LOG BUILDING NEWS

All the News About Fits

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How Log Buildings Resist Lateral Loads

By Tom Hahney © 2000

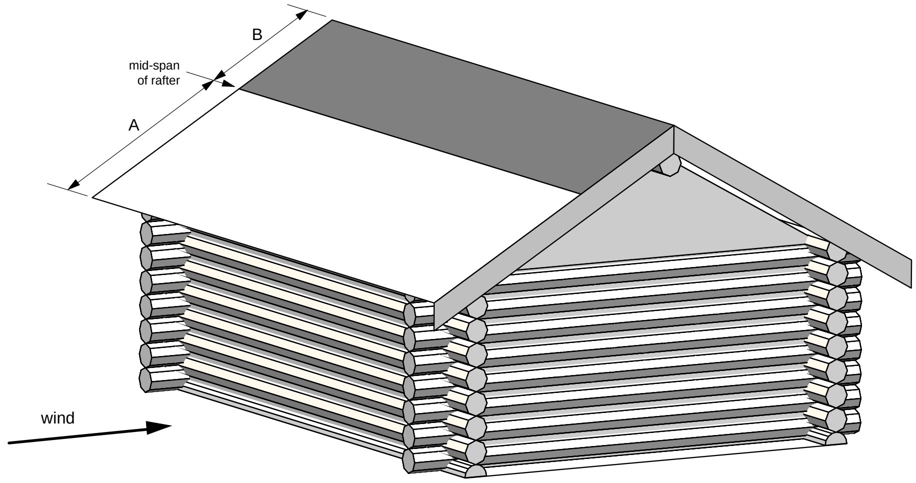

Figure 1 *A simple test building: four log walls one story tall and the wind blowing at right angles to the ridge. All drawings © by the author.*

Buildings come under various stresses and strains, and they must be designed with these in mind. When forces act on a building in a direction that is parallel to the ground, like a strong wind, or earthquake loads, we call it lateral loading.

The interlocking joinery in a handcrafted scribe-fit log structure creates a building that acts differently than a conventional wood-framed building under lateral loading. This article introduces a model that is based on log joinery and the concept of a beam that is supported along its length as well as at its ends, and that is loaded horizontally—from the side.

Although this model for lateral loading was developed for scribe-fit buildings, it may be possible to use all or part of the model to analyze manufactured and chinked log buildings depending on how a particular building is constructed. But here I will address scribe-fit buildings only. One important part of this model is that the logs have their original organic forms — the swelling around knots and undulations of their surfaces.

Stick Frame vs. Log Models:

I will begin with wind loading and how a log building is different than a conventionally framed building. Let's consider a rectangular building with a pitched roof, and with the wind blowing on the building from a direction perpendicular (90°) to the ridge (Figure 1 & Figure 1.1). In this example, the log building has four log walls, all one story, and with gable ends that are conventionally framed. The logs are joined, as usual, with a long groove as shown in Figure 2, Figure 2.1 and Figure 2.2, and corner notches as shown in Figure 3. This is the common type of handcrafted scribe fit log joinery used today. (Other types of corner and long groove notches may have similar or better resistance to loads and can be evaluated on a case-by-case basis.)

The studs in the windward wall of a conventionally framed building act like vertical beams when they are pushed on by wind (Figure 4). The wind load on the lower half of the windward wall is handled by the foundation, and the wind load on the upper half of the windward wall and on the windward roof is handled by the roof diaphragm. The roof diaphragm, in turn, transfers its load to the gable walls. The gable walls act as shear walls that transfer the load into the foundation through the stiffness of their construction. The stiffness of a frame wall is based on the thick-

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ness, type and orientation of wall sheathing, spacing and size of studs, and the fastener's size and spacing.

For the log building let's consider the wind pushing on the roof, and on the top log in that wall. Ignoring uplift forces for the moment, what parts of the log building keep the top log of the windward wall from being pushed off of the building?

Think about the top log in the windward wall as a horizontal beam, loaded by the force of the wind blowing on the area that is equal to the surface area of the top log, plus the area of the windward roof supported by this top log. The area of the windward roof supported by the top log is equal to the length of the roof times the vertical height from the eave to the mid span of the rafters (that is, the bottom half the roof)—this is the 'A' portion of the roof in Figure 1 and 1.1.

The top log is held in place by corner notches and a long groove. The wind load (F 1) on the roof and on the top course of the windward log wall (1 W) is resisted by the long groove in the top log (1 W) and by the log below it (2 W). Log 2 W resists moving by getting help from almost all of the logs in the building. Here's how:

Each log transfers the load from the windward wall long groove to the log below, all the way down the wall. At the corner notches, the force from the windward wall logs is transferred to the side wall logs. In turn, each side wall log is stabilized by friction with the log below it, and so on down the full height of the building.

Additionally the leeward (down-wind) wall of the building adds

Friction

$F = \mu N$

F = friction force
μ = coefficient of friction
material and surface roughness dependent
wood on unpolished steel = 0.70
smooth wood on smooth wood = 0.60
N = the normal force, i.e.
the weight of the logs and other loads carried by the logs

Example using just the weight of the log
Friction between log X and log Y:
F = 0.70 x 37#/ft = 25.9 #/ft of log length
If wall log is 30' long F = 30' x 25.9 #/ft = 777#

Where:
μ = 0.70
N = 37#/ft

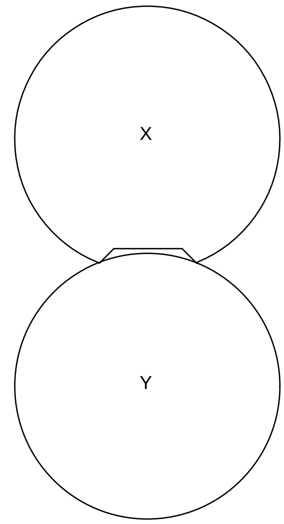

Figure 2 *The friction between logs, where the long groove touches, helps prevent sliding along their lengths.*

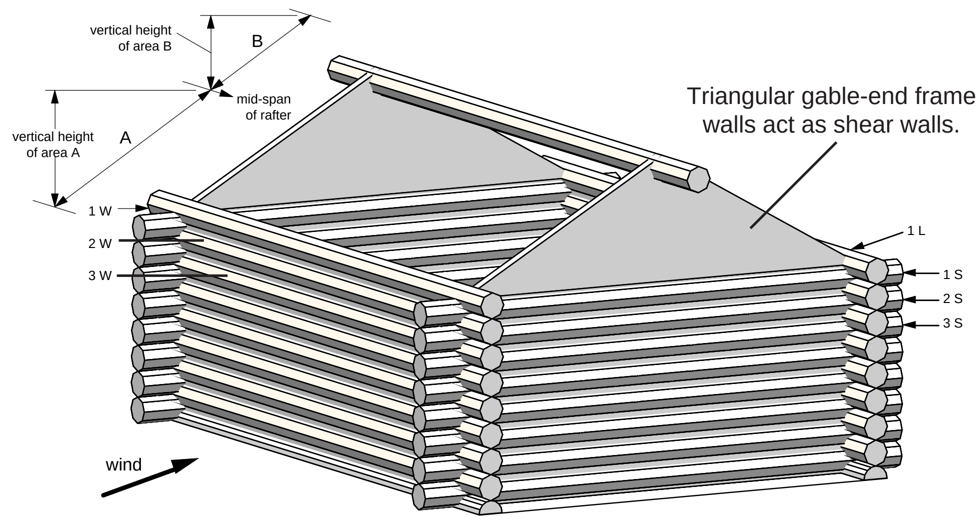

Figure 1.1

UPLIFT on roof is transferred to the plate logs by:

1--Rafter connections to Log 1W and by ridge connection to Log 1S by the gable frame wall.
2--Log 1W connected to Log 2S (through-bolts or lag screws).
3--Weight of 8 wall logs and roof framing resist uplift.

WIND on Area 'B' tries to move ridge and is resisted by:

1--Gable end frame shear walls taking load to Log 1S.
2--Log 1S movement is resisted by: friction between Log 1S and Log 2S; and by corner notch with Log 2W and 2L; and by long groove with Log 3W and 3L and corner notch with Log 3S, and so on.
3--Lag screws or through-bolts.

WIND on Area 'A' tries to move log 1W and is resisted by:

1--Log 1W long groove on Log 2W
2--Lag screws or through bolts between 1W and 2W.
3--Corner notch with Log 1S.
4--And then movement of Log 1S is resisted by: friction with log 2S; and by corner notch with Log 1L and so with 1L long groove on Log 2L and lag screws or through-bolts; and by corner notches with Log 2W and 2L and their long grooves below; and by lag screws and through-bolts.

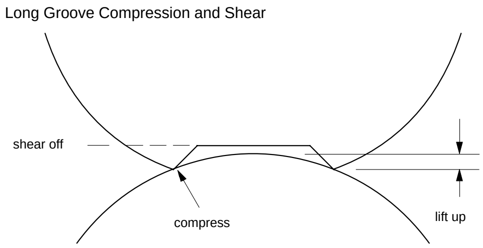

Figure 2.1 *To move a log sideways in the wall, one edge of the groove would have to shear off, or the log would have to be lifted high enough to pass over the log below.*

resistance. As the top course of the side wall (1 S) attempts to move, it is not only resisted by the friction force between itself and the log below it, 2 S, but also by the logs in the leeward wall below 2 L (the second log down on the leeward wall). The corner notch at the leeward corner of the building transfers load from 1 S to 2 L. This attempt to move log 2 L is resisted by the long groove between it and log 3 L, and so on down the wall.

This system of interlocking corner notches and long grooves provides resistance to lateral loads, and any attempt to move the top windward wall log is resisted by most all of the logs of the windward, leeward and side walls.

Long Groove Mechanical Resistance

Let's look at the windward and leeward logs. Figures 2.1 and 2.2 are cross sections of the long groove that show how this joinery resists a load that is trying to push a windward or leeward log off of the log below it. As long as uplift is taken care of, the full length of the long groove would need to be sheared off before there would be significant movement.

Long Groove Friction

Some of the strength of a log side wall comes from the friction between two adjacent logs where their long groove touches. Much of the friction comes from the irregularities of the original natural forms: the swelling around knots and undulations of the surface. Figure 5 shows how this can happen. In addition, the edges of long grooves are usually sharp, and as such, they 'bite' into the log below. Sometimes, the edges of the long groove even slightly crush the wood fibers

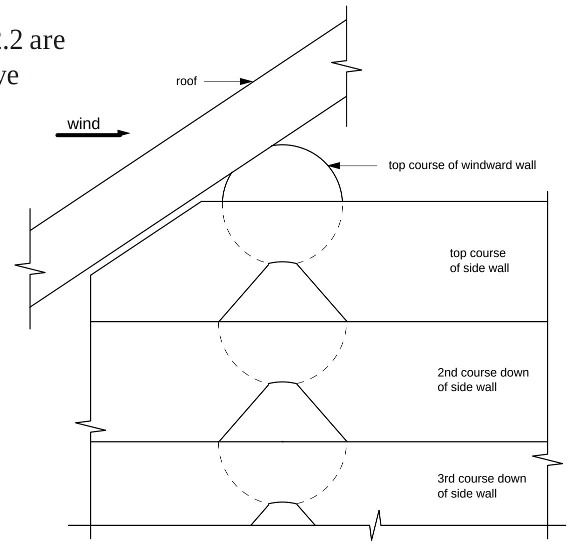

Figure 3 *One typical corner joint in log homes. Because the logs interlock at the corners, to move a log laterally requires logs in the adjoining wall to slide on each other.*

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of the log below. Resistance comes from the natural log shapes combined with the biting action.

The 1974 edition of the *Wood Handbook: Wood as an Engineering Material* tells us that the coefficient of friction depends on the moisture content of the wood and the surface roughness. Coefficients of static friction for wood on unpolished steel are approximately 0.70 for dry wood and 0.40 for green wood. Coefficients of static friction for smooth wood on smooth wood are 0.60 for dry wood and 0.83 for green wood.

Because dry wood has a lower coefficient than green wood, and because the building will be dry for all but its first several years at most, it seems reasonable to use dry values for the coefficient. Because the logs are not touching as a smooth surface to a smooth surface, but as a sharp long groove pressed into an irregular surface, I feel that using 0.70 is reasonable.

Here's how we use this number. The equation for the friction developed between two materials is: $F = uN$. F is the friction force developed, u is the coefficient of friction, and N is the normal force, or the force pressing the edges of the long groove into the top of the log below. N is at least equal to the dead load resting on the long groove, which in our case for log 1 S would be the weight of the roof supported by 1 S, plus the weight of the gable end framing, plus the weight of log 1 S itself.

Uplift

It is common to have wide roof overhangs on log homes. Our first concern is that the roof is attached securely to the top logs (see *Log Building News* #2, page 1). It is best to use fasteners that are designed to work with green wood—lag screws and deformed shank nails, for example, and not 16d sinkers.

Once the roof is adequately fastened to the plate logs we need enough dead weight to keep the roof from lifting off in a wind. There may be enough dead load just from the combined weight of the roof system and the plate log. If the dead weight is not enough to resist uplift, then the top course of logs can be lag bolted to the logs below. In areas of high winds, or if the wall logs are light, then several of the top courses will need to be connected together to add enough weight to withstand uplift forces.

The connection between the foundation and the sill log is rarely a

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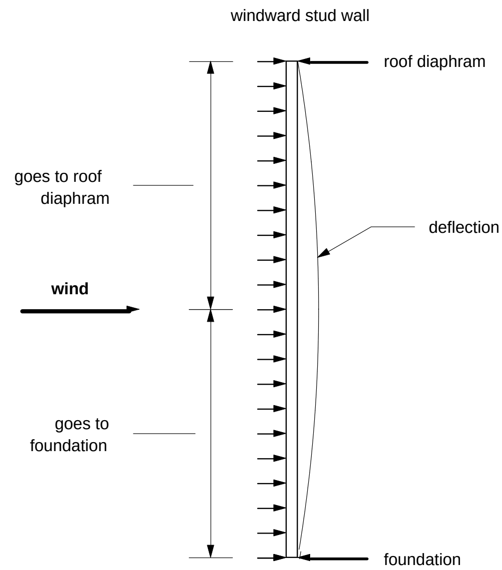


Figure 4 *A wall, when loaded from the side (lateral load), acts like a vertical beam.*

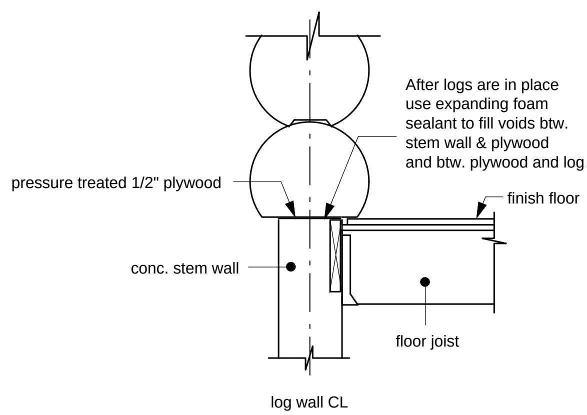
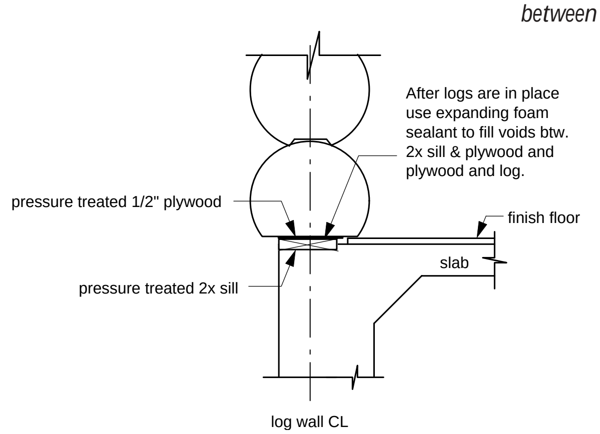


Figure 5 *Connecting the sill logs to the foundation is a concern when winds are high, though friction may be enough. In seismic zones, you need a mechanical connection between the walls and foundation.*



concern with wind. The total weight of the log walls and all additional dead loads carried by the walls, the normal force, N, in the equation $F = uN$, will be quite high. As long as enough friction can be developed between the bottom log and the foundation, see Figure 5, then lateral loads from wind are not a concern. In lake or ocean coastal regions, and where wind can be high, it is important to check this connection.

Seismic

When building in a seismic area it is important that all wall logs be secured to each other and to the foundation so that uplift and lateral forces are effectively dealt with. Through-bolts connecting the top course of logs to the foundation are effective. The size of bolts and washers, and their placement, will be specific to the building and its site. As long as the logs have good contact with each other, and are adequately attached to the foundation, then the joinery and friction resistance discussed will work for earthquake loads.

As the building settles, through-bolts must be kept tight. Because the interface between the bottom course of logs and the foundation is different than between courses of logs, it is important to design and build for this difference.

The friction force between the sill log and the foundation can only be relied on if uplift is prevented. Seismic forces increase with the weight of the building, so the highest seismic forces typically occur at the top of the foundation. It may be necessary to connect the lower course of logs to the foundation with additional mechanical means, such as steel drifts or bolts, in order to provide enough resistance to the lateral loads of earthquakes.

Log buildings survive quite well in an earthquake as long as they stay on their foundation—in fact, log joinery helps dissipate the seismic energy.

Summary

To review, an analysis of log joinery leads to a unique model that deals with lateral loading. Friction plays a role in this model, as well as the ability of the structure to act as an interconnected whole. In many structures, wind loads are usually a concern only for the roof and the top several courses of logs.

Seismic loads require that all logs in the building be adequately secured to the foundation so that uplift is prevented. Once uplift is eliminated, then friction and interlocking joinery work to our advantage. This model should let designers and builders move away from having to create a shear wall with logs by using steel drifts, lag screws, pegs, and the like.

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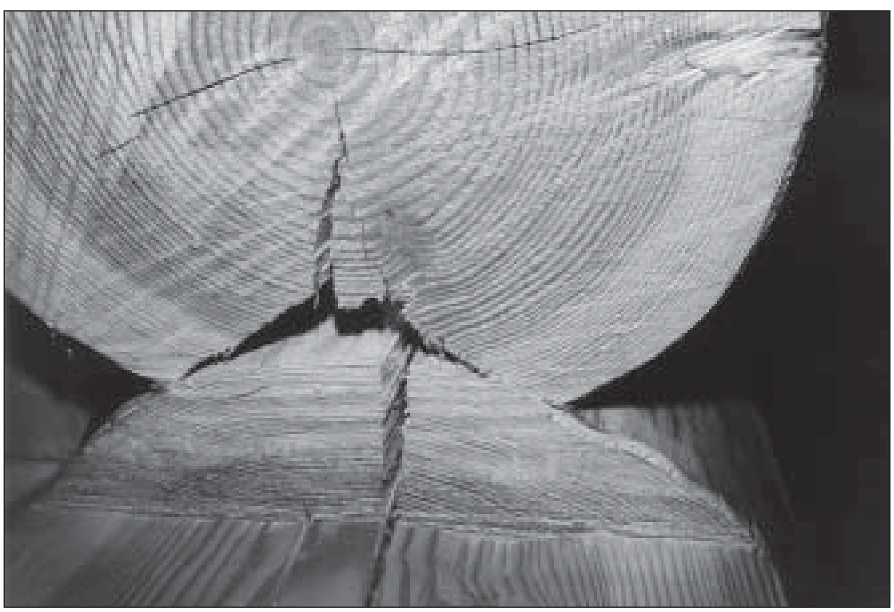

Figure 2.2 *Close up photo of a typical long groove in cross section.*

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