Technical Q & A

Lateral Load Capacity of Toe-Nailed Truss-to-Truss Girder Connections

by Scott Coffman, P.E.

Find out what documentation is necessary when truss-to-truss girder connections are used in construction applications.

Toe-nailing is often used to attach corner and end jack trusses to corner and hip girder trusses, respectively. The relatively short spans and light end reactions associated with most jack trusses makes toe-nailing an efficient and effective attachment method. The International Building Code (IBC), International Residential Code (IRC), and ANSI/TPI 1-2002 require that truss-to-truss girder connection information be included on the truss design drawing. Because of this, it is not uncommon for building code officials and building designers to request "certification" of this connection. The challenge is to address these connections in a timely manner and to know what documentation is available or can be provided.

Question

How much capacity does a toe-nailed connection have to resist the gravity and uplift reaction loads from a jack truss attached to a girder truss?

RAFTER SPANS FOR COMMON LUMBER SPECIES (Ground snow load=30 psf, ceiling not attached to rafters, L/Δ = 180)												
			DEAD LOAD = 10 psf					DEAD LOAD = 20 psf				
			2 × 4	2 × 6	2 × 8	2 × 10	2 × 12	2 × 4	2 × 6	2 × 8	2 × 10	2 × 12
			Maximum rafter spans[a]									
RAFTER SPACING (inches)	SPECIES AND GRADE		(feet - inches)	(feet - inches)	(feet - inches)	(feet - inches)	(feet - inches)	(feet - inches)	(feet - inches)	(feet - inches)	(feet - inches)	(feet - inches)
24	Douglas fir-larch	SS	7-11	12-6	15-10	19-5	22-6	7-8	11-3	14-2	17-4	20-1
	Douglas fir-larch	#1	7-1	10-5	13-2	16-1	18-8	6-4	9-4	11-9	14-5	16-8
	Douglas fir-larch	#2	6-8	9-9	12-4	15-1	17-6	5-11	8-8	11-0	13-6	15-7
	Douglas fir-larch	#3	5-0	7-4	9-4	11-5	13-2	4-6	6-7	8-4	10-2	11-10
	Hem-fir	SS	7-6	11-10	15-7	19-1	22-1	7-6	11-0	13-11	17-0	19-9
	Hem-fir	#1	6-11	10-2	12-10	15-8	18-2	6-2	9-1	11-6	14-0	16-3
	Hem-fir	#2	6-7	9-7	12-2	14-10	17-3	5-10	8-7	10-10	13-3	15-5
	Hem-fir	#3	5-0	7-4	9-4	11-5	13-2	4-6	6-7	8-4	10-2	11-10

Table 1. Excerpt from Table R802.5.1(3) of the 2006 IRC showing allowable rafter spans for various sizes and species of lumber.

Answer

The IBC and IRC provide significant insight into wood members and their connections. Table 2308.10.3 of the 2003 and 2006 IBC and Table R802.5.1 (see Table 1 for excerpt) of the 2003 and 2006 IRC provide maximum rafter spans for common lumber species at various on-center spacing and load conditions.

Similar tables are provided for ceiling joists. Minimum fastener requirements are provided in Table 2304.9.1 (items 27 and 28) of the IBC and Table R602.3 (1) of the IRC for rafter connections to a valley, hip rafter and ridge beam (see Table 2 for excerpts).

An open end jack truss (see Figure 1) meeting the same design parameters would perform in a similar manner as a rafter and ceiling joist and generate comparable reactions. The top chord and bottom chord of the jack truss should correspond to the rafter and ceiling joist tables provided in the code. For these situations, the nail connections specified by the code are also applicable to jack trusses. An inquiring code official or building designer, therefore, can be directed to these specific provisions of the code for verification of this type of connection with jack trusses.

at a glance

- The relatively short spans and light end reactions associated with most jack trusses makes toe-nailing an efficient and effective attachment method.
- An open end jack truss (see Figure 1) meeting the same design parameters would perform in a similar manner as a rafter and ceiling joist and generate comparable reactions. The top chord and bottom chord of the jack truss should correspond to the rafter and ceiling joist tables provided in the code. For these situations, the nail connections specified by the code are also applicable to jack trusses.

Although this approach is usually successful, some code officials and building designers may request additional verification. For these situations, the lateral load capacities of a toe-nailed connection for various nails and species of wood are required. Table 3 on page 16 provides the nominal lateral design capacity on a per toe-nail basis, while Table 4 provides similar information for two-, three- and four-nail connections. Both tables were developed using the yield limit equations for dowel-type fasteners provided in the 2005 National Design Specification® (NDS®) for Wood Construction. The capacities listed can be used for toe-nailed connections for attaching a 2x_ end jack truss to a single or multiple 2x_ hip girder truss (see Figure 2 on page 16) or for toe-nailed connections for attaching a 2x_ corner jack truss to a corner girder truss that intersect at a 45° angle as shown in Figure 3. Please note that the connection between the corner jack and corner girder assumes that the chords of the jack truss are bevel cut and that the nails are driven at a 90° angle to the face of the jack into the girder

Continued on page 16

TABLE 2304.9.1 FASTENING SCHEDULE		
CONNECTION	FASTENING[a,m]	LOCATION
27. Jack rafter to hip	3 - 10d common (3" x 0.148") 4 - 3" × 0.131" nails 4 - 3" 14 gage staples	toenail
28. Roof rafter to 2-by ridge beam	2 - 16d common (3-1/2" x 0.162") 3 – 3" x 0.131" nails 3 – 3" 14 gage staples	toenail

TABLE R602.3(1) FASTENER SCHEDULE FOR STRUCTURAL MEMBERS		
DESCRIPTION OF BUILDING ELEMENTS	NUMBER AND TYPE OF FASTENER[a,b,c]	SPACING OF FASTENERS
Roof rafters to ridge, valley or hip rafters: toe nail	4-16d (3-1/2" × 0.135")	Not Applicable

Table 2. Excerpts from Table 2304.9.1 of 2006 IBC and Table R602.3(1) of 2006 IRC respectively, showing minimum fastener requirements for rafter connections to valley, hip rafter and ridge beam.

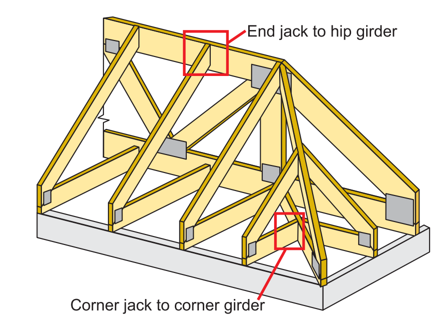

Figure 1. Open jack hip framing

Nail Type	Inches		Capacities for Truss Chord Species (lbf)				
			SP	DF-L	HF	SPF	SPFs
	Dia.	Length	G = 0.55	G = 0.5	G = 0.43	G = 0.42	G = 0.36
16d Common	0.162	3.50	128	117	101	97	78
12d Common	0.148	3.25	106	98	85	83	67
10d Common	0.148	3.00	106	98	82	80	64
16d Box	0.135	3.50	94	85	74	73	62
12d Box	0.128	3.25	84	77	66	65	56
10d Box	0.128	3.00	84	77	66	65	53
16d Gun Nail	0.131	3.50	88	81	70	68	59
12d Gun Nail	0.131	3.25	88	81	70	68	58
10d Gun Nail	0.131	3.00	88	81	70	68	55

Table 3. Nominal Lateral Design Capacity per Toe-Nail.

Footnotes:

1. Nominal lateral design capacities in table have already been adjusted by the toe-nail factor and represent normal load duration values. To determine the adjusted lateral design values, multiply the table values by all other applicable adjustment factors provided in NDS®.
2. Nominal lateral capacities are based on framing conditions depicted in Figures 2 and 3.
3. Nominal lateral capacities are for a single-shear connection with both members of the same species. If the two members are of different species, use the species with the lowest specific gravity to determine the lateral load capacity of the fastener.
4. Species designation is: SP = Southern Pine, DF-L = Douglas Fir-Larch, HF = Hem-Fir, SPF = Spruce-Pine-Fir and SPFs = Spruce-Pine-Fir (South).
5. Nominal lateral capacities assume full penetration of the toe-nail into the supporting member.
6. Apply fire retardant treated lumber adjustment factors per manufacturer's specifications.
7. For nail capacities not shown here, consult a design professional.

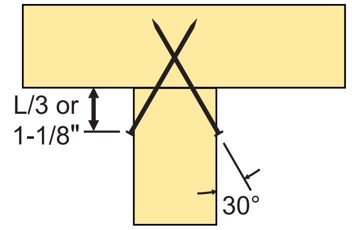

Figure 2. End jack to hip girder.

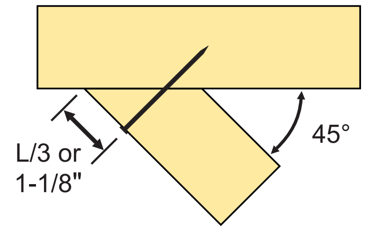

Figure 3. Corner jack to corner girder.

Nail Type	Number of Toe-Nails	Capacities for Truss Chord Species (lbf)				
		SP	DF-L	HF	SPF	SPFs
		G = 0.55	G = 0.5	G = 0.43	G = 0.42	G = 0.36
16d Common	2	256	234	203	194	156
	3	383	351	304	291	234
	4	511	468	405	388	312
12d Common	2	212	196	169	166	134
	3	319	294	254	249	202
	4	425	392	339	332	269
10d Common	2	212	196	164	160	128
	3	319	294	246	240	192
	4	425	392	328	320	256
16d Box	2	188	171	148	146	125
	3	281	256	222	219	187
	4	375	342	295	292	249
12d Box	2	168	154	133	129	112
	3	251	232	199	194	168
	4	335	309	266	259	224
10d Box	2	168	154	133	129	106
	3	251	232	199	194	159
	4	335	309	266	259	212
16d Gun Nail	2	176	161	139	136	118
	3	264	242	209	204	177
	4	352	322	279	272	236
12d Gun Nail	2	176	161	139	136	116
	3	264	242	209	204	174
	4	352	322	279	272	232
10d Gun Nail	2	176	161	139	136	110
	3	264	242	209	204	165
	4	352	322	279	272	220

Table 4. Nominal Lateral Design Capacity per Toe-Nail Joint Connection (see footnotes for Table 3).

Technical Q&A

Continued from page 15

In both cases, the nails are assumed to be installed at either L/3 (i.e. length of nail divided by 3) or 1-1/8" from the end of the jack truss (see Figures 2 and 3 above).

Example

A roof corner jack frames into a hip corner jack comprised of SP lumber. The truss design drawing for the corner jack displays a 200-lb top chord calculated reaction from snow and roof dead loads. The toe-nail connection of 2 - 16d gun nails would be sufficient to transfer the gravity load [i.e., 200 / (1.15*88)] = 1.97 or 2 nails. The same truss design drawing also indicates that a maximum top chord wind uplift reaction of 295 pounds must be resisted. The toe-nail connection of 3 - 16d gun nails would be required to transfer the wind uplift load [i.e. 295 / (1.6*88)] = 2.11 or 3 nails. The top chord connection of 3 - 16d gun nails must be used. Nails should be specified by diameter and length, e.g. 0.131" by 3-1/2", to eliminate confusion over the type and size of nail to use. A similar analysis must be performed for the bottom chord. This toe-nail connection information may be shown on the truss design drawing, a standard detail, or a schedule that identifies the truss type, reaction, and nail size and quantity required.

The building code and ICC Evaluation Service Report ESR-1539 (visit **Support Docs** at **www.sbcmag.info** to view this report) provide some prescriptive guidelines for number of nails per connection. Table 4 has been prepared considering this information, which is generally to limit the connection to a maximum of three toe-nails for 2x4 chords and four toe-nails for 2x6 chords.

As previously mentioned, consideration must be given to the lumber size when evaluating any nailed connection. Toe-nail connections must be installed in a specific manner to obtain the calculated capacity and too many nails may split the lumber, rendering the connection inefficient. For this reason, toe-nailed connections supporting gravity and uplift load reactions from trusses and lumber are typically limited to reactions of less than 500 lbs. The support of larger reactions requires more sophisticated connections such as prefabricated metal hangers, lag screws, bolts, or split ring and shear plates.

When applied in accordance with the provisions of NDS and the building code, toe-nailing provides a verifiable and acceptable connection.

Conclusion

Toe-nailing has long been recognized as an acceptable means of attaching intersecting light-frame wood structural members together. For certain applications, toe-nailing can also be used to effectively attach wood trusses to girder trusses and other structural wood supports. The National Design Specification (NDS) for Wood Construction provides the engineering basis for toe-nail and slant-nail connections. When applied in accordance with the provisions of NDS and the building code, toe-nailing provides a verifiable and acceptable connection.

The building code and Tables 3 and 4 of this article can be used to verify the adequacy of toe-nailed connections between jack trusses and the supporting girder. The truss designer must communicate this information to the field, usually on the truss design drawing, to satisfy the building code and TPI 1. SBC

Scott Coffman, P.E. works for Builders FirstSource in Sumter, SC and has more than 25 years in the wood design and component industry. To pose a question for this column, call the WTCA technical department at 608/274-4849 or email technicalqa@sbcmag.info.

STRUCTURAL BUILDING COMPONENTS™

THE FUTURE OF FRAMING

www.sbcmag.info

Dear Reader:

The mission of ***Structural Building Components Magazine (SBC)*** is to increase the knowledge of andto promote the common interests of those engaged in manufacturing and distributing of structuralbuilding components to ensure growth and continuity, and to be the information conduit by stayingabreast of leading-edge issues. SBC will take a leadership role on behalf of the component industryin disseminating technical and marketplace information, and will maintain advisory committees consisting of the most knowledgeable professionals in the industry. The opinions expressed in SBC are those of the authors and those quoted solely, and are not necessarily the opinions of any affiliated association (WTCA) .

Truss Publications, Inc.

6300 Enterprise Lane • Suite 200 • Madison, WI 53719
608/310-6706 phone • 608/271-7006 fax
www.sbcmag.info • admgr@sbcmag.info