Substituting T-braces for continuous lateral braces on wood truss webs

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Introduction

Web bracing in trusses is essential for several reasons. With one lateral brace, a compression member is able to carry up to four times the normal load; when two lateral braces are used, the member may carry a load up to nine times more. Lateral braces resist lateral deflection in the webs and decrease the effective buckling length of the web members (Underwood et al., 2001).

T-braces increase the effective stiffness of webs — allowing higher compressive design loads (Shrestha et al., 2001).

Truss webs are assumed to be loaded axially — either in compression or tension. When the design compression load exceeds the unbraced web capacity, the truss designer can specify a lateral brace at the center of the web to increase the design load capacity. In some cases, two braces are needed at the third points to further increase the load capacity of the web. Compression members with an L/d greater than 50 and tension members with an L/d greater than 80 require lateral bracing regardless of the load level in the web (Truss Plate Institute, 1995). The truss designer typically notes the need for permanent bracing on the truss design drawing by placing a small rectangle on the web (See Figure 3, for example, where bracing is required on webs B-K, C-J, E-J and F-I). The contractor has two options for bracing webs when required—either Continuous Lateral Braces (CLBs) or T-braces.

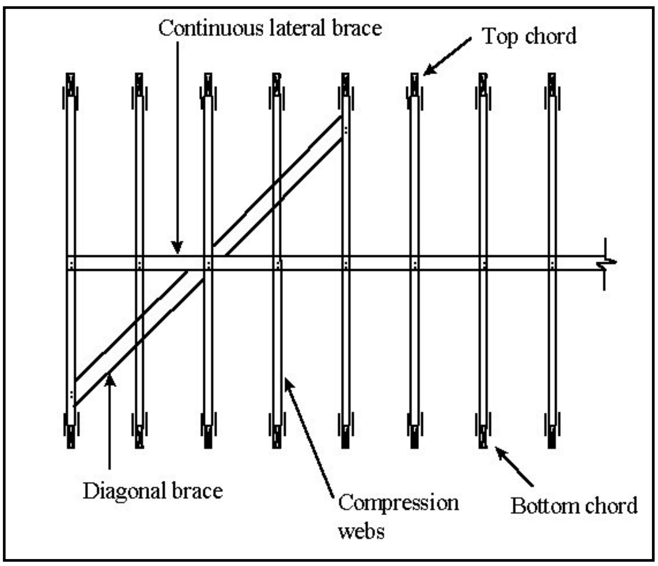

Figure 1. Elements of continuous lateral bracing for webs in a roof system.

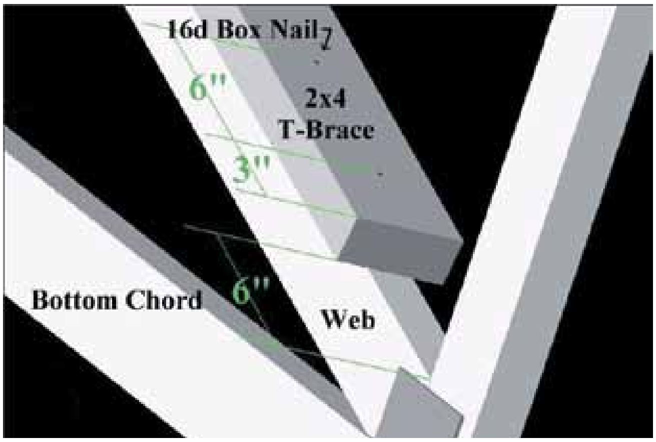

Figure 2. Correct installation of a 2x4 T-brace on a web as assumed in the development of Tables 1a,1b,1c, and 1d.

The first option, when using CLBs, is a piece of lumber that extends through several trusses, attached to a web member at the center, or two pieces attached at the 1/3 points. Figure 1 shows how the CLB is placed into the roof system and the diagonal bracing that is also required. CLBs are commonly used in construction, especially with trusses spaced 2-ft. on-center.

For trusses with a 4-ft. to 10-ft. spacing, a T-brace approach may be a more practical option, requiring less lumber than a CLB system. T-braces can be installed on the ground, eliminating a fall hazard, and no web diagonal bracing is needed when the truss is installed in the roof. A T-brace, as defined by this paper, is a 2x4 piece of stress-rated-lumber that is attached symmetrically to the narrow edge of the compression web member as shown in Figure 2. The T-braces tested and used in this paper to create design tables extend within to six inches from either end of the web. The minimum allowable nail size required is 16d Box (0.135 in x 3.5 in) nails, placed at 6 inches on center with the first nail 3 inches from the end (Shrestha et al., 2001).

Design Procedure

The procedure used to reach the allowable load values presented in Tables 1a,1b,1c, and 1d is from the National Design Specification (NDS) for Wood Construction (AF&PA, 1997). The allowable load is found using the tabulated allowable compression parallel to grain,

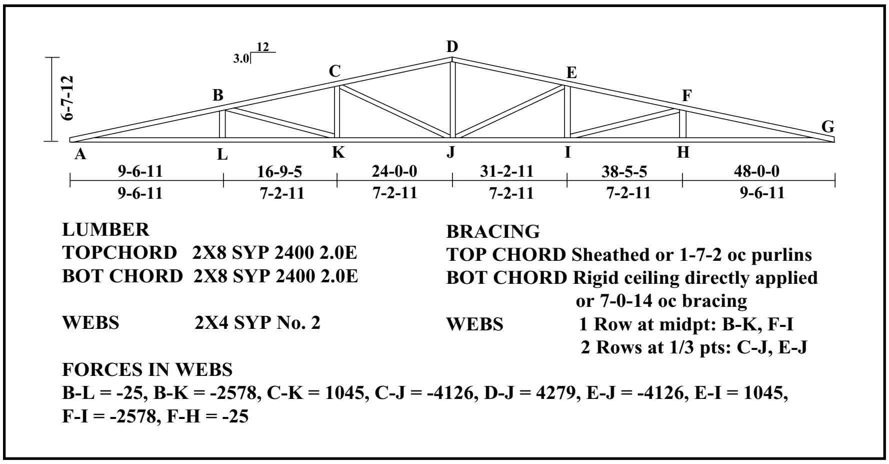

Figure 3. Example truss design drawing showing web forces.

appropriate adjustment factors, and properties of the lumber.

Design criterion for a compression member is:

$f_c \le F_c'$

where:

$f_c = P/A_W$ = compression stress parallel to grain, psi,

F_c' = Adjusted allowable compression stress parallel-to-grain, psi,

P = Allowable load in the web, lbs., and,

A_W = Cross-sectional area of the web, in.^{2}.

The allowable load in a web with a specific length is:

$P = A_W F_c C_D C_P C_M C_t C_i$

where:

F_c = tabulated allowable compression stress parallel-to-grain, psi,

C_D = load duration factor,

C_p = column stability factor,

C_F = size factor for sawn lumber,

C_M = wet service factor,

C_t = temperature factor, and

C_i = incising factor.

As stated before, the F_c values are tabulated in the NDS. The load duration factor for a snow plus dead load combination is 1.15. The size factor is 1.0 for Southern Pine; for other species, the size factor is tabulated in the NDS Supplement.

The column stability factor is given by:

$$C_p = \frac{1+(F_{cE}/F_c^*)}{2c} \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{(F_{cE}/F_c^*)}{c}}$$

c = 0.8 for sawn lumber

$F_c = F_c C_D C_F$

$F_{cE} = K_{cE} E_T/(L_e/d)^2$

KcE = 0.3 for visually graded lumber, 0.418 for machine stress rated lumber.

E'_T = modified modulus of elasticity of T-braced web, as determined by Equation 4 (Shrestha et al., 2001), psi

L_e = effective length of the web, in

$L_e = L_W K_e$

K_e = buckling length coefficient

L_W = unbraced web length, in

d = least dimension of web member, typically equal 1.5 in.

A buckling length coefficient of K_e = 0.8 has been commonly used in truss design and was proven to be accurate in laboratory tests (Grant et al., 1986).

A regression equation was proposed by Shrestha et al. (2001) to determine the stiffness of a web with a T-brace attached. In this paper, the format of the equation is slightly modified:

$E'_T=[1.20E_W 1_W+0.363E_B I_B+AR-B]/I_W$

where:

E'_T = effective modulus of elasticity of web, psi,

E_W = modulus of elasticity of the web, psi,

I_W = weak axis moment of inertia of a 2x4 web equal to 0.984 in.^{4},

E_B = modulus of elasticity of the 2x4 T-brace, psi,

I_B = strong axis moment of inertia of a 2x4 T-brace equal 5.359 in.^{4},

L_W = web length, in,

L_B = T-brace length, in.

$R = L_B/L_W \le 8/9$

A = Constant equal 34.8x106 lb.-in.^{2}, and

B = Constant equal 27.9x106 lb-in.^{2}.

T-Brace Design Tables

Tables 1a and 1b are specific to Southern Pine webs only. As stated in the footnote, the loads are conservative when used for other grades and species with lower Fc values and lower E values. Tables 1c and 1d are specific to Douglas Fir-Larch and Spruce-Pine-Fir webs, respectively. These two tables are conservative for other grades and species, with the exception of Southern Pine, that have lower Fc and E values than stated.

Table 2 is a reference for the Modulus of Elasticity, E, for several species groupings and grades of lumber. These values were taken directly from the NDS Supplement (AF&PA, 1997).

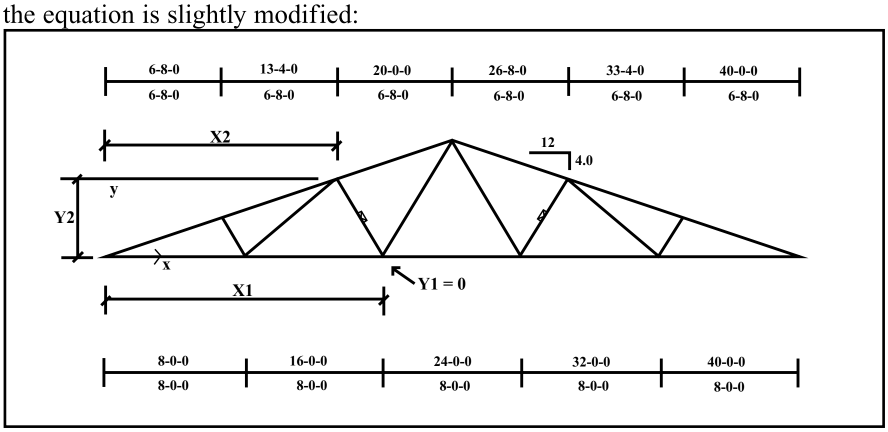

Figure 4. Truss used to determine unknown web lengths.

Design Examples

1. How to find the web load on a truss design drawing:

The web load will be indicated on a truss drawing as a force in pounds and identified with the web end points. If the web is in compression, the force will either be negative or labeled with a "C". In Figure 3, the force in member B-K is -2,578 lbs., so it is in compression.

2. How to determine web length:

If requested, truss manufacturers could print the web length directly on the truss design drawing. When the length is not specified, use the following steps and Figure 4 to estimate it:

i. Find points X1, X2, Y1 and Y2 on the truss drawing. X1 and X2 can be read directly from the drawing or requested from the truss designer. In the example, X1 = 16 ft. (192 in.) and X2 = 13 ft.-4 in. (160 in.).

ii. Length Y2 can be calculated using X2 and the roof slope: Y2=X2* (slope). Y2 in the example is 160*(4/12) = 53.3 in. In a typical post frame truss with a flat bottom, Y1 would equal 0.

iii. Use the following equation to find the length of the web, L_W:

$$L_W = \sqrt{(X1 - X2)^2 + (Y2 - Y1)^2}$$

Substituting the numbers from the example into the equation,

$$L_W = \sqrt{(192 - 160)^2 + (53.3 - 0)^2},$$

L_W = 62.6 in. Round to the nearest web length that produces the lower allowable compression load in the applicable table based on web grade and species grouping.

For a T-brace to work, there are specific requirements that must be met. First, LW must be less than 14 ft (168 in.) to meet NDS slenderness restrictions of $L_e/r < 173$ (Shrestha et al., 2001). Secondly, the formulas used in this paper are only valid for the web lengths shown in the tables, 2x4 webs and 2x4 stress rated T-braces. The design data presented do not apply to 1x4 braces or a nailing schedule other than tested. A closer nail spacing and longer or larger diameter nails are permitted provided they do not split the lumber.

3. One CLB

In Figure 3, the truss design drawing calls for a single CLB on member B-K (and F-I). From the drawing, the load in this web is -2,578 lbs., which means it is in compression. The webs are 2x4 No. 2 Southern Pine and the

Table 1a

Allowable compression load for a 2x4 No. 3 or Stud grade Southern Pine1,2 web of a specific length having a 2x4 T-brace with E value as shown.

Truss web length (in.)	Modulus of Elasticity (E), million psi 0.9	1	1.1	1.2	1.3	1.4	1.5	1.6
54	3680	3840	3980	4120	4230	4340	4440	4520
56	3740	3890	4020	4140	4250	4350	4440	4520
58	3780	3910	4030	4140	4250	4340	4420	4500
60	3800	3920	4030	4140	4230	4320	4400	4470
62	3800	3910	4020	4120	4210	4290	4370	4440
64	3790	3890	4000	4090	4180	4260	4330	4400
66	3760	3870	3960	4060	4140	4220	4290	4360
68	3730	3830	3930	4020	4100	4180	4250	4320
70	3700	3790	3890	3970	4050	4130	4200	4270
72	3660	3750	3840	3920	4000	4080	4150	4210
74	3610	3700	3790	3870	3950	4020	4090	4160
76	3560	3650	3740	3820	3890	3970	4030	4100
78	3510	3600	3680	3760	3840	3910	3980	4040
80	3460	3540	3620	3700	3780	3850	3910	3980
82	3400	3490	3570	3640	3720	3790	3850	3920
84	3350	3430	3510	3580	3650	3720	3790	3850
86	3290	3370	3450	3520	3590	3660	3730	3790
88	3230	3310	3380	3460	3530	3600	3660	3720
90	3170	3250	3320	3390	3460	3530	3600	3660
92	3110	3190	3260	3330	3400	3470	3530	3590
94	3050	3130	3200	3270	3340	3400	3460	3530
96	3000	3070	3140	3210	3270	3340	3400	3460
98	2940	3010	3080	3140	3210	3270	3330	3390
100	2880	2950	3020	3080	3150	3210	3270	3330
102	2820	2890	2960	3020	3080	3150	3210	3260
104	2770	2830	2900	2960	3020	3080	3140	3200
106	2710	2770	2840	2900	2960	3020	3080	3140
108	2650	2720	2780	2840	2900	2960	3020	3070
120	2230	2290	2340	2400	2460	2510	2560	2620
132	1890	1940	1990	2040	2090	2140	2190	2230
144	1620	1660	1700	1750	1790	1840	1880	1920

1 Tabulated values are conservative for other 2x4 grades and species groupings that have Fc values equal to at least 975 psi and E values equal to at least 1.4 million psi.

2 For 2x4 T-brace extending to within six inches of web member ends, attached by 16d Box nails (0.135 in x 3.5 in) and placed at 6 inches on center starting at 3 inches from the brace ends.

Table 1b

Allowable compression load for a 2x4 No. 2 Southern Pine1,2 web of a specific length having a 2x4 T-brace E value as shown.

Truss web length (in.)	Modulus of Elasticity (E), million psi 0.9	1	1.1	1.2	1.3	1.4	1.5	1.6
54	5360	5730	6110	6490	6860	7240	7610	7990
56	5480	5830	6180	6530	6870	7220	7570	7920
58	5540	5860	6190	6510	6840	7160	7490	7810
60	5550	5850	6160	6460	6770	7070	7370	7680
62	5530	5810	6100	6380	6660	6950	7230	7520
64	5470	5740	6010	6280	6540	6810	7080	7350
66	5400	5650	5910	6160	6410	6660	6910	7160
68	5320	5550	5790	6030	6260	6500	6740	6970
70	5220	5440	5670	5890	6110	6340	6560	6780
72	5110	5320	5530	5750	5960	6170	6380	6590
74	5000	5200	5400	5600	5800	6000	6200	6400
76	4890	5080	5260	5450	5640	5830	6020	6210
78	4770	4950	5130	5310	5490	5670	5850	6030
80	4650	4820	4990	5160	5340	5510	5680	5850
82	4530	4700	4860	5020	5180	5350	5510	5670
84	4420	4570	4730	4880	5040	5190	5350	5500
86	4300	4450	4600	4750	4890	5040	5190	5340
88	4190	4330	4470	4610	4750	4900	5040	5180
90	4080	4210	4350	4480	4620	4750	4890	5020
92	3970	4100	4230	4360	4490	4620	4750	4870
94	3860	3990	4110	4240	4360	4480	4610	4730
96	3760	3880	4000	4120	4240	4350	4470	4590
98	3660	3780	3890	4000	4120	4230	4340	4460
100	3560	3670	3780	3890	4000	4110	4220	4330
102	3470	3580	3680	3790	3890	4000	4100	4210
104	3380	3480	3580	3680	3780	3880	3990	4090
106	3290	3390	3490	3580	3680	3780	3870	3970
108	3200	3300	3390	3490	3580	3670	3770	3860
120	2600	2670	2750	2820	2900	2980	3050	3130
132	2150	2210	2270	2330	2400	2460	2520	2590
144	1800	1860	1910	1960	2010	2070	2120	2170

1 Tabulated values are conservative for other 2x4 grades and species groupings that have Fc values equal to at least 1,650 psi and E values equal to at least 1.6 million psi.

2 For 2x4 T-brace extending to within six inches of web member ends, attached by 16d Box nails (0.135 in. x 3.5 in.) and placed at 6 inches on center starting at 3 inches from the brace ends.

Table 1c

Allowable compression load for a 2x4 No. 3 Douglas Fir-Larch web of a specific length having a 2x4 T-brace with E value as shown

Truss web length (in.)	Modulus of Elasticity (E), million psi							
	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6
54	4900	5280	5650	6030	6400	6780	7150	7530
56	5050	5400	5750	6100	6450	6800	7150	7500
58	5140	5470	5790	6120	6440	6770	7090	7420
60	5180	5480	5790	6090	6400	6700	7000	7310
62	5180	5460	5750	6030	6320	6600	6890	7170
64	5150	5420	5680	5950	6220	6490	6750	7020
66	5100	5350	5600	5850	6100	6350	6610	6860
68	5030	5270	5500	5740	5980	6210	6450	6690
70	4950	5170	5390	5620	5840	6060	6290	6510
72	4860	5070	5280	5490	5700	5910	6120	6330
74	4760	4960	5160	5360	5560	5760	5960	6160
76	4660	4840	5030	5220	5410	5600	5790	5980
78	4550	4730	4910	5090	5270	5450	5630	5810
80	4440	4610	4780	4960	5130	5300	5470	5640
82	4340	4500	4660	4820	4990	5150	5310	5470
84	4230	4380	4540	4690	4850	5000	5160	5310
86	4120	4270	4420	4570	4710	4860	5010	5160
88	4020	4160	4300	4440	4580	4720	4860	5010
90	3910	4050	4180	4320	4450	4590	4720	4860
92	3810	3940	4070	4200	4330	4460	4590	4720
94	3710	3840	3960	4080	4210	4330	4460	4580
96	3620	3740	3850	3970	4090	4210	4330	4450
98	3520	3640	3750	3860	3980	4090	4210	4320
100	3430	3540	3650	3760	3870	3980	4090	4200
102	3340	3450	3550	3660	3760	3870	3970	4080
104	3260	3360	3460	3560	3660	3760	3860	3960
106	3170	3270	3370	3460	3560	3660	3760	3850
108	3090	3180	3280	3370	3470	3560	3650	3750
120	2500	2580	2660	2730	2810	2880	2960	3040
132	2070	2130	2190	2260	2320	2380	2450	2510
144	1740	1790	1840	1900	1950	2000	2060	2110

1 Except for Southern Pine, tabulated values are conservative for other 2x4 grades and species groupings that have F_c values equal to at least 775 psi and E values equal to at least 1.4 million psi.

2 For 2x4 T-brace extending to within six inches of web member ends, attached by 16d Box nails (0.135 in x 3.5 in) and placed at 6 inches on center starting at 3 inches from the brace ends.

Table 1d

Allowable compression load for a 2x4 Stud grade Spruce-Pine-Fir1,2 web of a specific length having a 2x4 T-brace with E value as shown.

Truss web length (in.)	Modulus of Elasticity (E), million psi							
	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6
54	4450	4820	5200	5570	5950	6320	6700	7070
56	4630	4980	5330	5680	6030	6370	6720	7070
58	4750	5070	5400	5720	6050	6370	6700	7020
60	4810	5110	5420	5720	6030	6330	6630	6940
62	4830	5120	5400	5690	5970	6260	6540	6830
64	4820	5090	5360	5630	5890	6160	6430	6690
66	4790	5040	5290	5550	5800	6050	6300	6550
68	4740	4980	5210	5450	5690	5920	6160	6400
70	4670	4900	5120	5350	5570	5790	6020	6240
72	4600	4810	5020	5230	5440	5650	5870	6080
74	4510	4710	4910	5110	5310	5510	5710	5910
76	4420	4610	4800	4990	5180	5370	5560	5750
78	4330	4510	4690	4870	5050	5230	5410	5590
80	4230	4410	4580	4750	4920	5090	5260	5430
82	4140	4300	4460	4630	4790	4950	5110	5280
84	4040	4190	4350	4500	4660	4810	4970	5120
86	3940	4090	4240	4390	4530	4680	4830	4980
88	3840	3990	4130	4270	4410	4550	4690	4830
90	3750	3880	4020	4150	4290	4420	4560	4690
92	3650	3780	3910	4040	4170	4300	4430	4560
94	3560	3690	3810	3930	4060	4180	4310	4430
96	3470	3590	3710	3830	3950	4070	4180	4300
98	3380	3500	3610	3730	3840	3950	4070	4180
100	3300	3410	3520	3630	3740	3840	3950	4060
102	3210	3320	3420	3530	3630	3740	3840	3950
104	3130	3230	3330	3440	3540	3640	3740	3840
106	3050	3150	3250	3350	3440	3540	3640	3730
108	2980	3070	3160	3260	3350	3450	3540	3630
120	2410	2490	2560	2640	2710	2790	2870	2940
132	1990	2060	2120	2180	2240	2310	2370	2430
144	1670	1730	1780	1830	1890	1940	1990	2040

1 Except for Southern Pine, tabulated values are conservative for other 2x4 grades and species groupings that have Fc values equal to at least 725 psi and E values equal to at least 1.2 million psi.

2 For 2x4 T-brace extending to within six inches of web member ends, attached by 16d Box nails (0.135 in x 3.5 in) and placed at 6 inches on center starting at 3 inches from the brace ends.

desired T-braces are 2x4 Stud Spruce-Pine-Fir (SPF). From Table 2, the E is 1.2 million psi for Stud grade SPF. By following the method described above, the calculated web length was 91.2 in. Use Table 1b because the webs are made from No. 2 Southern Pine. Round 91.2 in. up to 92 in. since the table value is less for 92 in. compared to 90 in. From the column labeled E = 1.2 million psi and the row labeled 92 in., the allowable load in the web is 4,360 lbs. A SPF T-brace is adequate on web B-K (and F-I) in place of a CLB.

4. Two CLBs

Also in Figure 3, two CLBs are shown on member C-J (and E-J). The load in this member is -4,126 lbs. The webs are 2x4 No. 2 Southern Pine and the T-braces that we would like to use again are 2x4 Stud SPF (E = 1.2 million psi). The calculated web length was 100 in. Reading from Table 1b, the maximum load that this web could carry with a T-brace is 3,890 lbs. Using a Stud SPF T-brace on member C-J instead of a CLB would not be adequate because 3,890 lbs. is less than 4,126 lbs. However, from Table 1b, using a T-brace with an E of 1.5 million psi would produce an allowable web load greater than the 4,126 lbs. required.

Discussion

Using higher grades of web material or using larger webs (2x6 or 2x8) are possible ways to eliminate or reduce the amount of CLBs needed. For example, a 2x6 web will carry about 50 percent more load than a 2x4 of the same grade and species, possibly reducing the need for a CLB. The value of using a higher grade of 2x4 web lumber varies with the web length. For short webs, a No. 2 Southern Pine (SP) web will carry up to 69 percent more load

Table 2

Typical 2x4 lumber grades and species groupings that may be used as T-braces.

2x4 Grade and Species Groupings*E, million psi
Stud or No. 3 Western Woods0.9
Stud or No. 3 Spruce-Pine-Fir (South) 1.0
Stud or No. 3 Douglas Fir-South 1.1
Stud or No. 3 Hem FirStud or No. 3 Spruce-Pine Fir 1.2
No. 1 Douglas Fir-South or No. 2 Hem-Fir 1.3
Stud or No. 3 Douglas Fir-LarchStud or No. 3 Douglas Fir-Larch (North)No. 2 Non-Dense, No. 3, or Stud Southern Pine 1.4
No. 1 or No.1 & Better Hem-Fir, or 1650f-1.5E MSR 1.5
No. 2 or No.1 Non-Dense Southern PineNo. 2 Douglas Fir-Larch 1.6
*The NDS (1997) Supplement contains a complete list of species and tabulated E values for consideration by the bracing designer.

than a Stud or No. 3 SP web. For very long webs, a No. 2 SP web will carry about 14 percent more load than a Stud or No. 3 SP web.

The load carrying capacity of T-braced SP webs of No. 3 and No. 2 grade can readily be seen by inspection of Tables 1a and 1b, respectively. For example, assuming a T-brace with an E of 1.2 million psi and LW equal 60 in., the No. 2 web will carry 56 percent (6460/4140) more load than a No. 3 or Stud grade web. It may be a good practice to use a minimum of No. 2 SP webs in long span post-frame trusses to minimize the number of CLBs specified on the truss design drawing, and when a CLB is noted on the truss design drawing, a T-brace is more likely to substitute for the CLB.

Conclusion

The T-brace design tables provided in this paper show the allowable load that can be applied to a 2x4 truss web with a 2x4 T-brace. When a CLB is required on a web, a 2x4 T-brace may be substituted only if the web load is lower than the tabulated value for the web grade and species, web length, and T-brace E. T-braces are recommended when the trusses are 4 to 10 ft. on center because they can be installed on the ground before the trusses are lifted onto the roof. Also, by using T-braces on the webs instead of CLBs, it is likely that less lumber and labor will be required to erect the trusses and install permanent web bracing. The methods used in this paper were developed specifically for selected 2x4 webs braced with a 2x4 and installed as depicted in Figure 2.

Literature Cited

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Appendix A

Sample T-Brace design assuming a 2x4 Stud Southern Pine web 54 inches long and a 2x4 Stud Spruce-Pine-Fir T-brace.

$E_W = 1.4\text{x}10^6$ psi (F_c = 975 psi from NDS-97 Supplement)

$E_B = 1.2\text{x}10^6$ psi (from Table 2 or NDS-97 Supplement)

$E'T = (1.20\ E_W I_W + 0.363\ E_B I_B + A\ R - B)/I_W$

where the units of E_W and E_B are psi, the units of I_W and I_B are in.^{4}, A equals 34.8x10^6 lb.-in.^{2}, B equals 27.9x106 lb-in2, and when R>8/9, then use R = 8/9.

R= (54-6-6)/54 = 0.778

$E'_T = (1.20 * 1.4\text{x}10^6 * 0.984 + 0.363 * 1.2\text{x}10^6 * 5.359 + 34.8\text{x}10^6 * 0.778 - 27.9\text{x}10^6)/0.984$

$E'T = 3.21\text{x}10^6$ psi

$L_e = K_e L_W$ = 0.8*54 in. = 43.2 in.

L_e/d = 43.2/1.5 = 28.8

$F_{cE} = K_{cE}E'/(L_e/d)^2$= 0.3*3.21x 10^6/(28.8)2 = 1,161 psi

$F_c^* = F_c C_D$ = 975*1.15 = 1,121. psi (Snow plus dead load assumed.)

Note: For other than Southern Pine, add CF to Fc* calculation.

F_{cE}/F_c^* = 1161/1121 = 1.036

c=0.8

$C_p = (1+1.036)/1.6 - \{((1+1.036)/1.6)^2$

$$C_p = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{(F_{cE}/F_c^*)}{c}}$$

$- 1.036/0.8\}^{1/2}$ = 0.703

$F_c' = F_c C_D C_p$ = 975*1.15*0.703= 788. psi

$P_{allowable} = F_c' A$ = 788* (1.5*3.5) = 4,137. lbs.

A note on Load Values in Tables 1a-1d.

In Tables 1a, 1b, 1c, and 1d, the allowable value of P increases with web lengths up to a point and then it decreases slightly. This result is contrary to the typical column relationship whereby the allowable load is inversely related to the effective length of the column. For example, for the case of a 0.9 million psi T-brace in Table 1a, the unusual behavior stems from the equation for F_{cE}, which increases in value up to L_W equal 62 in. The allowable load, P, is dependent on the Column Stability Factor, C_P, which is dependant on F_{cE}. In this particular application of a T-braced web, F_{cE} is adversely affected by L_W in the usual manner, but positively affected by E_T because E_T is a linear function of R. R equals (L_W -12)/ L_W and increases with L_W up to a constant value of 8/9. When L_W is greater than 62 in. for the example case, F_{cE} begins to decrease, so both C_P and the allowable load decrease.

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