to install windows or doors is beneficial to the fire performance of the opening. When the buck is largely self-supporting and consists of nominal 2x or larger lumber, the buck protects the ends of the logs and the bottom of the header; the buck will be sacrificed to the fire rather than the log. Therefore, the header log(s) can be assumed to experience the same charring as the remainder of the log wall.

Conclusion

The fire resistive nature of solid wood walls is a combination of the insulating response of the charred wood at the surface with the slow rate at which flame will spread along the wood surface. In addition to those qualities, a solid wood wall has no concealed cavities in a log wall through which the fire may travel. Combined with the selection of beam and deck second floor and roof options often incorporated into log buildings, log structures can provide exceptional endurance and integrity in a fire.

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Design Ambiguities: A Modern Southern House?

David C. Lewis, Ph.D.

Introduction

The purpose of this paper is to introduce a comparison for comprehending and applying an ambiguity in ecological design. The particular intent is to illustrate that three general factors of ecological design – energy consumption, durability, and indoor environmental quality – are not necessarily compatible with one another when designing and constructing a wood house for the southeastern United States. In other words, design and construction decisions required to reduce energy consumption do not necessarily ensure the durability of a building. As a result, it is necessary to understand the relationships among the attributes of these three factors and to acknowledge that the degree of "sustainability" must result from how the designer prioritizes the attributes so to appropriately respond to the specific climatological, geographic, and cultural conditions of the setting.

To those even cursorily familiar with the southeastern United States, the subtitle should appear to be oxymoronic – a modern southern house? The southeast United States, or as it is better known "the South," is identified by its stately European-inspired mansions and its vernacular housing. Both hearken to a bygone era, be it to an across-the-ocean style or to a bucolic, agrarian lifestyle. However, and even more ironic, the contemporary, suburban house superficially mimics these precedents, which verges on the comical when mixed together. These houses make no attempt to look modern, nor "act" southern – climatically.

The goal for this exposition of the southern house is to educate people that residences should "act" southern rather than just look southern. Underlying this goal is the premise that the performance of a wall, roof, and floor gives that feature its identity, while the visual pattern only provides apparent coherence. This premise differs categorically from the modernist tenet "Form Follows Function," particularly the singular, linguistic interpretation of the exterior form expressing interior function. It also acts as a critical commentary on style as the sole means of identity. The porch illustrates the point. The porch has long been associated with southern architecture. If two buildings are side-by-side, the one with a porch is considered southern. Why? The porch is an exterior room that shades the exterior walls of the house, which in turn reduces the temperature difference between interior and exterior. The covered porch also provides extensive overhang that sheds water away from the foundation and ensures that the moisture content in the crawl space is low. Abstracting the situation to the level of performance requirements, in this case providing a reduced temperature differential and lowered humidity allows the designer to think beyond the idea of physical or stylistic features, such as the porch. The designer may accomplish these environmental concerns through a double-skin wall and overhang, or with a set of strategically placed projections and a drainage system. By recognizing the physics of the climate, an architect can focus on and highlight that physical condition with the design. In particular, it will pro-