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Calculating Loads on Headers and Beams

Understanding how loads are transferred through a structure and act on structural members is the first step to sizing headers and beams

Most builders automatically choose double -2 x 8 or -2 x 10 headers to frame windows and doors in every house they build. These headers work to support most residential loads and coincidentally keep the window tops to a uniform height. A neat solution, but is this an efficient and cost effective use of material? The same is true for beams like structural ridge beams and center girders. Too often builders gang together 2-inch dimension lumber to support roof and floor loads without considering other options. You can't beat sawn lumber for most small window headers, but as spans and loads increase, stronger materials are a better choice. Sawn lumber limits design potential and in some cases just doesn't work. Parallam, Timberstrand, Laminated Veneer Lumber and Anthony Power Beam are examples of alternative materials that provide builders with some exciting choices.

This 2-part series will review how sawn lumber and these engineered materials measure up as headers and beams. Part I will show how to trace structural loads to headers and beams. Part II will review sizing procedures, performance and cost of these materials for several applications.

Part 1

Doing Work

The job of headers and beams is a simple one. They transfer loads from above to the foundation below through a network of structural elements. The idea behind sizing headers and beams is straight-forward: Add together all live loads and dead loads that act on the member and then choose a material that will resist the load. The beam must be strong enough so it doesn't break (Fb value) and stiff enough so that it doesn't deflect excessively under the load (E value). However, the process for sizing these structural elements can be complicated if you are not an engineer. Here is a simplified approach that will help you specify the appropriate material for many applications.

The first step is the same for sawn- and engineered wood materials: add up all the loads acting on a header or beam and then translate this load into terms of *how much load each lineal foot of header or beam will feel*. In beam-speak you say: this header must carry X-pounds per lineal foot. This translation is the key to any structural sizing problem. Armed with this information you can determine the minimum size, span or strength of the beam. Engineered wood components are sized using span tables that match various spans to pounds per foot of beam. For sawn-lumber you can use Tables 21.25-B, 21.25-C or 21.25-D from the Uniform Dwelling Code or you must perform mathematical calculations.

Loads are considered to be either ***distributed*** or ***point*** loads. A layer of sand spread evenly over a surface is an example of a pure distributed load. Each square foot of the surface feels the same load. Live and dead loads listed in the building code for roofs and floors are approximations of distributed loads. Point loads occur when a weight is imposed on one spot in a structure, like a column. The load is not shared equally by the supporting structure. Analysis of point loading is best left to engineers. We will consider only distributed loads. This will enable us to size beams for most common applications.

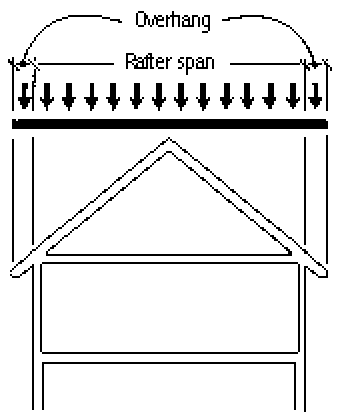

Figure 1

Let's trace distributed loads for several different houses. Assume that all are located in the same climate, but have different loading paths because of the way they are built. These examples illustrate how distributed loads are assigned to structural elements. Our sample homes are in Zone 1 (Figure 21.02) where the snow load is 40 pounds per square foot of roof area (treat snow as live load). Check your code book for live loads and dead loads in your region. All loads are listed as pounds per square foot and assumed to act vertically over the roof area projected upon a horizontal plane as required by COMM 21.02 (1) (b) 1., (footprint area). (SEE FIGURE 1)

Headers

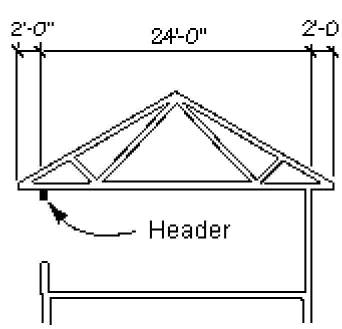

Figure 2

Header Example #1

Here, each square foot of roof system delivers 40 pounds of live load and 15 pounds of dead load (55 psf total) to the structural support system. Remember, these loads are distributed uniformly over the entire surface of the roof. The exterior wall (and the headers within) will carry all loads from the mid-point of the house (between the supporting walls) to the outside of the house (including the roof overhang). The distance in this case is 12 ft+ 2 ft = 14 ft. So, each lineal foot of wall must carry the loads imposed by a 1-foot wide strip in that 14 ft region. In technical terms, the wall has a tributary width of 14 ft. From this we can readily see that each lineal foot of wall supports:

Conditions:

live load (snow):	40 psf x 14ft = 560 pounds per lineal foot
roof dead load:	15 psf x 14ft = 210 pounds per lineal foot
total load:	= 770 pounds per lineal foot

It is important to list live load, dead load and total load separately because live load is used to compute stiffness and total load is used to calculate strength.

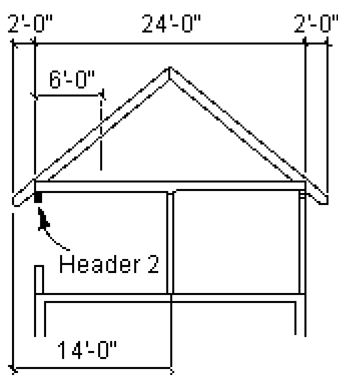

Figure 3

Header Example #2

This house is identical to our first example except it is stick-built. As a result, the live load, dead load and distribution of forces are different. Unlike the trussed roof, live load and dead load of the rafters and ceiling joists must be accounted for as separate systems. Since it is possible to use the attic for storage, the live load of the attic floor is set at 20 psf according to the UDC (Table 21.02).

Conditions:

live load (snow):	40 psf x 14ft = 560 pounds per lineal foot
roof dead load:	10 psf x 14ft = 140 pounds per lineal foot
ceiling live load:	20 psf x 6ft = 120 pounds per lineal foot
ceiling dead load:	10 psf x 6ft = 60 pounds per lineal foot

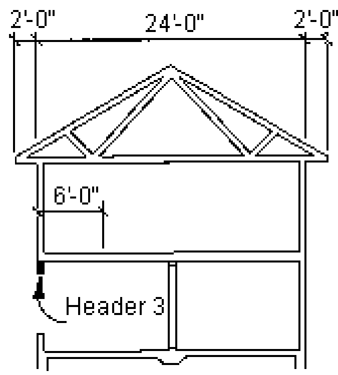

Figure 4

Header Example #3

Again, this house has the same width dimension, but it has 2 levels. Loads are contributed to the lower header by the roof, upper walls and 2nd floor system. The Architectural Graphic Standards lists the weight of an exterior 2x6 wall as 16 pounds per ft^2. So an 8-foot tall wall weighs 8 ft x 16 pounds/ft^2 = 128 pounds per lineal foot. The loads delivered to the header are:

Conditions:

live load (snow):	40 psf x 14ft = 560 pounds per lineal foot
roof dead load:	15 psf x 14ft = 210 pounds per lineal foot
upper level wall:	= 128 pounds per lineal foot
2nd floor live load:	40 psf x 6 ft = 240 pounds per lineal foot
2nd floor dead load:	10 psf x 6 ft = 60 pounds per lineal foot
total load:	=1198 pounds per lineal foot

Beams

Ridge Beam Example

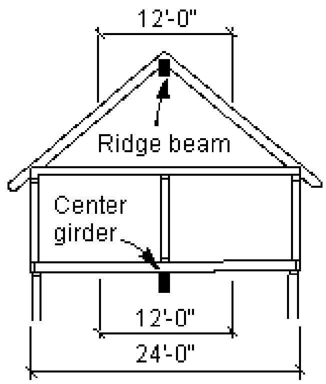

Figure 5 - This figure illustrates 2 structural elements: a structural ridge beam and a center girder. Both have a tributary area of 12'0". The load per foot of beam is determined the same way as for headers.

Ridge Beam Conditions

live load (snow):	40 psf x 12 ft = 480 pounds per lineal foot
roof dead load:	10 psf x 12 ft = 120 pounds per lineal foot
total load:	= 600 pounds per lineal foot

Girder Example

The center beam carries half of the floor load, the partition load and half of the second floor load. Live and dead loads are given in the building code. The weight of the partition is listed in the Architectural Graphic Standards as 10 pounds per square foot.

B) *First Floor Girder Conditions*

1st floor live load:	40 psf x 12 ft = 480 pounds per lineal foot
1st floor dead load:	10 psf x 12 ft = 120 pounds per lineal foot
8-foot tall partition:	= 80 pounds per lineal foot
2nd floor live load:	40 psf x 12 ft =480 pounds per lineal foot
2nd floor dead load:	10 psf x 12 ft =120 pounds per lineal foot
total load:	=1280 pounds per lineal foot

In Summary

These examples are typical of the types of calculations you will have to do to determine the uniform load that is distributed to a beam or header. You must establish how much of a load each lineal foot of header or beam receives. The next step is to use the technical literature from any of the companies that make engineered wood components to determine span and beam size. They all correlate allowable spans to load per foot of beam. Span listings are based on allowable deflection, live load and dead load, which are all listed in your building code book. In part 2 "Sizing Engineered Headers and Beams" we compare cost and performance of some engineered wood products to sawn lumber.

Part 2

In Part 1, "Calculating Loads On Headers and Beams", we learned how to trace load paths and translate roof, wall and floor loads into pounds per lineal foot of supporting beam. We know how to measure the forces acting on a beam, now we'll use this information to choose the appropriate structural material to resist the loads. We will compare the performance and cost of sawn-lumber, LVL, Timberstrand, Parallam and Anthony Power Beam in several different applications.

Simplified Sizing Using Tables

No matter what material we specify, beams must provide adequate strength, stiffness, and shear resistance. Structural ability of sawn- and engineered-wood beams is predicted through mathematical calculation. Formulas that determine the allowable span and size of a beam rely on a host of variables like species, grade, size, deflection limit and type of load. You can do these calculations yourself or you can use span tables from the Uniform Dwelling Code Tables 21.22-A-1 and 21.22-A-1. Technical experts have computed many combinations of these variables and present a variety of solutions in the form of span tables.

Sawn-Lumber span tables are convenient tools. You merely look for the distance you need to span; match the load per foot of beam to the appropriate Fb (strength) and E (stiffness) values listed; and bang: you have a winner! Span tables are easy to use, but they have limitations. They don't provide fine-tuned results. Most beam tables only list values for *whole-foot* spans like 11'0", 12'0", etc. And even though span tables provide limited data, they are very long. American Forest & Paper Association's ***Wood Structural Design Data*** provides span recommendations for solid-sawn wood beams up to 32 feet, but the table runs a hefty 140 pages. The WSDD is an extremely useful book (WSDD costs $25. Call 800-890-7732). Get it for your reference library. The WSDD tables only list values for solid wood beams at deflection limits of L/360. But you can trick WSDD tables into giving you values for double or triple 2-by beams with other deflection limits. Just do the following:

- determine the total load per foot of beam
- pick the span you want (pick 4'0" for example)
- select the Fb column of the lumber you intend to use (in AF&PA Design Values for Joists and Rafters #2 hem-fir = Fb @1104 psi & E @1,300,000 psi--- so use span table column Fb 1100)
- Choose the row for the size of lumber used in the double header: use 2x6 in this example. Note: a single 2x6 will support 347 pounds per lineal foot of beam. Therefore, a double 2x6 carries 2 x 347 = 694 pounds per lineal foot.

- The required E-value does not change when you double the 2x6 because as you double the allowable load, you are doubling the thickness of the beam.
- The table lists spans with a deflection limit of L/360, normal for floor loads. If you size a roof beam like a structural ridge that has an L/240 limitation, you would multiply the minimum E-value by 0.666 (785,000 x 0.666 = 522,810 in this case). For L/180 multiply by 0.5.
- Make sure the shear value (Fv) for the species and grade you use exceeds the Fv listed in the span table. Fv does not change when you double the thickness.

Engineered Wood manufacturers are quick to point out that their products provide superior strength and stiffness. The claims are basically true, but you do pay for the improved performance. Strength-reducing characteristics like knots, grade and slope of grain are controlled during manufacturing process so that the end product represents a more efficient use of the wood fiber. Engineered wood is consistent from one piece to the next because each piece is made more-or-less the same. No matter what product you specify, structural performance is controlled by strength (Fb) and Stiffness (E). An LVL product that has an Fb of 3100 will carry more load than and LVL product with an Fb of 2400. So be careful when you compare products. All of these high-performance products are cost effective in some applications. And at times, they make or break a design. Span tables for engineered wood are used in a very similar way as those for sawn lumber. Building codes allow reductions in live loads based on duration of load. For example a roof is subjected to a full snow-load only a small percentage of time during the course of a year, so this is factored into the roof's load calculation. Usually, each manufacturer automatically applies these reductions and clearly labels the appropriate application in the various tables for floors and roof conditions. Be careful: some manufacturers require that you *slope-adjust* your roof loads. In other words, some manufacturers do not base roof loads on horizontal projection, but rather base loads on the actual length of the rafter. Look carefully at the literature before you assign roof loads per-foot of ridge beam or header. Typically shear values are incorporated into the tables and required bearing length at the ends of beams are given too. Tables are limited to whole-foot spans, but the values can be interpolated for fractional lengths. The tables used to size engineered lumber are provided by manufacturers free of charge.
To size engineered beams and headers you begin with load per foot of beam. With engineered wood, you use both live load and dead load values. Live load determines stiffness and total load is used to determine strength.

The sizing steps are:

- determine the total load and live load per foot of beam
- identify the type of load you are supporting (roof snow, non snow or floor)
- pick the span you need
- Match the total load and live load values to the values listed in the tables. The thickness and depth of the required member will be listed.

Considerations

Sawn Lumber has it limitations. Its bending strength is often only 1/2 that of engineered wood products. As a result, it doesn't clear-span long distances, comes in sizes only up to 2x12, and select structural grades are not always available. Select structural grades are special-ordered in many locations. Also, not every species is readily available. For example, Douglas-fir is difficult to buy in some eastern markets. But overall, for short spans, sawn-lumber is tough to beat.

Laminated Veneer Lumber (LVL) is strong, stiff, versatile and it spans long distances. I was able to use LVL for every application in the case-house. Typically, LVL comes 1 ¾" thick and ranges in depth from 7 ¼" up to 18".

To fine-tune the load-carrying potential of a LVL beam, just add another ply to the side of a beam. Labor is a factor. It takes time to laminate multiple layers of LVL. But the upside is that 2 workers can usually handle the weight of each lamination as it is assembled. LVL is carried as a stock item in most lumber yards and it is familiar to most building code officials and designers.

Anthony Power Beam (APB) is a relative newcomer to the structural beam market positioned to compete with LVL and Parallam. APB is a laminated beam product that comes in 3 ½" and 5 ½" widths to match standard 2x4 and 2x6 wall thicknesses. Depths range from 7 ¼" to 18", matching standard I-joist depths. There is also a wider 7" version available in depths up to 28 7/8". APB requires very little labor because is comes "fully assembled", but it is fairly heavy. The 18-foot garage header for our house weighs in at 380 pounds. APB is a new product and its penetration is somewhat limited so you may have to look for a local supplier. Call Anthony Forest Products direct to find a distributor.

Parallam, manufactured by Trus Joist MacMillan (TJM), virtually defines the term: parallel strand lumber (PSL). PSL is an assembly of long, thin strands of wood veneer glued together to form continuous lengths of beam. The wood fiber used is strong and stiff. Several widths from 1 ¾" – 7" are available in depths of 9 ¼" – 18". Parallam dimensions are compatible with the other engineered wood products like I-joists and LVL. Parallam has been around for a while, but still -- not all sizes are available in all regions. It is best to plan your design well ahead of schedule. Like APB, Parallam comes fully assembled and is comparably heavy. It is a good choice for long clear spans where sawn lumber is impractical.

TimberStrand FrameWorks Header, a laminated strand lumber (LSL) made by TJM, is the latest entry into the structural header and beam competition. LSL is made by upgrading low-value aspen and poplar fiber into high-grade structural material. The Fb and E values are certainly no match for APB, LVL and PSL, but the performance of TimberStrand is impressive. It worked for most of the applications in our case house. It is worth noting that the 18-foot garage-door header application pushed TimberStrand beyond its structural limit. TimberStrand Header comes only in 3 ½" widths in depths that range from 4 3/8" to 18". This product is new and distributors don't want to stockpile inventory. It is a cost-effective option for many applications, but it can be very hard to find.

Additional Resources
Paul Fisette
Anthony Forest Products Company, P.O. Box 1877, El Dorado, Arkansas 71730, 800-221-2326, http://www.anthonyforest.com
Trus Joist MacMillan, P.O. Box 60, Boise, ID 83706, 800-628-3997
Louisiana Pacific, 11 S.W. Fifth Ave., Portland, OR 97204, 800-777-9105 (mfg. lumber and engineered wood)
Furman Lumber Company, P.O. Box 130, Nutting Lake, MA 01865, 800-843-9663, http://furmanlumber.com (distributor of lumber and engineered wood products)
Prime Source, 315 Morgan Lane, West Haven, CT 06516, 800-745-3319. (distributor of Parallam, TimberStrand and lumber.)
All illustrations are provided through the courtesy of the Journal of Light Construction.